Towards a new food system assessment: AgMIP coordinated global and regional assessments of climate change

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Abstract
Agricultural stakeholders need more credible information on which to base adaptation and mitigation policy decisions. In order to provide this, we must improve the rigor of agricultural modelling. Ensemble approaches can be used to address scale issues and integrated teams can overcome disciplinary silos. The AgMIP Coordinated Global and Regional Assessments of Climate Change and Food Security (CGRA) has the goal to link agricultural systems models using common protocols and scenarios to significantly improve understanding of climate effects on crops, livestock and livelihoods across multiple scales.

The AgMIP CGRA assessment brings together experts in climate, crop, livestock, economics, and food security to develop Protocols to guide the process throughout the assessment. Scenarios are designed to consistently combine elements of intertwined storylines of future society including, socioeconomic development, greenhouse gas concentrations, and specific pathways of agricultural sector development. Through these approaches, AgMIP partners around the world are providing an evidence base for their stakeholders as they make decisions and investments.

Keywords
Ensembles, simulations, farming systems, uncertainty, sustainable development.

Introduction
The Agricultural Model Intercomparison and Improvement Project (AgMIP) was founded in 2010 to advance systems approaches for understanding climate change impacts and adaptation. It has expanded to be a worldwide science community that compares and improves crop, livestock, pest, water, and economic models in order to enhance scientific capabilities. There are now over 900 members of AgMIP from all over the world and from many partner and donor institutions. The collaborators have focused on a wide range of challenges facing the agricultural sector, including its role in food security and poverty (Rosenzweig et al 2013). AgMIP activities rest on 3 pillars: Next-Generation Knowledge, Data, and Tools; Modelling for Sustainable Farming Systems; and Coordinated Global and Regional Assessments (Figure 1).

The AgMIP conducts protocol-based activities that utilise model ensembles, cross-disciplinary approaches, and multiple temporal and spatial scales to create integrated assessment frameworks. These utilise climate scenarios, pathways of economic and technological development, and adaptation strategies to explore how livelihoods and food security may be affected by changing climate and how policies may be devised to develop resilience of farming systems. The scientific approach of AgMIP has two tracks. The first is to develop and test agricultural systems models and the second is to conduct multi-model assessments. These multi-model assessments address challenges such as current and future climate systems and pathways to sustainability.

Agricultural models require data collected from field experiments that capture accurately the growing season weather, with-in field soil characteristics, farmer management practices, and choice of cultivar. These data are used by modellers to develop, calibrate, evaluate, and improve their models. Measurements of growth stages are needed as well as crop yields. For experimental data, AgMIP ranks sentinel site data sets as platinum, gold, or silver, according to how comprehensive and accurate they are (Boote et al. 2016).

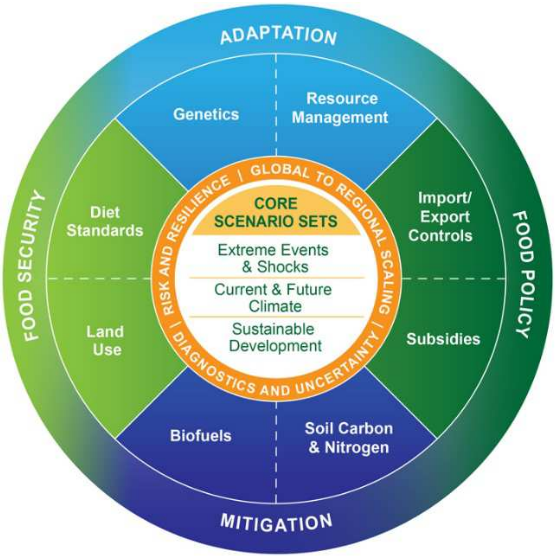

Figure 1. Coordinated Global and Regional Integrated Assessments (CGRA) framework to provide guidance on adaptation, mitigation, food security, and food policy as climate changes (Rosenzweig et al. 2015).

Next-generation knowledge, data, and tools

What is needed for agricultural systems modelling is the creation of the next generation of knowledge, data, and tools. These next-generation data and models will enable significant advances in decision support systems, improved assessments of the benefits of new technologies or management, understanding of climate extremes and change, trade-offs between productivity gains and environmental risks, and pathways to sustainability.

A main activity of AgMIP has been the formation of individual crop model intercomparison and improvement projects (Asseng et al. 2013). AgMIP had developed model intercomparison teams for wheat, maize, rice, sugarcane, millet/sorghum, groundnut, potatoes, canola, grassland/pastures, soils and crop rotations, bioenergy, and crop/water/temperature. Other activities and cross-cutting themes include sentinel site experiment data, sensitivity tests, and uncertainty.

Individual crop studies have yielded several key insights, including:

- Median of crop model ensembles, reproduce observed yields better than any single model;
- This occurred with both minimal and high levels of calibration;
- Number of crop models in ensembles needed was ~5-10;
- Crop responses to CO_2, temperature, and water remain key sources of uncertainty; models need to be improved to account for this;
- Consistent message: yield is reduced with rising temperature, with shorter life cycle (grain-fill) being the primary cause.

Modelling for sustainable farming systems

AgMIP addresses the challenges of climate extremes and change on agriculture through the use of decision-making models and assessments. These models and assessments simulate pathways to sustainable farming systems to achieve local-to-global food security. The tools and protocols AgMIP scientists are developing can be used worldwide to assist stakeholders in their ongoing climate-smart decisions.

For the past five years, UK DFID has funded AgMIP to develop new fundamental innovative protocol-based methodologies of regional integrated assessments (RIA) in Sub-Saharan Africa and South Asia, thereby enhancing the capacity of developing countries to address the challenges brought on by current and future climate stresses. One of the study regions of this project was Nkayi, Zimbabwe (Homann Kee-Tui et al. 2017).

The study engaged provincial-level stakeholders and farmers to design options for improving crop and livestock production, which could be implemented within the next 5 years if the right decisions were made to support farmers. Packages for improving crop and livestock management were designed and their impacts evaluated for three categories of farmers: Very poor (farm size 1.3 ha, no cattle); Poor (farm size 1.8 ha, 8 cattle or less), and Better-off (farm size 2.5 ha, more than 8 cattle). The results of this analysis are presented in Figure 2.

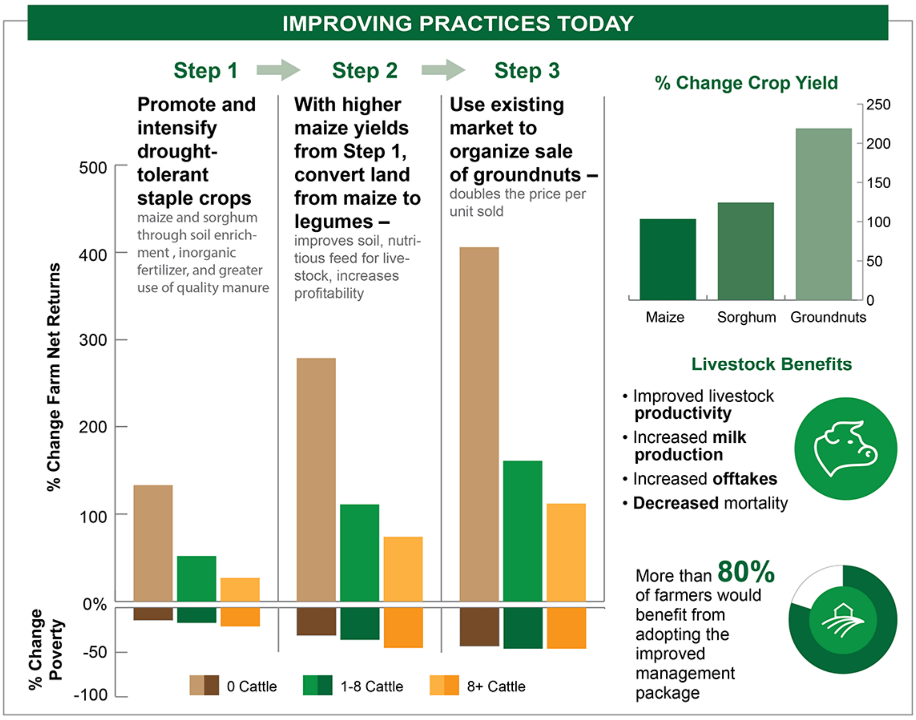

Figure 2. Results from AgMIP Regional Research Team in Nkayi, Zimbabwe: Impact of improved management practices for crops and livestock if implemented today (poverty rate used is less than $1.25 per person per day) (Homann Kee-Tui et al. 2017).

Coordinated Global and Regional Assessments (CGRA)

The AgMIP Coordinated Global and Regional Assessment (CGRA) approach enables study of changes in all the trajectories of change that will directly impact agriculture and those whose livelihoods depend on it. These trajectories include our changing climate, how economic growth will process, how technology will develop, how farm practices will change and how changing population and dietary preferences will affect the demand for food. Socioeconomic development, farm management, agricultural technologies, and food demand that will have direct CGRA relevance utilise the framework shown in Figure 1. The axes across adaptation and mitigation to food security and food policy help to explore major questions of how policies can be devised to achieve sustainable outcomes under multiple stresses and challenges. The worldwide AgMIP community of science is conducting more than 24 protocol-based activities that cross scales and disciplines, including the Global Gridded Crop Model Initiative (Figure 3) and the Global Economics Team (Figure 4). Key aspects of the approach are that it directly engages with stakeholders, delivers cutting-edge science, and utilises the latest information technologies. Addressing major societal challenges requires collaboration and coordination to ensure that models and modellers connect efficiently and effectively, and that assumptions and scenarios are consistent across the simulations, disciplines, and scales involved.

Conclusion

AgMIP is an exciting effort that produces consistent multi-model, multi-discipline, and multi-scale assessments of agricultural and food security impacts. It significantly improves the characterisations of uncertainty and risk. The CGRA is being used to conduct an assessment of the impacts of 1.5 °C and 2.0 °C warming on agriculture, for the Intergovernmental Panel on Climate Change (IPCC) Special Report on Global Warming of 1.5 °C. This is the first time that global and regional scales are being linked explicitly in such an assessment. Through the development of Representative Agricultural Pathways (RAPs), the AgMIP CGRA provides a logically consistent set of drivers and outcomes for global decision-makers and regional agricultural planners. The AgMIP CGRA results will contribute to international climate policy, national adaptation and mitigation planning, and development aid.

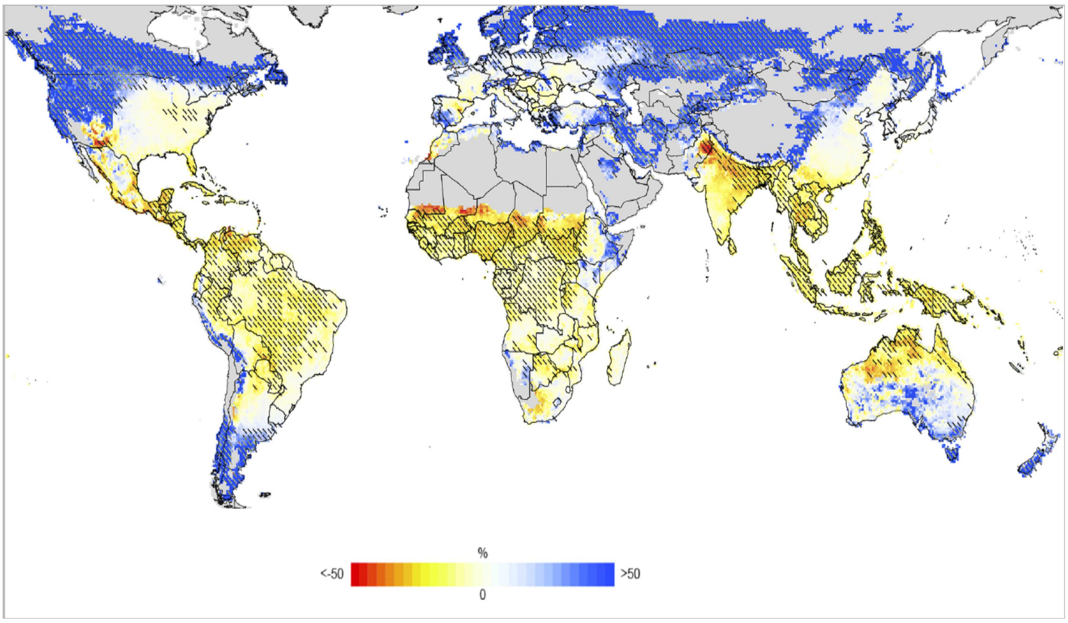

Figure 3. Median maize yield changes (%) for RCP8.5 (2070–2099 compared to 1980–2010 baseline) with CO_2 effects for 35-member ensemble (five global climate models and seven global gridded crop models). Hatching indicates areas where more than 70% of ensembles agree on directionality of yield change. Grey areas indicate historical areas with little to no yield capacity (Rosenzweig et al. 2014).

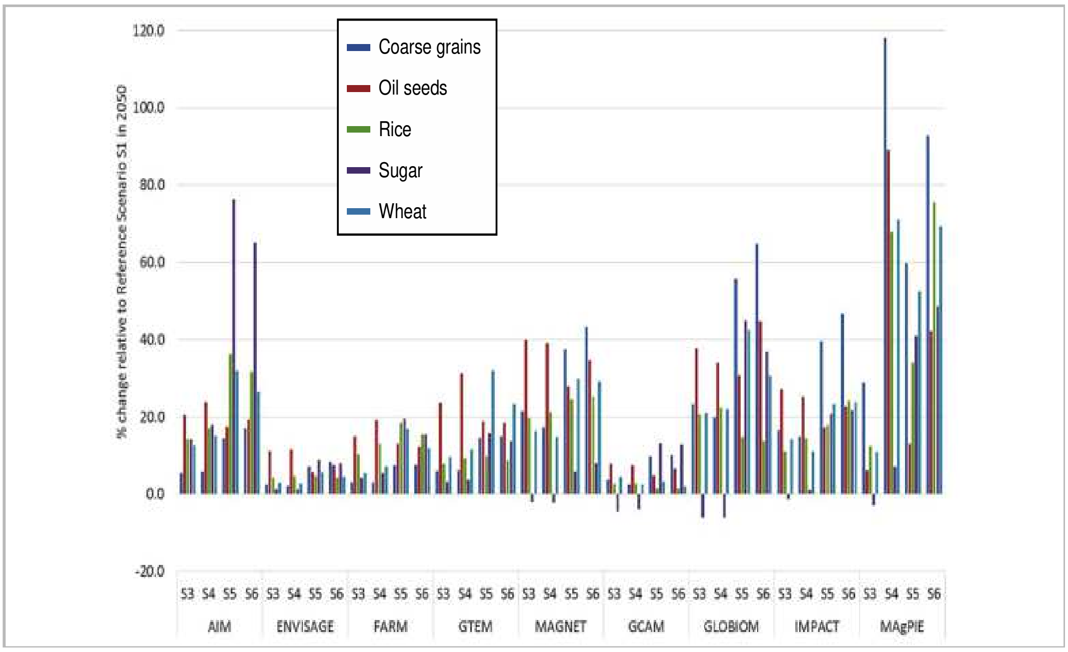

Figure 4. Effects of climate change on agricultural prices for five different commodities using nine global economic models (Nelson et al. 2014).

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