AgMIP The Agricultural Model Intercomparison and Improvement Project

Linking Climate, Crop, and Economic Models for Adaptation: The Agricultural Model Intercomparison and Improvement Project




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and AgMIP participants all over the world

Aspen Global Change Institute – August 5th, 2014

UKaid from the Department for International Development

USDA

USAID

CGIAR

Research Program on Climate Change, Agriculture and Food Security

CCAFS

NASA

AgMIP Activities and Initiatives

AgMIP is an international community of 650+ **climate scientists**, **agronomists**, **economists**, and **IT experts** working to improve assessments of **future food security**

Visit www.agmip.org for more information

Links to CCAFS, Global Yield Gap Atlas, ISI-MIP, Global Futures, MACSUR, et al.

The Food Security Challenge

Biophysical Challenges
Yield Gaps and Plateaus

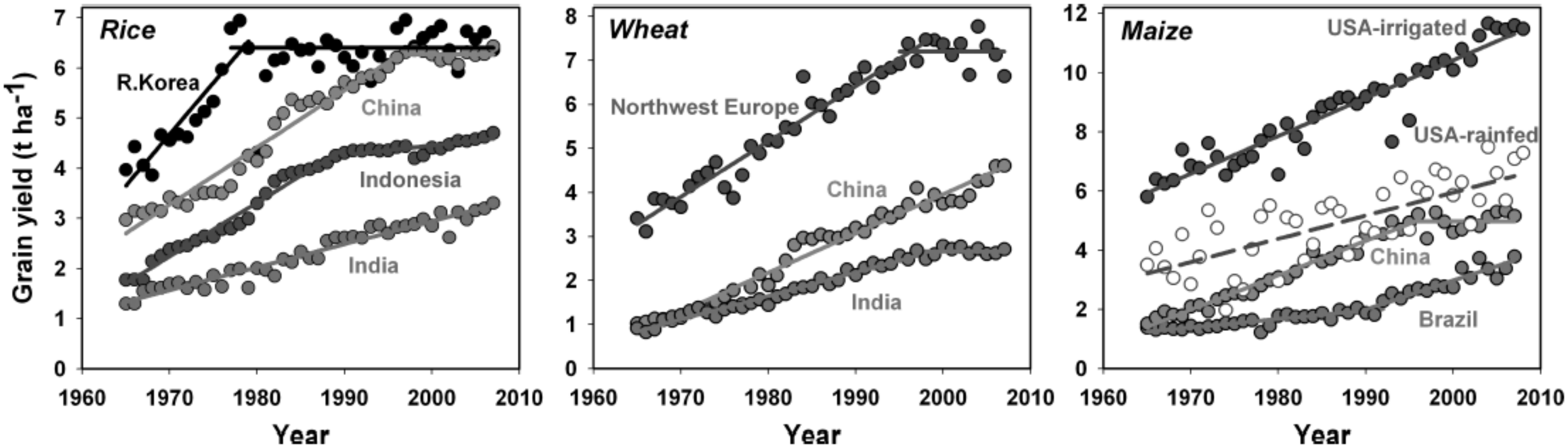


Fig. 2. Grain yield trends of the three major cereals in selected countries. USA maize yields are means for the western Corn Belt and Great Plains states: CO, KS, NE, ND, OK, SD, TX, and WY.

Cassman et al., 2011

Many places produce far less than their potential

Cannot assume that yields will always increase

Yield gains not keeping up with demand

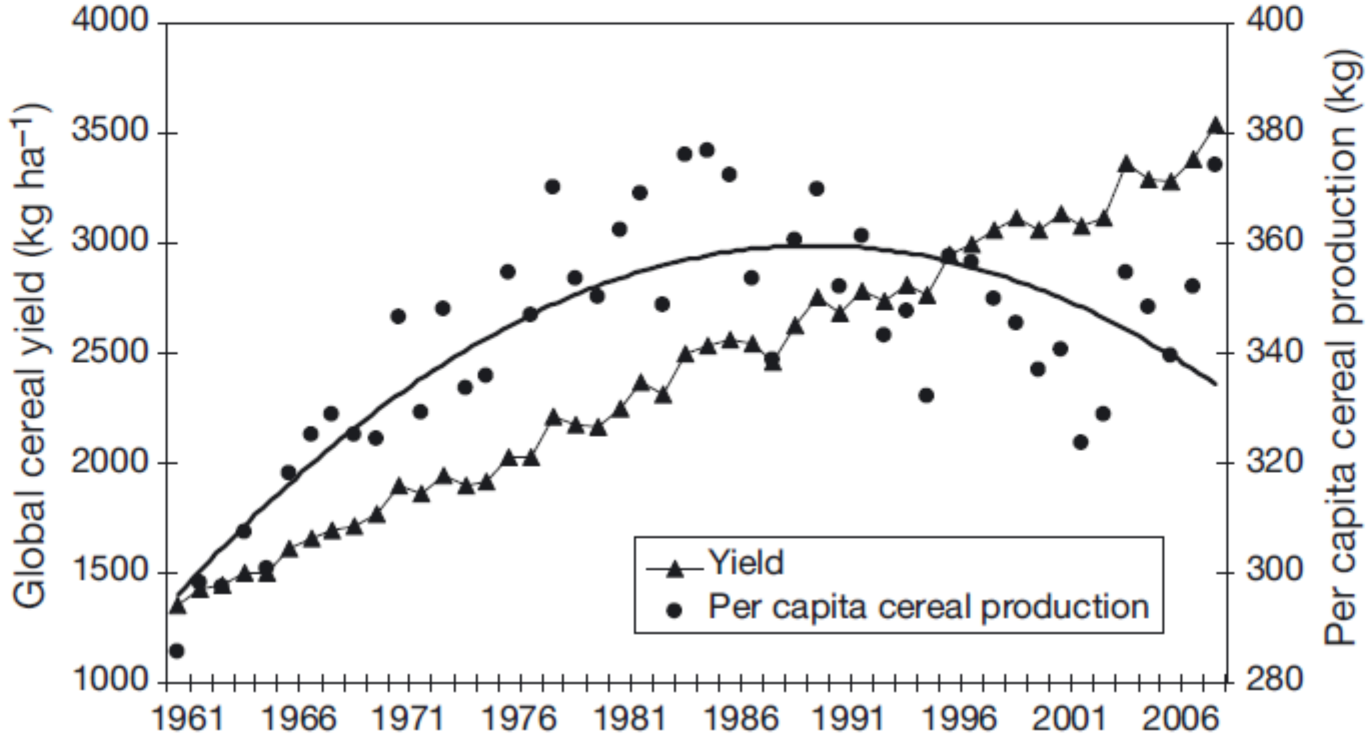
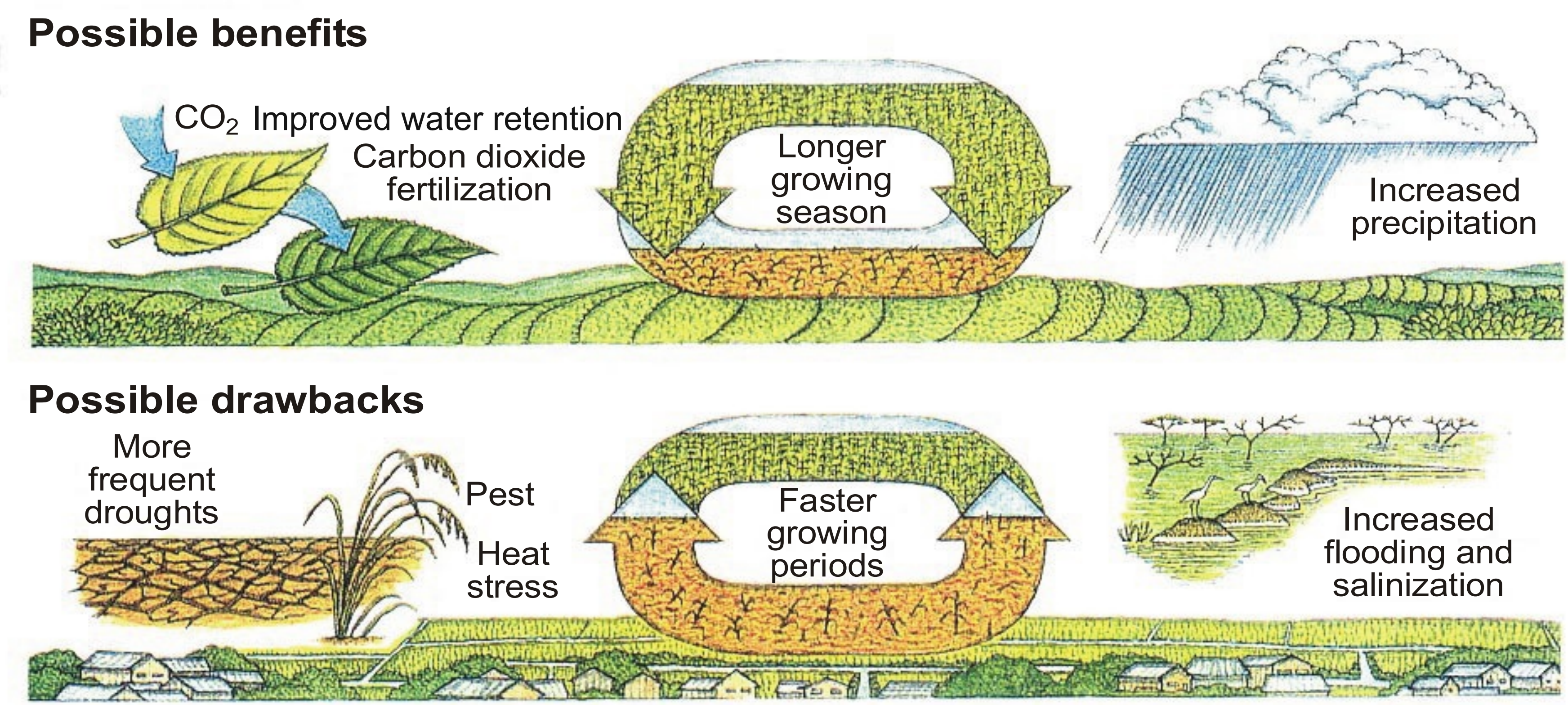


Fig. 1. Average global cereal yields and per capita cereal production (kg) for 1961–2008 (annual global per capita cereal production, calculated as total global production for a given year divided by total global population for that year) (FAO 2010a)

Selvaraju et al., 2011

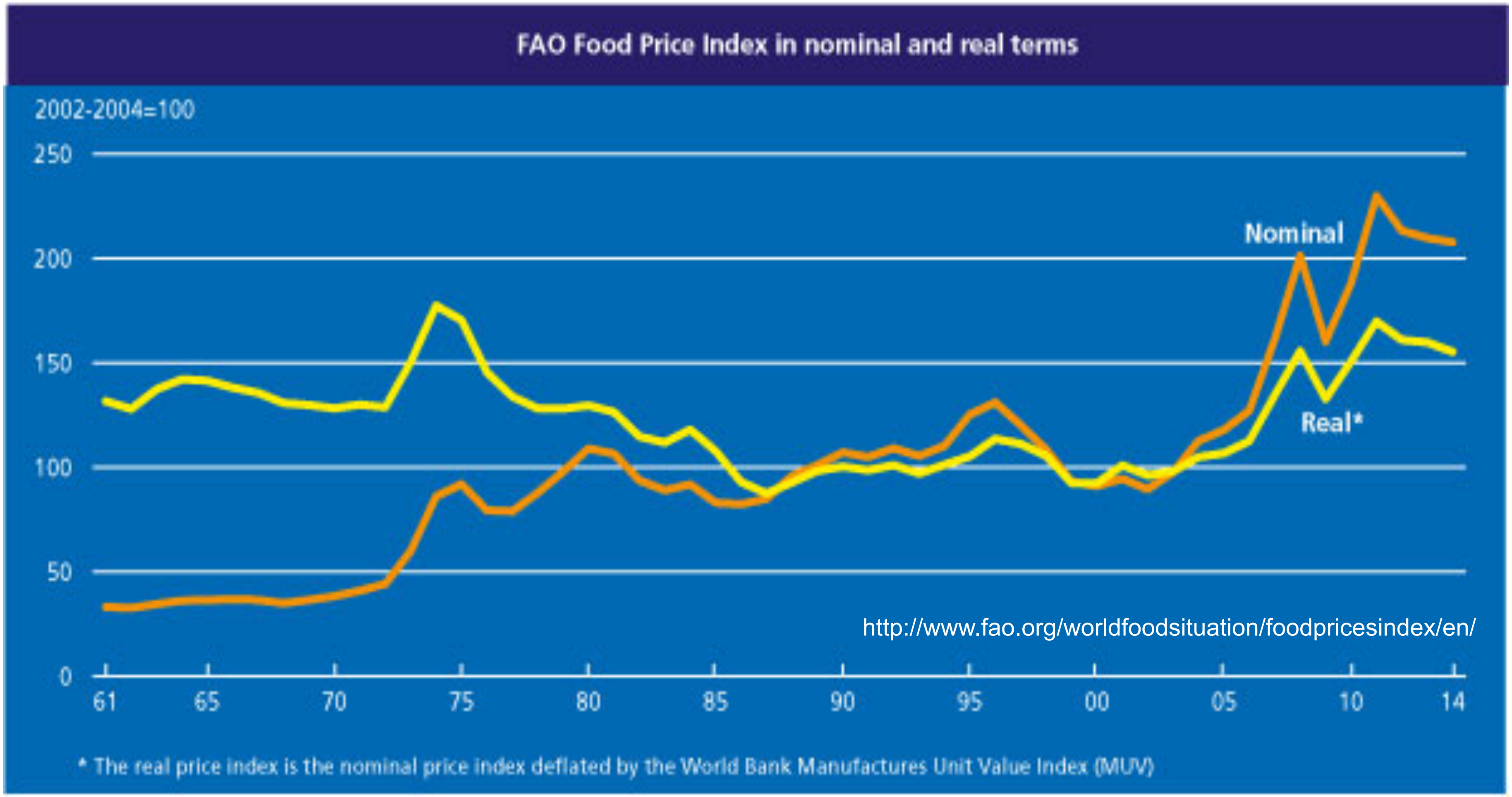
Biophysical Impacts of Climate Change are complex



Based upon Bongaarts, J., Scientific American, 1992

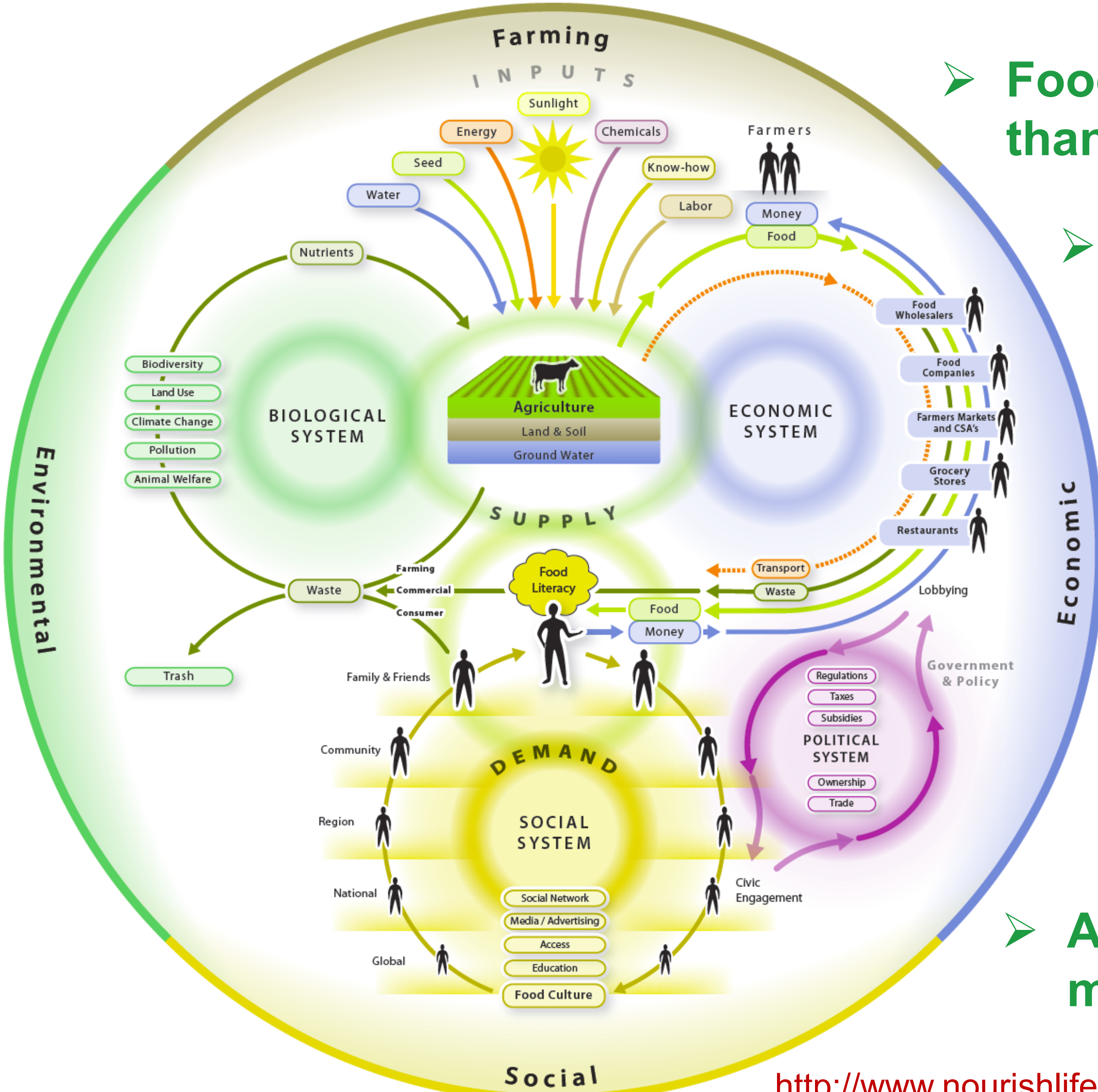
- **Niche growing areas are particularly vulnerable**
- **Additional fertilizers and water transport will be necessary to maintain current crop locations**

Socio-economic Challenges
Price Spikes



- **Long downward trend in real food prices has reversed**
- **Increasing volatility – lower stocks, higher demand, climate threats**

Expanded ‘Food System’ Approach

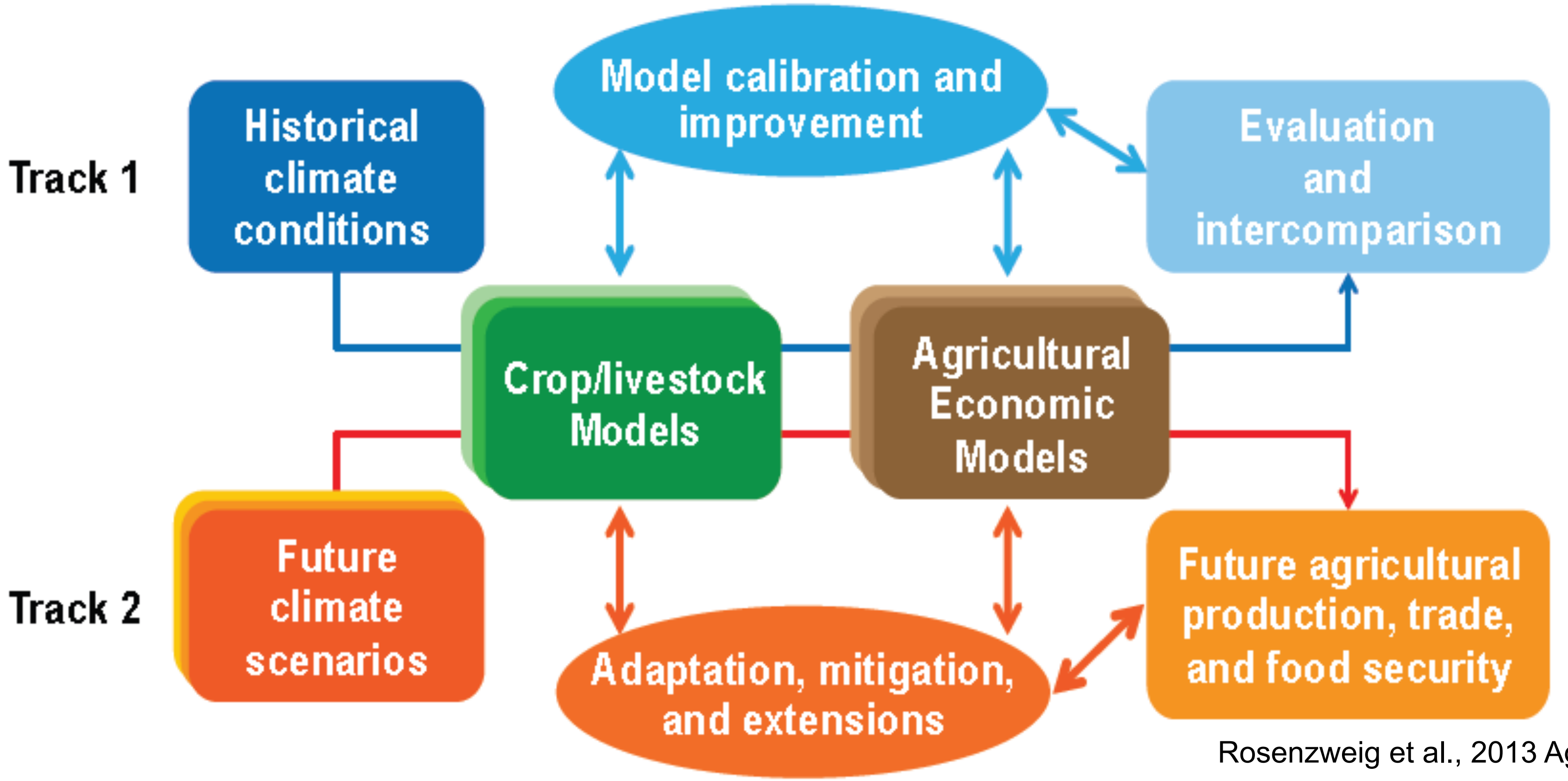


- Food system is much more than supply and demand
  - Spans local to global scales with a lot of potentially volatile points
    - Very difficult to predict future conditions
  - Need to represent complexities via models or scenarios
- Adaptation can build a more resilient system

http://www.nourishlife.org/teach/food-system-tools/

Linking disciplinary models

Two-Track Science Approach



Rosenzweig et al., 2013 AgForMet

Track 1: Model Improvement and Intercomparison

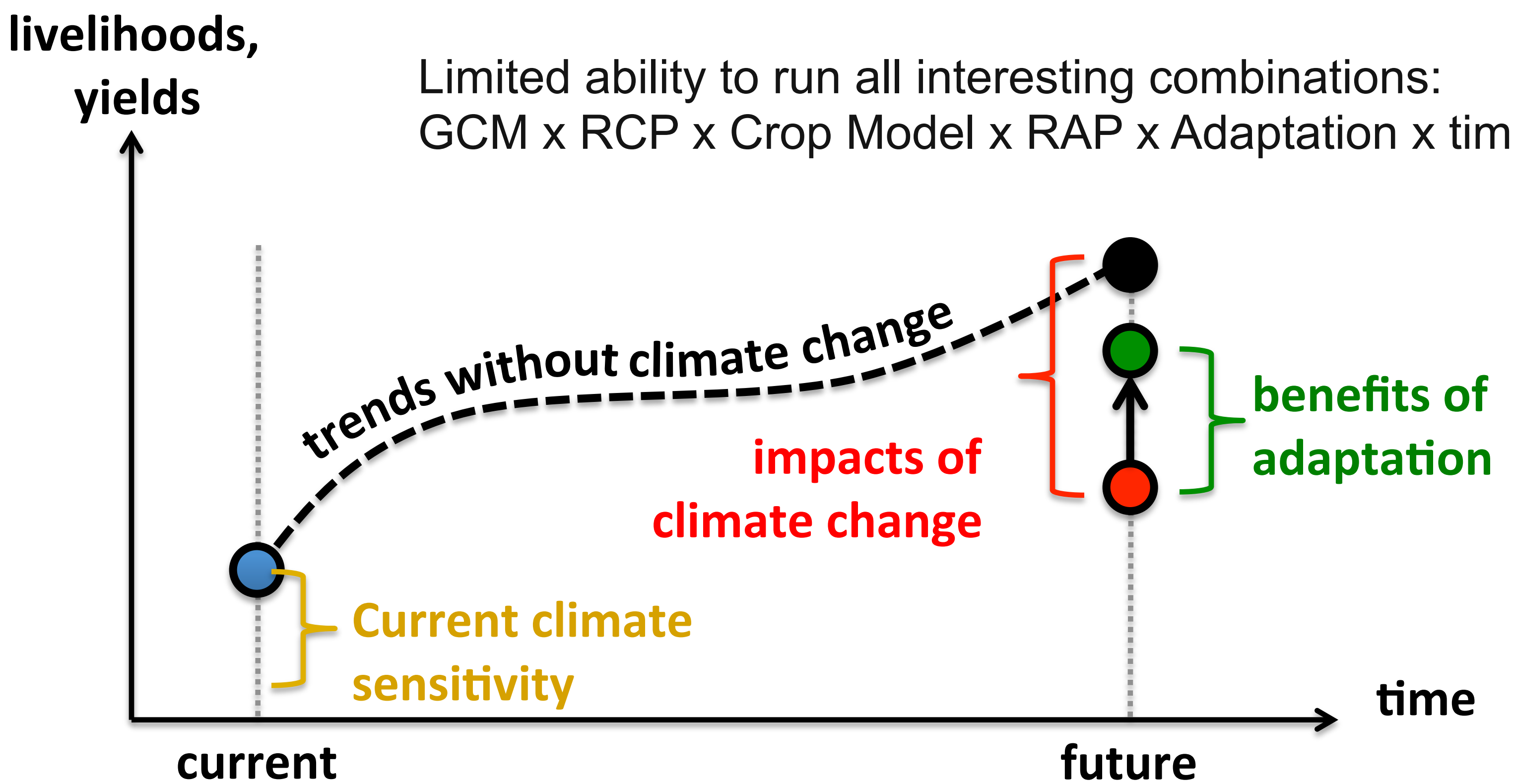
Track 2: Climate Change Multi-Model Assessment

Enables testing of adaptation strategies

Core Questions for Integrated Assessment

1) **What is the sensitivity of current agricultural production systems to climate change?**
2) **What is the impact of climate change on future agricultural production systems?**
3) **What are the benefits of climate change adaptations?**

Limited ability to run all interesting combinations:
GCM x RCP x Crop Model x RAP x Adaptation x time slice



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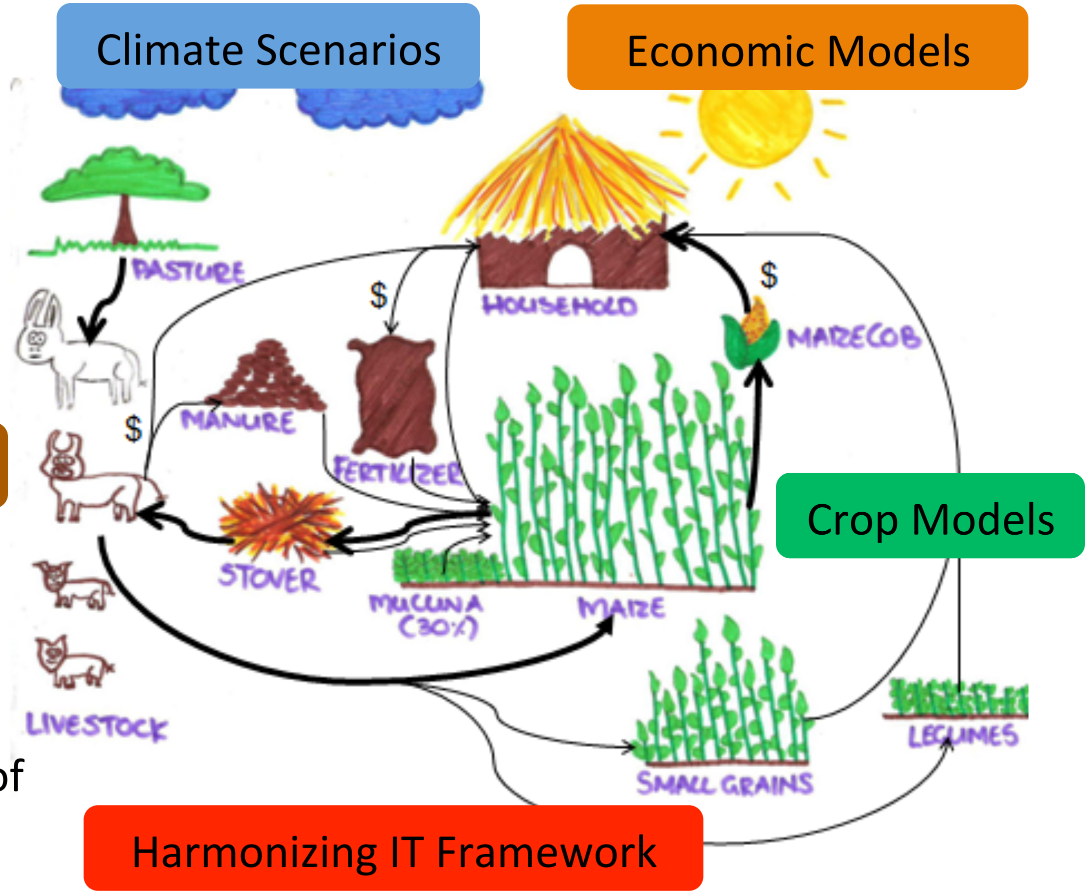
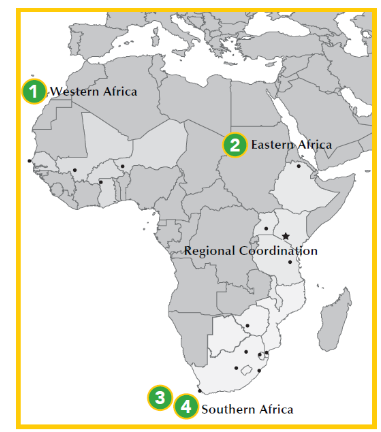
Building a Transdisciplinary Regional Integrated Assessment Framework

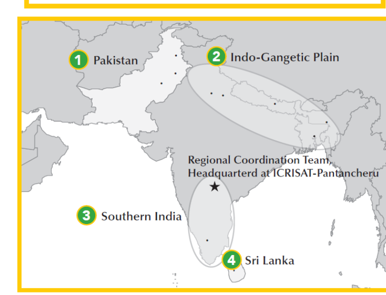
Livestock Models



Schematic courtesy of Masikati et al., AgMIP CLIP team

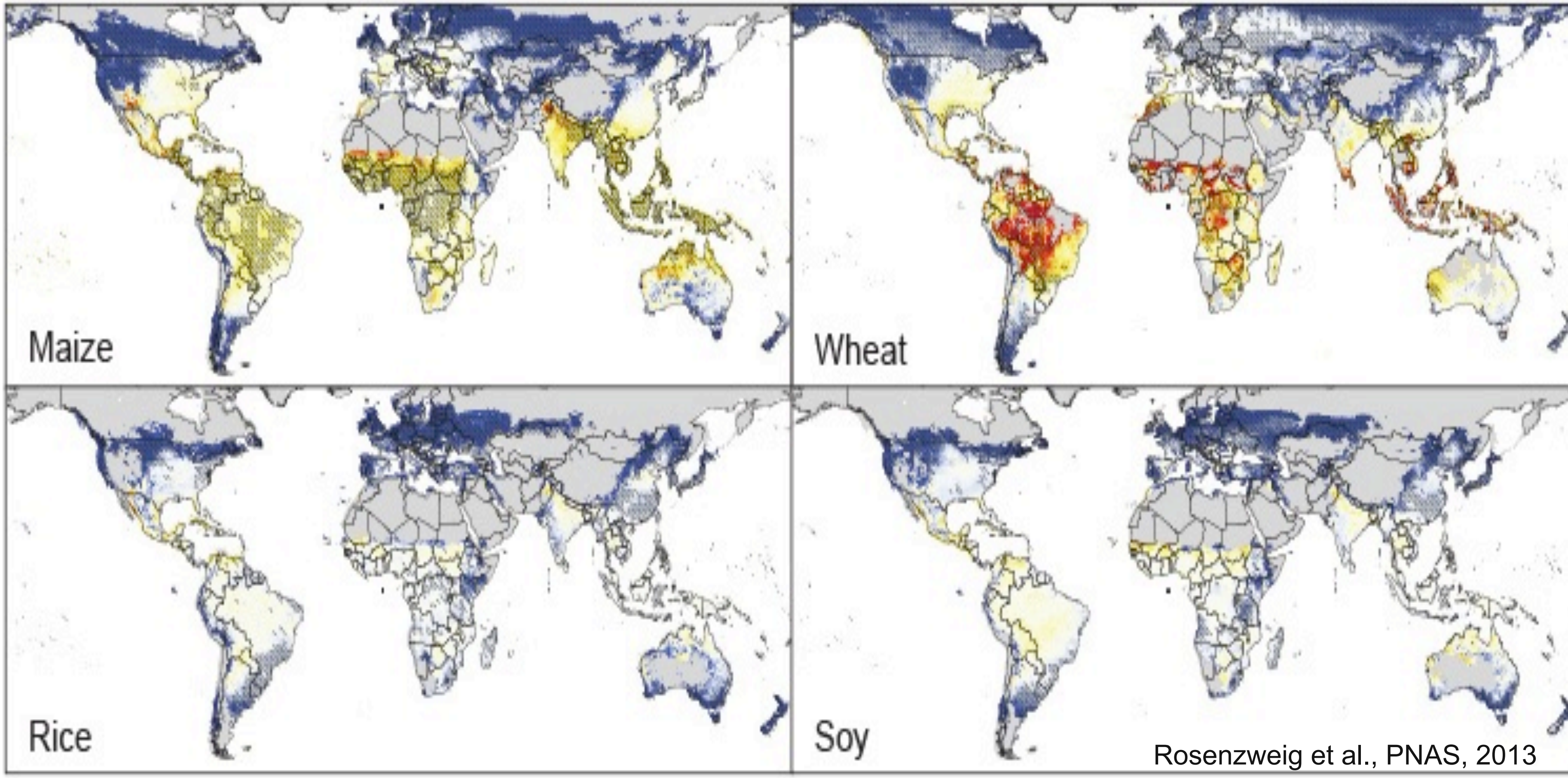
60 institutions
120+ scientists in Sub-Saharan Africa and South Asia



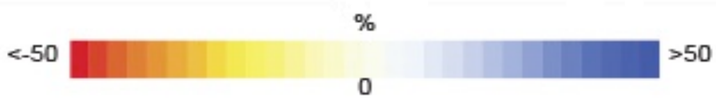


Utilize farm surveys (100+ farms) to enable the evaluation of distributions of gainers, losers, adopters, resilience, and successful strategies in the face of climate change

Global Gridded Crop Model Results



Hatched areas indicate >70% model agreement



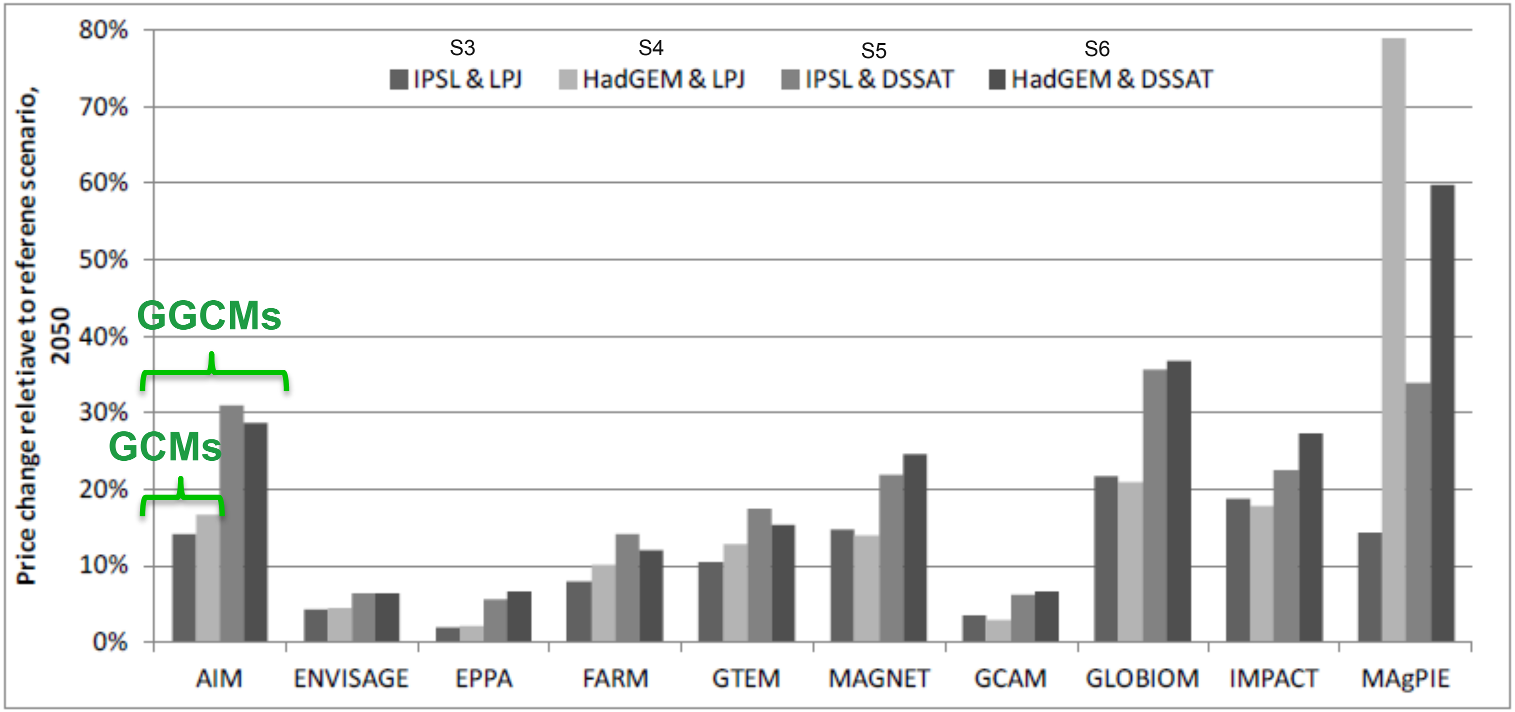
2080s RCP.5

median of 7 GGCMs and 5 GCMs – from AgMIP-led agricultural contribution to ISIMIP

New global gridded activities have 10+ models, with historical validation, carbon-temperature-water-nitrogen sensitivity tests

Global Economics Models

Effects of climate change on agricultural prices
(2050 RCP8.5 relative to results without climate change in 2050)



Source: Model results as of February 15, 2013

Note: All changes relative to the reference scenario for the same year.

AgMIP Global Economics Model Intercomparison

10 Global Economics Models, 2 GCMs, 2 crop models

Von Lampe et al., Agricul*tural Economics, 2013*

Baseline from SSP2

Climate change is projected to exert upward pressure on agricultural prices, but with large uncertainty that we are connecting to model approaches

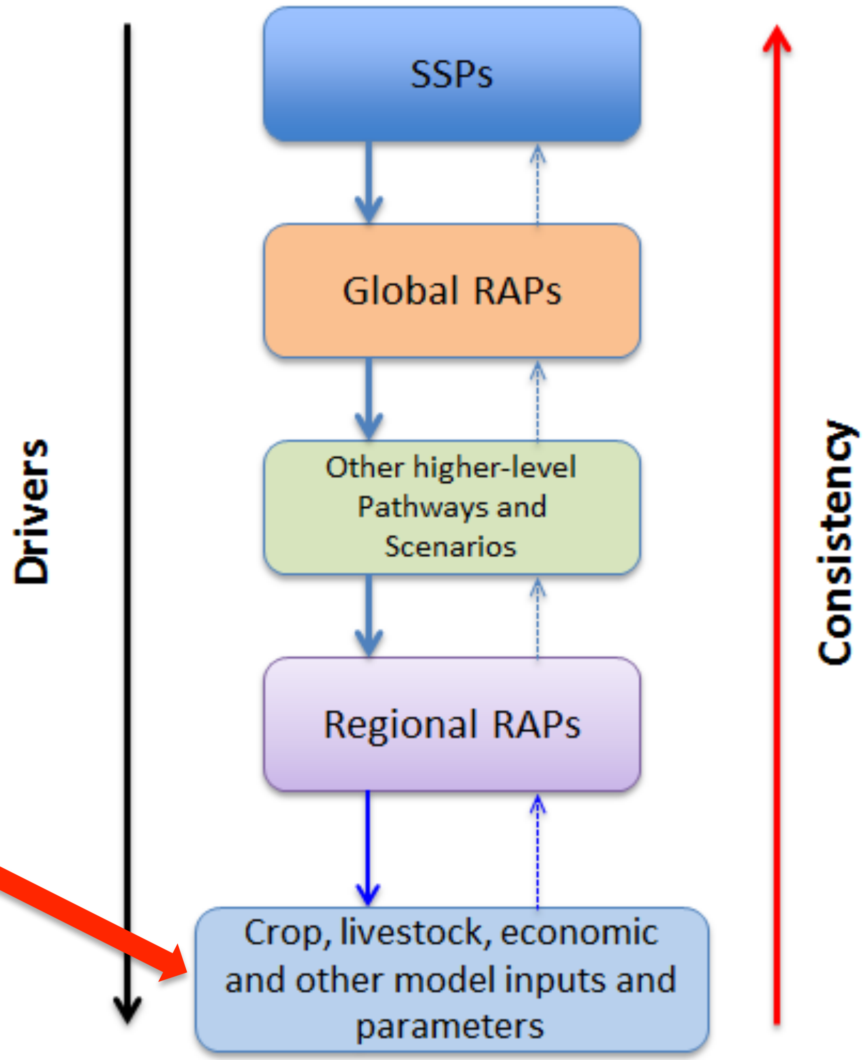
Model uncertainty: GEM > GGCM > GCM
Partial Equilibrium Models generally respond more than CGEs

Creating consistent agricultural scenarios

Global and Regional Coordination Socio-Economic Pathways and Scenarios

Need to add agricultural sector details to gauge development baseline before agricultural adaptations

Adaptation packages

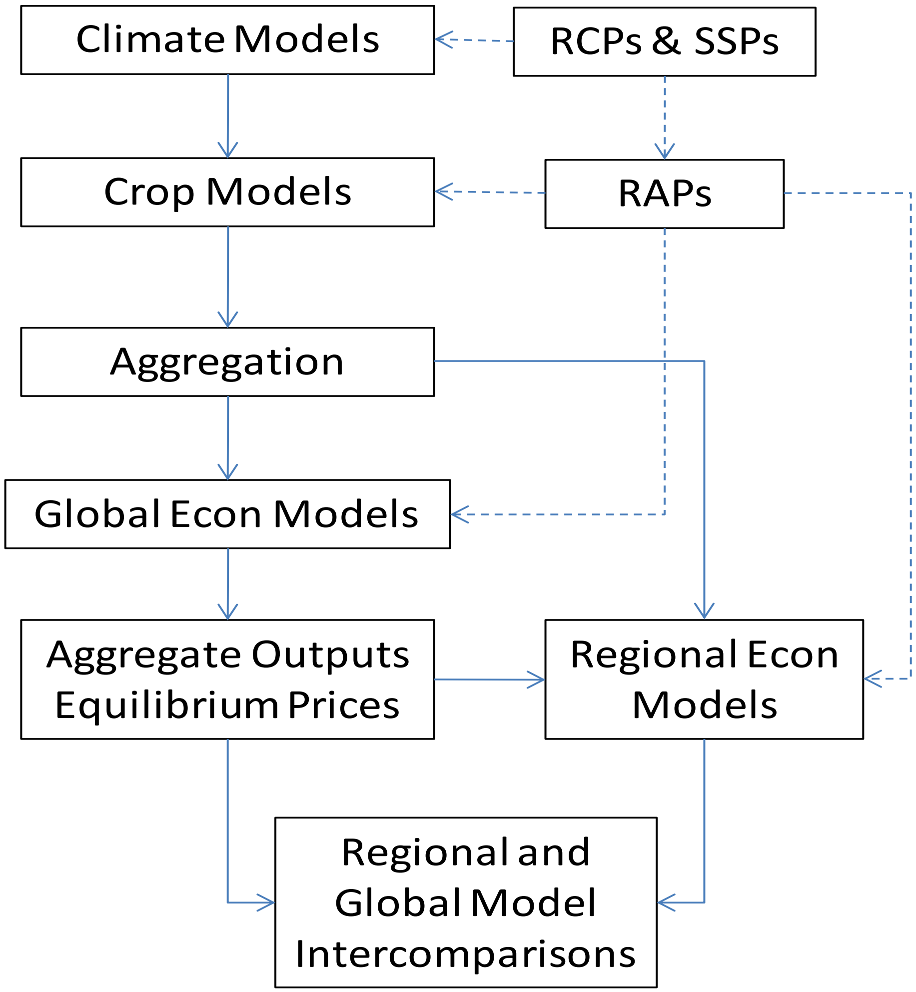


Representative Agricultural Pathways (**RAPs**): *improved seeds, fertilizer subsidies, crop insurance, agricultural labor, household size,*

Antle, et al., in prep.

RAPs for different Agricultural Models

RAPs have common narrative across scales: Scenarios for each scale/model link to provide required parameters



Point-based crop models:

Seeds, irrigation, fertilizer, soil fertility factors, post-process factors (improvements in non-modeled parameters; e.g., pests)

Global gridded crop models:

Seeds, fertilizer, irrigation, productivity multipliers (improvements in non-modeled parameters; e.g., pests)

Regional Economic models:

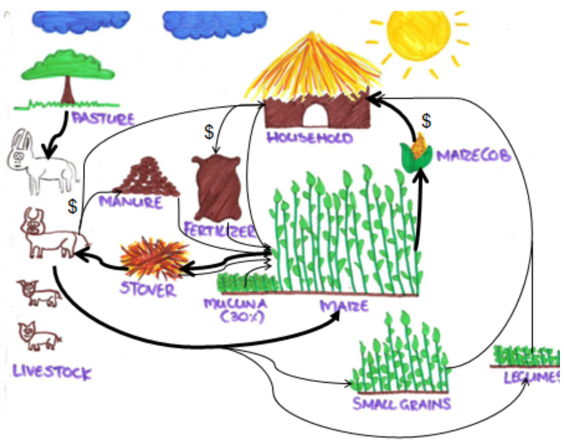
Fertilizer subsidies, commodity prices, crop insurance, labor availability, mechanization, household size, off-farm income, etc.

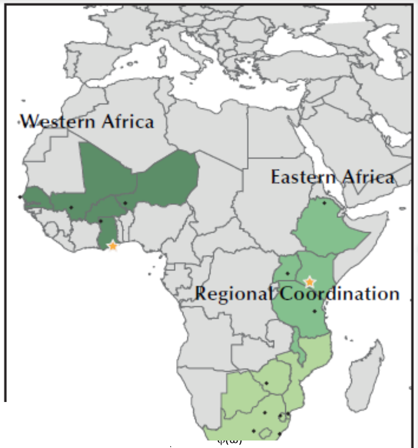
Global Agricultural Economic models:

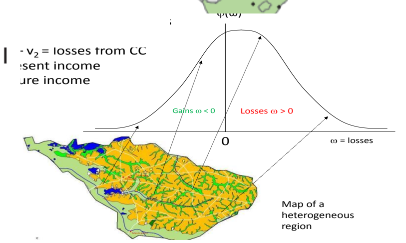
Productivity trends, land use, irrigation (each model has slightly different needs)

Coordinating across scales

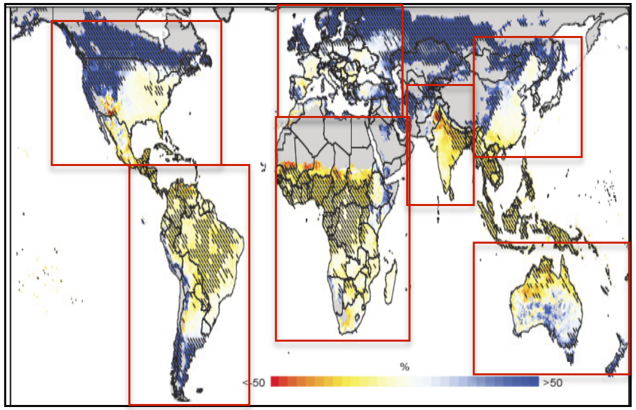
Track 2 -- Coordinated Global and Regional Multi-Model Assessments -- RCPs, SSPs, RAPs, IT



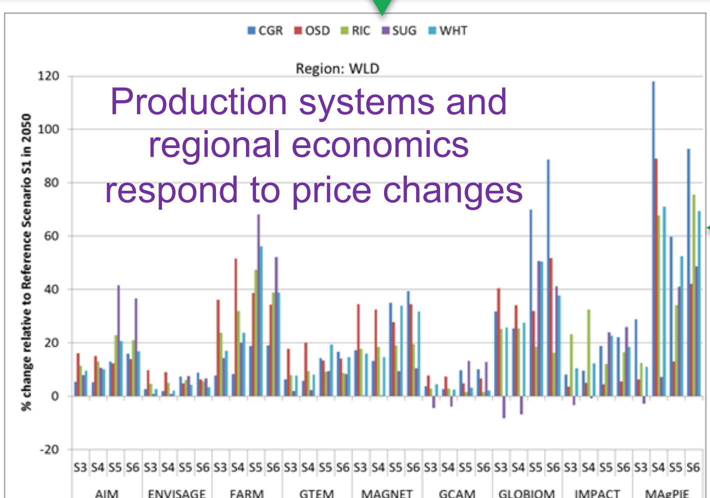




RRTs – Farming systems biophysical and socioeconomic models



GGCMI -- High-resolution gridded crop modeling for gap-filling and aggregation in each region



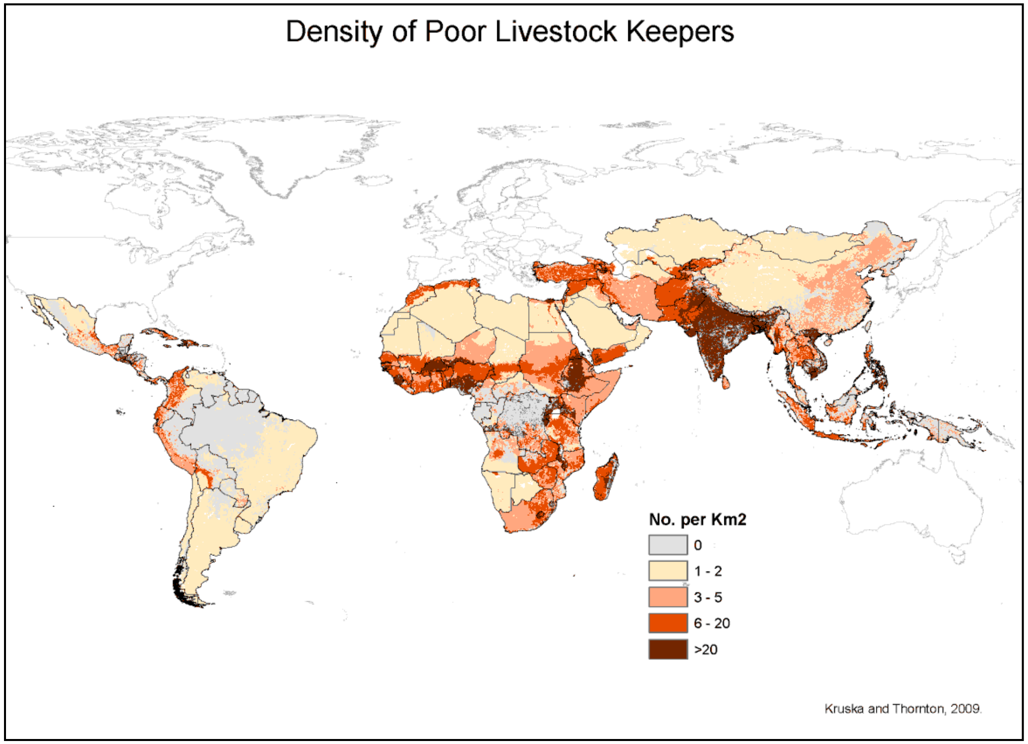
Production systems and regional economics respond to price changes

Global Economics – Model analysis of world and regional prices


Acknowledging what we do not know

Other Important Factors

- **Water Resources, Inland and Coastal Flooding**
- **Grasslands, Rangelands, and Livestock**
  - **Examining livestock effects to understand land-use competition**
- **Mitigation**
- **Soil Degradation**
- **Pests/Diseases**
- **Ozone**
- **Near-term climate scenarios**
  - **Developing statistical approaches**

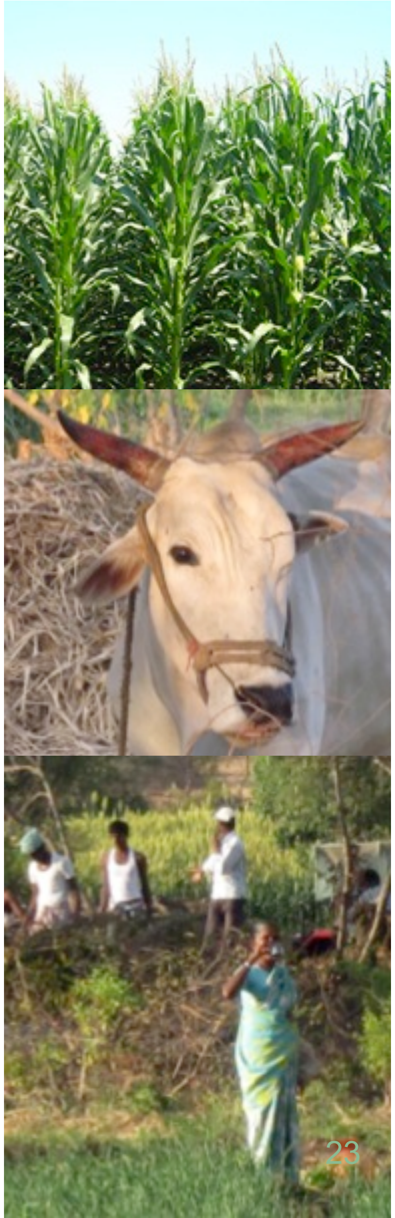


Need to factor in whether results are likely to be optimistic or pessimistic

Recognizing What We Have Learned

What AgMIP has learned so far

- **Tremendous interest** in agricultural research community in interdisciplinary multi-model research and assessment
- **Median of crop model ensembles** best reproduces observed conditions
- **Crop responses to CO_2, temperature, and water** remain key sources of uncertainty
- **Regional integrated assessments** are extending methods for projecting changes in farm systems
- **Global crop yield impacts** project greater vulnerability in lower latitudes and are vulnerable even in earlier decades; **model uncertainty now explicitly characterized**
- **Limitations in fresh water** for irrigation may compound climate impacts in many regions, while abundance could help in others.
- Climate change projected to exert **upward pressure on agricultural prices.**
- **Crop and economic model uncertainty** is large and generally greater than global climate model uncertainty, **depending on scales and methods**
- **Limited ability to run the number of scenarios and tests required for complete understanding of biophyscial and societal uncertainties**



Thank you!

More info at www.agmip.org

Crop Model Intercomparison Pilot Studies and Integrated Assessment Regions

- AgMIP has conducted Intercomparisons of wheat (27+ models), maize (22+), Rice (18+), and sugarcane (3+) models – uncertainties remain substantial
- Pilots under development: Millet/Sorghum, Potato, Grasslands, Bioenergy
- Regions under development: North America, Latin America/Caribbean, Europe, Sub-Saharan Africa, South Asia, East Asia, Australia

Rosenzweig et al., 2013; Li et al., 2014
Asseng et al., 2013;; Bassu et al., 2014

Impacts Response Surface Analysis

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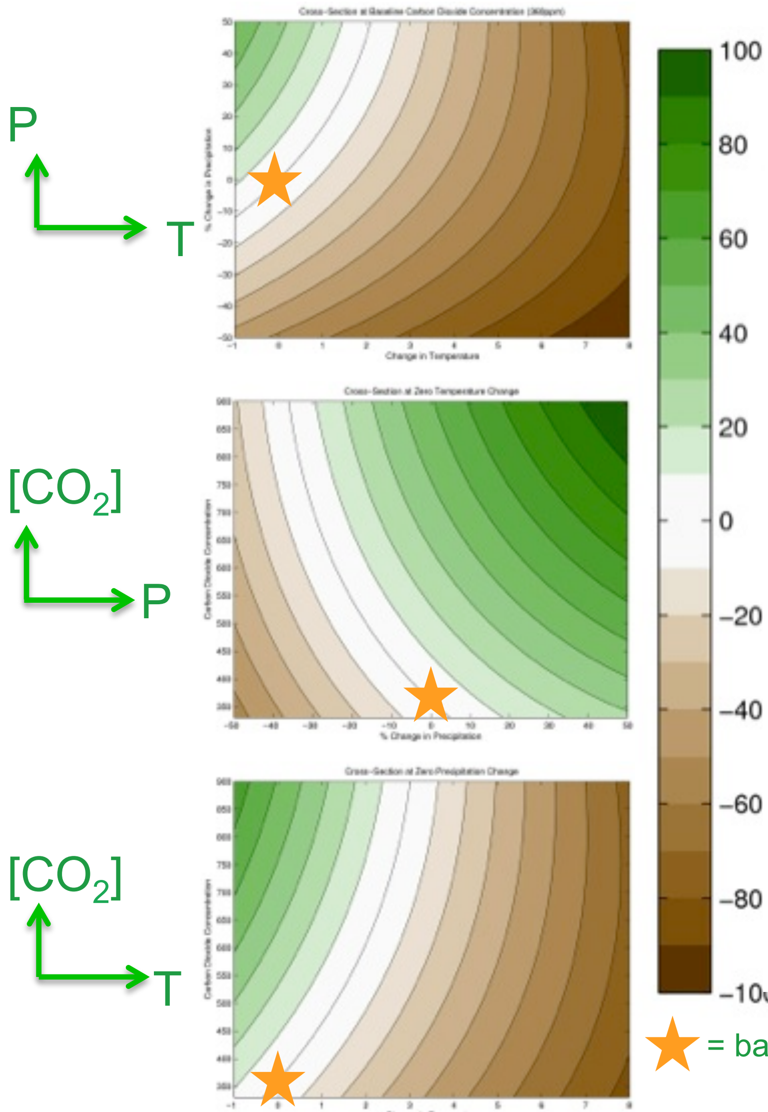
This row proxy for climate variability

This row crucial for climate change

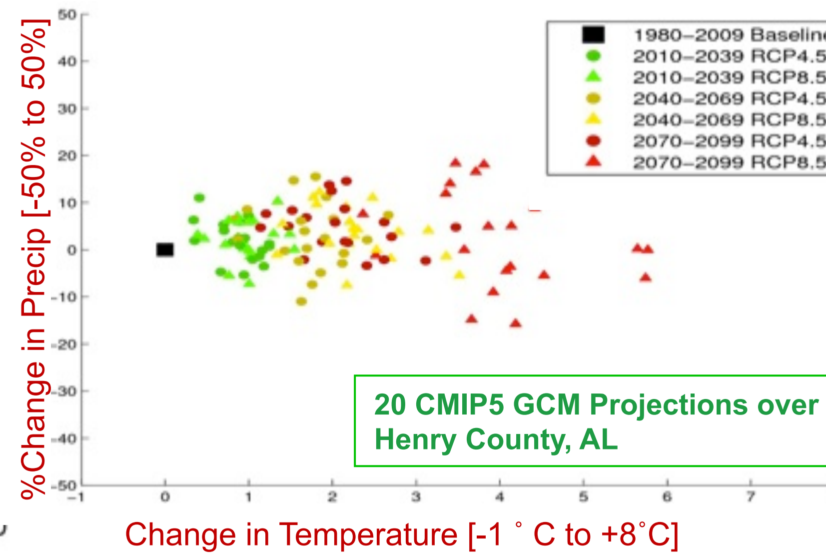


★ = baseline

Left: Cross Sections of Emulated Impacts Response for 30-year mean Peanut yield in Henry County (% change in yield)

Below: 20 CMIP5 GCM ΔT and Δ P projections over Henry County, AL; 2 RCPs and 3 time slices

From Ruane et al., 2014



20 CMIP5 GCM Projections over Henry County, AL

Cross Sections of Hypercube Emulator for percentage changes in 30-year mean Peanut yield, from Ruane et al., 2014.

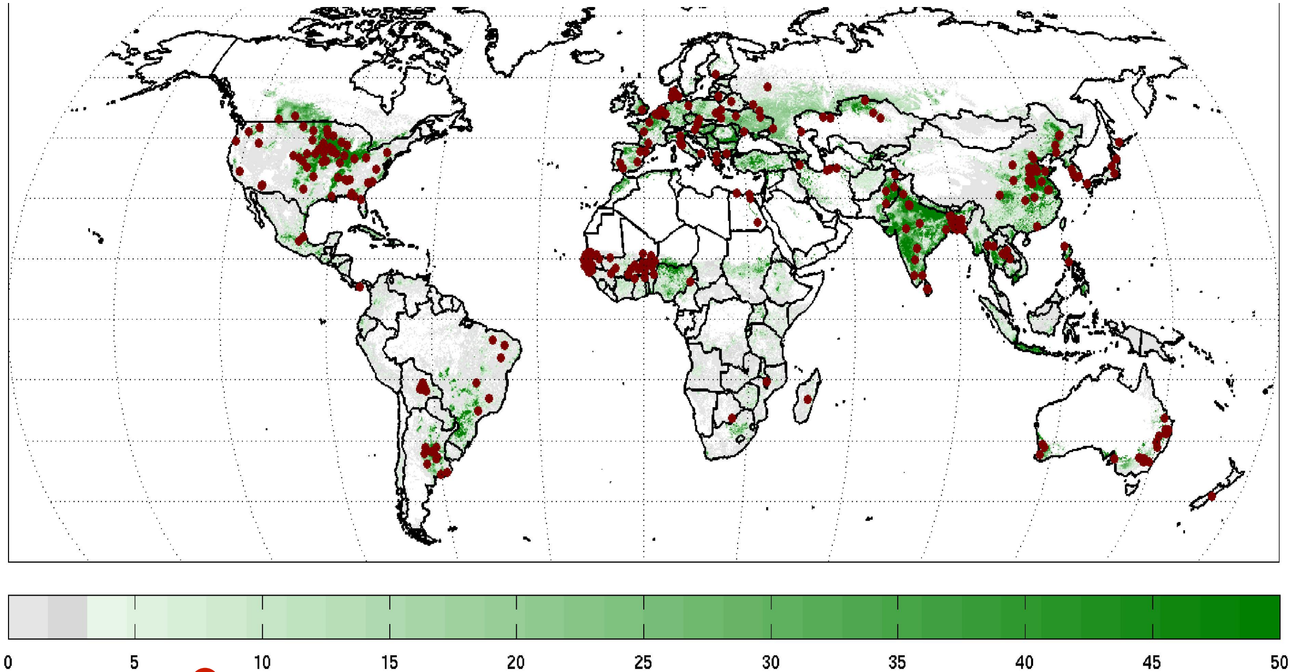
For more information, see www.agmip.org/c3mp

The Coordinated Climate-Crop Modeling Project (C3MP)

Alex Ruane, Sonali McDermid, Nicholas Hudson, Cynthia Rosenzweig, L. R. Ahuja, Saseendran S. Anapalli, Jakarat Anothai, Senthold Asseng, Dumont Benjamin, Federico Bert, Patrick Bertuzzi, Virendra S. Bhatia, Marco Bindi, Ian Broad, Davide Cammarano, Ramiro Carretero, Uran Chung, Giacomo De Sanctis, Thanda Dhliwayo, Frank Ewert, Roberto Ferrise, Thomas Gaiser, Guillermo Garcia, Sika Gbegbelegbe, Vellingiri Geethalakshmi, Edward Gerardeaux, Richard Goldberg, Brian Grant, Edgardo Guevara, Holger Hoffmann, Huanping Huang, Flavio Barbosa Justino, Asha S. Karunaratne, Ann-Kristin Koehler, Soora Naresh Kumar, Arunachalam Lakshmanan, Xiaomao Lin, Qunying Luo, Graciela Magrin, Yuji Masutomi, Theodoros Mavromatis, Greg McLean, Santiago Meira, Monoranjan Mohanty, Marco Moriondo, Lamyaa Negm, Francesca Orlando, Isik Ozturk, Zhiming Qi, Johanna Ramarohetra, Helene Raynal, Gabriel Rodriguez, Vaishali Sharda, Lu Shuo, Ward Smith, Afshin Soltani, K.Srinivas, Dillip Kumar Swain, Fulu Tao, Kindie Tesfaye, Maria I. Travasso, Giacomo Trombi, Federico E. Viscarra, Enli Wang, Hong Wang, Lee Byun-Woo, Yang Xiaoguang, Ban Ho Young, Jin I. Yun, and Zhigan Zhao

As of Global 4th Annual Workshop -- October 28, 2013

All C3MP Submitted Sites and Major Croplands (Percentage Area)



C3MP submitted site archive as of 02/01/2014

Area fractions from Monfreda et al., 2008

C3MP sites

Each ran 99 sensitivity tests:

ΔT = -1 to +9 C

Δ P = -50 to +50%

$[CO_2]$ = 330 to 900ppm

C3MP Archive

1000+ simulation sets

- **51 countries**
- **19 crop models**
- **14 crops**

Documentation of irrigation, N levels, growing season, calibration, key publication, and other key site attributes

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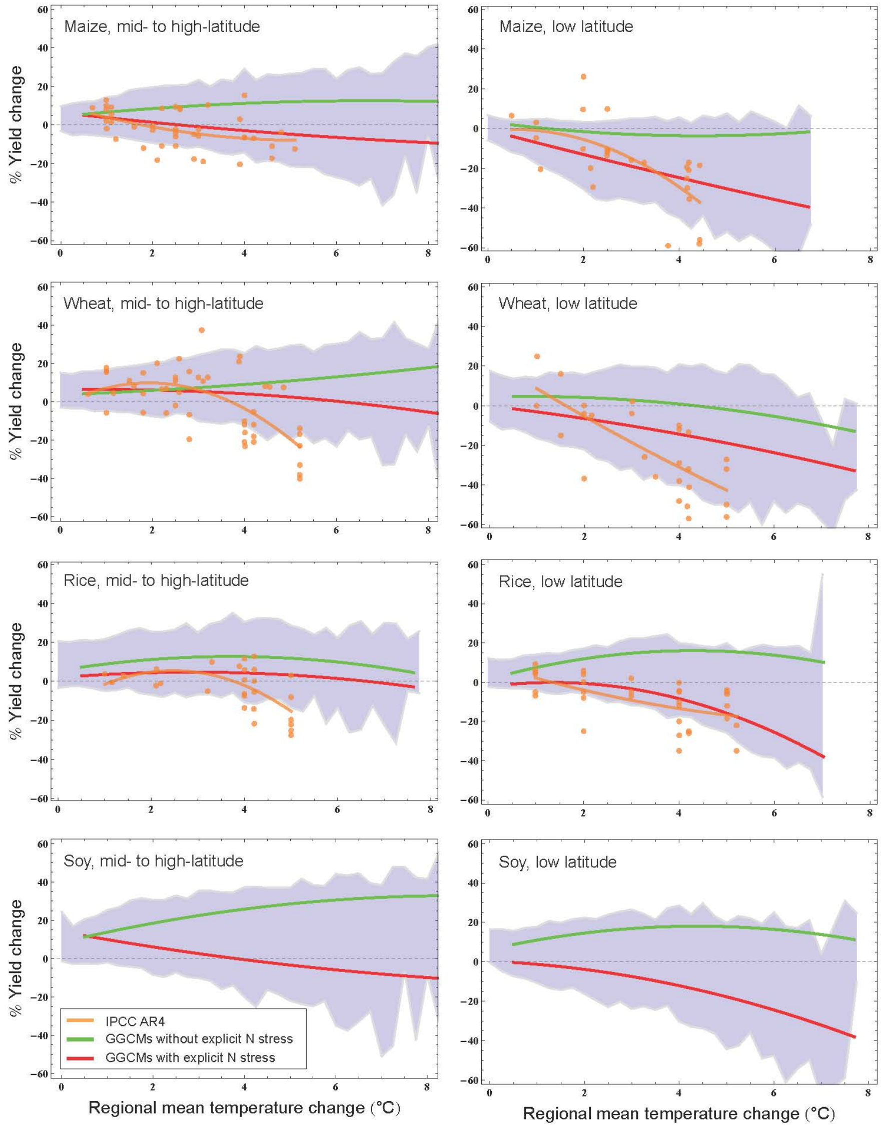
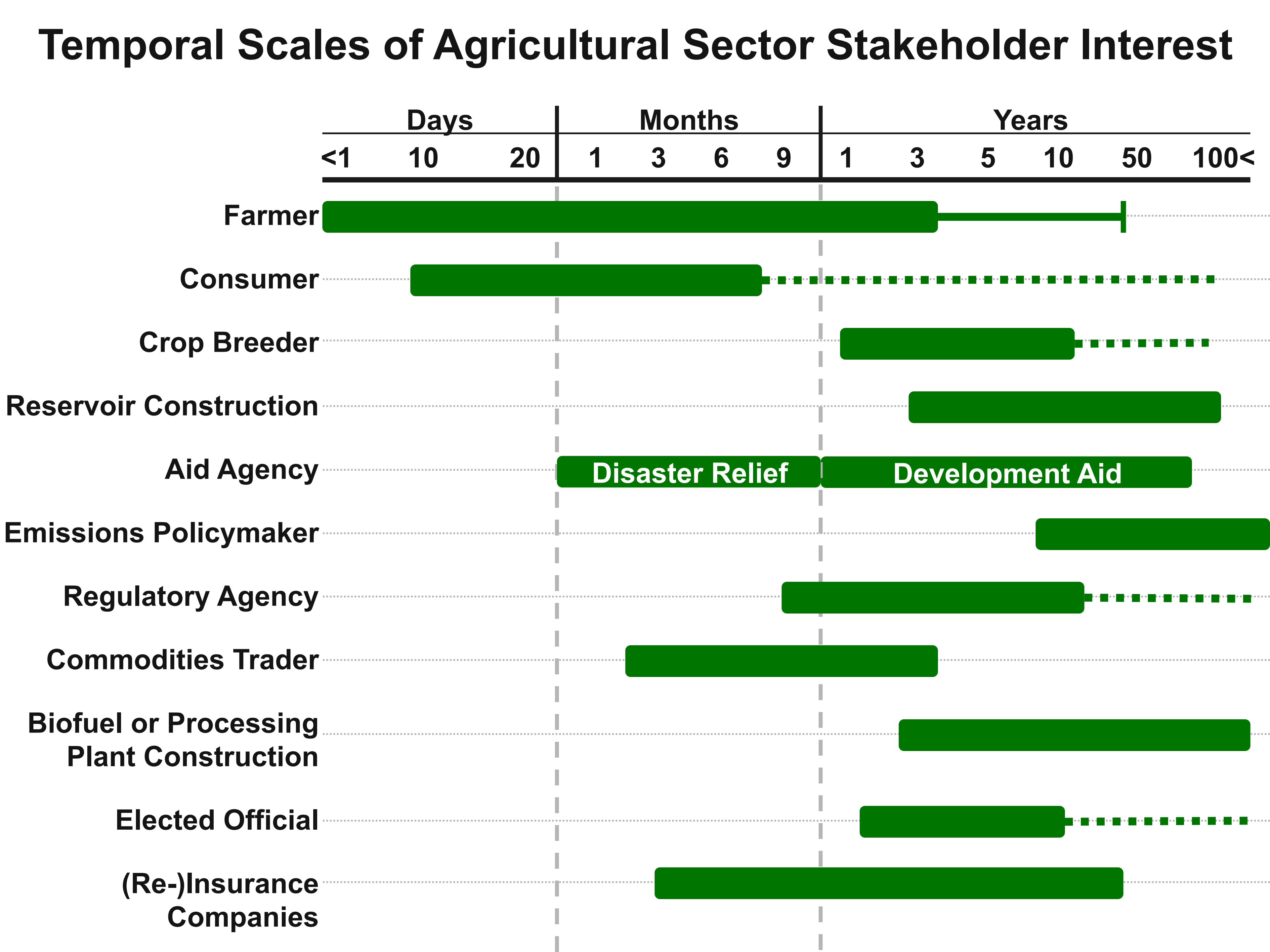
Findings for AR5



- **In contrast to previous assessments, AgMIP global gridded crop model results with realistic nitrogen fertilization show steadily decreasing yields for wheat, maize, and soybean in mid and high-latitude regions even for small temperature increases**
- **Crops in lower latitudes show greater vulnerability**
- **For the first time, crop model uncertainty has been characterized, highlighting the need for continuing rigorous model evaluation and improvement.**

(from Rosenzweig et al., 2013; PNAS)


Temporal Scales of Agricultural Sector Stakeholder Interest
Days
Months
Years
<1
10
20
1
3
6
9
1
3
5
10
50
100<
Farmer
Consumer
Crop Breeder
Reservoir Construction
Aid Agency
Disaster Relief
Development Aid
Emissions Policymaker
Regulatory Agency
Commodities Trader
Biofuel or Processing Plant Construction
Elected Official
(Re-)Insurance Companies