AgMIP - Agricultural Production, Sustainability and Climate Change

Senthold Asseng
Outline

1. Global Food Security
2. AgMIP
3. Climate change impacts
4. Concluding remarks
The Agricultural Challenge

- Food Security - Increased demand
  - Population increase
The Agricultural Challenge

- **Food Security - Increased demand**
- **Population increase**

**People:**
- 3 B in 1960
- 7.3 B now
- >9 B in 2050

- 800 M undernourished
  (declined by 100 M in last 14 year)

- **BUT** (West et al. 2014 Science)...
The Agricultural Challenge

- Food Security - Increased demand (Population increase)
- Need 60% more food in 2050 (Alexandratos & Bruinsma 2012 FAO Report)
- Increase nutritional value
- Reduce environmental impact (Irrigation in agriculture = 70% of global water withdrawals with India, Pakistan, China, USA = 72% of all irrigation) (West et al. 2014 Science)

High risk of surface water pollution across the world

Ippolito et al. 2015 Environmental Pollution
The Agricultural Challenge

Phosphorus loading in the Mississippi–Atchafalaya River Basin

Hunter et al. 2017 BioScience
The Agricultural Challenge

Climate Change

- Food Security - Increased demand
- Increase nutritional value
- Reduce environmental impact
Carbon dioxide acts like a blanket, absorbing IR radiation & preventing it from escaping into outer space. -→ net effect heating of Earth
Past temperature trend

NASA
Future temperature trend

Knutti and Sedlaczek 2013 Nature CC

‘Business as usual’

2015 Paris Agreement
The Agricultural Challenge

- Food Security - Increased demand
- Increase nutritional value
- Reduce environmental impact

Climate Change

- Temperature increased by 1.0 °C
- By 2050: Atmospheric CO₂ >500ppm
- By 2100:
  - More extremes (heat, droughts, rainfall).
  - Temperature +2 to 4 °C

(IPCC 2014)
Complexity

Food production system

Increasing Food Demand

Nutritional value

Climate Change

Environmental impact & sustainability
## Potential climate change impacts

<table>
<thead>
<tr>
<th>Change</th>
<th>Positive Impact</th>
<th>Negative Impact</th>
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<tbody>
<tr>
<td>1. Temperature increase</td>
<td>• Less frost damage</td>
<td>• Faster phenology</td>
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<td></td>
<td>• Improved winter growth</td>
<td>• Reduced chill hours</td>
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<td></td>
<td>• Earlier planting</td>
<td>• Increased heat stress</td>
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<td>2. Increased CO₂</td>
<td>• Growth stimulus (if nutrients not limiting)</td>
<td>• Increased water use</td>
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<td></td>
<td>• Increased water use efficiency</td>
<td>• Increased pest/disease</td>
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<td>3. More intense rainfall (Florida)</td>
<td>• Reduced diseases? (longer dry periods)</td>
<td>• Reduced nutrition</td>
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<td></td>
<td></td>
<td>• Warmer canopies (increased heat stress)</td>
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<td>• Increased weeds</td>
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<td>• More runoff</td>
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<td>• More chemical leaching</td>
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<td>• More irrigation</td>
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</table>
Potential climate change impacts

What is the quantitative impact of Climate Change on agriculture?
Modeling (Wheat) Cropping Systems

- Breeding
- Cultivar
- Agronomy
- Crop Management
- Soil
- Time

Factors:
- Ozone
- CO₂
- Light
- Temperature
- Rainfall/Irrigation

Carter 2013
AgMIP

Agricultural Model Intercomparison and Improvement Project

Led by Cynthia Rosenzweig, James W. Jones, Jerry Hatfield & John Antle
AgMIP Mission

Provide effective science-based agricultural decision-making models and assessments of climate variability and change and sustainable farming systems to achieve local-to-global food security.
AgMIP is a distributed climate-scenario simulation program:

- for historical model intercomparison and future climate change conditions,
- with participation of multiple crop and agricultural economics modeling groups around the world.

Rosenzweig et al., 2013 AgForMet
3 Focus Areas

Modeling for Sustainable Farming Systems

Coordinated Global and Regional Agricultural Assessments

NextGen Knowledge Products, Improved Models, Data
Phase 2 (2015-2020)

NextGen Models

Model calibration and improvement

Evaluation and intercomparison

Historical climate conditions

Agricultural System Models
Crops, economics, livestock, pest & disease, etc.

Future climate scenarios

Adaptation, mitigation, and extensions

Future agricultural production, trade, and food security

Sustainable Farming Systems and Climate-Smart Agriculture

Multi-model assessments

Rosenzweig et al., 2013 AgForMet
Regional Research Teams

5-year project, UK DFID funded
8 regional teams, 18 countries, ~200 scientists
Protocols for data, models, scenarios designed and implemented by multi-disciplinary teams and stakeholders

Rosenzweig and Hillel (Eds)
*Handbook of Climate Change and Agroecosystems*
Imperial College Press, 2015
AgMIP Regional Integrated Assessment – 5 Attributes

- Farming systems
- Transdisciplinary: biophysical/socio-economic
- Multi-scale: field, farm, region, global data and models
- Multiple climate and crop models
- Distributional results: impacts on poverty

Antle et al., 2015
For protocols, up-to-date events, and news; and to join AgMIP listserv – www.agmip.org
AgMIP-Wheat

25 models consistent across 2 data sets:

a) 4 pilot locations – contrasting conditions
b) 6 CIMMYT hot locations (2 cultivars)
Model ranking (to observation)

4-pilot locations – contrasting conditions

6-CIMMYT hot locations (2 cultivars)

No best model!
Multi-model ensembles

Asseng et al. 2015 Nature CC
Multi-model ensembles

- Multi-model ensemble median is a better predictor than any single model!

- Wheat yields --- Asseng et al. 2013 Nature CC
- Wheat yields (heat stress) --- Asseng et al. 2015 Nature CC
- Wheat variables --- Martre et al. 2014 GCB
- Maize yields --- Bassu et al. 2014 GCB
- Rice yields --- Li et al. 2014 GCB
- Potato yields --- Fleisher et al. 2016 GCB
Multi-model ensembles to reduce uncertainty

Required number of crop models to achieve <13.5% simulated impact variability (-)

Colors represent different CO₂ levels

Mean (+/- STD) of all locations

Asseng et al. 2013 Nature CC

(13.5% = Mean exp CV% (Taylor et al. 1999))
Simulating heat stress

Senescence acceleration routine with heat

Model A  Model B  Model C  Model D

Heat = 9 days around anthesis

Liu et al. 2016 GCB

Observed = symbols  Simulation = lines
Improved simulation of heat stress

Growing season mean $T$: 15°C, 22°C, 27°C

Total biomass (t/ha)

Observed = symbols
Multi-model simulation = shades (red shade = improved models)
Multi-model simulation medians = lines

Maiorano et al. 2016 FCR
Multi-model ensembles to reduce uncertainty

- Model improvements reduce required number of models in multi-model ensembles

  Maiorano et al. 2016 FCR
  Wang et al. 2017 Nature Plants
Wheat Yield decline with increasing temperature

30 model ensemble median (& mean of 30 years)

- 6% decline in global wheat production for each degree in global warming

Asseng et al. 2015 Nature CC
Experiments

Crop models

Statistical models

Senthold Asseng, AgMIP - Agricultural Production, Sustainability and Climate Change, APEC Climate Symposium, 18-20 August 2017, Can Tho, Vietnam
Impacts of global temperature increase on **global** yield estimates for major crops (using 4 methods)

**Yield impact with 1°C increase in global temperature (%)**

**Impacts of 1°C**

(For wheat: *Liu et al. 2016 Nature CC*)

*Zhao et al. 2017 PNAS*
Concluding remarks

1. Food security is a huge & complex challenge; increasing yields is part of it,

2. AgMIP – THE key international program for impact assessments,

3. Multi-model ensemble = best predictor across environments,

4. Global crop yields decline by 3-8% for each degree in global warming,

5. Need for: regional impact assessments, economic feedback, adaptations, other crops, GHG emissions, nutrients, other factors.

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