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**
  - **<u>Population increase</u>**

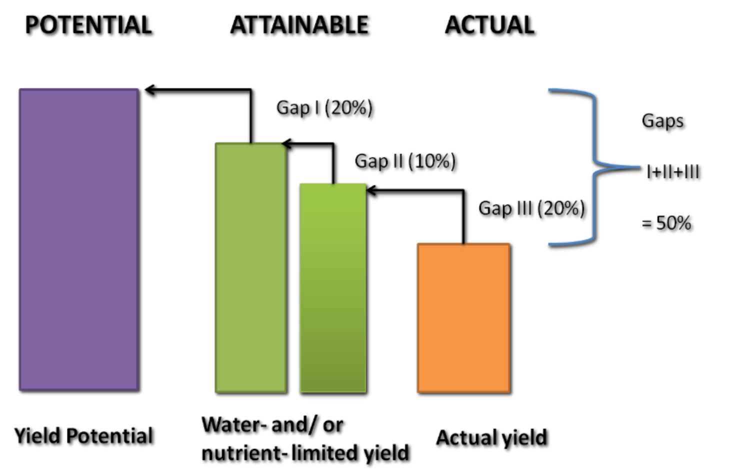
People:

- **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)…

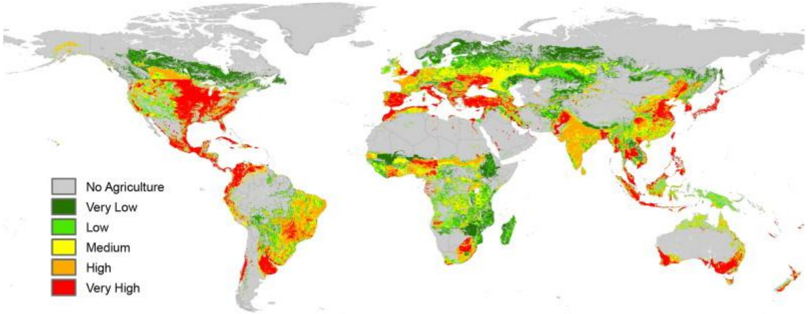
Undernourished population



The Agricultural Challenge

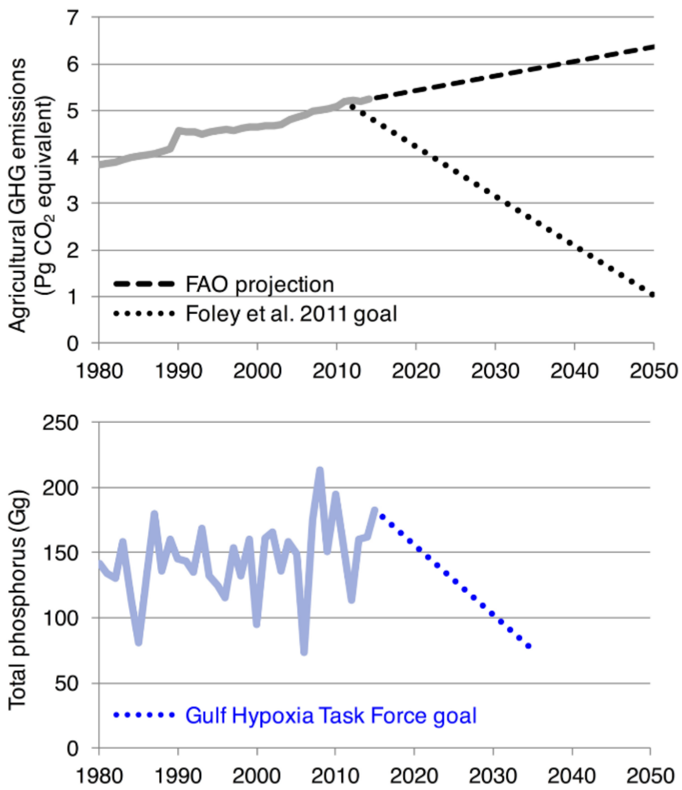
- **Food Security - Increased demand** **(Population increase)**
- **Need 60% more food in 2050**
  (Alexandratos & Bruinsma 2012 FAO Report)
- **Increase nutritional value**
- **Reduce environmental impact**
  (Irrigation in agriculture = 70% of global water withdrawals with India, Pakistan, China, 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



(k t)

Phosphorus loading in the Mississippi–Atchafalaya River Basin

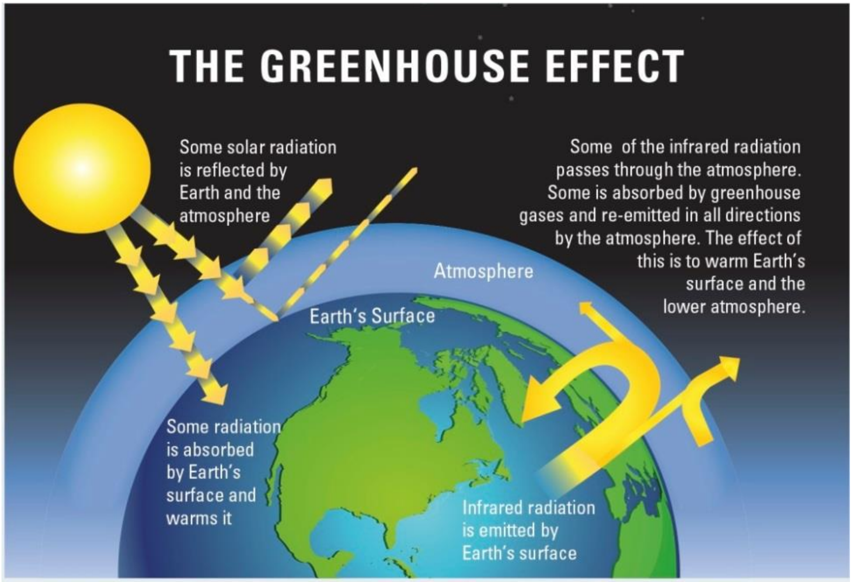
Hunter et al. 2017 BioScience

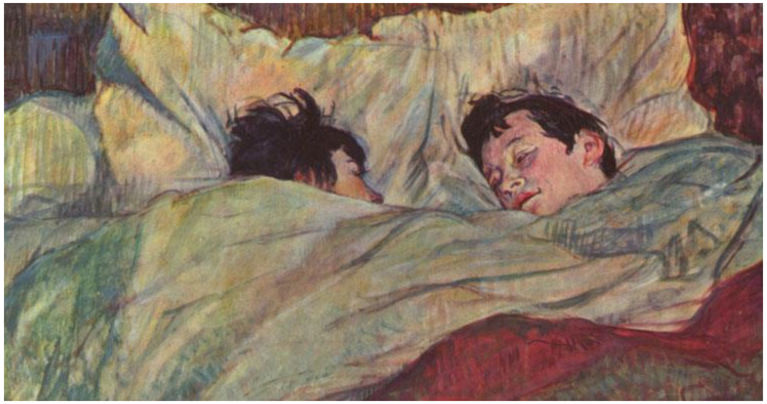
The Agricultural Challenge

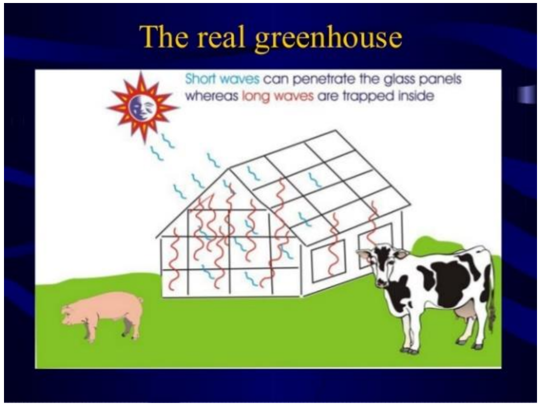
- Food Security - Increased demand
- Increase nutritional value
- Reduce environmental impact

Climate Change

Climate change & green house effect

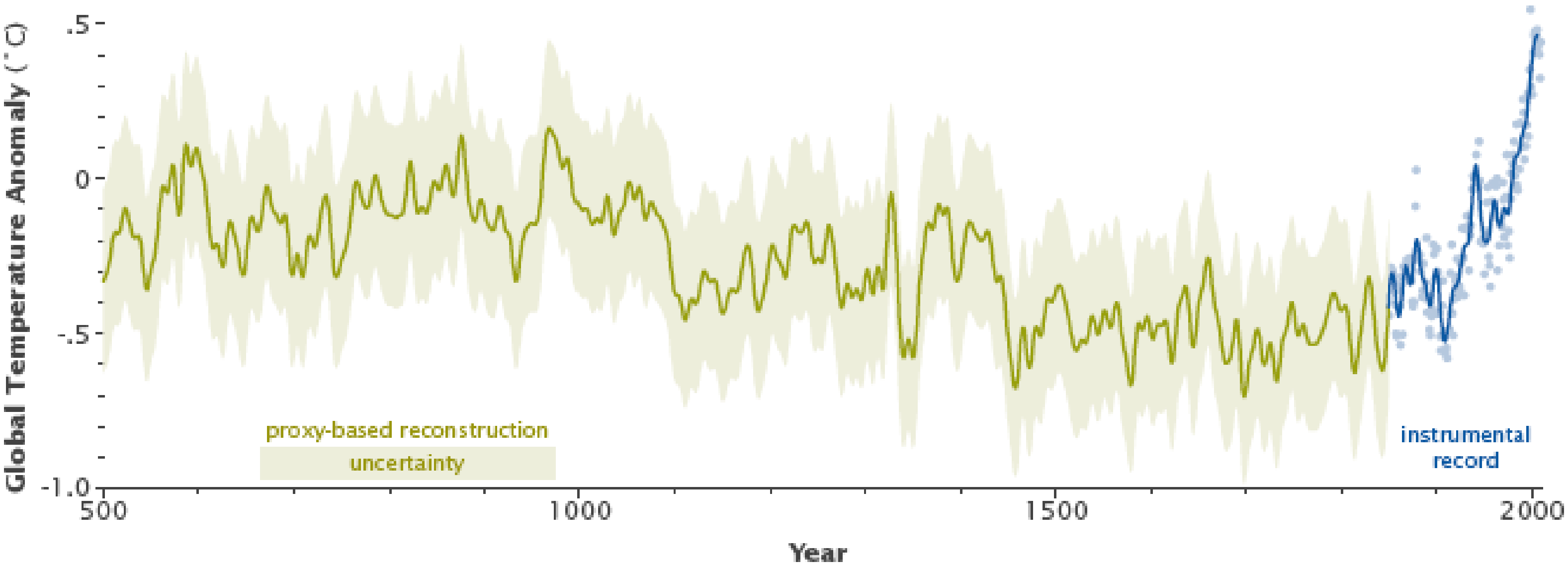






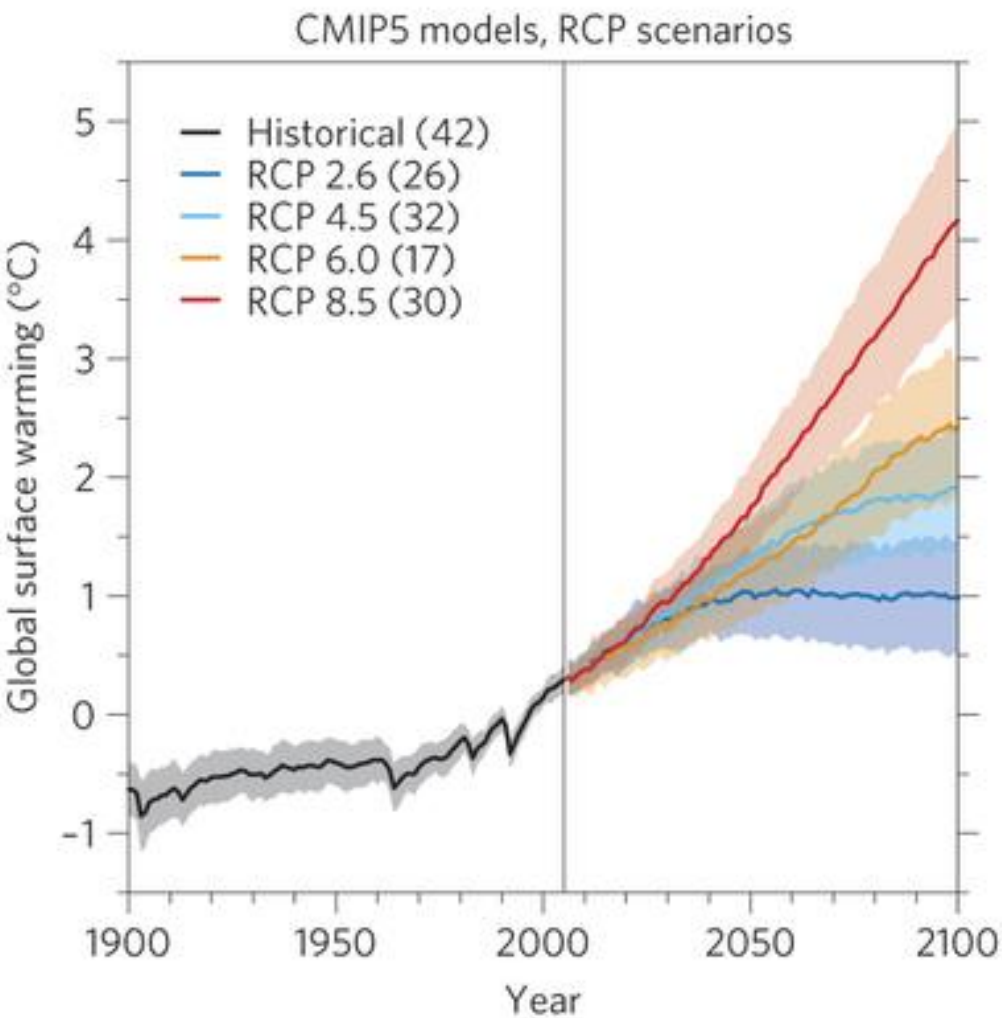
<u>Carbon dioxide</u> acts like a blanket, absorbing IR radiation & preventing it from escaping into outer space. -→ net effect heating of Earth

Past temperature trend



NASA

Future temperature trend



‘Business as usual’

2015 Paris Agreement

Knutti and Sedlacek 2013 Nature CC

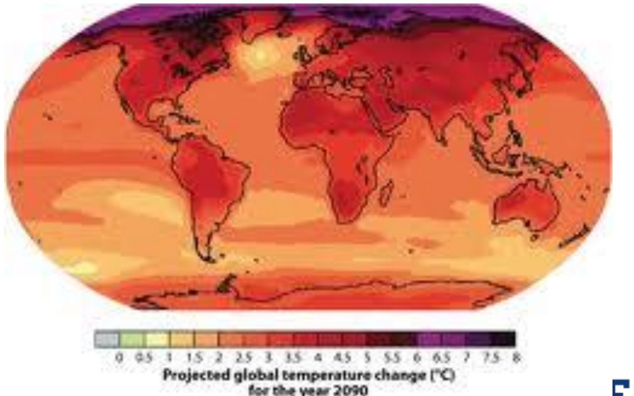
The Agricultural Challenge

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

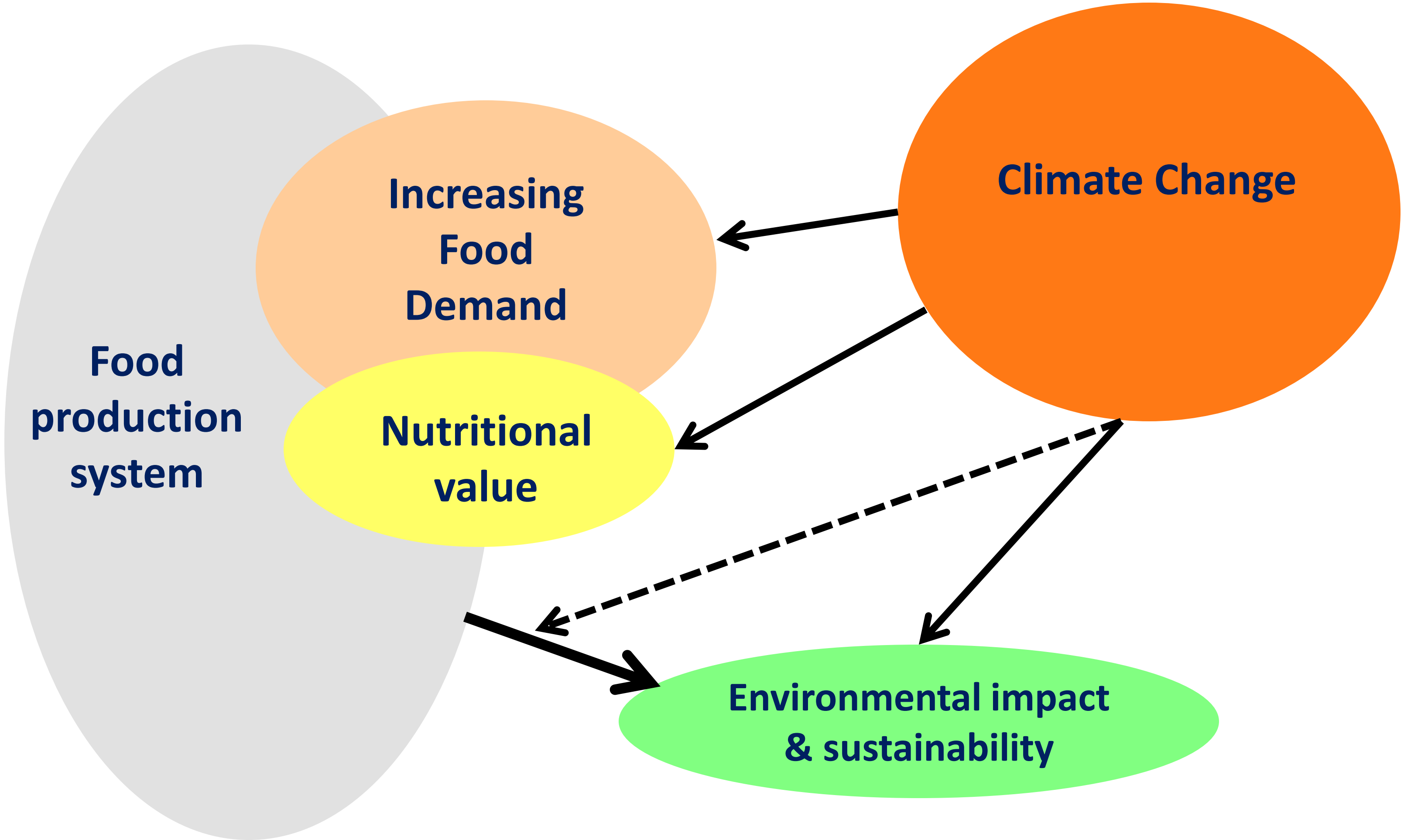
Climate Change

- Temperature increased by 1.0 ºC
- By 2050: Atmospheric CO_2 >500ppm
- By 2100:
  - More extremes (heat, droughts, rainfall).
  - Temperature +2 to 4 ºC

(IPCC 2014)



Complexity


Food
production
system
Increasing
Food
Demand
Nutritional
value
Climate Change
Environmental impact
& sustainability

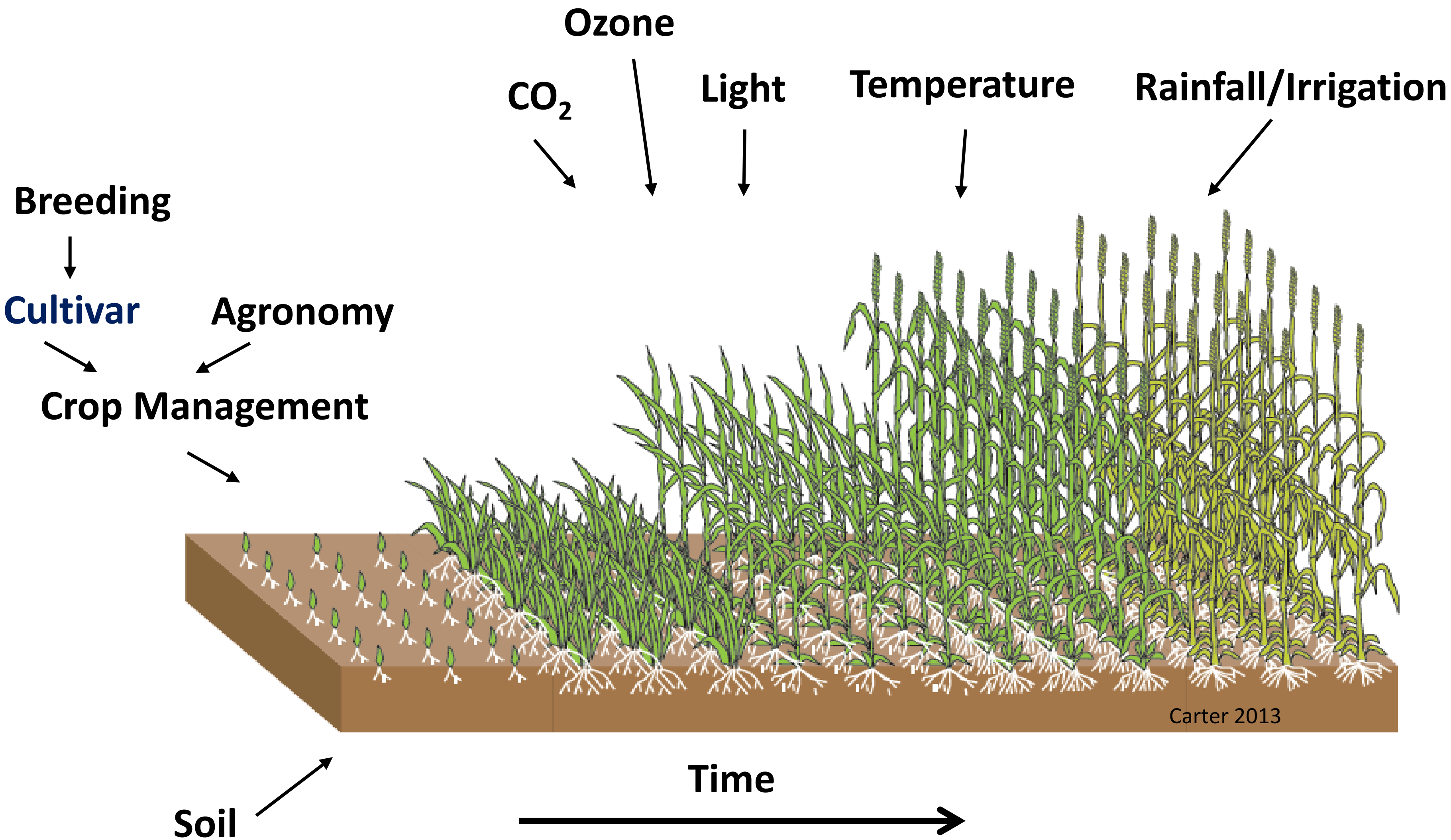
Potential climate change impacts

Change	Positive Impact	Negative Impact
1. Temperature increase	• Less frost damage • Improved winter growth • Earlier planting	• Faster phenology • Reduced chill hours • Increased heat stress • Increased water use • Increased pest/disease
2. Increased CO_2	• Growth stimulus (if nutrients not limiting) • Increased water use efficiency	• Reduced nutrition • Warmer canopies (increased heat stress) • Increased weeds
3. More intense rainfall (Florida)	• Reduced diseases? (longer dry periods)	• More runoff • More chemical leaching • More irrigation

Potential climate change impacts

What is the <u>quantitative</u> impact of Climate Change on agriculture ?

Modeling (Wheat) Cropping Systems



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

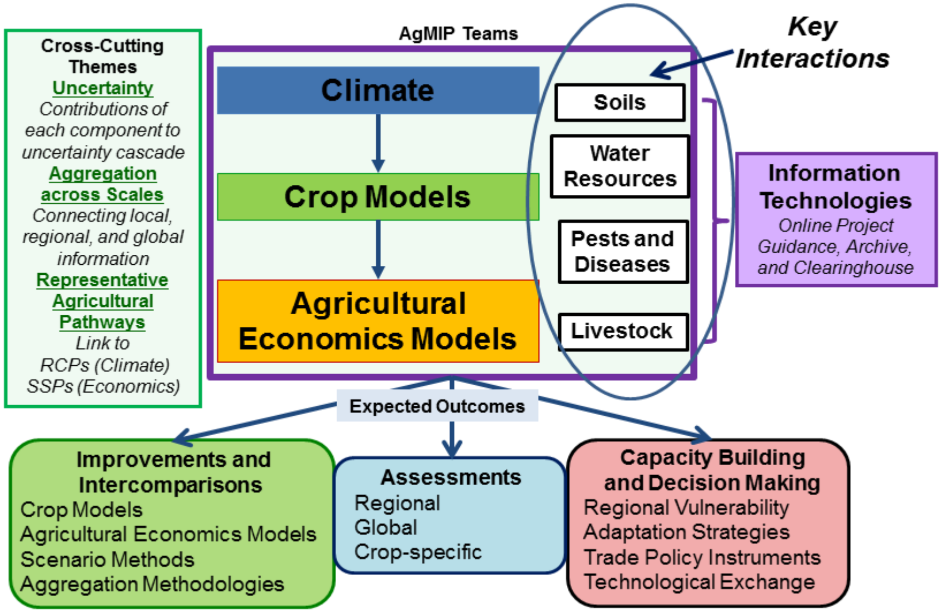
Near Arusha, Tanzania

AgMIP

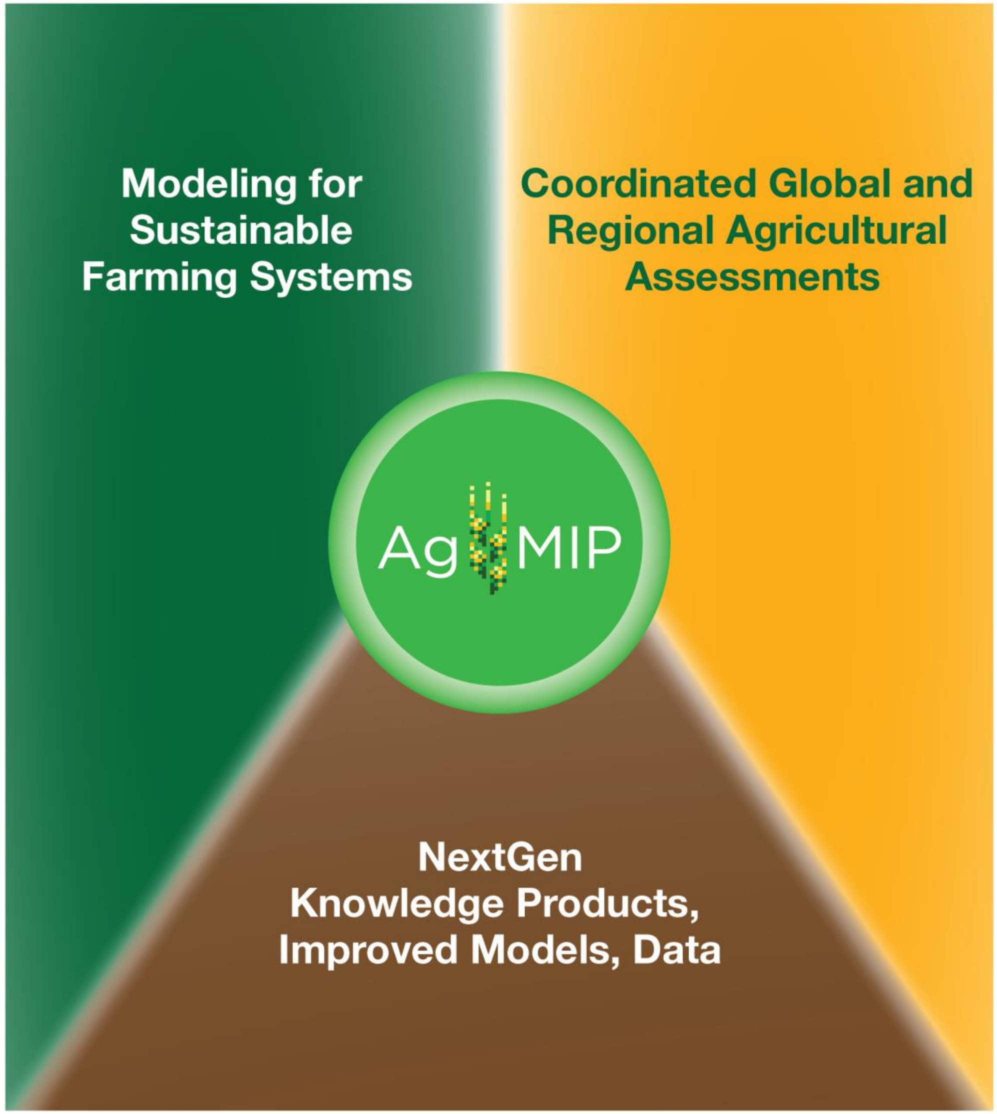
AgMIP is a distributed climate-scenario simulation program:

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

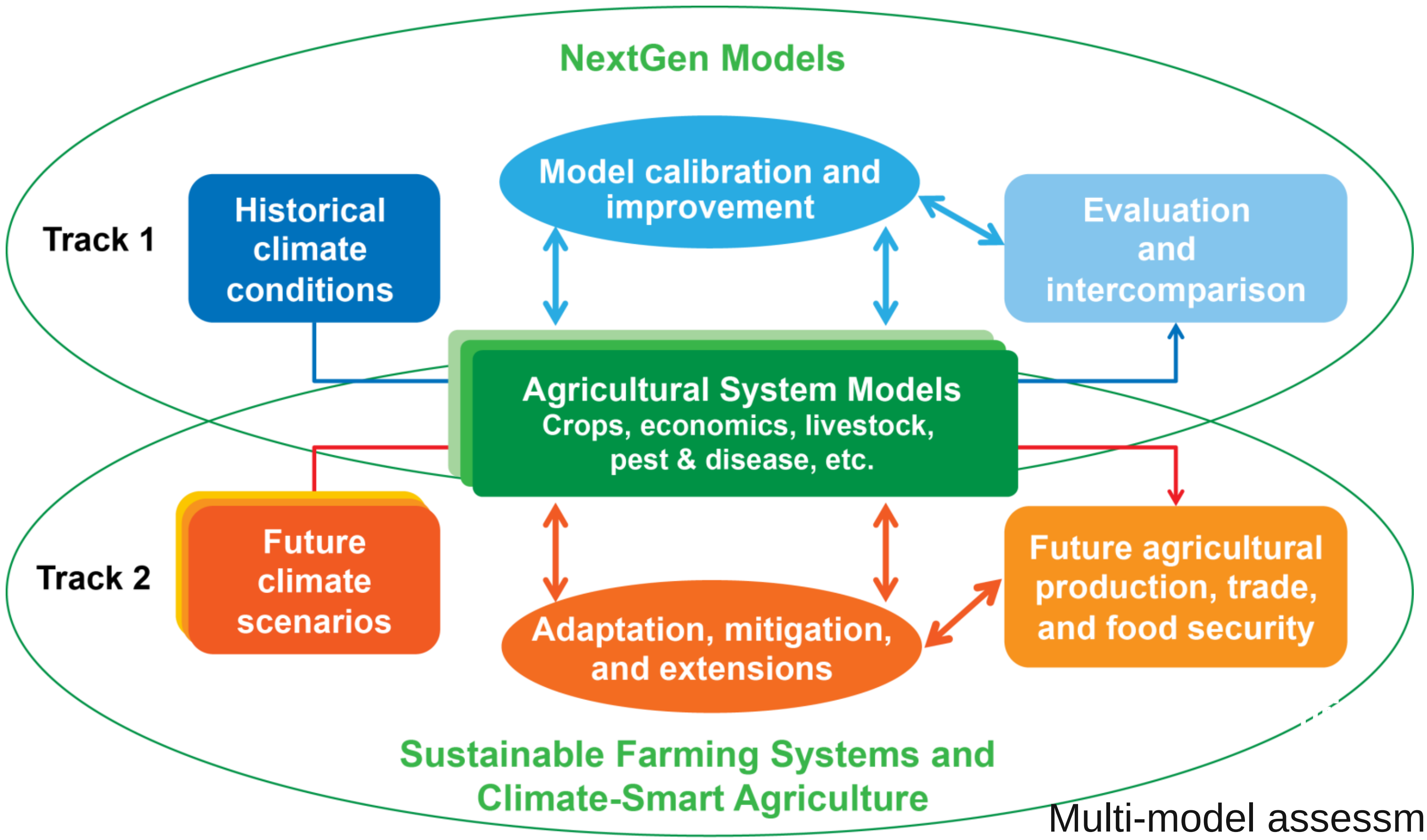
Rosenzweig et al., 2013 AgForMet



3 Focus Areas



Phase 2 (2015-2020)



Multi-model assessments

Rosenzweig et al., 2013 AgForMet

Worldwide Science Community


[redacted]


[redacted]


[redacted]

Over 850 members


[redacted]


[redacted]

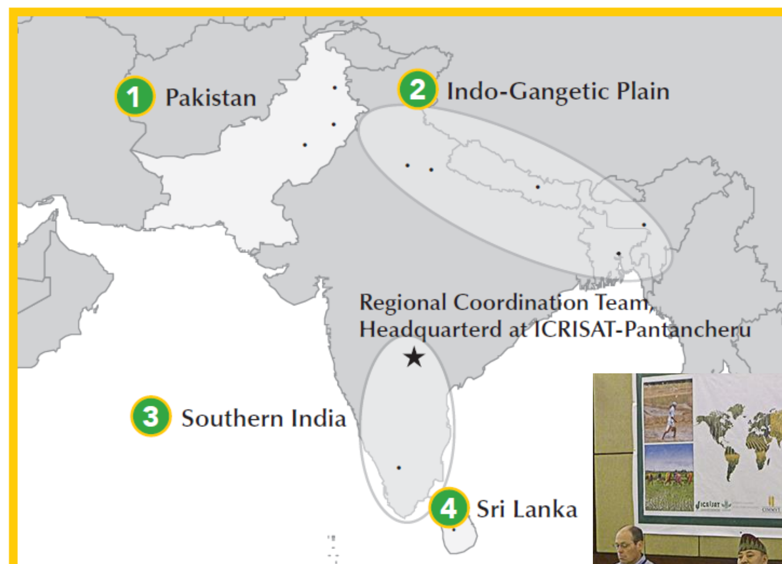

[redacted]


[redacted]

Regional Research Teams

Pretoria, South Africa
2013

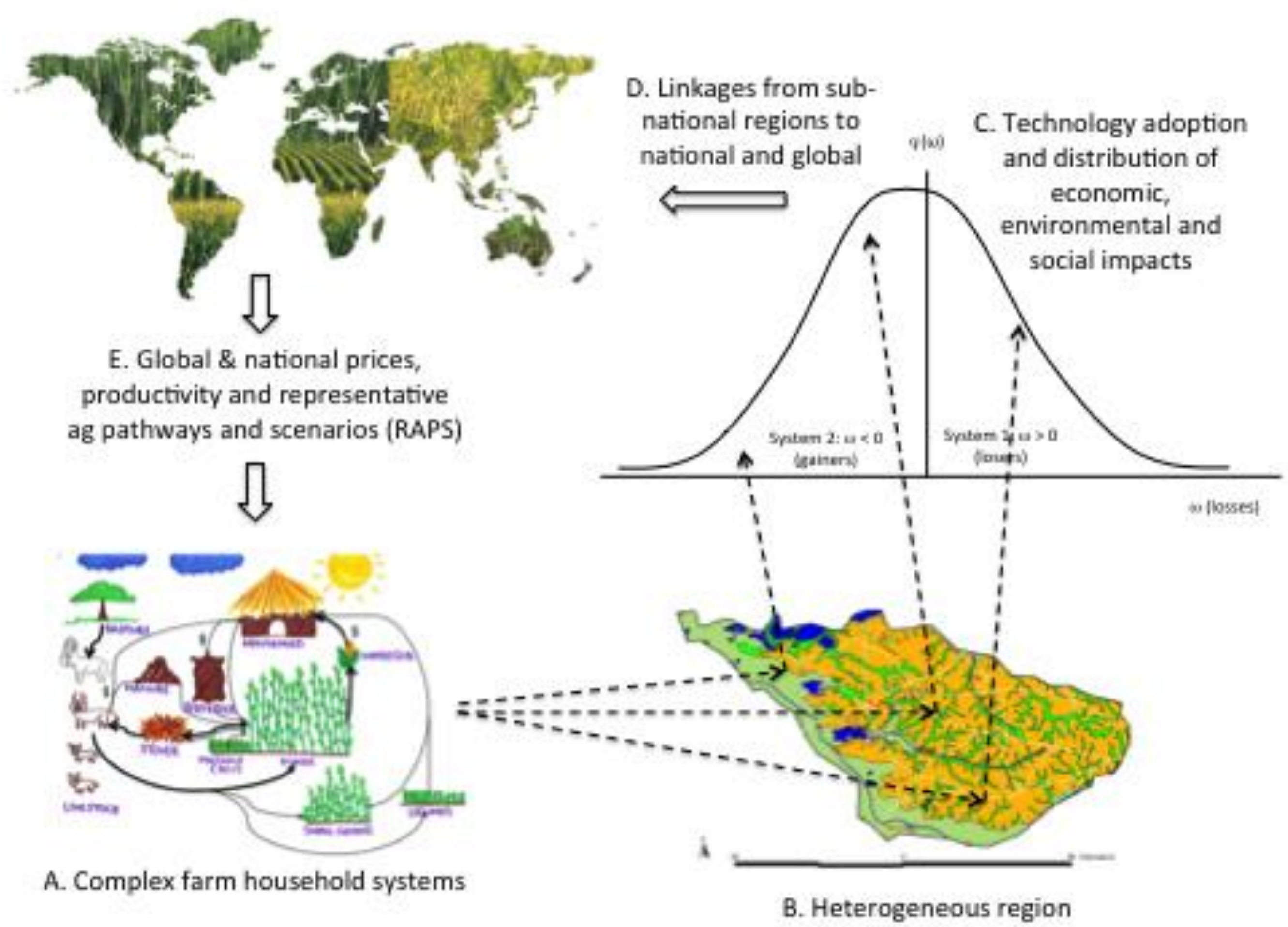
5-year project, UK DFID funded
8 regional teams, 18 countries, ~200 scientists
Protocols for data, models, scenarios designed and implemented by multi-disciplinary teams and stakeholders



Katmandu, Nepal, 2013

Rosenzweig and Hillel (Eds)
Handbook of Climate Change and Agroecosystems
Imperial College Press, 2015

AgMIP Regional Integrated Assessment – 5 Attributes

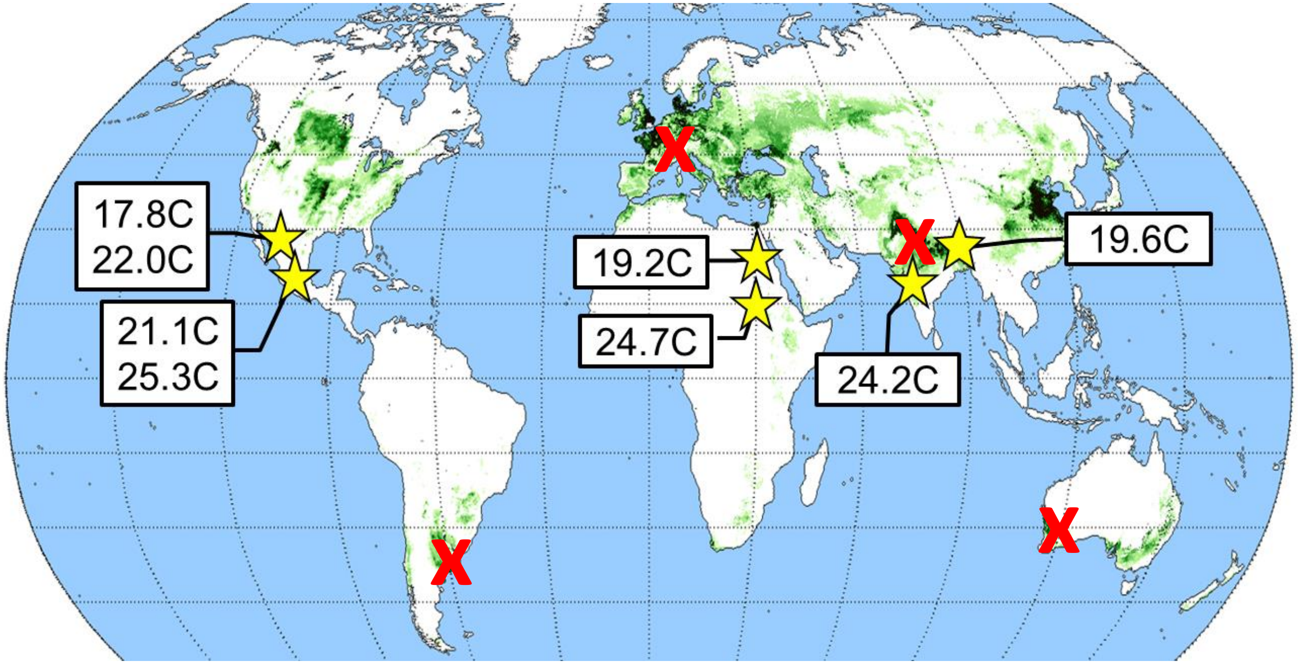


- Farming systems
- Transdisciplinary: biophysical/ socio-economic
- Multi-scale: field, farm, region, global data and models
- Multiple climate and crop models
- Distributional results: impacts on poverty

Antle et al., 2015

For protocols, up-to-date events, and news; and to join AgMIP listserv – www.agmip.org

AgMIP-Wheat



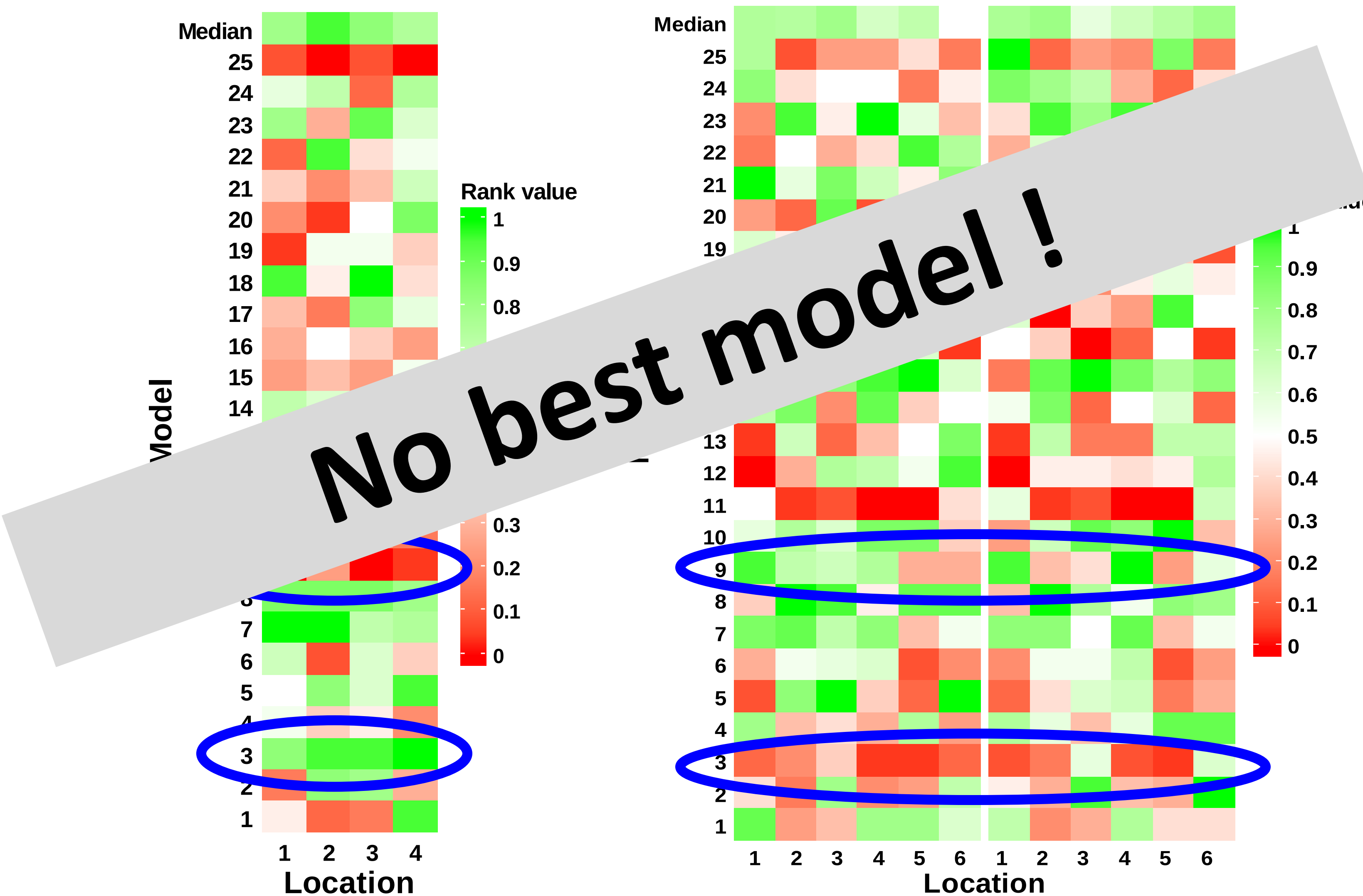
25 models consistent across 2 data sets:

a) 4 pilot locations – contrasting conditions

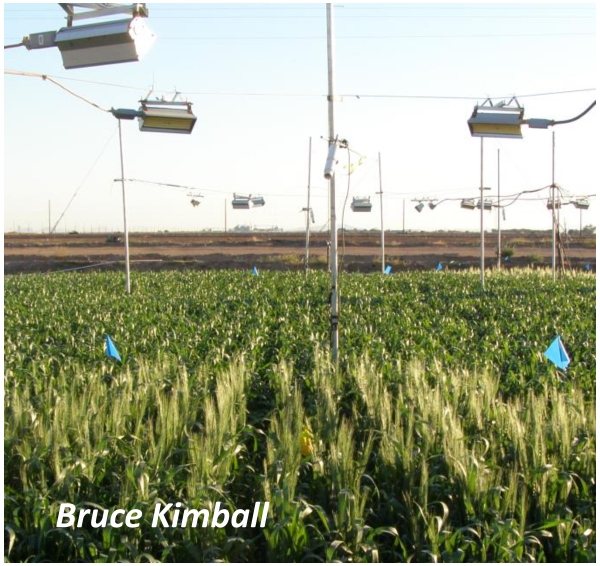
b) 6 CIMMYT hot locations (2 cultivars)

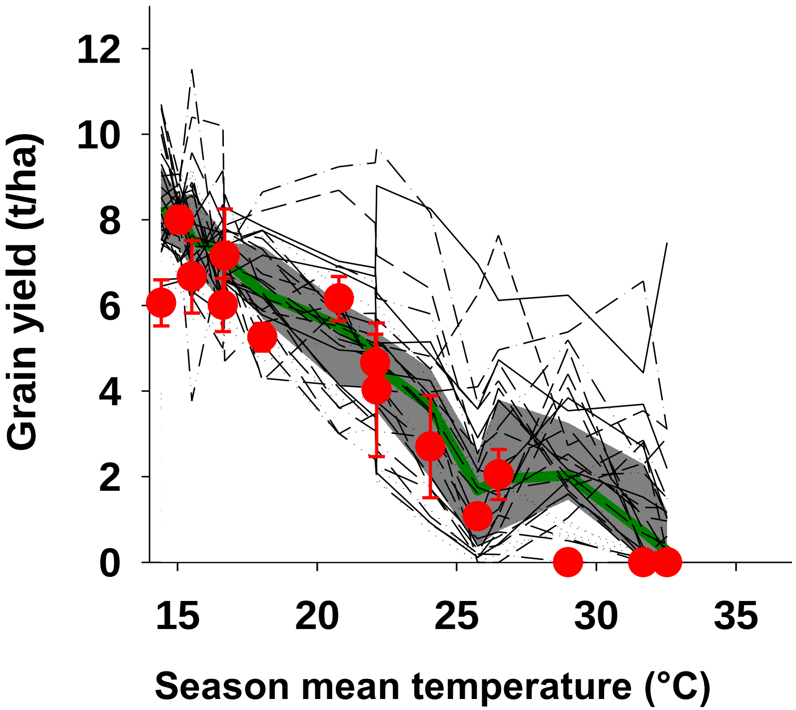
Model ranking (to observation)

4-pilot locations – contrasting conditions 6-CIMMYT hot locations (2 cultivars)



Multi-model ensembles





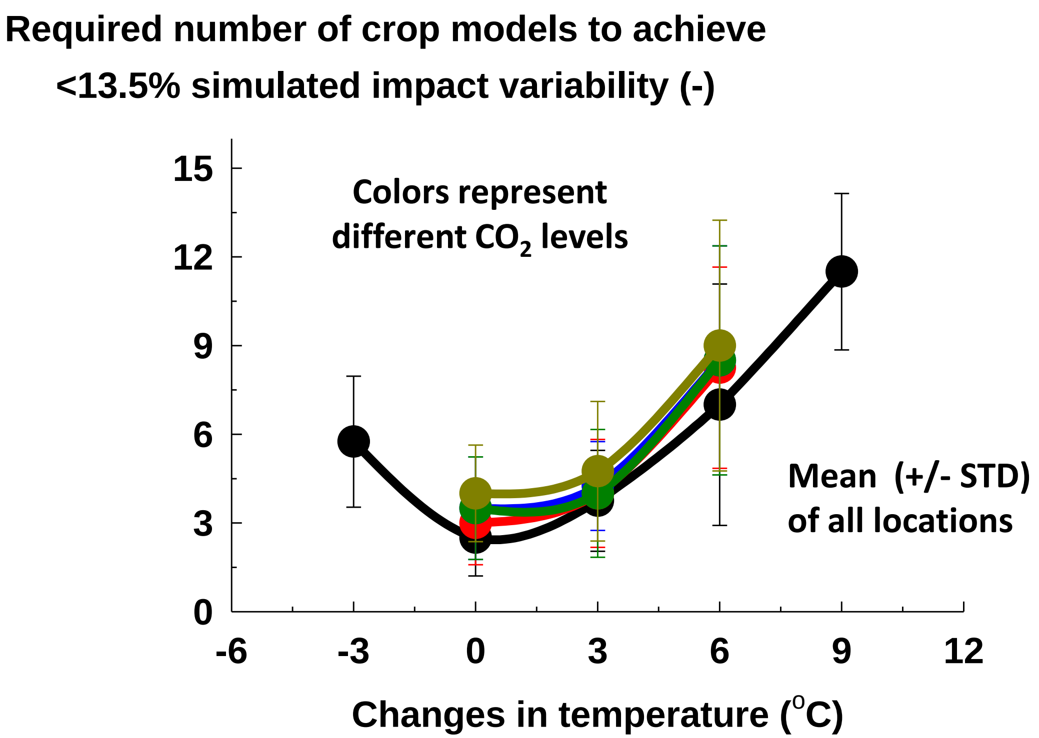
Asseng et al. 2015 Nature CC

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



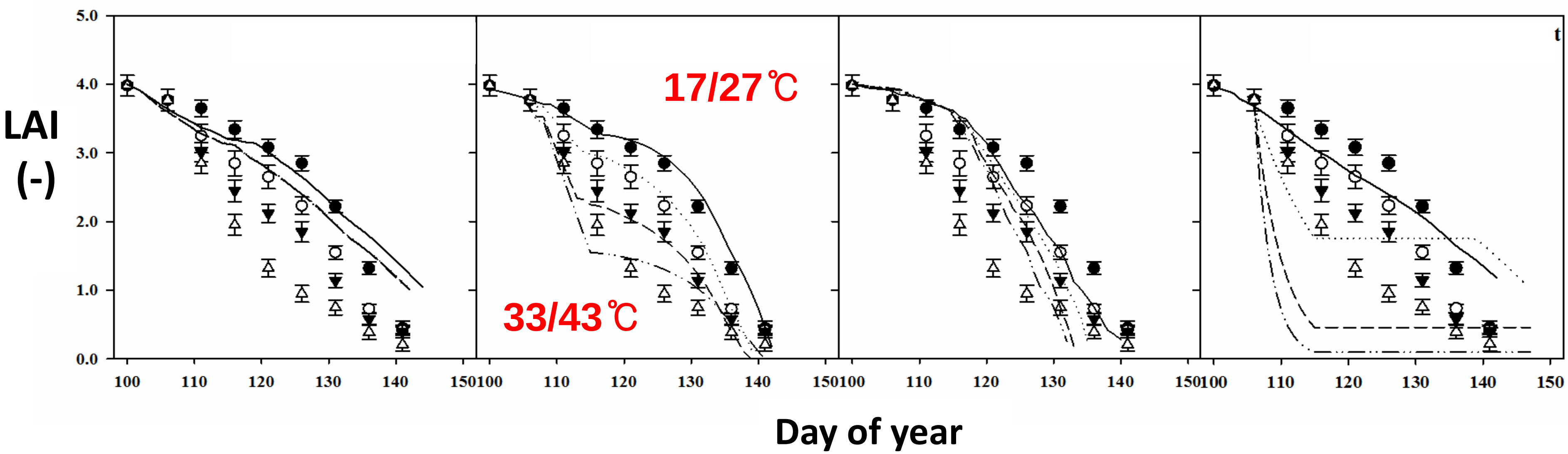
Asseng et al. 2013 Nature CC

(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

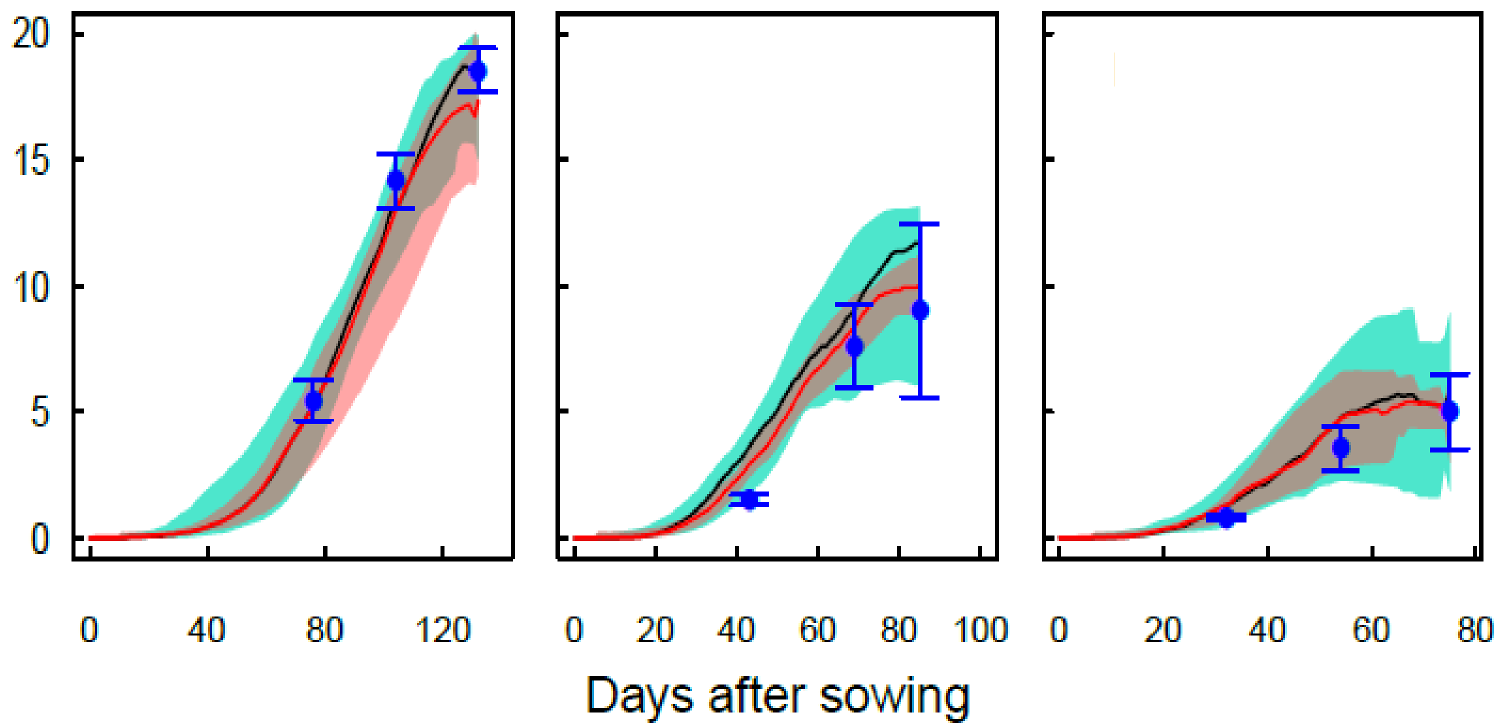
Liu et al. 2016 GCB

Observed = symbols **Simulation = lines**

Improved simulation of heat stress

Growing season mean T: 15°C 22°C 27°C

Total biomass (t/ha)



Maiorano et al. 2016 FCR

Observed = symbols

Multi-model simulation = shades (red shade = improved models)

Multi-model simulation medians = lines

Multi-model ensembles to reduce uncertainty

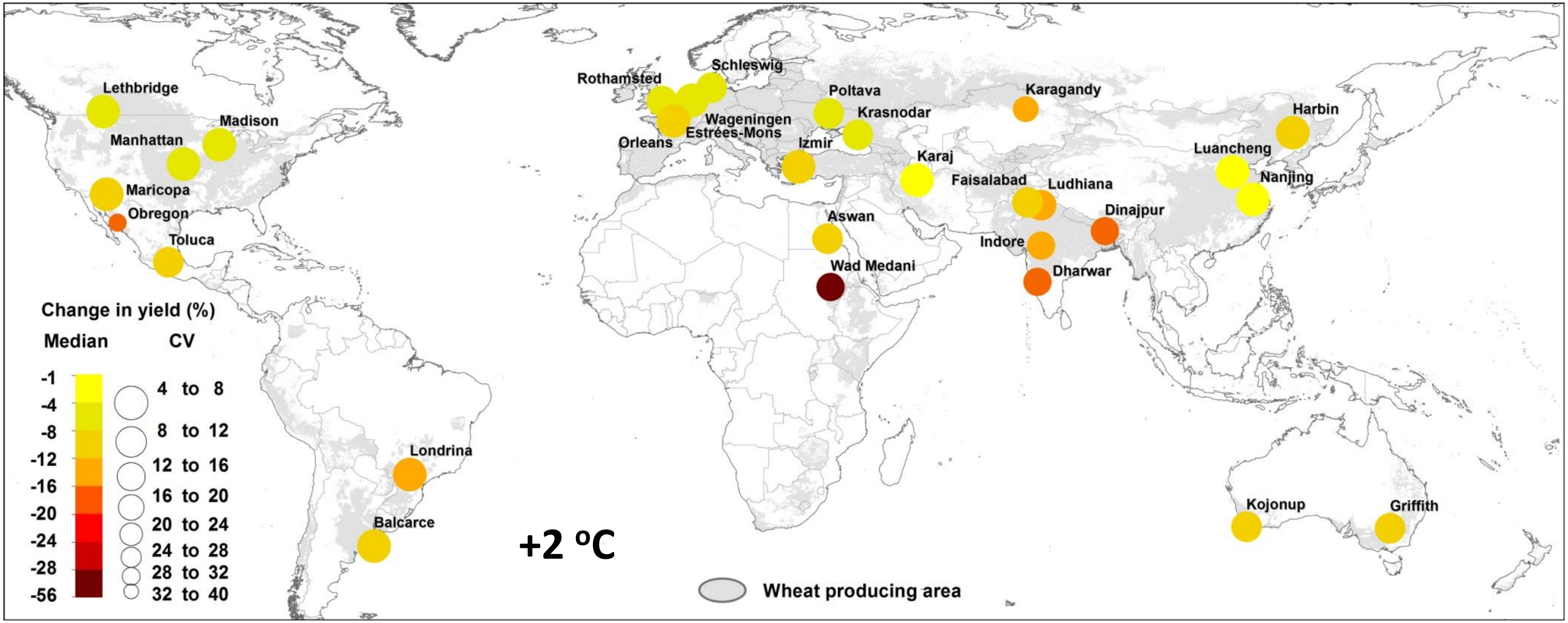
- ***Model improvements reduce required number of models in multi-model ensembles***

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)



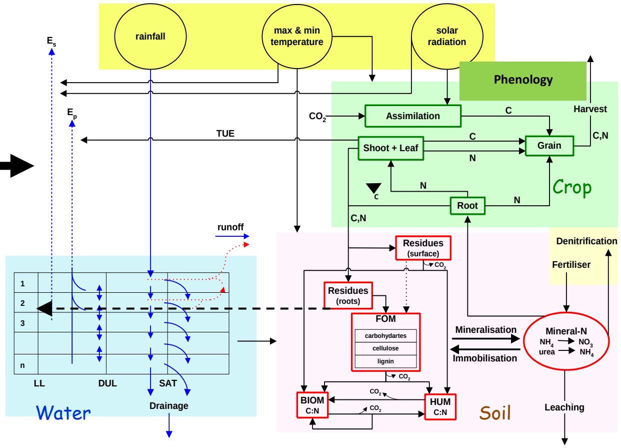
➢ **6% decline in global wheat production for each degree in global warming**

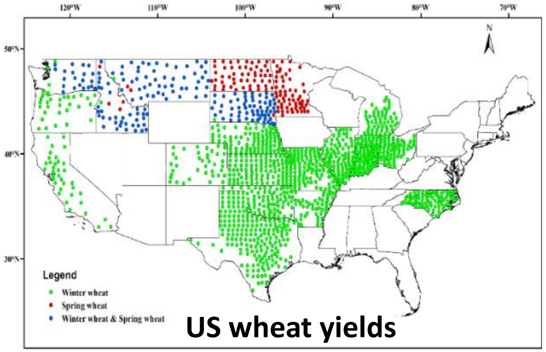
Asseng et al. 2015 Nature CC

Experiments

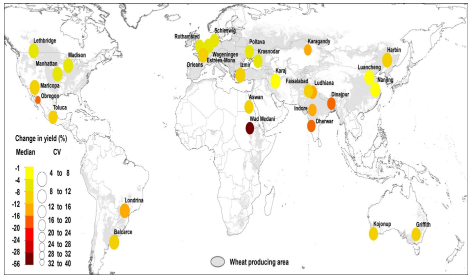
Crop models

Statistical models

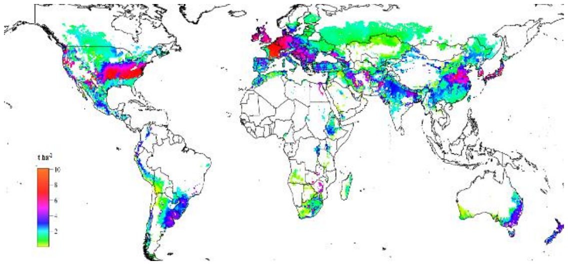




Multi-model points



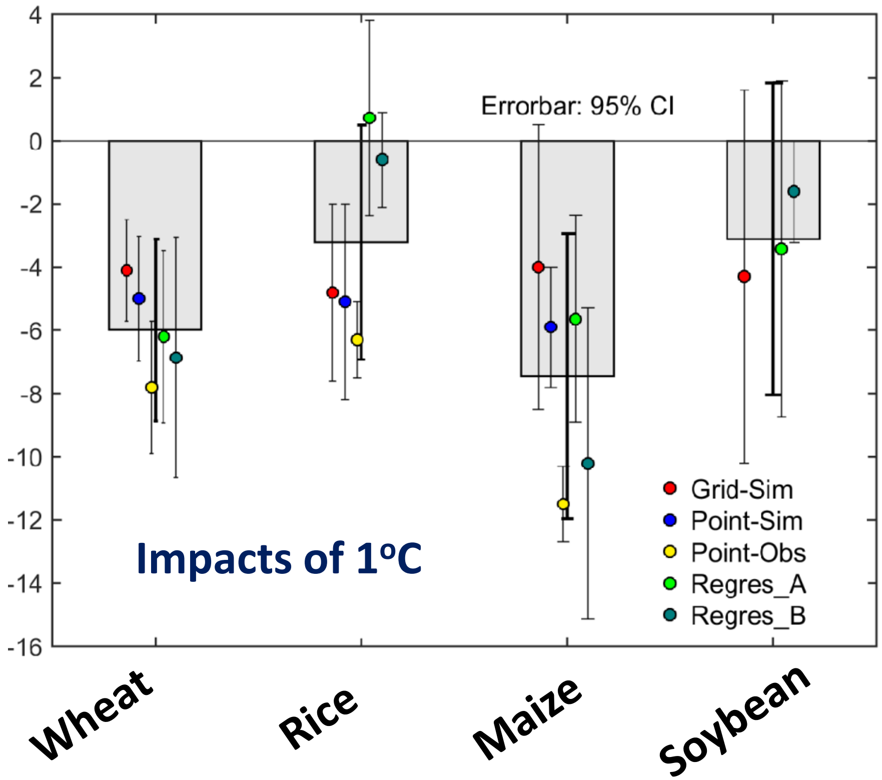
Global-gridded

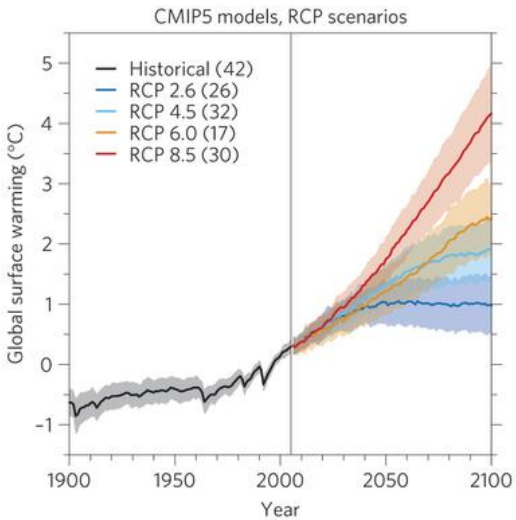


Impact

Impacts of global temperature increase on global yield estimates for major crops (using 4 methods)

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





Knutti and Sedlacek 2013 Nature CC

Zhao et al. 2017 PNAS

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

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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