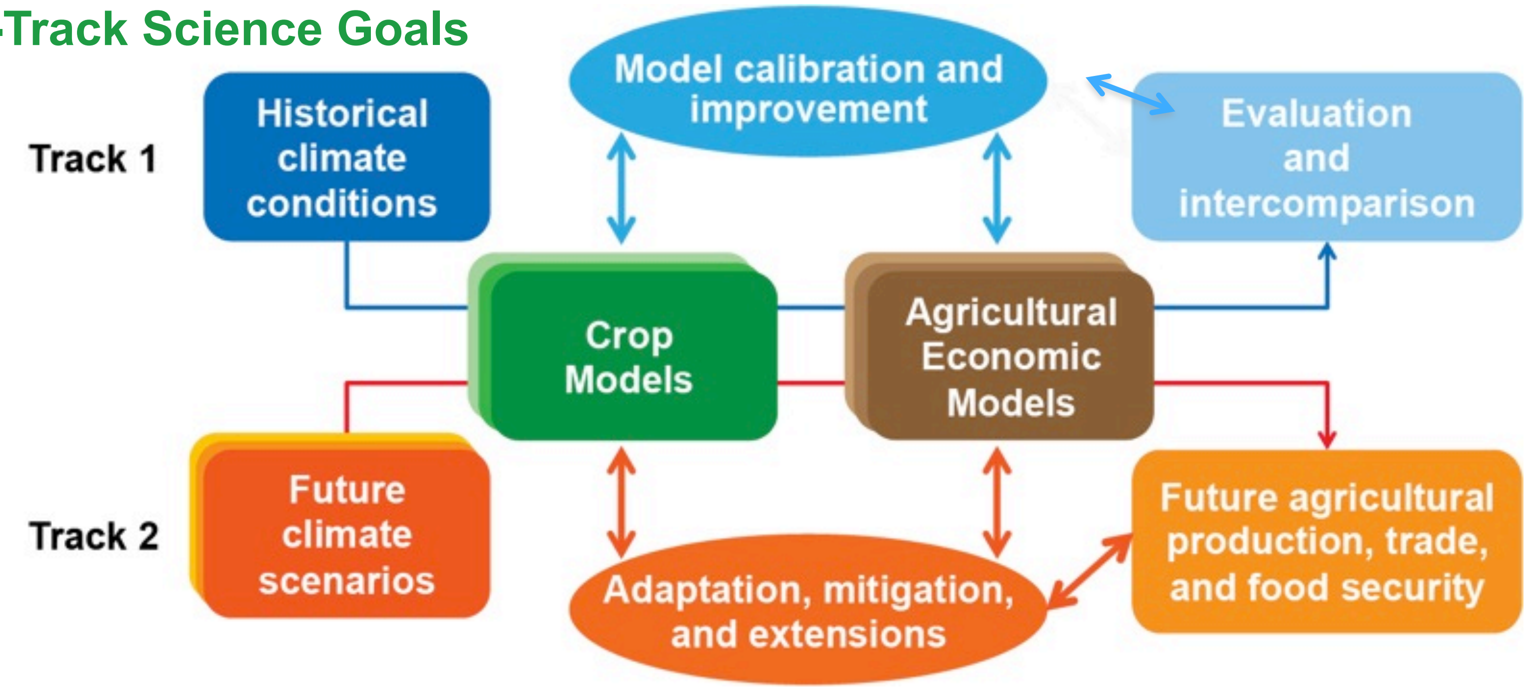
Using Point-Based Crop Models in Impact Assessments

Two-Track Science Goals



Track 1: Intercomparing, testing, and improving models for climate/mgt/genetics

Track 2: Using models for assessment of agric production & food security

Important to test crop models for accurate predictions against actual data on growth, yield, water use under climatic/mgt variation (CO2, temperature, water).

AgMIP The Agricultural Model Intercomparison and Improvement Project

Crop Modeling Activities – A Review

- **AgMIP Crop Modeling Teams**.
  - Wheat team (Asseng, Ewert, Martre) – 33 models
  - Maize team (Bassu, Durand, Lizaso, Boote) – 23 models
  - Rice team (Li, Hasegawa, Zhu, Yin) – 16 models
  - Sugarcane team (Singels, Thorburn, Marin)
  - Potato (Fleisher, Quiroz)
  - Maize Model Improvement Group (Tollenaar)
  - Soil Carbon & N Mineralization (Basso)
  - New: bioenergy (Kakani/LeBauer), canola (Wang), peanut (Singh), sorghum, crop-water-ET

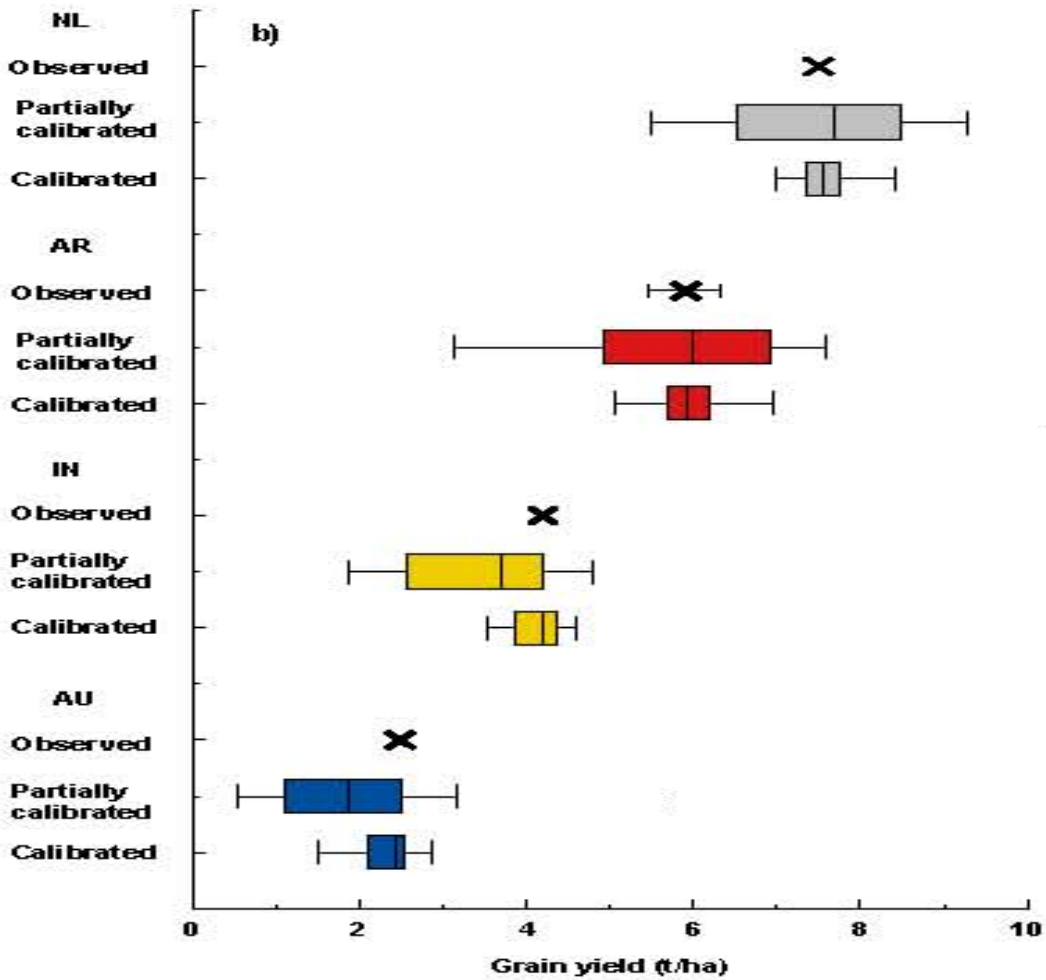
- **Activity 1** –**Conduct sensitivity analyses** across an ensemble of models (does predicted response to factors differ across models?), relative to CO_2, temperature, rainfall, & management. Use 4 sentinel sites. Use standardized protocols across crops
- **Activity 2** – **Test models against observed data on response to CO2, temperature**, soil water, soil carbon mineralization, N fertilization, sowing date, and management. Requires time-series and end-of-season data. Improve code!
- **Activity 3** – Evaluate climate-smart **adaptations**/technology change

What We Learned: Crop Model Intercomparisons

- **Median of crop model ensembles** reproduces observed yields better than any single model. Need Multi-Model!!!
- **Crop responses to CO_2, temperature, and water** remain key sources of uncertainty, need to improve models
- **Consistent message** from wheat, rice, and maize research teams: 1) yield is reduced with rising temperature, 2) shorter life cycle (grain-fill) is primary cause, Can it be adapted? 3) Elevated temperature effects on phenology & grain-set not modeled well.

Presently testing wheat, rice, maize models against response data. Code improvement beginning.

Asseng et al. 2013. Nature Climate Change Journal



Ensemble of wheat models predicted yields accurately even if uncalibrated (given only phenology info.)

No individual model predicted all sites accurately.

Same case for rice & maize model intercomparison

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Asseng et al. 2013. Nature Climate Change Journal

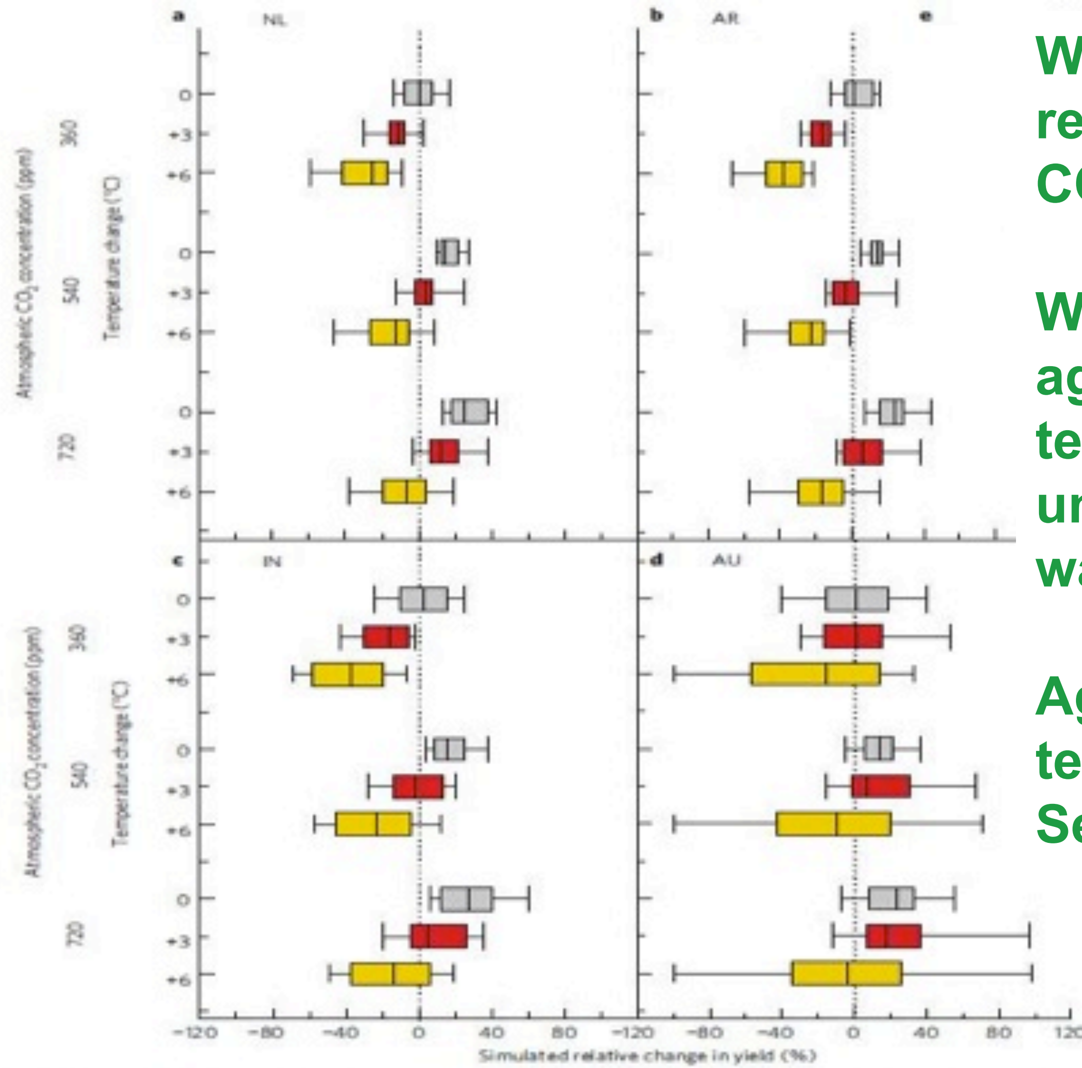


Figure 3 | Sensitivity of simulated and observed wheat to temperature and CO_2 change. a–d, Simulated relative mean (30-year average, 1981–2010) grain yield change for increased temperatures (no change, grey; +3 °C, red; +6 °C, yellow) and elevated atmospheric CO_2 concentrations for the Netherlands (NL; **a**), Argentina (AR; **b**), India (IN; **c**) and Australia (AU; **d**). For each box plot, vertical lines represent, from left to right, the 10th percentile, 25th percentile, median, 75th percentile and 90th percentile of simulations based on multi-models. **e**, Observed range of yield impacts with elevated CO_2 (refs 23,24). Observed range of yield impacts with increased temperature[10,24] (extrapolated, based on separate experiments with 40–345 ppm elevated

Wheat models relatively agreed on CO2 response.

Wheat models did not agree on response to temperature, and uncertainty grew at warmer temperatures.

AgMIP wheat: Next tested against Hot Serial Cereal data.

AgMIP Rice – Sensitivity to CO2

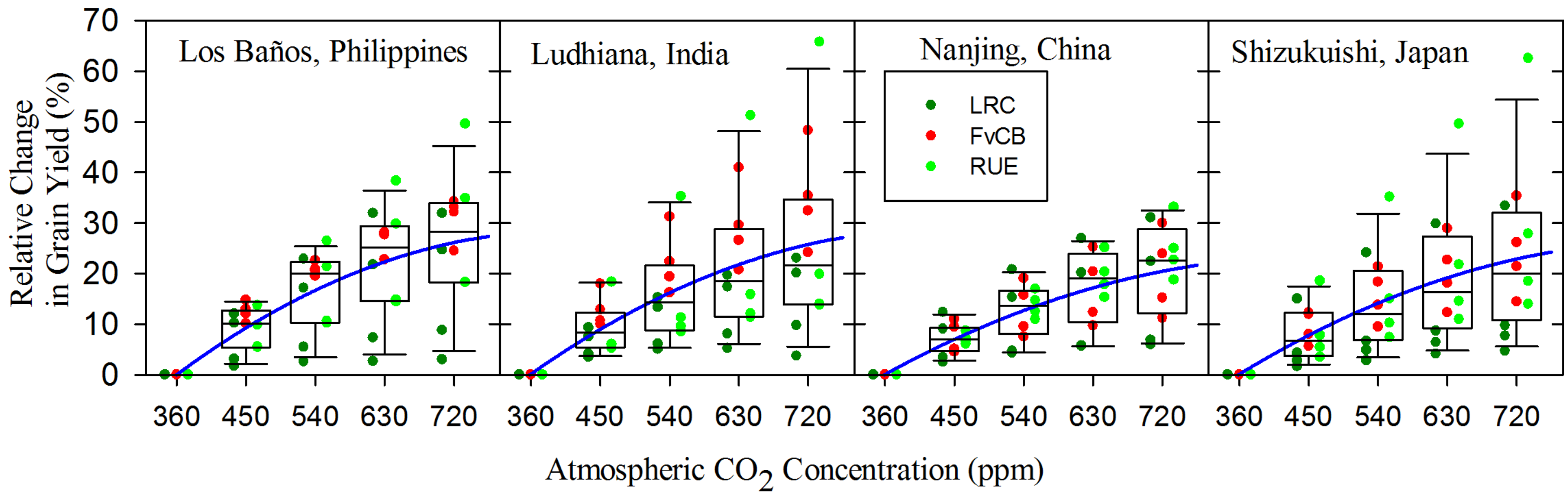
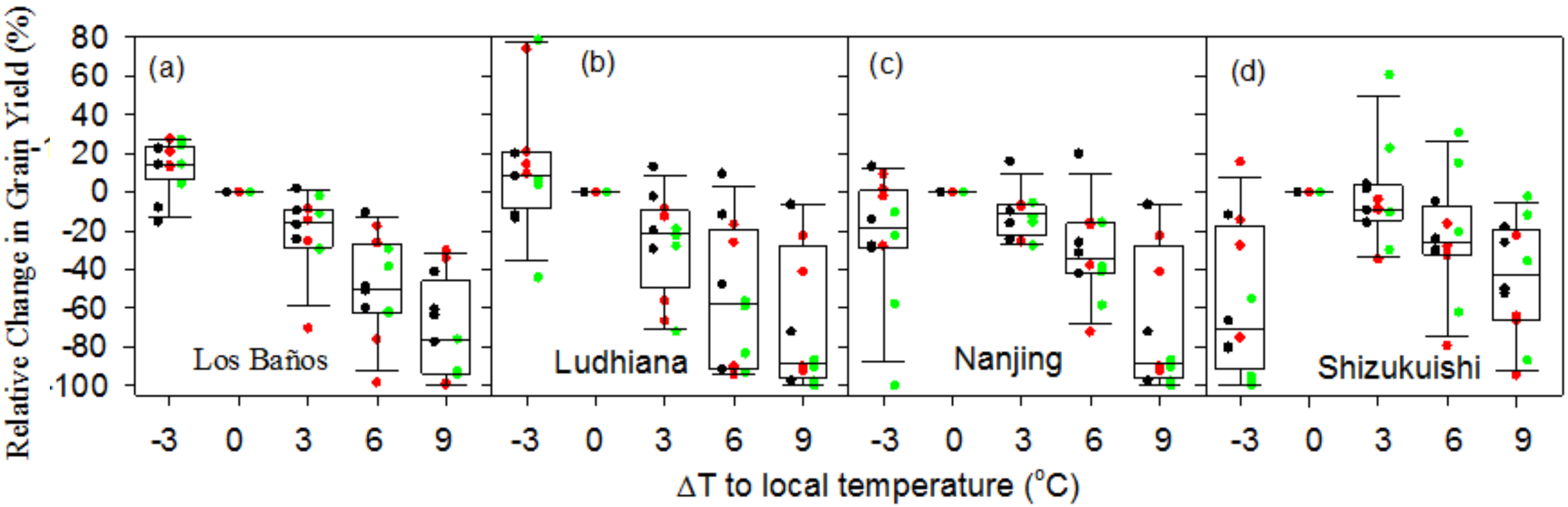


Fig. 2. The variation of model responses to CO_2 elevation in four sentinel datasets. Models were classified into three photosynthesis groups as: canopy radiation use efficiency (RUE); light-response curve of single-leaf (LRC); and Farquhar-von Caemmerer-Berry biochemical (FvCB).

No major difference in CO2 responsiveness associated with photosynthesis method. But considerable variability in CO2 responsiveness among models. Now testing against CO2-FACE data.

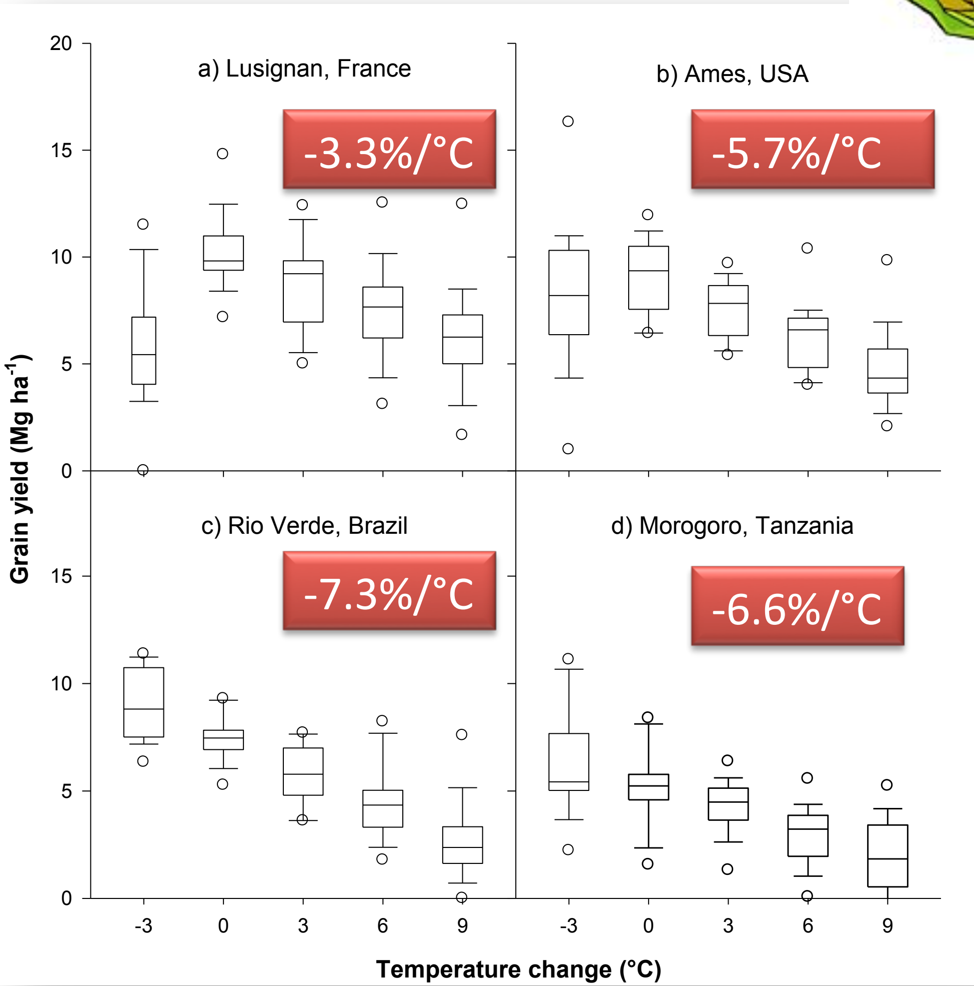
AgMIP Rice – Sensitivity to temperature

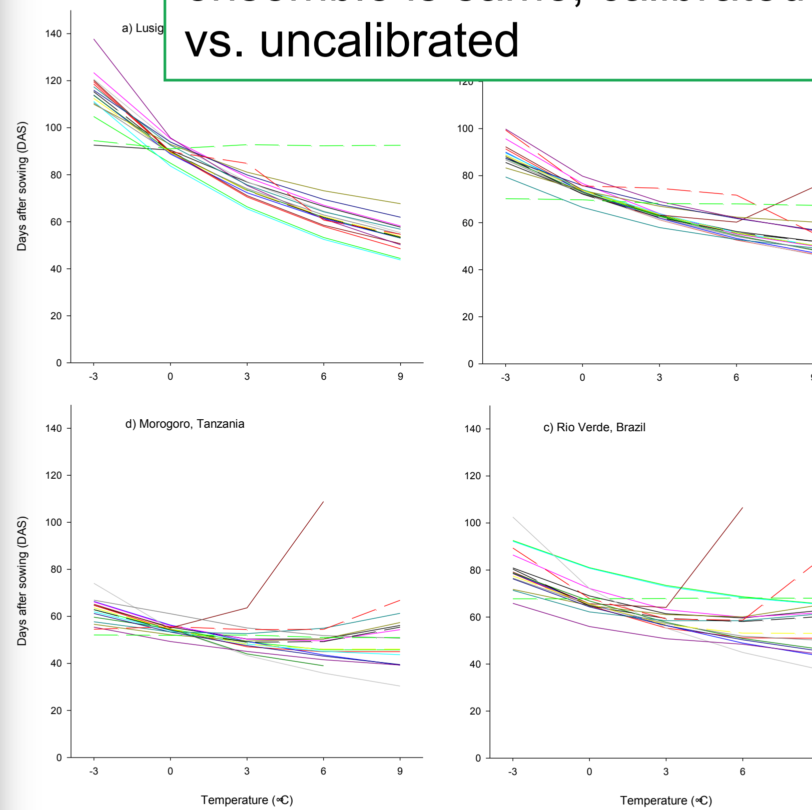


Yield reductions with rising temperature. Cooler increased yield, except in northern Japan (Shizukuishi), and China. Larger variability among models at colder or warmer temperature. Now testing against elevated temperature data.

Bassu et al. 2014. Global Change Biology

Message # 2 – Slope of yield decline with temperature for ensemble is same, calibrated vs. uncalibrated





Maize models agreed on yield decline with increasing temperature above ambient. Temperature response is same with or without calibration. Yield decline mostly attributed to reduction in crop life cycle, but is this correct (?).

Using Point-Based Crop Models in Impact Assessments

- **Are the models adequately parameterized and tested for response to climatic factors** (temperature, CO_2), water deficit, N response, and management)?

- **How good are the required site-specific inputs?** If estimated from proxy, the model reliability will be less.
  - Weather data (on-site rainfall)
  - Soil water holding traits, rooting depth, drainage traits
  - Soil carbon content and stable C pools, soil pH
  - Soil initial conditions: soil water, nitrate, ammonium, residue
  - Management information (sowing date, sowing density, row spacing, amounts and dates of fertilization & irrigation)
  - Cultivar (genetic information, calibrated from experiments)

- **Testing against field data** –Need to test the site-specific models against historical yield data over multiple years at a given site (to evaluate response to low rainfall seasons, and evaluate productivity given the soil fertility and applied fertilizer).
- **Tested against district yields:** works if simulated and aggregated over representative soils, sowing dates, management, and cultivars typical for the district.

Using Point-Based Crop Models in Impact Assessments

- **Limits of Genetic Adaptation:** Restrict to feasible range of traits (consult plant breeders and literature).
  - Regain life cycle duration to anthesis and maturity (relatively easy to do for many crops in many regions. Genetic variation exists)
  - Heat tolerance (genetic variation is sparse and small)
  - Drought tolerance (deeper rooting and extract to lower limit)
  - Good published work on this with IFPRI Global Futures Fellows for wheat, peanut, chickpea, sorghum, millet, potato.
- **Limits of Management Adaptation:**
  - Yield gain possible with added N fertilizer – depends on region (almost no gain in US, EU, China, but large gains in Africa)
  - Yield gain possible with irrigation – depends on water supply
- **Limits to technology trend in yield.** Not safe to project linear trends in yield increase over 50-100 years. There are physiological limits to yield potential. Need to consult crop physiologists and breeders.
  - Propose backcasting of yield improvement to evaluate management, genetic, and weather effects on yield technology trends.
  - Then go forward, considering physiological limits, with re-gained life cycle and projected genetic improvements feasible for the crop and region. Large potential in Africa, small in US and EU.