Multi-model-based analysis of climate change impact in maize mega-environments

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Objective:

Worldwide, maize is one of man's most important food sources. Global maize production has increased steadily, but it is affected by several climatic factors, which in turn affect its price and market. This study aims to assess the impact of increasing temperatures on maize grain yields at high-temperature sites in South Asia. Crop simulation models and a statistical model were used to evaluate the potential of different modeling approaches for identifying climate change impact hotspots for maize mega-environments, which are classified depending on climate. Yield changes were compared across sites and models.

Calibration and Validation:

Study areas:

Agua Fría and Tlaltizapán: Lowland tropical and mid-altitude, respectively; rainfed maize field

- Agua Fría (state of Puebla)
  - Tropical station
  - 50-hectare area
  - Altitude: 100 meters above sea level
  - Average annual rainfall: 1,200 mm
  - Growing seasons: November-April and May-October
  - Clay loam soils of pH 7.5-8.5.
- Tlaltizapán (state of Morelos)
  - Intermediate altitude station
  - 46-hectare area
  - Altitude: 940 meters above sea level
  - Average annual rainfall: 840 mm
  - Growing season: June-September
  - Calcareous clay soils of pH 8.0-8.4.

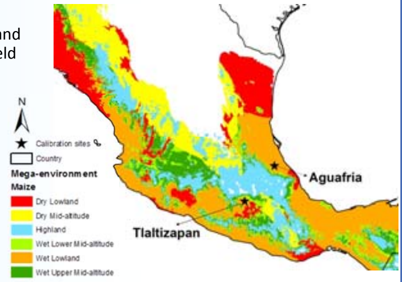
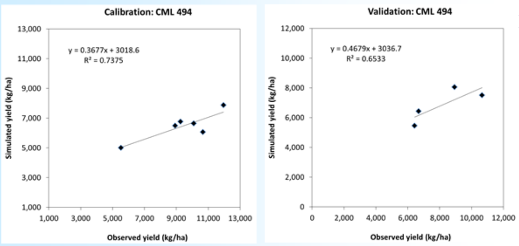


Figure 1. Study areas in Mexico.

Crop model: Crop Environment Resource Synthesis (CERES)-Maize
Cultivar: Tropical hybrid
Soil profile: WISE 3.1 soil profile database
Weather: Data was collected from 2005 to 2010 at two study site weather stations.
Nitrogen fertilizer: 150kg/ha
Additional crop managements (e.g. irrigation, planting and maturity dates and grain moisture): Referred to crop management experimental documents.



- The result of calibration for maize crop parameters showed 86% agreement between simulated and observed yields. The simulation of validation showed 81% agreement with the observed yields.

Figure 2: Comparison between simulated and observed maize grain yield for calibration and validation at Agua Fría and Tlaltizapán from 2005 to 2010.

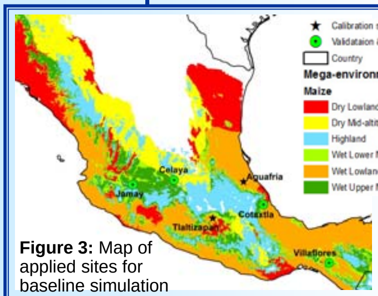
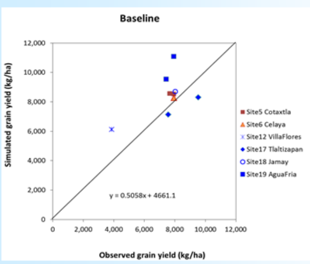


Figure 3: Map of applied sites for baseline simulation

Applied sites: Six sites in Mexico
- Dry lowland: Cotaxtla
- Dry mid-altitude: Celaya
- Wet lowland: Agua Fría, Tlaltizapán and Villaflores
- Wet upper mid-altitude: Jamay

Crop model: CERES-Maize
Cultivar: Tropical hybrid
Soil profile: WISE 3.1 soil database
Weather data: NASA-Power climate data from 1983 to 2012



- The baseline simulation results in different mega-environments showed 55% agreement when compared to observed yields.

Figure 4: The simulation results under baseline climate for 30 years in six different mega-environments in Mexico

Application:

Application areas: India and Bangladesh
Weather data: NASA-Power climate data from 1983 to 2012
Crop models: CERES-Maize, CSM-IXIM, and SALUS v1.0 simple
Cultivar: Tropical hybrid
Soil and crop management:
- WISE 3.1 soil database
- Biotic stress: None-set
- Abiotic stress: Rainfed

- The all-crop simulation models in this study showed average grain yield reductions between 5% and 35% ºC^{-1} (Figure 6).

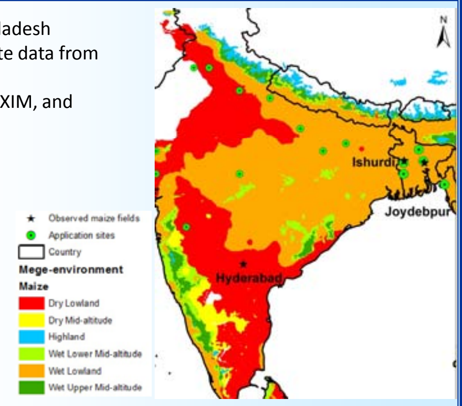


Figure 5: Map of applied sites in India and Bangladesh.

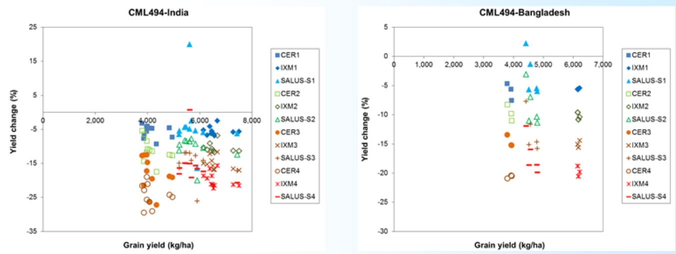


Figure 6: Comparison between simulated yield change and grain yield for India and Bangladesh with three models under temperature changes of 1 ºC to 4 ºC.

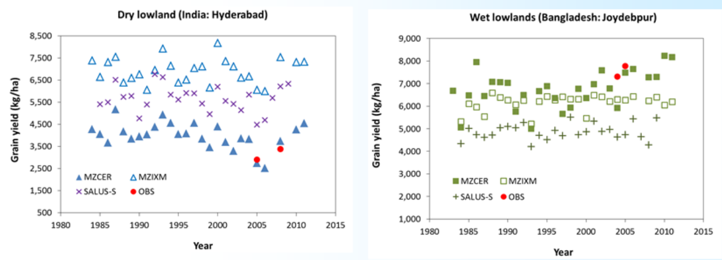


Figure 7: Comparison between simulated grain yield and observed grain yield in Hyderabad, India, (left) and Joydebpur, Bangladesh, (right) under two different mega-environments.

Conclusions

- The simulations of the process-based crop models and the statistical model showed average grain yield reductions between 5% and 35% ºC^{-1}.
- All simulations showed lower yields at warmer locations with warmer temperatures.
- Analysis is needed of long-term yield responses to different mega-environments for at least the last several decades (e.g. 1991-2000 or 2001-2010).

References:

Hoogenboom et al., 2010: Decision Support System for Agrotechnology Transfer (DSSAT) Version 4.5.0.43 [CD-ROM].
Lizaso et al., 2011: CSM-IXIM: A New Maize Simulation Model for DSSAT Version 4.5.
Basso et al., 2010: Long-term wheat response to nitrogen in a rainfed Mediterranean environment: Field data and simulation analysis. European Journal of Agronomy 33:132-138.

Acknowledgements:

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