Impact of Climate Change on Crop Yield - A Case Study of Rainfed Corn in Central Illinois

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The procedures

DATA OF GLOBAL MODELS

Uncertainty

Downscaling - global ~ region

REGIONAL CLIMATE CHANGE

LOCAL IMPACT

Impact assessment

Downscaling - region ~ local

LOCAL CLIMATE PROJECTION
Uncertainties in Climate Change Projections

- Emission scenarios:
  - Which greenhouse gases are emitted into the atmosphere? Where? When?
  - Demographic, economic, technological, environmental...
- Uncertainty with climate sensitivity

The increase in the equilibrium global-mean surface air temperature due to a doubling of atmospheric CO2 concentration

Regional variability
Occurring between models as different regional responses, and within models through chaotic behaviors and modes of climate variability, especially multi-decadal variability

(After Winstanley, 2004 Illinois Water Conference)
Model Uncertainty Quantification

- Output from a single GCM
- Average of the outputs from a set of GCMs (equal trust for all GCMs)
- Probability-weighted multimodel ensemble average, \( T = \sum_{i=1}^{N} p_i \cdot T_i \) (higher trust is assigned to the GCMs which have better performance with historical data)

**Premise**: Models being able to reasonably reproduce past climate also perform well at predicting future climate
Simple Multimodel Ensemble Average Method (SMMEM)

Root Mean Square Error Minimization Method (RMSEM)

“Best solution” from the max entropy method (Laurent and Cai, 2007)

Simple Multimodel Ensemble Average Method (SMMEM)
GCM skill score (suitability) in terms of precipitation for three regions

Height of the column = skill score or suitability of a GCM

- **NW US**: Area of study
  - 10. INM-CM3.0
  - 8. GISS-ER
  - 15. MRI-CGCM2.3.2
  - 15. MIROC3.2(hires)
  - 15. MIROC3.2(medres)

- **Central US**: Area of study
  - 12. MIROC3.2(hires)
  - 12. MIROC3.2(medres)
  - 13. ECHAM5/MPI-OM
  - 16. CCSM3
  - 17. PCM

- **CE US**: Area of study
  - 8. GISS-ER
  - 13. ECHAM5/MPI-OM
  - 14. ECHAM5/MPI-OM
  - 16. CCSM3
  - 17. PCM

**Height Values**
- 0.2
- 0.09
- 0.2
- 0.19
- 0.3
The Procedures

1. Downscaling: global ~ region
   - DATA OF GLOBAL MODELS
   - UNCERTAINTY

2. Downscaling: Region ~ local
   - REGIONAL CLIMATE CHANGE
   - HYDRO & CROP MODEL

3. Impact assessment
   - LOCAL IMPACT

   - LOCAL CLIMATE PROJECTION
Pattern scaling method: Calculate $(\Delta P_R, \Delta T_R, \Delta \text{Rad}_R)$ assuming each of these changes at the regional scale is proportional to the global warming through an in-variant scaling factor.

Monte Carlo simulation: Generate a number of sets $\{\Delta P_R, \Delta T_R, \Delta \text{Rad}_R\}$

Data clustering: Generate a representative set of climate change scenarios from the Monte Carlo simulation samples.
LARS-WG (Semenov and Barrow, 1997), weather generator, a numerical model which produces synthetic daily time series of a suite of climate variables with certain statistical properties.
The PDF of the average temperature (T) and total precipitation (TP) between Apr. 15th and Oct. 14th, Central Illinois, present and 2055
Monthly precipitation, Temperature, and solar radiation change (2055) in Central Illinois -- A drier and hotter summer during the corn growth season and wetter and warmer pre- and post-crop seasons.
The Procedures

1. **DATA OF GLOBAL MODELS**
   - Uncertainty
   - Downscaling: global ~ region

2. **REGIONAL CLIMATE CHANGE**
   - Downscaling: Region ~ local

3. **LOCAL IMPACT**
   - Impact assessment
   - Hydro & Crop model

**LOCAL CLIMATE PROJECTION**
SWAP (Soil Water Atmosphere Plant model)

Van Dam et al. (1997)
Complementary CDFs of the average growing season (April 15 – October 14) soil water deficit index (SWDI)
Complementary CDF of relative crop yield
PDF of relative crop yield
Comparing individual uncertainty sources: GCM, emission scenarios, climate sensitivity, and crop response coefficient.

The complementary CDF of relative yield for present and 2055 under five scenarios, respectively, and all four uncertainty sources together.
Summary

• A drier and warmer summer and wetter and warmer pre- and post-crop seasons

• Soil water deficit levels may increase in the flowering and yield formation stages, resulting in larger variability and vulnerability in 2055 than at present

• The mean yield of rainfed corn yield in Central Illinois will decline by 23 – 34% and the probability that the yield may not reach 50% of the potential yield ranges from 32 – 70 %, if no adaptation measures are instituted

• Among the multiple uncertainty sources, the GHG emission projections may have the strongest effect on the risk estimate of crop yield reduction