Motivation

Rice, wheat, maize provide 60% of calories. Sorghum another important cereal in semi-arid regions of Africa and India (Ray et al. 2012)

Warmer days and heavy precipitations more frequent in agricultural zones (IPCC 2012, Lobell et al. 2011)

- What is the vulnerability of cereal portfolio globally and regionally?
Crop distribution

Global distribution of the predominant crop in 50x50km cells around 1998-2002 as in the MIRCA2000 dataset (Portmann et al. 2010)
Methodology

- Estimate **yield response** to weather using a statistical model accounting also for **adaptation**

- Analysis of future **vulnerability** using the new IPCC warming (RCP) and socio-economic scenarios (SSP)
Yield response: data

Weather daily data from Twentieth Century Reanalysis (NOAA)
Gridded, daily data

Cereal yields from FAO (1961-2010)
Country level annual
Yield response: data

Weather daily data from Twentieth Century Reanalysis (NOAA)

Gridded, daily data

- Gridded crop calendar (Sacks et al. 2010)
- Gridded agricultural maps (Portmann et al. 2010) to weight cells based on share of harvested area
- Irrigated vs. rainfed

⇒ Distribution of daily precipitation ($P$) and temperature ($T$) by crop during the growing season

Cereal yields from FAO (1961-2010)

Country level annual
Yield response: modeling weather variation

Estimate yield response to a change in the distribution of daily T and P, not just averages

What is the effect on yields of a change in exposure to days with

⇒ high daily mean temperature?
⇒ low, medium, heavy rainfalls?
Distribution of daily T and P in the growing season

Ex: Maize

Temperature (°C)

Precipitation (mm)
Yield response: results

RED: High temperature
GRAY: Low precipitation
BLUE: High precipitation

Point estimates of statistically significant (10% confidence level) elasticities.

Positive number = reduction in yields
Negative number = increase in yields
Yield response: results

- Impacts on yields are persistent especially in the case of wheat and maize

- Yields adjust to weather shocks, but adaptation takes time to complete, 6-20 years => policy plays a role
Methodology

- Estimate yield response to weather using a statistical model accounting also for adaptation

- Analysis of future vulnerability using the new IPCC warming (RCP) and socio-economic scenarios (SSP)
Future exposure: climate scenarios

Two warming scenarios:
High warming RCP 4.5 and RCP 8.5

5 CMIP5 models:
CCSM4, CNRM-CM5, GFDL-CM3, MIROC5, MPI-ESM-MR

Current climate: decadal mean between 2006 and 2015
Future climate: decadal mean between 2045 and 2055

van Vuuren et al. 2011
Future exposure in 2050 – Change in distribution e.g. Maize
Future exposure in 2050 – Change in distribution e.g. Maize

**Maize Growing season. Temperate regions**

- **1961-2010**
  - Temperature (°C)
  - History
- **2046-2055**
  - Future RCP 8.5

**Maize Growing season. Tropical and Sub-tropical regions**

- **1961-2010**
  - Temperature (°C)
  - History
- **2046-2055**
  - Future RCP 8.5

**Maize, Growing season. Temperate regions**

- **1961-2010**
  - Precipitation (mm)
  - History
- **2046-2055**
  - Future RCP 8.5

**Maize, Growing season. Tropical and Subtropical regions**

- **1961-2010**
  - Precipitation (mm)
  - History
- **2046-2055**
  - Future RCP 8.5

Graphs by mod

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**History**

- **Future RCP 8.5**
Future exposure in 2050 (multi-model mean)

Additional days (in 2050 vs. present) with mean temperature >30°C

Additional days (in 2050 vs. present) with mean precipitation >15 mm

Multi-model Mean: CMIP5 models CCSM4, CNRM-CM5, GFDL-CM3, MIROC5, MPI-ESM-MR
Future cereal vulnerability in 2050

Future cereal production will also depend on

• Future harvested area

  ➢ Possible significant changes for some African countries, but not globally nor for major producers (FAO-OECD 2012)

• Future food system

  ➢ Yields grow with economic growth (fertilizers, technology, and machinery)
  ➢ Use the estimated yield elasticity to per capita GDP to project future yields with slow (SSP3) and fast (SSP5) growth in per capita income
Future cereal vulnerability in 2050

Mean +/- 2SD - CMIP5 models: CCSM4, CNRM-CM5, GFDL-CM3, MIRO5, MPI-ESM-MR

-23 bn kcal
Future cereal vulnerability in 2050

Mean +/- 2SD - CMIP5 models: CCSM4, CNRM-CM5, GFDL-CM3, MIROC5, MPI-ESM-MR

-23 bn kcal
Future cereal vulnerability in 2050

RCP8.5 Warming Current Food System

-23 bn kcal

RCP8.5 Warming Yields under SSP5

-42 bn kcal

Fast Growth
SSP5

Mean +/- 2SD - CMIP5 models: CCSM4, CNRM-CM5, GFDL-CM3, MIROC5, MPI-ESM-MR
Future cereal vulnerability in 2050

Fast Growth SSP5

-23 bn kcal

Fast Growth SSP5

-42 bn kcal

Mitigation (RCP 4.5, SSP5)

-40 bn kcal

Mean +/- 2SD - CMIP5 models: CCSM4, CNRM-CM5, GFDL-CM3, MIROC5, MPI-ESM-MR
Major producers

Change in regional calorific supply

RCP8.5 Warming
Future yields under SSP5

% reduction

Cereal mix

Mean +/- 2SD - CMIP5 models: CCSM4, CNRM-CM5, GFDL-CM3, MIROC5, MPI-ESM-MR
“Clear” losers

Change in regional calorific supply

RCP8.5 Warming
Future yields under SSP5

% reduction

Cereal mix

Mean +/- 2SD - CMIP5 models: CCSM4, CNRM-CM5, GFDL-CM3, MIROC5, MPI-ESM-MR
In absolute number big producers would lose the most...

..but relative numbers (%) highlight the vulnerability of small, poor countries (e.g. Liberia, Swaziland, Lesotho, Zimbabwe Guatemala)
Discussion

Climate change will reduce the calorific supply from the top producers

- Possibility of a «systemic» risk, given that maize and wheat are also the most traded cereals
- What if countries that lose a large fraction of their production cannot import?

Yields adjust to weather shocks, but adaptation takes between 6 to 20 years. During the adjustment impacts can be significant

- Irrigation plays a role
- Role of policy at facilitating the adaptation process
Thank you!

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Future exposure in 2050: model uncertainty

RCP 8.5

Exposure to high temperature
Difference in frequency (days >30°C)
- significantly more frequent
- more frequent
- slightly more frequent
- slightly less frequent
- less frequent
Major losers in % terms (multi-model mean)