SCENARIOS OF GLOBAL CROP PRODUCTION
INTERACTION BETWEEN CLIMATE MITIGATION POLICY & LAND USE
IMPLICATION FOR FOOD SECURITY

GCAM workshop, November 29–30, 2011
BACKGROUND

• Wise et al., 2009 Science
  – Applying a Universal Carbon Tax regimes decreases GHGs emissions from land use but increases global food prices
  – Consequences on future dietary choice
  – Considered only CO₂ emissions

• RCP 4.5 (Thomson et al., 2010 Climate Change)
  – CH₄ and N₂O are included

• Thomson et al., 2010 PNAS
  – Cost of food is more sensitive to mitigation policy (RCP4.5 vs. no climate mitigation) than Agricultural Productivity Growth (APG) scenarios (FAO past trends, i.e. high-APG vs. zero-APG)
  – FAO projection: future crop yield will continue to increase → Uncertain!
  – Sensitivity to the impacts of climate change
BACKGROUND

The GCAM Model

The Energy System

Energy Supply
- Coal, Gas, Oil
- Renewables
- Electricity
- Hydrogen

Energy Markets
- Fossil fuel prices
- Electricity prices
- Hydrogen prices

Energy Demand
- Transportation
- Buildings
- Industry

Energy System Emissions

Climate
- Concentrations
- Radiative Forcing
- Global Mean Temperature Rise
- Sea Level Rise

Agriculture & Land Related Emissions

Agricultural Supply
- Crops
- Livestock
- Forest Products
- Bioenergy

Agricultural Markets
- Crops prices
- Livestock prices
- Forest Product prices
- Bioenergy prices

Land Use & Land Cover

Commercial Biomass

Regional GDP

Regional Labor Productivity

Regional Labor Force

Technologies/ Farm

Regional Land Characteristics

Economy

Regional Resource Bases

Regional Energy Conversion Technologies

Energy Demand Technologies
Drivers of Agricultural Productivity

- Climate
- Extreme weather events
- Farming management practices:
  - Irrigation
  - Fertilizer application
  - Choice of planting dates
  - Selection of crop variety
- CO$_2$ fertilization effect
- Other factors: pest, diseases, economy
Proposition:

Linking the geospatially explicit global crop yield model PEGASUS to GCAM

Deryng et al. (2011): Simulating impact of climate change on crop yields and benefits of farmers adaptation (choice of crop cultivars, planting dates decision)

C3 crop: spring wheat
C4 crop: maize
C3 crop, N-fixing: soybean
PEGASUS
Predicting Environmental Goods And Services Using Simulations
IRRIGATION & FERTILIZER APPLICATION

Input data in PEGASUS:
- Irrigated cropland areas
- National rate of fertilizer application (NPK)

Fertilizer data (P. Potter, 2008)

MIRCA 2000 (Portman et al, 2010)
1. Planting date decisions are driven by mean climate conditions:
   - Temperature-limited regions: planting occurs when it gets warm enough to allow the plant to grow (spring-type crops)
   - Moisture-limited regions (not temperature-limited): planting occurs at the start of the rainy season
Region 1: Temperate region with winter snow and long frost period (> 4 months)
Region 2: Temperate region with winter snow but short frost period (< 4 months)
Region 3: Temperate region with no winter snow (minimum Temperature < 5°C)
Region 4: Moisture-limited tropical region: minimum temperature >5°C, long dry season (> 30 days)
Region 5: Not climate limited: minimum temperature >5°C, no dry season (<30 days)
ADAPTATION OPTIONS

1. Planting date decisions are driven by mean climate conditions:
   - Temperature-limited regions: planting occurs when it gets warm enough to allow the plant to grow (spring-type crops)
   - Moisture-limited regions (not temperature-limited): planting occurs at the start of the rainy season

2. Selection of crop cultivars:
   - Different cultivars have different thermal time requirements
   - Farmers select cultivars of a crop adapted to the local climate
   → Ex. cultivars grown in colder climates have smaller thermal time requirement, thus shorter growing period
Choice of Crop Cultivars
Thermal Time Requirement

- Length of growing period depends on thermal time accumulation, i.e Growing Degree Days (GDD)
- GDD are accumulated when daily temperature is above a minimum and below a maximum temperature thresholds (specific of each crop type)
IMPACT OF CLIMATE CHANGE ON GLOBAL CROP YIELD

EFFECT OF ADAPTING PLANTING DATES DECISION AND CHOICE OF CROP CULTIVARS

Deryng et al., 2011
Impact of Climate Change on Global Crop Yield

Effect of Adapting Planting Dates Decision and Choice of Crop Cultivars

On average, farmers could trim global yield declines by 18% for maize, 12% for spring wheat and 7% for soybeans.

Deryng et al., 2011
Effect of Climate Variability on Crop Yield

• Daily climate input (temperature, precipitation, fraction of sunshine hours)

• Water stress impact on daily biomass production → sensitivity to droughts

• Heat stress impact at flowering (Teixeira et al., in press, Challinor et al., 2005)

→ Ongoing model development
Basic Structure of CIAS – PEGASUS

Community Integrated Assessment System
Warren et al. (2008)

- Global GHG emissions scenarios (Stern, SRES, RCPs)
- Global climate model emulator MAGICC 6
- Downscaling climate module ClimGen
- Crop yield model PEGASUS (stochastic weather generator)
CIAS – PEGASUS – GCAM

**Key Inputs/Outputs**

- **CIAS:**
  - GHGs concentrations (incl. CO$_2$), Downscaled climate data

- **PEGASUS:**
  - Crop yield
  - Cropland area (suitability)
  - Chemical fertilizer application

- **GCAM:**
  - Agriculture Prices
  - Land use
  - Crop consumption – demand
  - GHG emissions (CO$_2$, CH$_4$, N$_2$O)
Proposition: linking CIAS-PEGASUS to GCAM to look at the effect of:

1. Climate change and climate variability
2. Production cost
3. Farming technologies
4. Climate mitigation policy

on agricultural productivity, land use, food prices and future dietary choice
Some Interesting Questions …

• How much more fertilizer could be used to increase yield in the future?
• What would be the impact of increasing fertilizer application on yield and GHGs emissions?
• LU scenarios: intensification vs. cropland expansion? Land competition for biofuel
• Trade scenarios: local production vs. free trade scenarios?
THANK YOU!

Please, Comments & Questions?

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