Agricultural Impacts in GCAM

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Joint GCAM Community Modeling Meeting and GTSP Technical Workshop
Joint Global Change Research Institute
College Park, Maryland, USA
Thursday, September 20, 2012
Brief description of how agricultural impacts are included in GCAM

Two of work on impacts:

- Exogenously specified climate effects on agriculture only
  - Approach
  - Results
  - Limitations

- Endogenously specified climate effects on all ecosystems
  - Approach
  - Preliminary Results
  - Limitations
The world is divided into 151 regions.

Farmers allocate land across a variety of uses in order to maximize profit.

There is a distribution of profits for each land type across each of the 151 regions.

The actual share of land allocated to a particular use is the probability in which that land type has the highest profit.

The variation in profit rates is due to variation in the cost of production:
- As the area devoted to a particular land use expands, cost increases.
- Yield is fixed within each region for each crop management practice.
Climate changes affects both the yield of crops and the carbon density of different ecosystems.

- CO₂ fertilization tends to increase these values
- Temperature & precipitation have a mixed effect

Both yield and carbon density are exogenously specified in GCAM.

- We read these parameters in for each land cover type (e.g., corn, rice, wheat, pasture, forest, etc.) and each of the 151 regions.

Adjusting yield and carbon density will affect:

- The profitability of land – this will result in different land allocations.
- The carbon storage of land – this will result in different land use change emissions
Exogenously specified yield changes:

- We adjusted yields based on a study that linked temperature rise to crop yield.
- We only considered agricultural commodities.
- We only adjusted yields.
- Data was only provided for two regions and three crops. We mapped these changes to all regions and crops.
Exogenously Specified Yield Change: Input Assumptions

Change in Yield for Mid- to High-Latitude Wheat

- Most Increase
- Most Decrease
Exogenously Specified Yield Change: Results

Cropland Area

Forest Area

Reference, w/o Impacts

Reference, w/ Impacts

Reference, w/o Impacts

Reference, w/ Impacts
Exogenously Specified Yield Change: Results

Purpose Grown Bioenergy

- Reference, w/ Impacts
- Reference, w/o Impacts

Land-Use Change Emissions

- Reference, w/ Impacts
- Reference, w/o Impacts
Exogenously Specified Yield Change: Results

**Cropland Area**
- 550, w/ Impacts
- 550, w/o Impacts

**Forest Area**
- 550, w/ Impacts
- 550, w/o Impacts
Exogenously Specified Yield Change: Results

Purpose Grown Bioenergy

- 550, w/ Impacts
- 550, w/o Impacts

Land-Use Change Emissions

- 550, w/ Impacts
- 550, w/o Impacts
Exogenously Specified Yield Change: Results

**CO₂ Prices**

2005$/tC

- 550, w/ Impacts
- 550, w/o Impacts

**CO₂ Prices in 2095**

- 550, w/ Impacts
- 550, w/o Impacts
The input data was not spatially explicit (only 2 latitudinal regions).

The input data only included results for 3 crops. We had to make assumptions about yield impacts on other crops.

We did not change carbon sequestration potential of ecosystems.

We don’t know exactly what was included in each of the data points in the meta data (some may include CO$_2$ fertilization, while others may not).

We have assumed correlation across impacts in regions & crops that may not exist.
Endogenously specified yield and carbon density changes:

- We coupled GCAM to the Community Earth System Model.
- We adjusted yields and carbon density based on changes in NPP and heterotrophic respiration, as provided by the community land model.
- We considered both agriculture and forestry, commercial and non-commercial.
- Data was provided at the grid cell level for ~15 Plant Functional Types.
Endogenously Specified Yield and Carbon Density Changes: Approach

The iESM

Fossil Fuel & Industrial Emissions (Gridded)

1. GCAM_HD
   (15 ghgs, aerosols, SLS; 14 geopolitical regions; 151 Ecoregions)

2. GLM
   (½ x ½ degree grid land-use-land-cover.)

ESM1
   (3. CLM & 4. CCSM)

LU-LC emissions
LU-LC

Carbon Density and Productivity

 Experiment 1.2: RCP 4.5, with feedback from the CLM-CCSM calculations

- 15-year time steps;
- Lagged adjustment:
- Sneaker-net.
Endogenously Specified Yield and Carbon Density Changes: Preliminary Results

Two effects:

1. Increased yield $\Rightarrow$ decreased cropland area $\Rightarrow$ increased forest area $\Rightarrow$ increased terrestrial sequestration

2. Increased carbon density $\Rightarrow$ increased terrestrial sequestration
Endogenously Specified Yield and Carbon Density Changes: Limitations

- We have lagged climate variables by 15 years (5 years in the fully coupled version).

- We only have two types of crops (C3 & C4).

- Disentangling the effect of climate change from the effect of land cover change is difficult.

- Model run time is significant (500-1000 processor hours per year of simulation)
DISCUSSION