Climate Impact on Land Use

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Motivation

• Interaction between land use and climate change
  – Land cover and land use change affect global and regional climate
  – Climate affects potential land productivities and thus land use

• To evaluate how climate affect the amount of land use by different sectors at regional level
Toward IAM-Earth System Model Interactions

Integrated Assessment Model

iPETS Model

Spatial land use

Implement in CLM/CESM

Feedback: Land productivity for agriculture
Modeling approach

• Multiple types of land:
  – Two (physical) land types distinguished by Length of Growing Period: high productivity, low productivity

• Land competition
  – Three land-use sectors: crops, animal products and forestry
  – Different uses (cropland, pasture, forestland) imply different costs

• Explicit and endogenous
  – Model structure allows new land to be brought into production when necessary
Climate Impacts

• Total amount of land in each land type
  – Length of Growing Period: Number of days suitable for crop growth at each grid cell
    • Average daily temperature > 5°C
    • Soil water balance

• Land Productivity Coefficient
  – Extreme events
  – Diseases/pests
  – CO₂ fertilization
iPETS: 9-Region “CGE” Model, with Trade

(CGE = Computable General Equilibrium)
Final Goods
Energy
Materials
Integrated Population-Economy-Technology-Science Model (iPETS Model)

Households
Consumption, Savings, Capital, Labor

Final Goods Producers
Consumption, Investment, Government, Exports, Imports

Intermediate Goods Producers
Oil, Gas, Coal, Electricity, Refined Fuels, Materials

Energy
Materials

Land Use Distribution:
Cropland, Forestland, Pasture

Labor
Capital
Land
Production Tree

Example for Crop sector

Land an input to production

Climate impact on productivity

Climate impact on total area
Scenarios: Latin America

- Baseline: RCP 8.5
- Alternative scenarios
  - S1: Reduction of total available land
    - Areas for both land types reduce 10% at 2100
  - S2: Reduction of high productive land and increase of low productive land with total fixed
    - 10% of high productive land converts to low productive land at 2100
  - S3: 20% reduction of productivity coefficient for both types of land in all sectors
  - S4: 20% reduction of productivity coefficient for high productive land in all sectors
  - S5: 20% reduction of productivity coefficient for cropland for both types
Land Use in 2100: S1

Constraint: 10% reduction in total available land

Results: % change in land use

Results: % change in prices

Low productive land  High productive land  Total land in production
Land Use in 2100: S2

Constraint: 10% high productive land -> low productive

Results: % change in land use

<table>
<thead>
<tr>
<th></th>
<th>Low productive land</th>
<th>High productive land</th>
<th>Total land in production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cropland</td>
<td>-15%</td>
<td>0.00%</td>
<td></td>
</tr>
<tr>
<td>Pasture</td>
<td>-10%</td>
<td>0.00%</td>
<td></td>
</tr>
<tr>
<td>Forestland</td>
<td>-5%</td>
<td>0.00%</td>
<td></td>
</tr>
<tr>
<td>Total Used</td>
<td>0%</td>
<td>0.00%</td>
<td></td>
</tr>
</tbody>
</table>

Results: % change in prices

- Food: 0.00%
- Crop: -0.10%
- Animal Product: -0.20%
Land Use in 2100: S3

Constraint: land productivity coefficients for both types in all sectors: ↓ 20%

Results: % change in land use

Results: % change in prices

- Low productive land
- High productive land
- Total land in production
Land Use in 2100: S4

Constraint: land productivity coefficients for high productive land: ↓ 20%

Results: % change in land use

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Cropland</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Pasture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forestland</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Used</td>
<td>-1%</td>
<td>0%</td>
<td>1%</td>
</tr>
</tbody>
</table>

Results: % change in prices

- Food: 6%
- Crop: 6%
- Animal Product: 7%
Land Use in 2100: S5

Constraint: crop land productivity coefficients for both types: ↓ 20%

Results: % change in land use

<table>
<thead>
<tr>
<th>Land Type</th>
<th>Low productive land</th>
<th>High productive land</th>
<th>Total land in production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cropland</td>
<td>-10%</td>
<td>-8%</td>
<td>-6%</td>
</tr>
<tr>
<td>Pasture</td>
<td>-4%</td>
<td>0%</td>
<td>2%</td>
</tr>
<tr>
<td>Forestland</td>
<td>-2%</td>
<td>4%</td>
<td>6%</td>
</tr>
<tr>
<td>Total Used</td>
<td>-8%</td>
<td>4%</td>
<td>6%</td>
</tr>
</tbody>
</table>

Results: % change in prices

<table>
<thead>
<tr>
<th>Sector</th>
<th>Food</th>
<th>Crop</th>
<th>Animal Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>% change</td>
<td>0%</td>
<td>6%</td>
<td>4%</td>
</tr>
</tbody>
</table>
Conclusions

• Productivity changes potentially driven by climate change affect land use in multiple ways
  – Effects differ across land types and land use sectors

• ↓ (↑) in land supply in certain type
  – Amount of land used of that particular type in production ↓ (↑)
  – Drives food price ↑ (↓)

• ↓ in land productivity
  – Food prices ↑
  – Amount of land use can go ↑ or ↓
  – Additional investigation of productivity effects on land use is needed
Next Step

- Global model: Inter-regional effects

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