Uncertainty in land resource projection associated with constant, bioclimatic land units in an integrated assessment model

Alan V. Di Vittorio
Lawrence Berkeley National Laboratory

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Global distributions of Paddy Rice Production

PaddyRice production cumulative distribution comparison

Cumulative probability

Production (t)
AEZ boundaries affect projected land use/cover

Global percent change in land area (new minus old)

- fodder crops +13%
- biomass +8.3%
- harvested forest -3.4%
- grain crops -2.4%
- other crops +1.8%
- pasture -9.3%
**IAMs have different regions/land units**

- Unquantified spatial uncertainty confounds inter-model comparison and ensemble analysis

<table>
<thead>
<tr>
<th>Model</th>
<th>Regions</th>
<th>Land units for projection</th>
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<tbody>
<tr>
<td>IMAGE (RCP 2.6)</td>
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<td>half-degree grid</td>
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<tr>
<td>MiniCAM (RCP 4.5)</td>
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<td>GCAM: 151 land units</td>
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<td>AIM (RCP 6.0)</td>
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<td>MESSAGE (RCP 8.5)</td>
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</tr>
</tbody>
</table>
Land cover inconsistencies across IAMs and ESMs can alter the global carbon cycle

Change in global area (from 2015)

- **Forest**
  - Area change: 7.7 M km²
  - Simulation: CLM–NEWLUT

- **Pasture**
  - Area change: 4.4 M km²
  - Simulation: CLM–OLDLUT

- **Forest**
  - Area change: 5.1 M km²
  - Simulation: GCAM–NEWLUT

- **Pasture**
  - Area change: 4.1 M km²
  - Simulation: GCAM–OLDLUT

Di Vittorio et al., 2014
Different land use/cover representations in ESMs obscure land use change effects on regional climate.

- Uncertainty chain:
  - IAM land use spatial uncertainty
  - Land use/cover translation
  - ESM land cover

Temperature effect of RCP 8.5 land use change for 2071-2100 (Brovkin et al. 2013)
In the context of coupled whole earth system modeling

• How do we make robust projections of land resources in the context of projected climate change?

• How do spatial boundaries influence land resource projection?
SDWG principles

- Uncertainty in CESM inputs fosters dialogue
- Highlights need for CESM land use/cover/management development
Agro-Ecological Zones (AEZs) are bio-climatically defined.
Current land units become heterogeneous.
Workflow to create new AgLU crop and land rent inputs

1. Data
   - Identify land cells
     - Optional: recalibrate to different FAO data year
   - Calculate crop production and harvested area per 18 AEZs X 226 GTAP countries

2. Aggregate original land rents by use sector to 87 GTAP countries

3. Disaggregate crop land rents to 18 AEZs based on production and price

4. Disaggregate forest land rents to 18 AEZs based on original land rents and forest area
## Data required to create new AgLU crop and land rent inputs

### Spatially explicit data
- VMAP0 countries (246)
- AEZ countries (160)
- SAGE data:
  - crop yield, area
  - cropland
  - pasture
  - land area
  - potential vegetation
- HYDE3.1 data:
  - urban
  - land area
- AEZ boundaries

### Tabular data
- GTAP countries (226, 87)
- FAO countries (241)
- GTAP (SAGE) crops
- GTAP use sector
- GTAP land rent
- FAO crops
- FAO crop production
- FAO producer prices
- FAO crop yield, area
  - for recalibration
New land data system is robust
e.g., Paddy Rice for 226 countries
New land data system is robust
e.g., forest land rent

87 regions by AEZ  14 regions by AEZ

Cumulative probability

Land Rent (US$)  New AEZs  Original AEZs
GTAP
Each crop is uniquely affected by new land units.
AEZ boundaries affect projected land use/cover

SE Asia percent change in land area (new minus old)

- fodder crops +40%
- biomass +12%
- harvested forest -15%
- pasture -13%
- grain crops -5.7%
- other crops +6.8%
- grassland -1.7%

Year:
- 2010
- 2040
- 2070
- 2100
AEZ boundaries affect crop production

Global percent change in crop production (new minus old)

- Palm fruit: +22%
- Fodder grass: +14%
- Fodder herb: +6%
- Pasture: -3.3%
- Biomass: -11%
AEZ boundaries affect crop prices

Global percent change in crop prices (new minus old)

- Palm fruit: -5.9%
- Biomass: +2.1%
- Pasture: -9.1%
- Fodder herb: -13%
- Fodder grass: -19%
- Misc crop: +2.7%
- Root tuber: -1.9%

Year:
- 2010
- 2040
- 2070
- 2100
AEZ boundaries affect biomass energy

Percent change in biomass energy (new minus old)

- Former Soviet Union +31%
- Southeast Asia -2%
- Global -11%
- India -40%
- Eastern Europe -71%

Year: 2020, 2040, 2060, 2080, 2100
AEZ boundaries affect LULCC emissions

Change in LULCC emissions (MtC/yr) (new minus old)

Up to 50% change in annual net global LULCC emissions
Summary

• AEZ-based land units do not consistently meet homogeneity assumption for land use projection

• Reproducibility: New land data system performs better than GTAP with respect to FAO data

• Global distributions of crop production, harvested area, and forest land rent are different between the original and new land units

• Global and regional land resource projections are different between original and new land units

• Feedbacks: climate, impact, and land use
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Global distributions of Paddy Rice Production

14 regions

32 regions
AEZ boundaries affect projected land use/cover

Global change in land area (percent; new minus old)

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- Biomass +8.3%
- Other crops +1.8%
- Grain crops -2.4%
- Harvested forest -3.4%
- Pasture -9.3%

- Fodder crops +16%
- Biomass +4.3%
- Grain crops -3.0%
- Harvested forest -3.4%
- Pasture -7.4%

14 regions

32 regions
Current land units become heterogeneous
Current AEZs become heterogeneous
Current AEZs become heterogeneous

Length of growing period (for no TZ change): ECHAM 2100 – original
Current AEZs become heterogeneous

Length of growing period (for +1 TZ change): ECHAM 2100 – original