The effects of land unit boundaries on GCAM land use and land cover projection

Alan V. Di Vittorio
Lawrence Berkeley National Laboratory

With special thanks to Page Kyle and Pralit Patel

IA/GCAM annual workshop
21 October 2014
Global distributions of Paddy Rice Production
AEZ boundaries affect projected land use/cover

Southern South America (new minus old)

- Crops +7%
- Biomass +130%
- Managed forest -12%
- Pasture -14%

Change in land area (thous km²)

Year:
- 2010
- 2040
- 2070
- 2100

Land allocation:
- Urban
- Crops
- Pasture (grazed)
- Forest (managed)
- Biomass
- Forest (unmanaged)
- Shrubs
- Grass/other pasture
- Desert
Different boundaries give different “local” estimates.

Temperature maximum, Jan. 1, 2003

- Cell size is 2.5 minutes (~5 km)
- 1 degree (~100 km) per side
- 0.5 degree (~50 km) per side
- 0.25 degree (~25 km) per side

10.66 °C
12.00 °C
12.24 °C
12.66 °C

4
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 use projection</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMAGE (RCP 2.6)</td>
<td>26</td>
<td>half-degree grid</td>
</tr>
<tr>
<td>MiniCAM (RCP 4.5)</td>
<td>14</td>
<td>GCAM: 151 land units</td>
</tr>
<tr>
<td>AIM (RCP 6.0)</td>
<td>24</td>
<td>half-degree grid</td>
</tr>
<tr>
<td>MESSAGE (RCP 8.5)</td>
<td>11</td>
<td>half-degree grid</td>
</tr>
</tbody>
</table>
Land cover inconsistencies across IAMs and ESMs can alter the global carbon cycle

Change in global area (from 2015)

Forest
- 7.7 M km²
- 66% increase

Pasture
- 4.4 M km²
- 94% decrease

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 use change in the context of projected climate change?

• How do spatial boundaries influence projected land use?
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

2. **Calculate crop production and harvested area per 18 AEZs X 226 GTAP countries**

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

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

5. **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
Global distributions of Paddy Rice, by country

Production (t) vs. Harvested area (ha) cumulative distribution comparison.
Distribution differences for Paddy Rice, by country

PaddyRice % production difference histogram comparison

- GTAP – FAO
- Original AEZs – FAO

Production difference (%)
Each crop is uniquely affected by new land units.
Global distributions of forest land rent, by GTAP land unit

Forestry land rent cumulative distribution comparison

Cumulative probability

Land Rent (US$)

GTAP
Original AEZs

New AEZs

Land Rent (US$)

Original AEZs

GTAP
AEZ boundaries affect projected land use/cover

Russia (new minus old)

Change in land area (thous km²)

- Biomass +78%
- Pasture +8%
- Managed forest -12%

Year
AEZ boundaries affect projected land use/cover

Central Asia (new minus old)

- Biomass: +600%
- Managed forest: -33%
- Pasture: -22%
- Crops: -21%
AEZ boundaries affect projected land use/cover

Northern South America (new minus old)

Change in land area (thous km^2)

- Crops: +6%
- Biomass: +inf
- Managed forest: -21%
- Pasture: -1.7%
- Unmanaged forest: -1.1%

Year

Change in land area (thous km^2)
Summary

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

• New software performs better than GTAP with respect to FAO data: Reproducibility?

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

• Regional land use/cover distributions are different between the original and new land units

• Feedbacks: climate, impact, and land use
Summary

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

• New software performs better than GTAP with respect to FAO data: Reproducibility?

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

• Regional land use/cover distributions are different between the original and new land units

• Feedbacks: climate, impact, and land use
Summary

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

• New software performs better than GTAP with respect to FAO data: Reproducibility?

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

• Regional land use/cover distributions are different between the original and new land units

• Feedbacks: climate, impact, and land use
Summary

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

• New software performs better than GTAP with respect to FAO data: Reproducibility?

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

• Regional land use/cover distributions are different between the original and new land units

• Feedbacks: climate, impact, and land use
Summary

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

• New software performs better than GTAP with respect to FAO data: Reproducibility?

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

• Regional land use/cover distributions are different between the original and new land units

• Feedbacks: climate, impact, and land use
Opportunities

• Optimize GCAM land units

• New spatial land delineation
  • AgLU coincides with water module?
  • AEZ x watershed?

• Facilitate spatial data consistency across global models
This work is supported by the Director, Office of Science, Office of Biological and Environmental Research of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231 as part of their Integrated Assessment Research Program.
Different resolutions have different biases

Switchgrass in Illinois, simulation vs obs

Di Vittorio and Miller, 2014
Land use distribution assumes uniform vegetation productivity within zones.
Current land units become heterogeneous.

Length of growing period (LGP): ECHAM 2100 – original
Land use distribution assumes uniform vegetation productivity within zones

- Do projected Agro-Ecological Zones alter land use trajectories?
Current AEZs become heterogeneous
Current AEZs become heterogeneous.

Length of growing period (for no TZ change): ECHAM 2100 – original
Current AEZs become heterogeneous
Global distributions of Maize, by country

Maize production cumulative distribution comparison

Maize harvested area cumulative distribution comparison
Global distributions of Oil Palm Fruit, by country

**OilPalmFruit production cumulative distribution comparison**

**OilPalmFruit harvested area cumulative distribution comparison**
Global distributions of Wheat, by country

Wheat production cumulative distribution comparison

Wheat harvested area cumulative distribution comparison
Distribution differences for Maize, by country

Maize % production difference histogram comparison

Maize % harvested area difference histogram comparison

Production difference (%)  Harvested area difference (%)

Frequency

GTAP – FAO
Original AEZs – FAO

GTAP – FAO
Original AEZs – FAO
Distribution differences for Oil Palm Fruit, by country
Distribution differences for Paddy Rice, by country

PaddyRice % production difference histogram comparison

PaddyRice % harvested area difference histogram comparison

Production difference (%)  Harvested area difference (%)
Distribution differences for Wheat, by country

Wheat % production difference histogram comparison

Wheat % harvested area difference histogram comparison

Production difference (%)  Harvested area difference (%)
Global distributions of Maize, by land unit

Maize production cumulative distribution comparison

Maize harvested area cumulative distribution comparison

Cumulative probability

Production (t)

Harvested area (ha)
Global distributions of Oil Palm Fruit, by land unit

Oil Palm Fruit production cumulative distribution comparison

Oil Palm Fruit harvested area cumulative distribution comparison

Production (t) | Harvested area (ha)

Cumulative probability

GTAP, Original AEZs, New AEZs
Global distributions of Wheat, by land unit

Wheat production cumulative distribution comparison

Wheat harvested area cumulative distribution comparison

Production (t) vs. Cumulative probability

Harvested area (ha) vs. Cumulative probability

GTAP, Original AEZs, New AEZs