Downscaling economic projections of land cover & land use change for carbon management and Earth system modeling: a multi-scalar approach

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Carbon management - defined

- **Conducting activities that alter carbon sources or sinks.**
- Usually done to reduce net CO$_2$ emissions (and other GHG emissions).
- Different from observation or monitoring.
  - Requires knowledge of direct and indirect consequences of human action on carbon dynamics.
  - Often requires higher spatial and temporal resolution for attribution purposes (Duren and Miller 2011).

How might we model local management options across large scales within a global context?

Zhang et al. 2010. GCB Bioenergy.


Zhang et al. 2010. GCB Bioenergy.
Carbon management - consistency among scales

- Consistent land areas:
  - high resolution sums to course resolution;
  - distribution of land classes is similar geographically

- Consistent estimates of C stocks

- understanding drivers of land cover change and adoption of management strategies

- $$$
- See presentation by Thomson et al.
  (decision support theme)
Conceptual diagram of the North American CO$_2$ budget: sources, sinks, and lateral movement


Human Dimensions. Economically driven. Management and Adaptation opportunities
Some current downscaling options - conducted independently of one another

Land area and management data (e.g., inventory or model output) can be spatially distributed based on remotely-sensed land cover.

Data input:
- County NASS or FIA; Regional land-cover change model
- FAO; Global land-cover change model

Baseline land cover:
- National Land Cover Data; Cropland Data Layer (<100m)
- MODIS (>500m; often >0.5 degree)

Receiving model:
- EPIC, Century, DNDC
- CLM, Earth system models
New downscaling option
- consistent and multi-scalar

Data input:
- County NASS or FIA;
- Regional land-cover change model
- MODIS or better land cover; multiple if needed
- FAO;
- Global land-cover change model

Baseline land cover:

Receiving model:
- EPIC, Century, DNDC
- CLM, iESM

Two options:
1. start with <100m downscaling and grid up to other needed resolutions.
2. use one consistent method for downscaling to multiple resolutions, thereby maintaining total land areas.
Multi-scalar earth system modeling

Global Earth System Model (Climate, Biogeochemistry)

Global Integrated Assessment Model (Socioeconomics, Energy Technology)

Boundary Conditions

Regionalization

Regional Earth System Model
- Atmosphere
- Land
- Ocean & Coasts
- Biogeochemistry

Regionalized Integrated Assessment Model
- Socioeconomics
- Energy-Economics
- Agriculture & Land Use
- Water

Regional Sectoral Models
- Energy Infrastructure
- Building Energy Demand
- Crop Productivity
- Water Supply
- Water Management
- Land Use, Land Cover

Feedbacks

Data Exchange

### Categorization of current methods

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Spatial Distribution</th>
<th>LULC Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Mixed</td>
<td>Heterogeneous</td>
</tr>
<tr>
<td>High</td>
<td>Pure</td>
<td>Homogeneous</td>
</tr>
</tbody>
</table>
Consistent downscaling method

1. Reconcile land classes
2. Estimate land cover transitions

D1
Revised current or future LULC realization
Whole distribution

D2
Revised current or future LULC realization
Percentage distribution

B
Baseline (current) LULC distribution

C
Environmental factors or geospatial constraints

3. Distribute new land cover (A) to baseline land cover (B), constrained by environmental factors (C), and based on (1) reconciled land classes and (2) land cover transitions

\[ X_1 = \sum_{i=1}^{\infty} LC_{1M_i} - LC_{1B} \quad \text{Eq. 1} \]
\[ X_2 = \sum_{i=1}^{\infty} LC_{2M_i} - LC_{2B} \quad \text{Eq. 2} \]
\[ \sum (+X_1, +X_2, +X_3, \ldots) = \xi \left( \sum (-X_1, -X_2, -X_3, \ldots) \right) \quad \text{Eq. 3} \]

Where LC is total area per land class in model output (M) subtracted from total land area per class in baseline (B) data.
• Obtain or generate estimates of fields or land parcels
• Maintain parcel and original grid ID throughout processing
• Set up programming and GIS to work with >2GB files and data input x 10^6
• Follow steps in preceding diagram
• Regrid parcels with revised land cover, maintaining original grid IDs
Results - Pure-homogeneous land realization

POLYSYS 2030 land realization based on meeting EISA 2007 cellulosic ethanol mandate
Results – Pure-heterogeneous land realization

GCAM 2050 land realization based on no-policy scenario
Results – *Mixed spatial distribution*

- *Export table of all grid cells and attribute (not attribute summary table)*
- Maintain original grid ID throughout processing
- Follow steps in preceding diagram
Results – Mixed-heterogeneous realization

GCAM 2050 land realization based on no-policy scenario

Percentage of crop per grid cell (Percent Corn)
- 0 - 8
- 8.1 - 15
- 15.1 - 21.9
- 22 - 28.5
- 28.6 - 34.8
- 34.9 - 40.4
- 40.5 - 45.6
- 45.7 - 51
- 51.1 - 57.9
- 58 - 75.7
### Results

<table>
<thead>
<tr>
<th>Grid cell value</th>
<th>Corn</th>
<th>Other grain</th>
<th>Oil crop</th>
<th>Wheat</th>
<th>Fodder (herbaceous)</th>
<th>Pasture</th>
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<tbody>
<tr>
<td>1.0</td>
<td>19.4</td>
<td>0.2</td>
<td>32.2</td>
<td>0.5</td>
<td>4.0</td>
<td>31.9</td>
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<tr>
<td>2.0</td>
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<td>0.3</td>
<td>29.4</td>
<td>0.0</td>
<td>5.0</td>
<td>13.5</td>
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<tr>
<td>3.0</td>
<td>39.1</td>
<td>0.1</td>
<td>38.1</td>
<td>0.0</td>
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<td>10.0</td>
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<td>28.3</td>
<td>0.0</td>
<td>6.4</td>
<td>15.4</td>
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<td>39.3</td>
<td>0.1</td>
<td>46.2</td>
<td>0.0</td>
<td>2.4</td>
<td>5.7</td>
</tr>
</tbody>
</table>

Sample of grid attribute table showing the percentage of land classes for first ten grid cells. Total number of grid cells in a 0.05 degree grid for Iowa equals 6396. Percent area does not equal 100, because many other classes that are represented in the grid (e.g., urban area, water, forest) are not included in this table.
Current/Future: CMS Phase 2 Flux Project

Estimating Global Inventory-based Net Carbon Exchange from Agricultural Lands (West, PI)

- Global crops, livestock, humans, and import/export, by national and sub-national areas
- MODIS global mosaicked land cover data from GLCF via NASA ACCESS project (Emanuel, PI)
- Downscaling methods presented here
- Spatially distributed carbon stocks and fluxes associated with agricultural activities
Future: Research

- Similar distributions for crops, forests, urban area.
- Similar distributions for NPP. Also examining how spectral reflectance can be used in the distribution process.
Conclusions

• Regional (management) to global (climate) link.
• Attribution (needed for carbon monitoring and management)
• Improved carbon source / sink estimates
• Improve ability to assess management options, mitigation, adaptation.
Acknowledgments

NASA - Carbon Monitoring System

PNNL — Laboratory Research and Development Program

North American Carbon Program