A Continental United States High Resolution NLCD Land Cover – MODIS Albedo Database to Examine Albedo and Land Cover Change Relationships

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J. Wickham, US EPA, RTP, NC
C. Barnes, ASRC InuTeq, USGS-EROS, Sioux Falls, SD
M. Nash, US EPA, Las Vegas, NV
Extra-tropical forests are warm relative to surrounding fields

Extra-tropical deforestation produces a cooling effect

Boreal deforestation greater cooling; temperate deforestation less cooling
Extra-tropical forests are warm relative to surrounding fields


Diffenbaugh 2009. Influence of modern land cover on climate of the U.S. *Climate Dynamics* 33:945.


Brovkin et al. 2006. Biophysical effects of historical land cover changes simulated by six ... *Climate Dynamics* 26:587.


Brovkin et al. 2004. Role of land cover changes for atmospheric CO² increase and climate ... *Glob. Change Biol.* 1:1


Importance of the warming effect of extra-tropical forests

Many organizations promote forestation (afforestation & reforestation) as a climate mitigation strategy.

- UNFCC, IPCC, U.S. federal agencies

Forestation-oriented climate mitigation policies must account for biogeophysical effects in addition to biogeochemical effects (carbon sequestration)

Importance of accounting for biogeophysical effects


Why might extra-tropical forests warm?

Forests are darker (lower albedo) than surrounding herbaceous vegetation

- Albedo difference is accentuated in presence of snow
- The cooling effect of transpiration is only seasonally active
- Crops have lower stomatal resistance than forests (Bonan 1997)
- Forests “trap” heat at night (Lee et al. 2011)

The effect of albedo on radiative forcing extends beyond the boundary layer; leads to tropospheric cooling (Davin and de Noblet-Ducoudré 2010).
Albedo

Albedo difficult to measure, labile, and differences between forest and cropland albedos are often small (Alton 2009, Hollinger et al. 2010).

**PFT Model 1 Model 1 Model 1 Model 1 Model 1**

<table>
<thead>
<tr>
<th>PFT</th>
<th>Model 1</th>
<th>Model 1</th>
<th>Model 1</th>
<th>Model 1</th>
<th>Model 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>BDT</td>
<td>0.15</td>
<td>0.15</td>
<td>0.19</td>
<td>0.13</td>
<td>0.18</td>
</tr>
<tr>
<td>NDT</td>
<td>0.13</td>
<td></td>
<td>0.14</td>
<td>0.13</td>
<td>0.13</td>
</tr>
<tr>
<td>BET</td>
<td></td>
<td>0.11</td>
<td>0.11</td>
<td>0.13</td>
<td>0.12</td>
</tr>
<tr>
<td>NET</td>
<td>0.10</td>
<td>0.15</td>
<td>0.13</td>
<td>0.11</td>
<td>0.14</td>
</tr>
<tr>
<td>Grass</td>
<td>0.18</td>
<td>0.20</td>
<td>0.19</td>
<td>0.20</td>
<td>0.20</td>
</tr>
<tr>
<td>Crop</td>
<td>0.19</td>
<td>0.20</td>
<td>0.16</td>
<td>0.20</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Adapted from Hollinger et al. (2010). BDT=broadleaf deciduous tree; NDT=needle-leaf deciduous tree; BET=broadleaf evergreen tree; NET=needle-leaf evergreen tree; *=max of reported range.

A “variance” of ± 0.02 in albedo produces significant changes in regional climate simulations (He et al. 2012).
NLCD Land Cover – MODIS Albedo Dataset

Dataset Characteristics

Albedo
- 14 years (2000-2013); 46 dates/year; year 2000 is without January through mid-February
  - maximum of 638 observations/pixel (if no missing values)
- Only high quality albedo observations included
- Spatial resolution\(^1\) = 480 m\(^2\)
- Includes snow-covered & snow-free observations
- Spatially aligned to NLCD (NLCD albers equal-area projection)
- Layers of number of observations / pixel for each of 46 dates (total, snow-cover, study period)

NLCD
- Homogenous at 480m\(^2\)
- Elevation, slope, and aspect
- 14 of 16 NLCD classes (480m\(^2\)); collapsed 4 urban categories into 2

Availability
- www.mrlc.gov (not yet)

\(^1\) Nominal MODIS spatial resolution do not equal actual spatial resolutions
NLCD Land Cover – MODIS Albedo Dataset

Number of observations per pixel

Number of days:
- 0 - 121
- 122 - 242
- 243 - 363
- 364 - 484
- 485 - 605
NLCD Land Cover – MODIS Albedo Dataset

Number of snow-covered observations per pixel

Number of days
- 0
- 1 - 30
- 31 - 60
- 61 - 196
Analysis

Albedo
- Components of variance for static NLCD classes
- Effect of land-cover change on albedo
NLCD Land Cover – MODIS Albedo Dataset

Albedo components of variance

Variance components
1. Year
2. Tile (geography)
3. Year*tile
4. Pixel (within tile)
5. Year*pixel(within tile)
6. Day of year (season)

Selection
1. 5 tiles / NLCD class
2. 50 pixels / tile
**NLCD Land Cover – MODIS Albedo Dataset**

Albedo components of variance

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Type III SS</th>
<th>Mean Square</th>
<th>F value</th>
<th>Pr &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Evergreen Forest</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tile</td>
<td>4</td>
<td>0.491</td>
<td>2.3728</td>
<td>153.37</td>
<td>0.0001</td>
</tr>
<tr>
<td>Year</td>
<td>12</td>
<td>0.057</td>
<td>0.0048</td>
<td>28.81</td>
<td>0.0001</td>
</tr>
<tr>
<td>Tile*year</td>
<td>48</td>
<td>0.279</td>
<td>0.0058</td>
<td>33.02</td>
<td>0.0001</td>
</tr>
<tr>
<td>Pixel(tile)</td>
<td>245</td>
<td>4.414</td>
<td>0.0180</td>
<td>101.42</td>
<td>0.0001</td>
</tr>
<tr>
<td>Pixel*tile(year)</td>
<td>2940</td>
<td>0.536</td>
<td>0.0002</td>
<td>1.89</td>
<td>0.0001</td>
</tr>
<tr>
<td>DOY</td>
<td>45</td>
<td>0.496</td>
<td>0.0555</td>
<td>574.90</td>
<td>0.0001</td>
</tr>
<tr>
<td><strong>Deciduous Forest</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tile</td>
<td>4</td>
<td>1.332</td>
<td>0.3330</td>
<td>24.54</td>
<td>0.0001</td>
</tr>
<tr>
<td>Year</td>
<td>12</td>
<td>0.227</td>
<td>0.0189</td>
<td>137.78</td>
<td>0.0001</td>
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<tr>
<td>Tile*year</td>
<td>48</td>
<td>0.249</td>
<td>0.0052</td>
<td>37.43</td>
<td>0.0001</td>
</tr>
<tr>
<td>Pixel(tile)</td>
<td>245</td>
<td>3.449</td>
<td>0.0139</td>
<td>103.26</td>
<td>0.0001</td>
</tr>
<tr>
<td>Pixel*tile(year)</td>
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<td>0.410</td>
<td>0.0001</td>
<td>1.45</td>
<td>0.0001</td>
</tr>
<tr>
<td>DOY</td>
<td>45</td>
<td>23.083</td>
<td>0.5130</td>
<td>5328.78</td>
<td>0.0001</td>
</tr>
</tbody>
</table>


All factors were significant; pixel-to-pixel variability [pixel(tile)] was often the third most significant factor following the expected dominant factors of season (DOY) and geography (tile).
NLCD Land Cover – MODIS Albedo Dataset

Albedo components of variance

Deciduous forest

○ = inter-quartile range
NLCD Land Cover – MODIS Albedo Dataset

Albedo components of variance

13-year albedo profiles for two cropland pixels ~25km apart
**NLCD Land Cover – MODIS Albedo Dataset**

**Effect of land-cover change on albedo**

**Time series regression of albedo using land-cover change pixels**

<table>
<thead>
<tr>
<th>Change</th>
<th># models</th>
<th># sig. models</th>
<th># non-sig. models</th>
<th>Min Change</th>
<th>Max Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>41 &gt; 71</td>
<td>15</td>
<td>9</td>
<td>6</td>
<td>0.002</td>
<td>0.015</td>
</tr>
<tr>
<td>42 &gt; 71</td>
<td>13</td>
<td>10</td>
<td>3</td>
<td>0.001</td>
<td>0.030</td>
</tr>
<tr>
<td>41 &gt; 52</td>
<td>4</td>
<td>0</td>
<td>4</td>
<td>0.001</td>
<td>0.010</td>
</tr>
<tr>
<td>42 &gt; 52</td>
<td>20</td>
<td>15</td>
<td>5</td>
<td>0.002</td>
<td>0.039</td>
</tr>
<tr>
<td>42 &gt; 82</td>
<td>8</td>
<td>8</td>
<td>0</td>
<td>0.014</td>
<td>0.064</td>
</tr>
</tbody>
</table>

Notes: 41 > 71 = deciduous forest to grassland; 42 > 71 = evergreen forest to grassland; 41 > 52 = deciduous forest to shrubland; 42 > 52 = evergreen forest to shrubland; 42 > 82 = evergreen forest to cropland.

Min & max change = minimum and maximum differences in mean albedo across all models per change class after separating into before and after change groups.
Effect of land-cover change on albedo

Time series regression of albedo using land-cover change pixels

Albedo = 0.1378 + 0.0000026718(date)
Pr > |t| < 0.0001 (intercept); = 0.2626 (slope)
1. Compiled high resolution, long-term (14 years) land cover – albedo using NLCD and MODIS.

2. There are several components to variance in albedo; non-stationarity in features within a land cover class was consistently a significant factor in albedo variability in addition to the expected factors of season and geography; topographic factors were never significant.

3. Land-cover change (so far) does not always result in distinct changes in albedo, and before and after (land-cover change) mean albedos tend to smaller than those reported in the literature.
NLCD Land Cover – MODIS Albedo Dataset

Questions


