The future direction for LCLUC validation activities

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with contributions from NELDA Project team
and GOFC-GOLD Land Cover Implementation Team
Figure 4. (a) Map of Russian forest biomass as predicted by the MODIS land-cover product (MOD12Q1). (b) Map of Russian forest biomass as predicted by the GLC2000 land-cover product (Bartalev et al. 2003).
Introduction

1. As the land cover community matures, an increasing emphasis on validation and accuracy assessment - a difficult, somewhat unpleasant and surprisingly expensive activity

2. The GOFC-GOLD LC IT has proposed to support the broader community through validation

3. Idea is to collect ground reference data independent of any single land cover product to support validation of many land cover datasets

4. Intent is to supplement and complement ongoing validation activities associated with individual land cover datasets
GLOBCOVER (2005/6)

Beta version in review by GEO task team
Dataset release: September 2008
Supporting Developments

1. Prior experiences with global land cover validation
2. Emergence of LCCS - and its value in promoting consistency in land cover descriptors used in legends for land cover datasets
3. Development of community consensus on “best practices” for global land cover accuracy assessment (CEOS WGC report)
International consensus on technical issues

“Best Practices Document”

Strahler et al., 2006
A “Living Reference Dataset”

A set of validation sites distributed around the globe

Based on high resolution (a few meters) imagery interpreted by regional experts (the regional networks)

Checked annually for land cover change, and updated periodically

Limited set of land cover classifiers
  life form - (trees, shrubs, herbaceous)
  cover
  leaf type
  leaf phenology
Categories in existing global datasets

Terminology: land cover classifiers (LCCS)

- Classifiers commonly used to characterize land cover worldwide
  - i.e. life form & surface type, leaf type & phenology, terrestrial/aquatic

Common classifiers (Terminology standard)

- Basic set of standardized classes based on combination of common classifiers and independent of any cartographic standard
  - i.e. broadleaved evergreen trees, herbaceous crops, built up area

Generic classes (Thematic standard)

- Application of cartographic generalization (MMU) to generic classes
  - Definition of mixed categories or using density thresholds
  - i.e. Closed to open (>15%) broadleaved evergreen forest (> 5m)
Thematic standards

Common classifiers (Terminology standard)
- Classifiers commonly used to characterize land cover worldwide
  - i.e. life form & surface type, leaf type & phenology, terrestrial/aquatic

Generic classes (Thematic standard)
- Basic set of standardized classes based on combination of common classifiers and independent of any cartographic standard
  - i.e. broadleaved evergreen trees, herbaceous crops, built up area

Mapping Categories (Cartographic standard)
- Application of cartographic generalization (MMU) to generic classes
- Definition of mixed categories or using density thresholds
  - i.e. Closed to open (>15%) broadleaved evergreen forest (>5m)

Reference database (GLC2000)

Comparative validation & assessment

Trees (>15%)

GLC2000

IGBP

MODIS

UMD

Combined Classes

Probability

Shrubland

Grassland

Agricultural cropland

Non vegetated land
Field data

High resolution imagery

Transfer function

Aggregate & Relate

High resolution “Product”

Moderate resolution “Product”

Accuracy Assessment

for one product, at one site, at one point in time
NELDA

(Northern Eurasia Landcover Dynamics Analysis)

08/04/2009
Olga N. Krankina, OSU
Approach

• Combine remote sensing data (Landsat, MODIS) and local knowledge of land-cover conditions and change to validate and improve land cover / land-cover change products for Northern Eurasia
  – establish a set of test sites
  – use these sites to validate global and regional land cover / change products
  – produce a new, updated land cover map for Northern Eurasia based on MODIS data
### Similarity matrix for the GLC2000 and MODIS-PFT legends

<table>
<thead>
<tr>
<th>GLC-2000.LCCS (rows)</th>
<th>MODIS.PFT (columns)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Needleleaf evergreen tree</td>
<td>Needleleaf deciduous tree</td>
<td>Broadleaf deciduous tree</td>
<td>Shrub</td>
<td>Grass</td>
<td>Cereal crop</td>
<td>Broadleaf crop</td>
<td>Urban and built-up</td>
<td>Snow and ice</td>
<td>Barren or sparsely vegetated</td>
<td>Water</td>
<td></td>
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</tr>
<tr>
<td>1 Tree Cover, broadleaved, evergreen</td>
<td>T</td>
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<tr>
<td>2 Tree Cover, broadleaved, deciduous, closed</td>
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<tr>
<td>3 Tree Cover, broadleaved, deciduous, open</td>
<td>T</td>
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<tr>
<td>4 Tree Cover, needle-leaved, evergreen</td>
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<tr>
<td>5 Tree Cover, needle-leaved, deciduous</td>
<td>T</td>
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<tr>
<td>6 Tree Cover, mixed leaf type</td>
<td>T</td>
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<tr>
<td>7 Tree Cover, regularly flooded, fresh water</td>
<td>T</td>
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<td>T</td>
<td>ts</td>
<td>th</td>
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<tr>
<td>8 Tree Cover, regularly flooded, saline water</td>
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<td>lw</td>
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<tr>
<td>9 Mosaic: Tree cover / Other natural vegetation</td>
<td>T</td>
<td>T</td>
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<td>T</td>
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<td>H</td>
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<td>lw</td>
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<tr>
<td>10 Tree Cover, burnt</td>
<td>T</td>
<td>T</td>
<td>T</td>
<td>T</td>
<td>ts</td>
<td>th</td>
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<td>th</td>
<td>tb</td>
<td>tb</td>
<td>tb</td>
<td>lw</td>
</tr>
<tr>
<td>11 Shrub Cover, closed-open, evergreen</td>
<td>ts</td>
<td>ts</td>
<td>ts</td>
<td>ts</td>
<td>S</td>
<td>sh</td>
<td>sh</td>
<td>sh</td>
<td>sb</td>
<td>sb</td>
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<td>sb</td>
<td>lw</td>
</tr>
<tr>
<td>12 Shrub Cover, closed-open, deciduous</td>
<td>ts</td>
<td>ts</td>
<td>ts</td>
<td>ts</td>
<td>S</td>
<td>sh</td>
<td>sh</td>
<td>sh</td>
<td>sb</td>
<td>sb</td>
<td>sb</td>
<td>sb</td>
<td>lw</td>
</tr>
<tr>
<td>13 Herbaceous Cover, closed-open</td>
<td>th</td>
<td>th</td>
<td>th</td>
<td>th</td>
<td>sh</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>hb</td>
<td>hb</td>
<td>hb</td>
<td>lw</td>
</tr>
<tr>
<td>14 Sparse Herbaceous or sparse shrub cover</td>
<td>tb</td>
<td>tb</td>
<td>tb</td>
<td>tb</td>
<td>sb</td>
<td>hb</td>
<td>hb</td>
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<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>lw</td>
</tr>
<tr>
<td>15 Regularly flooded shrub and/or herbaceous cover</td>
<td>ts</td>
<td>ts</td>
<td>ts</td>
<td>ts</td>
<td>S</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>hb</td>
<td>hb</td>
<td>hb</td>
<td>lw</td>
</tr>
<tr>
<td>16 Cultivated and managed areas</td>
<td>th</td>
<td>th</td>
<td>th</td>
<td>th</td>
<td>sh</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>hb</td>
<td>hb</td>
<td>hb</td>
<td>lw</td>
</tr>
<tr>
<td>17 Mosaic: Cropland / Tree Cover / Other natural vegetation</td>
<td>T</td>
<td>T</td>
<td>T</td>
<td>T</td>
<td>S</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>hb</td>
<td>hb</td>
<td>hb</td>
<td>lw</td>
</tr>
</tbody>
</table>
Agreement in dominant vegetation cover (54%)
Agreement matrix for GLC-2000 and MODIS.PFT dominant vegetation types excluding water, 1000 km$^2$

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree</td>
<td>2,395</td>
<td>1,697</td>
<td>351</td>
<td>7</td>
<td>4,450</td>
</tr>
<tr>
<td>Shrub</td>
<td>200</td>
<td>1,922</td>
<td>105</td>
<td>31</td>
<td>2,258</td>
</tr>
<tr>
<td>Herbaceous</td>
<td>24</td>
<td>698</td>
<td>160</td>
<td>34</td>
<td>916</td>
</tr>
<tr>
<td>Barren</td>
<td>12</td>
<td>973</td>
<td>64</td>
<td>183</td>
<td>1,232</td>
</tr>
</tbody>
</table>

| Agreement | 91% | 36% | 23% | 72% | 53%      |

| Total     | 2,630 | 5,290 | 680 | 255 | 8,855    |
NELDA Test Sites
NELDA Land Cover

Change Map

Legend:
- Water
- Built
- nonTree
- Tree (undisturbed)
- 1980's Disturbance
- 1990's Disturbance
- 2000's Disturbance

4/8/2009
Olga N. Krankina, OSU
Approaches to validation
- Visual comparison
- Comparison of class areas
- Confusion matrices
  - % agreement
  - per-class omission/commission errors
Comparison of class areas

Carpathians

Chita

08/04/2009

Olga N. Krankina, OSU
Deriving confusion matrix: example for one 1 km pixel
### Agreement matrix for St. Petersburg site, km²

<table>
<thead>
<tr>
<th>GLC-2000</th>
<th>Trees</th>
<th>Shrubs</th>
<th>Herbaceous</th>
<th>Barren</th>
<th>Water</th>
<th>Commission</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trees</td>
<td>11,264</td>
<td>1,103</td>
<td>2,635</td>
<td>177</td>
<td>298</td>
<td>4,213</td>
</tr>
<tr>
<td>Shrubs</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Herbaceous</td>
<td>324</td>
<td>444</td>
<td>926</td>
<td>97</td>
<td>32</td>
<td>1,499</td>
</tr>
<tr>
<td>Barren</td>
<td>39</td>
<td>44</td>
<td>96</td>
<td>239</td>
<td>25</td>
<td>404</td>
</tr>
<tr>
<td>Mosaics</td>
<td>535</td>
<td>671</td>
<td>1,349</td>
<td>133</td>
<td>33</td>
<td>2,186</td>
</tr>
<tr>
<td>Water</td>
<td>167</td>
<td>33</td>
<td>87</td>
<td>47</td>
<td>940</td>
<td>1,107</td>
</tr>
<tr>
<td>Omission</td>
<td>1,066</td>
<td>1,194</td>
<td>2,460</td>
<td>517</td>
<td>1,030</td>
<td></td>
</tr>
</tbody>
</table>

**Agreement = 73.2%, Kappa = 50.5%**
Agreement of coarse resolution and Landsat-based maps at NELDA sites

<table>
<thead>
<tr>
<th>Location</th>
<th>Carpathians</th>
<th>St. Petersburg</th>
<th>Komi</th>
<th>WestSib</th>
<th>Priangare</th>
<th>Chita</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agreement</td>
<td>74.8%</td>
<td>83.9%</td>
<td>68.7%</td>
<td>73.0%</td>
<td>67.0%</td>
<td>76.1%</td>
</tr>
</tbody>
</table>

Legend:
- MODIS-IGBP (2001 v4)
- MODIS-IGBP (2001 v5)
- GLC-2000
- GLOBCOVER (v2.2)

Bar charts show the percentage agreement for each location:
- Carpathians: 74.8%, 83.9%, 68.7%, 73.0%, 67.0%, 76.1%, 73.2%, 69.4%, 40.0%, 45.9%, 25.9%, 67.2%, 67.6%, 70.0%, 74.2%, 80.0%, 83.4%, 84.6%, 85.5%, 67.7%, 73.3%, 70.2%, 75.7%
- St. Petersburg: 74.8%, 83.9%, 68.7%, 73.0%, 67.0%, 76.1%, 73.2%, 69.4%, 40.0%, 45.9%, 25.9%, 67.2%, 67.6%, 70.0%, 74.2%, 80.0%, 83.4%, 84.6%, 85.5%, 67.7%, 73.3%, 70.2%, 75.7%
- Komi: 74.8%, 83.9%, 68.7%, 73.0%, 67.0%, 76.1%, 73.2%, 69.4%, 40.0%, 45.9%, 25.9%, 67.2%, 67.6%, 70.0%, 74.2%, 80.0%, 83.4%, 84.6%, 85.5%, 67.7%, 73.3%, 70.2%, 75.7%
- WestSib: 74.8%, 83.9%, 68.7%, 73.0%, 67.0%, 76.1%, 73.2%, 69.4%, 40.0%, 45.9%, 25.9%, 67.2%, 67.6%, 70.0%, 74.2%, 80.0%, 83.4%, 84.6%, 85.5%, 67.7%, 73.3%, 70.2%, 75.7%
- Priangare: 74.8%, 83.9%, 68.7%, 73.0%, 67.0%, 76.1%, 73.2%, 69.4%, 40.0%, 45.9%, 25.9%, 67.2%, 67.6%, 70.0%, 74.2%, 80.0%, 83.4%, 84.6%, 85.5%, 67.7%, 73.3%, 70.2%, 75.7%
- Chita: 74.8%, 83.9%, 68.7%, 73.0%, 67.0%, 76.1%, 73.2%, 69.4%, 40.0%, 45.9%, 25.9%, 67.2%, 67.6%, 70.0%, 74.2%, 80.0%, 83.4%, 84.6%, 85.5%, 67.7%, 73.3%, 70.2%, 75.7%

Bar charts for each location show the percentage of each land cover type for each dataset.
Carpathians Landsat Classification Comparison to Global Products

<table>
<thead>
<tr>
<th></th>
<th>Tree</th>
<th>Shrubs</th>
<th>Herbaceous</th>
<th>Bare</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>MODIS-IGBP 2001v4</td>
<td>84</td>
<td>33</td>
<td>26</td>
<td>16</td>
<td>-1,500</td>
</tr>
<tr>
<td>MODIS-IGBP 2005v5</td>
<td>88</td>
<td>50</td>
<td>32</td>
<td>15</td>
<td>-1,000</td>
</tr>
<tr>
<td>GLC-2000</td>
<td>63</td>
<td>0</td>
<td>9</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>GlobCover</td>
<td>75</td>
<td>28</td>
<td>13</td>
<td>39</td>
<td>500</td>
</tr>
</tbody>
</table>

Area (Thousand hectares)
Take home messages

- Map selection matters
- Map performance depends on location and classes of interest
Conclusions

Validation of LC maps is a pressing need
  • currently activities are very limited

Community consensus on general framework for global land cover validation and accuracy assessment
  • efficiency of validation network is essential
  • independent of any single land cover product to support validation of many land cover datasets
  • global network with stratification by geographic regions, areas where maps differ, important rare land-cover classes
  • quantitative results to guide users (including error matrix for each map and region)

Details of validation methods are evolving
  • VCF and land cover change maps

Expanding the network of validation sites requires community effort
Globe-flower – *Trollius asiaticus*