Production of 500 m Global Land Cover Data using MODIS 2008 Data

GLCNMO  2nd Version
by Global Mapping Project
Global Mapping Project

By National Mapping Organizations (NMO) of 166 countries and 16 regions

Global Map:
Digital geographic information covering the global earth's surface with 8 layers including “Land Cover” (GLCNMO)

8 layers: Transportation, Boundary, Drainage, Population Centers, Elevation, Land Cover, Vegetation, Land Use
History of Global Mapping Project

- **1992**
  - Agenda 21 was adopted at Earth Summit.
  - Japan proposed “Global Map” concept.

- **1996**
  - ISCGM was established.

- **2000**
  - Started providing Global Map data

- **2002**
  - Johannesburg Summit (WSSD) Global mapping is included in adopted “Implementation Plan”.
Global Land Cover Datasets

300m-1km 20-class map

GLCC (IGBP-DISCover) AVHRR 1992

UMD LC AVHRR 1981, 1994

MODIS LC by BU MODIS 2000

GLCNMO MODIS 2003

GLCNMO MODIS 2008

GLCNMO MODIS 2013

GLC2000 VEGETATION 2000

GlobCover ENVISAT 2005

GlobCover ENVISAT 2009

30m 10-class map by China Landsat 2009, 2010
Existing six global land cover datasets

IGBP

UMD

MODIS LC

GLC2000

GLCNMO

GlobCover
The main satellite data used for GLCNMO 2008: MODIS data

- global coverage
  (except Antarctica and over 80deg.N lat.)
- 500 m resolution
- 7 bands (visible to SWIR)
- Observation year: 2008
- 16-day composite
- 23 periods/year
Original MODIS 2008 Data

~10 x 10 lat/long tiles in Sinusoidal projection

Processed at CEReS, Chiba University: Mosaic, Re-projection (to geographic lat/long) and Cloud removal
MODIS Data 2008/12/02–17

Before cloud removal

After cloud removal
MODIS 2003 July

1-km, 16-day composite, 7-bands MODIS 2003
<table>
<thead>
<tr>
<th>GLCNMO code</th>
<th>Supervised classification</th>
<th>Individual mappig</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Broadleaf evergreen forest</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Broadleaf deciduous forest</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Needleleaf evergreen forest</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Needleleaf deciduous forest</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Mixed forest</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>Tree open</td>
</tr>
<tr>
<td>7</td>
<td>Shrub</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Herbaceous</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Herbaceous with sparse tree / shrub</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Sparse vegetation</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Cropland</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Paddy field</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Cropland / other vegetation mosaic</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>Mangrove</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>Wetland</td>
</tr>
<tr>
<td>16</td>
<td>Bare Area, consolidated (gravel,rock)</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Bare Area, unconsolidated (sand)</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Bare Area, unconsolidated (sand)</td>
<td>Urban</td>
</tr>
<tr>
<td>19</td>
<td></td>
<td>Snow / ice</td>
</tr>
<tr>
<td>20</td>
<td></td>
<td>Water bodies</td>
</tr>
</tbody>
</table>
Classification

14 classes
Training data 7-13 classes continentally
20-140 sub-classes continentally
at least 100 pixels per sub-class
Decision tree method
continentally

6 classes (water, urban, tree open, snow/ice, mangrove, wetlands)
Individual mapping
Classification flow

- Combined method of supervised classification and individual mapping

- Decision tree method was Selected

- Collection of training data using integrated potential map, Google Earth image, and MODIS images
Reference map for the collection of training data

Agreement of six global land cover data for ‘cropland’

complete agreement
Distribution of 2080 training polygons
Classification

6 classes (water, urban, tree open, snow/ice, mangrove, wetlands)

Individual mapping
Water

- Thresholding of MODIS Tasseled Cap Transformation (TCT) indices

- MOD44W and SRTM DEM were used as reference data
Salt lakes in Central Asia

(a) MODIS 2008/04/06

(b) MODIS 2008/07/27

(c) GLCNMO 2003

(d) GLOBCover

(e) MOD44W

(f) GLCNMO 2008

Aral Sea

Chimboy Lake

Water
Urban

Data used: population, DMSP/OLS, Impervious, MODIS

Population data 2008 (1km) → Area of a pixel → Population density (1km) → Resampling to 500m pixel → Threshold → Integration (exclude (2), (3), and (4) from (1)) → Urban map

DMSP-OLS 2008 (1km) → ISA 2010 (1km) → MODIS 2008 (500m) → Maximum NDVI of 23 periods → Four types of countries:
  - type 1: low income
  - type 2: lower middle income
  - type 3: upper middle income
  - type 4: high income

GDP per capita 2008 Country (IMF)

Threshold:
- (2) Area of less nighttime light
- (3) Area of less impervious surface
- (4) Area of more vegetation

Urban Data used: population, DMSP/OLS, Impervious, MODIS
## Urban

### Comparisons of Urban area

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
<tr>
<td>Landsat ETM+ 2007</td>
<td>GRUMP</td>
<td>GLC2000</td>
<td>GLOBCover</td>
</tr>
<tr>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
<td><img src="image7.png" alt="Image" /></td>
<td><img src="image8.png" alt="Image" /></td>
</tr>
</tbody>
</table>

**Ha Noi, Viet Nam**
Global wetlands locations in the Ramar Convention

163 countries participate in and 2056 wetlands are contained.
Total surface area of designated sites (hectares): 193,861,739

The Ramsar definition of "wetlands" is a broad one, including not just marshes, fen and peatland, but also lakes, coral reefs, temporary pools, even underground caves, and all sorts of other systems everywhere from the mountains to the sea, including man-made habitats.

(source – the Convention on Wetlands website)
Flow of wetland mapping

MODIS 500 m data (2008)

TC brightness (23 periods)

TC Greenness (23 periods)

TC wetness (23 periods)

Selection of best band

Wetland site in Ramsar (>1000 km²)

Extract one wetland

Threshold

Integration of each wetland

Final wetlands map

Google Earth imagery
Distribution of 904 validation points for GLCNMO 2008
<table>
<thead>
<tr>
<th>GLCNMO 2008 (20 classes)</th>
<th>GLCNMO 2008 (8 aggregated classes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall accuracy</td>
<td>77.9%</td>
</tr>
<tr>
<td></td>
<td>91.4%</td>
</tr>
<tr>
<td>-------------------------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td>1. Forest</td>
<td>1. Broadleaf evergreen forest&lt;br&gt;2. Broadleaf deciduous forest&lt;br&gt;3. Needleleaf evergreen forest&lt;br&gt;4. Needleleaf deciduous forest&lt;br&gt;5. Mixed forest&lt;br&gt;6. Tree open&lt;br&gt;7. Shrub&lt;br&gt;8. Herbaceous&lt;br&gt;9. Herbaceous with sparse tree/shrub</td>
</tr>
<tr>
<td>2. Other natural vegetation</td>
<td>8. Herbaceous&lt;br&gt;9. Herbaceous with sparse tree/shrub</td>
</tr>
<tr>
<td>3. Cropland</td>
<td>11. Cropland&lt;br&gt;12. Paddy field&lt;br&gt;13. Cropland/other vegetation mosaic</td>
</tr>
<tr>
<td>4. Wetland</td>
<td>14. Mangrove&lt;br&gt;15. Wetland</td>
</tr>
<tr>
<td>5. Bare area/ Sparse vegetation</td>
<td>16. Bare Area, consolidated (gravel, rock)&lt;br&gt;17. Bare Area, unconsolidated (sand)&lt;br&gt;10. Sparse vegetation</td>
</tr>
<tr>
<td>6. Urban</td>
<td>18. urban</td>
</tr>
<tr>
<td>7. Snow/ice</td>
<td>19. Snow/Ice</td>
</tr>
<tr>
<td>8. Water</td>
<td>20. Water</td>
</tr>
</tbody>
</table>

Total: 269 128 128 86 129 54 55 55 904

Producer's accuracy (%): 95.5 83.6 82.0 86.0 94.6 98.1 96.4 100
Data availability

- Land cover product
- Training data
- MODIS data

1. CEReS Chiba Univ. website

or

2. Data sharing system “CEReS Gaia”
A New Geospatial Data Sharing/Overlay System for Land Environmental Studies

CEReS Gaia
Eight features of CEReS Gaia

1. Free access without user registration

http://gaia.cr.chiba-u.jp/portal
Acceptable data to CEReS Gaia are:
georeferenced data by latitude/longitude such as
  satellite image, thematic data,
  scanned map, ground measured data,
  ground photos, geo-registered documents
and their related files

Acceptable formats are:
  GeoTIFF for raster
  shape file for vector
  lat/long information can be given to photos/documents
  any other formats for related files
Input to the system

Data share

Forest fire

Flood map

Changing Aral

Land cover map

Ground photo
3. Data upload by registered users

By simple user registration,

You can upload GeoTiff image, Shape vector, documents of any format, and other files from your PC.
4. Options of accessibility for uploaded data:
- single use, group use, or public release
- display only or downloadable

personal use

share within a group

You can form a user group or join into a user group

publish data
**CEReS Gaia**

5. Data search

- **Search by area**
  - Image: Raster data
  - Vector: line, point, polygon...
  - Document: PDF, HTML, WORD

- **Search by keywords**

- **Search by polygon**

- **Search results**

- **Metadata and thumbnail**
6. Overlaid display with transparency among user’s data, registered data, and WMS image

Simple transparency of one image & Trilateral transparency
7. 
Cluster system, expandable
User structure of CEReS Gaia

- superuser
  - system manager
    - group leader
      - unreg. user
      - reg. user
    - reg. user
  - system manager
    - group leader
      - unreg. user
      - reg. user
    - reg. user
  - system manager
    - group leader
      - unreg. user
      - reg. user
    - reg. user

Internationally expandable

- server
- disk

reg. user: registered user
unreg. user: not registered user
8. Open source to system managers except linkage among clusters and data access control
Geospatial data sharing/overlay system

“CEReS Gaia”

- Data overlay
- Free use
- Internationally expandable
- Open source

POTAL SITE
- User friendly interface
- Data accumulation
- International data sharing

User: researchers interested in earth surface environment
Initial Data

- Landsat data: Landsat GeoCover
- MODIS data: global, 2003 and 2008
- DMSP OLS data: nighttime lights
- DEM: global ASTER GDEM
- Population data: LandScan(2008)
- the Harmonized World Soil Database by FAO, etc.
- Constructed impervious surfaces by NGDC
- Global land cover: GLCNMO and its training data
- Global percent tree cover
Invitation to CEReS Gaia

♦ As a non-registered user: Access the site <http://gaia.cr.chiba-u.jp/portal>. You can see existing registered data. You can also overlay your own GeoTIFF or shape format data onto the registered data.

♦ As a registered user: You can upload your own data for the public data dissemination.

♦ As a user group: You can share data only within the user group.

♦ As a system manager
  Responsibilities: maintenance of hardware and approval of user groups
  Requirements: manage a server system
  spend a limited time for the communication with users
Schedule of CEReS Gaia

2010-2012.8 development
2012.9-2013 improvement
2014-continuing use

Launched August 2012
Thank you

Cluster system

CEReS GAIA

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Flow of GLCNMO2008 mapping

- **MODIS 2008**
  - continental cloud-free MODIS data
  - Decision tree method
  - Merge subclasses to 14 classes (Result of supervised classification)
  - Acceptable? by the comparison with reference maps/images
    - yes
    - no
      - Change parameter of classification
      - addition/deletion/modification of training data
      - Existing training data for MODIS 2003
      - Potential land cover maps
      - reference regional land cover/vegetation maps
      - Google Earth reference maps/images
      - Individual maps of Tree open, Wetland, Mangrove, Snow/ice, Urban, and Water (Figure 5-10)

- **Existing six global land cover data**
  - Validation data
  - Validation
  - Post-processing (Figure 11)
  - Integration
  - Check by NMOs (Appendix 2)
  - Merge subclasses to 14 classes (Result of supervised classification)
  - Acceptable? by the comparison with reference maps/images
    - yes
    - no
      - Change parameter of classification
      - addition/deletion/modification of training data
      - Existing training data for MODIS 2003
      - Potential land cover maps
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      - Individual maps of Tree open, Wetland, Mangrove, Snow/ice, Urban, and Water (Figure 5-10)
1. MODIS 2008 Data

Cloud removal model for MODIS 2008 data

- Original 16 day composite still remains many clouds

- After cloud removal, we have a cloud-free dataset of MODIS 2008
Map of ground-truth sites (for TD)

<table>
<thead>
<tr>
<th>Land cover type (PTC)</th>
<th>Forest (75[50]-100%)</th>
<th>Vegetation (0-25[45]%)</th>
<th>Non-vegetation (0-5%)</th>
<th>Urban (0-30%)</th>
<th>Snow (0-5%)</th>
<th>Water (0-5%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original sites</td>
<td>320</td>
<td>575</td>
<td>46</td>
<td>71</td>
<td>11</td>
<td>17</td>
</tr>
<tr>
<td>Added sites</td>
<td>331</td>
<td>1298</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>