

# A NEW GLOBAL LAND COVER MAP, GLCNMO

R. Tateishi<sup>a,\*</sup>, Bayaer<sup>a</sup>, M. A. Ghar<sup>a</sup>, H. Al-Bilbisi<sup>a</sup>, J. Tsendayush<sup>a</sup>, A. Shalaby<sup>a</sup>, Alimujiang Kasimu<sup>a</sup>, N. T. Hoan<sup>a</sup>, T. Kobayashi<sup>a</sup>, B. Alsaadeh<sup>a</sup>, Md. M. Rahman<sup>a</sup>, E. Tsevenge<sup>a</sup>, Y. Yamada<sup>b</sup>, and S. Kajikawa<sup>b</sup>

<sup>a</sup> Chiba University, Center for Environmental Remote Sensing, 1-33 Yayoi-cho, Inage-ku Chiba, 263-8522 Japan - tateishi@faculty.chiba-u.jp

<sup>b</sup> Geographical Survey Institute of Japan, 1 Kitazato Tsukuba 305-0811 Japan - kajikawa@gsi.go.jp

**KEY WORDS:** Land Cover, Global, Mapping, MODIS

## ABSTRACT:

The Global Mapping Project organized by International Steering Committee for Global Mapping (ISCGM) has produced a new 1km global land cover data called Global Land Cover by National Mapping Organizations (GLCNMO) as one of eight layers of Global Map data. It has twenty land cover classes defined by Land Cover Classification System (LCCS). Fourteen classes out of twenty were derived by supervised classification, and the rest of six classes such as urban, tree open, mangrove, wetland, snow/ice, and inland water were classified independently using MODIS and/or other source data. This land cover mapping has the following features. (a) Eight periods of 16-day composite 7-band 1-km MODIS data of 2003 year were used as primary source data. (b) Training data for supervised classification were collected using Landsat image, MODIS NDVI seasonal change pattern, and comments from National Mapping Organizations with the reference of Google Earth, Virtual Earth and existing regional maps. (c) Urban areas were extracted using Gridded Population density, DMSP data, and MODIS NDVI. (d) Tree open areas were mapped from percent tree cover data derived from the same MODIS data. (e) Inland water and ocean were mapped by clustering of MODIS data<sup>1</sup>.

## 1. INTRODUCTION

Land cover is one of key environmental parameters. After the availability of global satellite data such as NOAA/AVHRR, global land cover map was produced using satellite data. The first one was IGBP-DISCOVER (GLCC website) using AVHRR data of 1992. University of Maryland and Boston University have produced global land cover data using MODIS data independently (UMDLCC website)(BULC website), and Joint Research Centre (JRC) of European Commission produced GLC2000 using SPOT/VEGETATION data of 2000 (GLC2000 website). Though several global land cover data are available, their accuracy is not very high. Better global land cover data is necessary for reliable scientific use of the data.

Global Mapping project (ISCGM website) is an international project to develop eight basic global datasets by the cooperation of National Mapping Organizations. One of the products is global land cover data which is called Global Land Cover by National Mapping Organizations (GLCNMO). GLCNMO was produced using mainly MODIS data observed in 2003. This paper described how GLCNMO was produced.

## 2. POLICY OF LAND COVER MAPPING

Basic policy of the production of GLCNMO is as follows.

(1) use of global 1km satellite data

(2) cooperation of National Mapping Organizations for intermediate check of the classification trial

(3) publication of training data

There have been several global land cover mapping projects so far. However no project releases or publishes training data or

reference data they used. Accumulation and common use of training data (or ground truth data) by different projects increases reliable knowledge of global land cover, and it follows better land cover mapping in the future.

(4) independent mapping for the classes which are difficult to be classified by automatic digital classification method.

In this mapping project, six out of twenty land cover classes were found difficult to be classified by supervised method. Therefore these six land cover classes were classified individually by different methods.

## 3. DATA USED

### 3.1 MODIS data

The main data used in this mapping project is MODIS data observed in 2003. The source MODIS data is MODIS/TERRA Nadir BRDF- Adjusted Reflectance 16-DAY L3 Global 1 KM SIN Grid Product (MOD43B4 NBAR). This is 16-day composite, 7-band, 1-km, 10-degree tile data. The source data were processed to remove cloud contamination, and reprojected into latitude/longitude coordinate system, and mosaicked to make five continental data (Eurasia, North America, South America, Africa, and Oceania) and two island regions in the Ocean.

### 3.2 Other data

**3.2.1 Satellite data:** Other satellite data used are Landsat +ETM data (GLCF website) and DMSP/OLS data (DMSP/OLS website). Landsat data were used to collect training data, and DMSP/OLS data were used for urban mapping.

**3.2.2 Global land cover data:** Existing global land cover data such as GLC2000 (GLC2000 website), land cover by Boston

\* Corresponding author.

University(BULC website),GLCC(GLCC website), were used mainly to decide candidates of training data.

**3.2.3 Thematic data:** Some thematic data such as population density data, World mangrove atlas, snow data derived from MODIS, and shoreline vector data were used for individual land cover class mapping. Population density data used is LandScan Dataset which comprises a worldwide population database compiled on a 30" by 30" latitude/ longitude grid (Population website). World mangrove atlas is initially published by a hard copy (Spaldings 1997), and updating digital version is available through internet (UNEP-WCMC Interactive Maps website). A Global Self-consistent, Hierarchical, High-resolution Shoreline Database (GSHHS) is continuously updating vector shoreline data available through internet (GSHHS website).

**3.3 Regional land cover maps**

Approximately two hundred existing regional maps were used as reference to check intermediate classification result and to find suitable locations of training data. Table 1 shows only a part of them as examples.

The Atlas of Canada
National Land Cover Database 2001(USA)
Forests and Protected Areas of Brazil
Forests and Protected Areas of Argentina
Corine land cover 2000 (CLC2000) 100 m - version 8/2005
Vegetation Atlas of China(2001)
Forest cover map of Insular Southeast Asia
Agriculture and Forest Land in China,Mongolia and the States of the FSU
Afghanistan Land Cover 2002
Land Cover / Land Use of South Africa
2001/02 Land Use of Australia Version 3 (non-agricultural and interpretive agricultural land use)
Australia's Major Vegetation Groups
Circumpolar Arctic Vegetation Map
Global Distribution of Current Forests

Table 1 Examples of regional maps used as reference

**4. LEGEND**

Twenty land cover types including water were defined using Land Cover Classification System versions (LCCS2) developed by FAO(LCCS website). In the actual mapping process, initially defined land cover legend was slightly modified through the collection of training data. In other words, definition of legend and collection of training data are interactive process. Table 2 shows the finally defined land cover legend for GLCNMO.

code	GLCNMO land cover class
1	<b>Broadleaf Evergreen Forest</b>
2	<b>Broadleaf Deciduous Forest</b>
3	<b>Needleleaf Evergreen Forest</b>
4	<b>Needleleaf Deciduous Forest</b>
5	<b>Mixed Forest</b>

6	<b>Tree Open</b>
7	<b>Shrub</b>
8	<b>Herbaceous</b>
9	<b>Herbaceous with Sparse Tree / Shrub</b>
10	<b>Sparse Vegetation</b>
11	<b>Cropland</b>
12	<b>Paddy field</b>
13	<b>Cropland /Other Vegetation Mosaic</b>
14	<b>Mangrove</b>
15	<b>Wetland</b>
16	<b>Bare area, consolidated (gravel, rock)</b>
17	<b>Bare area, unconsolidated (sand)</b>
18	<b>Urban</b>
19	<b>Snow / Ice</b>
20	<b>Water Bodies</b>

Table 2. Land cover legend for GLCNMO

**5. TRAINING DATA**

Collection of training data is the most important part of land cover mapping. The following steps were performed in this study for fourteen land cover classes: 1 Broadleaf Evergreen Forest, 2 Broadleaf Deciduous Forest, 3 Needleleaf Evergreen Forest, 4 Needleleaf Deciduous Forest, 5 Mixed Forest, 7 Shrub, 8 Herbaceous, 9 Herbaceous with Sparse Tree / Shrub, 10 Sparse Vegetation, 11 Cropland, 12 Paddy field, 13 Cropland /Other Vegetation Mosaic, 16 Bare area, consolidated (gravel, rock), and 17 Bare area, unconsolidated (sand).

- (1) GLC2000 land cover map was used to select candidates of training regions
- (2) Landsat data observed around 2000 were used as a background image when training sites are selected by shape file.
- (3) MODIS NDVI seasonal patterns are drawn for each training polygon. If different training polygons of the same land cover class, for example cropland, have different NDVI patterns, these training data are assigned as different subclasses, for example cropland A and cropland B.
- (4) Trial of classification by supervised method
- (5) Compare intermediate classified result with regional land cover maps. It was also checked by National Mapping Organizations participating in Global Mapping project.
- (6) If no good agreement with regional land cover maps, unsuitable training data are deleted with the reference of Landsat, NDVI pattern, and Google Earth/Virtual Earth. Necessary additional training data are selected with reference of regional land cover maps and Google Earth/Virtual Earth.
- (7) Modification of training data are repeated until the classified result has no serious difference from regional land cover maps.

Final numbers of training polygons are 824 for 105 subclass in Eurasia, 492 for 47 subclass in North America, 136 for 30 subclass in South America, 124 for 39 subclass in Africa, and 31 for 16 subclass in Oceania. Globally 1497 training polygons were collected.

**6. CLASSIFICATION**

**6.1 Main classification**

Subclasses of fourteen land cover classes of Table 2 were classified by supervised method of MODIS data for each continent. Maximum likelihood method by ENVI software was applied for MODIS seven bands and NDVI of eight 16-day

composite periods in 2003 for every 1.5 months. Classified result of subclass level were merged into fourteen classes.

## 6.2 Partial mapping

Six land cover classes, which are Water, Urban, Tree open, Permanent snow/ice, Mangrove, and Wetland, were extracted independently as follows. Furthermore Antarctica and Regions over 80 degree north latitude were mapped separately due to unavailability of the MODIS data in these regions.

**6.2.1 Shoreline and inland water:** Unsupervised classification and visual labelling are the main method to extract water area. MODIS seven bands of three periods in 2003 were used for cluster analysis. Three 16-day periods in a year were selected from less snow seasons. Labelling was done with the reference of Landsat TM/ETM+, GLC2000, and global shoreline GSHHS data (GSHHS website).

There are mainly two reasons for errors of extracted water areas. One is that shallow water areas are labelled as land. The other case is that terrain shadow areas are assigned as water. These error parts were corrected manually.

**6.2.2 Urban:** Urban areas were extracted using population density data (Population website), MODIS/NDVI data, and DMSP/OLS data. Common areas after threshold processing for these three data were assigned as urban area (Alimujiang 2007). The main input data is population density data. MODIS/NDVI was used to exclude large green area such as a park in populated area. DMSP/OLS was used to exclude villages in developing countries with large population.

**6.2.3 Tree open:** Global percent tree cover data were produced by the authors using the same MODIS data used in this study (Rakhmatuloh 2007, ISCGM website). 15% to 40% of tree cover areas of this product were assigned as "Tree Open."

### 6.2.4 Permanent snow/ice:

Permanent snow/ice areas were mainly mapped by threshold processing of 5-km global percent snow cover data, MODIS/Terra Snow Cover Global 0.05Deg CMG (MOD10C2) data set (MOD10C2 website). Some part was mapped by unsupervised and labelling processing of 1-km MODIS data.

**6.2.5 Mangrove:** Mangrove were extracted by visual interpretation of Landsat ETM+ images and by digitizing World Atlas of Mangrove.

**6.2.6 Wetland:** The common wetland areas in GLC2000 and IGBP-DISCover were used as wetlands in GLCNMO.

**6.2.7 Antarctica:** Shoreline of Antarctica was copied from Global Map Antarctica which is originally coastlines of VMAP Level 0 (NGA).

**6.2.8 Regions over 80 degree north latitude:** Regions over 80 degree north latitude were mapped using GLC2000 because of no availability of the used MODIS data.

## 7. MAPPING BY INTEGRATION

The GLCNMO was produced by integration and resampling. Six independently extracted classes were overlaid on classified result with fourteen classes by maximum likelihood method for five continents and two ocean regions. Then approximate 1-km pixels were resampled to exact 30 arc second pixels. And, five continental and two island regions land cover data were mosaicked and Antarctica and regions over 80 degree north

latitude are added to complete global coverage. Figure 1 shows the produced GLCNMO. At the time of writing this paper, validation of the result has not yet completed.

## 8. CONSIDARATIONS

Through this mapping project, the following things were learned.

- Trial of land cover mapping by unsupervised classification had problem in labelling process for clusters with small areas. To cope with this problem, unsupervised with labelling method can be applied only partially. This means difficult area for labelling must be classified by other method, i.e., supervised method. For this reason, unsupervised method was not used as a main classification method in this project.

- Many times, more than ten times, of classification trials are required in the modification process of training data. Therefore one trial of classification process for one continent must be completed within a limited time, for example a few days. Maximum likelihood method was selected by this condition.

- Maximum Likelihood method used in this project has a condition that number of training pixels of one class must be more than the number of input variables. For some class such as cropland, it is difficult to collect large homogeneous training site. Therefore in order to reduce the minimum number of training pixels, number of input variables were reduced by using only eight 16-day periods instead of using all 23 periods.

- Without existing regional land cover maps and Google Earth/Virtual Earth, this mapping project has not completed. Accumulation of existing regional maps gives reliable knowledge of global land cover to the map producer, and they are useful to check the intermediate classified result. Combination of existing regional maps and Google Earth/Virtual Earth are effective to select training data.

- Through the water area mapping, we found errors in even the most reliable existing water area data, GSHHS. Clustering of MODIS data of selected seasons are found to be effective for the extraction of water area. However shallow water and terrain shadow area must be manually corrected.

- Urban, mangrove, and wetland are difficult to be classified by MODIS data. They need to be extracted by other methods. Urban was successfully mapped in this project. However global extraction of mangrove and wetland must be studied in the future.

- Though cropland was classified by supervised method in this study, it is a difficult class to be classified due to its heterogeneity even in the same region. Satellite data of Landsat or ASTER level resolution are more suitable for cropland mapping, however such better resolution satellite data has usually lack of phenological information due to long observation interval. Cropland mapping is one of future subjects in global land cover mapping.

## 9. CONCLUDING REMARKS

As one of the activities of Global Mapping project by more than 100 National Mapping Organizations, a new global land cover

map, GLCNMO, was produced using MODIS data observed in 2003. Not only land cover map data but also training data used for classification are published through internet. Publication of training data is carried out in order to accumulate reliable ground truth data for better mapping in the future. Another outcome of this study is to learn that individual land cover class mapping, for example mangrove mapping or wetland mapping, should be promoted for the future better global land cover mapping.

## REFERENCES

Alimujiang K. and R. Tateishi, 2007. Global urban mapping using coarse resolution remote sensing data with the reference of Landsat imageries. *The 28<sup>th</sup> Asian Conference on Remote Sensing*, Kuala Lumpur, Malaysia Nov. 12-16, 2007 CD

Rakhmatuloh, D. Nitto, H. Al Bilbisi, K. Arihara, and R. Tateishi, 2007. Estimating percent tree cover using regression tree method with very-high-resolution QuickBird images as training data, *Journal of the Remote Sensing Society of Japan*, Vol.27, No.1, pp.1-12

Smith, J., 1987a. Close range photogrammetry for analyzing distressed trees. *Photogrammetria*, 42(1), pp. 47-56.

Spalding, M., F. Blasco and C.Field, 1997. World mangrove atlas, Internatinal Society for Mangrove Ecosystems(ISME), World Conservation Monitoring Centre (WCMC), Internatinal Tropical Timber Organization (ITTO), 178p.

BULC website  
<http://duckwater.bu.edu/lc/mod12q1.html>  
 GLCC website

<http://edcns17.cr.usgs.gov/glcc/>  
 DMSP/OLS website  
<http://www.ngdc.noaa.gov/dmsp/maps.html>  
 GLC2000 website  
<http://www-gem.jrc.it/glc2000/ProductGLC2000.htm>  
 GLCF website  
<http://glcfapp.umiacs.umd.edu/index.shtml>  
 GSHHS website  
<http://www.soest.hawaii.edu/wessel/gshhs/gshhs.html>  
 ISCGM website  
<http://www.iscgm.org/>  
 LCCS website  
<http://www.glc-lccs.org/>  
 MOD10C2 website  
<http://modis-snow-ice.gsfc.nasa.gov/>  
 Population website  
<http://www.ornl.gov/sci/landscan/index.html>  
 UMDLCC website  
<http://www.glc.umiacs.umd.edu/data/landcover/>  
 UNEP-WCMC Interactive Maps-Mangrove  
<http://www.unepwcmc.org/resources/publications/otherpubs.htm>

All websites above were accessed on April 24, 2008

## ACKNOWLEDGEMENTS

This global land cover mapping was carried out as an activity of Global Mapping project. Authors express sincere gratitude for participating National Mapping Organizations for their contribution of intermediate validation. They also thank U.S. Geological Survey for providing MODIS data.

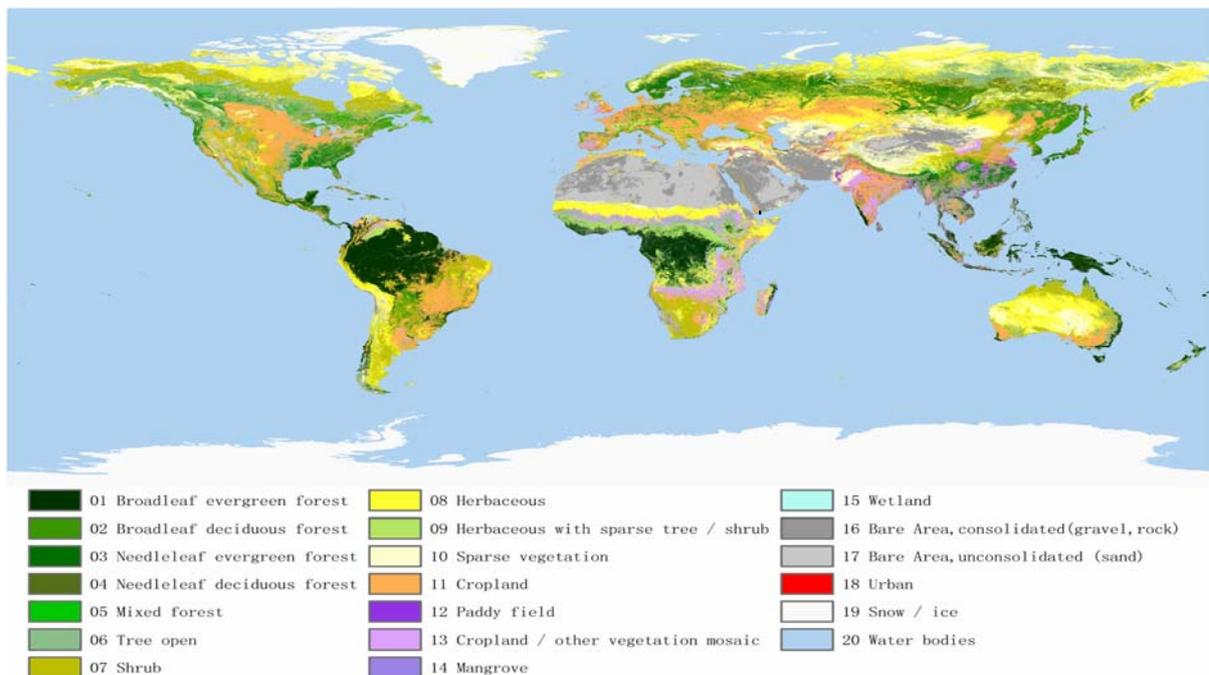


Figure 1 A new global land cover map, GLCNMO

<sup>i</sup> The produced global land cover data is released from the web site of Global Mapping Project (<http://www.iscgm.org/>).