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Land cover mapping of Asia - problems and solutions of continental/ global land cover mapping

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Abstract: This paper reviews continental/global land cover mapping projects and their methodologies with the focus on the Land Cover Working Group (LCWG) / Asian Association on Remote Sensing (AARS) project which completed its project and is distributing the 30-second land cover dataset of Asia from the author. Furthermore, the paper identifies necessary efforts for successful future continental/global land cover mapping.

Resumen: Este artículo revisa los proyectos de elaboración de mapas de cobertura terrestre a escalas continental y global, así como sus metodologías, enfocándose en el proyecto Grupo de Trabajo de Cobertura Terrestre (LCWG)/Asociación Asiática sobre Percepción Remota (AARS), el cual culminó y está en la fase de distribución del segundo conjunto de datos de 30 segundos de cobertura terrestre en Asia por parte del autor. De manera adicional, el artículo identifica los esfuerzos necesarios para asegurar el éxito futuro en la elaboración de mapas de cobertura terrestre a escalas continental y global.

Resumo: Este artigo revê os projectos de mapeamento da cobertura terrestre continental/global e as suas metodologias, com ênfase para o projecto completado pelo Grupo de Trabalho sobre a Cobertura Terrestre (LCWG)/Associação Asiática para a Detecção Remota (AARS) e cujo autor está a distribuir o conjunto dos dados referentes à Ásia. O artigo identifica, igualmente, os esforços necessários para um mapeamento da cobertura terrestre continental/global futura, com sucesso.

Key words: Asia, AVHRR, classification system, ground truth, land cover.

Needs of continental/global land cover mapping

Users of land cover information are scientists of global change study, policy makers of regional/ national land use, and educators. Among them, the global change study has become the main needs for land cover that is one of key parameters in matter/energy circulation models. In 1990s, many continental/global land cover mapping projects started. Some of them have already completed and are distributing their products. Some others are continuing their efforts of mapping. The next section gives brief information of land cover mapping projects.

Projects

Asia, LCWG/AARS

The Land Cover Working Group (LCWG) was established in the Asian Association on Remote Sensing (AARS) in 1993 in order to develop 1-km

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land cover dataset of the whole Asia for general purpose. The Working Group completed the land cover dataset in 1999, and it is distributed as a CD-ROM from the author. The CD-ROM includes not only land cover dataset but also ground truth data, description of methodology, and information about the working group. The web site <http://asi-aserv.cr.chiba-u.ac.jp/cd/index.htm> provides the same contents as the CD-ROM. Fig. 1 shows the product, AARS Asia 30-second land cover data set. The methodology of land cover mapping is described in the later part of this paper.

Europe, PELCOM

The 10 minutes pan-European land use database of the Dutch National Institute for Public Health and the Environment (RIVM), is a first step towards meeting the demands of environmental and agricultural studies on a European scale. However, a major drawback of the 10 minutes pan-European land use database is that it is based on statistical and spatial data from different sources that differ in spatial accuracy, reliability, age and nomenclature. For that reason the PELCOM project has been formulated. It aims at the establishment of a 1-km pan-European land cover database that can be updated frequently and which is based on the integrative use of multi-spectral and multi-temporal 1-km resolution NOAA-AVHRR satellite data and ancillary data. The project started in September 1996 and finished in January 2000. The project was carried out within an international framework, in which ALTERRA, Green World Research (formerly DLO Winand Staring Centre) functioned as the project coordinator. (from the CD-ROM of PELCOM, contact: s.mucher@alterra.wag -ur.nl).

The countries with large territory such as USA, Canada, and Australia have also developed 1-km land cover dataset of their country using NOAA AVHRR data. The following are projects for global land cover mapping.

IGBP DISCOVER

The U.S. Geological Survey (USGS), the University of Nebraska-Lincoln (UNL), and the European Commission's Joint Research Centre (JRC) have generated a 1-km resolution global land

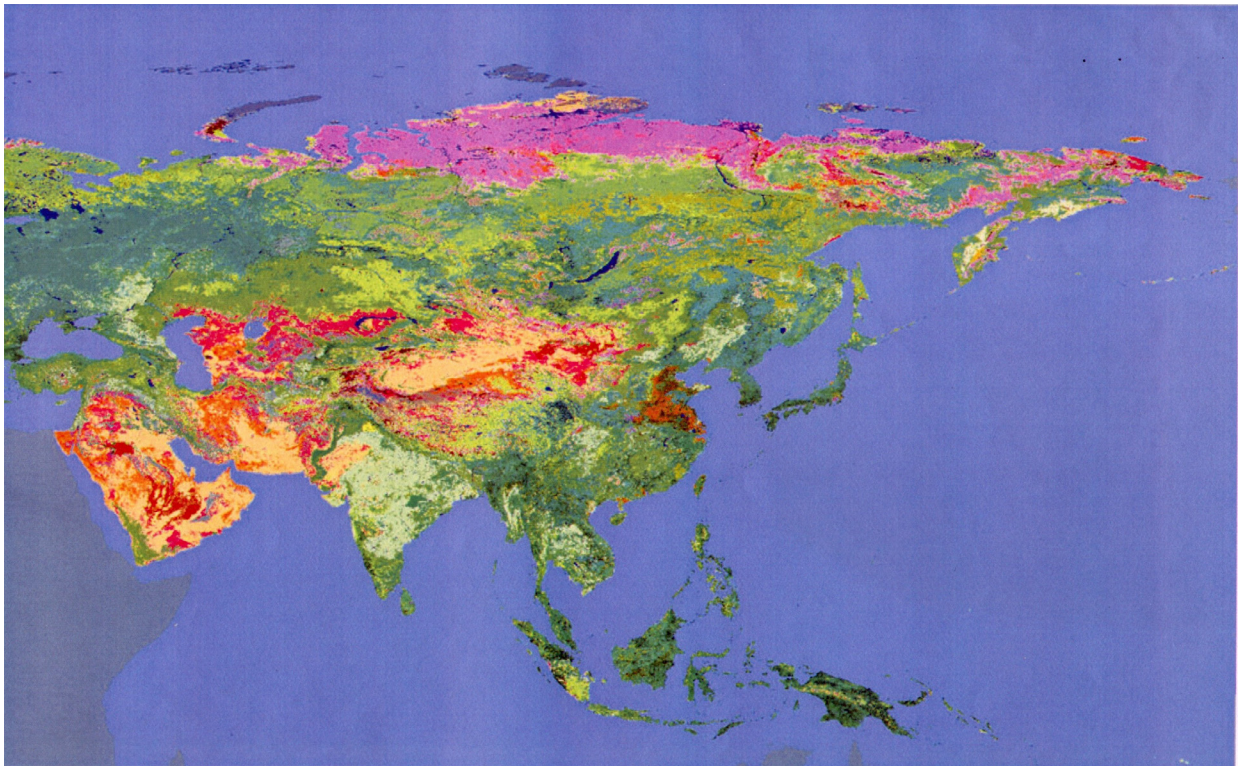

Fig. 1. AARS Asia 30-second land cover data set.

cover characteristics data base for use in a wide range of environmental research and modeling applications. The global land cover characteristics data base was developed on a continent-by-continent basis. All continental data bases share the same map projections (Interrupted Goode Homolosine and Lambert Azimuthal Equal Area), have 1-km nominal spatial resolution, and are based on 1-km AVHRR data spanning April 1992 through March 1993. This effort is part of the National Aeronautics and Space Administration (NASA) Earth Observing System Pathfinder Program. The data base has been adopted by the International Geosphere-Biosphere Programme Data and Information System office (IGBP-DIS) to fill its requirement for a global 1-km land cover data set. (from <http://edcdaac.usgs.gov/glcc/glcc_ na.html>)

GLC 2000

The Global Land Cover 2000 (GLC 2000) project was initiated by European Commission's Joint Research Centre (JRC) for the purpose of creation of global land cover map using SPOT-4 VEGETATION of the year 2000. The classification system of the project is based on the Land Cover Classification System (LCCS) by Food and Agriculture Organization (FAO). The guideline and basic methodology are provided by the JRC. After the classifications of regional/local areas by more than 30 partners, the JRC will integrate their results for global mapping by the end of 2002.

Global mapping project

In order to cope with global environmental problems, reliable geographic information of the whole globe is indispensable. Global Mapping Project was advocated by Ministry of Construction of Japan aiming to develop digital geographic data sets (Global Map) of the whole globe. The purpose of the Global Map is to accurately describe the present status of the global environment under international cooperation of National Mapping Organizations (NMOs). With the recommendation of the United Nations, 81 countries and areas have participated in this project as of November 2000. The International Steering Committee for Global Mapping (ISCGM) has been playing a central role in the development of the Global Map data sets. The Geographical Survey Institute (GSI), Japan actively involves in the ISCGM and provides technical assistance for the development of the Global Map. (from <http://www1.gsi.go.jp/iscgm-sec/index.html>)

Methodology of land cover mapping

General methodology

The general methodology of land cover mapping for continental/global area consists of the following steps:

1. Determination of classification system
2. Preparation of ground truth data based on the predetermined classification system
3. Preprocessing of satellite data
4. Classification by satellite data
5. Correction and modification
6. Validation using ground truth data

1. Determination of classification system

Land cover classification system is decided considering the purpose of the land cover mapping project. Usually classification systems of different projects vary.

2. Preparation of ground truth data based on the predetermined classification system

Ground truth data are used as training sample data in classification processing or as correct data in validation step. The information sources of ground truth are field survey, existing maps, or satellite images with better resolution. Since field survey is time consuming and needs much budget, the latter two sources are usually used.

3. Preprocessing of satellite data

So far continental/global land cover mapping has used NOAA AVHRR data because it was the only satellite data with global coverage before the launch of Terra/MODIS in 1998. The AVHRR data needs several types of preprocessing such as atmospheric correction, correction of scan angle effect, correction of solar zenith angle effect, and cloud removal. Atmospheric correction is applied only for Rayleigh scattering and ozone absorption, but not for aerosol scattering due to the difficulty to estimate its type and concentration without ground measurement. Other types of preprocessing have been studied by many researchers but there is no standard method.

4. Classification by satellite data

The main information from satellite image used for large area land cover classification is

phenological information, which shows seasonal change of vegetation. It is usually represented as time series normalized difference vegetation index (NDVI) in a year, for example 10-day composite NDVI or monthly NDVI. The clustering of time series NDVI is a typical classification method for continental/global mapping. The labeling (identifying) land cover types of each cluster is done by comparing clusters with ground truth data.

5. Correction and modification

Since a cluster may correspond to multiple land cover types, manual labeling with local knowledge is indispensable.

6. Validation using ground truth data

This is the most difficult part of processing because it is difficult to prepare ground truth data with a wide variety of land cover types in continental/global area.

Method used in AARS/LCWG

The method used in land cover mapping by LCWG/AARS is well described in <http://asiaserv.cr.chiba-u.ac.jp/cd/index.htm>. Here in this paper, only characteristics of the method is described below:

Satellite data

Global Land 1-km AVHRR Data Set was used as the source of satellite data. 10-days composite data of AVHRR NDVI, channel 4, and channel 5 were used for this project. NDVI data from April 1, 1992 to March 31, 1993 and channel 4 and channel 5 data from April 1, 1992 to October 31, 1992 were used. For further information about Global Land 1-km AVHRR Data Set: <http://edcwww.cr.usgs.gov/landdaac/1KM/1kmhomepage.html>

Determination of classification system

Hierarchical classification system is decided by the working group.

Preparation of ground truth data based on the predetermined classification system

The ground truth data were collected mainly from existing maps of working group members, and the limited part were acquired from ground surveys in Kazakhstan, Uzbekistan and Turkmenistan during 1996 and 1998.

Preprocessing of satellite data

The source AVHRR data were corrected only for Rayleigh scattering and ozone absorption. After acquiring AVHRR data, monthly composite was calculated from the original 10-day composite by maximum composite method for further cloud removal. The original map projection, the Interrupted Goode Homolosine projection, was transformed to Plate Carree projection (latitude-longitude coordinates) for easier use of the classification result.

Classification by satellite data

The clustering was applied to monthly ratio of surface temperature to NDVI. The surface temperature was derived from AVHRR channel 4 and channel 5 data. This ratio includes phonological information. The clustering results were compared with ground truth data and labeled to land cover types.

Correction and modification

Some parts of the mapped area were not classified correctly, for example, wrong labeling of actual urban area to bare ground. Therefore, manual correction after computer classification was necessary. Furthermore, all ground truth data were overlaid to the computer classification result. In other words, if the classified pixel was not the same as the ground truth, its land cover type was changed to that of ground truth data.

Validation using ground truth data

Since not enough ground truth data for validation were prepared, validation was not done.

Problems and solutions in continental/global land cover mapping

Common problems in the present efforts of continental/global land cover mapping are described in this section for the first four steps of classification procedure, and solutions to these problems are proposed here. The difficulty in the remaining steps, the last two steps, are easily resolved if enough ground truth data are prepared.

Determination of classification system

Continental or global land cover mapping is different from local mapping because continental/global mapping area is common to all map producers. In other words, all map producers for continental/global area have the same mapping area. On the other hand, it is reasonable for each mapping project to have a different classification sys-

tem based on its mapping purpose, for example, input to climate change modeling or food and agricultural management. However, there is a considerable overlap in the efforts of different continental/global mapping projects. The problem is many mapping projects define their own land cover classification system independently. The proposed solution is to try to use the Land Cover Classification System (LCCS) developed by Food and Agriculture Organization (FAO) <http://www.fao.org/sd/2001/en0101_en.htm>. The LCCS is comprehensive hierarchical classification system that allows a suitable 'legend' for each mapping project. In the LCCS, the 'legend' means a category system for a specific mapping, whereas 'classification system' is a comprehensive category system that allows many different legends. Though the LCCS is not a complete classification system, it is the only system that is developed as a standardized comprehensive classification system. The author's suggestion is to use the LCCS for land cover mapping, to find its shortcomings, and to notify it to the FAO, and to improve the LCCS. The author believes that the trial use of the LCCS is the shortest way to develop standard classification system for continental/global land cover mapping.

Preparation of ground truth data based on the predetermined classification system

In the project of the global land cover map, IGBP DISCOVER, the visual interpretation of middle resolution satellite images, Landsat, by many scientists from different countries were applied. It needed much budget and human work. Most other projects collect ground truth from existing local maps and survey results. The largest problem in continental/global land cover mapping is the difficulty of collection of ground truth data. The proposed solution is to develop the global land cover ground truth (GLCGT) database by the cooperation of many land cover mapping projects and many land cover related scientists. The information source will be a combination of systematic ground truth collection by the interpretation of better resolution satellite images and non-systematic ground truth collection by gathering existing local land cover mapping results from worldwide scientists through internet. The author started a web site for the latter ground truth collection method by the cooperation with Science University of Tokyo. This web site <http://oblb www.cv.noda.sut.ac.jp/gluc/index.htm> is called Global Land Use/Land Cover (GLUC) meta-database that allows input of meta-data of land use/land cover maps and enables to search registered meta-data and its browse image. The collection of meta-data is the first step, and then ground truth data will be extracted from their registered data by converting their own legends to a standard classification system, a potential candidate of which is the LCCS.

Preprocessing of satellite data

The atmospheric correction is a common problem in many applications in remote sensing. Specific problems of preprocessing for continental/global mapping come from the use of wide scan angle and time series (daily or several days interval) images. The method to cope with the effect of directional reflectance due to a wide scan angle and a composite method of time series images for cloud removal were developed by many researchers, but they are not standardized yet. This is not a serious problem. In the near future, the best method among them will become a standard method.

Classification by satellite data

The most widely used satellite data for continental/global land cover mapping is NOAA AVHRR data that has five channels from visible to thermal infrared. The Terra/MODIS (USA, launched in 1999) and ADEOS-II/GLI (Japan, will be launched in 2002) are advanced sensor aiming to global mapping of many environmental parameters including land cover. These sensors have 36 channels, and approximately half of that is for land application. When using AVHRR data, clustering of time series NDVI was the typical classification method. However, when using the new data such as MODIS or GLI, suitable and effective combination of channels and seasons for classification has to be selected.

Land cover change mapping

After a continental/global land cover map is produced, periodical revision for several years will be planned in order to know the land cover change. For example, the Global Mapping project plans to add a latest land cover map every five years. The Pathfinder AVHRR land dataset since 1981 is the

only available satellite data for global coverage and for twenty years <http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/LAND_BIO/Pathfinder_Data_Desc.html>. Though these data have a potential of change monitoring, land cover change detection using these data is difficult due to its coarse resampled resolution of 8 km. The new sensors such as MODIS or GLI have a better resolution of 250 meters. The global and long time series observation by 250 meters resolution will provide a new possibility of land cover change detection for continental/global area. In any land cover change, its initial stage of change begins from a small area change that is difficult to detect by 250 meter pixels. Therefore, sub-pixel classification to a basic land cover types such as forest, grassland, agricultural land, and no vegetation, is effective for change detection. The estimate of area cover percentage of the basic land cover types within a pixel can be used to detect a small area land cover change when using global coverage 250 m or 1 km resolution satellite data.

Conclusions

This review paper introduces main projects of continental/global land cover mapping with a focus of land cover mapping of Asia by LCWG/AARS. The six steps of continental/global land cover mapping procedure are explained. The two main challenges for better continental/global land cover mapping are identified. One is the development of standard classification system. The author suggests using the Land Cover Classification System (LCCS) by FAO because it is the best available classification system, which can be a standard, though it is not a perfect classification system. The other one is the development of global land cover ground truth (GLCGT) database. The main feature of the GLCGT database is cooperative development by many projects and researchers and open use for any people. One attempt for GLCGT database is the start of the internet-base Global Land Use/Land Cover (GLUC) meta-database.

References

AARS Asia 30-second Land Cover Data Set:
http://asiaserv.cr.chiba-u.ac.jp/cd/index.htm
Global land cover data set, IGBP-DISCOVER:
http://edcdaac.usgs.gov/glcc/glcc_na.html
Global Land Cover 2000 (GLC2000):
http://www.gvm.sai.jrc.it/glc2000/defaultGLC2000.htm
Global Land Use/Land Cover (GLUC) meta-database
http://oblbwww.cv.noda.sut.ac.jp/ gluc/index.htm
Global Mapping project:
http://www1.gsi.go.jp/ iscgm-sec/index.html
Land Cover Classification System
http://www.fao.org/sd/2001/en0101_en.htm
Pathfinder AVHRR land dataset:
http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/LAND_BIO/Pathfinder_Data_Desc.html