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A 2010 update of National Land Use/Cover Database of China at 1:100000 scale using medium spatial resolution satellite images

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ABSTRACT

A project to map national land use/cover in China was initialized in the latter half of the 1990s. A national land use/cover database of China (NLUD-C, hereafter) at 1:100000 scale that contains Chinese land use/cover data of five periods (1980s, 1995, 2000, 2005 and 2008) was developed during the project. To elucidate long-period sequence land use/cover data for land use/cover change driving factor analysis and ecological environment change research, this database was updated in 2010. Because the NLUD-C focuses more on the thematic and location precisions of land use/cover change dynamics, remote sensing images with approximately 30 m spatial resolution, visual interpretation, field survey and large amounts of auxiliary information were applied during the update process. The results reveal that the change of land use/cover is more complex with 35 change forms among the first-level types and 480 change forms among second-level types between 2008 and 2010. The amount of land use/cover change patches reaches 108,006, and the dynamic area is 40,083.68 km^2. In addition, the NLUD-C accuracy for the selected polygons is more than 96.67%, and the accuracy of the selected first-level types is more than 95.41%.

1. Introduction

Land use/cover change (LUCC) science has emerged as a fundamental component of global environmental change and sustainability research, and LUCC research is playing an increasingly important role in global change research (Lambin et al., 1999; Turner, Lambin, & Reenberg, 2007). Since the 1980s, a series of international programs on global environmental changes have been progressively carried out. Requiring collaboration from a wide range of disciplines and studies encompassing the local, regional and global scales, these activities have been increasingly conducted in conjunction the World Climate Research Program (WCRP), the International Geosphere-Biosphere Program (IGBP), International Human Dimensions Program on Global Environmental Change (IHDP) and the International Program on Biodiversity (DIVERSITAS). Furthermore, research on Earth system change and its effects on sustainable development has also been started by the Earth System Science Partnership (ESSP) (Liu & Deng, 2010). However, research on LUCC, as the core part of global change, has been specifically performed by scientists only since 1992. The International Institute of Applied Systems Analysis (IIASA) launched a project to simulate the LUCC in Europe and Northern Asia in 1995 (Heilig, 1995). The IGBP and IHDP jointly initiated a LUCC research project and established a LUCC conceptual framework in the same year (Turner et al., 1995). To understand the relationship between LUCC and greenhouse gas emissions, starting in the fiscal year 1997, a U.S. global change research program performed further research on forest classification with higher spatial resolution images in North America and tropical forests and built a detailed catalog, while still observing global land cover at a 1 km spatial resolution (Subcommittee on Global Change Research, 1996). In 2003, to improve the understanding of land system dynamics in the context of the earth system function, the IGBP and IHDP initiated a core project focusing on further land research, the Global Land Project (GLP, 2005). Chinese government has also taken a series of actions to develop research programs to study global change issues and mapping global land use/cover change was the first four major research projects initiated by the Ministry of Science and Technology of China (Xu et al., 2013).

With the promotion of the aforementioned projects, seven sets of global land use/cover data that are widely used by the international science communities have been established: (1) the DISCover land cover dataset with 1 km spatial resolution from the IGBP (Loveland & Belward, 1997a,b; Loveland et al., 2000), (2) UMd land cover dataset with 1 km spatial resolution from the University of Maryland (Hansen, Defries, Townshend, & Sohlberg, 2000), (3) GLC2000 land cover dataset with 1 km spatial resolution from the European Commission's Joint Research Center (Bartholomé & Belward, 2005), (4) GlobCover land cover dataset with 300 m spatial resolution from the European Space Agency (Bicheron, Huc, Henry, Bontemps, & Lacaux, 2008), (5) MODIS land cover products with 1 km spatial resolution from NASA (Friedl et al.,

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2002; Friedl et al., 2010), (6) GLCNMO land cover dataset with 1 km spatial resolution from the International Steering Committee for Global Mapping (Tateishi et al., 2010), (7) Global land cover dataset with 30 m spatial resolution from the National High-tech R&D Program of Ministry of Science and Technology of China (Gong et al., 2013; Yu, Wang, & Gong, 2013). These global land cover datasets with different mapping methodologies and criteria have been promoted and developed by different countries and international organizations. Because of the variations in the classes and thresholds applied, time of data collection, sensor type, classification techniques, use of in situ data and other aspects of the datasets, when the datasets are used at a continental or regional level, there is poor agreement in many cases (Gong et al., 2013; Herold, Mayaux, Woodcock, Baccini, & Schmullius, 2008; McCallum, Obersteiner, Nilsson, & Shvidenko, 2006). Furthermore, these land cover datasets are focused more on describing the land cover distribution, but they lack a description of the land cover change process.

In China, most research on LUCC and its driving factors has been conducted at a provincial or river basin scale (Buhe, Tsuchiya, Kaneko, Ohtaishi, & Halik, 2007; Chen, Liu, Wang, Yan, & Guo, 2009; Chen, Wang, Fu, & Qiu, 2001; Gao, Liu, & Chen, 2006; Wang, Liu, & Ma, 2010; Ye & Fang, 2009; Zhang, Sun, Zhang, & Tong, 2008), but less research has been conducted at a whole nation scale. At present, there are few representative studies on LUCC in China. Wu and Guo (1994) investigated national land use and the mapping of land use at 1:100000 scale in China by generating extensive field surveys and interpreting aerial photographs and Landsat images acquired during the late 1970s and early 1980s. This was the first national land use survey and mapping program that used a standard methodology and routines. Based on the standardized and unified data collected from numerable and valuable historical documents and various statistical reports that were published, Ge, Dai, He, Pan, and Wang (2008) analyzed the national land use change during the past 300 years in China (He, Ge, Dai, & Lin, 2007) and the change and the driving factors of cultivated land and forest before the middle of the 20th century in China (Ge & Dai, 2005). In 1999, the Ministry of Land and Resources launched the Program of National Land Use Change monitoring through remote sensing. However, the objective of the program was only to investigate the transition from cultivated land to construction land (Zhang & Zhang, 2007). Research on vegetation classification by remote sensing was stated since the 1990s in China. Sheng, Chen, Xiao, and Guo (1995) carried out a macro classification of vegetation in China with NOAA/NDVIs. Pan et al. (2003) developed a method for integrated analysis of multi-source data for vegetation classification at the continental scale also based on NOAA AVHRR data.

A project to totally map the national land use/cover in China using remote sensing and geographic information system techniques was initiated in the latter half of the 1990s. In the late 1990s, the Chinese Academy of Sciences organized eight research institutions and approximately 100 scientists to conduct a nationwide land use/cover classification project. The first National Land Use/cover Database of China (NLUD-C, hereafter), at 1:100000 scale, was established by the project in 1998 and describes the status of land use/cover in China in 1995 (Liu et al., 2005). After that, the NLUD-C was updated three times in 2000, 2005, 2008 and expanded to the end of the 1980s. Currently, the NLUD-C has five periods of land use/cover data and four sets of land use/cover change dynamics data, and it has been the main source of authoritative data for land use/cover change studies focusing on change from the end of 1980s in China (Liu & Deng, 2010; Liu et al., 2005, 2009, 2003). At the same time, the NLUD-C also provides important underlying surface data for global environment change and carbon cycle research (Huang, Liu, Shao, & Xu, 2012; Tao, Zhang, Liu, & Yokozawa, 2009; Tian et al., 2003; Wang et al., 2002; Yan, Cao, Liu, & Tao, 2007).

Most of the current large-scale land use/cover studies do not contain sufficient description on land use/cover dynamics, and this substantially limits their value. For research on land use/cover change and its driving factors or such applications as global environment change and climate change, it is more valuable to have a land use/cover database covering many periods with data capable of revealing long-term land use/cover change dynamics. Therefore, the NLUD-C must be continuously updated. The purpose of this paper is to introduce the methodology and process of updating the NLUD-C at 1:100000 scale continuously using remote sensing and GIS techniques in 2010.

2. Data and methodology

2.1. Land use/cover classification system

Because of the complexity of LUCC and its related research, there is no uniform classification system that is accepted by most scientists. One generally used classification system with 17 land cover types was designed by the IGBP, and it is employed by the DISCover, UMd and MODIS land cover datasets. The other generally used land cover classification system is the Land Cover Classification System (LCCS) proposed by the FAO. Unlike the IGBP classification system, the LCCS does not directly define each land cover type, instead only presenting a framework. Users can choose part of the LCCS and design more land cover types based on the framework according to special needs.

A hierarchical classification system of 25 land use/cover classes (Table 1) was applied in the first NLUD-C, and this classification system was inherited and used during several subsequent updates since 1995. The characteristics of this classification system are as follows:

(1) Integrated land use and land cover information as a whole
The NLUD-C classification system is more concerned about the utilization status of land by human beings than global land cover classification systems. For example, to emphasize the difference in utilization attributes, we detailed the first level of built-up land with urban and rural settlement and industry-traffic land. Human-made facilities for water reservation, such as reservoirs and ponds, were separated from the lake because of the difference between natural and human-made attributes. In addition, to ensure the integrity and applicability of the NLUD-C, this classification system comprehensively considers the characteristics of land use and land cover in China. For example, cultivated land is the most attention-receiving type in the study of land use in China. Therefore, we detailed the first level of cultivated land with paddy and dry land. Gobi is inherited from the relief map as an independent type of land use.

(2) Suitable for visual interpretation
Considering the characteristics of the method and the remote sensing resources employed during updates, the land use/cover types in the NLUD-C classification system should be obtained conveniently from remote sensing images by visual interpretation, and they should meet the needs for application at the national scale. The type that is most different from the generally used classification system in global land cover mapping is forest. Because only a single image was employed for our visual interpretation, it was very hard to distinguish evergreen-deciduous or broad-leaved forest based on lack of forest seasonal variation information. We used forest, shrub, sparse woods and other woods as the second-level types of woodland instead of broad vs leaved and evergreen vs deciduous type of forest classification. We also refined the second-level types of grassland with coverage instead of natural characteristics.

To maintain the agreement with the existing database, the 2010 update of the NLUD-C retrains this classification system.

2.2. Sources of remote sensing data

When monitoring land use/cover and its change at a scale of 1:100,000, it is optimal to use remote sensing data with a spatial resolution of approximately 30 m (Feranec, Hazeu, Christensen, & Jaffrain,