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A spatial comparison of four satellite derived 1 km global land cover datasets

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Abstract

Global change issues are high on the current international political agenda. A variety of global protocols and conventions have been established aimed at mitigating global environmental risks. A system for monitoring, evaluation and compliance of these international agreements is needed, with each component requiring comprehensive analytical work based on consistent datasets. Consequently, scientists and policymakers have put faith in earth observation data for improved global analysis. Land cover provides in many aspects the foundation for environmental monitoring [FAO, 2002a. Proceedings of the FAO/UNEP Expert Consultation on Strategies for Global Land Cover Mapping and Monitoring. FAO, Rome, Italy, 38 pp.]. Despite the significance of land cover as an environmental variable, our knowledge of land cover and its dynamics is poor [Foody, G.M., 2002. Status of land cover classification accuracy assessment. Rem. Sens. Environ. 80, 185–201]. This study compares four satellite derived 1 km land cover datasets freely available from the internet and in wide use among the scientific community. Our analysis shows that while these datasets have in many cases reasonable agreement at a global level in terms of total area and general spatial pattern, there is limited agreement on the spatial distribution of the individual land classes. If global datasets are used at a continental or regional level, agreement in many cases decreases significantly. Reasons for these differences are many—ranging from the classes and thresholds applied, time of data collection, sensor type, classification techniques, use of in situ data, etc., and make comparison difficult. Results of studies based on global land cover datasets are likely influenced by the dataset chosen. Scientists and policymakers should be made aware of the inherent limitations in using current global land cover datasets, and would be wise to utilise multiple datasets for comparison.

Keywords: Land cover; Earth observation; Global change; Environmental monitoring

1. Introduction

An increasing number of international environmental agreements place global change at the top of international scientific and political agendas, including the Kyoto Protocol, the Convention on Biological Diversity, the Convention to Combat Desertification and the Ramsar Convention on Wetlands. There are over 700 multi-lateral environmental agreements and over 1000 bilateral agreements dealing with different aspects of the environment and global change (Mitchell, 2003). Each of these agreements requires a unique set of information for implementation, monitoring and compliance. The needed information is currently coming from in situ data, models and remotely sensed data. A key component of the data needed within the global change framework is ecosystem-based information. However, while our knowledge of ecosystems has increased dramatically, it has not kept pace with our ability to alter them (WRI, 2000). One crucial parameter of the needed ecosystem information is land

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cover. Land cover is defined as the observed (bio) physical cover on the earth's surface (Di Gregorio and Jansen, 2000). In spite of the significance of land cover as a key environmental parameter our knowledge about it and in particular its dynamics is poor and to some extent infantile (Foody, 2002). We are far from producing geospatially consistent high-quality data at an operational level (Giri et al., 2005).

Both the policy and the science communities, with a manifold of disciplines, have great expectations that satellite observations can provide improvements with respect to our knowledge on continental and global land cover issues. Remote sensing can deliver data in a transparent and repeatable fashion without bias. Scientists, international organizations, NGOs and policy-makers have had increased access to satellite-based land cover descriptions of the globe over the last decade with more products planned for delivery in the near future. Users must therefore increase their understanding of the potential differences between the available global land cover products before they are used in monitoring, compliance and estimating conditions and trends.

The purpose of this study is to highlight for the user community some of the potential differences between the four existing (freely downloadable) global land cover datasets when compared at the global level. Armed with this information, the user may choose to more carefully select one dataset versus another for a particular study, or to use multiple datasets. We do not indicate preference of one map over another, nor do we identify the accuracy of any of the individual datasets.

2. Global land cover mapping

Prior to the existence of global satellite measurements suitable for deriving land cover maps, land cover datasets were assembled from a wide variety of data sources (Mattews, 1983; Henderson-Sellers et al., 1986). Townsend et al. (1991) found the information from conventional ground-based data contained significant deficiencies. Not only did the total area occupied by different classes vary substantially between datasets, but the detailed spatial distribution often varied substantially even where the total global estimates of a cover were similar. The absence of suitable land cover information at the global scale led in part to the attempts to retrieve this information from satellite observations. These efforts have thus far produced the following four freely available global satellite-based 1 km land cover products which are in wide use by the international science community (see Table 1): (1) International Geosphere Biosphere Project (IGBP) (Loveland et al., 2000) http://edcsns17.cr.usgs.gov/glcc/globe_int.html; (2) University of Maryland (UMD) (Hansen et al., 2000) http://www.geog.umd.edu/landcover/1km-map.html; (3) Global Land Cover 2000 (GLC2000) (Fritz et al., 2003) http://www-gvm.jrc.it/glc2000/; and (4) MODerate resolution Imaging Spectroradiometer (MODIS) (Strahler et al., 1999) http://duckwater.bu.edu/lc/mod12q1.html.

Three of the four datasets utilized the IGBP land cover classification (UMD utilised a simplified IGBP approach), which includes 11 categories of natural vegetation covers distinguished by life form, 3 classes of urban and cropland mosaic lands and 3 classes of non-vegetated lands for a total of 17 classes (Strahler et al., 1999). The legend aimed to be exhaustive, so that every part of the earth's surface was assigned to a class; exclusive so that classes would not overlap; and structured so classes are equally interpretable with 1-km data, higher resolution satellite imagery or ground observation (Loveland et al., 2000). Alternatively, the GLC2000 classification utilises the Land Cover

Table 1
Characteristics of the four satellite derived global land cover datasets compared in this study

	IGBP	UMD	GLC2000	MODIS
Sensor	AVHRR	AVHRR	SPOT Vegetation	Terra MODIS
Time of data collection	April 1992–March 1993	April 1992–March 1993	November 1999–December 2000	October 2000–October 2001
Input data	12 Monthly NDVI composites	41 Metrics derived from NDVI and bands 1–5	Daily mosaics of 4 spectral channels and NDVI	12, 32-Day composites of 8 input parameters
Classification technique	Unsupervised clustering	Supervised classification decision tree	Generally unsupervised classification	Supervised decision-tree classifier, neural networks
Classification scheme	IGBP (17 classes)	Simplified IGBP (14 classes)	FAO LCCS (23 classes)	IGBP (20 classes)
Validation	High resolution satellite images	Used other digital datasets	Statistical sampling	Confusion matrices, confidence values
Supplemental data	DEM, ecoregions, vegetation, land cover	Coarse/fine resolution satellite data	Data from other sensors	Fine resolution imagery with ancillary data