ISPRS Journal of Photogrammetry and Remote Sensing xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

ISPRS Journal of Photogrammetry and Remote Sensing

journal homepage: www.elsevier.com/locate/isprsjprs

Assessing global land cover reference datasets for different user communities

N.E. Tsendbazar *, S. de Bruin, M. Herold

Laboratory of Geo-Information Science and Remote Sensing, Wageningen University, Droevendaalsesteeg 3, Wageningen 6708 PB, The Netherlands

ARTICLE INFO

Article history:
Available online xxxx

Keywords:
Global land cover
Validation
Reference datasets
User groups
User requirements
Dataset suitability for users

ABSTRACT

Global land cover (GLC) maps and assessments of their accuracy provide important information for different user communities. To date, there are several GLC reference datasets which are used for assessing the accuracy of specific maps. Despite significant efforts put into generating them, their availability and role in applications outside their intended use have been very limited. This study analyses metadata information from 12 existing and forthcoming GLC reference datasets and assesses their characteristics and potential uses in the context of 4 GLC user groups, i.e., climate modellers requiring data on Essential Climate Variables (ECV), global forest change analysts, the GEO Community of Practice for Global Agricultural Monitoring and GLC map producers. We assessed user requirements with respect to the sampling scheme, thematic coverage, spatial and temporal detail and quality control of the GLC reference datasets. Suitability of the datasets is highly dependent upon specific applications by the user communities considered. The LC-CCI, GOFC-GOLD, FAO-FRA and Geo-Wiki datasets had the broadest applicability for multiple uses. The re-usability of the GLC reference datasets would be greatly enhanced by making them publicly available in an expert framework that guides users on how to use them for specific applications.

1. Introduction

Observation of land cover at the global scale is essential for understanding and monitoring global change and for coordinating actions to mitigate and adapt to climate change (Herold et al., 2008). Information on these assessments is used by governments, scientific communities and international initiatives (Bontemps et al., 2011b). Many climate models, dynamic vegetation models, hydrological models, and carbon (stock) models use land cover datasets as one of the model inputs (Hibbard et al., 2010; Verburg et al., 2011). These users have many different requirements on global land cover (GLC) maps and their accuracy assessments. Climate modellers, for example, typically use GLC maps at 1-km spatial resolution or coarser (Kooistra et al., 2010) whereas this resolution is too coarse for GLC change studies to detect small-scale changes, e.g. by forest logging (GOFC-GOLD, 2011). Accuracy assessment of GLC maps should account for these different user requirements and use suitable reference datasets in the assessments.

Over the last two decades, several global land cover (GLC) maps have been produced using remote sensing data, and GLC mapping is progressing towards higher spatial resolution datasets (Mora et al., 2014). The summary of current GLC products and their future trends are discussed in detail by Mora et al. (2014). GLC maps are commonly validated using higher-quality reference data, such as independent validation datasets and regional maps, or they are cross validated against training datasets (Friedl et al., 2002; Hansen et al., 2000; Mayaux et al., 2006). Currently, there are several independently-validated GLC datasets, namely IGBP-DIS, GLC2000, GlobCover5, GlobCover9, GLCNMO, and FROM-GLC (Bontemps et al., 2011a; Defourny et al., 2006; Gong et al., 2013; Mayaux et al., 2006; Scepan et al., 1999; Tateishi et al., 2011). The accuracy of existing GLC maps typically varies between 67% and 81%, and while it is lower (10–50%) in some regions of the world (Frey and Smith, 2007; Mora et al., 2014). The users of the GlobCover map and the Land Cover-Climate Change Initiative (LC-CCI) maps have stressed that the current quality of GLC maps should be improved (Bontemps et al., 2011b; Herold et al., 2011). The reason is that errors in GLC datasets add to modelling uncertainties; thus lower quality GLC datasets can have a strong impact on the final model outcomes (Nakaegawa, 2011; Sertel et al., 2010).

The generation of reference datasets for accuracy assessment of GLC maps is a difficult task. The current reference datasets were generated by visual interpretation of satellite images, regional maps and geo-tagged photos. Enormous effort is required to analyse a large number of satellite images and interpret the land cover type.

* Corresponding author. Tel.: +31 317 482072.
E-mail address: nandin.tsendbazar@wur.nl (N.E. Tsendbazar).

http://dx.doi.org/10.1016/j.isprsjprs.2014.02.008
0924-2716/

Please cite this article in press as: Tsendbazar, N.E., et al. Assessing global land cover reference datasets for different user communities. ISPRS J. Photogram. Remote Sensing (2014), http://dx.doi.org/10.1016/j.isprsjprs.2014.02.008

For example, 39 international experts interpreted 379 confidence sites of the IGBP-DIS dataset during a two-week workshop (Scepan et al., 1999); 253 Landsat images were pre-processed, and international experts interpreted 1265 sample sites for the GLC2000 dataset (Mayaux et al., 2006); and 16 international experts completed on-screen collection of ground data for 4258 sample sites for the GlobCov5 validation dataset (Defourny et al., 2011b). Despite the efforts put into generating these reference datasets and the scarcity of validation data, their use is mainly limited to the original intended use and only a few studies reported re-using these datasets for other uses (FAO, 2001; Göhmann et al., 2009).

In addition to the existing GLC validation datasets, there are a number of existing and evolving datasets that provide reference information for GLC maps and other global level assessments such as forest and agricultural studies. There are training datasets for MODIS and GLCNMO product generations (Friedl et al., 2010; Tateishi et al., 2011). Volunteer-based Geo-Wiki and View-IT datasets also provide an inexpensive way of collecting potentially useful land cover reference data (Clark and Aide, 2011b; Fritz et al., 2009). Other datasets such as the FAO-FRA remote sensing survey focusing on a statistical sample-based assessment of global forest change have also been generated (Potapov et al., 2011).

The above mentioned reference datasets on GLC have potential of being used for applications outside their original scope. A thorough analysis of the efficient use of all available data for GLC map validation and calibration has not been previously investigated. To move towards the efficient use of reference datasets for GLC map validation, Olofsson et al. (2012) proposed a new reference dataset that is created independent of any GLC map. Boston University and the Global Observation for Forest Cover and Land Dynamics (GOFC-GOLD) are jointly generating a database for GLC map validation that can be augmented and used for different map validations (Olofsson et al., 2012; Stehman et al., 2012). However, the question of efficient use still remains for available and other upcoming GLC reference (GLCR) data. Currently, there is no assessment providing information on how these datasets can be used beyond their original scope and what the implications would be for specific user applications having different requirements on GLC maps and their validations. This situation can limit the value of the existing GLC reference (GLCR) datasets for various applications and can hinder informed decision making concerning the usefulness of GLCR datasets for particular studies.

The objectives of this paper are to (1) analyse the published literature to provide information on GLCR datasets and their user requirements, and (2) assess the potential uses and limitations of different GLCR datasets for four targeted GLC map user groups, namely the climate modelling community, global forest change analysts, the Group on Earth Observation (GEO) community of practice (CoP) for Global Agricultural Monitoring and producers of improved GLC maps. Analysing the characteristics of the GLCR datasets and their re-usability is important for understanding and reducing inconsistencies of reference datasets for the GLC mapping community. This will also help users of GLC datasets to make better-informed selections of reference datasets and reduce the uncertainty in their applications.

Section 2 reviews the characteristics of the GLCR datasets as well as the main requirements of GLCR for different user groups and describes the methods for assessing the suitability of the GLCR datasets for different user groups. The results of the assessments are provided in Section 3. Section 4 discusses the results and the main findings of the study are concluded in Section 5.

2. Methods

The general procedure followed for the analysis is shown in Fig. 1. We reviewed the main dataset characteristics which are related to GLCR datasets (Section 2.1). Next, we compared the GLCR metadata (Section 2.2). The main user requirements were identified through a literature review (Section 2.3). Finally, the suitability of GLCR datasets for user groups was assessed by using the metadata of the GLCR datasets and the identified user requirements (Section 2.4).

2.1. Characteristics of reference datasets

Different characteristics related to the sampling and response design protocols need to be considered when generating and assessing reference datasets. Information from these protocols is used in the analysis and estimation protocols (Stehman and Czaplewski, 1998). In addition, the thematic classification scheme determining the class legend, hierarchical classifiers and thematic detail of the land cover information need to be considered (Herold et al., 2006).

Sampling design is an important aspect determining both the cost and statistical rigor of the thematic map accuracy assessment (Congalton and Green, 2009). An appropriate sampling unit, sample size and sample selection scheme should be considered carefully depending on the purpose, budget, and extent of the study. Area sampling units of pixels, blocks of pixels, and polygons can be used for accuracy assessment, and their choice may have an impact on sampling schemes and accuracy estimates (Stehman and Czaplewski, 1998). The minimum mapping unit (MMU) is also specified since it can influence the size of the area sampling units (Stehman and Wickham, 2011). For statistically sound accuracy assessments using limited resources, different approaches are adopted to determine the required sample size, e.g. using confidence intervals, allowable error, and significance levels (Foody, 2009; Janssen and Van der Wel, 1994). Design-based probability sampling schemes, e.g. simple random,

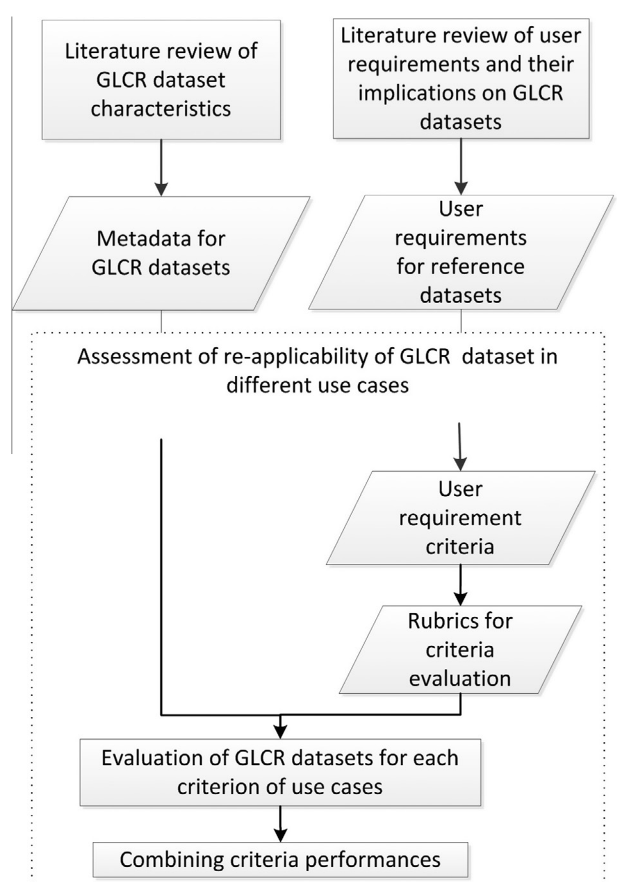

Fig. 1. General analysis procedure.