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Development of 2010 national land cover database for the Nepal

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ABSTRACT

Land cover and its change analysis across the Hindu Kush Himalayan (HKH) region is realized as an urgent need to support diverse issues of environmental conservation. This study presents the first and most complete national land cover database of Nepal prepared using public domain Landsat TM data of 2010 and replicable methodology. The study estimated that 39.1% of Nepal is covered by forests and 29.83% by agriculture. Patch and edge forests constituting 23.4% of national forest cover revealed proximate biotic interferences over the forests. Core forests constituted 79.3% of forests of Protected areas where as 63% of area was under core forests in the outside protected area. Physiographic regions wise forest fragmentation analysis revealed specific conservation requirements for productive hill and mid mountain regions. Comparative analysis with Landsat TM based global land cover product showed difference of the order of 30–60% among different land cover classes stressing the need for significant improvements for national level adoption. The online web based land cover validation tool is developed for continual improvement of land cover product. The potential use of the data set for national and regional level sustainable land use planning strategies and meeting several global commitments also highlighted.

1. Introduction

In the last few decades the Hindu Kush Himalayas (HKH) has undergone rapid economic, social, and environmental changes. However, there is a lack of cohesive information on these changes and how they are impacting on land cover and land cover change. Nonetheless, it is clear that land cover change in the HKH is driving change in ecosystems and their services (Koschke et al., 2012). The HKH region extends over 3500 km encompassing all or parts of eight countries: Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan. The region contains 10 of Asia's largest river systems, which provide water and ecosystem services to the 210 million people living in mountain areas, as well as the 1.3 billion people downstream (Molden and Sharma, 2013). The region is extremely fragile in terms of land cover diversity and its association with variable terrain, climate, and socio–demographic interactions. The HKH region is significantly rich in terms of biodiversity, but is also one of the least studied in the world (Sharma and Chettri, 2005). The Intergovernmental Panel on Climate Change (2007) has recognized the HKH region as a 'data-deficit area'. Although scientists and institutions are attempting to fill some of the gaps, reasonable and reliable sources of data for the development of accurate land cover maps for the HKH are scarce. The available data in the region are sporadic, inconsistent and inaccessible (Bajracharya et al., 2010).

Nepal has a high-level of diversity and complexity in terms of altitude, terrain, biodiversity, and socio-demography and is broadly representative of the land cover diversity in the HKH region (Bhattarai et al., 2009). There is a need to understand the interactions between these diversities to support land resources use, development, and conservation (Zomer and Susan, 2001). Climate Change impacts, habitat fragmentation, and high population density are changing in the way people in Nepal (and the HKH) are using land and causing land use conflicts. These multiple drivers of change and the interactions between them need to be understood so that policy makers and planners can better manage Nepal's natural resources.

According to the 2011 census, Nepal has a total population of 26.5 million, with a population growth rate of 1.35% per annum. The overall literacy rate (for the population aged 5 years and above) has increased from 54.1% in 2001 to 65.9% in 2011 (National Population

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and Housing Census, 2012). Nepal's current forest policy and legislation classifies the country's forests mainly according to tenure or control over the land as government-managed, community-managed, leasehold, religious, private, and protected forest (Acharya, 2002). According to the Food and Agriculture Organization of the United Nations (2010) country report, the forest living biomass (above and below ground biomass) is 484 million metric tonnes (359 million metric tonnes above and 126 million metric tonnes below).

Satellite remote sensing is as an important tool in providing reliable historical and current land cover information at the local, national, regional, and global levels (Foley et al., 2005). At the global level, numerous efforts have been made to provide satellite-based land cover and forest cover information (Reis, 2008; Schweik, 1997; Xian et al., 2009), including GLOBCOVER (Arino et al., 2007; Bontemps et al., 2011), annual MODIS land cover (Friedl et al., 2002, 2010), MODIS VCF (DiMiceli et al., 2011), the rescaling of MODIS VCF at 30 m (Sexton et al., 2013) and detection forest cover changes provided by Global Forest Watch (World Resources Institute, 2013). Public domain satellite data and online visualization tools like Google Earth and BHUVAN allow end users to assess the accuracy of land cover data based on very high resolution satellite images and observations.

In Nepal, institutional-level national land cover assessments were conducted in 1963, as part of a forest resources survey (FRS) using aerial photography, and in 1986 for a land resources mapping project (LRMP) using satellite data. Since then, no national-level land cover assessments have been conducted and subsequent assessments have focused only on national forest cover mapping, for example, the multi-stakeholder forestry programme (MSFP) and national forest inventory (NFI). A number of individual researchers have also tried to fill the land cover data gap in their own capacity at various scales (Bhattarai et al., 2009; Carson B et al., 1986; Gautam, 2002; Jackson et al., 1998; Niraula et al., 2013), but none of these have produced land cover maps with national coverage using standardised classification scheme.

In Nepal, landscape changes and social change patterns have been observed as a function of land use change, and these have implications for social and ecosystem functions and services (Millette et al., 1995). Nepal's community forestry programme is acknowledged to be one of the most successful forest conservation initiatives in the world (Niraula et al., 2013). However, despite the success of this programme and the importance of forests in supporting livelihoods of the people of Nepal and providing ecosystem services to those downstream, there has been little research on land cover and land cover change. A comprehensive understanding of the changing patterns of land cover over the last two decades and its drivers at the national and sub-national level is lacking. This lack of data and information has been one of the major limitations on policy and decision makers in addressing regional environmental issues including the development of greenhouse gas (GHG) inventories, the evolution of reducing emissions from deforestation and forest degradation (REDD) mechanisms, and the assessment of land degradation, as well as optimal land use planning (Dangi, 2012). This study is expected to be useful in addressing such regional issues and informing initiatives in relation to Nepal's national and global commitments, such as its communications to the United Nations Framework Convention on Climate Change (UNFCCC).

The present study on land cover assessment of 2010 is taken up as part of regional initiative on developing consistent and harmonized temporal land cover databases over HKH region. At the initial level, study was conducted using public domain Landsat TM data of 2010 and 2011 by adoption of geographic object based image analysis (GEOBIA) classification technique. The land cover product validation system is developed as part of the study using online web based tool. The assessment of land cover patterns in relation to historical trends and implications over natural resources management over different physiographic regions and potential application for different national and global commitments initiatives also described. Considering the number of global land cover datasets and studies are available, we compared our land cover product with global product of Gong et al. (2013) to explore the possible adoption of global algorithms for national monitoring systems. In this study the forest fragmentation and edge effects was calculated by dividing the land cover into forest and non-forested areas. An online crowd source-based validation tool was developed to collect and analyse feedback from voluntary participant.

2. Study area

The study area covers the whole of Nepal, which falls between latitudes 26°22′N to 30°27′N and longitudes 80°04′E to 88°12′E and shares an international border with China to the north and India to the south, east, and west. With a total land area of 147,181 km^2. Nepal is divided into five physiographic regions: High mountain, Middle mountain, Hill, Siwalik and Tarai (Fig. 1). Administratively, Nepal has 75 districts and 4057 village development committees (VDCs). These 75 districts are divided into 14 administrative zones, which are grouped into five development regions: far western, mid-western, western, central and eastern.

Nepal is predominantly mountainous, with elevations ranging from 60 m in the southern plains to 8848 m at Mount Everest in the north, which is the highest point on the Earth. The climate and topography nurture about 118 ecosystems, 75 vegetation types, and 35 types of forest (MFSC, 2006). Four biodiversity hotspots are located within the Nepal Himalaya (Chettri et al., 2008). Average temperatures in Nepal increased at a rate of 0.06 °C between 1977 and 1994. Precipitation in eastern Nepal also shows an increasing trend, whereas precipitation in the western and central parts show a negative trend of <700 mm/decade (Nepal et al., 2012). About two-thirds of households (about 64%) use firewood as the usual source of fuel for cooking (National Population and Housing Census, 2012).

3. Material and methods

3.1. Data and software used

For land cover mapping, Landsat TM satellite images of 30 m spatial resolution of 2009, 2010 and 2011 were used (Table 1). Altogether, 11 scenes (185 × 185 km each) of Landsat TM were used covering the entire study area. In some cases, alternative images of different season of the same row and path were deployed to ensure the accurate identification of land cover features. The satellite images of November 2010 to February 2011 period were chosen representing mostly green to semi deciduous conditions. All images were downloaded from open source data of the United States Government Survey (USGS) Global Visualization Viewer (GloVis). RapidEye images (5 m spatial resolution) captured in 2010 were also used as support information for the separation of shrub land and forest areas during image interpretations.

To understand the variation in topography, a shuttle radar topography mission (SRTM) 3 arc-second (approximately 90 m resolution) digital elevation model (DEM) was used. From an accuracy point of view, SRTM is more reliable than other open source DEMs because it uses radar techniques (Nikolakopoulos et al., 2006).

For satellite image processing and classification, ERDAS Imagine 9.3 and eCognition Developer 8.7 were used. Map formation and