Forest Cover and Land-use Change in Rural Mountain District Darchula of Farwestern Nepal

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Abstract

The description of land-use dynamics provides insights into the ecological and biogeographical processes. Additionally, the relationship of human and biological components, as well as climatic conditions, are well incorporated in land-use analysis. In the present communication, we analyse forest and land-use land cover (LULC) changes at various spatial and temporal scales in order to better understand the geo-ecological and socio-cultural complexities using aerial photography, satellite imagery and topographic maps. Evidence of forest cover change was found to occur over time. Community based forest management systems aided restoring forest cover whereas overexploitation and human migration led to forest degradation. However, more recently (between 2010 and 2016), the cover of forest increased slightly, which is consistent with the countrys' efforts to improve forest cover., These findings serve as a hope of better human-nature interactions in the future and suggests more integrated and periodic research is needed for precise forest cover monitoring.

Key words: Land-use, Forest, Kailash Sacred Landscape, Nepal.

Introduction

The high elevation gradient, complex topography, fragility, high warming rate, biodiversity hotspots and close proximity to indigenous communities make the Himalaya environment a rare combination of climatic, anthropogenic, geology, culture, ecology and topographic characters (Korner, 1998). However, they are threatened by global climate change (Yao *et al.*, 2006), and impacted by human induced forest degradation, deforestation and habitat fragmentation (Houghton, 2003; Das, 2008). Climate change has left several biological fingerprints including change in land cover and land-use (Comarazamy *et al.,* 2012) as well as change in species composition, range and distribution shift of species and alterations in phenology of organisms (Billings, 1974; Menzel, 1999; Parmesan and Yohe, 2003). However, mountainous regions very sensitive to climate change and curtailed by land-use and land cover change (Becker and Bugmann, 2001; Khanal, 2002) are least studied (Schickkoff, 2005; Shrestha, 2005; Xu *et al*., 2007; Regmi, 2008; Bernstein *et al*., 2008; Eriksson *et al*., 2009; Elliott, 2012). Covering an understudied area like the Himalaya mountains and considering attributes like land-use/cover change may give insights to analyze the alterations on socio-economy, culture, ecology and landscapes and help understand the broad geo-ecological paradigm (Chhetri, 2015). Analysis of socio-cultural information within the framework of GIS/Remote Sensing has proven to be a valuable entity for validation of driving forces of land-use land cover change in Himalaya as well as other landscape (Paudel and Anderson, 2010, Rimal *et al.,* 2017a). Ecological complexity and heterogeneity can be understood by considering a complex view that includes many relevant factors (climate, topography, and land-use, human, culture), and considers a cross scale (coarse and finer) study (Holtmeier, 2009). The description of land-use dynamics provides insights into the ecological and biogeographical processes and relationship between human and biological components and climatic conditions (Gunderson and Holling, 2002; Shi and Wu, 2013). However, digital maps of recent land-use and land cover change (LULC) and developments in the Nepal Himalaya are scarcely available. Thus, in the present communication, we aim to identify the latest changes of land-use land cover and assess the changes at various spatial and temporal scales in order to understand the geo-ecological and socio-cultural complexities.

Methodology

Study area

This study was carried out in the Darchula district, Far Western Nepal, a part of Kailash Scared Landscape (KSL). The KSL, a trans-boundary landscape within China, India and Nepal has been set up to conserve ecosystem services and biodiversity of the area through sustainable resource management (Chettri *et al.,* 2009; Uddin *et al.,* 2015). The KSL contains some of the highest and most remote mountains in the world, including the sacred Mount Kailash (6,638 m), which is located on the edge of the Tibetan Plateau and the border of Nepal and Tibet. The landscape's bioclimatic zones include hot and semi-arid regions in the southwest, lush green and humid valleys in the mid-hills, extensive mountain forests, moist alpine meadows, remote and arid trans-Himalayan valleys, and high altitude grasslands and steppes, as well as extensive permanent snow and ice ranges (Zomer *et al*., 2013). The landscape exhibits significant heterogeneity, both geographically and culturally, covering at least four major geological and physiographic zones and inhabited by seminomadic *Raute* tribe and a minority ethnic group *Byanshi-Sauka*. Ranging from below 400 masl to over 6,600 masl and characterized by extreme variations in topography, the ecosystems of the KSL range from moist subtropical to temperate, alpine, and cold high altitude desert bio-climates (Zomer *et al*., 2013).

Our study area, Darchula district is one of the most inaccessible and underdeveloped regions of Nepal and faces numerous conservation and development challenges. The district with 233,700 ha area with trans-himalayan and mountain geography has facilitated the strengthening of unique biodiversity and indigenous knowledge of plant use (Negi et al., 2017). The diverse geographic has given support to high level of biodiversity including an array of forest types (such as moist subtropical broadleaf to temperate oak forests, alpine conifers, and high altitude pastures) (Zomer and Oli, 2011; Elliott, 2012). The harsh climate, poor accessibility, marginality, and high level of poverty manifests high dependency on natural resources leading to overexploitation (Roy *et al*., 2009). The rugged terrain, geographic heterogeneity, and unsustainable harvesting (Kunwat *et al.*, 2012; Kunwar *et al.*, 2015) pose a serious threat to the land-use systems, with implications for natural biodiversity and human development (Uddin *et al*., 2015).

Methods

Most recent studies use aerial photography and satellite imagery as data sources for tracking and assessing land use and land cover change for environmental monitoring (Zhao *et al.,* 2016; Paudel *et al.,* 2016; Wang *et al.,* 2017) complex area monitoring and mapping. Geographic information system (GIS) and remote sensing (RS) software provide a rich set of tools for detailed LULC monitoring and analysis, including spatiotemporal change at global to local scales (Rimal, 2017b). The release of freely available high-resolution satellite images (i.e., Google Earth), which approach the quality of aerial photographs, opened up new possibilities. Google Earth is frequently used to display scientific results (Scambos *et al*., 2007) but in some cases also as a data source (Sato and Harp, 2009).

The LULC data was obtained from multiple sources covering approximately three decades (eg, National remote sensing center for 1984, Master plan for forestry sector 1985, LRMP 1986, Cadastral survey after 1992, National level forest inventory 1994, Japan forest technology association 2000) (GoN 2008). Recently, the Department of Forest has prepared forest resource map in 2016 (DFRS, 2015) and Uddin et al. (2015) published land cover change dynamics of Kailash Nepal. The Kailash sacred landscape is a transboundary landscape among Nepal, India and China. However, comparison of the database over-time is largely hindered by the validity regarding the purpose, methodology, accuracy, data sources and scale of information. So in this study we analyze the forest and land cover change of Darchula using time series data from 1996 to 2016 and assess the changes spatial and temporal scales.

Geometric rectification was carried out using a road network map in the local projection system (i.e., UTM). Image enhancement, contrast stretching, and false color composites were created to improve the visual interpretability of the image by increasing apparent distinctions between the features. Knowledge-based visual interpretation, texture, and association analysis were performed at the preliminary stage. Rivers, roads, settlement and buildings were manually delineated by interactive interpretation procedures (following the tonal, textural, contextual, pattern, size, shape, shadow, association, and site pattern of each sample category (Zong *et al*., 2014). Identification was also done with the help of topographic maps, supervised and isodata classification maps. Attributed tables of previous maps before digitization and after digitization were compared and the changes were identified. Topographic maps of high mountain regions provide useful information about terrain (altitude, slope, depressions, etc.) Rivers, contours and village boundaries were used to create a DEM and hillshade of the district. The DEM was used to assign the elevation. The image files of the three layers were stacked in ERDAS photogrammetry and maps were produced in Arc GIS by using the DEM (Zoomer *et al*., 2002). Excel was used for further analysis of the attribute tables.

Data acquisition and analyses

A topographical map published by the Survey Department, Government of Nepal, 2001, for the study area with a scale of 1:25,000 was used as the reference map for the analysis of images. The map was based on an aerial photograph at a scale of 1:50,000 taken in 1996. All the required digitized layers were collected from the Department of Survey, Nepal. However, many of the datasets are available and generated by digitizing topographic maps scaled 1:25,000 so in most cases the spatial and semantic resolution of information is too poor to be used in local spatial analyses. Again digital data extracted from 1:25,000 or 1:50,000 scaled maps only cover small parts of the investigation area and therefore seldom meet the needs for research (Gspurning *et al.*, 2004). Thus, remote sensing techniques and digital methods of data analyses were used that provide an accuracy assessment, independent from the local situation and the cartographer. Henceforth, three consecutive maps (1990, 2000, 2010) of the same area were collected and their features were analyzed at temporal scales. Moreover, three time-series atmospherically corrected surface reflectance (SR) Landsat images for the year 1996, January 9, 2006 March 1 and 2016 February 17 (Path/Row, 144/39) were obtained from the United State Geological Survey (USGS) website https://earthexplorer.usgs.gov/ for further analysis and verification. SR data are ready for application analysis as they include atmospheric correction, geometric correction and other requirements and they are useful for land cover monitoring (Rimal *et al.,* 2017). The maximum cloud-free images were included in the study. All the images were clear and nearly free of clouds. However, some images contained seasonal snowfall cover in the northern part. All data was projected in UTM (i.e. UTM WGS 1984, Zone 44N). A topographical map published by Survey Department, Government of Nepal, 2000 (scale 1:25000) was used as the reference for image analyses. Google Earth image was used for ground-truthing. A 30 m digital elevation model (DEM) data was collected form SRTM. All obtainable images, pre-processing, stacked, subset and classification were accomplished using ENVI software and classified using support vector machines

(SVM). A modified version of land cover classification scheme was used for remotely-sensed data as recommended by Anderson *et.al* 1976 (Table 1).

Land cover types	**Description**
Urban (Built up)	Urban and rural settlements, commercial areas, industrial areas, construction areas, traffic, airports, public service areas (school, college, hospital)
Cultivated land	Wet and dry croplands, orchards
Forest	Evergreen broad leaf forest, deciduous forest, scattered forest, low density sparse forest, degraded forest/ Mix of trees (<5 m tall), other natural covers
Grass	Mainly grass field- (dense coverage grass, moderate coverage grass and low coverage grass)
Barren land	Cliffs/ small landslide, bare rocks, other permanently abandoned land
Sand	Sand area, other unused land, river bank
Water	River, lake/pond, canal, reservoir
Ice and Snow cover	Perpetual/ temporary snow cover, Perpetual ice/ glacier lake

Table 1. Land cover classification scheme

Results and Discussion

Land cover

The land cover of the Darchula district shows that the district has the least cover of agricultural lands and the most cover of forests, snow cover and barren land. The northern area of the district is ruderal, bare and dry due to steep slope angles. Southern and western parts of the district are lowland, more accessible and cultivated. Because of the steep slope and fragile geology (Figure 1), forest degradation is serious and further vegetation loss is anticipated (Uddin *et al.*, 2015a) since 70 percent of the population of KSL area is dependent on agriculture (Zomer and Oli, 2011). As traditional farming in the district yields food crops for only about six months a year, alternative livelihood strategies like transhumance, animal husbandry and collection of forest products are very common. Human communities that inhabit in remote, rugged and rich ecosystems use diverse livelihood strategies such as utilization of different ethno-ecological environments, sometimes defined in accordance with altitudinal gradient and distance of accessibility (Aldunate *et al.,* 1981) and associated with adaptive measures to the changed environment.

Forest cover until 1990

The change in forest cover in the district was non-linear however, insignificant over time. The change of forests subjected to cultivation purpose was elusive. There was severe deforestation before 1970s due to forest nationalization (Forest Nationalization Act 1957) and cadastral survey (Chand and Wilson, 1987) and it was aggravated due to pressure of fuel wood, fodder collection and grazing (Chhetri and Pandey, 1992). Forests were considered an open access commodity and the rate of forest degradation for cropland was intense until the 1970s; resulting in imbalance of economic development, human activities and the overall environment (Collins and Jenkins, 1996). Decreasing forest cover by 50% and increasing croplands by 55% was reported in the Karnali zone between 1950 and 1972 (Bishop, 1990). Community managed forest system introduced in the Darchula district in 1979 was a breakthrough in controlling the deforestation and reiterating the green cover (Campbell, 1987), nonetheless, the recovery was slow but consistent in the early years between 1980 and 1990 (Gautam *et al*., 2004). However, some local and indigenous forest management interventions were in place in Byans, Huti and Pipalchauri (Darchula) (Chand and Wilson, 1987) before 1979 to derail the degradation. Between 1979 and 1986, there was a consistent increase in forest cover (MPFS, 1988) with less than five percent increase between 1978 and 1998 in the Baitadi and Darchula districts (Chaudhary *et al.,* 2010). Entire Mountainous areas of Nepal experienced increased forest cover between 1979 and 1985 (Nield, 1985), including the Darchula district (Chand and Wilson, 1987). Over time, district community forest management took momentum and the forest cover increased.

Year	Forest (ha)	Shrubland (ha)	River/Water body (ha)	Barren land (ha)	Others (ha)
1990	58,940 (25.2%)	16,924 (7.2%)	788 (0.3%)	14,844 (6.3%)	142,834 (61.1%)
1996	57,639 (24.6%)	16,965 (7.2%)	824 (0.3%)	18,100 (7.7%)	140,172 (59.9%)
2000	58,021 (24.8%)	16,663 (7.1%)	762 (0.3%)	18,201 (7.7%)	140,053 (59.9%)
2006	59,220 (25.3%)	16,464 (7.0%)	779 (0.3%)	13,700 (5.8%)	143,537 (61.4%)
2010	57,544 (24.6%)	16,644 (7.1%)	884 (0.3%)	15,684(6.7%)	142,944 (61.1%)
2016	59,090 (25.2%)	17,105 (7.3%)	596 (0.2%)	13,035 (5.5%)	143,874 (61.5%)

Table 2: Selected land cover of Darchula district between 1990 and 2016

Forest cover after 1990

However, the handing over the government owned forests to communities was discontinued in 2005, and has resulted in decreased in forest cover. There was a 9% decrease in forest cover in the district between 2001 and 2016, consistent to the findings of Uddin *et al.* (2015a). Built up areas (settlement, buildings, roads) were rapidly increased, as seen in other areas (LRMP, 1986; Acharya and Dangi, 2009; Humagain, 2012, Uddin *et al.,* 2015b). Whole the country faced the severe deforestation in the recent decades with 0.01% per annum (Reddy *et al.,* 2018). We speculate that the intensive changes in the recent years could be due to anthropogenic causes such as increasing human migration and laying the land fallow provoking rampant growth of non-native invasives. The forests once degraded were laid unattended and aggravated by the growth of ruderals. A social factor, continuous out-migration from the study area for menial work in India and low-land Terai (Poertner *et al.,* 2011) has left agricultural lands fallow, led to lack of labor (Maren *et al.,* 2013), and a change in indigenous land-use management systems (Pant *et al.,* 2005), also fomented forest degradation. Increasing forest degradation and shrub cover were anthropogenic and attributed by overgrazing, forest fires, over-exploitation and out-migration (Ekholm, 1975). Contested with the earlier studies (Khanal, 2002; Humagain, 2012; Uddin *et al.* 2015a; Paudel *et al.* 2016), forest cover was not subjected to change into cultivated land in Darchula district.

The decade long land-use change analysis of the district revealed that the change in forest cover between 1990 and 2010 was negative (Table 2). There was a 2.36% forest cover loss between 1990 and 2010 in Darchula district. This finding was supported by the intensive changes of NDVI at northern part of the district (Kunwar *et al.,* 2016). A recent study by Uddin *et al*., (2015a) on land cover change and forest fragmentation of Northern Darchula showed that there was a 9% decrease in forest cover and 12% increase in cropland between 1990 and 2009. Cropland expansion, high dependency on forest, and overexploitation of forest resources are the major drivers of land-use change and fragmentation and inevitable over time as urbanization, human migration, population growth, etc. are under way. A further 4% decline in forest cover and 5% increase in cropland were predicted by 2030, together with a slight increase in grassland and barren area (Uddin *et al.,* 2015a) may worsen the forest cover of the district.

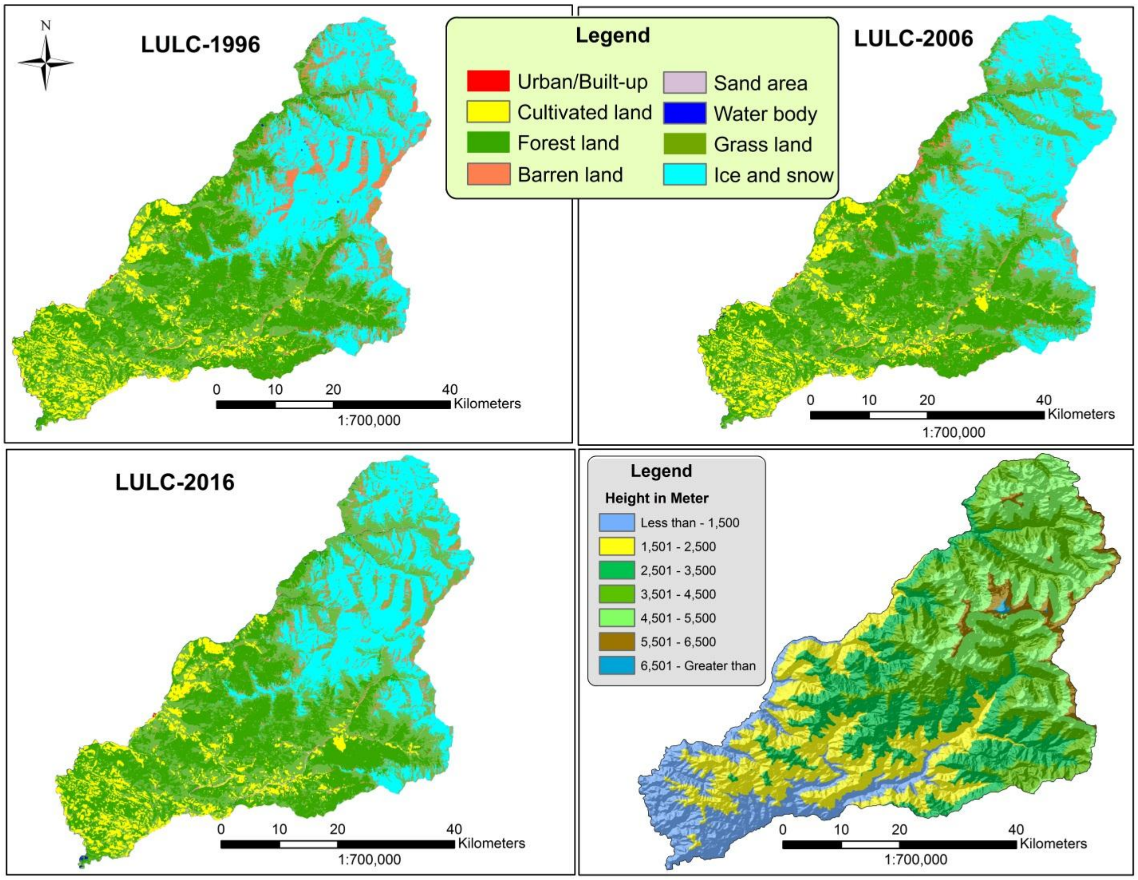

Figure 1. Land use and land cover of Darchula, 1996-2016

Moreover, time-series atmospherically corrected SR Landsat images of 1996, 2006 and 2016 revealed that there was a gradual increase in grasslands at the cost of recession of snow cover. (Figure 1, Table 1). Since the deforestation is least in far western Nepal (5.5%) during 1930-2014 (Reddy et al. 2018) and the negligible in mountainous areas (Schweik et al. 2003) resulting in insignificant changes in forest cover between 2006 and 2016 (Table 1) in our mountainous district of far western Nepal. There was a little transition in recent decade between 2006 and 2016 however in the last five years the cover has been increased, consistent with the government record (DFRS, 2015). DFRS (2015) recorded that the forest cover of the nation is 40% which was a slight increment from the last monitoring. We expect a better human-nature interaction in Darchula district in the days ahead in the nexus of forest restoration and sustainable development.

Overall, the forest growth was outpaced by the pressures associated with population growth, migration and effacing indigenous forest management knowledge. The changes in land-use practices, including sedentarization of pastoralists, overharvesting of high-value medicinal plants, uncontrolled livestock grazing, and rapid increases in the number of tourists in alpine areas, and the resultant pressures, have led to degradation of forest resources in the KSL (Rawat *et al.*, 2014). The local communities depend largely on the high-altitude rangelands for their livelihoods and for cash income from collection and sale of non-wood forest products namely *Ophiocordyceps sinensis* (Berk.) G.H.Sung (Himalayan caterpillar fungus) and aromatic herbs (Dadal, 2010; Chaudhary *et al.,* 2010; Kunwar *et al.,* 2015).

Conclusions

This study applies state-of-art methods by combining three geospatial tools: Arc GIS, ERDAS Imagine and Google Earth for interpretation of geophysical characteristics of an area for future use of research. The change in forest cover in the district was non-linear, however, insignificant over time. The regained forest cover with the help of community based management system was jeopardized by the recent changes. The loss of forest cover until 2010 was analogous to the alteration of human socio-culture, weather pattern and lifestyle. High dependency on forest and over-exploitation of forest resources were the major drivers of the change and they are still in place as urbanization, human migration, population growth and exploitation of government forests are under way. However, there was a little transition between 2010 and 2016, analogous to the countrys' forest cover trend is a hope of better human-nature interactions in the days ahead.

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