LAND USE AND LAND COVER CHANGE IN RELATION TO INTERNAL MIGRATION AND HUMAN SETTLEMENT IN THE MIDDLE MOUNTAINS OF NEPAL

BHAWANA K C
February, 2015

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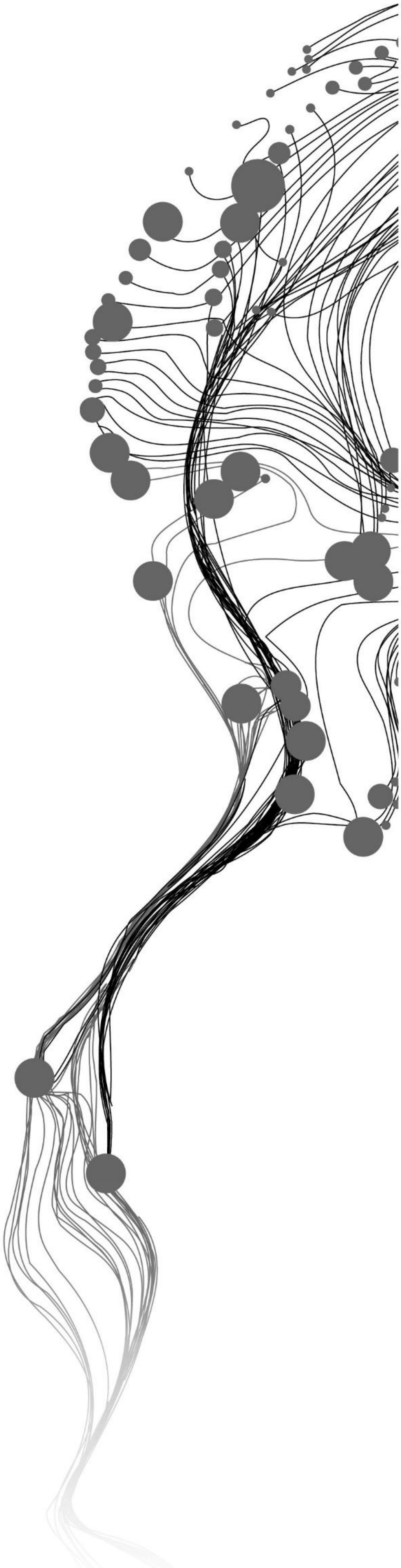

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BHAWANA K C
Enschede, The Netherlands, February, 2015

Thesis submitted to the Faculty of Geo-Information Science and Earth Observation of the University of Twente in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation.
Specialization: Natural Resources Management

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ABSTRACT

Understanding the complexity of Land Use and Land Cover (LULC) changes and their drivers at a local or landscape level is essential to better understand the relationship between human and the environment, and to support local planning process for the sustainable management of ecosystem goods and services. Internal migration is a common and ongoing phenomenon in the middle mountains of Nepal which largely determine the resource use, its distribution and management. Most of the research conducted so far emphasized the issues related to outmigration of people and its consequences. However, increasing trend of internal migration, its relation and consequences to LULC changes has not been well documented. Therefore, this research was designed to answer the question how LULC has changed in the last 25 years due to internal migration, and how the changes in human settlements have impacted the surrounding landscapes in the middle mountains of Nepal.

The LULC change analysis from the year 1988 to 2013 was conducted using Landsat images with Support Vector Machines. The internal migration pattern of households in the study area was analysed by an interaction with local communities through focus group discussions. Based on the internal migration pattern, whole landscape was divided into higher (above 1400 m) and lower (below 1400 m) landscape. The fragmentation analysis was carried out in each landscape using FRAGSTAT software. Consequently, the impacts of different human settlement densities on surrounding LULC were analysed using ArcGIS and FRAGSTAT software.

The results reveal that the forests in the study area have increased gradually in the last two decades with an overall decrease in shrub/grass and agriculture. A trend of household migration from high to low elevations villages has been revealed, although the trend was not uniform in all villages. The fertile agriculture lands in the valley floors, construction of rural road with accumulation of income opportunities, and facilities along the road head were found as pull factors for internal migration. Similarly, erratic rainfall, natural hazards, decreasing agriculture production and productivity, limited income opportunities and labour shortage were reported as major push factors for migration of people from uplands towards the valley floors. At higher elevations, forest had increased at the cost of agriculture and shrub/grass, while at lower elevations, forest was more or less constant with increase in agriculture at the cost of shrub/grass. However, the agriculture have become geometrically complex in shaped in lower elevations due to expansion of settlements and infrastructure development. Near to the settlements (within 0.5 km; inner buffer), the low density settlement had highest coverage of shrub/grass and lowest forest. However, the area around the medium and high density settlements had higher percentage of agriculture followed by forests. Far away from the settlements (1 km from inner buffer; outer buffer), the medium density settlement had largest coverage and dominance of forest. However, the areas around the medium density settlement had large number of forest patches compared to the high density settlement. Among all, the areas around the high density settlement had largest percentage of agriculture and more homogenous and compact forests. Agriculture was found to be more fragmented near to settlements compared to the areas far from the settlements.

The research suggests that internal migration plays an important role in LULC change in the middle mountains of Nepal. The unplanned migration of people and its impacts on natural resources may lead to food shortage and environmental degradation in the long run. So, the government need to formulate policy to regulate internal migration in a planned way. Moreover, the land use planning should be taken as integrated and interdisciplinary approach rather than considering it in isolation. Despite the increase in human population, community based forest management have demonstrated successes in maintaining and recovering forests in the fragile mountainous ecosystems of Nepal.

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ABBREVIATIONS

AREA_AM	Area Weighted Patch Mean Area
CF	Community Forest/Forestry
ED	Edge Density
FGDs	Focus Group Discussions
Ha	Hectare
LPI	Largest Patch Index
LULC	Land Use and Land Cover
M	Metre
PLAND	Percentage of Landscape
SVMs	Support Vector Machines
VDC	Village Development Committee

1. INTRODUCTION

1.1. Background

Land Use and Land Cover (LULC) changes are one of the most important and easily detectable indicators of change in ecosystem and livelihood support systems (Gilani et al., 2014). Understanding the complexity of LULC changes, its assessment and monitoring are essential for sustainable management of natural resources, environmental protection and food security (Drummond et al., 2012; Foley et al., 2005; Garedew et al., 2009; Jin et al., 2013). Studies on LULC changes are also helpful to predict likely future trends, and to make decisions for natural resource management planning (Fan et al., 2007; Gilani et al., 2014; Prenzel, 2004).

Humans have directly or indirectly affected the earth surface through various activities. Land use is defined by the purposes for which humans exploit the land cover (Lambin et al., 2003) and shaped by human, socio-economic and political influences (Geist & Lambin, 2002). Land cover refers to the biophysical earth surface (Geist & Lambin, 2002). Therefore, to understand the dynamics of LULC changes it is important to understand human dimension and its effects. Verburg (2010) have stated that LULC change as a result of diverse interactions between society and the environment. Many studies (Drummond et al., 2012; Lambin et al., 2003; 2001; Liu, 2001) have shown that the human dimensions are affected by social, ecological and economic factors, and an interdisciplinary approach is required to understand and address the relationship between environment and society (Garedew et al., 2009; Liu, 2001; Manson, 2006; Wilson, 1998). Liu (2001) states an urgent need to integrate environment with human dimensions, including its behaviour and socio-economics, in order to understand and manage ecological patterns and processes. Garedew et al., (2009) have emphasized that there is a need to conduct research beyond one disciplinary boundary and explore the methods which can integrate the LULC change studies, socio-economic data and learning of different stakeholders. Socio-economic factors may cause changes in LULC by imposing various land based practices, and through the decisions and actions of institutions managing natural resources. Likewise, the LULC change, on the other hand, may cause changes in land use decisions (Lambin & Meyfroidt, 2010). Lambin et al., (2003) have listed various factors such as changing opportunities created by market, loss of adaptive capacity, increased vulnerability, changes in social organization, changes in attitudes, access to resources, income distribution, urban rural interaction, labour availability, infrastructure, governance are the fundamental causes of land use change.

Remote sensing data and geo-spatial tools provide information and opportunities to understand and quantify the rate of changes occurring on the earth's surface over time (Guerschman et al., 2003; Huang et al., 2009). Selection of appropriate satellite images and methods pose key challenges for monitoring LULC changes (Xin et al., 2013). Many researchers have applied Landsat images to monitor LULC changes (Bhattarai & Conway, 2007; Drummond et al., 2012; Jansen et al., 2008), in spite of being medium resolution data. It is being popular because of its free availability and for having the longest record of global-scale data for earth observation (Gilani et al., 2014). Hansen & Loveland (2012) have reviewed a large area monitoring of land cover change using Landsat data.

Many studies on LULC changes have been conducted in the tropical forests where deforestation and forest degradation is high. Though tropical forests cover less than 10% of the total land area, they represent largest terrestrial reservoir of biological diversity. More than 50% of known plant species grow in the tropical forests (Mayaux et al., 2005). Many studies have shown that the tropical forests are depleting at an alarming rate. Study conducted by Skole & Tucker (1993) using Landsat satellite images on Brazilian Amazon basin concluded that tropical deforestation increased from 78,000 square kilometres in 1978 to 230,000 square kilometres in 1988 causing severe effect on biological diversity. Tropical moist forests are being depleted at a rate of 2% per year (Myers, 1993). Myers (1993) extrapolate that the deforestation of tropical forest in 1991 would be approximately 148,000 square kilometres risen to 1.97% of the total remaining i.e. 7,500,000 square kilometres based on previous research. This constitutes an annual deforestation rate of 3.4% for all tropical moist forests. Based on the rate of 1991 deforestation rate, the researcher projected that all remaining tropical moist forest would be eliminated within another 50 years. Another research on tropical deforestation shows that from 1980s to 1990s, the deforestation rate of tropical forest increased approximately by 10%, most notably on Southeast Asia (Defries et al., 2002). Similarly, Achard et al., (2002) concluded that between 1990 and 1997, 5.8 $\pm$ 1.4 million hectares of humid forest were lost each year together with annual 2.3 $\pm$ 0.7 million hectares degraded area. Out of three continent (Latin America, Africa and Southeast Asia), the research revealed that the South east Asia had the highest percentage of deforestation rate. Study of land cover change from 1981 to 2000 shows that the Asia has the highest rate of land cover changes especially dry land degradation, rapid increment of crop land in Southeast Asia in expense of forest and forest degradation in Siberia (Lepers et al., 2005). A research conducted to quantify deforestation of humid tropical forest from 2000 to 2005 showed to be 1.39% of the total biome area (Hansen et al., 2008) representing 27.2 million hectares in area and 2.36% of humid tropical forest.

Environmental issues in Nepal has been much discussed following the theory of Himalayan environmental degradation, e.g. Eckholm (1976), proposed that population growth in the upland hills and mountains leads to deforestation and environmental degradation associated with soil erosion, downstream flooding and silting. However, Ives & Messerli (1989) revealed that the forests of upland hills and mountains are more or less intact despite of population growth, challenging the theory of Himalayan environmental degradation. In addition, several studies (Gautam et al., 2003; Government of Nepal, 2013; Kanel, 2004; Niraula, et al., 2013; Pandit & Bevilacqua, 2011; Tachibana & Adhikari, 2009) have revealed that forest condition has been significantly improved in the hills and mountains of Nepal following the initiation of community forestry (CF) program and prominent source for supplying forest products to local households (Adhikari et al., 2004; Pandit & Bevilacqua, 2011; Mahat et al., 1986). Study conducted from 1989 to 2000 in the Chitwan valley of Nepal, shown that community based forest management was successful in halting and reversing the ongoing trend of deforestation and forest fragmentation (Nagendra et al., 2007). Similarly, Gautam et al., (2002) found higher rate of conversion of shrub land to forest and higher rate of forest regeneration through strict protection strategies of user groups in compare to those Village Development Committees (VDCs) without community forest. Niraula et al., (2013) have concluded that community based forest management have reduced the slash-and-burn agricultural practices, reduced incidence of forest fire, spurred tree plantation and encouraged the conservation and protection of trees. The CF program encouraged and authorized local communities to develop local rules and institutional arrangements to protect, manage and utilize the forest resources and successfully managed over 28 % of forest resources (out of total 5.8 million ha) in Nepal (District Forest Office, 2011).

Changes in population, social dynamics and changes in land use practices are very important for a country like Nepal as the country has diverse socio-cultural setting with fragile geography and land use practices (Nepal Climate Vulnerability Study Team, 2009). Nepal is known for its diversified physiographic regions, as well as for its diversified culture, religion and reliance on a caste system. Subsistence farming is the main occupation in Nepal. According to United Nations Development Programme (2009), more than 66% of people in Nepal depend on subsistence agriculture for their livelihood and more than 60% of cultivated land is based on monsoonal rainfall (Central Bureau of Statistics, 2008). The farming system has relationship with forests and other ecological services such as water, nutrient cycling and cultural services. About two-thirds of households (i.e. about 64%) in the country use firewood as a source of fuel for cooking (Government of Nepal, 2012a). The land use practice in the mountains of Nepal is directly related to water and energy, forest, agriculture, food security, and the impacts of climate induced disasters (Agrawala et al., 2003; Nepal Climate Vulnerability Study Team, 2009; Shrestha et al., 2010).

Migration is a common and ongoing phenomenon in Nepal. According to Lee (1966), migration is a permanent or semi-permanent change of residence which are influenced by various factors. These factors may be associated with the area of origin, the area of destination, intervening obstacles between place of origin and destination for migration and personal factors i.e. factors related to the person who decide to migrate. Although migration decisions are based on various factors such as population growth; decreasing land productivity, conflict, and impacts of environmental factors on agriculture and natural resources have also been reported to be largely responsible for emigration of farming based communities from the mountains of Nepal (Gentle & Maraseni, 2012; Massey et al., 2007; Shrestha & Bhandari, 2007; Tacoli, 2009). However, in contrary to a general trend of population growth, the national population and housing census of Nepal (2011) shows that there is a general trend to depopulation in 27 hills and mountain districts of Nepal recorded negative population growth rate during the last decade (GoN, 2012a; 2012b). According to Sherbinin et al., (2008), discussion about a linkage between migration and the environment would be incomplete without discussing the role of remittances on rural areas. People receiving remittance in terms of pension and working abroad have diversified their income sources and rate of internal migration among that group is comparatively higher in compared to households without receiving any remittance (Adhikari & Hobley, 2011; Chapagain & Gentle, 2015). Between 2000 and 2011, the number of labour emigrants increased six folds and remittances to the home country increased by 27 times in Nepal. The share of remittances to the gross domestic product has increased to 25% from 2001 to 2011 (World Bank, 2010; 2011). Among the remittance earners, 85% of emigrants come from rural families (Government of Nepal, 2012a). The increasing flow of remittances is largely contributing in rural economy and may be one of the factors impacting on land use decisions and migration of people.

A general trend of migration of rural households from remote uplands to the valley floor and to urban and semi-urban areas known as internal migration has been reported. Out of many factors, Maimaitijiang et al., (2015) have emphasized population migration as one of the key drivers for LULC change. In rural hills and mountains of Nepal, internal migration has occurred from the uplands to the agriculturally rich but semi-urban valley floors. In the upland villages, migration and other factors such as decreased crop productivity, shortage of labour and government policies has led to abandonment of farmlands which had increased food insecurity, poverty among the marginal and small farmers across the community and different types of geomorphic damage (Khanal & Watanabe, 2006). On the other hand, the valley floors with semi-urban environments have experienced increased population, unplanned expansion of settlements and increased demand for drinking water and firewood. On the semi urban areas where there is irrigation facilities and market, the farming system have become intensive following double or triple crop rotation and vegetable production (Brown & Shrestha, 2000). The population of Lamjung district from western hills of Nepal, the study district, has decreased by 5.3 % in a 10 year period from 2001 to 2011. While the population of Beshisahar, the district headquarters of Lamjung, has increased by almost three times in the same period (Government of Nepal, 2012a) as a result of rapid internal migration of people from remote uplands.

The research conducted by Paudel et al., (2012) have concluded that approximately one third of agricultural land i.e. around 33% across the mid hills of Nepal had already abandoned due to migration.

Similarly, many past research have shown that there is an increasing trend of abandonment of agricultural land in the mountains of Nepal (Jackson et al., 1998; Khanal & Watanabe, 2006). Mainly the marginal agricultural lands which are very distant from farmer's residence, less fertile and very close to forest have been abandoned. Some of the main causes of land abandonment are labour shortage, wildlife damage, outmigration for jobs, migration to urban areas, increased labour cost, alternative income sources such as remittance, pension and foreign job, rural road construction, distant agriculture fields, urban employment, education and low productivity (Khanal & Watanabe, 2006; Paudel et al., 2012). Similarly the research conducted on different geographical regions in Nepal conducted by Chapagain & Gentle (2015) have shown that the chain of water hazards such as drought and erratic rainfall causing loss of crops, livestock, income and employment which ultimately causes human migration. Decrease in agricultural productivity, farm size and inadequate income opportunities are reported as key reasons for rural-urban migration in hills of Nepal (Maharjan et al., 2012). In addition, a case study conducted on Lamjung district of Nepal shows that the main cause of land abandonment are migration both temporarily and permanently (Paudel et al., 2012). A study conducted on Chitwan valley of Nepal reported that perceived decline in productivity and land cover and increased time required to gather firewood leads to movement within immediate vicinity keeping the effects of other social and economic variables constant. It concluded mostly environmental deterioration leads to short-distance moves within the immediate vicinity. However, the study conducted by K.C., (2011) have contradictory findings. He said that the expansion of agricultural land was conspicuous at higher elevation ranging from 1150 to 2000 m with loss of forest while the conversion on lower elevations was lower. The study has also concluded that the land use change pattern is largely determined by socio-economic conditions of people living adjacent to the forest land. Similar types of study were conducted on other parts of the world. A study conducted by Robson (2010) in Oaxaca, Mexico have concluded that significant percentage of households have now started buying their food from market instead of cultivation by themselves. The area of land under cultivation has become less than one hectare per household. Many families have abandon their fields and mostly, cultivating those fields which are closer to human settlements.

The abandonment of farm land increased the occurrence of land degradation (Melendez-Pastor et al., 2014), incidence of fire (Romero-Calcerrada & Perry, 2004) and occurrence of invasive species (Schneider & Geoghegan, 2006). This causes negative socio-economic and environmental consequences, stability of terrace hill slopes and ultimate impacts on food security and local livelihoods (Khanal & Watanabe, 2006). The study conducted by Smadja (1992), Khanal & Watanabe (2006) and Jackson et al., (1998) shown that cultivation on mountain slope and its maintenance contributes to slope stability in a natural fragile environment while the abandonment of land without maintenance leads to slope instability, landslide and erosion. Abandoned agricultural land are mostly subjected to landslide, floods and different form of geomorphic damage. Simple land abandonment is not sufficient to induce plant colonization especially where there is practice of animal grazing and soil are poor (Khanal & Watanabe, 2006). The abandoned land had mostly converted to grassland and shrub land (Jackson et al., 1998). Similar types of studies had been conducted to other parts of the world. For example, the study conducted on Southern Chile shows that the amount of agricultural land had been decreased in between 22 years (1985 to 2007) and the abandoned land had been covered by natural vegetation. In this area, distance to secondary road was key driver of land abandonment and said that the probability of land abandonment was increased with increasing distance to secondary roads (Díaz et al., 2011). Abandonment of land by framers in Spanish Mediterranean mountains have reduced the pressure of livestock which have leads to pasture loss as a result of the spread of scrub and increase the incidence of forest fire (Lasanta et al., 2009) However, some research has shown that replacement of abandoned land by natural vegetation leads to increase in ecosystem services (Izquierdo & Grau, 2009). Grau & Aide (2007) have concluded that rural-urban migration leads to disintensification of land use in fragile ecosystem of mountains and thus stimulates ecosystem recovery and biodiversity protection.

The recent study conducted by Uddin et al., (2014) on five physiographic regions of Nepal namely high mountain, middle mountain, hill, siwalik and terai shows that both the number of forest patch and total edge was highest on hill followed by middle mountain region of Nepal indicating proximate biotic interference. The study conducted on mountain watershed in Nepal shows that the number of forest patches had decreased by merging of forest patches due to forest regeneration and plantation activities between 1976 and 2000. Though, the area under forest had been increased, there is higher edge effects at the forest patch. It also shows that the fragmentation of low land agricultural areas was increased due to expansion of settlements and infrastructural development in the lowlands areas (Gautam et al., 2003). Increase in forest edge may have both positive and negative effects on biodiversity depending on the local condition. According to the study conducted on state of Oaxaca, Mexico, the Robson & Berkes (2011) have stated that low intensity of forest use and rotational agriculture have increased spatial heterogeneity of forest in terms of structure and composition creating biodiversity rich forest-agricultural mosaic. The agricultural abandonment initiate dramatic change on ecological succession, patch size and edge effects. In spite of increase in forest cover through agricultural abandonment, it will reduce the forest-agriculture mosaic reducing the edge contrast between forest and open areas leading to decline in local biodiversity. The study done by Harper et al., (2005) suggested that edge causes changes in forest structure, composition, regeneration and mobility leading to negative consequences on biodiversity.

The LULC change in Nepal is largely determined by combined effects of various factors such as socio-economic, demographic and environmental changes. However, there is a lack of integrated analysis of these factors in relation to LULC change and its change pattern. Thus, this study attempts to analyse periodic satellite images to study LULC change in relation to internal migration and impacts of human settlements on its surrounding landscape to understand the relationship between human and the environment interaction in the middle mountains of Nepal.

1.2. Justification

Understanding of changes in socio-demographic factors, forest resources, land use practices and economic factors has theoretical and policy implications (Cote & Nightingale, 2011; Nightingale, 2003; Ostrom, 2009). Understanding interrelationship between these factors is important to know human-environmental complexities to design natural resource management and land use policies (Liu, 2001). However, the knowledge generated so far is mostly focused on sectoral areas rather than integrating critical issues related to social, economic, ecological and environmental dynamics and their implications (Liu, 2001). Understanding the dynamics and driving forces behind LULC changes at the local level is fundamental to support local planning processes (Tekle & Hedlund, 2000), and to predict land use changes for future planning purposes (Lambin et al., 2003). Likewise, understanding an interaction between human societies and their ecosystems at local scale is important to predict and sustainable management of ecosystem goods and services (Lambin et al., 2003). However, a lack of holistic analysis of various socio-economic, environmental and demographic factors always remains a constraint for natural resources and land use planning in Nepal. There are few studies (Gautam et al., 2002, 2003; Jackson et al., 1998) conducted to understand LULC change over a period of time using periodic satellite images and only few research to understand the change pattern and factors responsible for LULC change. Most of the research conducted so far emphasized the issues of outmigration of people out of district or abroad or international labour migration and its consequences (Adhikari & Hobley, 2011; Maharjan et al., 2012; Poertner et al., 2011; Seddon et al., 2002). However, the issues related to internal migration and its consequences on natural resources and LULC change has not been well integrated in those studies. Sherbinin et al., (2008) have emphasized that further research in Asia is required to understand how natural resources are affected by migration and how the processes affect the LULC because of lack of ample information on this subject. Therefore, this study attempts to analyse relationship between surrounding LULC changes in relation to internal migration and human settlements. For this research, internal migration means movement of people from remote upland to semi-urban valley floors within a study area; a short distance movement of people. It is expected that the results will help to support decision making and will allow more reliable projections and more realistic scenarios for planning process. Ultimately, the research findings are expected to provide better understanding for sustainable land use management in Nepal.

1.3. Research Aim

The aim of this study is to detect the land use/land cover change in relation to internal human migration between 1988 and 2013 in the middle mountains of Nepal and to examine the impacts of human settlements on its surrounding landscapes.

1.4. Specific Objectives

- To detect the land use/land cover changes in the middle mountains of Nepal between 1988 and 2013.
- To examine internal migration patterns of households in the study area.
- To quantify the fragmentation patterns of the land use/land cover types between 1988 and 2013.
- To examine the impact of the density of human settlements on its surrounding landscape, i.e. the composition (diversity and relative abundance) and configuration (shape and spatial arrangement) of land use/land cover types.

1.5. Structure of the Thesis and Research Approach

The thesis has been structured into five chapters. The first chapter presents background of the research, problem statement, aims of the study, specific objectives, and the review of relevant literature. Chapter two focuses on description about the study area, data and software used for analysis and methods applied in the research. Chapter three provides results of analysis; whereas chapter four presents discussions of the key results. The last chapter draws conclusions and provides recommendations for the future research including theoretical and policy implications of this research. Figure 1 shows the overall research approach of the thesis.

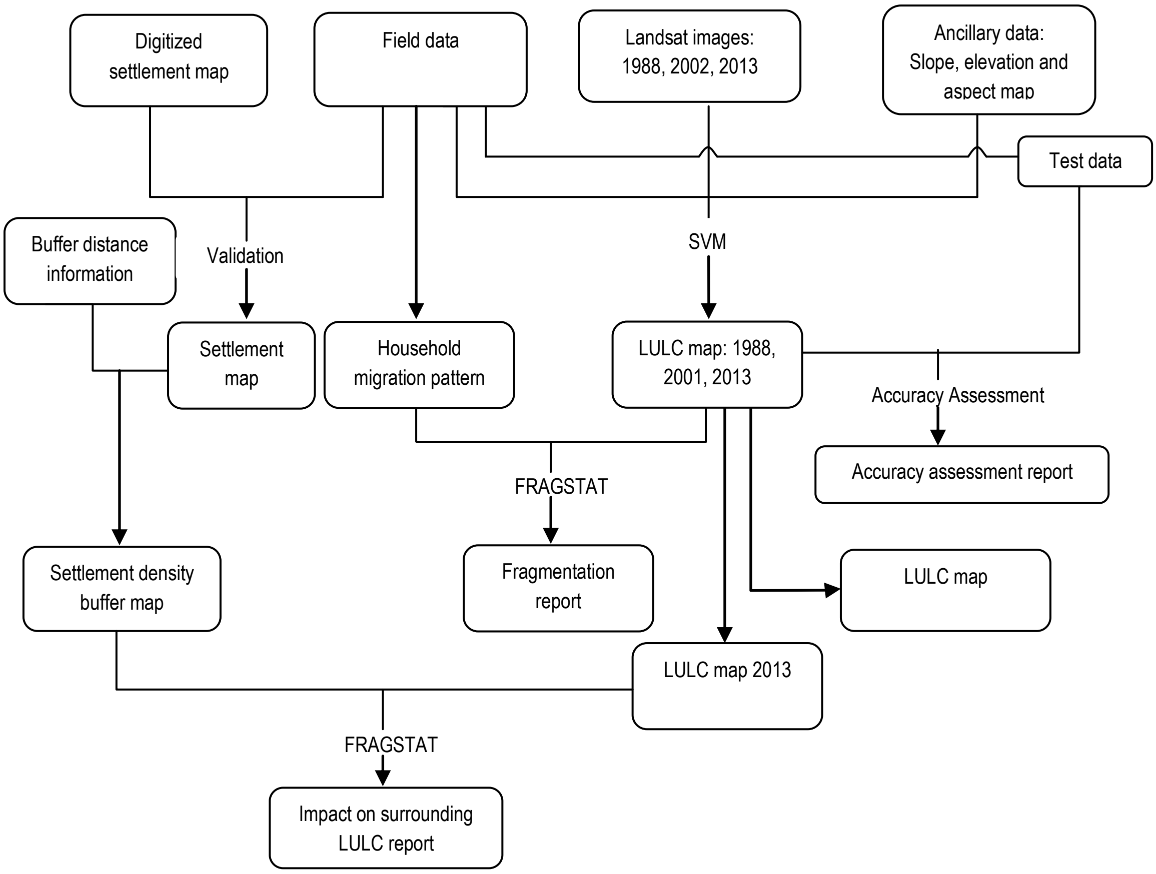


Figure 1. Framework of the overall research approach

2. MATERIALS AND METHODS

2.1. Study Area

The study area is located in Lamjung district in the 'middle mountains' region of Nepal (Figure 2). The district covers an area of 1692 square kilometre (District Development Committee, 2011). It is located on $28^0$03'19" to $28^0$30'38" north latitude and 84^0 11'23" to $84^0$38'10" east longitude. Of total area, 45.3% of the land surface lies between 1000 and 2500 m, 4.8% from 2500 to 6000 m and 17.3% between 500 to 1000 m (Gurung, 2004). Whereas, 1.4% of land surface lies above 6000 m and remaining 1.2% below 500 m. The discrepancy between maximum and minimum temperature is 26 ^{0}C to 18 ^{0}C respectively. The study area mostly receives maximum rainfall from July to September. There is occasional hailstorm during the Spring and Autumn seasons. The climate is suitable for a year-round cultivation as they receive ample amount of monsoon rain and mostly the snowfall is limited on high ridges above 2000 m (Gurung, 2004). The average annual rainfall is around 2944 mm in the district. The district has lateritic, sandy, loamy and sandy loamy soil. The study area is dominated by sub-tropical forest zone containing species such as *Alnus nepalensis* (Uttis), *Schima wallichii* (Chilaune), *Castanopsis indica* (Katus), *Rhododendron arboreum* (Gurans), *Juglans regia* (Okhar) and *Michelia champaca* (Champ). Of the total area, 16.85% of land is under cultivation, 8.91% of land is not cultivated, 13.25% is a grazing land, 39.04% forest, 10.33% shrub land and remaining are others. The others include rocky areas, lakes, ponds, waterways or settlements (Land Resource Mapping Project, 1986).

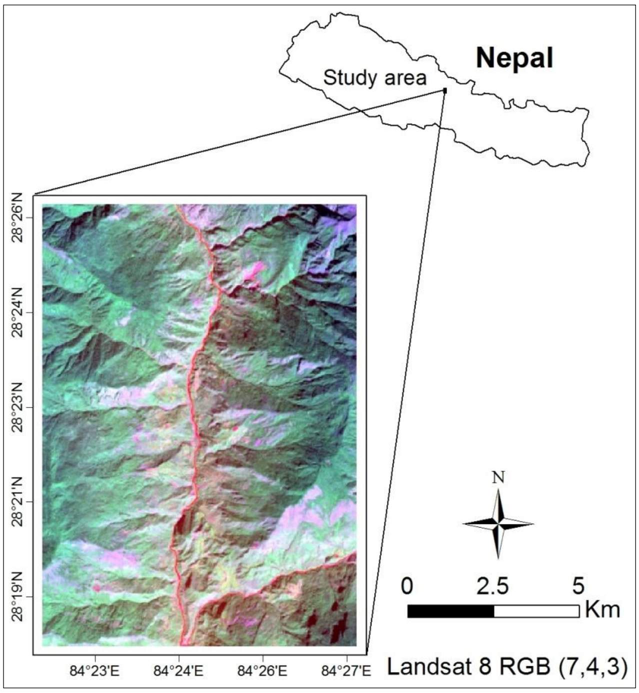


Figure 2. Location map of the study area in Nepal

Over two thirds of the population of the district depends upon subsistence agriculture and livestock for their livelihoods. The Marsyangdi River passes north to south through the middle of the district. The forests in this district complement agricultural practices by providing forest products, grazing land, and environmental services to stabilize land and to regulate water resources (District Forest Office, 2011). Photographs presented below (Figure 3) provide the overview of the study area.

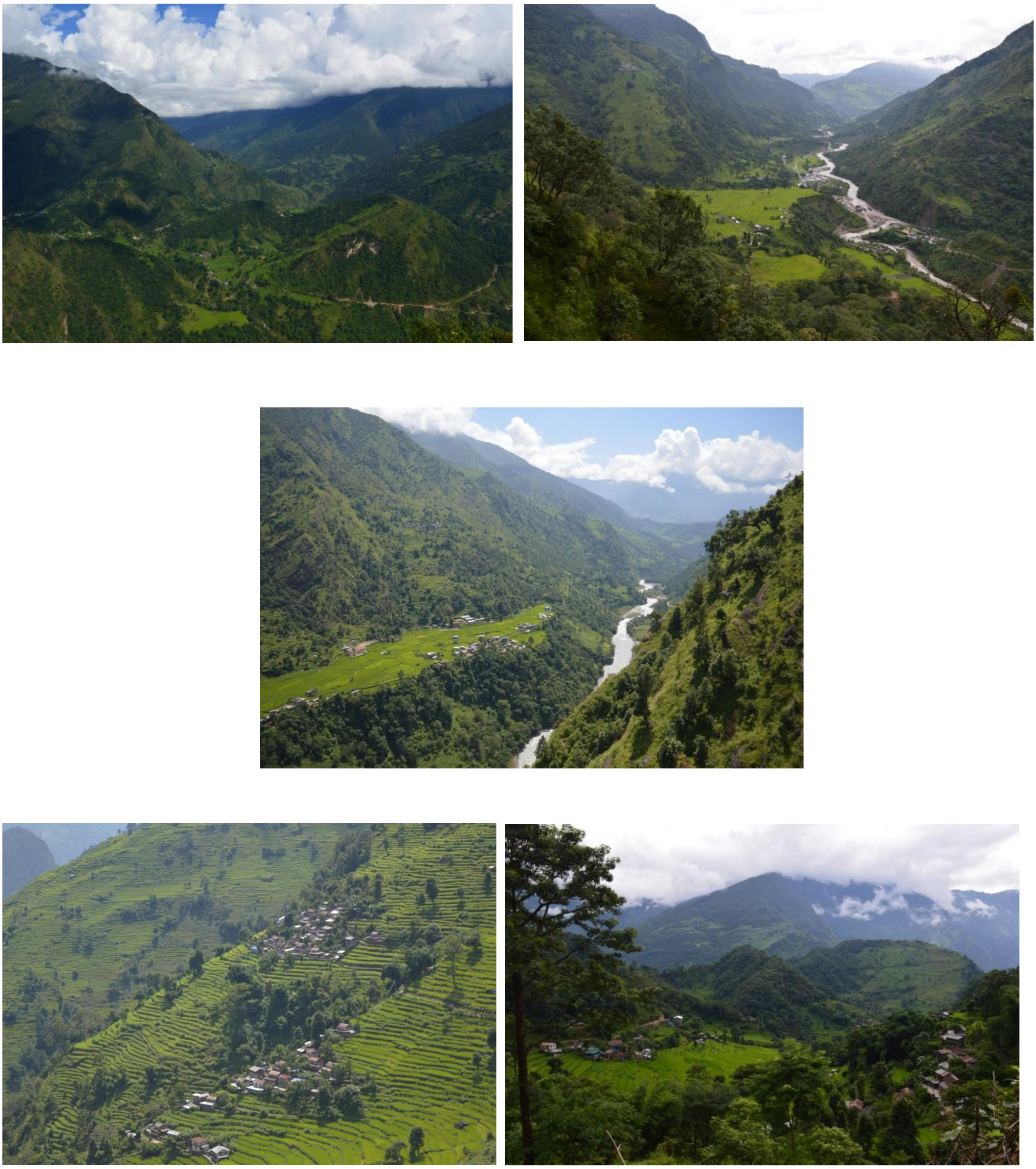


Figure 3. Overview of the study area

Out of total forest in Lamjung district, 20,094.56 hectares of forest (30.02%) have already been handed to local community as Community Forest (CF) (District Forest Office, 2014). Similarly, 7,629 square kilometre area of district have been gazette as conservation area in 1992 known as Annapurna Conservation Area (ACA) , first and largest protected area in Nepal (District Forest Office, 2011). This ACA is managed by Annapurna conservation area project together with local communities organized as Conservation Area Management Committees. Through its establishment phase, the conservation area management committees have been involved in decision making and management of natural resources of conservation area (Baral, 2009). The Annapurna conservation area consist of eight Village Development Committees (VDCs) of Lamjung district. Out of 61 VDCs in the district, this study covers five VDCs namely Ghermu, Bahundada and Bhulbhule where local communities managed forest as community forest and remaining two Taghring and Khudi VDCs under conservation area. In both types of modalities of management (CF and ACA), local communities are the main actors who are responsible for management, conservation and utilization of natural resources, mainly forest. The district has a representation of caste, culture and ethnic identities including a mixed population of indigenous nationalities such as *Gurung*, *Magar*, *Tamangs*, *Dalits* and other castes.

2.2. Methods

2.2.1. Remote Sensing Data Acquisition and Pre-processing

Three satellite images namely Landsat 5, Landsat 7 ETM +and Landsat 8 for year 1988, 2001 and 2013 respectively were obtained from the United States Geological Survey (USGS) Earth Resources Observation and Science Data Centre (http://www.usgs.gov). The images were geo-referenced and fit to the Universal Transverse Mercator (UTM) projection system (zone: 45, datum: WGS-84). These images were acquired during late October and early November, in autumn season i.e. dry season with relatively clear sky. The boundary of the study area is arbitrary rather than the political boundary of the VDCs as it is delineated according to the catchment of a watershed i.e. Marsyangdi watershed.

In Nepal, there was a major change in forest policy during early 1980s when the government started to handover national forest to local communities. So, the year 1988 was chosen as an initial date. It is difficult to see changes in forest with less than l0 years. So, the images with nearly 10 years difference is taken into account.

Based on the objectives of study, literature review and prior field experience of the researcher, four land use/land cover classes namely forest, shrub/grass, agricultural and others were considered for LULC classification for this research purpose. The forest has been considered as an area with at least 0.5 hectares trees and tree canopy cover of more than 10% (Forest and Agriculture Organization, 2012). The shrub/grass category include both grass/pasture and shrub. The grass land is an area covered with less than 10% tree canopy with short vegetation. Agricultural land include ploughed fields, areas currently under crop, and land being prepared for cropping with field pattern. Whereas the other category include bare lands, built up land, water bodies and sand. Bare land are areas without field pattern and vegetation or very little vegetation where the soil exposure is very apparent and stony areas. Water body includes both natural and human-made water bodies which are either static or flowing. Built up areas include houses and other human made features and infrastructure.

Each household were digitized as a point in the study area with the help of Google Earth image before the field work (Figure 4). The study assumes that there was no significant change in human settlements in the study area from year 2013 to 2014.

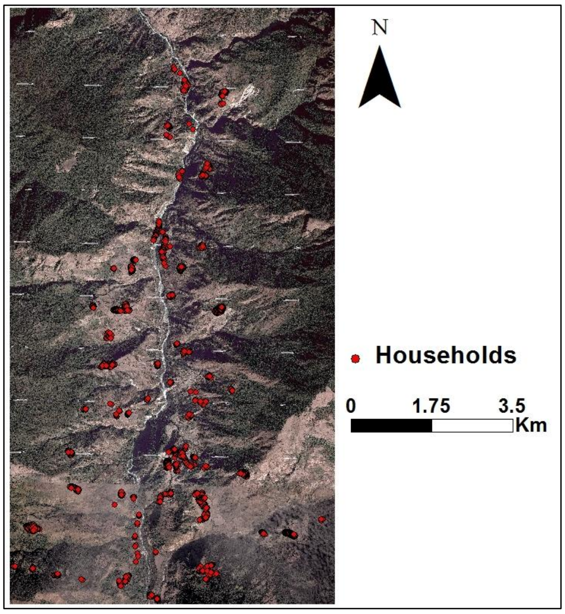


Figure 4. Map showing spatial distribution of human settlements with google image as background

2.2.2. Field Data Collection

To fulfil the objectives of the research, two types of data were collected from the field; I) Ground truth data for LULC classification and accuracy assessment, and II) Focus group discussions (FGDs) to collect data on human migration pattern, distribution of human settlements and impacts of human settlements on its surrounding landscape.

2.2.2.1. Ground Truth Data Collection

The selection of ground truth sample points for the LULC classification was based on a stratified random sampling method as LULC sample points were selected based on each land cover/use classes (Forest, Shrub/grass, Agriculture and Others). While taking sample points, it was taken care that the sample point of specific land cover had not been changed i.e. same land cover over the last 30 years. Before the field work, the LULC which had not been changed over last 30 years were identified with the help of Google Earth image and Landsat images of 2013, 2001 and 1988 based on visual interpretation and prior field experience. Then, 25 sample points for each land cover/use class were selected randomly from identified LULC prior to field work.

In total, 100 sample points were collected from field. However, it was difficult to follow random sampling in field due to complexity of study area and time cost as it was impossible to access to some areas. The ground truth sample points were verified with local farmers who are living in the same place from many years with the help of printed Google images. In the field, the geographical coordinate of each sample plot was recorded using hand-held Global Positioning System (GPS) and other information was recorded in data sheet. The size of sample plots was 90 m*90 m to reduce the positional error caused by hand-held GPS and USGS geo-referencing. It was ensured that the distance between the sample points is separated by at least 500 m distance to reduce the effect of spatial auto correlation (Nahuelhual et al., 2012). The sample size and distance between the samples were based on visual interpretation as it was impossible to measure these parameters in field.

2.2.2.2. Focus Group Discussions (FGDs)

The Focus Group Discussion (FGD) is also called as a group interview where a researcher conducts a form of in-depth interview with research participants (Kitzinger, 1995; Robinson, 1999; Theobald et al., 2011; Webb & Kevern, 2001). It is conducted with a small group of people who share their ideas, insights and experiences on a specific topic selected by a researcher (Kitzinger, 1995; Kumar, 1987; Morgan, 1984; Powell & Single, 1996; Robinson, 1999). A moderator, mostly the researcher, facilitate and guide the discussion among the participants to generate responses (Kumar, 1987; Morgan, 1984). The quality of information in FGD largely depends upon a facilitator or a moderator, and thus a moderator should be non-judgemental, good listener, and sensitive to ethical, religious and cultural aspects of the participants (Powell & Single, 1996). The FGD is particularly applicable when the research conducted for a short time duration; subject under study is complex and consists of many variables; and existing knowledge is not adequate to address pertinent issues or if there is need for additional in-depth data (Kitzinger, 1994; Morgan, 1984; Powell & Single, 1996).

Considering availability of time and geographical remoteness, nine FGDs were conducted in this research at different research locations. The participants of FGDs and their locations were purposively selected to represent different settings of study area ensuring representation of different caste, class, ethnicity and gender dimensions. As suggested by many authors (Khan & Manderson, 1992; Kumar, 1987; Powell & Single, 1996; Robinson, 1999; Jayasekara, 2012), the number of participants in FGD ranged from 4 to 10 depending upon the depth of issues to be discussed and interest of research participants. In this research, the researcher facilitated the FGDs and the objective and purpose of the research was shared and prior consent on note taking were obtained prior to discussion as suggested by many authors (Kumar, 1987; Powell & Single, 1996). The FGDs were guided by a list of questions as checklists (Appendix I). The information generated from FGDs were noted by the researcher, analysed it according to the need of research questions, and presented as bar diagrams and interpreted in sentences as required.

The year wise migration pattern and distribution of human settlements in the last 25 years was collected through FGDs. In addition, FGD participants were also interviewed about ongoing socioeconomic and environmental changes and its implications, pull and push factors of migration, land abandonment, road construction, market and remittance and its influence in rural economy. The different distance from human settlements where human can have influence were identified through FGDs. Also, the number of households digitized from Google image was verified during field work and geographical coordinate of villages were recorded using GPS. Figure 5 shows some photographs which provides the overview of field work.

Figure 5. Photographs showing interview and discussion with local people during field work

2.2.3. Data Analysis

2.2.3.1. Land Use/Land Cover Classification

The Landsat data was used to classify land use/land cover. The detailed step followed for LULC classification is outlined in Figure 6. A supervised statistical learning technique, i.e. Support Vector Machine (SVMs), was used to classify Landsat images in ENVI 5.1. The total ground sample points was randomly divided into two groups allocating 60% of samples as training data for classification, and remaining 40% as testing data for accuracy assessment of classified maps.

The ancillary data namely elevation, slope and aspect map was incorporated as a band during classification derived from ASTER 30 m Digital Elevation Model (DEM). The reason behind incorporating ancillary data considering: i) Elevation as one of the limiting factors for agricultural activities in mountainous areas; ii) Preference of most of the farmers to have farm land on low flat areas instead of very steep terrain; and iii) Aspect plays an important role in the distribution of vegetation and types of agricultural crops grown in a field. Many studies have said that the use of ancillary data provide more information during classification to get high accurate classified maps. For example, Fahsi et al., (2000) , Skidmore (1989) and Wang et al., (2009) have shown that the classification accuracy had been increased by using ancillary data.

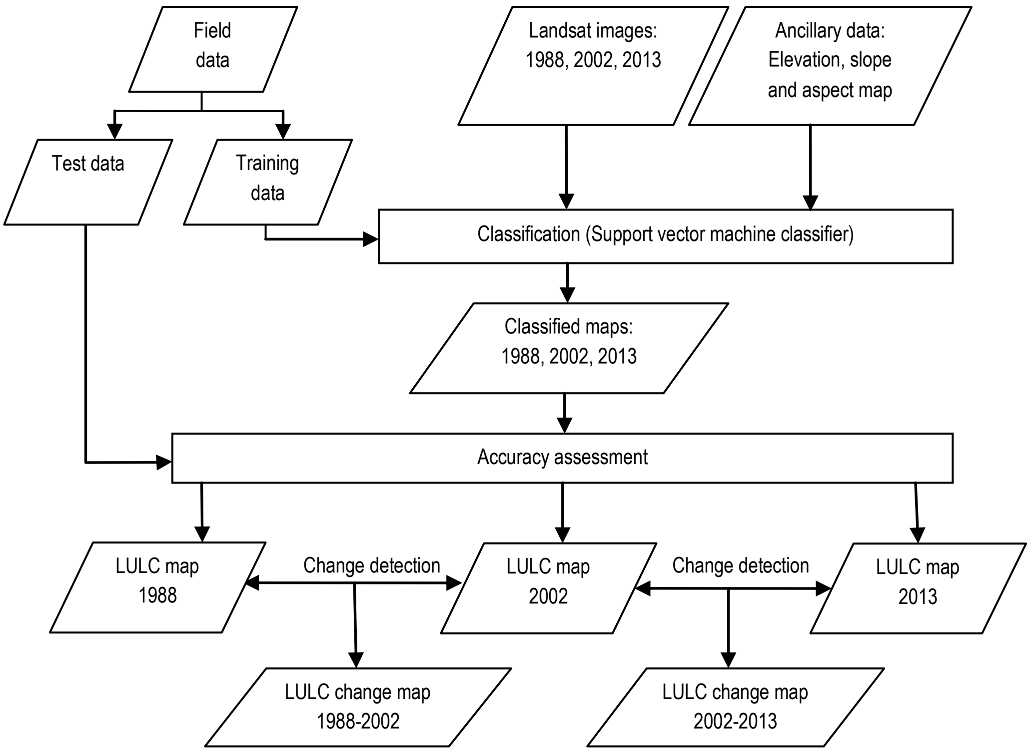


Figure 6. Detailed step used for LULC classification

Selection of Image Classifier

The Support Vector Machines (SVMs) is a robust method and being very popular in remote sensing in recent years. It was first introduced as a machine learning method by Cortes & Vapnik (1995). Many studies such as Heikkinen et al., (2010), Huang et al., (2008), Knorn et al., (2009), Kuemmerle et al., (2009), Liu et al., (2006), Tuia & Camps-Valls (2009) and Warner & Nerry (2009) have successfully applied SVMs for their study. The SVMs was selected for this study because they are able to handle small training data to produce high accuracy classified map (Mantero et al., 2005), effective to handle complex distribution of heterogeneous landscape (Warner & Nerry, 2009) and not sensitive to sample size. According to Huang et al., (2002) and Kavzoglu & Colkesen (2009), SVMs are found superior in comparison to other traditional classifiers such as maximum likelihood classifier. Similarly, Foody & Mathur (2004a) concluded that the SVMs classifier are more accurate than comparable classification derived with the use of the other classification techniques. However, the output depends on the type of kernel used, selection of parameter for the chosen kernel and the method used to generate SVMs.

Support Vector Machines (SVMs)

Support Vector Machines (SVMs) is a supervised non-parametric statistical learning techniques, with no assumption made on the underlying distribution of the training data sets (Mountrakis et al., 2011). It is based on the principle of structural risk minimization (Alcantara et al., 2012). According to Tso & Mather (2009), as SVMs is based on the distribution of training sample, it minimizes the misclassification error. It is a binary classification (Zuo & Carranza, 2011) which form a separating optimal hyperplane based on the distribution of training sample in a feature space (Tso & Mather, 2009). The optimal hyperplane is a liner decision function with maximal margin between the vectors of two classes (Cortes & Vapnik, 1995). According to Cortes & Vapnik (1995), a small amount of training sample known as support vector determine the maximal margin while constructing the optimal hyper plane. Only the support vector which lie on the edge of class distribution in feature space will take part in classification while other training samples do not provide any contribution (Foody & Mathur, 2004b) (Figure 7). In reality, different classes may overlap one another and make the linear separability difficult (Mountrakis et al., 2011). However, the idea of soft margin i.e. to allow for error on training set, convolution of the dot-product i.e. extending the surfaces from linear to non-linear (Cortes & Vapnik, 1995) and the selection of kernel type help to address this problem.

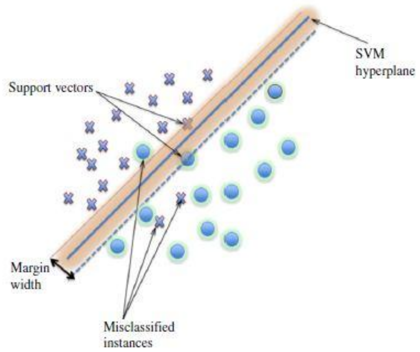


Figure 7. Linear support vector machine example

source: adapted from Burges, (1998)

Implementation of Support Vector Machines (SVMs)

At first, the SVMs was developed for classifying the training data by linear boundaries without any error which is impossible in reality. So, an idea of soft margin such as cost penalty parameter (*C*) was introduced where the training data can be classified with some errors (Cortes & Vapnik, 1995). The *C* factors penalized the training data which are located on the wrong side of the SVMs hyper plane. The larger *C* value causes over fitting of training data and reduces the generalization capability (Tso & Mather, 2009). In some cases, it is not possible to separate the data by linear hyper plane. In such situation, the data are classified on higher dimensional space to improve the separation of classes, known as nonlinear SVMs. The kernel helps to separate the training data into a high dimensional space. According to Courant & Hilbert (1953), kernel that can be used to construct SVMs must meet Mercer's condition. The most common kernel which employed for SVMs classification are Linear kernel and Gaussian Radial Basis Function (RBF) kernel. At first, the linear kernel was chosen which contain only the cost penalty parameter (*C*) for the SVMs. Then, RBF kernel was chosen. The study conducted by Kavzoglu & Colkesen (2009) shows that SVMs with RBF kernel outperform the maximum likelihood classifier in terms of overall and individual class accuracies. RBF use two parameters namely gamma in kernel function (γ) and the cost penalty parameter (*C*). The choice of kernel depends on different situation. When the number of features are very large, it is good to use linear kernel instead of RBF kernel (Hsu et al., 2010; Karatzoglou et al., 2006). According to Karatzoglou, Meyer, & Hornik (2006), RBF kernels are generally used when there is no prior knowledge about the data. Compare to others, RBF has fewer numerical difficulties and nonlinearly map sample into higher dimensional space (Hsu et al., 2010). Various parameter pair (C, γ) values were randomly selected and evaluated. According to Hsu et al., (2010), the main aim of identifying good (C, γ) is to accurately predict the unknown data from the classifier. Many studies have been conducted to explore the effects of choosing kernel type and kernel parameter. For example, Huang et al., (2002) have concluded that the selection of kernel type and kernel parameter affect the performance of SVMs by affecting the shape of the decision boundaries located by the SVMs. Similarly, Kavzoglu & Colkesen (2009) have also said that the classification accuracy may show variation depending upon the choice of kernel function and its parameters.

Training the Model

At first, for the linear kernel, the *C* was selected from various ranges ranging from 1 to 15. Likewise for the RBF kernel, the *C* and γ parameter was again selected from various ranges. At first, the γ was kept fixed at 0.111 which is a default value and *C* changes from 1 to 15 respectively. However, the linear kernel with *C* at 9 generated the highest classification accuracy and Kappa coefficient for three subsequent images compared to RBF kernel. So, the *C* at 9 was applied for training data to produce final classification map.

Accuracy Assessment of Classified Maps

In this study, the accuracy assessment of classified maps was carried out using confusion/error matrix and kappa coefficient (Cohen, 1960). According to Jiang & Liu (2011), overall accuracy, producer's accuracy and user's accuracy should be used for the accuracy assessment as they directly interpretable as probabilities of correct classification. The confusion matrix is the only way to effectively compare two maps quantitatively (Congalton, 2005). Cohen (1960) has described kappa coefficient as coefficient of agreement. According to Foody (1992), Kappa coefficient is the proportion of agreement obtained after removing the proportion of agreement that could occur by chance. It lies on a scale between 0 and 1 where 1 represents a complete agreement (Cohen, 1960). Congalton (1991) had used kappa statistics to statistically compare classification accuracies of maps using z-test. According to Yang (2007), the kappa values greater than or equal to 0.75 is excellent agreement beyond chance, values below 0.40 or equal is poor agreement and values between 0.40 and 0.75 is fair to good agreement beyond chance.

2.2.3.2. Internal Migration Pattern of Households

In the study area, usually people migrate from higher to lower elevations as internal migration to get better facilities and income opportunities. From the field visit, it was found that normally people above 1400 m elevations migrate to below 1400 m elevations. Based on FGDs, the internal migration trend of households from the village located above 1400 m to villages located below 1400 m was quantified from year 1983 to 2014 on each ten years interval.

2.2.3.3. Quantification of Landscape Fragmentation

The studies on quantifying LULC changes do not provide any information about the local pattern of change over time. For this study, the fragmentation analysis was done as proxy for the effects of human intervention cause by internal migration. Three classified maps for different years 1988, 2001 and 2013 was the input to analyse the fragmentation of different LULC types.

Based on migration pattern of households, whole landscape was divided into two categories i.e. above and below 1400 m elevations (Figure 8). The area with 1400 m and above was masked from DEM on ENVI and exported to ArcGIS as shapefile for further analysis. To explore the local change pattern over time due to internal migration, the fragmentation analysis was done in these two parts separately. The quantification of landscape composition and configuration was done using FRAGSTATS software (http://www.umass.edu/landeco/research/fragstats/fragstats.html).

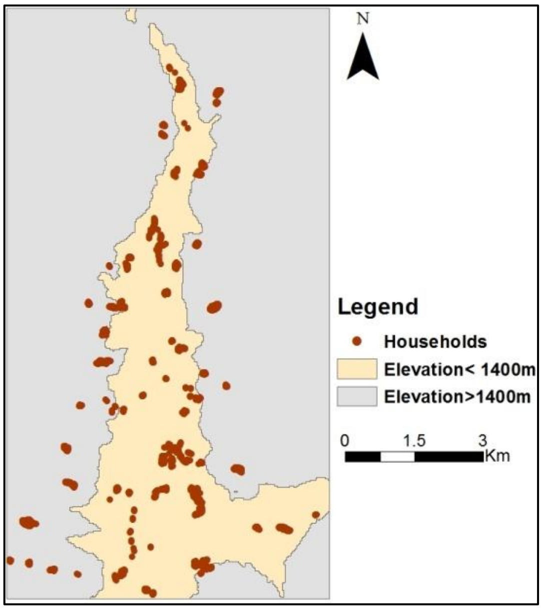


Figure 8. Map showing spatial distribution of human settlements according to elevation range

The FRAGSTATS is a spatial pattern analysis program for categorical map in order to quantify the landscape structure (McGarigal & Marks, 1994). It calculates different statistics to quantify landscape composition and configuration at three levels namely patch level, class level and a landscape as a whole. The patch level metrics calculate on each individual patch within each class. Class indices calculate the spatial pattern and distribution of each patch type/class within a landscape. Whereas, landscape level metrics consider all patch types simultaneously within a landscape (Gounaridis et al., 2014; McGarigal et al., 2012). Landscape composition indicates the diversity and relative abundance of patch types without considering the shape and location of patches within the mosaic. Whereas, landscape configuration represent the spatial character, arrangement and orientation of patches within the landscape (McGarigal & Marks, 1994).

Many of the landscape metrics are partially or completely redundant. Following a review of various studies (Liu et al., 2013; López-Barrera et al., 2014; Paliwal & Mathur, 2014) conducted on landscape fragmentation and based on requirement of research, four landscape metrics at class level namely Largest patch index (LPI), Percentage of landscape (PLAND), Area Weighted Mean Patch Area (AREA_AM) and Edge density (ED) were selected (Table 1). Šímová & Gdulová (2012) have reviewed a sensitivity of landscape metrics to various scale.

Table 1. Description of the landscape metrics

Landscape metrics	Acronyms	Units	Descriptions
Edge Density	ED	Meter/ Hectare	Refer spatial heterogeneity and shape complexity of a class
Largest Patch Index	LPI	Percentage	Dominance of a class in the landscape
Area Weighted Patch Mean Area	AREA_AM	Hectare	Represent degree of habitat fragmentation
Percentage of landscape	PLAND	Percentage	Represent composition of landscape

Percentage of landscape (PLAND) are the measures of landscape composition which computes how much percentage of the landscape is comprised by a particular patch type (McGarigal et al., 2012). Largest patch index (LPI) quantifies the percentage of landscape comprised by the largest patch (Cayuela et al., 2006). Total edge is a measure of total edge length of a particular patch type at class level (McGarigal & Marks, 1994) . Whereas, Edge density (ED) is the total edge based on per unit area (m/ha) for the class (Nagendra et al., 2006). It is considered as best metric for landscape configuration. ED is expected to increase when there is high spatial heterogeneity (forest composition, structure, abundance and distribution of species) and shape complexity is high. When comparing classes of identical size, total edge and edge density are completely redundant. Area Weighted Mean Patch Area (AREA_AM) is the sum, across all patches of the corresponding patch value multiplied by the proportional patch area divided by the sum of patch areas (McGarigal et al., 2012). Increase in patch size indicate merger of patches and thus decrease in fragmentation of particular patch type. Detail description of landscape metrics are in McGarigal et al., (2012) and McGarigal & Marks, (1994).

2.2.3.4. Impact of Human Settlements on its Surrounding Land Use/Land Cover Types

The average size of village on study area was found to be approximately 200 m by 200 m during the field work. Therefore, square with 200 m by 200 m grid size was chosen to form a continuous grid over study area. The continuous grid was established through fishnet in ArcGIS. Then, the map where each household was digitized as point was overlay with continuous grid map. The density of households was calculated per 0.04 square kilometre area. Based on number of households within each grid in density buffer map, human settlements were categorized into three groups namely low, medium and high density settlement ranging from 1-15, 16-30 and 31-95 number of houses respectively. These three categories were selected based on distribution patterns of households on the study area found during field work.

Following this, three samples from each category were selected purposively for further analysis to avoid overlapping and to include all elevation range under consideration as well as to avoid bias results. The different buffer distance were identified through FGDs. The multiple ring buffer with 0.5 km and 1.5 km from centre of human settlement was created around the selected samples of settlements to generate the density buffer map. The buffer distance was selected based on discussion with local people, field observation and prior field experience. The inner buffer, 0.5 km from centre of human settlement, is the distance where local people concentrate much of its daily activities. Whereas, outer buffer, 1 km distance from inner buffer, is used for agriculture which is far away from their settlements, livestock grazing, firewood and fodder collection. For example, Figure 9 shows the multiple ring buffer map around three selected high density human settlements. The density buffer map was used to mask the LULC classified map of 2013.

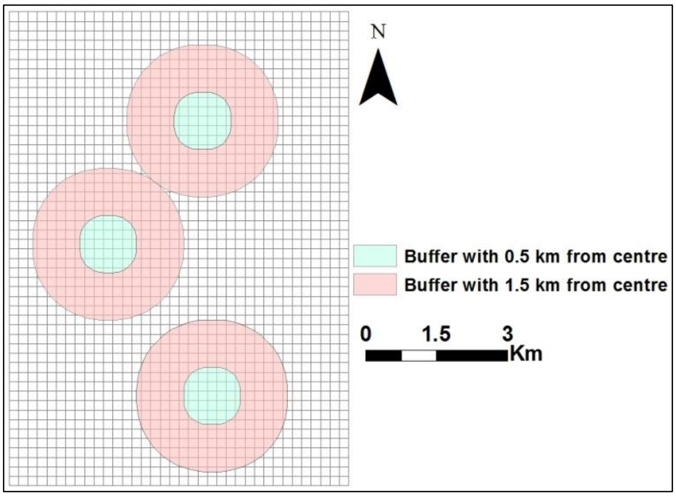


Figure 9. Multiple ring buffer of 0.5 km and 1.5 km around three samples of high density human settlements

According to different buffer distance, the composition and configuration of LULC types for different density of settlements was calculated in FRAGSTAT software. The four landscape metrics namely Largest patch index (LPI), Percentage of landscape (PLAND), Area Weighted Mean Patch Area (AREA_AM) and Edge density (ED) were selected for this purpose. Three samples for each type of density settlement was selected to avoid bias during analysis. Then, the three individual results were average for each settlement type to get final results.

3. RESULTS

3.1. Land Use/Land Cover Classification

3.1.1. Classification Results

Three classification results were obtained as shown in Figure 10. In general, the higher elevation covers more forest area than lower elevation as forest area decreases with decreasing elevation. From visual interpretation, forests in most of the lower areas have been converted to agriculture, and most of the agriculture lands at higher areas have been converted to forests within 25 years.

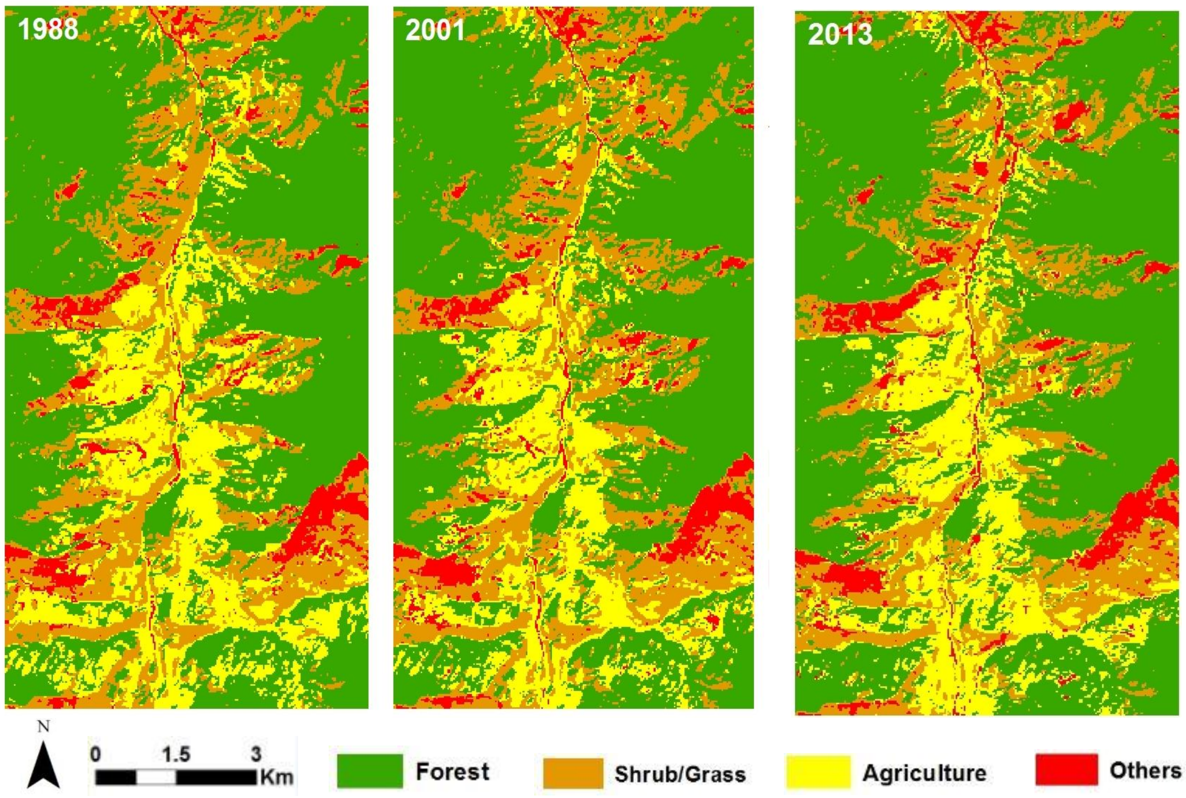


Figure 10. Land cover/use classified maps

Figure 11 revealed that there is gradual increase in forest area from 52.21% in 1988 to 55.30% in 2013. The shrub/grass increased by nearly 1.5% from year 1988 to 2001 but it has been decreased by 3% in a decade between 2001 and 2013. The agriculture decreases tremendously from year 1988 to 2001 by 3% and then increased slightly from year 2001 to 2013. Similar to a trend of increasing forest cover, the others class has also been gradually increasing from year 1988 to 2013.

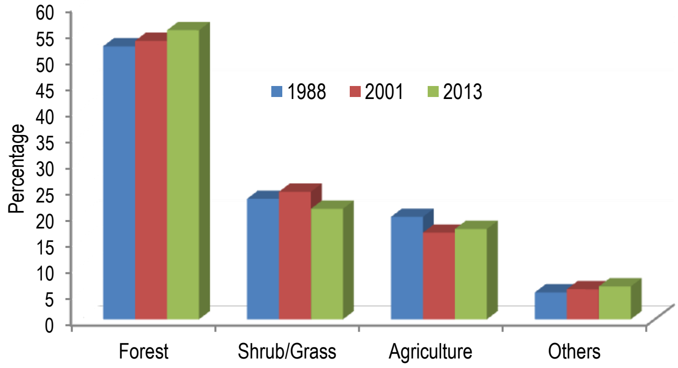


Figure 11. Percentage of change in land cover/use over period of time

3.1.2. Change Detection Statistics of Classified Maps

The LULC change map from year 1988-2001, 2001-2013 and overall change from 1988-2013 is presented on Figure 12. The change detection statistics was calculated by comparing classified maps of 1988, 2001 and 2013 to each other and presented in the Tables 2, 3 and 4. The tables show that from year 1988 to 2001 there was a major conversion of agriculture to forest and shrub/grass. Likewise, there was a major conversion of shrub/grass to agriculture and forests, and some forests to agriculture. There is a general trend that the agriculture and shrub/grass had been converted to others land cover/use in a 25 years period.

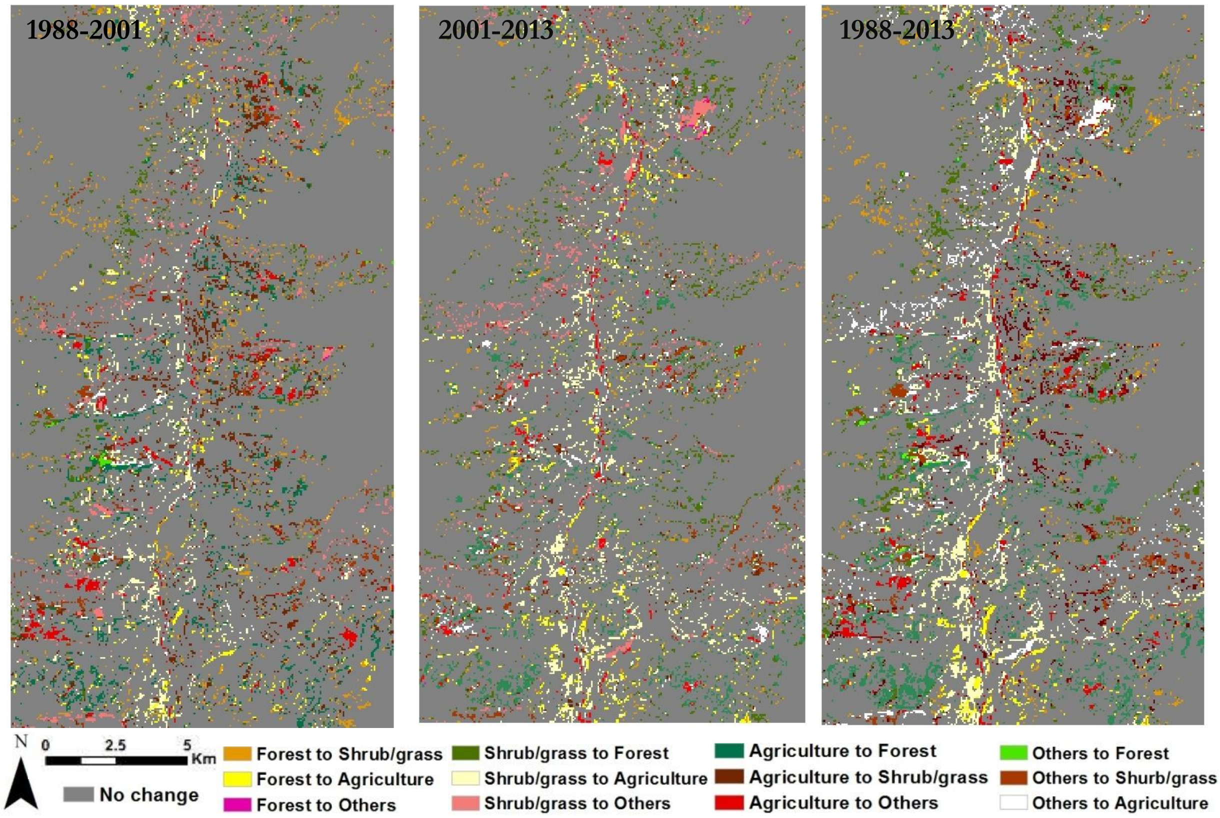


Figure 12. Land cover/use change map

Table 2. Change detection statistics for year 1988 to 2001

		Classified Image 1988 (Area in square kilometre)			
		Forest	Shrub/Grass	Agriculture	Others
Classified Image 2001	Forest	44.87	1.13	2.04	0.08
	Shrub/Grass	1.52	17.54	2.08	0.91
	Agriculture	0.76	1.28	12.66	0.28
	Others	0.02	0.87	0.92	3.39

Table 3. Change detection statistics for year 2001 and 2013

		Classified Image 2001 (Area in square kilometre)			
		Forest	Shrub/Grass	Agriculture	Others
Classified Image 2013	Forest	46.24	1.89	1.80	0.03
	Shrub/Grass	0.77	17.04	0.48	0.80
	Agriculture	1.06	2.04	12.04	0.47
	Others	0.05	1.08	0.65	3.9

Table 4. Change detection statistics for year 1988 to 2013

		Classified Image 1988 (Area in square kilometre)			
		Forest	Shrub/Grass	Agriculture	Others
Classified Image 2013	Forest	44.84	1.83	3.18	0.10
	Shrub/Grass	1.26	15.33	1.58	0.93
	Agriculture	1.00	2.36	11.96	0.29
	Others	0.07	1.30	0.98	3.33

3.1.3. Accuracy Assessment

Confusion matrix presents the overall classification accuracy of three classified maps of 1988, 2002 and 2013 (Table 5). The table shows that highest accuracy was achieved with an overall accuracy of 95% on 2013. A kappa z-test for pair wise comparison was done between the three classified images (Table 6). The every calculation shows that the Z value is less than 1.96. The Z test shows that there was no statistically significant difference between the two classified maps at 95% level of confidence. The change in accuracies of the classified maps is due to real change in LULC of study area and comparison can be made between two different classified maps. The classified image of 2013 shows a highest kappa value 0.933 (Table 6). Since, all the calculated kappa values of the three classified maps are greater than 0.75, it is the excellent agreement beyond chance i.e. the results meet the accuracy assessment.

Table 5. Confusion matrices for SVMs classification of 1988, 2001 and 2013 Landsat images using different types of land cover/use: Forest, Shrub/Grass, Agriculture and Others.

Land cover/use map	**LULC classes**	**Ground Truth data**				**Classification accuracy (%)**	
		Forest	Shrub/ Grass	Agriculture	Others	Producer's accuracy	User's accuracy
1988 Classified map	Forest	10	1	0	0	100.00	90.91
	Shrub/Grass	0	8	1	0	80.00	88.89
	Agriculture	0	0	9	2	90.00	81.82
	Others	0	1	0	8	80.00	88.89
	Overall accuracy	87.50%					
2001 Classified map	Forest	10	1	1	0	100.00	8.33
	Shrub/Grass	0	8	0	0	80.00	100.00
	Agriculture	0	0	9	1	90.00	90.00
	Others	0	1	0	9	90.00	90.00
	Overall accuracy	90.00%					
2013 Classified map	Forest	10	1	0	0	100.00	90.91
	Shrub/Grass	0	8	0	0	80.00	100.00
	Agriculture	0	0	10	0	100.00	100.00
	Others	0	1	0	10	100.00	90.91
	Overall accuracy	95.00%					

Table 6. The Z-statistic comparing the performance of three classified maps of year 1988, 2001 and 2013 with overall accuracy and Kappa coefficient in the last two columns.

Images	**1988**	**2001**	**2013**	**Overall accuracy (%)**	**Kappa**
1988	-			87.50	0.833
2001	0.47	-		90.00	0.867
2013	1.60	1.13	-	95.00	0.933

3.2. Internal Migration Trend of Households

The migration trend of households varied according to the location of villages at different elevation (Figure 13 and Figure 14). Figure 13 shows a general trend of decreasing number of households in most of the villages located above 1400 m elevations. The decreasing number of households was more pronounced in a period between 1993 and 2003. Inverse to the trend of migration of villages located above 1400 m, Figure 14 shows that the number of households were gradually increasing in the villages located below 1400 m elevation. At lower elevations, the number of households were found to be drastically increased from the year 1993 and onwards.

The results revealed that there is a general trend of household movement from high to low elevation villages within a small geographical unit. However, the pattern of changes in household movement is not uniform in all villages.

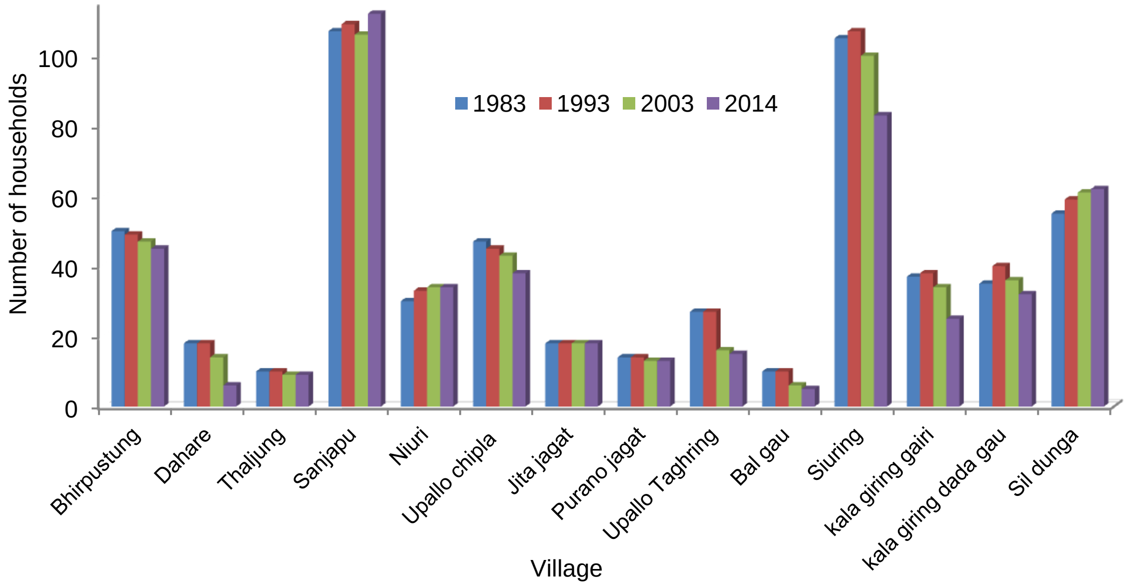


Figure 13. Trend of changes of households number at different villages located above 1400 m elevation during year 1983 to 2014

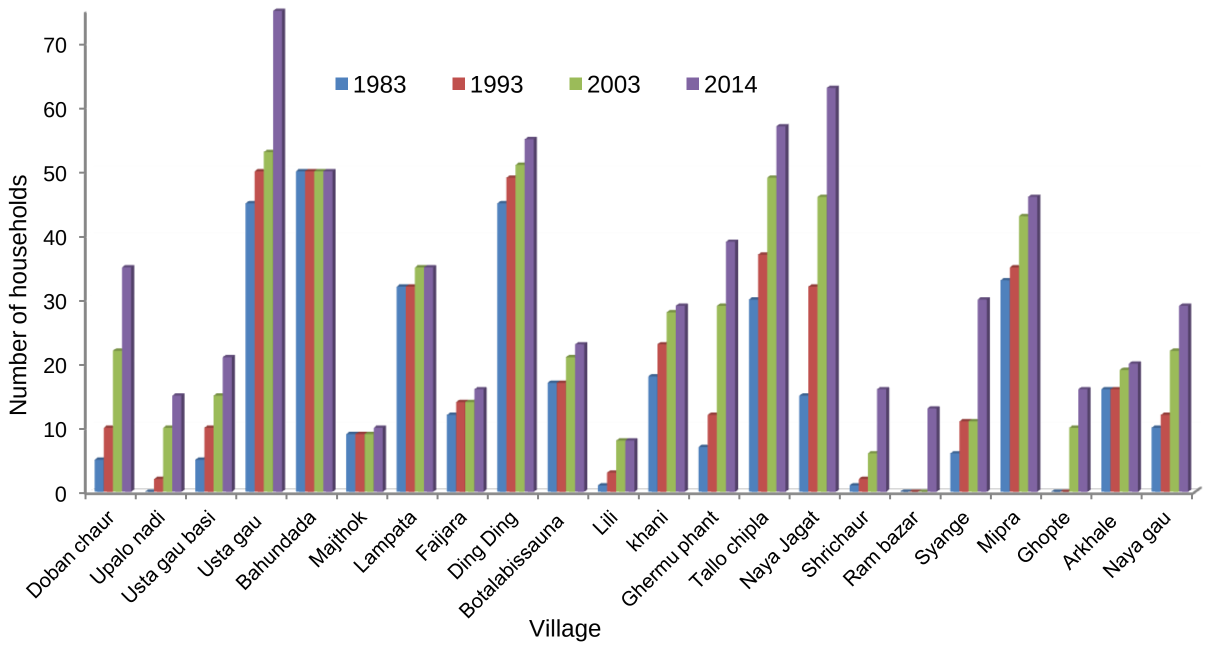
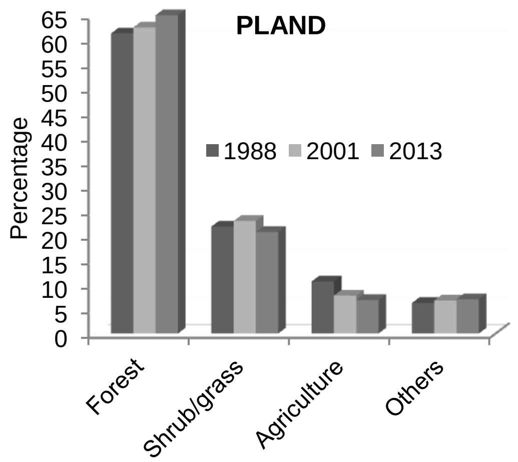


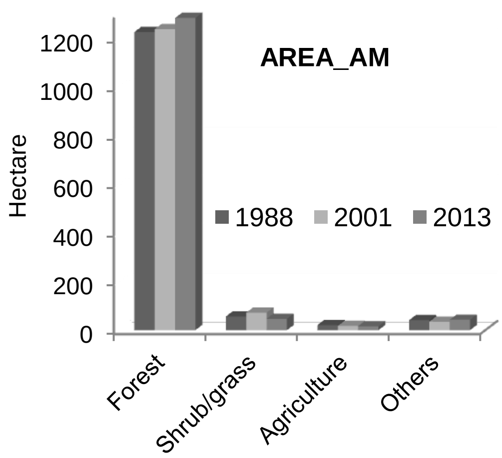
Figure 14. Trend of changes of households number at different villages located below 1400 m elevation during year 1983 to 2014

3.3. Landscape Fragmentation

The quantification results of upper and lower landscape (above and below 1400 m elevations) provide very important changes in landscape fragmentation for different four LULC classes (forest, shrub/grass, agriculture and others) from year 1988 to 2013.

In the upper landscape, the forest cover had increased gradually from 61% in 1988 to 65% in 2013 with increase in mean patch area (Figure 15). This suggests that number of forest patches had decreased and thus merger of small patches of forest showing increased in mean patch area. While the ED of forest increased by 1.5 m/ha in first decade, it has again decreased by less than 1% in the last decade. The decrease in edge effects at last decade with increase in mean patch area suggests the merger of forest patches and being more compact compared to first decade. Out of all, the forest has largest dominance over the landscape followed by shrub/grass. In contrast, the percentage of agricultural coverage has decreased tremendously by 4% from year 1988 to 2013 with both decrease in ED and AREA_AM. This indicates that agriculture is becoming more compact or circular in shape and small in size over 25 year period. There is fluctuation in case of shrub/grass which has first increased and then decrease in PLAND, LPI, ED and AREA_AM. This indicates that the percentage of shrub\grass at higher elevation is decreasing and being small in size and compact in shape. One of the interesting results is that the percentage of others class has increased gradually followed by increase in ED with fluctuation in other metrics (Figure 15).





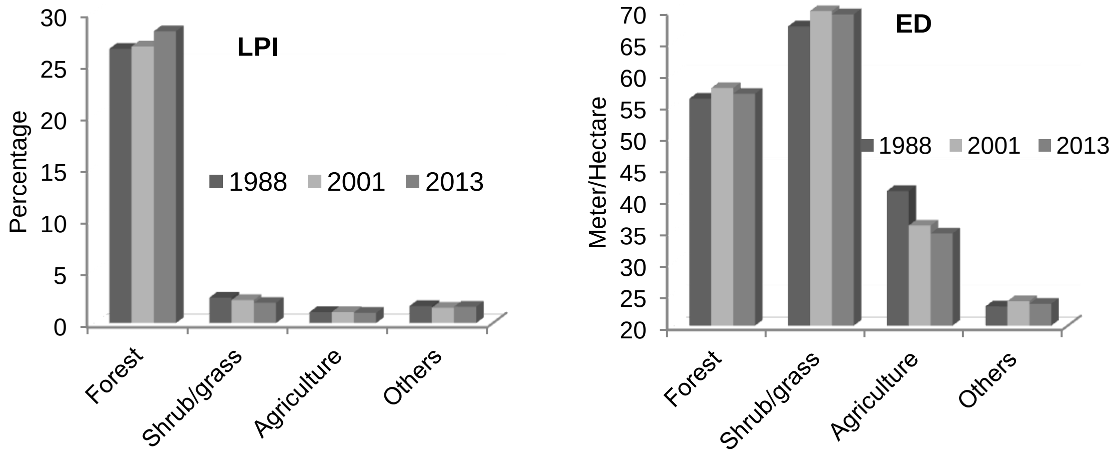


Figure 15. The time series (1988-2013) of four landscape metrics namely Percentage of landscape, Area weighted mean patch area, Largest patch index and Edge density respectively for upper landscape

In contrary to a trend in upper landscape, agriculture has highest dominance over the landscape at lower elevation. The percentage of agriculture had first decreased in first decade and then increased on second decade by 6% (Figure 16). However, the AREA_AM has increased dramatically from 245 hectare (ha) in 1988 to 546 in 2001 and further raised up to 725 ha in 2013 with gradual increase in ED. This shows that size of agriculture is increasing but geometrically complex or irregular in shape. The PLAND of forest cover is almost same all the time i.e. around 26% but the mean patch area first decreased by 8 ha and increased by 29 ha from year 2001 to 2013. Similar to a trend of forest at upper landscape above 1400 m, the ED of forest had increased by 5% from year 1988 to 2013 without significant change in percentage of forest coverage. This suggests that the forest size increased in year 2001 to 2013 with merger of patches. But, the increase in ED suggests that the forest is being elongated in shape. The PLAND of shrub/grass increased by 2% and then decreased by nearly 6% in the last decade. Similarly, there is a drastic decrease in mean patch area from 45 to 30 ha in the year 1988 to 2001 and further decreased by 2 ha with overall increase of 6 m/ha edge in the last 25 years. It indicates that the shrub\grass is being more small in size and irregular in shape. The others class has increased gradually with gradual increase in dominance over the landscape. Moreover, there is gradual increase in mean patch area per hectare together with gradual increase in edge m/ha. The other classes are being more aggregated and bigger in size but irregular in shape (Figure 16).

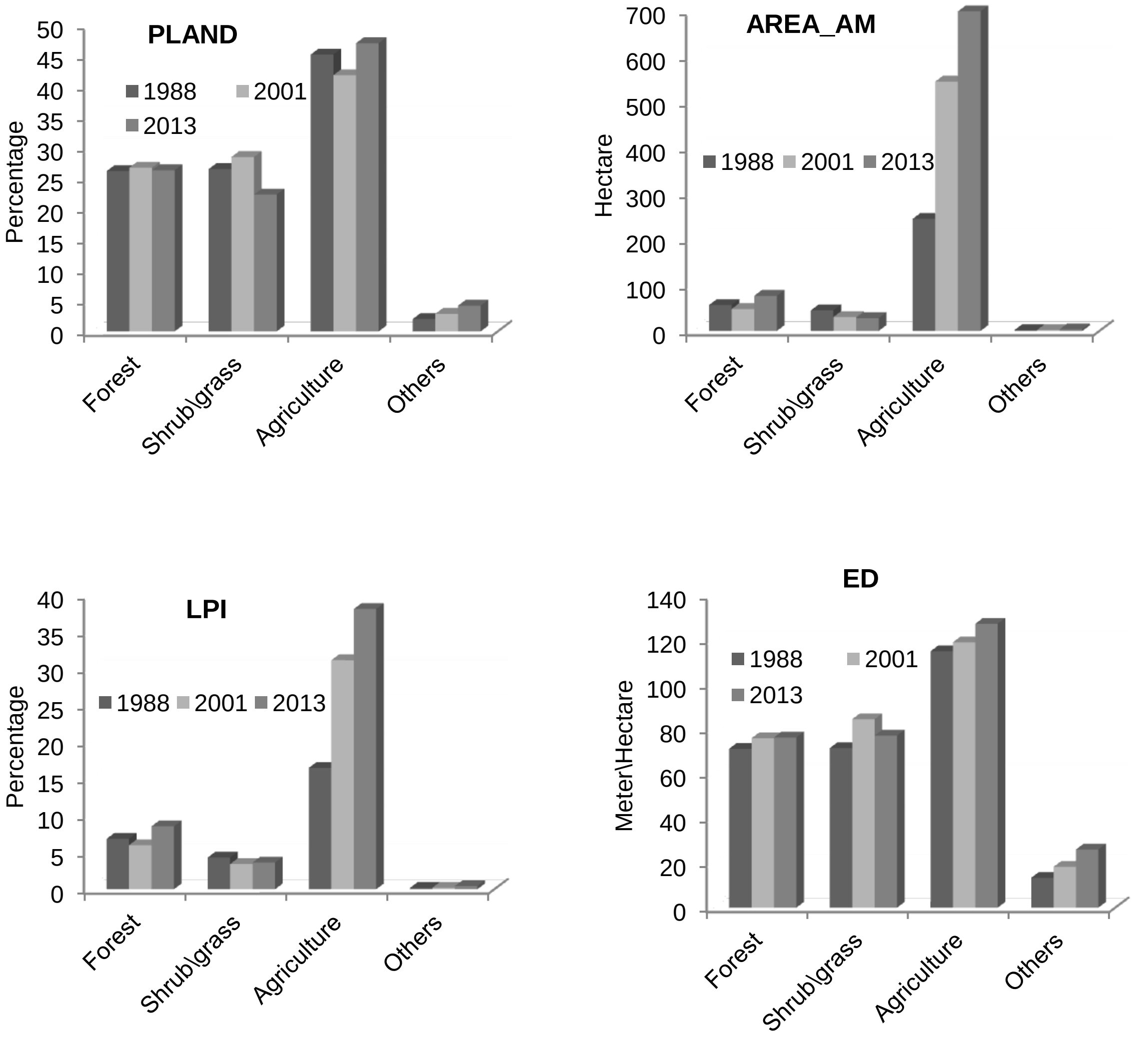


Figure 16. The time series (1988-2013) of four landscape metrics namely Percentage of landscape, Area weighted mean patch area, Largest patch index and Edge density respectively for lower landscape.

3.4. Impact of Density of Human Settlements on its Surrounding Landscape

The distribution of low, medium and high density human settlements were mapped using a 200 m by 200 m grid (Figure 17). From distribution of human settlements map, buffer map for each density type was obtained which was used for further analysis.

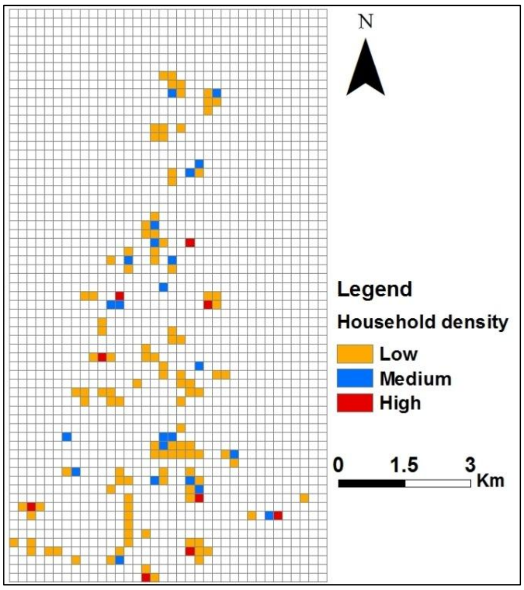


Figure 17. Map showing distribution of low, medium and high density human settlement on continuous grid of 200 m by 200 m for year 2013

3.4.1. Near to Settlements (Inner Buffer, 0.5 km Distance from Centre of Human Settlements)

The medium and high density has highest percentage of forest cover compared to low density (Figure 18). The research revealed that the coverage of forest and its mean patch area is less where there is low density of households. In between medium and high density, medium density has highest mean patch area with low edge effects m/ha showing forest is more continuous and compact in shape. Forest near to low density settlements are more fragmented and irregular in shape compared to medium and high density having higher edge effects.

The coverage of shrub/grass has decreased greater than 10% in both medium and high density in comparison to low density settlements. Accordingly with the decrease in percentage of cover of shrub/grass, there is decrease in patch area.

The research shows that high density settlements has highest percentage of agriculture followed by medium and low density with low patch area accordingly. In medium and high density, the forest and agriculture has highest dominance while in low density, the forest and shrub/grass has the highest dominance. The mean patch area follow the same trend similar to LPI except in case of forest. The mean patch area of forest is highest at medium density than in high density households. The medium density has less irregular and compact shape of forest, shrub/grass and agriculture in comparison to high density settlements.

The percentage of others keeps on decreasing gradually when it moves from low to high density settlements with gradual decrease in mean patch area and edge density. Likewise, the ED for all cover types was highest for low density followed by high density except for others class. In others, the medium has 7 m/ha higher edge compared to high density settlements and nearly 20 m/ha higher for low density. The result indicates that the others are more accumulated, small and compact in shape in medium and high density settlements.

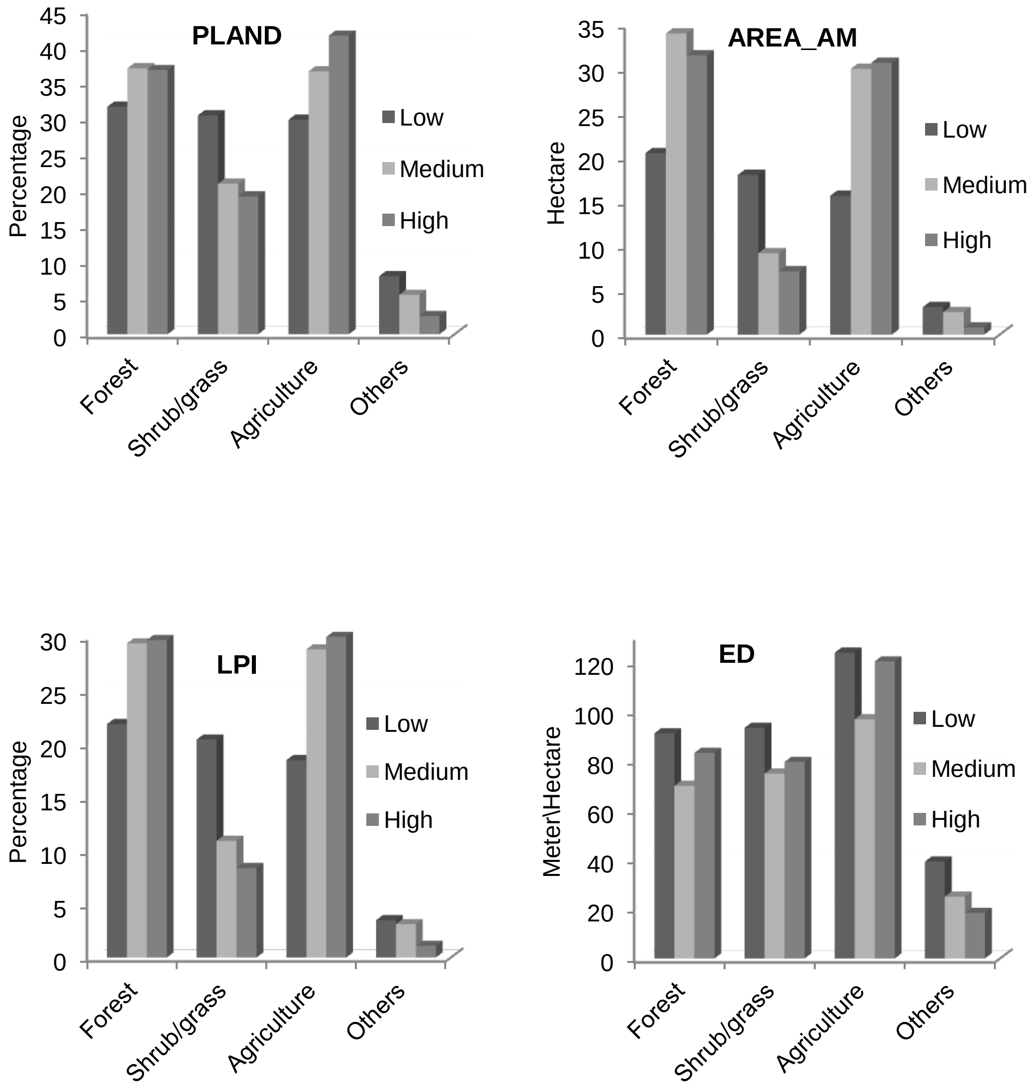


Figure 18. Bar diagrams of the four landscape metrics in low, medium and high density settlements in inner buffer

3.4.2. Far Away From Settlements (Outer Buffer, 1 km Distance from Inner Buffer)

In the outer buffer, the medium density settlement has largest coverage and dominance of forest followed by low density. Surprisingly, high density has less forest among all (i.e. 6% and 5% less) comparing to medium and low density settlements respectively (Figure 19). However, AREA_AM of forest in medium density settlement is less by 100 ha compare to high density with high edge effects. It suggests that high density has large continuous patch, and medium density has large number of forest patches. The low density has lowest m/ha edge effects suggesting forest being more homogenous and compact in shape but small in size compare to other settlement.

All types of settlement have same percentage of shrub/grass. However, the high density has largest mean patch area with less ED suggesting number of patches of shrub/grass is less and compact in shape. The low density has less hectare of AREA_AM of shrub/grass in outer buffer with highest edge effects. It shows that the low density settlements have many small patches of shrub/grass with irregular shape compared to other types of settlements.

High density settlement has largest percentage and dominance of agriculture among all followed by low density. However, low density has low mean patch area compared to medium and high density settlement. It indicates agriculture is more fragmented and small in shape at outer buffer of low density settlement compared to medium and high. The edge effects of agriculture is higher at inner than outer buffer revealing agriculture is more fragmented and geometrically complex/irregular in shape near to settlement compared to far distance.

Medium density has 2 % more coverage of others and 2 hectare less mean patch area with high edge effects among all. High density has highest dominance of others compared to all. It indicates that others class for high density settlement are much larger and compact in shape compared to medium. Others category are small in size with more irregular shape in low density settlements.

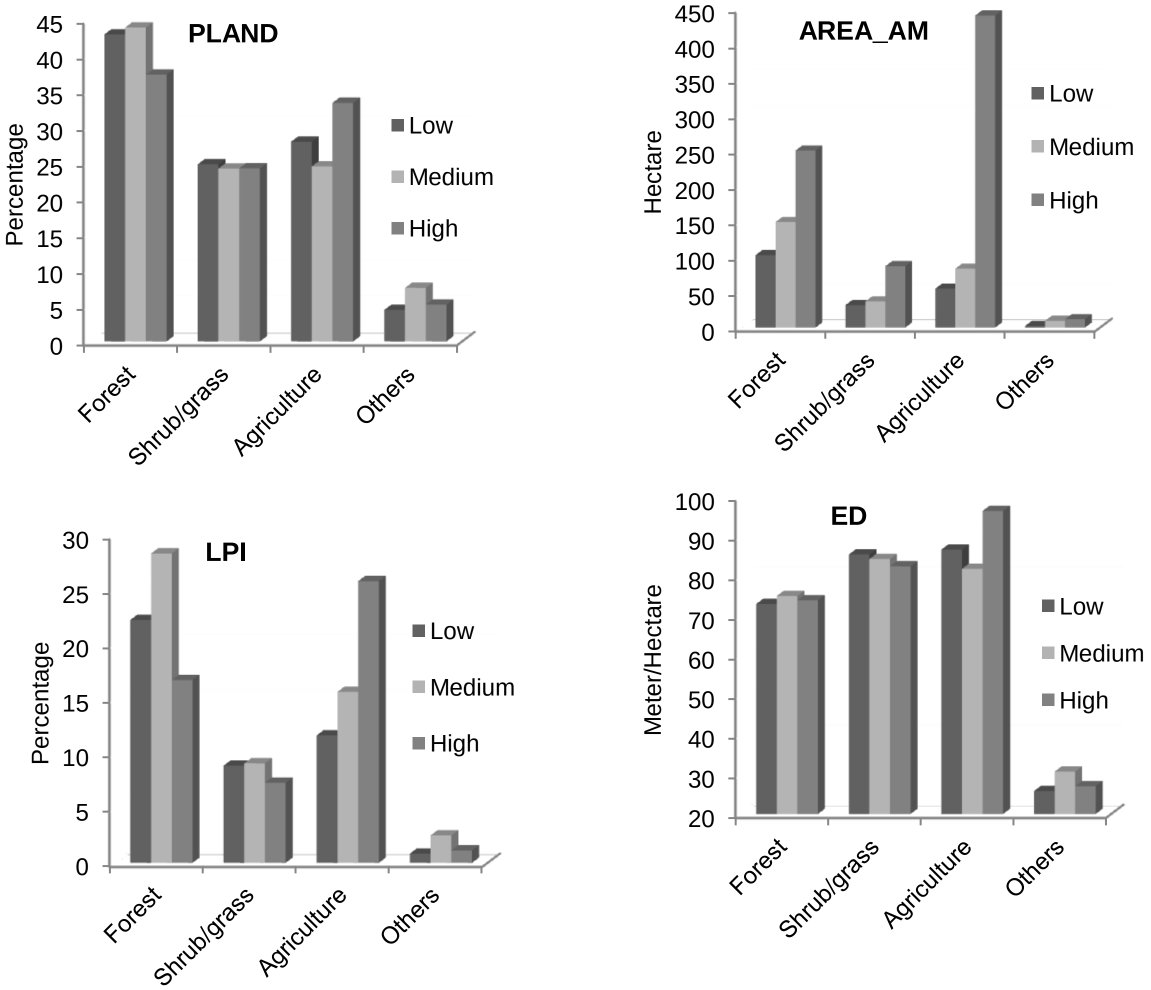


Figure 19. Bar diagrams of the four landscape metrics in low, medium and high density settlements in outer buffer

4. DISCUSSION

4.1. Increased Forest Cover and its Drivers

Among all LULC types, the research found that there was a gradual increase in forest during the 25 year period, mainly at the cost of shrub/grass and agriculture. Also, there was a gradual increase in others class.

The increase in forest may be largely due to conversion of agriculture and shrub/grass into forests. This may be gradual reduction of shifting cultivation and forest fire following the implementation of community based forest management regimes in the study area viz., Community Forestry (CF) and declaration of Annapurna conservation area, a pioneer initiatives in community based conservation in Nepal. Participants in Focus Group Discussions (FGDs) reported that community managed forest management and conservation programs had contributed in conversion of agricultural land under shifting cultivation into forests and shrub/grass. Similarly, there was a massive plantation of saplings and forest protection to promote natural regeneration under the community based forest/conservation programs. As a result, shrub and natural regenerations have gradually converted into forests. The result showed similarity with the findings of the other studies conducted on different parts of Nepal (Gautam et al., 2002; Gautam et al., 2003; Government of Nepal, 2013; Kanel, 2004; Niraula, et al., 2013; Tachibana & Adhikari, 2009). The studies also indicated a positive trend in forest protection and enhanced natural regeneration following the implementation of the CF in Nepal. Similar to this finding, Nagendra et al., (2007) have concluded a higher rate of forest regeneration and conversion of shrub to forest in community based forest management in comparision to the areas without community based forest managment.

Another reason behind the expansion of forest coverage may be due to the gradual conversion of abandoned agriculture land into shrub/grass and forests. Paudel et al., (2012) indicated that about one third of agricultural land had already abandoned in the mid hills of Nepal due to various reasons including out migration of people. As reported, the decrease in number of livestock and thus decreased pressure to the forests in terms of grazing, collection of fodder and other forest products may lead to increase in forest. The participants of FGD said that more than 50% people had stopped rearing of large domestic animals such as buffalo and cows; instead they have started to move towards keeping goat, sheep and poultry which consumes less fodder that they used to collect from the nearby forests. Jackson et al., (1998), in a similar study in the middle hills of Nepal, also revealed that the abandoned agriculture had mostly been converted into shrub/grass. Gautam et al., (2003) found a similar trend in land cover\use changes in one of the mountain watersheds of Nepal where forest coverage was increased with decrease in agrciulture areas. The research showed a general trend of decreasing shrub/grass coverage from year 1988 to 2013. The result coincide with the findings of Gautam et al., (2002), who mentioned proportion of shrub loss was more than 50% in the Village development committees where there was the implementation of CF program.

In reverse to the trend of shrub/grass, there was gradual increase in other category. There may be three possible reasons behind it as: (i) expansion of human settlements and other infrastructure development activities; (ii) road construction; and (iii) increasing frequency of natural hazards such as landslides and floods leading to exposed soil conditions. The FGD participants reported the construction of secondary road from Beshisahar, district headquarters of Lamjung, to nearby mountain district named Manang was began in 1997. The expansion of road network has converted part of agriculture, shrub/grass and forest into others category. In addition to this, the unplanned road construction in the rural mountains of the study area has increased frequency of landslides and soil erosion resulting the conversion of some agriculture, shrub/grass and forests into land cover category other.

In the research area, people harvest paddy crops from late October to early November. Following the harvesting of paddy, agricultural fields remains barred with exposed soil conditions. It may caused difficulty in differentiating agriculture and others land cover\use category. The context showed possibilities that some bare areas were misclassified as agriculture and vice versa in image classification due to exposed soil conditions at the time of satellite image analysis. In addition, the water courses of some rivers remain comparatively dry in the autumn in comparison to other seasons. So, some areas may misclassified as agriculture. Similarly, relief and shadow may lead to misclassification in mountainous region. To reduce the possible effects of misclassification and to get high accurate maps, the slope, elevation and aspect map were incorporated as ancillary data during classification. Fahsi et al., (2000), in a study carried out in the rugged areas in the Atlas mountain of Morocco, has also suggested that incorporation of ancillary data can considerably improve land cover classification by reducing the effect of relief on satellite images.

This research support that conversion of abandoned agriculture and land under shifting cultivation to forest, and community based forest management are responsible for recovery of forest. This implies that involvement of local community with well-defined rights and responsibilities creates a sense of ownership and shared responsibility which ultimately leads to sustainable management of natural resources. This is utmost especially in a context where livelihoods of the local communities largely depend upon natural resources.

4.2. Trend of Internal Migration

The research found that internal migration of people was one of the major drivers for LULC change, however, the trend of migration was varying according to elevation of villages within a small geographical unit of the district. An increasing trend of outmigration of households was identified in the villages located at relatively higher elevations (above 1400 m), whereas, at lower elevations (below 1400 m), the number of households was in an increasing trend due to immigration of households. The research revealed that trend of population growth is not uniform even within a small geographical units within the districts. According to FGDs, out of total, less than 5% of households have been externally migrated to district headquarter and other cities from study area. For example as describe in section 1.1, the overall population of Lamjung district decreased by 5.3% in a 10 year period from 2001 to 2011, while population of district headquarters increased by almost three times in the same period (Government of Nepal, 2012a; 2012b). This research finding also supports the result of population census in Nepal which shows different trends of population growth in the mountains and other district. The census revealed depopulation in 27 hills and mountain districts of Nepal between 2001 and 2011 in a context where average annual national population growth was 1.35 % (Government of Nepal, 2012a; 2012b).

According to the participants of Focus Group Discussion (FGD), a trend of migration of people from higher to lower elevations has been increased in the study area in the last two decades. The migration of people from uplands to the valley floors has been further increased after 1997 following beginning of Beshisahar to Manang road construction along the Marsyangdi valley floors. The study area lies in the Annapurna circuit, a globally known trekking route around Annapurna mountain range of Nepal. The Annapurna trekking route for foreign trekkers was opened in 1977. The opening of this route has created income and employment opportunities such as opening of hotels, grocery shops, and employment opportunities as tourist guides, cooks and porters along the tourist routes. It has resulted in migration of people from high elevation uplands towards the road head in the valley floors.

Participants in FGD reported that population is decreasing in the higher elevation villages because of both pull and push factors of migration. As reported, the push factors were repeated crop failure due to erratic rainfall and landslides, decreasing farm productivity, water stress, labour scarcity for agriculture, high labour cost, and ultimately loss from subsistence agriculture in the uplands. While, the major pull factors for internal migration towards low lands, i.e. near to road head and valley floors, were reported as better services and income opportunities and fertile land with irrigation facilities. The increasing trend of internal migration also led to abandonment of agriculture at the higher elevation.

An increasing trend of internal migration was found within a short distance as well as towards the nearby cities and district headquarters. The increase in number of households at lower elevation was also due to the migration of people from other places beyond the study area. It has been reported that motivation for migration was found higher among young people and those separated from the family. Many young people have migrated for income, employment and educational opportunities leaving old people, women and children in the remote upland villages. The FGD participants reported that people having relatively high income source through pension and overseas jobs had high migration rate compared to others, as also reported by Adhikari & Hobley (2011) and Chapagain & Gentle (2015) in the similar studies. The world bank reported that the contribution of remittance to the gross domestic product in Nepal has increased by 25% from year 2001 to 2011 (World Bank, 2010; 2011). Among all, 85% of remittance earners were from rural families (Government of Nepal, 2012a). Though there is a long history of emigration of people from the mountains and hills of Nepal, the trend has rapidly increased following people going abroad for employment and receiving remittances. Between 2000 and 2011, the number of international labour migration in Nepal increased six folds and remittances of country increased by 27 times (World Bank, 2010; 2011).

The finding implies that movement of people within short distance or internal migration is in an increasing trend and it is unplanned. This plays an important role in the use, management and distribution of natural resources, and consequently results in LULC changes in the landscape. The accumulation of income, employment and facilities along the road head and valley floors with the construction of secondary road, as well as decrease in crop production and productivity in the uplands are the major factors responsible for migration. Many migration related research conducted so far emphasized the issues of outmigration of people abroad or out of districts and its consequences, however, an increasing trend of internal migration of people within the district has been not well analysed especially in the context of LULC change. In this context, the finding of this study relating internal migration of people and its consequences on LULC change has further contributed in understanding the complexity of human environmental relationship.

4.3. Impact of Internal Migration on Landscape

The research showed that there was a gradual increase in forest cover with overall increase in edge effects from 1988 to 2013 at higher elevations. The increase in forest cover was found mainly at the cost of shrub/grass and agriculture. Inverse to the trend at higher elevation, there was a gradual increase in agriculture in the cost of shrub/grass at the lower elevation. However, percentage of forest was more or less constant over the period of time with high edge effects at lower elevation. At both elevation ranges (higher and lower), other land cover class had increased gradually in the last 25 years.

The increasing trend of human migration from high elevations and implementation of community based forest management were identified as two major drivers to increase forest cover at high elevation. According to local people, as a result of youth migration, children, women and the elderly people were only living in many houses at the upper elevation (as already discussed in section 4.2). The FGD participants of Taghring village reported that about 20% of agriculture lands have been already abandoned in the upland/high elevation villages. Among all, the agriculture lands which are far away from the settlements and relatively less fertile have been mostly abandoned as reported by many researcher such as Paudel et al., (2012), Jackson et al., (1998) and Khanal & Watanabe (2006). Consequently, agriculture practices have been reduced in terms of crop intensity and size of fields due to lack to human resource, high labour cost and decrease in agricultural productivity as reported by other studies (Khanal & Watanabe, 2006; Paudel et al., 2012; Robson, 2010). The abandoned land had been converted either into forests or as shrub/grass. The finding supports the finding of Gautam et al., (2002) who concluded that forests in the high elevation has increased in the expense of shrub and via establishment of plantations and natural succession of trees. Local people also reported that many abandoned lands had been invaded by invasive species and led to erosion and landslide in the long run. With gradual increase in forest area, there was an increase in edge effects suggesting forest is being more heterogeneous and irregular/elongated in shape. The findings showed similarity with the results of Gautam et al., (2003) and (Uddin et al., 2014) that reported increase in forest cover with increase in edge effects. Robson (2010) and Robson & Berkes (2011) have stated that agricultural abandonment bring changes on patch size and edge effects as well as spatial heterogeneity of the forests. The increase in edge may have both positive and negative impacts on biodiversity at the landscape, and an in-depth study is required to understand this complexity. Robson & Berkes (2011) have suggested that despite of forest recovery, decline in land use activity may result in a gradual loss of forest-agriculture mosaic, leading to localised decline in biodiversity.

In contrast to higher elevation, forest coverage was more or less constant in the lower elevation over a 25 year period. There was increase in mean patch area showing merger of forest patches at year 2013 despite of tremendous increase in number of households and market. For example, in one of the village of the study area named Ghermu Phant had only 7 households in 1983, but in 2014 there were 39 households in the same village. Similar to the findings of Gautam et al., (2004), the research found that there was higher fluctuation in forest located at lower elevation. This shows that the forest is more or less intact despite of population growth. The finding shows similarity with a research of Ives & Messerli (1989) that reports population growth may not necessarily contributes in forest degradation and shows contradiction with the theory of Himalayan environmental degradation (Eckholm, 1976) that have stated that population growth in the upland hills and mountains leads to deforestation and environmental degradation.

As reported by FGD participants, instead of continuing traditional agriculture, many people in the lower elevation had diversified their income sources such as tourism and grocery business, job and off seasonal vegetable farming as well as use alternative sources of energy (Biogas and Liquid petroleum gas) for cooking. Likewise, pressure on fodder trees has been reduced following the reduction of large livestock (as discussed in section 4.1). Such changes may have reduced pressure on forests at lower elevation. Gautam et al., (2004) have found proportionately higher amount of net improvement in the forests which are located around urban and semi-urban areas compared to rural areas.

At lower elevations, there is increase in edge density of agriculture due to expansion of settlements and other infrastructure development activities such as road construction through the middle of agriculture fields. As a result, agriculture is geometrically complex in shape though there is increase in mean patch area. With increase in settlement and market, agriculture land has been increased accordingly to fulfil the needs of growing population. In the research area, local people were doing intensive cultivation even in a small piece of land using modern agricultural technologies such as off seasonal vegetable farming at tunnel, as well as use of fertilizers and hybrid seed varieties to increase the production. At lower landscape the other category was increased basically due to expansion of human settlement, infrastructure development, increased incidences of landslides and soil erosion with unplanned road construction (as discussed in the section 4.1). Others are also increasing gradually in the upper landscape though there was a decrease in population density. The research found that the frequency of landslides and soil erosion was higher in the abandoned agriculture lands due to lack of maintenance and protection measures by local people with exposed soil condition as also reported by Jackson et al., (1998), Khanal & Watanabe (2006) and Smadja (1992). It was also reported that some of the abandoned agriculture lands were invaded by invasive sepecies and further exxagerated the problem of landslide and erosion. The role of community based forest management to increase forest cover has already been discussed on section 4.1. Land in the upland is basically dry land due to lack of irrigation facility. Because of this, agriculture is limited as seasonal activity in the rainy season. Thus, some agriculture may be misclassified as land cover cateory others due to expose soil condition.

As discussed above, internal migration has been identified as one of the key factors of LULC change in the mountains of Nepal. It shows that the LULC change and its drivers are diverse within a small geographical unit. So, a location specific in-depth analysis of LULC change and its drivers is essential to understand the causes and consequences of LULC change. It suggests a need for site specific planning and implementation of activities for sustainable management of natural resources. The analysis also shows that LULC change is a result of interaction of various factors and thus, land use planning should be taken as an integrated approach rather than considering social, environmental and demographic factors in isolation.

The trend of agriculture land abandonment and resurgence of forest fits the general theory of 'forest transition' which have been discussed by many authors (Bae et al., 2012; Robson, 2010; Rudel et al., 2010; Rudel et al., 2005). The research findings question the conclusion made by Grau & Aide, (2007) that rural migration leads to recovery of ecosystem and biodiversity protection at landscape level. However, there may need a further in-depth study to understand whether the insurgency of forest due to land abandonment and changes in edge will have positive or negative impacts on local biodiversity.

4.4. Impact of Human Settlements on its Surrounding Landscape

The research found the presence of high shrub/grass with less coverage of forest and agriculture close to low density settlements. While, high and medium density settlements had largest percentage of agriculture followed by forest. Near to the settlements, the low density had lowest percentage of forest with high edge effect indicating the forest was heterogeneous and irregular in shape. The medium density had less irregular, homogenous and compact shape of forest, shrub/grass and agriculture compared to high density settlements. Others land cover category were more accumulated, small and compact in shape in medium and high density settlements compared to low density settlements at inner buffer.

At outer buffer, medium density had largest coverage and dominance of forest followed by low density. However, medium density had large number of forest patches, small in size compared to high density. The coverage of forest has increased with increasing distance from the settlement with low edge effect for low density settlement indicating forest is more homogeneous and compact in shape. Likewise, the low density settlement had largest coverage of shrub/grass having higher edge effects but lowest mean patch area at outer buffer. High density has largest percentage of agriculture while medium density has lowest percentage. Land cover category others category is small and irregular in shape at low density settlements compared to all.

There is a general assumption that population growth cause increasing rate of deforestation and forest degradation. However, the findings of this research question this general assumption as the findings showed no direct relationship between population growth and deforestation in the research area. At inner buffer, the medium and high density settlements had maintained a higher percentage of forest compare to low density settlements. As reported in the FGD, migration of youth have left old, women and children in most of the villages (as discuss in section 4.2). The elder people and children living at home were not able to contribute much on forest conservation and plantation. In low density settlements, cultivation have been confined near to settlements and agriculture activities became less with increase in distance from settlements due to lack of human resources. Also, people had started to bring food stuffs from the market instead of cultivation because of additional income from remittances. This result supports the findings of Paudel et al., (2012) that reported abandonment of agriculture land has been starting from marginal and distant patches in mid hills of Nepal. Likewise, K.C. (2011) have concluded that the percentage of food bought from the market is in increasing trend at the higher elevation mountains. Similar results were found in Oaxaca, Mexico, where cultivation has fallen to less than one hectare per households, people have started to buy food from the market instead of cultivating and the size of agriculture land has also been decreased (Robson, 2010).

The abandoned agriculture land had been converted into shrub/grass near to settlements and also converted into forest in the outer buffer. In the outer buffer, the forest was more homogenous and compact compared to the inner buffer. This findings agrees with the research findings of Jackson et al., (1998) and Díaz et al., (2011). The land cover change analysis in Mediterranean mountains have shown the expansion of forest at the expense of abandoned crop and grass land (Melendez-Pastor et al., 2014). A study on mountainous area of northern Mediterranean basin shows the land-use abandonment has led to expansion of shrub land and forest (San et al., 2013). Lugo & Helmer (2004) have also reported the establishment of new forest in Puerto Rico on abandoned land which was previously used as agriculture.

The medium and high density settlements had high coverage of forest compared to low density settlements. The reason may be due to effective conservation, afforestation, protection and management of forests by local communities close to settlements. According to participants of FGD, due to presence of high number of people at high and medium density settlements, people are able to allocate time for management and monitoring of forests compared to low density settlements. At inner buffer, both high and medium density settlements had less percentage of shrub\grass compared to low density settlements. It may due to two reasons: first, the conversion of shrub/grass into agriculture to fulfil the growing needs of people with expansion of population and market; and secondly due to the conversion of shrub/grass into forest or others (as discussed above, section 4.2). Due to agriculture abandonment, most of the agriculture land had been converted into shrub/grass at inner buffer of low settlements (as discussed above, section 4.3). However, the higher edge of shrub/grass at both inner and outer buffer was may be due to succession and forest regeneration which eventually converted into secondary forest. According to Robson & Nayak (2010) and Robson (2010), the abandoned agriculture fields provide enabling condition for succession and leads to heterogeneous forests. While, at outer buffer, the percentage of shrub/grass was high but the others was less. The others was less in case of medium and high density settlements may be because of either conversion of bare areas into agriculture, shrub/grass or to forest following the plantation of saplings (as discuss in section 4.2). The others were being more aggregated with less m/ha edge following the expansion of settlement and infrastructure development. However, at inner buffer the others category was also high for low density settlements, however, it is not reported as a general trend in previous studies. The result may be due to increased incidence of landslide and soil erosion due to lack of maintenance in the low density settlements as discussed above (Section 4.2). In addition to this, when agricultural lands became fallow after abandonment, it may be misclassified as land cover category others.

Settlements with high number of people have high percentage of agriculture to fulfil the needs of increasing population. The higher m/ha edge at inner buffer compared to outer buffer showed that agriculture fields are more fragmented near vicinity of settlements compared to far distance from human settlements due to expansion of settlements and infrastructure development. This support the findings of Gautam et al., (2003) where fragmentation of agricultural areas have increased due to expansion of settlements and infrastructure development. In the outer buffer, low density had the high percentage of agriculture compared to middle density, may be due to overlapping of outer buffer area in the study area. The study area comprised a mountainous settlement where people usually live in a cluster close to each other. Although, the physical distance between two villages was not high, actual time required to reach one to another village was quite high because of difficult terrains, high slopes and poor road/trail access between the villages. The study area for this research is small. Because of overlapping of buffer area between human settlements, it was not possible to select the different human settlements according to the different elevation which is one of the limitation of this research. Also, the overlapping of buffer area may influence the results.

As already discussed in the section 4.3, the finding of this section further contradicts to a general assumption that increase in population causes deforestation and forest degradation. The community based forest management practises have become successful to maintain high coverage of forest even in the area where there is high population density.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

This research has been designed to answer how land use and land cover (LULC) have changed in last 25 years due to internal migration, and how the changes in human settlements have impacted on surrounding landscapes in the middle mountains of Nepal. Internal migration is a natural and ongoing phenomena in the middle mountains of Nepal. Information about LULC change dynamics due to internal migration and impact of human settlement on surrounding landscape is essential to better understand the relationship between human and environment interaction in the middle mountains of Nepal. It is important for the planning of sustainable land use management in Nepal.

This concluding chapter summarises major findings according to the specific research objectives. Following this, the research implication on theories and policies are discussed along with recommendations. The chapter concludes by outlining new questions for future research.

Objective I. To detect land use/land cover changes in the middle mountains of Nepal between 1988 and 2013

The study shows that the remote sensing data with Support Vector Machines (SVMs) as classifier are successful in producing accurate land use and land cover maps and change statistics for the last 25 year period. The analysis revealed that the forest has increased gradually in the period 1988 to 2013 with an overall decrease in shrub/grass and agriculture. Likewise, the others land cover/use was also increasing gradually in the study area. Also, there is gradual conversion of abandoned agriculture and land under shifting cultivation into shrub/grass and forest. The community based forest management has positive impacts and thus, become successful in recovery of forest by promoting sense of ownership among local communities in forest management and thus contributing in stopping forest fire and shifting cultivation practices. Like other studies, this study also reinforce that the involvement of local community with well-defined rights and responsibilities is essential for the sustainable management of natural resources in the fragile mountains of Nepal.

Objective II. To examine the internal migration pattern of households

Based on focus group discussion with local peoples and field observation of the researcher, the whole landscape in the study area was divided into two categories as above and below 1400 m elevations. The migration pattern of households within a small geographical unit showed that there is general trend of household movement from high (above 1400 m) to low (below 1400 m) villages, although the trend is not uniform in all villages. The construction of rural road with accumulation of income, employment and service related facilities along the road head and valley floors as well as natural hazards such as landslide and erratic rainfall were reported as major drivers for short distance movement of people in the middle mountains of Nepal. Especially, the households having high income sources through pension, job, or remittances from abroad job have higher rate of migration compared to others.

Most of the research conducted so far emphasized the issues of outmigration of people either abroad or out of districts and its consequences. However, an increasing trend of short distance movement or internal migration of people within the district in relation to LULC change has been not well analysed. In this context, the findings of this study relating internal migration of people and its consequences on LULC change have further contributed in understanding the complexity of human environmental nexus.

Objective III. To quantify the fragmentation patterns of land use/land cover between 1988 and 2013

The research showed that there was a gradual increase in forest cover in the expense of agriculture and shrub/grass at higher elevations with overall increase in m/ha edge in last 25 years period. While, at lower elevations, the agriculture have become geometrically complex in shape due to expansion of settlements and other infrastructure development activities though there is gradual increase in size of agriculture. Despite of tremendous increase in number of households at lower elevation, the coverage of forest was more or less constant over the period of time. At both elevation, others category has increased gradually in the last 25 years.

This research suggests that internal migration plays an important role in LULC change in the middle mountains of Nepal. Together with, it greatly determine the resource utilization and its distribution over the landscape. The increase in forest at higher elevations shows a positive trend of forest restoration in the middle mountains of Nepal. The decreasing trend of agriculture and increasing natural hazards such as landslide and erosion at higher elevations may lead to food shortage and environmental degradation in the long run. Through community based forest management, the forest is more or less intact despite of population growth at valley floors. The findings suggests an integrated approach to manage natural resources with demographic changes.

Objective IV. To examine the impact of density of human settlements on its surrounding landscape

Near to the settlements (within 0.5 km distance from centre of human settlements), the low density settlement had lowest coverage, irregular shape and heterogeneous forest with highest coverage of shrub/grass compared to others. The medium and high density settlement had higher percentage of agriculture followed by forest. The medium density settlements had less irregular and compact shape of forest, shrub/grass and agriculture compare to high density settlements. At inner buffer, the others land use/cover category was more accumulated, small and compact in shape in medium and high density settlements compare to low density.

At outer buffer (1 km distance from inner buffer), medium density settlement had largest coverage and dominance of forest followed by low density. But, medium density had large number of forest patches compared to high density. The high density had more homogenous and compact forest among all having lowest m/ha edge. High density had largest percentage of agriculture. Others category was small and irregular in shape at low density settlements compared to all. Agriculture was found to be more fragmented and geometrically complex in shape near to the vicinity of settlements compared to far distance.

The research findings question to a general assumption that increase in population causes deforestation and forest degradation. In contrast to this assumption, the forest coverage was high and compact in shape where local communities were involve in management of forest though there is high population density.

5.2. Recommendations

LULC change is a complex phenomenon and it is a result of interaction between various factors. Although the research indicated a general trend of LULC change in relation to demographic changes at different altitudinal ranges, the level of change and its causes are not uniform even within a small geographical unit. The finding suggests a need for location specific in- depth analysis to understand the complex phenomenon. The land use planning should be taken as integrated and interdisciplinary approach rather than considering it in isolation.

Internal migration in the study area is a decade long ongoing phenomenon although it is happening in an unplanned way. The research finding suggests that the internal migration largely determine the resource use, its distribution and, in turn, contribution of natural resources on rural livelihoods. However, neither internal migration is happening in a planned way nor there is a government policy to regulate it. The research indicates that ongoing unplanned migration of people and its impacts on natural resources may lead to food scarcity and environmental degradation in the long run. To address this challenge, at first, the government of Nepal need to formulate policy to regulate internal migration of people in the mountains and hills in a planned way to reduce environmental degradation and for a better management of natural resources for improved livelihood of local communities. The participation of local community should be encouraged in the conservation and management of natural resources where the livelihoods of local people are highly dependent on natural resources. Further in-depth and site specific study is required to understand whether the forest transition and change in edge effects leads to increase in local biodiversity or not.

LIST OF REFERENCES

Achard, F., Eva, H. D., Stibig, H.-J., Mayaux, P., Gallego, J., Richards, T., & Malingreau, J.-P. (2002). Determination of deforestation rates of the world's humid tropical forests. *Science (New York, N.Y.)*, *297*(5583), 999–1002. doi:10.1126/science.1070656

Adhikari, J., & Hobley, M. (2011). *Everyone is leaving – who will sow our fields? The effects of migration from Khotang district to the Gulf and Malaysia*. Kathmandu: Nepal Institute of Development Studies.

Adhikari, M., Nagata, S., & Adhikari, M. (2004). Rural household and forest: an evaluation of household's dependency on community forest in Nepal. *Journal of Forest Research*, *9*(1), 33–44. doi:10.1007/s10310-003-0051-1

Agrawala, S., Raksakulthai, V., Aalst, M. Van, Larsen, P., Smith, J., & Reynolds, J. (2003). *Development and climate change in Nepal: Focus on water resources and hydropower* (pp. 1–64). Paris, Cedex 16, France: Organization for Economic Cooperation and Development (OECD).

Alcantara, C., Kuemmerle, T., Prishchepov, A. V., & Radeloff, V. C. (2012). Mapping abandoned agriculture with multi-temporal MODIS satellite data. *Remote Sensing of Environment*, *124*, 334–347. doi:10.1016/j.rse.2012.05.019

Bae, J. S., Joo, R. W., & Kim, Y.-S. (2012). Forest transition in South Korea: Reality, path and drivers. *Land Use Policy*, *29*(1), 198–207. doi:10.1016/j.landusepol.2011.06.007

Baral, N. (2009). *Institutional resilience of community-based conservation to the maoist insurgency in Nepal*. Virginia Polytechnic Institute and State University: PhD Dissertation.

Bhattarai, K., & Conway, D. (2007). Evaluating land use dynamics and forest cover change in Nepal's Bara district (1973–2003). *Human Ecology*, *36*(1), 81–95. doi:10.1007/s10745-007-9144-3

Brown, S., & Shrestha, B. (2000). Market-driven land-use dynamics in the middle mountains of Nepal. *Journal of Environmental Management*, *59*(3), 217–225. doi:10.1006/jema.2000.0355

Burges, C. J. C. (1998). A Tutorial on support vector machines for pattern recognition. *Data Mining and Knowledge Discovery*, *2*(2), 121–167.

Cayuela, L., Benayas, J. M. R., & Echeverría, C. (2006). Clearance and fragmentation of tropical montane forests in the Highlands of Chiapas, Mexico (1975–2000). *Forest Ecology and Management*, *226*(1-3), 208–218. doi:10.1016/j.foreco.2006.01.047

Central Bureau of Statistics. (2008). *Environmental statistics of Nepal 2008*. Kathmandu, Nepal: Central Bureau of Statistics (CBS).

Chapagain, B., & Gentle, P. (2015). Withdrawing from Agrarian Livel lihoods: Environmental Migration in Nepal. *Journal of Mountain Science*, *12*(2), 1–13.

Cohen, J. (1960). A coefficient of agreement for nominal scales. *Educational and Psychological Measurement*, *20*, 37–46.

Congalton, R. G. (1991). A review of accessing the accuracy of classificaions of remotely sensed data. *Remote Sensing of Environment*, *37*(35-46).

Congalton, R. G. (2005). Thematic and positional accuracy assessment of digital remotely sensed data. In *Proceeding of the Seventh Annual Forest Inventory and Analysis Symposium* (pp. 149–154).

Cortes, C., & Vapnik, V. (1995). Support- vector networks. *Machine Learning*, *20*(3), 273–297. doi:10.1007/BF00994018

Cote, M., & Nightingale, A. J. (2011). Resilience thinking meets social theory: Situating social change in socio-ecological systems (SES) research. *Progress in Human Geography*, *36*(4), 475–489. doi:10.1177/0309132511425708

Courant, R., & Hilbert, D. (1953). *Methods of mathematical physics*. *Quarterly Journal of the Royal Meteorological Society* (Vol. 80). New York: John Wiley & Sons. doi:10.1002/qj.49708034534

Defries, R. S., Houghton, R. A., Hansen, M. C., Field, C. B., Skole, D., & Townshend, J. (2002). Carbon emissions from tropical deforestation and regrowth based on satellite observations for the 1980s and 1990s. In *Proceeding of the National Academy of the United States of America.*

Díaz, G. I., Nahuelhual, L., Echeverría, C., & Marín, S. (2011). Drivers of land abandonment in Southern Chile and implications for landscape planning. *Landscape and Urban Planning*, *99*(3-4), 207–217. doi:10.1016/j.landurbplan.2010.11.005

District Development Committee. (2011). *Annual district development plan*. Lamjung: District Development Committee.

District Forest Office. (2011). *Community Forest User Group (CFUG) database record*. Kathmandu, Department of Forest, Nepal.

District Forest Office. (2014). *Monitoring and evaluation of community forest user groups*. Lamjung: District Forest Office.

Drummond, M. A., Auch, R. F., Karstensen, K. A., Sayler, K. L., Taylor, J. L., & Loveland, T. R. (2012). Land change variability and human–environment dynamics in the United States Great Plains. *Land Use Policy*, *29*(3), 710–723. doi:10.1016/j.landusepol.2011.11.007

Eckholm, E. (1976). Losing ground. *Envrionment*, *18*(3), 6–11.

Fahsi, A., Tsegaye, T., Tadesse, W., & Coleman, T. (2000). Incorporation of digital elevation models with Landsat-TM data to improve land cover classification accuracy. *Forest Ecology and Management*, *128*, 57–64.

Fan, F., Weng, Q., & Wang, Y. (2007). Land use and land cover change in Guangzhou, China, from 1998 to 2003, Based on Landsat TM /ETM+ Imagery. *Sensors*, *7*(7), 1323–1342. doi:10.3390/s7071323

Foley, J. a, Defries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., … Snyder, P. K. (2005). Global consequences of land use. *Science (New York, N.Y.)*, *309*(5734), 570–4. doi:10.1126/science.1111772

Foody, G. M. (1992). On the compensation for chance agreement in image classification accuracy assessment. *Photogrammetric Engineering and Remote Sensing*, *58*(10), 1459–1460.

Foody, G. M., & Mathur, a. (2004a). A relative evaluation of multiclass image classification by support vector machines. *IEEE Transactions on Geoscience and Remote Sensing*, *42*(6), 1335–1343. doi:10.1109/TGRS.2004.827257

Foody, G. M., & Mathur, A. (2004b). Toward intelligent training of supervised image classifications: directing training data acquisition for SVM classification. *Remote Sensing of Environment*, *93*(1-2), 107–117. doi:10.1016/j.rse.2004.06.017

Forest and Agriculture Organization. (2012). *FRA 2015 Terms and definitions* (No. Forest Resources Assessment Working Paper 180). Rome.

Garedew, E., Sandewall, M., Söderberg, U., & Campbell, B. M. (2009). Land-use and land-cover dynamics in the central rift valley of Ethiopia. *Environmental Management*, *44*(4), 683–94. doi:10.1007/s00267-009-9355-z

Gautam, A. P., Shivakoti, G. P., & Webb, E. L. (2004). Forest cover change, physiography, local economy, and institutions in a mountain watershed in Nepal. *Environmental Management*, *33*(1), 48–61. doi:10.1007/s00267-003-0031-4

Gautam, A. P., Webb, E. L., & Eiumnoh, A. (2002). GIS assessment of land use/land cover changes associated with community forestry implementation in the middle hills of Nepal. *Mountain Research and Development*, *22*(1), 63–69.

Gautam, A. P., Webb, E. L., Shivakoti, G. P., & Zoebisch, M. A. (2003). Land use dynamics and landscape change pattern in a mountain watershed in Nepal. *Agriculture, Ecosystems & Environment*, *99*(1-3), 83–96. doi:10.1016/S0167-8809(03)00148-8

Geist, H. J., & Lambin, E. F. (2002). Proximate causes and underlying driving forces of Tropical deforestation. *BioScience*, *52*(2), 143–150.

Gentle, P., & Maraseni, T. N. (2012). Climate change, poverty and livelihoods: adaptation practices by rural mountain communities in Nepal. *Environmental Science & Policy*, *21*, 24–34. doi:10.1016/j.envsci.2012.03.007

Gilani, H., Shrestha, H. L., Murthy, M. S. R., Phuntso, P., Pradhan, S., Bajracharya, B., & Shrestha, B. (2014). Decadal land cover change dynamics in Bhutan. *Journal of Environmental Management*. doi:10.1016/j.jenvman.2014.02.014

Gounaridis, D., Zaimes, G. N., & Koukoulas, S. (2014). Quantifying spatio-temporal patterns of forest fragmentation in Hymettus Mountain, Greece. *Computers, Environment and Urban Systems*, *46*, 35–44. doi:10.1016/j.compenvurbsys.2014.04.003

Government of Nepal. (2012a). *National population and housing census 2011 (National Report)* (Vol. 01). Kathmandu, Nepal.

Government of Nepal. (2012b). *National population and housing census 2011 (Village Development Committee/Municipality)* (Vol. 02). Kathmandu, Nepal.

Government of Nepal. (2013). *Persistence and change: Review of 30 years of community forestry in Nepal*. Ministry of Forests and Soil Conservation, Government of Nepal.

Grau, H. R., & Aide, T. M. (2007). Are rural–urban migration and sustainable development compatible in mountain systems? *Mountain Research and Development*, *27*(2), 119–123. doi:10.1659/mrd.0906

Guerschman, J. P., Paruelo, J. M., Bella, C. Di, Giallorenzi, M. C., & Pacin, F. (2003). Land cover classification in the Argentine Pampas using multi-temporal Landsat TM data. *International Journal of Remote Sensing*, *24*(17), 3381–3402. doi:10.1080/0143116021000021288

Gurung, H. (2004). *Landscape change in the Nepal hills Evidence from Lamjung*. Kathmandu, Nepal: International Centre for Integrated Mountain Development (ICIMOD).

Hansen, M. C., & Loveland, T. R. (2012). A review of large area monitoring of land cover change using Landsat data. *Remote Sensing of Environment*, *122*, 66–74. doi:10.1016/j.rse.2011.08.024

Hansen, M. C., Stehman, S. V, Potapov, P. V, Loveland, T. R., Townshend, J. R. G., Defries, R. S., … Dimiceli, C. (2008). Humid tropical forest clearing from 2000 to 2005 quantified by using multitemporal and multiresolution remotely sensed data SCIENCE. In *Proceedings of the National Academy of Sciences of the United States of America*.

Harper, K. A., Macdonald, S. E., Burton, P. J., Chen, J., Euskirchen, N. I. E. S., Brosofske, K. D., … Esseen, P. (2005). Edge Influence on Forest Structure and Composition in Fragmented Landscapes, *19*(3), 768–782.

Heikkinen, V., Tokola, T., Parkkinen, J., Korpela, I., & Jaaskelainen, T. (2010). Simulated multispectral imagery for tree species classification using support vector machines. *IEEE Transactions on Geoscience and Remote Sensing*, *48*(3), 1355–1364.

Hsu, C., Chang, C., & Lin, C. (2010). *A practical guide to support vector classification* (Vol. 1). Taiwan: National Taiwan University.

Huang, C., Davis, L. S., & Townshend, J. R. G. (2002). An assessment of support vector machines for land cover classification. *International Journal of Remote Sensing*, *23*(4), 725–749.

Huang, C., Goward, S. N., Schleeweis, K., Thomas, N., Masek, J. G., & Zhu, Z. (2009). Dynamics of national forests assessed using the Landsat record: Case studies in eastern United States. *Remote Sensing of Environment*, *113*(7), 1430–1442. doi:10.1016/j.rse.2008.06.016

Huang, H., Gong, P., Clinton, N., & Hui, F. (2008). Reduction of atmospheric and topographic effect on Landsat TM data for forest classification. *International Journal of Remote Sensing*, *29*(19), 5623–5642. doi:10.1080/01431160802082148

Ives, J. D., & Messerli, B. (1989). *The Himalayan dilemma: Reconciling development and conservation*. London, UK: Routledge London and New York.

Izquierdo, A. E., & Grau, H. R. (2009). Agriculture adjustment, land-use transition and protected areas in Northwestern Argentina. *Journal of Environmental Management*, *90*(2), 858–65. doi:10.1016/j.jenvman.2008.02.013

Jackson, W. ., Tamrakar, R. M., Hunt, S., & Shepherd, K. R. (1998). Land-use changes in two middle hills districts of Nepal. *Mountain Research and Development*, *18*(3), 193–212.

Jansen, L. J. M., Bagnoli, M., & Focacci, M. (2008). Analysis of land-cover/use change dynamics in Manica Province in Mozambique in a period of transition (1990–2004). *Forest Ecology and Management*, *254*(2), 308–326. doi:10.1016/j.foreco.2007.08.017

Jayasekara, R. S. (2012). Focus groups in nursing research: methodological perspectives. *Nursing Outlook*, *60*(6), 411–6. doi:10.1016/j.outlook.2012.02.001

Jiang, S., & Liu, D. (2011). On change-adjusted measures for accuracy assessment in remote sensing image classifciation. In *ASPRS 2011 Annual Conference*.

Jin, S., Yang, L., Danielson, P., Homer, C., Fry, J., & Xian, G. (2013). A comprehensive change detection method for updating the National Land Cover Database to circa 2011. *Remote Sensing of Environment*, *132*, 159–175. doi:10.1016/j.rse.2013.01.012

K.C, K. B. (2011). Linking physical, economic and institutional constraints of land use change and forest conservation in the hills of Nepal. *Forest Policy and Economics*, *13*(8), 603–613. doi:10.1016/j.forpol.2011.07.010

Kanel, K. R. (2004). Twenty five years' of community forestry: Contribution to millennium development goals. In *Fourth National Workshop on Community Forestry* (pp. 4–18). Babarmahal, Kathmandu, Nepal: Department of Forest-Community Forestry Division.

Karatzoglou, A., Meyer, D., & Hornik, K. (2006). Support vector machines in R. *Journal of Statistical Software*, *15*(9), 1–28.

Kavzoglu, T., & Colkesen, I. (2009). A kernel functions analysis for support vector machines for land cover classification. *International Journal of Applied Earth Observation and Geoinformation*, *11*(5), 352–359. doi:10.1016/j.jag.2009.06.002

Khan, M. E., & Manderson, L. (1992). Focus groups in tropical diseases research. *Health Policy and Planning*, *7*(1), 56–66.

Khanal, N. R., & Watanabe, T. (2006). Abandonment of agricultural land and its consequences. *Mountain Research and Development*, *26*(1), 32–40.

Kitzinger, J. (1994). The methodology of focus groups: the importance of interaction between research participants. *Scciology of Health and Illness*, *16*(1).

Kitzinger, J. (1995). Introducing focus groups. *BMJ*, *311*, 299–302.

Knorn, J., Rabe, A., Radeloff, V. C., Kuemmerle, T., Kozak, J., & Hostert, P. (2009). Land cover mapping of large areas using chain classification of neighboring Landsat satellite images. *Remote Sensing of Environment*, *113*(5), 957–964. doi:10.1016/j.rse.2009.01.010

Kuemmerle, T., Chaskovskyy, O., Knorn, J., Radeloff, V. C., Kruhlov, I., Keeton, W. S., & Hostert, P. (2009). Forest cover change and illegal logging in the Ukrainian Carpathians in the transition period from 1988 to 2007. *Remote Sensing of Environment*, *113*(6), 1194–1207. doi:10.1016/j.rse.2009.02.006

Kumar, K. (1987). *Conducting group interviews in developing countries* (Vol. 8). Washington DC.

Lambin, E. F., Geist, H. J., & Lepers, E. (2003). Dynamics of land - use and land -cover change in tropical regions. *Annual Review of Environment and Resources*, *28*(1), 205–241. doi:10.1146/annurev.energy.28.050302.105459

Lambin, E. F., & Meyfroidt, P. (2010). Land use transitions: Socio-ecological feedback versus socio-economic change. *Land Use Policy*, *27*(2), 108–118. doi:10.1016/j.landusepol.2009.09.003

Lambin, E. F., Turner, B. L., Geist, H. J., Agbola, S. B., Angelsen, A., Bruce, J. W., … Xu, J. (2001). The causes of land-use and land-cover change: moving beyond the myths. *Global Environmental Change*, *11*(4), 261–269. doi:10.1016/S0959-3780(01)00007-3

Land Resource Mapping Project. (1986). Land resource mapping project. Governement of Nepal.

Lasanta, T., Arnáez, J., Errea, M. P., Ortigosa, L., & Ruiz-Flaño, P. (2009). Mountain pastures, environmental degradation, and landscape remediation: The example of a Mediterranean policy initiative. *Applied Geography*, *29*(3), 308–319. doi:10.1016/j.apgeog.2008.09.006

Lee, E. S. (1966). A theory of migration. In *Demography* (Vol. 3, pp. 47–57). Springer.

Lepers, E., Lambin, E. F., Janetos, A. C., Fries, R. D. E., Achard, F., Ramankutty, N., & Scholes, R. J. (2005). A Synthesis of Information on Rapid Land-cover Change for the Period 1981 – 2000. *BioScience*, *55*(2), 115–124.

Liu, D., Kelly, M., & Gong, P. (2006). A spatial–temporal approach to monitoring forest disease spread using multi-temporal high spatial resolution imagery. *Remote Sensing of Environment*, *101*(2), 167–180. doi:10.1016/j.rse.2005.12.012

Liu, J. (2001). Integrating ecology with human demography, behavior, and socioeconomics: Needs and approaches. *Ecological Modelling*, *140*(1-2), 1–8. doi:10.1016/S0304-3800(01)00265-4

Liu, X., Li, Y., Shen, J., Fu, X., Xiao, R., & Wu, J. (2013). Landscape pattern changes at a catchment scale: a case study in the upper Jinjing river catchment in subtropical central China from 1933 to 2005. *Landscape and Ecological Engineering*, *10*(2), 263–276. doi:10.1007/s11355-013-0221-z

López-Barrera, F., Manson, R. H., & Landgrave, R. (2014). Identifying deforestation attractors and patterns of fragmentation for seasonally dry tropical forest in central Veracruz, Mexico. *Land Use Policy*, *41*, 274–283. doi:10.1016/j.landusepol.2014.06.004

Lugo, A. E., & Helmer, E. (2004). Emerging forests on abandoned land: Puerto Rico's new forests. *Forest Ecology and Management*, *190*(2-3), 145–161. doi:10.1016/j.foreco.2003.09.012

Maharjan, a., Bauer, S., & Knerr, B. (2012). Do Rural Women Who Stay Behind Benefit from Male Out-migration? A Case Study in the Hills of Nepal. *Gender, Technology and Development*, *16*(1), 95–123. doi:10.1177/097185241101600105

Mahat, T. B. S., Griffin, D. M., & Shepherd, K. . R. (1986). Human impact on some forests of the middle hills of Nepal 1 . Forestry in the context of the traditional resources of the state. *Mountain Research and Development*, *6*(3), 223–232.

Maimaitijiang, M., Ghulam, A., Sandoval, J. S. O., & Maimaitiyiming, M. (2015). Drivers of land cover and land use changes in St. Louis metropolitan area over the past 40 years characterized by remote sensing and census population data. *International Journal of Applied Earth Observation and Geoinformation*, *35*, 161–174. doi:10.1016/j.jag.2014.08.020

Mantero, P., Moser, G., Member, S., Serpico, S. B., & Member, S. (2005). Partially supervised classification of remote sensing images through SVM-based probability density estimation. *IEEE Transactions on Geoscinece and Remote Sensing*, *43*(3), 559–570.

Massey, D. S., Axinn, W. G., & Ghimire, D. J. (2007). *Environmental change and out-migration: Evidence from Nepal. Population and environment* (Vol. 32, pp. 109–136). Michigan, Univeristy of Michigan. doi:10.1007/s11111-010-0119-8

Mayaux, P., Holmgren, P., Achard, F., Eva, H., Stibig, H.-J., & Branthomme, A. (2005). Tropical forest cover change in the 1990s and options for future monitoring. *Philosophical Transactions of the Royal Society of London.*, *360*(1454), 373–84. doi:10.1098/rstb.2004.1590

McGarigal, K., Cushman, S., & Ene, E. (2012). FRAGSTATS v4: Spatial pattern analysis program for categorical and continous maps. University of Massachusetts, Amherst. Retrieved from http://www.umass.edu/landeco/research/fragstats/fragstats_release.html

McGarigal, K., & Marks, B. J. (1994). *FRAGSTATS: Spatial pattern analysis program for quantifying landscape structure V2.0* (Vol. 97331).

Melendez-Pastor, I., Hernández, E. I., Navarro-Pedreño, J., & Gómez, I. (2014). Socioeconomic factors influencing land cover changes in rural areas: The case of the Sierra de Albarracín (Spain). *Applied Geography*, *52*, 34–45. doi:10.1016/j.apgeog.2014.04.013

Morgan, D. L. (1984). Focus Groups: A New Tool for Qualitative Research. *Qualitative Sociology*, *7*(3), 253–270.

Mountrakis, G., Im, J., & Ogole, C. (2011). Support vector machines in remote sensing: A review. *ISPRS Journal of Photogrammetry and Remote Sensing*, *66*(3), 247–259. doi:10.1016/j.isprsjprs.2010.11.001

Myers, N. (1993). Tropical forests: The main deforestation fronts. *Environmental Conservation*, *20*(1), 9–16. Retrieved from http://www.scopus.com/inward/record.url?eid=2-s2.0-0027330548&partnerID=tZOtx3y1

Nagendra, H., Pareeth, S., & Ghate, R. (2006). People within parks—forest villages, land-cover change and landscape fragmentation in the Tadoba Andhari Tiger Reserve, India. *Applied Geography*, *26*(2), 96–112. doi:10.1016/j.apgeog.2005.11.002

Nagendra, H., Pareeth, S., Sharma, B., Schweik, C. M., & Adhikari, K. R. (2007). Forest fragmentation and regrowth in an institutional mosaic of community, government and private ownership in Nepal. *Landscape Ecology*, *23*(1), 41–54. doi:10.1007/s10980-007-9162-y

Nahuelhual, L., Carmona, A., Lara, A., Echeverría, C., & González, M. E. (2012). Land-cover change to forest plantations: Proximate causes and implications for the landscape in south-central Chile. *Landscape and Urban Planning*, *107*(1), 12–20. doi:10.1016/j.landurbplan.2012.04.006

Nepal Climate Vulnerability Study Team. (2009). *Vulnerability through the eyes of the vulnerable: Climate change induced uncertainties and Nepal's development prdiacaments*. Institute for Social and Environmental Transition-Nepal (ISET-N) and Institute for Social and Environmental Transition (ISET), Boulder, Colorado.

Nightingale, A. (2003). Nature–society and development: social, cultural and ecological change in Nepal. *Geoforum*, *34*(4), 525–540. doi:10.1016/S0016-7185(03)00026-5

Niraula, R. R., Gilani, H., Pokharel, B. K., & Qamer, F. M. (2013). Measuring impacts of community forestry program through repeat photography and satellite remote sensing in the Dolakha district of Nepal. *Journal of Environmental Management*, *126*, 20–9. doi:10.1016/j.jenvman.2013.04.006

Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science*, *325*(5939), 419–22. doi:10.1126/science.1172133

Paliwal, A., & Mathur, V. B. (2014). Spatial pattern analysis for quantification of landscape structure of Tadoba-Andhari Tiger Reserve, Central India. *Journal of Forestry Research*, *25*(1), 185–192. doi:10.1007/s11676-014-0444-3

Paudel, K. P., Dahal, D., & Shah, R. (2012). *Abandoned agriculture in mid hills of Nepal status, causes and consequences*.

Poertner, E., Junginger, M., & Müller-Böker, U. (2011). Migration in Far West Nepal. *Critical Asian Studies*, *43*(4), 661–665. doi:10.1080/14672715.2011.623531

Powell, R. A., & Single, M. (1996). Focus groups. *International Journal for Quality in Health Care*, *8*(5).

Prenzel, B. (2004). Remote sensing-based quantification of land-cover and land-use change for planning. *Progress in Planning*, *61*(4), 281–299. doi:10.1016/S0305-9006(03)00065-5

Robinson, N. (1999). The use of focus group methodology - with selected examples from sexual health research. *Journal of Advanced Nursing*, *29*(4), 905–913.

Robson, J. P. (2010). *The impact of rural to urban migration on forest commons in Oaxaca , Mexico*. University of Manitoba: Phd Dissertation.

Robson, J. P., & Berkes, F. (2011). Exploring some of the myths of land use change: Can rural to urban migration drive declines in biodiversity? *Global Environmental Change*, *21*(3), 844–854. doi:10.1016/j.gloenvcha.2011.04.009

Robson, J. P., & Nayak, P. K. (2010). Rural out-migration and resource-dependent communities in Mexico and India. *Population and Environment*, *32*(2-3), 263–284. doi:10.1007/s11111-010-0121-1

Romero-Calcerrada, R., & Perry, G. L. W. (2004). The role of land abandonment in landscape dynamics in the SPA 'Encinares del rı́o Alberche y Cofio, Central Spain, 1984–1999. *Landscape and Urban Planning*, *66*(4), 217–232. doi:10.1016/S0169-2046(03)00112-9

Rudel, T. K., Coomes, O. T., Moran, E., Achard, F., Angelsen, A., Xu, J., & Lambin, E. (2005). Forest transitions: towards a global understanding of land use change. *Global Environmental Change*, *15*(1), 23–31. doi:10.1016/j.gloenvcha.2004.11.001

Rudel, T. K., Schneider, L., & Uriarte, M. (2010). Forest transitions: An introduction. *Land Use Policy*, *27*(2), 95–97. doi:10.1016/j.landusepol.2009.09.021

San, A., Sanz, R., Fernandez, C., Mouillot, F., Ferrat, L., Istria, D., & Pasqualini, V. (2013). Long-Term Forest Dynamics and Land-Use Abandonment in the Mediterranean Mountains , Corsica , France, *18*(2).

Schneider, L., & Geoghegan, J. (2006). Land abandonment in an agricultural frontier after a plant invasion: The case of Bracken Fern in Southern Yucatán , Mexico. *Agricultural and Research Economics Review*, *35*(1), 167–177.

Seddon, D., Adhikari, J., & Gurung, G. (2002). Foreign Labor Migration and the Remittance Economy of Nepal. *Critical Asian Studies*, *34*(1), 19–40. doi:10.1080/146727102760166581

Sherbinin, A. de, Vanwey, L., McSweeney, K., Aggarwal, R., Barbieri, A., Henry, S., … Twine, W. (2008). Rural household demographics, livelihoods and the environment. *Global Environmental Change: Human and Policy Dimensions*, *18*(1), 38–53. doi:10.1016/j.gloenvcha.2007.05.005

Shrestha, A. . B., Eriksson., M., Mool, P., Ghimire, P., Mishra, B., & Khanal, N. R. (2010). Glacial lake outburst flood risk assessment of Sun Koshi basin, Nepal. *Geomatics, Natural Hazards and Risk*, *1*(2), 157–169. doi:10.1080/19475701003668968

Shrestha, S. S., & Bhandari, P. (2007). Environmental security and labor migration in Nepal. *Population and Environment*, *29*(1), 25–38. doi:10.1007/s11111-007-0059-0

Šímová, P., & Gdulová, K. (2012). Landscape indices behavior: A review of scale effects. *Applied Geography*, *34*, 385–394. doi:10.1016/j.apgeog.2012.01.003

Skidmore, A. K. (1989). An expert system classifies Eucalypt forest types using Thematic Mapper data and a digital terrain model. *Photogrammetric Engineering and Remote Sensing*, *55*(10), 1449–1464.

Skole, D., & Tucker, C. (1993). Tropical deforestation and habitat fragmentation in the Amazon: Satellite data from 1978 to 1988. *Science*, *260*.

Smadja, J. (1992). Studies of climatic and human impacts and their relationship on a mountain slope above Salme in the Himalayan Middle Mountains, Nepal. *Mountain Research and Development*, *12*(1), 1–28.

Tachibana, T., & Adhikari, S. (2009). Does community-based management improve natural resource condition? Evidence from the forests in Nepal. *Land Economics*, *85*(1), 107–131.

Tacoli, C. (2009). Crisis or adaptation? Migration and climate change in a context of high mobility. *Environment and Urbanization*, *21*(2), 513–525. doi:10.1177/0956247809342182

Tekle, K., & Hedlund, L. (2000). Land cover changes between 1958 and 1986 in Kalu district, Southern Wello, Ethiopia. *Mountain Research and Development*, *20*(1), 42–51. doi:10.1659/0276-4741(2000)020[0042:LCCBAI]2.0.CO;2

Theobald, S., Nyirenda, L., Tulloch, O., Makwiza, I., Soonthorndhada, A., Tolhurst, R., … Fergusson, P. (2011). Sharing experiences and dilemmas of conducting focus group discussions on HIV and tuberculosis in resource-poor settings. *International Health*, *3*(1), 7–14. doi:10.1016/j.inhe.2010.09.006

Tso, B., & Mather, P. M. (2009). *Classification methods for remotely sensed data* (2nd ed.). Taylor and Francis Group.

Tuia, D., & Camps-Valls, G. (2009). Semisupervised remote sensing image classification with cluster kernels. *IEEE Geoscience and Remote Sensing Letters*, *6*(2), 224–228. doi:10.1109/LGRS.2008.2010275

Uddin, K., Shrestha, H. L., Murthy, M. S. R., Bajracharya, B., Shrestha, B., Gilani, H., … Dangol, B. (2014). Development of 2010 national land cover database for the Nepal. *Journal of Environmental Management*, *2011*, 1–9. doi:10.1016/j.jenvman.2014.07.047

United Nations Development Programme. (2009). *Nepal human development report 2009*. Kathmandu.

Verburg, P. H., van Berkel, D. B., van Doorn, A. M., van Eupen, M., & van den Heiligenberg, H. a. R. M. (2010). Trajectories of land use change in Europe: a model-based exploration of rural futures. *Landscape Ecology*, *25*(2), 217–232. doi:10.1007/s10980-009-9347-7

Wang, T. J., Skidmore, a. K., & Toxopeus, a. G. (2009). Improved understorey bamboo cover mapping using a novel hybrid neural network and expert system. *International Journal of Remote Sensing*, *30*(4), 965–981. doi:10.1080/01431160802411867

Warner, T. a., & Nerry, F. (2009). Does single broadband or multispectral thermal data add information for classification of visible, near and shortwave infrared imagery of urban areas? *International Journal of Remote Sensing*, *30*(9), 2155–2171. doi:10.1080/01431160802549286

Webb, C., & Kevern, J. (2001). Focus groups as a research method: a critique of some aspects of their use in nursing research. *Journal of Advanced Nursing*, *33*(6), 798–805.

Wilson, E. O. (1998). *Consilience: The unity of knowledge*. Knopf, New York.

World Bank. (2010). *Nepal economic update April 2010*. Economic Policy and Povery Team South Asia Region, The World Bank.

World Bank. (2011). *Migration and remittance factbook 2011*. Wastinngton, DC: The World Bank.

Xin, Q., Olofsson, P., Zhu, Z., Tan, B., & Woodcock, C. E. (2013). Toward near real-time monitoring of forest disturbance by fusion of MODIS and Landsat data. *Remote Sensing of Environment*, *135*, 234–247. doi:10.1016/j.rse.2013.04.002

Yang, J. (2007). *Measurement of agreement for categorical data*. The Pennsylvania State University: Phd thesis.

Zuo, R., & Carranza, E. J. M. (2011). Support vector machine: A tool for mapping mineral prospectivity. *Computers & Geosciences*, *37*(12), 1967–1975. doi:10.1016/j.cageo.2010.09.014

APPENDIX 1

Checklist for Focus Group Discussion

1. Migration (a historical timeline with immigration/emigration details)
   - internal migration
   - out migration
   - coming inside that area
   - causes of migration (pull and push factors)
   - the impacts of migration on land use change
2. Remittance
   - Households receiving remittances
   - Effects of remittance on livelihood diversification.
   - Effects of remittance on migration
   - Major changes in livelihood options of households receiving/not receiving remittances.
3. Livestock (types, number, grazing)
   - Trend of livestock holding
   - Changes in livestock holding by households in the last 30 years.
4. Agriculture system (past and present)
   - changes in cropping pattern, crop intensity and crop diversity
5. Abandonment of agricultural land
   - where, why, when
   - predict and analyse the causes/drivers of land abandonment
6. Use pattern change
   - forest use(past and present), plantation, private forest, agro-forestry,
   - biogas, LPG gas
   - cash cropping
   - stall feeding
   - awareness
7. How people observe land use/cover change in their locality,
8. Which land use type is increasing and which is decreasing, why?
9. Community forestry is effecting land use change and why?
10. Influence of market (food supply from external sources, increasing remittances, road network, local job/employment opportunities etc) on land use/cover change.
11. Shifting cultivation – the trend, and why
12. Occurrence of fire – the trend and why
13. Infrastructure (road) – when it has been started and where there is road network – relationship between migration and road network?
14. Impact of human settlements on different distance