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Mapping and Modelling of Land Use Change in Nepal

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Abstract

Land use changes are a common occurrence resulting from different factors in Nepal. There is a need for better understanding of the temporal and spatial change dynamics of land uses as well as their future projections. This paper assesses the land use change and its impact on carbon stocks and provides future scenarios of land use changes and their impacts on carbon stocks. The methods involved classification of medium resolution satellite image using Object Based Image Analysis (OBIA) techniques, analysis of the change across three time frames, modelling the future land use, and assessment of the impacts on carbon stocks. OBIA was used for the image segmentation and image classification for the assessment of land uses present in two different periods i.e. 2010 and 1990. The classification of the images was carried out using the spectral characteristics of the Landsat images. Image indices, i.e., Vegetation Index were used for land use classification.

The land use changes over time and space was analysed using Geographical Information System (GIS) overlaying techniques. A future scenario model was prepared using Land Change Modeler of IDRISI software. The study has focused on the land use changes and their future projection based on the potential transition of the land uses. The comparison of land use maps from 1990 to 2010 shows that the different pattern of annual land use changes in different districts such as forest areas are increasing at annual rate of 0.3 per cent in Rasuwa, 2.3 per cent in Gorkha and 0.6 per cent in Chitwan. Similarly, the agricultural land is decreasing at the annual rate of 0.2 per cent in Rasuwa, 2.4 per cent in Gorkha and 0.8 per cent in Chitwan. Likewise, the future projection of land uses in all the three sites was made using the previous land use pattern and driving forces. There was a 0.1 per cent change annually in forest coverage in both Gorkha and Rasuwa whereas Chitwan showed higher rate of forest cover change of 0.2 per cent annually.

Key words: Land use change, Landsat Modelling, Object based image analysis

INTRODUCTION

Land use change (LUC) is a major cause of terrestrial carbon pool dynamics in the developing countries (Bajracharya *et al*. 2010). LUC is the conversion of land utilisation pattern from one dominant use to another, such as, forest, agriculture, grazing, settlements, and so on. It may lead either to degradation or restoration of the land (Bajracharya *et al.* 2010). The Intergovernmental Panel on Climate Change (IPCC) Good Practice Guideline (GPG) suggests monitoring of the rate deforestation by assessing areas of remaining forest, forest cover change to other land use types and other land use types converted back to forest during a known period of time (IPCC 2007). Clearly deforestation and restoration of forest land has a key role in emission to, or removal, of the atmospheric carbon (FAO 2006; Adhikari 2009). The course of LUC prevailing through the process of depletion of forest and vegetation on the land leads to loss of forest and soil carbon (Awasthi *et al.* 2002; Emiru and Gebrekidan 2013; Nega and Heluf 2013).

The IPCC (2003) and IPCC (2006) suggested for the interchange among six major classes *viz.* forest land, cropland, grassland, wetlands, settlements, and other land. Further, the land use change from forest land to other land types is considered as deforestation, while the land converted from other land use type to forest land can be considered as reforestation. The changes of the stock level of forest are considered as forest degradation or enhancement of forest (GOFC-GOLD 2010).

The land without the practice of forestation, silvo-pastoral activities and agro-forestry practices shows less contribution on the carbon sink either at above ground biomass or inside the soil over the time. Within the time span of recent 30 years since 1980s, Nepal has experienced severe deforestation and it is claimed that the implication of community forestry approach after 1990s has considerable contribution on the restoration of the forest areas (MPFS 1988; MFSC 2013). The current trend of LUC triggered due to the demographic pressure and climate change, the vegetation types of Nepal are being changed by spatial location as well as the altitudinal shift (Lillesø *et al.* 2005). The trend of the LUC due to the different drivers from past to the current date supports to generate the potential transition of LUC with respect to different drivers of LUC. The potential transition then leads to the future modelling of the LUC (Regmi *et al.* 2014). The mountainous country like Nepal has numerous drivers causing LUC. Clearly, the topographic conditions, altitude, slope, aspect and other terrain characteristics also determine the dynamic nature of land use change due to natural processes (Awasthi *et al.* 2002). The other important factor of LUC over time is the climatic factor. The climatic characteristics of the particular areas could also determine the process of LUC. Temperature and rainfall status of the areas may have fundamental role on the LUC. Those topographic and climatic factors would have somewhat longer term effect on the LUC. The anthropogenic interventions on land have short term impact on LUC. The anthropogenic activities like encroachment, overgrazing, exploitation of forest products has direct impact on forest and soil. Whereas economic factors and population growth are having indirect impact on forest and soil degradation as the population growth increases demand of resources and it puts pressure on resources i.e. forest and soil. Thus the study tries to find the dynamics of LUC over 30 years and to model the future changes of land use in the region.

There is a strong demand for assessing the dynamics of land use conversion from, and to the types of land uses such as forest, agriculture, agro-forestry and shrub/grass. The temporal land cover and land use assessment will suffice such need in one step. The next step involves finding the spatial LUC. That is because the overall trend of the changes in the pattern of LUC may be in one direction however the magnitude and sometime direction may be different from place to place due to the focused circumstances of agents or drivers of LUC. As the LUC occur in different spatial location in the course of different time domain, it is obvious that there are many driving forces to direct such changes. Thus the other logic of the study is to find out the drivers of changes and model the future changes in contextual scenarios like business as usual (BAU) or with some interventions i.e. population growth, management interventions, climate change scenario.

STUDY SITES

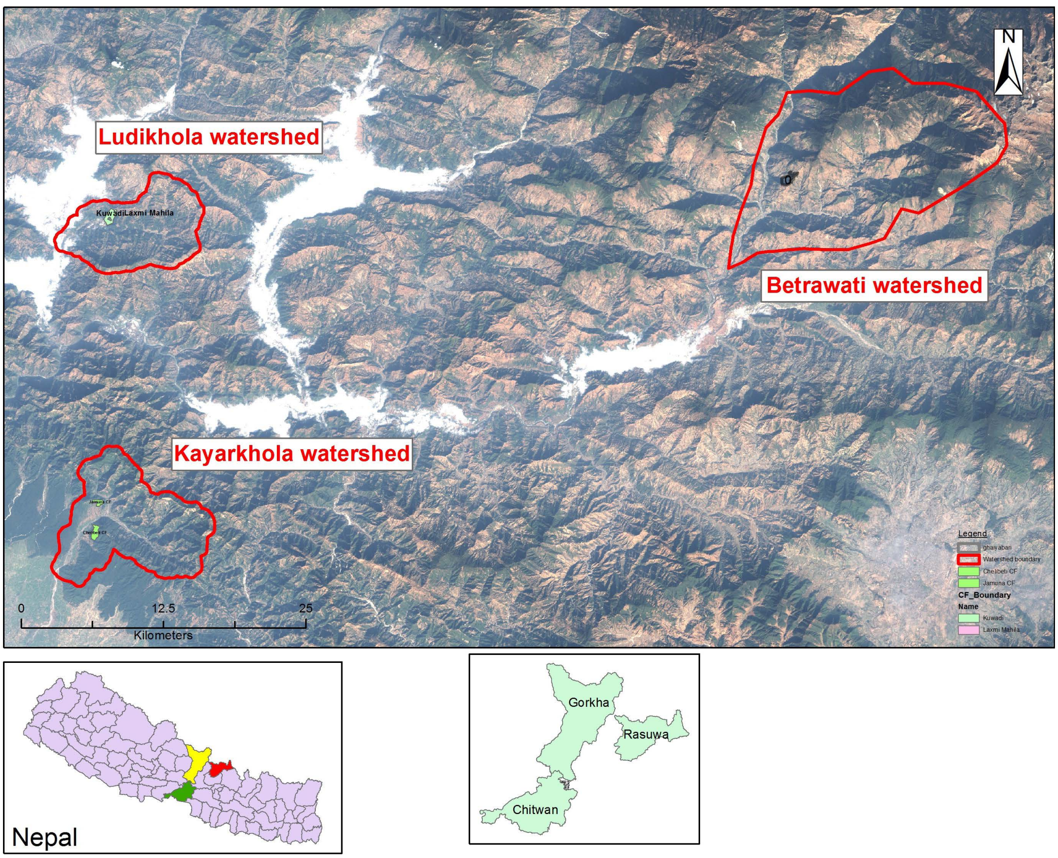


Figure 1: Map of the Study Districts Showing the Location of Watersheds

Watersheds from three districts of Nepal namely Gorkha, Chitwan and Rasuwa were selected for the study. The study sites fall in three eco-regions among the 200 Global Eco-regions. Thus during the selection of study sites difference in vegetation types, difference in altitudinal variations and difference in physiographic zone in Nepal were considered. The study site inside the Betrawati watershed of Rasuwa district represents the temperate forest in high altitude in high mountain.

Study site inside the Ludikhola watershed of Gorkha district represents the hill *Sal* (*Shorea robusta*) forest in the mid-hill with moderate altitude level. Finally, the Kayarkhola watershed of Chitwan district represents low altitude forest of foot hills of Nepal with *Shorea robusta* and associated species (See Table 1).

Table 1: Description of the Study Watersheds in Three Districts

Watershed	District	Altitude	Ecoregion	Forest type
Kayarkhola watershed	Chitwan	Below 500m	Himalayan Sub-Tropical	Subtropical moist broadleaf forest
Ludikhola watershed	Gorkha	500 to 1000 m	Himalayan Sub-Tropical	Subtropical moist broadleaf forest
Betrawati watershed	Rasuwa	1000 to 1500 m	Eastern Himalayan	Temperate Broadleaf and mixed forest

MATERIALS AND METHODS

Data Used

Primary and secondary data from various sources such as remote sensing, Survey Department and Field Survey were used during the analysis. The data used were mainly spatial layers, attribute information and reports from previous studies (Table 2).

Table 2: Data Obtained for the Land Use Change Analysis

Type of Data	Details of Data	Source	Characteristics
Satellite images	• Landsat Images	LANDSAT	Raster, 30m
Elevation data	• Digital Elevation Model (DEM)	Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)	Raster, 30m
Base Layers	• Village/Settlement location • Road Networks • River Networks • Admin layers	Department of Survey, Government of Nepal	Vector
Thematic Data	• Landuse/Land cover 1990 • Landuse/Land cover 2010	Classified	Raster, 30m

Tools Used

The analysis was done using different software and tools. Pre-processing of satellite imageries was done in ERDAS Imagine 2011. The image classification was done in eCognition by Definiens (Definiens 2007). Basic spatial analysis was done in ArcGIS and the modelling was carried in Land Change Modeler (LCM) Tool available in IDRISI.

Methods Used

The methods adopted LUC and its modelling are described in the following paragraphs and mainly includes land use change assessment, field verification, accuracy assessment, the drivers of change and modelling for the year 2030.

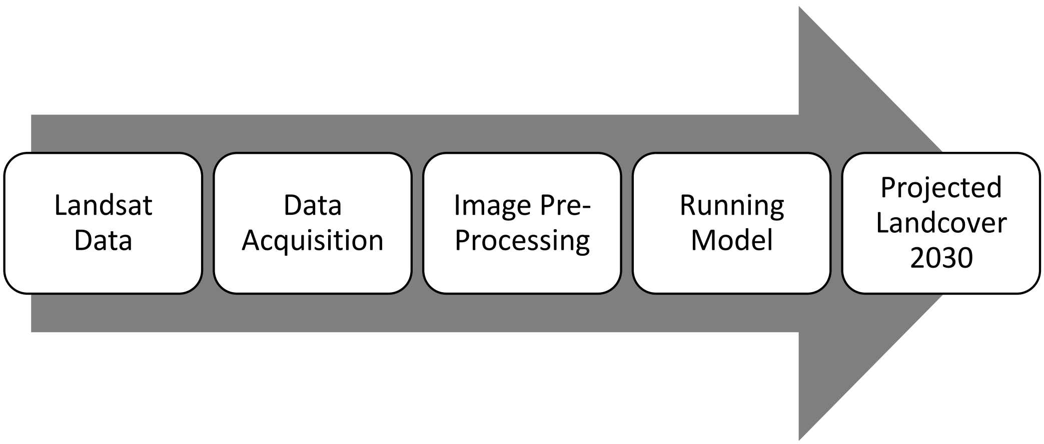


Figure 2: Flow Diagram of the Data Analysis Procedure

Assessment of Land Use Land Cover

The Landsat imageries were acquired for free from Earth Explorer of USGS for both the dates. The remote sensing tool support for the current and past land use pattern in the study areas through the historical imageries. Consistent other product on past and current land use pattern other than remote sensing could not be traced. Landsat Satellite mission has an immense archive of temporal imageries since 1990 with 4 bands to 7 bands data acquired using Landsat MSS to ETM+ sensor respectively. The images from 1990s and 2010s were selected for this study with consistent seasonality of the data. On top of the Landsat images other ancillary data such as DEM (Shrestha and Zinck 2001) and its other derivative i.e. slope and aspect raster layers supported during the preparation of rule-set for the classification (K.C. 2009; Gilani *et al.* 2015; Uddin *et al.* 2015).

Object Based Image Analysis (OBIA) techniques were used to classify Landsat images to obtain land use map for the specific date (Gilani *et al.* 2015; Uddin *et al.* 2015). The OBIA was suggested for the image classification as compared to the pixel based technique (Gholoobi *et al.* 2010). An OBIA technique comprises segmentation, rule-set development and running the classification. The multi-resolution segmentation technique was used with shape and size parameter which tells the size and tonal variation of object generated during the segmentation. Thus, the segmentation process generates objects having similar reflectance provided through size and shape parameters (Kellenberger 2006; Definiens 2007). The rule-set based on various possible parameters were developed using samples taken from the image and iterations to best classify the land use types. Image indices like normalised difference vegetation index (NDVI), land water mask (LWM), and soil adjusted vegetation index (SAVI) were used to prepare rule set to represent the real scenario of land use types. The rule set later applied with some other ancillary information to control the classification like slope, altitude and aspect factors which are also determinants of the natural conditions of land use types (Gilani *et al.* 2015).

Land use classes were broadly fixed for forest, agriculture, water body, and grassland which are actually limited due to the minimum mapping unit (MMU, 1 ha) of the Landsat images having 30 m spatial resolution capacity. Other land use type mainly comprises bare areas, landslides, river beds with sand and open spaces. Agriculture included both cultivated land and land remained fallow for not more than 5 years. The rule set adopted for the current image classification was also used for the images of other dates with some modifications on the thresholds of parameters due to the image characteristics. Due to the slow characteristics of change of water bodies, it was considered as same for all the dates. Post-classification techniques were also used for smoothing the output i.e. Sieve, filter and nearest neighbourhood to get the output free of salt and pepper effect due to noise of classification errors. This approach mainly uses the majority function to smooth the results. The classification process was supplemented through Google Earth images and aerial photographs available for the past dates and was used as a ground truthing data. The ground truthing data were also collected by integrating Google Earth technology and Global Positioning System (GPS) technologies. Random points for the watershed were generated using ArcGIS Random point generation tool and converted it to Keyhole Markup Language (KML) file to overlay it on Google Earth during the field cruising for field verification and ground truthing.

Field Verification

For the purpose of field verification, all the maps of different times were prepared using ArcGIS 9.3 along with the grids. Systematic Random points were generated using Fishnet Tool at regular intervals of 1km and generated the Latitude and Longitude values for those sample points. The locations of all sample points were uploaded to the GPS Garmin Unit aiming to support the navigation of those points in the ground during field verification. Furthermore, a KML file was generated using those sample points which is compatible with the Google Earth and has helped for the precise navigation of points in the field.

Accuracy Assessment

The collected field data were categorised as control and reference points. Those points which were not used for the ground verification were later used for the accuracy assessment. The reference points were also supplemented using Google Earth images and field survey was used to verify the current and past land uses. The total 56 random points at the interval of 1km was generated and by overlaying those points over Google Earth, reference classes were collected from the field. The accuracy assessment shows overall accuracy of 87.6 per cent conducted against the classified and reference from the field.

Spatial Change Dynamics

The changes dynamics among the classes, mainly forests to other classes, other classes to forest, and forest remaining as forest, were calculated between two different periods i.e. 1990 and 2010. The analysis shows the dynamics of forest area change during the study period within study sites. The spatial and temporal changes between classes were assessed using the spatial analysis tools of ArcGIS environment. The spatial analysis enabled the analysis of spatial changes using the map calculator from the land use map of time 1 (i.e. 1990) to time 2 (i.e. 2010).

$$LUC_{SP} = LU_{1990}\ X\ 10 + LU_{2010}$$

The spatial analysis used the multiplication of grid value of first thematic map plus second thematic map. The calculated layers having the values recodeable have recoded to get the spatial change map having areas remaining in the same class and changes from, and to, the classes.

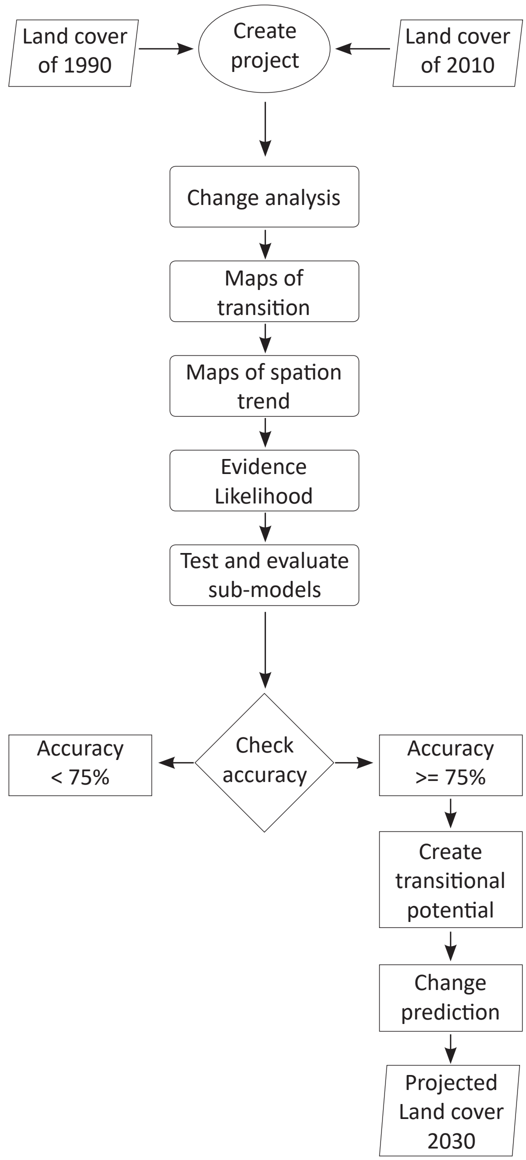


Figure 3: Flow Diagram of the Land Use Modelling Procedure

Drivers of Land Use Change

The key drivers of land use change are shown in Table 3. They consist of four main categories, i.e., climatic, socio-economic, topographic and management factors.

Table 3: Major Drivers of Land Use Change in the Study Watersheds

Drivers of land use change			
Climatic factor	**Socio-economic factor**	**Topography**	**Management**
Rainfall	Population: at ward level	DEM	Community Forestry
Temperature	Distance to Road	Altitude	Re-settlement
	Distance to River	Slope	
	Distance to the forest	Aspect	
	Villages	Soil Productivity	

MODELLING LAND USE CHANGE

The method of land use change modelling comprises of sub-methods of change analysis, characterising transition potentiality and the change prediction for future time line based on the previous changes of land use over the time. The LCM Tool of IDRISI was used for the analysis of changes, transition potentiality of land use and prediction in relation to the REDD+ (Reducing Emissions from Deforestation and Forest Degradation) project scenario. Considering the affecting factors such as distance from the road, distance from the river, and distance from the forest, the projection of potential transition and land use projection for the year 2030 has been made using the "Land Change Modeler".

RESULTS

The outcomes of the study provide the land cover for the years 1990 and 2010 having different classification schemes, the change scenario from 1990 to 2010 and the projected land use land cover for the year 2030.

Land Cover Maps

The land cover map layouts for three dates, namely, 1990 and 2010, were prepared and the resultant maps shown in Figure 4. The land cover and land use were analysed mainly adopting the classification scheme with five classes *viz.* forest, agriculture, settlement, bare areas and other land use.

Change Matrix

A land use change matrix of the different time periods from 1990 to 2010 were prepared as shown in the Table 4 below. The data shows that conversion between agriculture and forest areas seems more significant.

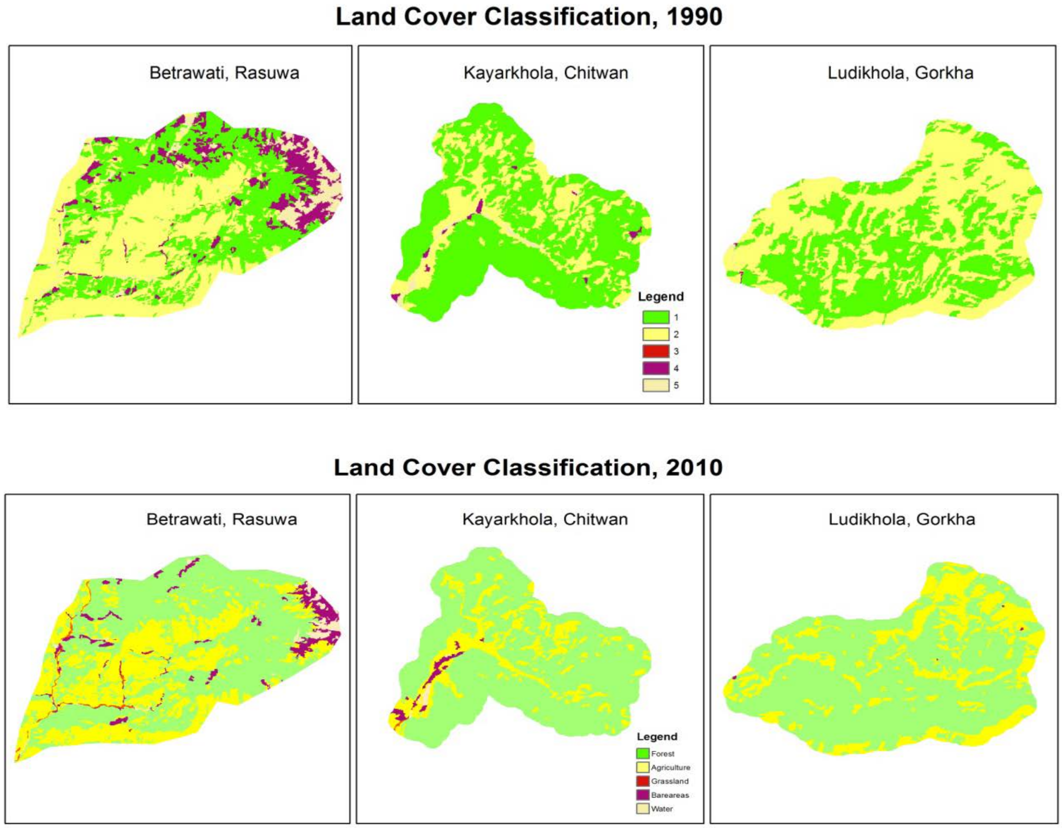


Figure 4: Land Use Change Maps of the Three Study Watersheds over Three Decades

Table 4: Land Cover Change from 1990 to 2010 (area in ha)

Class	Forest	Agriculture	Grassland	Bare areas	Water
Forest	19567	980	7	67	18
Agriculture	6974	11678	57	305	68
Grassland	0	0	0	2	0
Bare areas	1769	650	23	537	43
Water	444	356	95	531	386

Spatial Change

Finally, the spatial change maps for the periods from 1990 to 2010 across three decades were prepared as shown in Figure 5. The spatial changes of land use pattern indicate that the hot-spots of the changes within the watershed are in and around populated areas rather than distant and inaccessible areas.

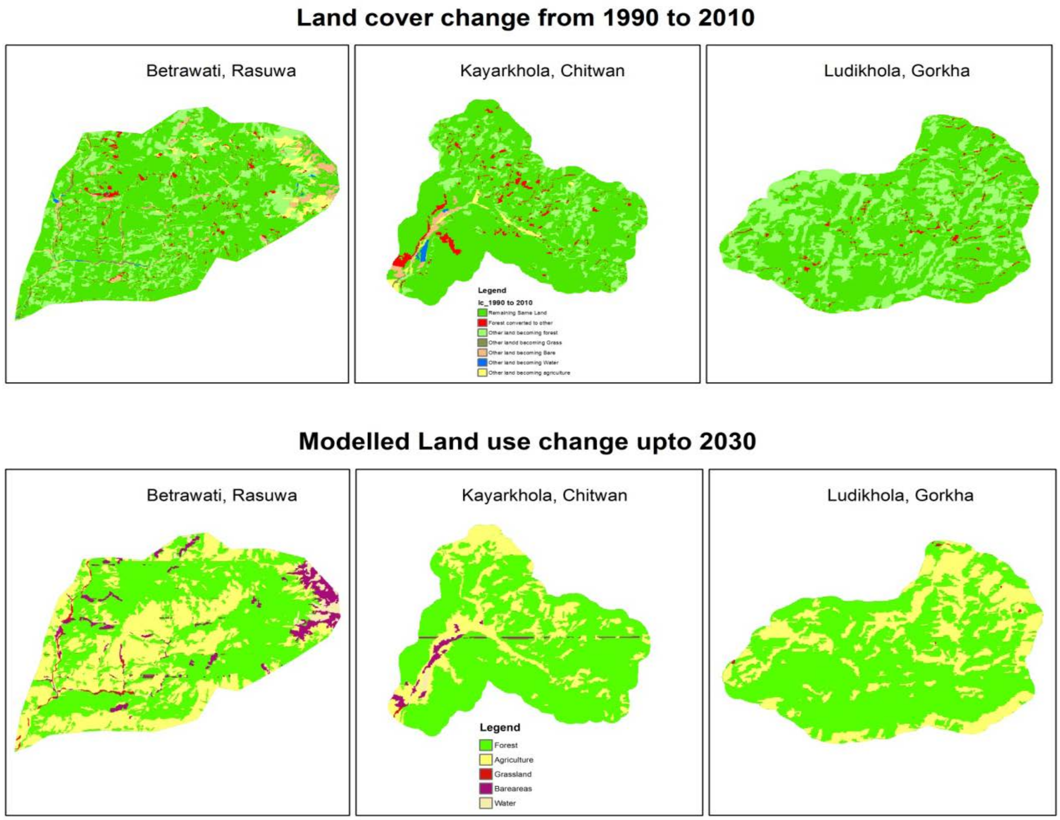
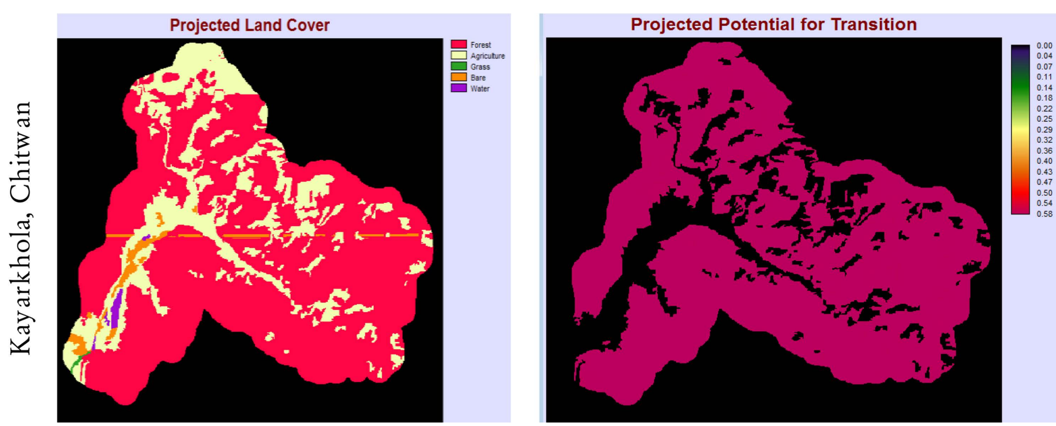


Figure 5: Land Cover Change Map (1990 to 2010) and Model Outputs (2030) for Land Use Change in the Study Watersheds over Three Decades

PROJECTING FUTURE LAND USE CHANGE



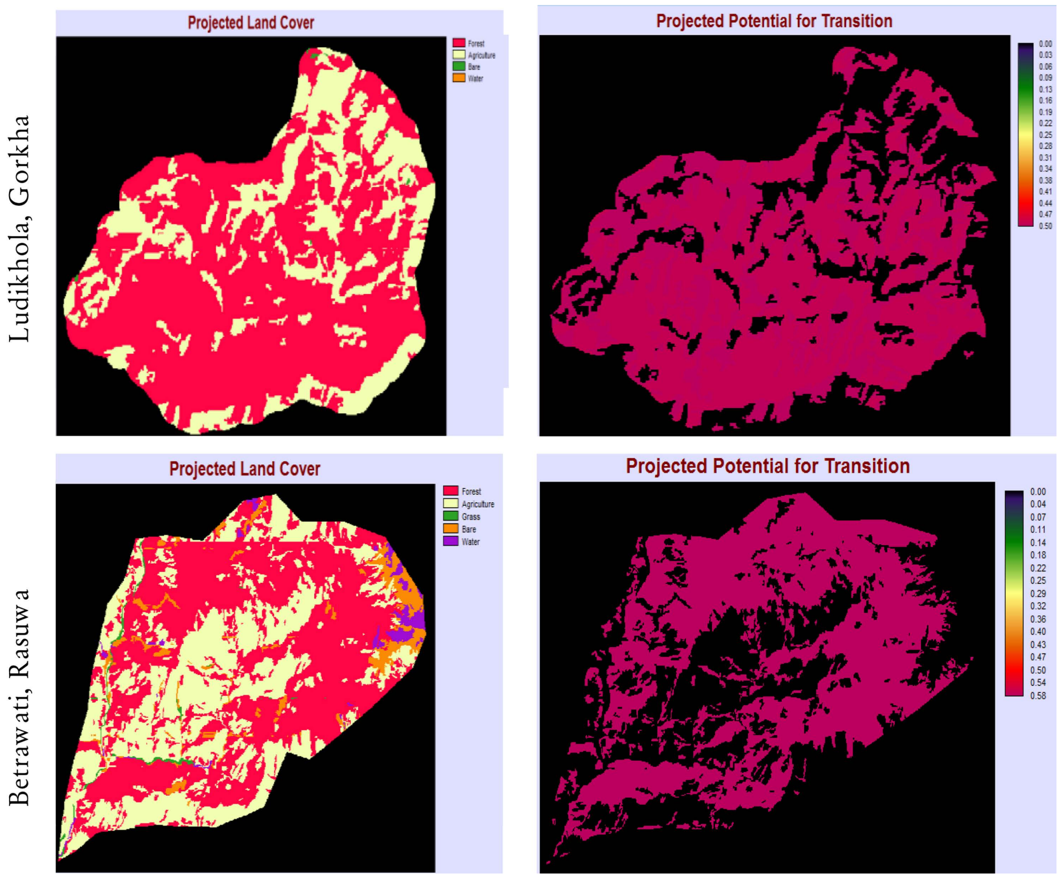


Figure 6: Projected Land Cover Maps for 2030

The projected land cover (Figure 6) shows that the land cover of Chitwan district will increase massively due to agricultural activity in the upper area with slight decrease in the middle portion. This has led the forest area to decrease by small percentage. Likewsie the projected land cover of Gorkha district of 2030 shows small changes in land cover in the middle section. The agricultural land has been increased in the middle section. On the other hand, lower sections of the watershed also show some increase in agricultural land which has altered the forest area. The projected land cover of Rasuwa district of 2030 shows increase in agricultural land similar to other district's projection. Also the water bodies on the upper part seem to expand than 2010 (Figure 6).

Annual Percent Change in Land Use

The forest cover from 1990 to 2010 shows increased rate of change in all study sites with higher rates in Gorkha while agriculture showed decreased rate in all sites with higher rate of decrease in Gorkha district. Other land cover types were also declining in Gorkha. Whereas, sites in Rasuwa showed more stability in terms of land cover dynamics (Table 6).

Table 6: District wise Annual Percent Change of Land Uses from 1990 to 2010

	Rasuwa			Gorkha			Chitwan		
Class	2010	1990	Annual Change (%)	2010	1990	Annual Change (%)	2010	1990	Annual Change (%)
Forest	14949	14055	0.3%	4970	3399	2.3%	7233	6430	0.6%
Agriculture	11033	11536	-0.2%	1553	2951	-2.4%	2060	2452	-0.8%
Others	2424	2871	-0.8%	150	305	-2.5%	559	955	-2.1%

The land use change over two decades from 1990 to 2010 is remarkable in the context of forest cover changes. Those changes are a result of several driving forces including population growth, urbanisation and food requirement of people in the form of cultivation directly and other drivers of land use change which shows more underlying in nature such as illegal felling, political will, political transition, economic trade-off etc.

Table 7: District wise Annual Percent Change of Land Uses from 2010 to 2030 (Projected)

	Rasuwa			Gorkha			Chitwan		
Class	2010	2030	% Change	2010	2030	% Change	2010	2030	% Change
Forest	14949	15368	0.1%	4970	5037	0.1%	8233	8501	0.2%
Agriculture	11033	11081	0.0%	1553	1642	0.3%	2060	2217	0.4%
Others	2424	1996	-0.9%	150	65	-2.8%	609	199	-3.4%

DISCUSSION

The forest cover has been increased in all study sites from 2010 to modelled land cover in 2030 where as Chitwan showed higher rate of increase. Chitwan has shown higher rates of increase in agriculture areas than other study sites and this site showed the higher rate of decrease in the other land cover types which shows the future dynamics of demographic changes in Chitwan.

Kayarkhola in Chitwan has community forestry practices, nevertheless, it has more adverse topographic conditions in terms of variation in altitude and diverse slope and aspects as a result of rugged topography. This has ultimately lagged forest restoration in one way and on the other hand the increase in population dynamics is also contributing to decrease in the forest area. The Betrawati watershed in Rasuwa also shows a decreasing trend of forest coverage which can be attributed to landslides and adverse topographic conditions which includes variation in altitude and slopes even though the watershed falls under the buffer zone of Langtang National Park.

The projection of LUC interestingly shows positive changes in forests in Chitwan and Agriculture are projected with positive changes in Rasuwa district. From the transition factors during the field visit and remote sensing data analysis, it was found that landslide is responsible for land use changes in Rasuwa whereas in Chitwan district, conservation practices and population growth are the factors which determine the LUC pattern over time. Similar trend of land cover and forest cover changes from 1990 and 2010 were reported by Uddin *et al.* (2015).

The current trend of LUC has been reported over two decades from 1990 to 2010 and is remarkable specifically in the context of forest cover changes (DFRS 2014; Uddin *et al.* 2015). Those changes are a result of several driving forces including population growth, urbanisation and food security of people in the form of cultivation. Moreover, other drivers of LUC exists which appear to be more of underlying factors such as political will, political transition, and economic trade-off among others. The trend of the LUC has also been shown in this piece of study in the three watersheds of Nepal. The future projection of land use and forest cover shows the future trend of LUC considering distance from the road head, distance from the river, topographic conditions among others.

CONCLUSION

In conclusion, the land use and land cover changes are affected due to different potential drivers such as road construction, agricultural expansion and natural factors such as landslide. There are considerable changes in the forest coverage to other land use type and from other land use type to forest during the period of 1990 to 2010. Chitwan showed somewhat balanced dynamics with approximately 1 per cent increase in forests and 1 per cent decrease in agricultural land annually.

The study suggests that increase in the forest coverage can ensure higher carbon sequestration in the forest. Decrease in the overall demand of forest products including timber and fuelwood from the local people can reduce pressure in the forest. For this, application of alternative energy schemes such as improved cook stove (ICS), Bio-gas plant and plantation program to enhance forest restorations considering the adverse climatic and topographic conditions in the area can be made.

A precise study could be made using a more systematic sampling in the region which will gain attention of the planners and policy makers and can enhance carbon sequestration and ensure sustainable management of the forests.

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