Land use land cover change in mountainous watersheds of middle Himalayas, Nepal

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Abstract

The study was aimed at examining land use dynamics in two typical mountain watersheds in Rasuwa district in the central development region of Nepal, namely Chileme and Bamdang. A comparative change analysis was performed for the last three decades i.e. 1976–1988, 1988–2000 and 2000–2006 using RS & GIS technology. The analysis was based on the multi-temporal Landsat and IRS images taken in December 1976, December 1988, December 2000 and January 2006. During the last three decades, forest cover has been reduced drastically with increasing population pressure and agricultural expansion. Some limiting factors such as socio-economic setup and policies have also contributed to these changes and resultant land use in the watersheds.

1. Introduction

Himalaya is the most complex and fragile ecosystem among the global mountain system. It figures a major biophysical setting of the earth (Singh 2006). The destabilization of fragile mountain slopes through deforestation, agriculture expansion and excessive grazing has increased land degradation in the mountain regions (Ives and Messerli 1989; Thapa and Weber 1995). More than 90% of the population lives in rural areas with exponential population growth and unequal land distribution forcing farmers to expand agriculture on marginal lands on high slopes (Rao and Pant 2000). The socio-economic scenario of hillside farmers in the mountain region is characterized by a simple subsistence economy, mainly for self-consumption. The agricultural expansion associated with population growth resulted in the modification of land use and land cover structure.

Different techniques have been evolved to collect, analyze and to present the natural resource data. Remote Sensing and GIS technology is accepted as an efficient and effective tool to gather the land use land cover change information, especially for the inaccessible areas (Ulbricht and Heckendorff 1998; Gautam et al. 2003, Joshi et al. 2005). Various attempts have been made to study land use land cover dynamics in the mountain regions (Joshi et al. 2004; Joshi and Gairola 2004) but only limited work describes the land use land cover change pattern. In the present paper, an attempt has been made for comparative study of the land use land cover dynamics in two watersheds situated in the same geographical area but varying resources and diverse social implication. The quantitative land use dynamics was assessed from temporal satellite images using state-of-the-art technology i.e. RS & GIS.

2. Study Area

The study area comprised of the Chileme and Bamdang watersheds in Rasuwa district. It is located in the central development region of Nepal. The study area and its location is presented in the Figure 1.

3. Materials and Methods

Landsat MSS from December 1976, Landsat TM from December 1988, Landsat ETM+ from December 2000 and IRS P6 LISS III from January 2006 were used for land use land over mapping. The satellite data were radiometrically and geometrically (rectification with UTM/WGS 84 projection) corrected. The datasets were maintained with sub pixel level accuracy.

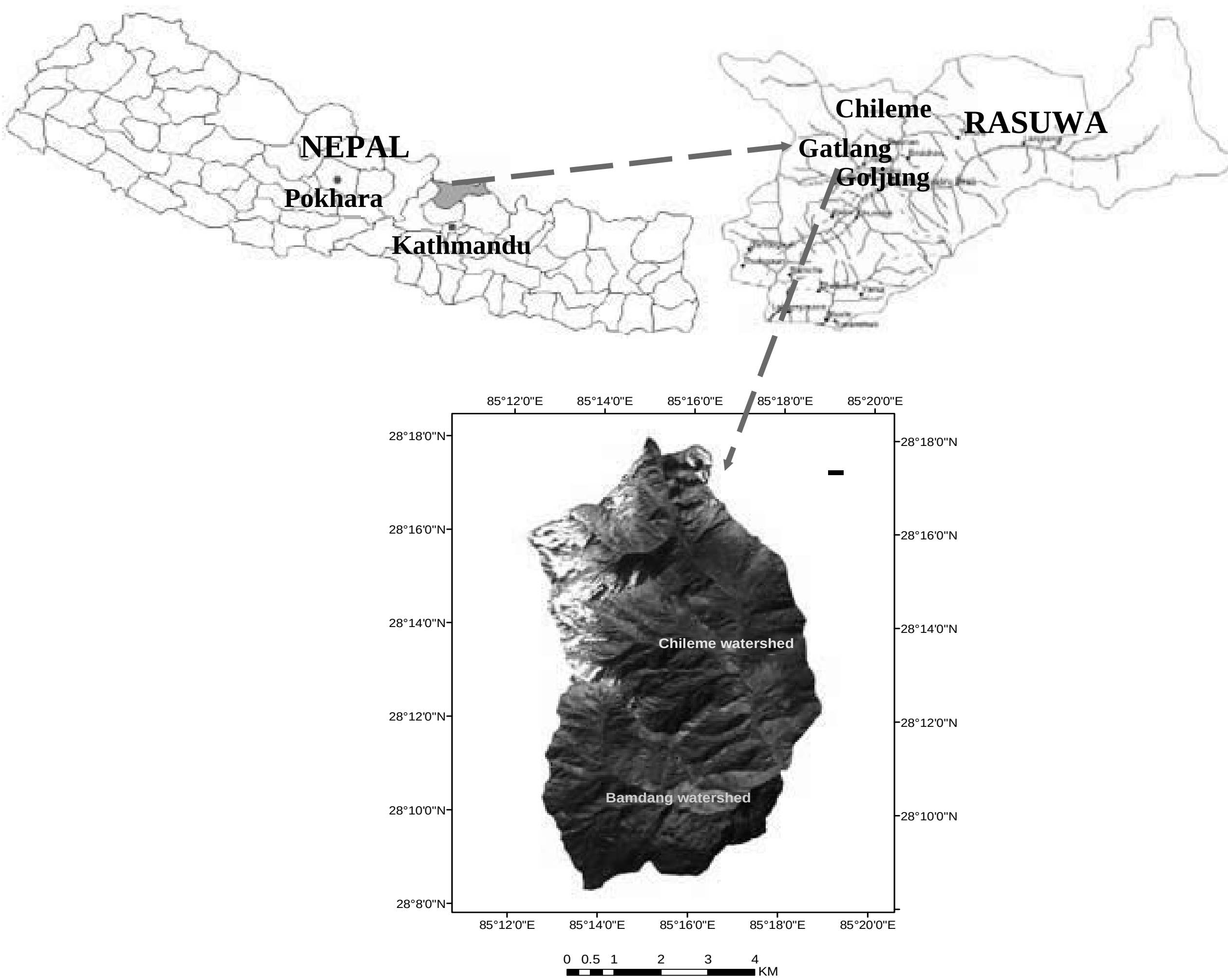

Figure 1. Study area and its location

Contour map was prepared in 40m contour intervals from 1:50000 scale topographic maps produced by the Department of Survey (Nepal). Similarly drainage and spot height map were prepared from the same topographic maps. A Digital Elevation Model (DEM) was generated in ARC/INFO software using contour, drainage and spot height map. Slope and aspect maps were derived from DEM in ERDAS software. The land use land cover maps of respective years were intersected with slope and aspect index map in ERDAS software to assess land cover distribution along the topography. Change detection was performed by intersecting thematic land use land cover map of 1976 and 1988, 1988 and 2000, and 2000 and 2006 in ERDAS. The time series land use maps were compared to locate change areas. The intersected maps were recoded into binary variables 1 and 0 representing “change” and “no change” areas. The slope and aspect maps were intersected with recoded changed/unchanged map to find out the role of topographic parameters on land use land cover change.

4. Results

On screen visual interpretation of satellite data was carried out to find out different land use land cover classes in conjugation with information from topographic maps and ground truth. The identification and delineation of land use classes with other cover types were done by following the standard visual interpretation technique. A uniform land use classification scheme was used while interpreting the land use classes. The land use map of the year 1976, 1988, 2000 and 2006 were prepared for both watersheds. Total 14 land use land cover classes were identified in Bamdang watershed whereas total 15 land use land cover classes were identified in Chileme watershed (Figure 2).

The major land use classes identified were forest and non-forest. Forest was further subdivided into pine mixed forest, mixed forest, conifer forest other than pine, degraded forest, shrubs/bushes, grassland, pasture, and scrub. Non-forest was further classified into tree-farm land, agriculture, water body and snow. Distribution of land use land cover in Bamdang and Chileme watersheds is shown in the Table 1 and 2 respectively.

The results of land use land cover change analysis showed, out of 8617.06 ha. geographical area 1702.74 ha. (19.76% area) was under change category in Chileme watershed and out of 4163.75 ha. geographical area 1292.28 ha. (31.03% area) was under change category in Bamdang watershed during 1976 and 1988. The analysis revealed a huge change in open pine mixed forest in Chileme and in open mixed forest in Bamdang watershed. A total 613.13 ha of open pine mixed forest was converted into other land use types, majority comprised of agriculture (216.63 ha) in Chileme watershed. Similarly, 248.25 ha open mixed forest was converted into other land use types, majority comprised of agriculture (60.63 ha) in Bamdang watershed.

During 1988 and 2000, 1390.44 ha area was assessed under change category in Chileme and 1089.31 ha in Bamdang watershed. During this time, the major changes were in open mixed forest in both watersheds. Total 538.63 ha open mixed forest was converted into other land uses especially degraded forest (466.81 ha) in Chileme and total 709.19 ha open mixed forest was converted into other land uses especially degraded forest (584.06 ha) in Bamdang watersheds. During 2000 and 2006, 282.94 and 239.19 ha area was assessed under change category in Chileme and Bamdang watersheds respectively. During 2000 and 2006, the major changes were in open mixed forest in Bamdang whereas the major changes assessed in shrubs and bushes in Chileme watershed. 49.25 ha open mixed forest was converted into other land use classes especially agriculture (22.75 ha) followed by degraded forest (21.25 ha) in Bamdang watershed whereas total 59.63 ha area converted into alpine pasture in Chileme watershed. The annual rate of change was assessed as 8.34%, 8.33% and 16.66 % in Bamdang and 5.61%, 10.90% and 16.67% in Chileme watershed during 1976 – 1988, 1988 – 2000 and 2000 – 2006 respectively. The present result demonstrated the effect of topography on land use land cover change. Slope and aspect maps were taken into consideration while analyzing change along topography. Change analysis revealed that there were very less changes up to 6 degree slope in both watersheds. As

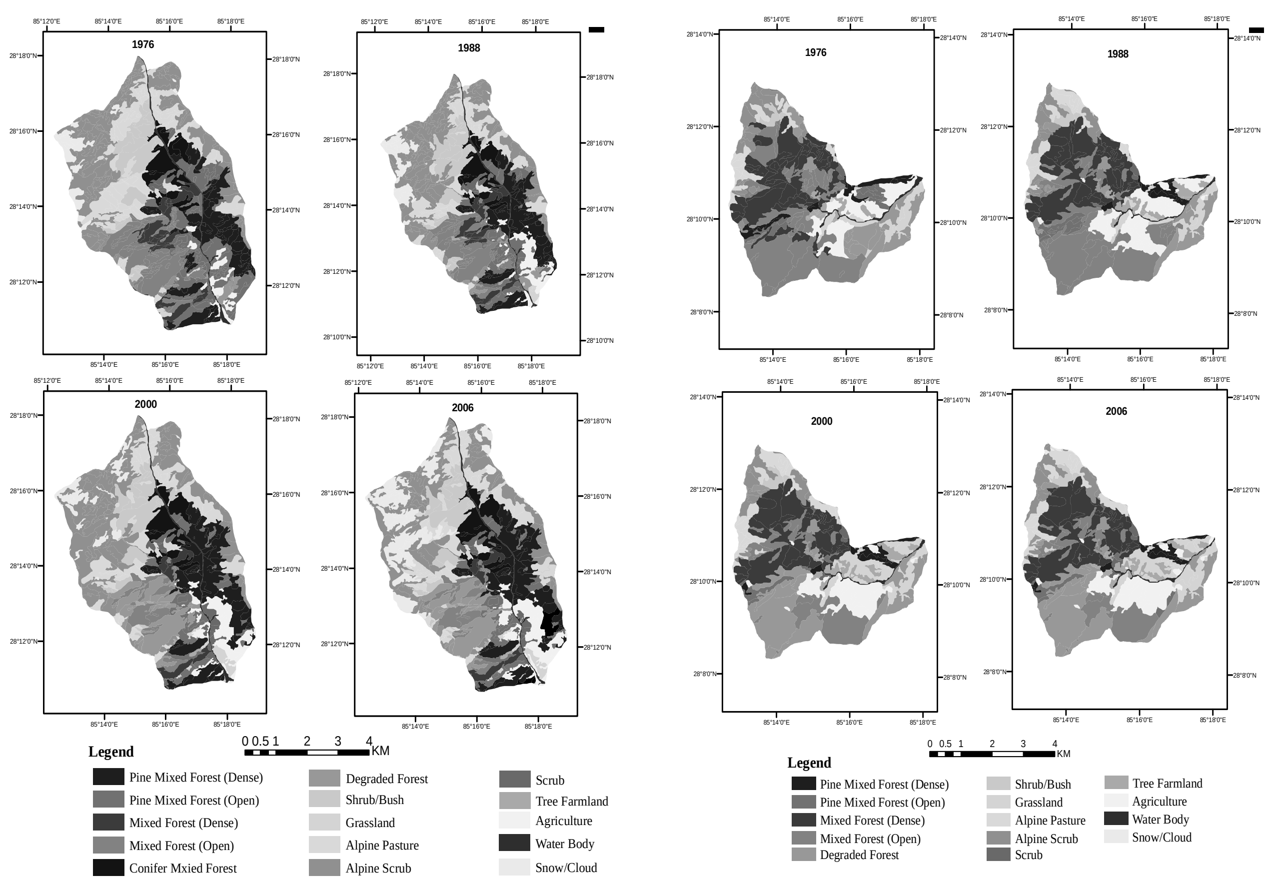

Figure 2: Land Use Land Cover map of Chileme and Bamdang watershed from 1976 to 2006

the slope increased the change areas were also increased. The change process was gradual between 6 to 25 degree slopes. However, very prominent changes were assessed between 25 and 55 degree in both watersheds. This process of change coupled with collected socioeconomic information revealed that people are shifting towards inaccessible areas for resource extraction. This might be because of the fact that resource in the gentle slope was already reached beyond the threshold of optimum utilization.

Table 1: Area statistics of different forest/land use land cover in Bamdang watershed

S.N.	Land Use Class	1976		1988		2000		2006	
		Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
A.	Forest								
1	Pine Mixed Forest (Dense)	147.69	3.55	114.63	2.75	117.38	2.82	113.81	2.73
2	Pine Mixed Forest (Open)	130.88	3.14	126.69	3.04	92.31	2.22	89.81	2.16
3	Mixed Forest (Dense)	988.31	23.74	948.44	22.78	943.50	22.66	959.81	23.05
4	Mixed Forest (Open)	1205.69	28.96	1242.19	29.83	561.94	13.50	540.44	12.98
5	Degraded Forest	459.19	11.03	295.38	7.09	923.81	22.19	891.06	21.40
6	Shrub/Bush	46.25	1.11	51.19	1.23	51.00	1.22	52.38	1.26
7	Grassland	195.56	4.70	164.25	3.94	341.00	8.19	348.56	8.37
8	Alpine Pasture	193.88	4.66	286.75	6.89	310.69	7.46	277.06	6.65
9	Alpine Scrub	294.25	7.07	241.06	5.79	216.56	5.20	206.19	4.95
10	Scrub	17.38	0.42	21.44	0.51	41.81	1.00	40.81	0.98
	Sub Total	3679.06	88.36	3492.00	83.87	3600.00	86.46	3519.94	84.54
B	Non-Forest								
11	Tree Farmland	85.69	2.06	139.69	3.35	162.31	3.90	196.75	4.73
12	Agriculture	355.44	8.54	499.25	11.99	365.38	8.78	405.94	9.75
13	Water body	43.56	1.05	32.81	0.79	36.06	0.87	33.00	0.79
14	Snow							8.13	0.20
	Sub Total	484.69	11.64	671.75	16.13	563.75	13.54	643.81	15.46
	Grand Total	4163.75	100	4163.75	100	4163.75	100	4163.75	100

Table 2: Area statistics of different forest/ land use land cover in Chileme watershed

S.N.	Land Use Class	1976		1988		2000		2006	
		Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
A.	Forest								
1	Pine Mixed Forest (Dense)	1156.44	13.42	1318.75	15.30	1310.25	15.21	1305.38	15.15
2	Pine Mixed Forest (Open)	1081.56	12.55	549.00	6.37	436.81	5.07	425.75	4.94
3	Mixed Forest (Dense)	391.38	4.54	327.63	3.80	197.13	2.29	193.63	2.25
4	Mixed Forest (Open)	924.50	10.73	924.75	10.73	386.75	4.49	382.94	4.44
5	Coniferous Forest	469.25	5.45	449.94	5.22	449.19	5.21	447.13	5.19
6	Degraded Forest	67.56	0.78	83.38	0.97	702.19	8.15	681.38	7.91
7	Shrub/Bush	653.94	7.59	696.31	8.08	658.38	7.64	602.31	6.99
8	Grassland	28.38	0.33	112.88	1.31	108.00	1.25	94.25	1.09
9	Alpine Pasture	1342.88	15.58	1049.38	12.18	1090.19	12.65	1047.50	12.16
10	Alpine Scrub	1859.88	21.58	2080.94	24.15	2216.00	25.72	1652.38	19.18
11	Scrub	98.25	1.14	234.19	2.72	208.44	2.42	199.56	2.32
	Sub Total	8074.00	93.70	7827.13	90.83	7763.31	90.09	7032.19	81.61
B.	Non-Forest								
12	Tree Farmland	0.00	0.00	7.06	0.08	24.00	0.28	28.88	0.34
13	Agriculture	181.69	2.11	342.88	3.98	452.50	5.25	522.00	6.06
14	Water body	95.06	1.10	90.38	1.05	96.31	1.12	88.32	1.02
15	Snow	266.31	3.09	349.62	4.06	280.938	3.26	945.67	10.97
	Sub Total	543.06	6.30	789.93	9.17	853.75	9.91	1584.87	18.39
	Grand Total	8617.06	100	8617.06	100	8617.06	100	8617.06	100

Aspect generally refers to the direction to which a mountain slope faces. It is also an important topographic characteristic, which affects the distribution and productivity of various forest types.

In both the watersheds, higher changes were assessed in south-east, south and south-west aspects. These slopes are highly illuminated for greater time period and consequently have high productivity accompanied with the changes. However, north, north-east and north-west aspects have relatively low productivity due to less solar illumination and resulting less human pressure.

5. Discussion

The present analysis identified three main driving forces responsible for land use land cover change in the study area. These are socio-economic driver, biophysical driver and management practices. Forest being the dominant natural resource, it covers an area of 63.42% in Bamdang and 46.88% in Chileme watershed. Annually 15.22 ha of land under forest and grassland in Chileme watershed and 11.23 ha in Bamdang watershed were converted into agriculture fields. The change analysis revealed three important changes namely increase in degraded forest, decrease in dense forest, and agricultural expansion. A similar trend was reported by Joshi et al. (2004) and Joshi and Gairola (2004) while working in Garhwal Himalaya, India.

It is generally accepted that the land use change may be prominent in gentle slope areas (Zeleke and Hurni 2001; Chen et al. 2001 and Semwal et al. 2004). But the present study showed a steeper slopes were also affected by land use change. This result supports the findings of Wakeel et al. 2005 while working with mid elevation zone of Central Himalaya in India. They found increasing amount of forest loss on steeper slopes. As presented earlier, it might be because of the resources in the lower slope were already used by the villagers and now they concentrate their activities in the higher slopes areas where resource are plenty.

Assessment of land use change has been a key to plan and implement sustainable land use planning to cope with global climate change. Global initiative and local action is of urgent need. The Bali Conference on Climate Change has agreed to consider a new initiative to help Emission Reduction from Deforestation and forest Degradation (REDD). Developing countries are facing challenges to make economic and policy incentives to reduce emissions from land use change (Santilli et al. 2005). It is possible to measure temporal forest carbon stocks by using remote sensing data with ground verification (Rosenqvist et al. 2003, Drake et al. 2003). Assessment of spatiotemporal land use change using remote sensing and GIS is starting points to begin REDD implementation (Herold and Johns 2007) at local level.

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