Photonirvachak
Journal of the Indian Society of Remote Sensing, Vol. 32, No. 2, 2004

LAND COVER DYNAMICS IN GARHWAL HIMALAYAS - A CASE STUDY OF BALKHILA SUB-WATERSHED

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ABSTRACT

The present paper focuses on land cover dynamics pattern in Balkhila sub-watershed situated in Garhwal Himalayas. This study contributes example from human shaped ecosystem in mountainous regions where fragmentation of natural resources is active. The remote sensing and GIS has been used to understand the land cover dynamics along the topography. The results report that the land cover dynamics is dependent on the aspect due to sun illumination. The altitude and slope are no more a barrier for resource extraction and the human activity zone is shifting towards higher altitudes and slopes. The changes are also defined along the road and settlements.

Introduction

Land cover pattern, with regard to both their space and time variations, are a function of societal characteristics and qualify as one of the major consequences of human interventions on the landscape. The Himalayan zone is one of the most sensitive regions in terms of its natural environment, stability and is characterized by its complexity. The land cover dynamics is in accelerating rate in these regions because of high dependency on natural resources for the livelihood. Moreover, the rugged terrain, variation in climate, and the requisite to maintain land cover compel the locals to extract the natural resources. The vastness and 'difficult to reach' nature of these areas poses serious limitations on ground observation; consequently field experimentation and information collection to understand and develop planning activities.

Remote Sensing is accepted as an efficient and effective tool to gather the information in the remote areas. In Himalayan region, use of this tool was introduced in mid eighties (Singh *et al.*, 1985; Tiwari *et al.*, 1985) to identify landscape/land use pattern (Singh *et al.*, 1984), mapping, monitoring (Joshi *et*

Recd. 29 May, 2003; in final form 7 Jan., 2004

al., 2003) and change detection (Rathore *et al.*, 1997). Only limited attempts have been made so far to use this tool in describing the land cover dynamics and its relation with topographic features in this region. The knowledge of these concepts is very useful for understanding the impact of climate change on land cover and *vice-versa*. In this paper we have studied the land cover dynamics in a mountain landscape of Garhwal Himalayan region during 1991-2001 and the dynamics with particular reference to topography in Himalayan region.

Study Area

Balkhila sub-watershed is an important watershed in Alaknanda basin in outer Garhwal Himalayan range and forms a part of Chamoli Garhwal in Gopeshwar district. It lies within 30° 23' N to 30° 33' N latitude and 79° 10' E to 79° 23' E longitude. The average altitude is varying from 600 m to 3600 m above mean sea level. The area of watershed is approximately 160 km^2. Climate of the area varies between subtropical to temperate on high elevation (more than 2000 m). This region is covered by mostly forest of oak, pine and conifer/spruce mixed. The patches of grassland are found on the high altitude. The lower altitudes are mostly occupied for the agricultural practices along the river. The agriculture fields are low productive, which fulfils the requirements of daily use only.

Materials and Methods

Data Used

Satellite Data

IRS-1D LISS III data path/row 96/49 of 01 February 2003 was used. As a historical data IRS-1A LISS II data path/row (28/46) of 20 February 1991 was used. The topographic maps of the study area at 1:50 000 scale were used for georeferencing and field data collection.

Field Data Collection

A reconnaissance survey was carried out to collect the ground information. The GIS database generated from the topographic sheets was further updated with the latest changes in the watershed. Ground truth was collected during the field visit with the help of satellite image, toposheet, GPS and magnetic compass. The image elements were correlated with the ground truthing and the interpretation key was developed. The tonal variation representing the different classes was marked on the hard copy image. The entries were made in the field description form at each of the sample point. Base maps including contour, drainage, road, settlement, village location and watershed boundary was extracted from the topographic sheets. The interpolation technique was used to generate digital elevation model, slope and aspect maps.

Visual interpretation

In mountain area, especially in Himalayas due to the terrain complexity, the spectral signature is influenced by elevation, aspect and slope. The same objects may show different reflectance or the different objects may have the same reflectance. In this situation, having the intensive ground truth, on-screen visual interpretation is employed. The interpretation key for the land use/land cover classification is given in table 1.

Land Use/Land Cover Mapping

IRS-1D LISS III data was used as the source for the land use/land cover mapping. The interpretation key formulated during fieldwork has been used. The shadowed areas were put to corresponding classes on the basis of ground knowledge. In order to achieve more accuracy, topography was used as important key to differentiate between forest types. Land Use/Land

Table 1: Key for visual interpretation of the image

Class	*Tone*	*Texture*	*Shape*	*Size*	*Pattern*
Oak	Dark Red	Smooth	Contiguous	Medium	Irregular
Oak Mixed	Dull Red	Smooth	Contiguous	Medium	Irregular
Pine	Brown to Reddish Brown	Medium	Contiguous	Large	Irregular
Fir/Spruce	Dark Black Red	Smooth	Contiguous	Small	Irregular
Conifer Mixed	Light Reddish Brown	Medium	Contiguous	Large	Irregular
Grassland	Light Red Color	Coarse	Contiguous	Large	Irregular
Scrub	Light Yellowish to Cyan	Coarse	Contiguous	Medium	Irregular
Agricultural woodland	Pink	Coarse	Regular	Small	Irregular
Agriculture1	Cyan	Smooth	Regular	Medium	Irregular
Agriculture2	Yellowish + Pink	Smooth	Regular	Medium	Irregular
Water body	Black Blue	Smooth	Linear	Small	Linear
Glaciers	Blue Black/white	Smooth	Regular	Small	Irregular
Cloud	White	Smooth	Contiguous	Large	Irregular
Snow	Light Sky Blue	Smooth	Contiguous	Large	Irregular

Cover (LULC) map for 2001 has been prepared. The same vector layer was displayed over IRS-1B LISS II dataset to prepare LULC map of year 1991. The vector layer was rectified to the polygons, which have been changed. With the repetitive editing of polygons LULC map of 1991 was finalized. For the pure forest cover classes, three density categories have been delineated *viz.*, high (>70%); medium (40-70%) and low (10-40%) on the basis of tone and texture.

Change Detection

The LULC map of 1991 and 2001 was overlaid to generate change matrix. The change and unchanged map was generated. The changes in the LULC were analysed along topography *viz.*, slope, altitude, aspect and human interference *viz.*, distance from settlement and road.

Results and Discussion

Land Use/Land Cover Mapping

The satellite data of 2001 and 1991 have been classified into eighteen (18) classes *viz.*, Oak (high density), Oak (medium density), Oak (low density), Oak mixed, Pine (high density), Pine (medium density), Pine (low density), Fir/Spruce, Conifer Mixed, Grassland, Scrub, Agriculture woodland, Agriculture1, Agriculture2, Water body, Glaciers, Cloud and Snow. The forest classes were mapped using topography as control (Fig. 1b and 1c). The area statistics of the land cover classes for year 1991 and 2001 is given in table 2.

Oaks (*Quercus leucotrichophora* and *Q. floribunda*) have been observed, namely the *Ban* oak found at the altitude of 1800-3020 m mainly at

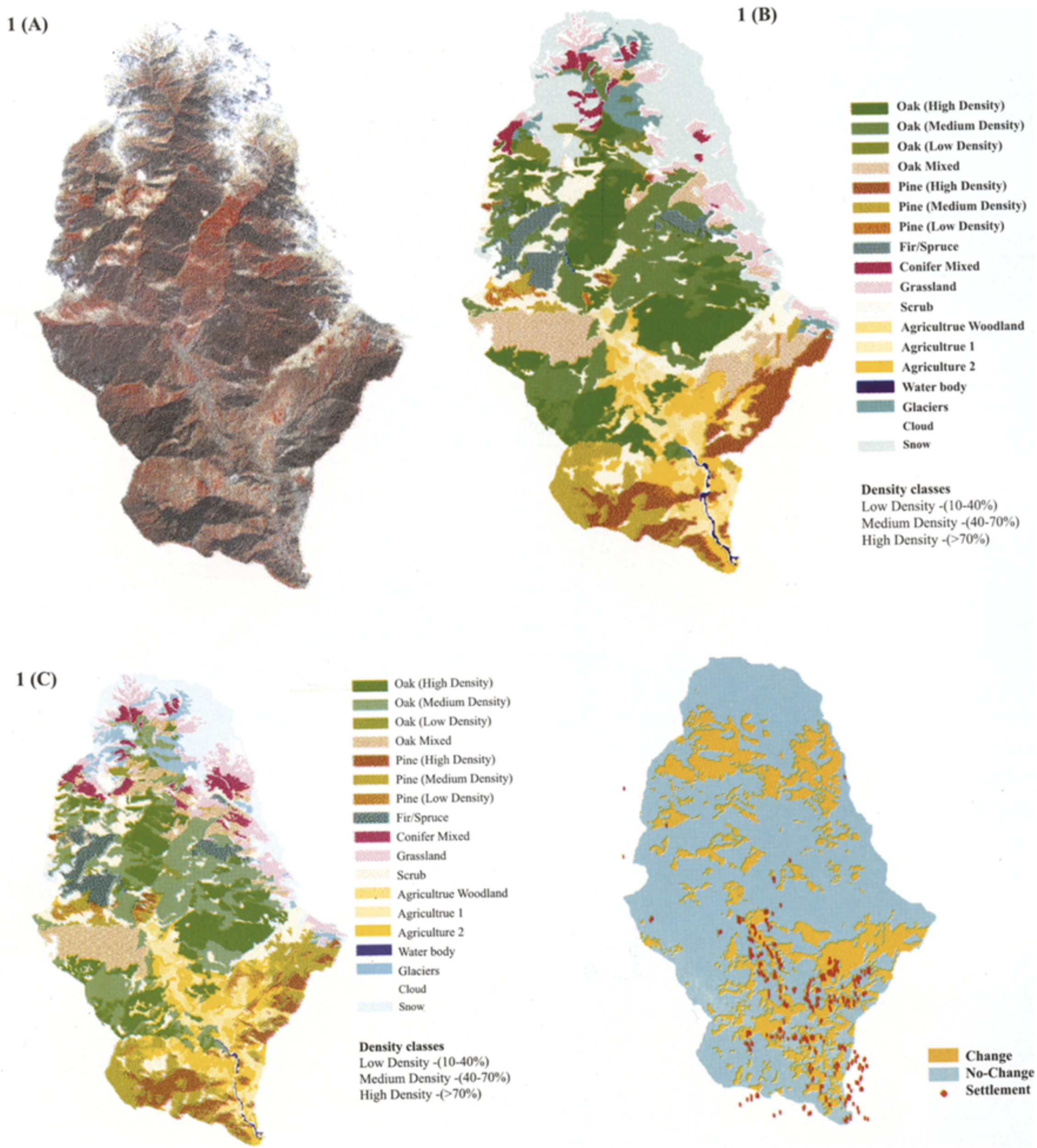


Fig. 1. Spatial maps of Balkhila sub-watershed showing (a) FCC of IRS-1D LISS III data, (b) Land Use/Land Cover (LULC) of 1991, (c) Land Use/Land Cover (LULC) of 2001, (d) Land Use/Land Cover Change

Table 2: Area statistics of land use/land cover

Classes	1991		2001	
	Area km²	Area (%)	Area km²	Area (%)
Oak (High Density)	24.31	15.15	19.73	12.29
Oak (Medium Density)	23.86	14.87	27.08	16.87
Oak (Low Density)	1.98	1.24	1.08	0.67
Oak Mixed	12.90	8.04	12.53	7.81
Pine (High Density)	10.16	6.33	8.26	5.15
Pine (Medium Density)	7.93	4.94	11.77	7.33
Pine (Low Density)	1.14	0.71	1.86	1.16
Fir/Spruce	5.16	3.22	5.10	3.18
Conifer Mixed	2.57	1.60	4.40	2.74
Grassland	7.60	4.73	9.35	5.83
Scrub	14.78	9.21	13.36	8.32
Agriculture woodland	5.64	3.52	5.75	3.58
Agriculture 1	5.97	3.72	7.16	4.46
Agriculture 2	7.09	4.42	9.43	5.88
Water body	0.43	0.27	0.37	0.23
Glaciers	3.76	2.34	4.62	2.88
Cloud	2.67	1.67	3.40	2.12
Snow	22.50	14.02	15.21	9.48
TOTAL	**160.46**	**100**	**160.46**	**100**

the northern aspect and *Moru* Oak at altitude of 2100 – 3020 m mainly on the southern aspect. In the present study, all the types of oak are classified into single class, as a Himalayan moist temperate forest distributed at an altitude of 1800 –3020 m above msl. Oak is used as fodder, fuel wood and plays a very important role as resource for the subsistence of the villagers. It has been modified more by human interventions. Low density oak has two components, one is open oak due to natural process, and another is lopped oak with the consequence of fodder and fuel wood collection. Oak mixed patch is found in the eastern part of the watershed with associate species of pine, *Syzigium* and oak scrub. These are the areas with maximum destruction for the extraction of fuel and fodder. Some of the low density oak formed due to excess extraction have been classified in this category. Because of the plantation done by the forest department and the blanket ban on cutting, the Pine trees have been slightly stabilized. The other reason of less extraction of these forests is low priority for fodder and fuel. Moreover, these are found on the ridge of the hill or on the steep slopes. The extraction is basically for the timber requirement. Sometimes, the resin is collected from these plants in this watershed and the bark of the tree is collected as fuel wood. Fir/ Spruce are found on the high ridges of the hills and near the snow covered peaks. The predominant species are Betula/Rhododendron, subalpine birch/ fir forest, dwarf Rhododendron scrub and Brich Rhododendron forest. Conifer mixed is the class with few junipers, dwarf deodar and pine specially Neoza pine forest (*Chilgoza*) and dry conifer species covering the area at higher altitudes. In satellite image, scrub and grasslands are showing similar spectral signature and are hard to differentiate. These were mapped on the basis of location and association. The grasslands are found on the higher slopes along the snow line where as the scrub is mapped in the lower areas. From the resource point of view, they are having the same function, i.e. offering the grass fodder for cattle. *Chrysopogon gryllus* Linn., *Themeda arundinacea* (Roxb) Ridley, *Saccharum spontaneum* Linn., *Aluda mutica* Linn., *Cynodon dactylon* Pers. are some of the common fodder species used. The grasslands are classified using topographic control and the distribution is found above an altitude of 3600 m, near the mixed conifers and fir/spruce. The main species is Salma (*C. gryllus* Linn.), which is the most productive, and preferred grass fodder.

Agriculture woodland is marked out from the agriculture due to its specific value as resource other than agriculture land. Trees, mainly oak, walnut (*Juglans regia* Linn.), and *Ficus auriculata* Wall, *F. nemoralis* Wall etc. are found along the edge of the agriculture land. These are very important for the villages located far from the forest as fodder and fuel wood during chilled cold season and often in the rainy days. These also help in stabilizing the soil erosion along the river. Agriculture is mainly confined in depressions, along gentle slopes and valley sides wherever the water source and soil conditions are favorable. Some agriculture fields are also located on ridges and even on slope on trial basis. The agriculture is classified as agriculture1 and agriculture2 as per the presence and absence of green cover. The crops are wheat, paddy, millet-mandua/khoda (*Eleusine coracana*), millet-"jhangora" (*Oplismenus frumentaceus*), amaranth-"marsa/chua/chaulai" (*Amaranthus polygamous*, *A. blitum*). Cash crops are potato, peas, chilli, beans etc. The production in these fields is only able to provide the grains for the house hold use only. Few or negligible people are able to use the production for income. The watershed has small river channels *viz.*, Amrit Ganga, Vir Ganga and few other gad, which bring water to the river Balkhila that is a major river adding to Alaknanda. In the present study, only the part of Balkhila river could be mapped due to resolution of the data used and purpose of study.

Land Cover Dynamics

The majority of the changes are found in the density of the forest types. The high density Oak forest has been reduced by 5 km^2. Similarly the high density Pine forest has also decreased. The conversion to agricultural lands is mainly from scrub and low-density pine forest. In the higher altitude as the area remained covered with the snow almost throughout the year, so variable cloud cover in two scenes have not been considered for understanding the nature of dynamics. In the low altitude area maximum changes are identified due to either presence of settlement or proximity to road. The changes are not only for the resource extraction but also expansion of the agricultural fields and settlements.

While there is preponderance of oak forest, the changes in the one decade have resulted high degree of fragmentation in this. The high density oak has been converted into the medium and low density oak. The number of forest patches has been observed to increase from 88 to 159 for high density forest and 144 to 259 for the medium density forest in the landscape (Table 3). Most noticeable feature is that the distribution of the pine has increased in this decade but at the same time the number of patches has also increased. The patches are more scattered in high and medium density pine. The high

Table 3: Land Cover (patch) dynamics

Land Cover (1991)	**No. of Patches (2001)**	**No. of Patches**
Oak (High Density)	88	159
Oak (Medium Density)	144	259
Oak (Low Density)	19	15
Oak Mixed	33	81
Pine (High Density)	47	121
Pine (Medium Density)	35	100
Pine (Low Density)	22	24
Fir/Spruce	15	20
Conifer Mixed	32	54
Grassland	70	95

altitude forests *viz.*, fir/spruce and conifer mixed has shown similar trend. The scatteredness is not a healthy indicator for the sustainable ecosystem management. This area analysis indicated that the vegetation fragmentation is increasing with alarming rate, because these small units are subject to further degradation and appear to be possible sites for forest to non-forest conversion.

Changes along the slope

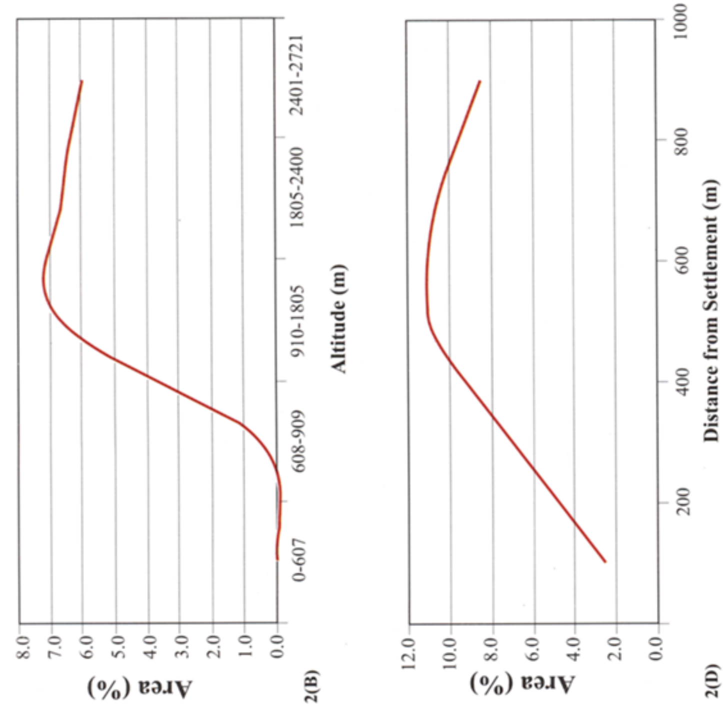
To study the role of slope and its effect on forest cover change the slope map was prepared and classes assigned as recommended by Food and Agriculture Organization (FAO). While analyzing the changes along the slope it was revealed that up to 14 percent slope, there is almost no change due to the fact that these areas are already saturated with the changes. The area under change is increasing with the increase in slope from 14 per cent to about 45-50 per cent. The changes above 50 percent are attributed to snow cover and clouds in two different date and time (Fig. 2a). It reveals the fact that the flat areas and valley bottoms are all saturated in terms of resource utilization/change and the movement of man is now towards higher slope for the resource extraction and expanding its niche.

Changes along the Altitude

The role of altitude in the land cover change was assessed from map prepared by recoding digital elevation model and assigning the classes (Nityanand and Kumar, 1989). The most active zone for the human activities was found to be from 900 to 2200 m (Fig. 2b). This showed that the human beings are moving towards higher altitudes to fulfill their needs in terms of food, fodder and fuelwoood, which are the only zones where forest cover is remaining.

Changes along the aspect

To assess the role of aspect in the change of vegetation cover, aspect map was recoded in eight aspect classes North, North East, East, South East, South, South West and West. The changes along South West, South and South East aspects are very prominent rather than other aspects (Fig. 2c). This phenomenon can be attributed to the aspects South West, South and South East are illuminated for the



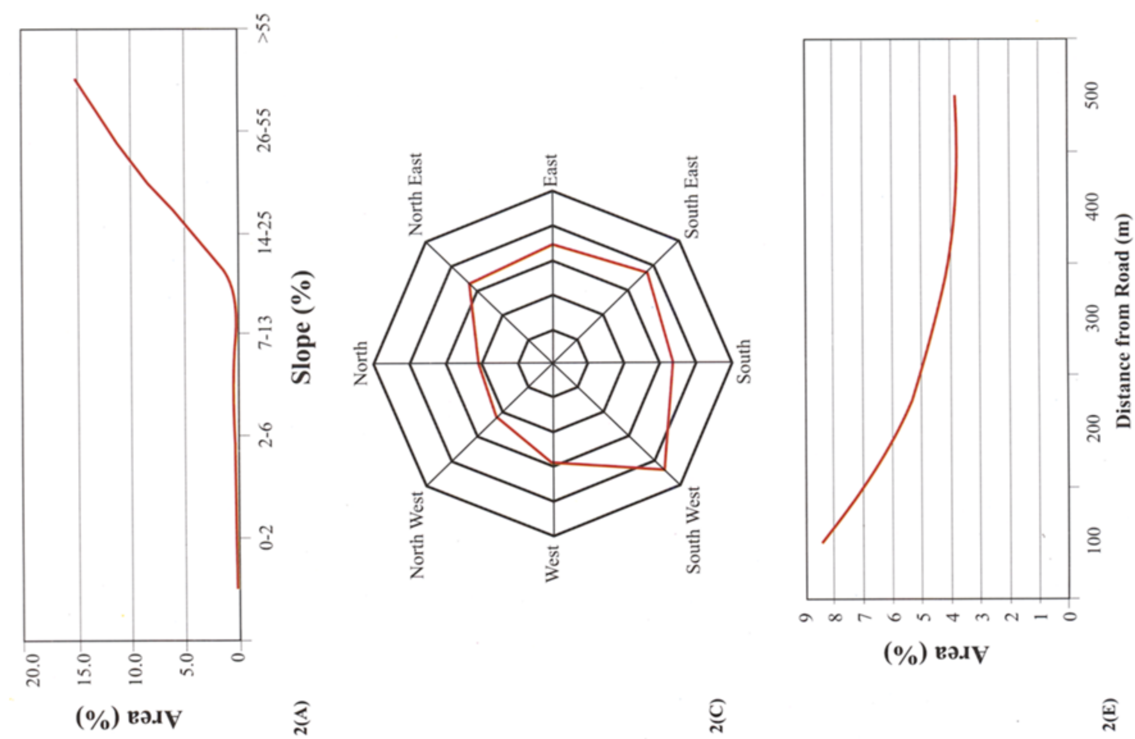


Fig. 2. Land Use/Land Cover dynamics of Balkhila sub-watershed showing changes along (a) slope, (b) altitude, (c) aspect, (d) Distance from Settlement and (e) distance from road

maximum time period during the movement of sun from east to west. Being the warmer places, these aspects are suitable for agriculture and other activities. Hence people prefer to reside on these aspects for their activities. Whereas the aspects North, North East and North West are having relatively lesser sun illumination. Thus, human pressure is lesser on these aspects; as a result the aspects are covered with vegetation with least or no impact of human activities.

Changes along the distance from settlement

Five buffer zones of 200 m each up to 1000 m have been created around the settlement for analyzing the trend of changes. It has been found that in the first buffer of 200 m the changes are least and as the distance is increasing from settlement the disturbance is also increasing up to second buffer i.e. 400 m. In the zone form 500 to 800 m distance from the settlement the changes are maximum (Fig. 2a). During ground observations it was found that the distances nearby are almost saturated with the changes and the villagers conserve the resources in the immediate surroundings to fulfill the needs of rainy or adverse climatic conditions. Thus the settlements have high impact on the land cover changes.

Changes along the distance from roads

The change analysis has been carried out on the buffer of 500 m at an interval of 100 m each (Fig. 2e). It was found that majority of the changes are taking place within zone of 100 to 200 m of distance from the road. On moving away from the road network the changes are decreasing. On reaching the 300 m away form the road the changes has been stabilised. Thus road network is also a major factor for changes in the land cover.

Conclusion

The forest cover change is found in entire landscape but more fragmentary in areas near high concentration of human settlement. The valley portion of the watershed is devoid of forest cover other than small agriculture woodlands and few oak patches. Hence, this area is for immediate attention to take suitable measures to rehabilitate the forest cover. The anthropogenic factors *viz.*, presence of human habitation and road network are important deriving forces for the land cover dynamics. The slope and altitude are no more physical constrains for the Himalayan landscape for the resource extraction. As the availability of the resource in the lower altitudes does not suffice the needs, the extraction or depletion is moving towards higher slopes and altitudes. The aspect has been seen an important parameters to understand the spatial nature of the dynamics.

The remote sensing is an emerging tool for identification of conservation areas. This has been illustrated in the present study particularly in view of developing the understanding of land cover dynamics in the montane landscape and with reference to appropriate inclusion of human dimensions. The understanding developed at this level can be used to assign weightages and priorities to different biotic, physiographic and topographic controls for modelling and predicting the LULCC.

Acknowledgements

The authors are thankful to Dr. P.S. Roy, Dean Indian Institute of Remote Sensing, Dehradun for the encouragement and timely suggestions.

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