Assessment of Changes in Land Use and Land Cover Patterns Using RS and GIS: A Case Study of Upper Beas Basin of Kullu Valley in Western Himalayas, India

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ABSTRACT
This study evaluates the LU/LC changes using RS and GIS tools. The study area, upper Beas river basin of Kullu Valley, falls in the middle Himalayas of Himachal Pradesh, India. The images of Land sat TM of 1991, Landsat ETM+ of 2001 and Landsat OLI of 2016 at 30 meters spatial resolution were used for the study. Both anthropogenic and environmental factors that are responsible for the changes in land use and land cover are evaluated. The study indicated positive changes in bare rock (20%), agriculture (1.72%), open forest (0.34%), settlement (built-up: 0.05%) and river (0.02%) and whereas negative changes are observed in snow cover (-18.3%), grass (-3.18%) and forest (-0.53%) during the years 1991-2001, and the trends remained similar with different magnitudes during 2001 – 2016. The decline in forest area and grass cover with parallel increase in agricultural area and associated urbanisation clearly infer the dominant role of manmade activities in controlling the LU/LC changes in this region. Depletion in snow cover of this region between 1991 and 2016 could be a consequence of the recession of the colder climatic belt to higher altitudes.

Keywords: Land use/cover, Remote Sensing and GIS, high altitude mountain region, human impact, climate change

I INTRODUCTION

Mountain systems constitute a significant fraction of continental area of about 20% and provide life support to 10 % of world's population. These systems typically display a rapid change in vegetation, hydrology and climate in relatively small scales. Snow, glaciers and permafrost in cold mountains are highly sensitive to climatic change and thus provide crucial information on the climate change and its impacts of natural resources and the socioeconomic condition of people. In addition, the dynamic changes in land use and land cover (LU/LC) are important for monitoring, evaluating, protecting and planning of the natural resources for sustaining the ecosystem on the bio-physical surfaces (Rawat et al. 2013). Land cover is the culmination of various attributes like green cover, hydrological components, biota, topography, soil, groundwater and anthropogenic structures on the earth's land surface and immediate subsurface (Lambin et al. 2003) whereas land use is the purposive engagement of land management approach put on the land cover by deliberate human expansion. Studies on the detailed understanding of the impact of anthropogenic and natural factors on land use pattern and its influence on ecology inferred that human dominated factors are widely accepted factors influencing the LU/LC (Munsi et al. 2010).

With the advent of geospatial techniques like remote sensing and GIS, the mapping of LU/LC and its analysis have become less complicated. Remote sensing and GIS tools were employed in many studies to deduce the industrial, agricultural and residential areas for better management of resources (Malczewski 2004; Rawat and Kumar 2015; Butt et al. 2015; Marina and Bogdan 2016). Applying RS and GIS techniques by means of digital change detection can help to assess the temporal changes over few decades in land use and land cover that is being witnessed due to shifting cultivation, deforestation and other environmental changes (Gibson and Power 2000). Atmosphere and land-use changes are two noteworthy worldwide ecological changes anticipated for the future. Changes in land cover patterns can straightforwardly affect energy and mass transitions. For illustration, when extensive regions of forest are cleared, reduced transpiration brings about less cloud development, less precipitation, and expanded drying. Simulations of the deforestation of Amazonia demonstrate that evapotranspiration and forest would be replaced by either desert or field (Dickinson 1992). Both field studies (Segal et al. 1988) and model simulations (Pielke et al. 1997) suggest that spatially alternating groups of vegetation with dry soil on a size of many kilometres can impact atmospheric dissemination and cloud arrangement and this would have larger impacts on climate (Dickinson 1991). Changes in land cover can modify the reflectance of the world's surface and actuate neighbourhood warming or cooling. Numerous resources are being applied to examine causes and, impacts of climate change (Houghton et al. 1990) and still there is a concern that the consequences of these studies may not be important to the decision makers as the researches do not include main considerations affecting climate change impacts (OTA 1993).

Recent studies in the Himalayan region have shown that land use and land cover have changed significantly in both time and space (Chandel et al. 2011; Singh 1998). Studies also indicated that in high altitude Himalayan region of Kullu valley covering upper Beas basin, the vulnerability to natural hazards is closely associated to anthropogenic interventions especially due to changes in land use and land cover (Chandel et al. 2011; Vijay et al. 2016). Using geospatial tools, the impact of tourism on land use/land cover during 1989-2012 and natural slope in the Manali town of the study area have been studied (Vijay et al. 2016). The change detection analysis has shown a continuous increase in the built-up area especially on landslide prone area (Vijay et al. 2016). A study by Nandy et al. (2015) on the environmental vulnerability of Kullu district during the period 1990-2010 reported that factors such as LU/LC changes, hydropower plants, transport connectivity, natural resources exploitation, forest canopy density, forest fire play a crucial role in impacting the land resources. The mountain systems of Kullu region are fragile environments and provide valuable natural resource support not only to upstream areas but also to downstream areas (GOI 2010; ICIMOD 2010) and any alteration to these ecosystem can pose long standing impacts on the hydrological and climatic facets (Vishwa et al. 2013; Bakke et al. 2016).

The selected area for this study is a part of Pir Panjal range of western Himalaya, which has envisaged tremendous developmental activities in the recent past (Vijay et al. 2016). In spite of the tremendous growth in the valley in recent years and its negative impacts on the land and water resources, there are no systematic studies on the quantification of the land use and land cover changes. In this study, an attempt has been made to apply the remote sensing and GIS techniques to assess the changes in land use/land cover in upper Beas river Basin of Kullu valley in Himachal Pradesh, India over the last 25 years. Understanding the impact of anthropogenic activities to land use changes and its implication on ecosystem's capacity to maintain an uninterrupted supply of services can help in planning better management of the resources.

II STUDY AREA

The study area is part of the upper Beas River Basin of Western Himalaya, which encompasses an area of about 1419 km^2 and spans between Rohtang in the North and confluence of river Parvati and Beas in the south of the Kullu Valley, Himachal Pradesh, India (Fig.1). It lies between North Latitudes 31°50' and 32°20' and East Longitudes 76°50' and 77°20'. Geomorphologically, the district is categorised into 5 geographic units namely mountainous area, snow covered area, denuded hills, valley area and terrace area. The topographic elevation of the study area ranges from 1000 to 6000 m above mean sea level and the terrain comprises deeply incised river valleys interspersed with high mountain ridges and massifs of very high, glacier mountain peaks (Prasad et al. 2016). Drainage in Upper Beas basin is mostly constituted by the glacial/ snow fed perennial rivers and tributaries covering an area of 80% of the study area (Sah and Mazari 2007). Climatically the region lies in the temperate zone extending to the tundra zone due to its higher elevation (~ 6000 m amsl).

A varied lithotectonic group exists in the study area comprising a variety of rocks from Precambrian to Quaternary (Sah and Mazari 1998). The upper basin of river Beas locally termed as Rohtang Gneissic Complex constitutes gneisses, granites and magmatites of the Vaikrita Group area (CGWB 2013). In the middle and gorge sections of the valley corridor, slates, garnetiferous schist, quartzite and limestone of the Jutogh Group dominate. Quaternary alluvial fans, fluvial terraces and relict periglacial slope deposits make up the shallow geological strata. The entire area of Kullu district can be divided into porous and fissured formations. Porous formation includes the unconsolidated sediments that are basically fluvial channel deposits, valley fill deposits, terrace deposits and alluvial fans. These sediments form the potential aquifers. Unconsolidated sediments underlie Kullu valley, Garsa valley, Manikaran valley, Lag valley and longitudinal valley all along the major rivers and khads. Fissured formation includes the semi-consolidated to consolidated sediments and are sedimentary, metamorphic and igneous in origin. This formation forms low to high hill ranges throughout the study area (Prasad et al. 2016).

The human interventions have changed the landscape of the study area to a great extent. The population density of the study region has increased from 28 to 69 persons/ km^2 during 1961 to 2001, which is about 300% growth (Sah and Mazari 2007). A comparison of the land use data of 1994-95 with 2000-01 indicate that the barren and non-agricultural land decreased to about 6% and land for non-agricultural uses increased to about 8% in 2000-01 (Sah and Mazari 2007). This clearly demonstrates the impact of increased urbanization in the study area. Depletion in water level of shallow aquifer was also reported in this district due to increased exploitation of the groundwater to augment growing needs of the population (Bhatti 2016).

III METHODOLOGY

Landsat TM dated 16 November 1991, Landsat ETM+ dated 18 October 2001 and Landsat OLI dated

19 October 2016 at 30 meters spatial resolution along with the Survey of India topographical sheet were used for LU/LC analysis. Toposheets of 1:50,000 resolution (143*3, 143*4 and H43F1) were used to prepare the base map for reference. The images were corrected geometrically to Universal Transverse Mercator (UTM) coordinate system (Kumar et al. 2016). Images were selected from same season to minimise the influence of seasonal variation. Images of October and November months were chosen because during this period the ice and snow cover is minimum and the area is relatively cloud free so that various geomorphologic and surface features are clearly visible for identifying and demarcating boundaries and calculating the corresponding areas. The LU/LC classification and mapping was carried out using ERDAS Imagine 2014 and ArcGIS 10.4 software (Mengistu and Salami 2007). Global Positioning System (GPS) readings were taken throughout the study area, this helped to obtain accurate location points for each LULC class and creation of training sample points for maximum likelihood classification in ArcGIS 10.4.

The LULC classes were studied by assigning perpixel signatures to the satellite data and differentiating the area on the bases of the specific Digital Number (DN) value of different landscape elements. The delineated classes were viz., (1) forest (2) open forest (3) grass (4) agriculture land (5) settlement (built-up) (6) river (7) snow and (8) bare rock. For each of the predetermined land cover/use type, training samples were selected by delimiting polygons around representative sites. Spectral signatures for the respective land cover types derived from the satellite imagery were recorded by using the pixels enclosed by these polygons. A satisfactory spectral signature is the one ensuring that there is 'minimal confusion' among the land covers to be mapped (Gao and Liu 2010). After that maximum likelihood algorithm was used for supervised classification of the images. To improve classification accuracy, reduction of misclassifications and to detect the changes in ERDAS IMAGINE 2014 post- classification comparison technique was used (Mengistu and Salami 2007).

The problem of mixed pixels was addressed by visual interpretation. With the help of GPS readings, topographical sheets and google earth maps, ground verification was done for doubtful and unclear areas. In this study, the visual analysis, reference data, as well as local knowledge was used to improve the results obtained using the supervised algorithm. For the accuracy assessment of land cover maps extracted from satellite images, stratified random method was used to represent different land cover classes of the area. The overall accuracy for the years 1991, 2001 and 2016 was 90%. Quantitative areal data of overall LU/LC changes as well as gains and losses in each category between 1991 and 2016 were then compiled.

IV RESULTS AND DISCUSSION

The satellite images of LU/LC from 1991, 2001 and 2016 have been taken to identify the changes occurred during the last 25 years in the study area. Images are classified based on eight LU/LC classes mentioned in methodology (section 3). Visual interpretation of images indicated that major portion is covered by forest followed by snow, bare rock, grass, agriculture, open forest, settlement and river in all the three images. The statistics of area (km^2 and %) in different land use/cover categories in upper Beas river Basin of Kullu Valley in the year 1991, 2001 and 2016 are given in Table 1. Fig. 3 depicts the LU/LC status of three study periods i.e., 1991, 2001 and 2016. The brief account of these results is discussed below.

(a) LU/LC Status

The year 1991 was taken as base year for the study because post 1991 the anthropogenic activities started rising significantly compared to previous years (Singh, 1989; Sah and Mazari, 1998). Table 2 and Figure 3(a) reveal that in the year 1991 about 34.3% (487 km^2) of the area was under forest, 22.6% (321 km^2) under snow, 20% (282 km^2) under bare rock, 13.8% (197 km^2) under grass, 6.1% (86.7 km^2) under agriculture, 2.7% (38.9 km^2) under open forest, 0.12% (1.7 km^2) under river and 0.34% (4.9 km^2) under built-up area. The order of dominance of land cover can be represented as;

Forest> snow>bare rock> grass> agriculture>open forest>settlement>river

(b) LU/LC Change

Results indicate that both positive and negative changes have occurred in the LU/LC pattern in the upper Beas Basin of Kullu valley during the last 26 years (Table 1 and Fig. 3). The detailed inventory of LU/LC in km^2 is shown in figure 4 while the % change of the attributes is shown in figure 5 for the year 1991, 2001 and 2016.

- During 1991-2001, positive changes are visible in open forest, agriculture, settlement, river and bare rock whereas negative changes are seen in forest, grass and snow.
- During 2001-2016, positive changes are noticed in agriculture, settlement, snow and bare rock whereas forest, open forest and grass showed negative change.

(i) Positive changes

- **Bare rock area**

In 1991 the bare rock in study area was 282 km^2, which shows an increasing trend between 1991 and 2001 (Fig. 4). From 2001 to 2016 (15 years) the area under bare rock has shown an increasing trend. The images of the year 1991, 2001 and 2016 displayed an increase in bare area 20% (1991 to 2001), 1.5% (2001 to 2016) shown in Fig.5. The possible reason that can be attributed to this growth in the bare rock area is reduction in snow cover in higher elevations. Studies have suggested decrease in snow fall as well as enhanced snow melting due to climate change related processes (Ming et al. 2008; Ramanathan and Carmichael, 2008). The reduction in snow cover from 90% to 55% was reported even at lower altitudes of 2480 m amsl by Kulkarni et al. (2010).

- **Agriculture area**

During the year 1991 to 2001, increase in agriculture area witnessed a 1.72% growth (24.4 km^2) while during the period between 2001 and 2016 it witnessed a 0.67% growth (9.5 km^2) as shown in Fig. 5. The expansion of agricultural land in the valley can mainly be attributed to increased need for food due to population rise and expansion of horticulture. In addition to local food needs, market forces also act in increasing the agriculture in this region. Expansion of agriculture land has resulted in diversion of forest land and grass cover areas. The increased area under agriculture is mostly related to extending the horticulture area to higher elevations which can be possibly related to socioeconomic factors (Sah and Mazari, 1998).

- **Settlements**

The settlement or total built-up area has shown a positive trend. It is 4.9 km^2 in 1991, 5.7 km^2 in 2001 and 6.7 km^2 in 2016 (Fig. 4). The areas such as Manali, Patlikuhl, Naggar and Bhuntar were urbanised due to tourism growth in addition to Kullu, which is the oldest urbanised town of the valley. The valley as a whole has witnessed a tremendous expansion in settlement area owing to population growth of both incumbent and temporary residents. The village core areas have expanded due to growth in tourism activity in relation to home stays in rural areas. Developmental activities in the Kullu valley have gained momentum from rest of the Kullu because of which rampant urbanization is mushrooming from the floor of the valley towards higher elevations. Better road connectivity to higher altitude is also augmenting the settlement growth and encroaching of the agricultural area for concretization in the study area. The study period reveals an increase in settlement in accordance with the population growth, which is evident from the data that the population growth of 14.7% between 2001 and 2011 (Census of India, 2001, 2011) and tourism growth of 241% between 1993 and 2001 in the study area and can be attributed to the regional influx of the tourism induced urbanization on the valley floor.

- **River**

The area under the river has increased from 0.12% to 0.14% between 1991 and 2001.The change was found to be very less, which can be interpreted as variation in flow of the river. In addition, the inundation of river in 1995 floods can be one of the main reasons for increase in river area. Melting of snow cover would lead to increase in glacial fed river flows, which will also increase the spread (area) of the rivers. It is also possible that high amount of rainfall in a given year can increase the river discharge and enhance the bank erosion leading to spread in the river area.

(ii) Negative change

- **Forest cover**

Between the period 1991 and 2001 the forest cover was reduced from 34.3% to 33.7% which further went down by 1.8% between 2001 and 2016. The decrease in forest cover is cumulative effect of deforestation for tourism activity and an altitudinal shift of agriculture and horticulture areas in the valley. Various studies have pointed out that both environmental factor such as climate change (IPCC, 2001) and anthropogenic factors (Negi et al. 2012) such as deforestation can affect forest cover.

- **Grass cover**

Area under the grass cover from 1991 to 2016 showed a declining trend (Fig. 4). Between 1991 and 2001 the decrease in grass cover was about 3.18% which further declined by 1.55% between 2001 and 2016 (Fig. 5). Change in grass cover can be attributed to anthropogenic factors, mainly to environmental changes. The growth of grass is temperature and climate dependent, and the changes in these factors can cause reduction in grass cover. A detailed study on the human caused environmental changes and its impact on plant diversity is carried out by Tilman and Lehman (2001).

(iii) Mixed change

- **Open forest**

All lands with a tree cover or canopy density between 10% and 40% are termed as open forests. Both positive and negative changes in open forest have been noticed (Fig. 5). During the period between 1991 and 2001 the open forest has been increased from 2.7% to 3.07% whereas between 2001 and 2016 a negative change is seen from 3.07% to 2.6%.

- **Snow cover**

The area under snow cover shows a decrease from 22.6% (in 1991) to 4.26% (in 2001). Global warming could be the reason for the decrease in the snow cover. The global warming has a significant impact on the reduction of snow cover. It was estimated that 18.3% of snow cover has been lost during one decade (1991-2001). A marginal increase of 5.81% in snow cover was observed during 2001 to 2016 (Fig. 5), which could be ascribed to the local climatic conditions. Snow cover is related to atmospheric temperature and studies by Shekhar et al. (2010) and Kulkarni et al. (2010) has detailed the seasonal temperature variations and its impact on snowfall in Indian Himalayan region. There is likelihood relationship between increase in snow cover and decrease in bare rock area and vice versa. Glacier retreat at different rates is reported in many studies on the adjacent district of Himalayan glaciers where changes in the permanent snow cover retreat has been witnessed but retreat rates were markedly more in the Parvati valley of Kullu district (Kulkarni et al. 2004). Global warming, climate change (Ming et al. 2008; Ramanathan and Carmichael, 2008) area are considered as principal contributors for glacial melt in Western Himalaya irrespective of the differences in the retreat of glaciers (Negi et al. 2012).

(c) Precipitation trends – LULC variations

Rainfall data of this region over the same period as that of the investigated period was plotted to identify correlation between LULC changes and amount of rainfall, if any. The range of annual rainfall varies from 644 to 1733 mm with an annual average of 1049 mm. It can be observed that there are no particular decrease or increase trends noticed over the investigated period. There was always a deficit in the rainfall as compared to average value of 1405 mm (source: CGWB 2013) excepting in 2010. Very high variations in rainfall are observed. The area of major classes of LULC, viz., forest, grass, agriculture, snow and bare rock were plotted against the corresponding year rainfall (Fig. 6). No direct linkage could be discerned between the rainfall and the variations in the areas for these classes, which indicate the contribution of other climatic factors as well as human activities. From the rainfall pattern and its correlation with LULC parameters, it can be inferred that the local climate can be the main driver for the LULC change, a similar observation was reported by Soheb et al. (2015).

Table 1

Statistics of area (km^2 and %) in different land use/cover categories in upper Beas river Basin of Kullu Valley in the year 1991, 2001 and 2016

Area	1991(Km^2)	1991(%)	2001(Km^2)	2001(%)	2016(Km^2)	2016(%)
Forest	487	34.3	480	33.7	453	31.9
Open forest	38.8	2.7	43.7	3.07	37.2	2.6
Grass	197	13.8	152	10.7	130	9.14
Agriculture	86.7	6.1	111	7.82	121	8.50
Settlements	4.89	0.34	5.7	0.39	6.7	0.47
River	1.71	0.12	1.9	0.14	2.0	0.14
Snow	321	22.6	60.6	4.26	82.6	5.81
Bare rock	282	19.9	565	39.8	587	41.3
Total	1419	100	1419	100	1419	100

Table 2

Statistics of amount of change in different LU/LC categories in upper Beas river Basin of Kullu Valley in year 1991, 2001 and 2016

Area	**Change in LU/LC**			
	1991-2001(%)	1991-2001(km^2)	2001-2016(%)	2001-2016(km^2)
Forest	-0.5	-7.6	-1.9	-26.6
Open forest	0.4	4.8	-0.5	-6.5
Grass	-3.2	-45.1	-1.5	-21.9
Agriculture	1.7	24.4	0.7	9.5
Settlements	0.05	0.8	0.08	1.1
River	0.02	0.25	0.005	0.07
Snow	-18.3	-260	1.6	22.0
Bare rock	20	283	1.6	22.4

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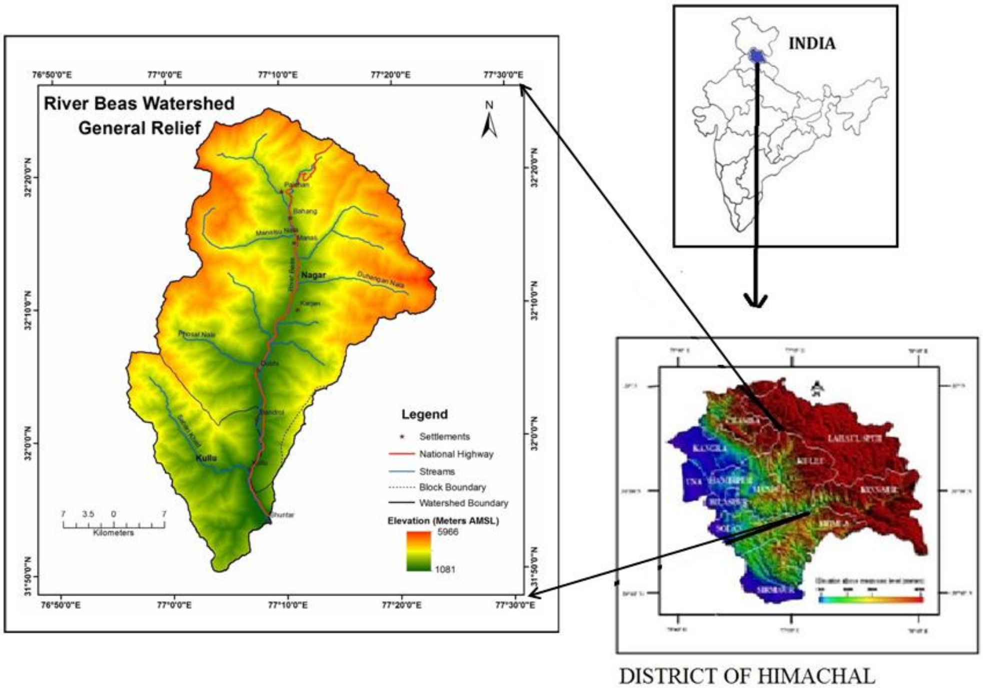

Fig.1 Location map of the study area

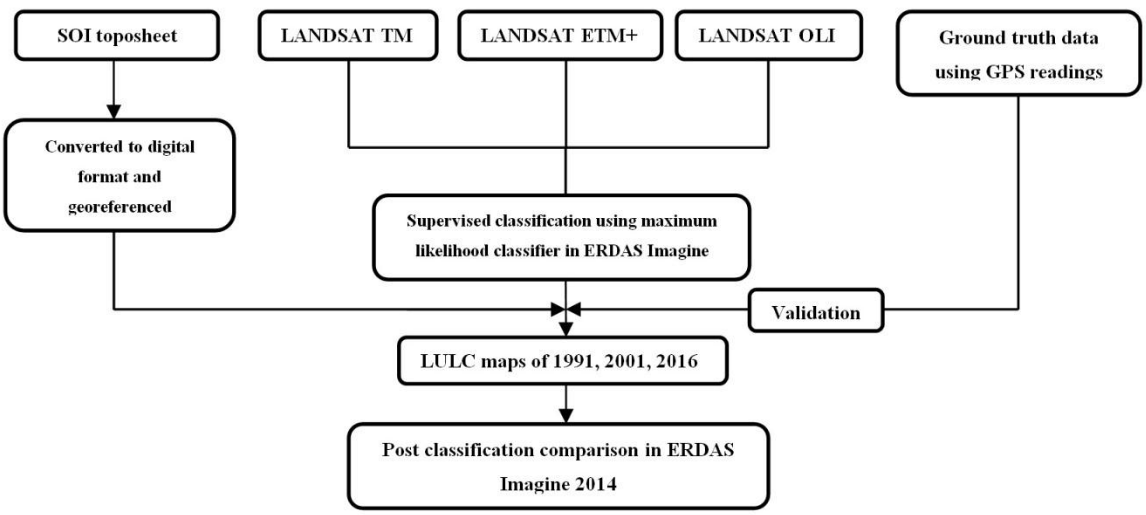

Fig. 2 Flow chart of land use/cover mapping

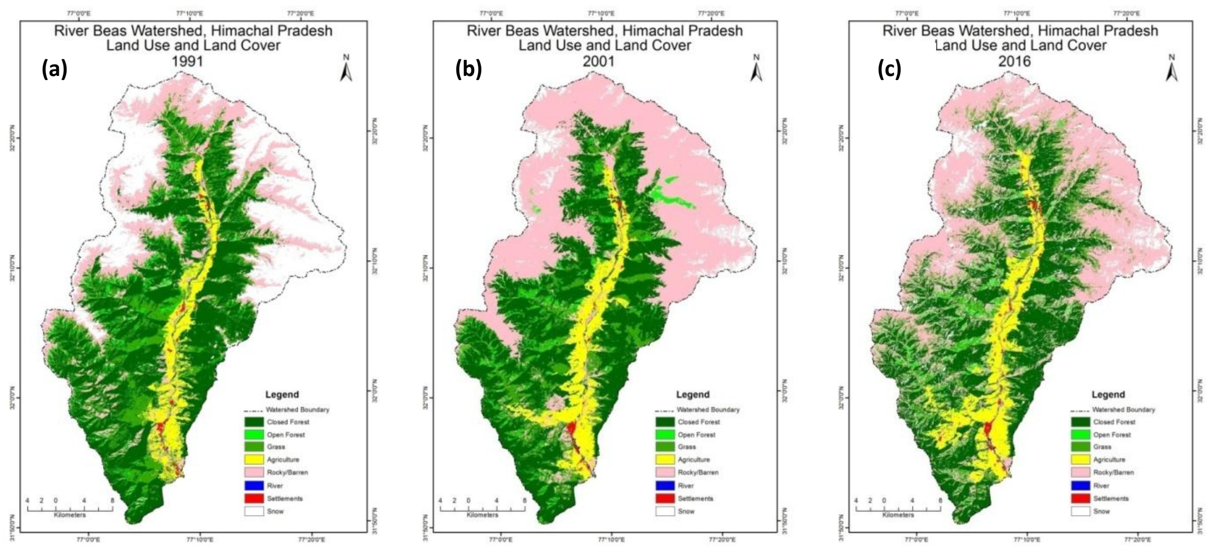

Fig.3 Classification results for Kullu region a) 1991, b) 2001 and c) 2016

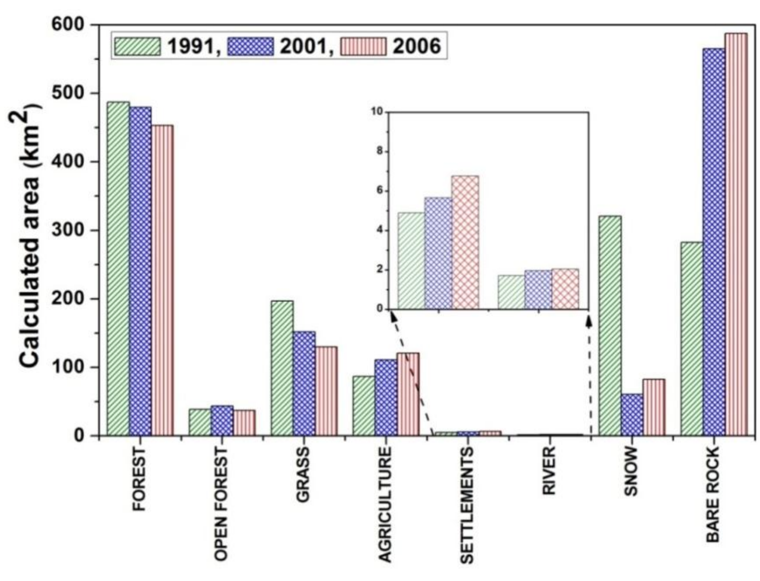

Fig. 4 Inventory of LU/LC in the study area

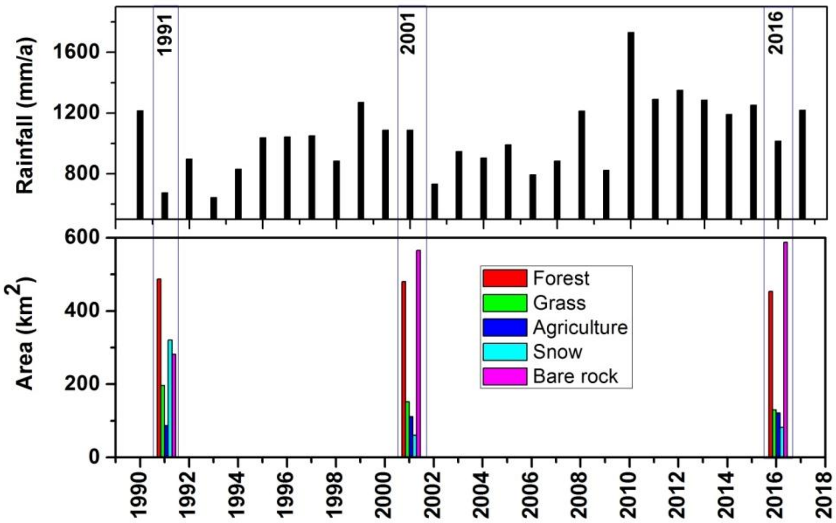

Fig. 5 Amount of change in different LU/LC categories

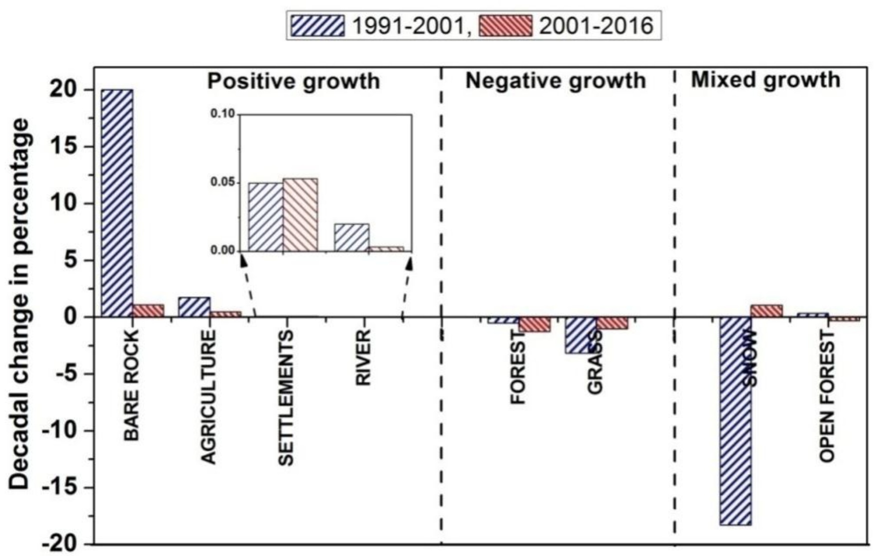

Fig. 6 Annual rainfall and the areas of major LULC classes of the study area

V CONCLUSION

The study conducted in upper Beas river basin of Kullu Valley in the middle Himalayas of Himachal Pradesh employs multi-temporal satellite data to detect the changes in LU/LC patterns in an accurate manner. The study reveals that both positive and negative changes are witnessed during the period of 26 years (1991-2016). During 1991-2001, the percent changes indicate a decrease in the snow (-18.3%), grass (-3.18%) and forest (-0.53%) while bare rock (20%), agriculture land (1.72%), open forest (0.34%), settlement (0.05%) and river (0.02%) show increased values. During the 2001-2016 the percent change in forest (-1.9%), grass (-1.55%), snow (-1.55%) and open forest (-0.46%) show a decrease while bare rock (1.58%), agriculture land (0.67%), settlement (0.08%), river (0.005%) show increased values.

The decline in the forest area and grass clearly signify the deforestation and an increase in the agricultural, horticulture and other anthropogenic activities. Settlement area has increased between 1991 and 2016 due to increased urbanization as a consequence of tourism. Depletion and retreat of snow cover between 1991 and 2016 can be attributed to the recession of the colder climatic belt to higher altitudes. No systematic pattern is observed in the rainfall of this area, however inter annual rainfall fluctuations are found to be high. This study displays the potential of remote sensing and GIS tools in monitoring the LU/LC changes in temporal and spatial scales that could help suggest pragmatic planning of various resources in sustainable manner.

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