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Land use land cover change and human – Environment interaction: the case of Lahaul valley

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ABSTRACT

Earth being the home of man any amount of human change brought about by developmental or other processes of change leaves an imprint on the earth's surface and this may best be studied through the process of land use and land cover change. Timely and accurate change detection of Earth's surface features is extremely important for understanding relationships and interactions between human and natural phenomena in order to promote better decision making. The present research paper studies the change in land use and land cover in the Lahaul valley over the last almost four decades viz. 1976, 1989, 2000, 2011. The analysis was carried out with the intent of understanding the change in man – environment relationship as it is expressed over the physical landscape.

For the purpose of the present study a multi-pronged methodology was adopted. Land use and land cover patterns at different points in time viz. 1976, 1989, 2000 and 2011 were analysed and compared. Data for this purpose was procured in the form of satellite imageries from LANDSAT. The sensors that collected this data were Multi Spectral Scanner (MSS), Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM+). The images were taken during the month of October (first week) when there is least possibility of disturbances and noise in the atmosphere. The snows have melted and the fresh snow is yet to fall. Base line information was obtained from the toposheets of the study area. The toposheets was at a scale of 1:250k. The resolution of the imageries was sixty meters for the 1976 imageries and for the rest was thirty meters.

The study indicates large scale modification of the valley. Both bio-physical and socio-economic forces are to account for this. There is an expansion in both the area under agriculture and the area under settlements. While this is likely to result in a further change in the man – environment interaction, it is also not without cultural implications for the study area.

Keywords: Human-environment interaction, land use/land cover, Himalayan mountains.

1. Introduction

The present paper studies the change in land use and land cover in the Lahaul valley over the last almost four decades. The analysis was carried out with the intent of understanding the change in man – environment relationship as it is expressed over the physical landscape. Earth being the home of man any amount of human change brought about by developmental or other processes of change leaves an imprint on the earth's surface and this may best be studied through the process of land use and land cover change (LULC).Although both the terms land use and land cover deal with the impact of human activities and imprint on the landscape there is a significant though slight difference between the two terms.

The term Land use relates to the human activity or economic function associated with a specific piece of land (Lillesand and Kiffer 2008). It comprises all the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it (FAO 1997). Essentially land use points to the ways in which man utilized the land resources during a given time period. The term Land cover relates to the type of features present on the surface of the earth (Lillesand and Kiefer 2008). Campbell (1987) defines it as the vegetation (natural or planted) or man-made construction that occurs on the earth.Land cover reflects the biophysical state of the earth's surface and immediate sub surface and includes the soil material, vegetation and water (Prakasam 2010). These two terms therefore imply different things even though they are at times used interchangeably. Land use refers to how land is used by human while land cover refers to the vegetation, structure or other features that cover the land (Consortium for Atlantic Regional Assessment 2006). Land cover denotes the physical or biological categorization of terrestrial surface i.e. grasslands, forests etc. whereas land use refers to the human purposes that are associated with the cover e.g. raising cattle, recreation or urban living (Meyer and Turner 1992).

Land use and land cover change also known as land change is a general term for the human modification of Earth's terrestrial surface (The Encyclopedia of Earth 2013). Changes in land use and land cover are among the most important human alterations affecting the surface of Earth (Lamkin et al. 2001). Land use and land cover changes involve both change in areal extent as well as conversion and modification at the micro-level (Turner II et al. 1995; Skole 1994). Land use and land cover conversion refer to a change from one land use or cover type to another, while land use and cover modification involves change in the function of an object without full conversion of its type (Skole 1994). It also involves the modification either direct or indirect of natural habitats and their impact on the ecology of the area (Meyer and Turner II 1992; Prakasam 2010). Land use and land cover change may be brought about by a variety of factors. Briassoulis (2013) has identified two major types of factors: bio-physical and socio-economic. In the context of the region of Lahaul, land cover changes play a more dominant role in land change patterns. This is because the demographic imprint on the region is relatively light. Nevertheless owing to the ecological vulnerability of the valley, even slight changes in the LULC patterns may have for reaching impacts on the physical environment.

2. Methodology

For the purpose of the present study a multi-pronged methodology was adopted. Land use and land cover patterns at different points in time viz. 1976, 1989, 2000 and 2011 were analyzed and compared. Data for this purpose was procured in the form of satellite imageries from LANDSAT. The sensors that collected this data were Multi Spectral Scanner (MSS), Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM). The images were taken during the month of October (first week) when there is least possibility of disturbances and noise in the atmosphere. The snows have melted and the fresh snow is yet to fall. Base line information was obtained from the toposheets of the study area. The toposheet was at a scale of 1:250,000. The resolution of the imageries was sixty meters for the 1976 imageries and for rest it was thirty meters. After acquiring the satellite data and supplementing it with other ancillary data including topographical sheets of the area and google earth tiles downloaded from Google Earth pro, the images were georeferenced and rectified. Image subsetting was carried out to extract the area being studied.

Image transformation was done to get all images on the same projection system. For feature identification and selection image enhancement was carried out using radiometric techniques.

The Normalized Differences Vegetation Index (NDVI) was calculated to enhance the spectral differences between these objects while Principal Component Analysis (PCA) technique has been applied for reducing the dimensionalities of the datasets. In addition to this ASTER Digital Elevation Model (DEM) was used to eliminate the possibility of land classes being wrongly categorized by adding some criteria. The technique used for analysis was hybrid classification (involving a merger of two techniques). Unsupervised classification was carried out using K mean classifier method. To check that the whole exercise had produced dependable results, accuracy assessment was also carried out. Finally change detection matrices for consecutive study years were generated. The land-use/land-cover categories identified were based on the classification provided by James R. Anderson (1971) and adopted by NRSC (National Remote Sensing Centre), Hyderabad. Nine main categories were identified. These included rural settlement area, agricultural area, evergreen forests, grasslands, scrubland, rocky barren surface, river line, lakes/ponds and finally snow and glaciers.

3. Analysis and discussion

3.1 Land use and land cover patterns (1976)

Out of a total area of 684102.4 hectares that comprised the valley of Lahaul in 1976, the largest portion was found to be under snow cover and glaciers (Map 1). This accounted for more than two-fifths (43.73%) of the total area at 299140 hectares. These may be identified as permanent snow fields since the image was taken in the first week of October when the summer sun has melted away all the fresh snow and the winter precipitation that comes in the form of snow and in the month of December-February (Govt of Punjab 1897) is yet to fall. These snowfields are important to Lahaul since they provide irrigation to the crops through snowmelt during the summer months. These snow fields are also of critical importance to the plain areas lying downstream along the Chenab since these feed the Chenab River as well. On the flip side the area remains vulnerable to avalanches owing to this extensive snow cover and the steep slopes. More than one fourth of the area (25.635%) was categorized under rocky barren surfaces (Table 1). This comprised area that was between the permanent snow line and the tree line. The steep slopes at considerable heights are devoid of both soil and vegetation cover.

Lahaul is a product of glacial processes that have become active after the initial tectonic uplift. The rocky barren surfaces are yet to develop any soil. The slopes are also yet to stabilise. A little less than one-fourth of area has been classified as grasslands (Map 1). These lie above the tree line and are in the nature of permanent pastures. The cold climate, high elevations and steep slopes do not lend themselves easily to agricultural use. However these grasslands during the summers are the temporary habitat of the transhumant tribal population of Himachal Pradesh particularly the Gaddi tribe. Lahaul and its grasslands fall enroute their path to Zanskar from Chamba. Grasslands also provide fodder to the livestock maintained by the local population of Lahaul. Lahulas are very alive to the need to preserve grasslands and Lahaul is one of the few places where even grasslands or ‘ghaasnis’ as these are called, are consciously maintained and irrigated.

Scrub land which accounted for about one – twelfth (8.213%) of the total area is another major land cover category (Table 1). This is essentially degraded land that has poor quality skeletal soil and supports scrub like vegetation especially shrubs like lantana. These are to be found on the severely eroded slopes subjected to excessive aridity which is typical of the

landscape of Lahaul.Evergreen forests essentially coniferous in nature comprise less than two percent of the landscape (Map 1). The trees found generally include the Pencil Cedar and Bhoj Patra and some Willow as well. Agriculture accounts for less than one percent of the total area. With less than 2 percent of the total area laying below the elevation of 3000m it is understandable why such a small proportion of the area is available for agriculture. The settlement area is negligible and accounts for less than 0.03% of the total area (Table 1).

Essentially it appears that land use and land cover in the valley of Lahaul in 1976 comprised largely of snowfields, rocky barren surface and grasslands (Map 1). It is a landscape typical of the high Himalayas especially the valleys beyond the PirPanjal that are denied the benefit of the south western Monsoon. Developed initially through tectonic uplift it is an arid landscape that has been subjected to glacial processes. The steep slopes that are yet to stabilize support very little vegetation while the land available for agriculture is severely limited by topography and climate. The land use land cover pattern that was visible during the seventies decade however changed considerable in the years to come, mainly in response to human action.

3.2 Land use land covers change 1976-1989

Over this period of more than a decade the most noticeable in fact striking change in land use and land cover pattern lay in the reduction of land under snow cover and glaciers (Map 2). The area reduced to less than two-thirds of its original extent (Table 1). Clearly this was indicative of a reduction of snow fall as well as a rise in average temperatures which led to a melting of the snow cover as well as a retreat in the glacial fields. The transfer of considerable area earlier under the category of snow and glacier to the category of rocky barren waste indicates a change of this nature (Map 2).

While the area in the category of snow and glacier has drastically decreased, there is almost a commensurate increase in the area under rocky barren waste which in 1989 accounted for more than two-fifths of the total area of the valley. However the fact that not a small chunk of area from snow and glaciers got transferred to evergreen forests hints at the fact that 1976 was probably a year of excessive snow fall and low temperatures that accounted for some of the forest as well as settlement area to be covered by snow even as early as the first week of October. Whatever be the reason, one cannot deny the very visible reduction in snow cover nor the variability in climate trends and the occurrence of extreme climate events. Another interesting development observed during this decade was the reduction of area under grasslands by almost twenty per cent. Substantial amount of the loss was accounted for by transfer of land to the category of scrub land. The other categories that gained at the cost of grasslands included agricultural area, evergreen forests and rocky barren land. Apparently on the one hand one notices degradation of soil profile and on the other increased human endeavor to being more land under the plough. The growth of scrub land and evergreen forests at the expense of grasslands is also indicative of a warming of the temperature regime that has increased the possibility of higher forms of vegetation growing at higher altitudes. The tree line has it seems shifted upwards altitudinally. Further the area under agriculture has increased and there is a visible increase in area under settlement also (Map 2). This may be accounted for by an increase in construction activities propelled by development initiatives like road construction, schools, health centers as well as houses. This has obviously increased the pressure on land as has an increase in the area under cultivation. However negligible population increase during this period points to the fact that the agriculture being extended is of a commercial nature.

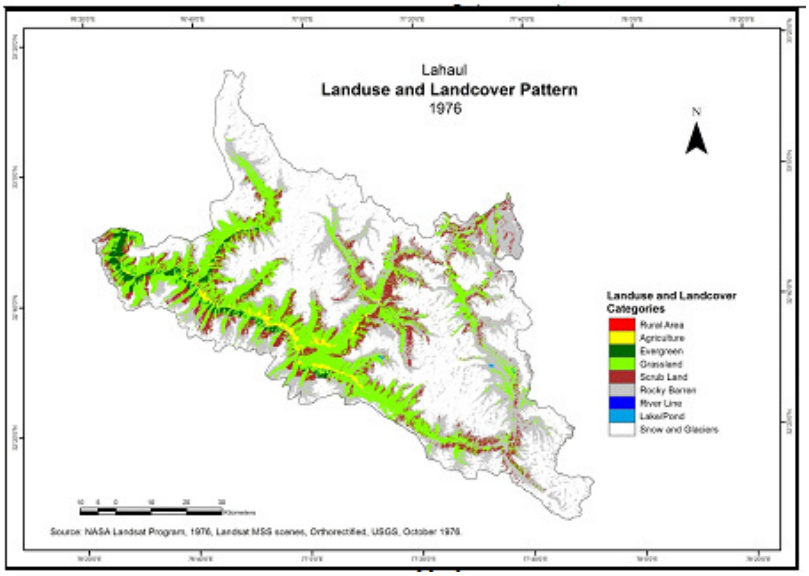

Figure 1: Lahaul Land use Land Cover Change (1976-2011)

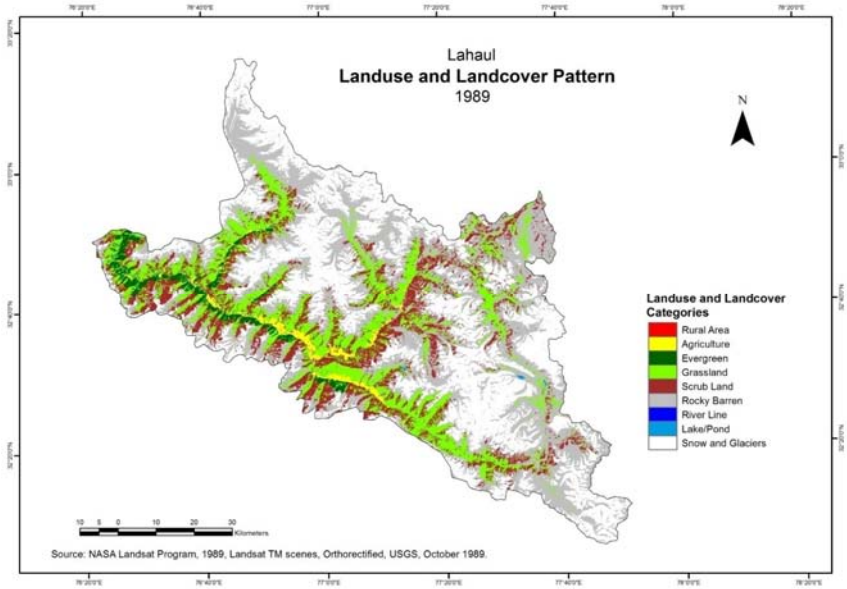

Figure 2: Lahaul Land use Land Cover Change (1976-2011)

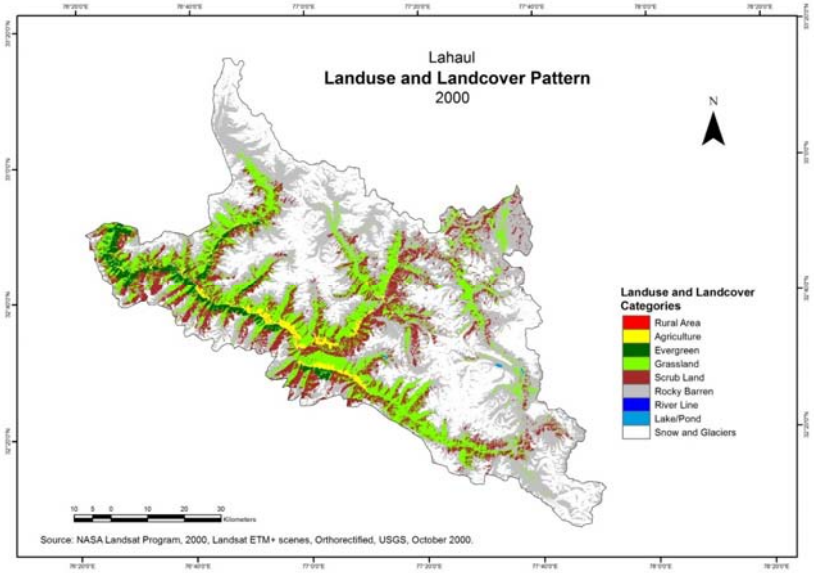

Figure 3: Lahaul Land use land cover pattern 2000

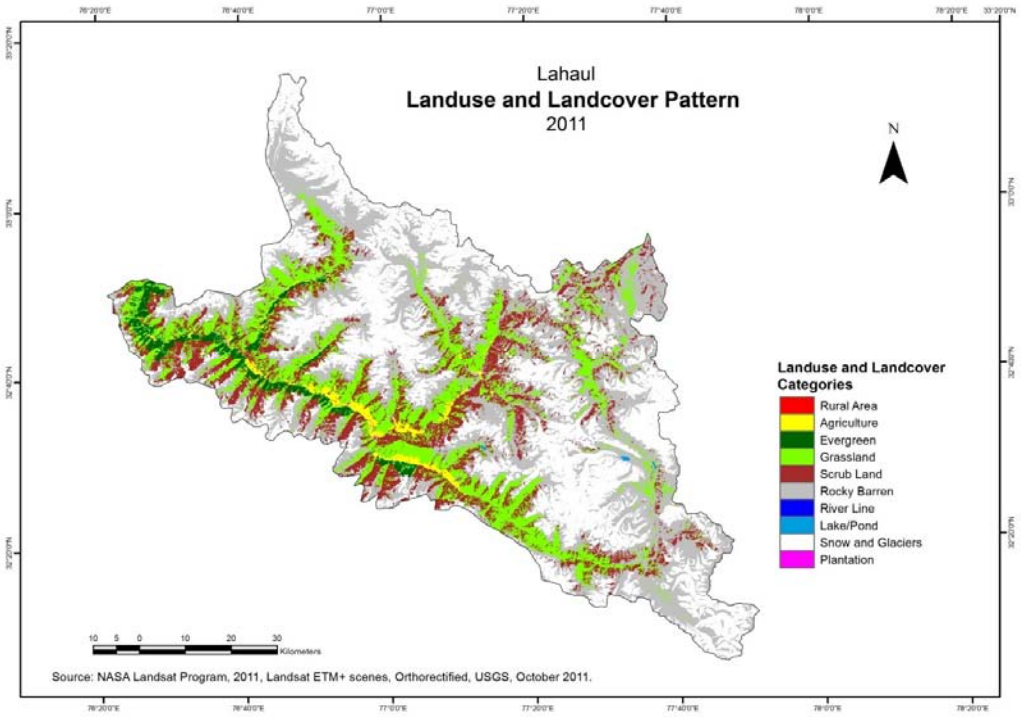

Figure 4: Lahaul Land use land cover pattern 2011

Table 1: Land use Land cover change 1976 -1989

Category	Rural Area	Agriculture	Evergreen	Grassland	Scrub Land	Rocky Barren	River Line	Lake/ Ponds	Snow/ Glaciers	Year Total (1976)
Rural Area	201.51 (100)	0	0	0	0	0	0	0	0	201.51 (0.03)
Agriculture	16.11 (0.28)	4059.54 (71.50)	213.66 (3.76)	1044.09 (18.37)	281.07 (4.95)	63.45 (1.12)	0	0	0.09 (0.001)	5678.01 (0.83)
Evergreen	0	9.63 (0.09)	10116.5 (96.39)	360.36 (3.43)	7.2 (0.07)	1.35 (0.01)	0	0	0	10495.04 (1.53)
Grassland	0	2145.96 (1.59)	3744.9 (2.77)	101792 (75.26)	13592.8 (10.05)	13880.2 (10.26)	0	15.48 (0.01)	80.91 (0.06)	135252.25 (19.77)
Scrub Land	0	0	0	0	56176.2 (100)	0	0	0	0	56176.2 (8.21)
Rocky Barren	0	0	0	0	0	175372 (100)	0	0	0	175372 (25.64)
River Line	0	0	0	0	0	0	1513.98 (100)	0	0	1513.98 (0.22)
Lake Pound	0	0	0	0	0	44.73 (16.38)	0.54 (0.19)	203.22 (74.42)	24.57 (9.00)	273.06 (0.04)
Snow and Glaciers	0	0	12.51 (0.004)	3187.71 (1.06)	2706.66 (0.90)	98168.7 (32.82)	67.32 (0.02)	11.43 (0.003)	194986 (65.18)	299140.33 (43.73)
Year Total (1989)	217.62 (0.03)	6215.13 (0.91)	14087.6 (2.06)	106384.2 (15.55)	72763.93 (10.63)	287530.4 (42.03)	1581.84 (0.23)	230.13 (0.03)	195091.6 (28.52)	684102.38 (100)

3.3 Land Use Land Cover Change (1989-2000)

The period spanning 1989-2000 saw a continuation of the pattern that first became visible in 1989. There was a further reduction in the area under snow and glaciers (Map 3). From comprising more than one-fourth of total area under this category in 1989, the proportion of land under this category reduced to about one-fifth of the total area in 2000. This accounted for a fall of more than twenty five percent in the area under this category. The largest proportion of the area was transferred to rocky barren area (Table 2). Rocky barren surfaces in 2000 accounted for close to half of the total area. There was a visible shrinking in the area under snow. The river line as well as area under the category of wetlands has also diminished (Table 2). It is a worrying fact for a place like Lahaul that as it is has an arid landscape. Some area that was earlier under grasslands has also deteriorated into rocky barren surface. This could be the result of avalanche related erosion of the soil cover. Grasslands that earlier accounted for more than fifteen per cent of the total area also exhibited a decreased acreage in the year 2000. A major portion of this loss may be attributed to its degradation into scrub land followed by rocky barren surface. Some amount of land also got transferred to agricultural land use and some to evergreen forest (Map 3).

In some places evergreen forest land, rocky barren surfaces and land under snow and glaciers got transformed into grasslands as well. This may be accounted for by intra-regional variations. Scrubland the fourth major land cover category gained some more land. It witnessed an increase of more than sixteen percent in its total area. Most of this land comes from grasslands, rocky barren surface and land under snow and glaciers (Table 2). There is a distinct movement towards the warming of this region with land cover associated with alpine regions converted to land cover associated with sub-alpine and temperate climatic regimes. Other land use land cover categories that show slight increases in their areas included the area under agriculture, the area under rural settlements and the area under evergreen forests (Map 3). In each of these categories one notices the human influence. It is to be expected that with time the human impact on the physical landscape would increase. Whether this is to the benefit of the landscape or not remains to be seen.

3.4 Land Use Land Cover Change (2000-2011)

The period spanning more than a decade from 2000-2011 show a slight reversal of trends established during the previous twenty five years. The most marked change was in the increase in the area under snow cover and glaciers (Map 4). According to the local sources the year 2011 saw an early and heavy snowfall. This could be the reason for the sudden increase in areal spread of the snow cover. Close to one third of the total area (32.408%) was reported to be under snow in the first week of October 2011. Over the decade there had been an increase of more than fifty percent in the area under snow. Most of this came from the area earlier under rocky barren surface. Clearly an increased precipitation is to account for it. Rocky barren surface in the same period was reduced by more than thirty percent (Table 3). While it lost the greatest amount of area to snow and glaciers some amount was transferred to grasslands and scrublands as well. A recent trend to plant Seabuckthorn, a native of the Ladakh region now being encouraged in Lahaul as well, could account for part of the growth in the area under scrubland. Grasslands too could have increased through human endeavour because field visit to the area showed that there was a concerted effort made to increase the area under grasses particularly close to the settlement area. Grasses are important for the purpose of fodder.

Table 2: Land use and land cover change 1989-2000

Category	Rural Area	Agriculture	Evergreen	Grassland	Scrub Land	Rocky Barren	River Line	Lake/ Pond	Snow and Glaciers	Year Total (1989)
Rural Area	217.62 (100)	0	0	0	0	0	0	0	0	217.62 (0.03)
Agriculture	7.65 (0.12)	6207.48 (99.88)	0	0	0	0	0	0	0	6215.13 (0.91)
Evergreen	0	15.84 (0.11)	13806.4 (98)	261.99 (1.86)	1.8 (0.01)	0.99 (0.007)	0.36 (0.002)	0	0.18 (0.001)	14087.56 (2.06)
Grassland	0	342.99 (0.32)	337.59 (0.32)	98825.2 (92.89)	5401.26 (5.08)	1476.27 (1.39)	0	0	0.54 (0.001)	106383.85 (15.55)
Scrub Land	0	0	0	0	72763.9 (100)	0	0	0	0	72763.9 (10.64)
Rocky Barren	0.18 (0.00006)	8.28 (0.003)	59.31 (0.02)	203.67 (0.07)	3690.36 (1.28)	280352 (97.50)	30.96 (0.01)	0.9 (0.0003)	3184.47 (1.11)	287530.13 (42.03)
River Line	0	0	0	0	0	15.75 (1.00)	1565.46 (98.96)	0.63 (0.04)	0	1581.84 (0.23)
Lake Pound	0	0	0	0	2.16 (0.94)	6.39 (2.78)	0	221.31 (96.17)	0.27 (0.12)	230.13 (0.03)
Snow and Glaciers	0.27 (0.0001)	0	47.88 (0.02)	332.91 (0.17)	2754 (1.41)	52162.7 (26.74)	14.22 (0.01)	51.39 (0.026)	139728 (71.62)	195091.46 (28.52)
Year Total (2000)	225.72 (0.03)	6574.68 (0.96)	14251.2 (2.08)	99623.77 (14.56)	84613.48 (12.37)	334014.1 (48.83)	1611 (0.24)	274.23 (0.04)	142913.5 (20.89)	684101.62 (100)

The area under grasslands, unlike in the previous years, during this decade saw a noticeable increase. Grasslands in this period have appropriated area from almost all other land use categories. The maximum contribution has been from the category of rocky barren surface but evergreen forests and scrubland also have transferred land to the category of grasslands. Again a slight cooling of the temperatures may have a role to play. Some agricultural land has also transformed into grassland (Table 3). This could be the result of human decisions. Scrubland is another category that has shown an increase in areal extent during this period (Map 4). This trend has remained consistent since 1976. Almost one-sixth of the total area is under scrubland. This area has increased by more than fifteen percent. Scrubland has gained area from evergreen forests, snow and glaciers and most of all from rocky barren surfaces. It has also lost area to rocky barren land, grasslands and agriculture (Table 3).

All other land use categories except evergreen forests have shown a marginal increase (Map 4). While the area of rural settlement has mostly impinged upon the agricultural area for its increase, agriculture has drawn on land from all categories except for rural settlement and water bodies, drawing the lion's share from the category of grasslands followed by scrublands. Evergreen forests exhibited a decline in areal extent. This category lost land to agriculture and grasslands. It is possible patches of forest may have been destroyed due to hazards such as avalanches or died because of the intense cold.

Table 4: Land use and land cover Change 1976 - 2011

Category	Rural Area	Agriculture	Evergreen	Grassland	Scrub Land	Rocky Barren	River Line	Lake /Pond	Snow and Glacier	Plantation	Year Total 1976
Rural Area	201.51 (100)	0	0	0	0	0	0	0	0	0	201.51 (0.03)
Agriculture	33.57 (0.59)	5497.2 (96.82)	0	0	0	0	0	0	0	147.24 (2.59)	5678.01 (0.83)
Evergreen	0.09 (0.0009)	18 (0.17)	9649.08 (91.94)	779.85 (7.43)	21.96 (0.21)	24.3 (0.23)	0.63 (0.01)	0	1.17 (0.01)	0	10495.1 (1.53)
Grassland	1.98 (0.001)	2430.63 (1.80)	3883.41 (2.87)	97558.5 (72.13)	19168.9 (14.17)	10905.7 (8.06)	0.99 (0.0007)	24.48 (0.09)	1248.21 (0.92)	29.16 (0.02)	135251.96 (19.77)
Scrub Land	0	0.09	0	610.83 (1.09)	54087.8 (96.28)	1476.81 (2.63)	0	0	0	0.72 (0.001)	56176.3 (8.21)
Rocky Barren	0.18 (0.0001)	16.65 (0.009)	51.48 (0.03)	12524.3 (7.14)	12535.4 (7.15)	122848 (70.05)	29.79 (0.02)	45.45 (0.03)	27320.9 (15.58)	0	175372.15 (25.64)
River Line	0	0	0	0	0	15.57 (1.03)	1498.14 (98.95)	0.27 (0.02)	0	0	1513.98 (0.22)
Lake Pond	0	0	0	0	2.16 (0.79)	8.73 (3.20)	0.18 (0.07)	260.73 (95.48)	1.26 (0.46)	0	273.06 (0.04)
Snow and Glacier	0	0.09 (0.00003)	61.38 (0.02)	3871.71 (1.29)	7932.33 (2.65)	94018.5 (31.43)	81.45 (0.03)	39.33 (0.01)	193136 (64.56)	0	299140.79 (43.73)
Year Total 2011	237.33 (0.03)	7962.66 (1.16)	13645.35 (1.99)	115345.19 (16.86)	93748.55 (13.70)	229297.61 (33.52)	1611.18 (0.24)	370.26 (0.05)	221707.54 (32.41)	177.12 (0.03)	684102.79 (100)

4. Conclusion

A study of the change in land use and land cover patterns in Lahaul over a period of four decades is indicative of large scale modification of the area. Both bio-physical and socio-economic forces are to account for this. On the one hand global process such as global warming and climate change are leading to a melting of glaciers in Lahaul, a reduction in the snow cover and an upward movement of the tree-line. This has made the region more susceptible to natural hazards like avalanches and extreme climate events like excessive snowfall, cloudburst and avalanches. On the other hand the impact of human activities on the landscape is no less visible. There is an expansion in both the area under agriculture and the area under settlement. While this is likely to result in a further change in the man – environment interaction, it is also not without cultural ramifications for the region.

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