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Land Change in Tirthan Valley: The Case of Great Himalayan National Park Conservation Area

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ABSTRACT Humans are dominant agent of landscape change. Off lately, anthropogenic induced changes have visibly degraded environment around the world putting a serious question over the sustainability of both natural and man-made ecosystems. The sustainability of the ecosystems has found to be directly linked to changes in LULC. The present study aims to analyse long-term land use change in the Tirthan Valley of Himachal Pradesh; the region is a part of protected area collectively known as GHNPCA. With the help of multi-temporal satellite images of LANDSAT, this study reconstructs the trajectory of land changes over a period of five decades. The data shows an increase in forest cover (7.29%), rocky/barren land (45.35%), agriculture/horticulture land (28.94%) and settlement/ built-up (190.48%) while decrease in pasture/open land (29.97%), snow cover (56.14%) and river/water body (54.52%). The results have shown significant land changes in post protected area status.

INTRODUCTION

The environmental issues and problems that humanity faces today can be attributed to the changes brought down to the landscapes around the world (Grimm et al. 2008). The anthropological and cultural forces in the form of land use/ cover change have tremendously altered the landscapes globally (Lambin and Geist 2008). The changes are so marked and profound that it is hard to find anywhere that is still untouched (Yang 2001; Nuwer 2016); therefore, it is being said that pristine landscapes are a myth (Denevan 1992). The ever-increasing population and subsequent demand for natural resources has resulted into transformation of landscapes at an immense scale (Tekle and Hedlund 2000; Musakwa and Wang 2018). The rate and intensity of such transformation are high especially in mountainous areas (Rao and Pant 2000); where land use/cover change and climatic variability have increased the landscape sensitivity thereby enhancing the ecosystem fragility (Pauchard et al. 2009).

The Himalayan landscape is characterized by fragile ecosystem, geologically unstable, complex topography, high rate of endemism, rich biodiversity, increasing population with limited land resource, distinct socio-cultural and economic practices which clearly place them differently from the downstream areas (Beniston et al. 1996; Rao and Pant 2000; Kidane et al. 2012).Therefore, any change in land use/cover in such an environment has clear implications and far-reaching impact over plain areas (Nepal et al. 2014). Resource utilization and infrastructure development have been identified as the major factors resulting in landscape alterations in Himalayan landscape (Gairola 2008).

The unprecedented population growth and subsequent developmental and infrastructural activities, change in agriculture pattern and practices, shift to horticulture, deforestation, grazing, forest fires, tourism, construction of roads and improved connectivity, rural to urban shift are some of the factors that have caused land use/ cover change in Western Himalayas thus putting immense pressure over limited available natural resources resulting into environmental degradation (Singh 1998; Tiwari 2000; Vishwa et al. 2013). Thus, land use/cover changes in combination with increased climatic variability have the potential to alter the ecosystem processes and cause biodiversity loss. The Protected Areas were created to ease the pressure over endemic flora and fauna so that ecosystems could thrive. The establishment of such areas was accompanied by creation of Ecozone/Buffer Zone to accommo-

date the indigenous communities thus although the pressure not fully stopped but it has shifted to greater extent over such Ecozone/Buffer zones (Guerra et al. 2019). The shifted pressure has turned these zones into some of the most intensively used land use/cover areas. In this way, these areas have become contesting grounds for socio-cultural and physical dimensions of human-environment interactions and resultant sustainability concerns.

Land resource forms the backbone of socio-cultural and economic activities in the Himalayan landscape (Raman and Punia 2012) whereas land use/cover change analysis has emerged as an important tool in tracing the landscape evolution in spatial and temporal framework (Ouedraogo et al. 2011). The socio-cultural, economic and biological factors are the primary drivers of any land use/cover change where changed land use/cover conditions in turn affect these factors (Sohl and Sohl 2012). Both natural and anthropogenic factors are responsible for driving land use/cover change whereby various natural ecosystem processes are disturbed thereby affecting human beings the most (Turner and Ruscher 1988; Ruiz-Luna and Berlanga-Robles 2003). The close observation of land use/cover change helps not only quantifying the dimensions and degree of landscape change but also helps in unraveling the forces responsible for such a change (Riebsame et al. 1994) and understanding of the changing dynamics of complex human-nature interaction over time.

The initial surveys for creation of a National Park in Western Himalayas and subsequent issuance of notification of intent in 1984 heralded the development of Great Himalayan National Park (GHNP) in Kullu district where a major part of the Tirthan Valley was incorporated into the park. The final notification of 1999 culminated the creation of protected area and subsequent restrictions imposed over entering the area. The analysis of the LULC maps and multiple field visits have demonstrated that the Tirthan Valley underwent land use/cover changes as a result of the creation of the protected area, formation of the Ecozone, restriction of access to the park area, changes in nature of agriculture pattern and practices in the Ecozone, grazing, deforestation, forest fires, World Heritage Status (WHS) in 2014 and subsequent increased tourism and resultant infrastructural and developmental activities. Therefore, the changes in LULC of the area can be attributed to the ecological protection in the protected area and subsequent development in the Ecozone.

The study aims to look into the historical land use/cover change over a period of almost 50 years where declaration of vast areas of Tirthan Valley as protected place have proven to be an important turning point for the subsequent land use/cover changes in the area. The study strives to analyze the LULC changes through proper identification and mapping of suitable LULC categories for different time periods (1972, 1981, 1991, 2001, 2011 and 2020) with major focus over forces responsible for driving LULC changes in temporal and spatial framework in both pre- and post-protected area designation phase.

Historical Background of LULC

Landscapes are essentially the result of shared relationship between people and place (Hunziker et al. 2007). The identified LULC categories in the Tirthan Valley are the result of historically shared human-environment relationship and their evolution over time. In this way, LULC is the outcome of continuous operating physical and cultural forces in the area. It is, therefore, pertinent to look into the background of prominent LULC categories that how they have been shaped and reshaped and forces responsible for the same.

The forest areas of Tirthan valley especially in the core zone are some of the most pristine and untouched forest resources of the state. The Valley is endowed with diverse range of natural vegetation some of which show affiliations to different climatic and sub-climatic ecosystems. A major part of the area lies in the Lesser Himalayas and therefore altitudinal variations, general physiography and topography, slope and aspect have led to the development of diverse plant communities resulting into rich assemblage of flora having universal value. The lower valley floor areas up to the height of 2,000 meters are occupied by Riverine forests, secondary scrub and forest edges while the zone from 2000-3000 meters is covered with temperate broad leaved and mixed conifers forests. Sub-alpine (Birch-Rhododendron) forests and alpine meadows and scrubs are found at an altitude of 3,000-4,500 metres. The forest cover is untouched in the high-altitude areas of the core zone while it has been cleared over time in the

area comprising present day Ecozone for agriculture, residential, domestic and commercial purposes especially in the relatively low-lying areas along the Tirthan River and its tributaries. The people have been dependent over the forest areas for grazing, collection of herbs and medicinal plants, hunting, timber and pilgrimage to sacred deities' places throughout the year. The percentage of forest cover is more in the Ecozone than in the Core zone due to the dominance of sub-alpine and alpine meadows, scrubs and rocky and snow bound areas in the high-altitude part. Although some of the forest areas have been modified by human induced changes, these are among the few areas in Western Himalayas still found to be in original state.

The socio-cultural and economic activities of the locals have always centered on livestock rearing and its management in the area. The pasture/open land areas in the high-altitude part of the core zone were important traditional grazing sites *(thaches)* where shepherds used to graze their livestock for centuries. The sub-alpine and alpine grasslands were important grazing sites not only for locals but also for migratory graziers from Suket region of district Mandi and Ani and Nirmand areas of Outer Kullu during summer months. People have been traditionally visiting these high-altitude grasslands for herb collection also, an important source of income for the locals. The herb collection and grazing activities altogether had detrimental affect over these high-altitude pasture lands in the past and still are affecting, although banned inside park. Besides these high-altitude *thaches*, there are grasslands locally known as *ghasnies* in the Ecozone, an important source of fodder during winter season. The pressure on these grasslands has increased due to restrictions over entering into the Core zone. These *ghasnies* are set to fire annually by the locals, as they believe doing such will bring good yield next season. Such fire incidences are not uncommon and have found to be associated with causing forest fires thus damaging huge patches of forest areas thereby affecting land use/cover. At much higher elevation these are important grazing grounds for cattle and livestock population of the Ecozone. The increased pressure over pasture/open land has turned them into one of the most intensively used land use category sometimes becoming reason of conflicts among locals.

Agriculture forms the backbone of the mountain economy and has been the primary occupation of the people in Tirthan Valley. The agriculture in the area had been mostly subsistence in nature where focus was over growing traditional crops adapted to local conditions (Harcourt 1871; Diack 1898). The government efforts in the form of supportive agriculture and horticulture policies and subsequent improvement in the road networks resulted into changing agriculture pattern and practices in the area. The improved connectivity and exposure to market economy have resulted into people switching over to horticulture and cash crops. In this way, agriculture fields with traditional crops have been taken over by cash crops and fruit trees while people are relying over food grains purchased from ration depots. Tourism and related infrastructural activities have also resulted into conversion of agriculture land into hotels, restaurants and home stays especially along roads and rivers. The booming of horticulture sector due to increased penetration of road network in otherwise interior areas with difficult terrain has led to enhanced demand for agriculture land. Thus, agriculture/horticulture land has been witnessed to be expanding at the cost of surrounding forest cover over the period of time.

The settlement activities in a mountainous set up is greatly regulated by hill geomorphology and guided by host of physical factors such as slope, aspect, topography, natural sources of water and connectivity. The slope, aspect and natural water sources have found to be an important consideration for habitation and agriculture activities in Tirthan Valley. The settlements in the Valley have been traditionally situated over much gentler slopes while relatively steeper slopes have been utilized for agriculture and horticulture activities after forming terraces. The settlements in such high-altitude areas are mostly in clustered form while they show linear pattern along the rivers (Negi and Irfan 2022). This has been noticed in the case of Tirthan Valley where villages are mostly scattered over the area while the settlements within villages are mostly clustered in nature following local slope, thus lacking any regular pattern. The traditional houses were built in *Kathkuni* style made of locally available material such as stone and timber thus putting huge pressure on forest areas. The population growth and

subsequent desire for nuclear families required individual houses resulting into increased construction activities thereby expanding built-up area over surrounding land. The improved connectivity due to construction of roads in otherwise interior areas, increased exposure to market forces and opening up of rural economy and recent growth in tourism sector are some of the factors that have led to more individual settlements/built-up in the village periphery and along roads especially next to Tirthan River and its tributaries. The settlement/built-up of the area has been found to be influenced by changed socio-economic forces which in turn affecting the land use/cover of the Tirthan Valley.

The rocky/barren land is scattered all over the area predominantly located on warm, dry, sun facing southern slopes. The grasslands or scrub vegetation around villages have been degraded by over-grazing and burning practices causing severe denudation over the years. The recent increase in the rocky/barren land can be attributed to much warmer conditions due to climatic variability where reduced snow cover exposed the rocky/barren land below. The river/water body with snow melts water and surface runoff as the main source supports the diverse flora and fauna of the Valley and has shaped the local landscape characteristics. The Tirthan khad inside the protected area is devoid of any human presence while the flood plain area of Palachan Gad between Gushaini and Tung and Tirthan River between Sai Ropa and Gushaini in the Ecozone have been encroached upon by tourism related developments resulting into increased river water pollution and changed land use/cover adjacent to water bodies. Snow Cover mostly found in the high-altitude areas in the eastern part have shown temporal and spatial variability where minimum area under snow cover during the last identified period illustrate climatic variability. Besides changes in rocky/barren land due to traditional practices (Over-grazing and burning of *ghasnies*) and encroachment near river/water bodies, all the changes in these three land use/cover categories (rocky/barren land, river/water body and snow cover) have been found to be caused due to natural/environmental factors.

Study Area

Tirthan valley is situated in Banjar tehsil of western Himalayan district of Kullu in Himachal Pradesh. The valley is named after a sacred water spring called *'Tirath'* which originates at Hanskund Peak (4800 metres) and flows through deep pristine forested areas. The spring is the source point of Tirthan stream which forms the valley between its origin at Tirath and a place called Larji where Tirthan is joined by another stream Sainj. The two ultimately merge into Beas River further downstream, an important tributary under Indus River system. The protected areas of River Sainj and Tirthan and their Eco-development zones are collectively referred to as the Great Himalayan National Park Conservation Area (GHNPCA).

The study area is situated between 31°44´29´´ and 31°33´00´´ north latitudes and 77°19´48´´ to 77°40´43´´ east longitudes. It is bounded in the north by Sainj Valley, in the east by Rupi Bhaba Sanctuary, in the south by Jalori Protected Forest (Outer Seraj) and in the west by Banjar valley of Kullu district. The areal extent of the study area is 405.7 km². Tirthan River is joined by a number of tributaries all along its course. *Tirthan khad* and *Palachan Gad* merge at Gushaini to form the Tirthan River. The climate of the area is typically Western Himalayan temperate and alpine type with four distinct season viz-a-viz. spring, rainy/summer, autumn and winter and precipitation is moderate over most of the year and abundant during rainy season (Ramesh et al. 1999).

The average temperature during summer season ranges between 20°C to 30°C and 0°C to 5°C during winter season. The precipitation is mostly in the form of snow during winter season where higher areas receive heavy to very heavy snowfall. The valley is covered with diverse vegetation from sub-tropical, temperate to sub-alpine and alpine. The main geomorphic processes that are active in the area are glacial, fluvial, denudation and structural where glacial and periglacial processes are dominant in the high-altitude areas and fluvial process is active in the lower valley floor. The geomorphic features identified in the Tirthan valley are highly dissected hills and valleys, piedmont slope, piedmont alluvial plain, younger alluvial plain, active flood plain, glacial terrain and snow cover. The area comprises of rocks belonging to three litho-tectonic groups referred to as the Vaikrita group, the Kullu group, and the Rampur/Naraul group comprising mostly schist, gneiss, migmatite, quartzite, marble, phyl-

lite, limestone, white-green quartzite and basic flows. These rock structures in association with local climatic conditions, topographic features and vegetation structure have given rise to sandy, alluvial and podsolic soils. A major part of the area lies in lesser Himalayas therefore being a part of larger Himalayan Ecosystem and due to varied altitudinal zones, physiographic features and climatic conditions, the Tirthan Valley is home to diverse floral and faunal species marked by high rate of endemism thereby making it an important biodiversity hotspot for which UNESCO has granted World Heritage Status (WHS) in 2014.

The study area is divided in four main zones viz. the Park area (Core Zone), Wildlife Sanctuary (WLS), Ecozone and Territorial Area (Fig. 1). In Tirthan Wildlife Sanctuary, certain human activities are allowed with some regulations while such activities are completely prohibited in the main park area. The Tirthan valley is surrounded by high ridges and snow-covered peaks in the northern, eastern and southern part and thus open and accessible towards the western side where most of its population resides. Therefore, a buffer zone of 5 km was delineated from the western boundary of the park as Ecozone accommodating around 89 villages. The administrative arrangements of the villages in the Ecozone have been entrusted with the park administration so that the developmental activities do not impinge upon the biological sensitivity of the buffer zone. The territorial area with Banjar as the major town is the most densely populated area in the Valley located on the western part and outside the ambit of park administration (Fig. 1). There is total 8 Panchayats in the Ecozone of the Tirthan valley namely Kandidhar, Kalwari, Shirikot, Nohanda, Pekhri, Tung, Shilhi and Mashiyar. Some of the villages under these Panchayats come under the Territorial administration.

Objectives

The present study aims to fulfill the following two objectives:

i. To examine the trend of Land use land cover (LULC) change in Tirthan Valley in temporal and spatial framework.
ii. To study the forces/factors responsible for changes in the land use land cover in the Tirthan Valley.

METHODOLOGY

The analysis of land use/cover change in the Tirthan Valley has been undertaken with the help of six multispectral satellite images accessed from USGS. The images downloaded are Landsat 1 (MSS), Landsat 3 (MSS), Landsat 5 (TM), Landsat 7 (ETM+), Landsat 5 (TM), and Landsat 8 (OLI/TIRS) for the time period 1972, 1981, 1991, 2001, 2011, and 2020 respectively (Table 1). The spatial resolution of the visible bands for Landsat 1 (MSS) and Landsat 3 (MSS) are 60 meters while that of Landsat 5 (TM), Landsat 7 (ETM+) and Landsat 8 (OLI/TIRS) images are 30 meters. The spatial resolution of panchromatic band for 2001 and 2020 images are 15 meters which provides detailed in-depth information. The seasonal consideration has been taken into account while selecting the satellite images for better visibility and atmospheric clarity. The images collected are either for the month of October or November to reduce the effect of cloud cover. In addition to satellite images, some secondary data have also been utilized in the form of topographical sheets (1: 50,000) and digital elevation model (DEM). The digital elevation is used to avoid misclassification of agricultural/horticulture land above 3000 meters from the mean sea level. Multiple field visits were also undertaken between 2016 and 2020 where different villages of the Ecozone were visited which not only helped in knowing the present status of the land use/land cover but drivers of land use/cover change during the same period. The field visits included in-depth interviews and focus group discussion with villagers and other stakeholders thus providing a glimpse about the nature of past human-environment relations and forces responsible for changes in the land use/cover of the Valley (Table 1).

The delineated classes are Forest Cover, Pasture/Open Land, Rocky/Barren Land, Snow Cover, River/Water Body, Agriculture/Horticulture and Settlement/Built-up. The land use/cover (LULC) classes were assigned unique identities by using training samples from different images. These training samples were used to generate signatures, which were then used to train the classifier. The maximum likelihood algorithm, a commonly used method in image processing (Lu and Weng 2007), was applied to classify the image. The resulting maps were compared to analyze the

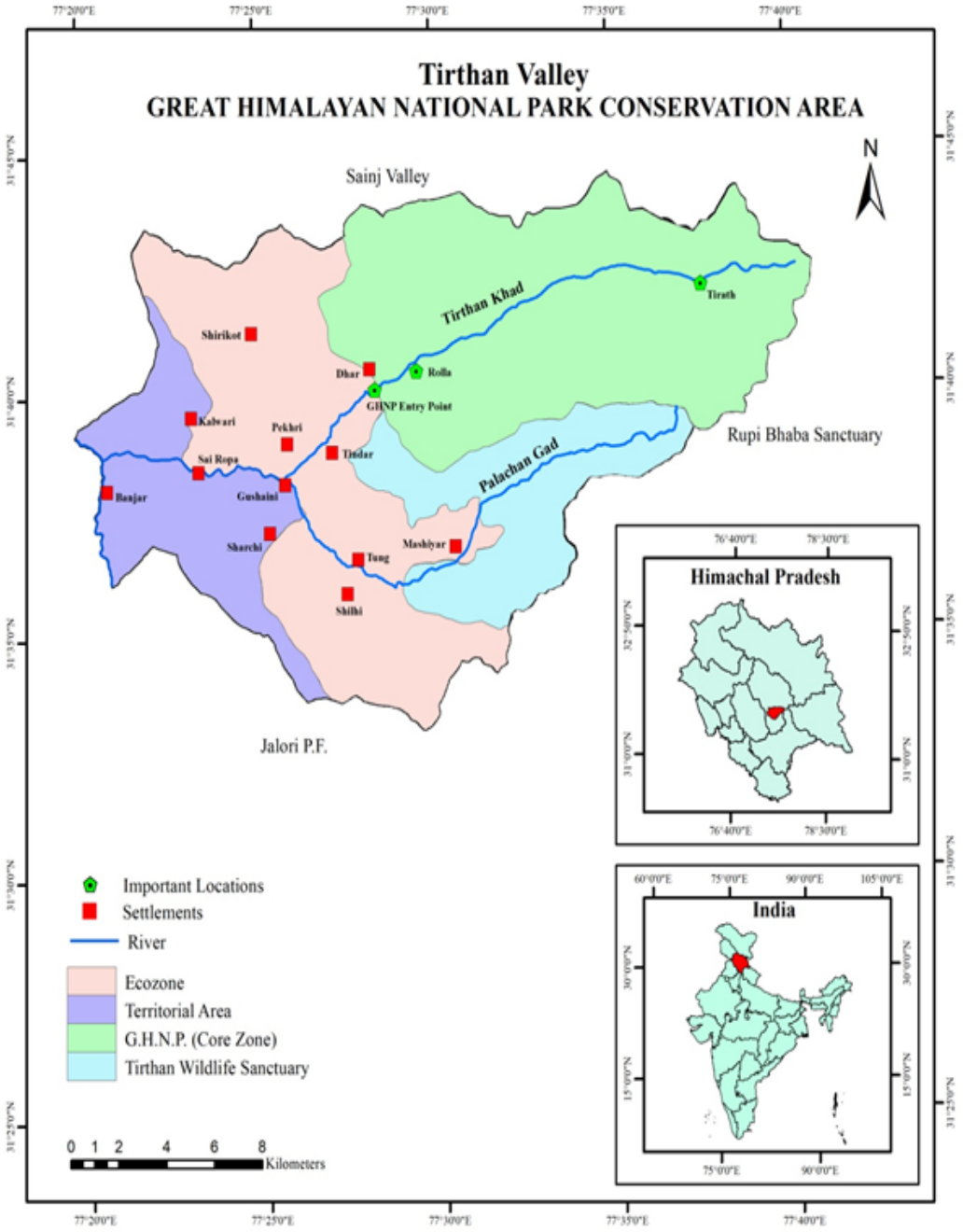

Fig. 1. Location of study area
Source: Prepared by Authors using SOI Topographical Sheets (1:50,000) and Map by GHNP Administration

Table 1: Details of satellite data used in the study

Year	*Satellite/Sensor*	*Acquisition date*	*Path/Row*	*Spatial resolution*	*Source*
1972	Landsat 1 (MSS)	15/11/1972	158/38	60	USGS
1981	Landsat 3 (MSS)	17/10/1981	158/38	60	USGS
1991	Landsat 5 (TM)	16/11/1991	147/38	30	USGS
2001	Landsat 7 (ETM+)	18/10/2001	147/38	30	USGS
2011	Landsat 5 (TM)	22/10/2011	147/38	30	USGS
2020	Landsat 8 (OLI/TIRS)	14/10/2020	147/38	30	USGS

Source: Prepared by Authors using data from Landsat 1 (MSS), Landsat 3 (MSS), Landsat 5 (TM), Landsat 7 (ETM+), Landsat 5 (TM), Landsat 8 (OLI/TIRS)

changes in the land use/cover categories. To study the LULC changes between 1972 and 2020, post-processing techniques were employed. Satellite images of 2001 and 2020, captured with a 15-meter spatial resolution in the panchromatic band were resampled to a 30-meter resolution using the nearest neighborhood algorithm. This resampling ensured similar resolution for both images. Additionally, an accuracy assessment was conducted using ground truth GPS data to ensure the validation of the results before proceeding with image comparisons. The overall accuracy rates for the years 1972 and 2020 were determined to be 89 percent and 92 percent, respectively. This rigorous validation process enhances the reliability and credibility of the findings, enabling more confident comparisons between the images from these two time points. In addition to classification, a change detection technique was applied to create a transformation matrix. This matrix illustrated the distribution and magnitude of changes in the LULC classes over time.

OBSERVATIONS AND DISCUSSION

The studies pertaining to land use/cover change have always been a part of geographical research. Off lately, such studies have received great impetus owing to advancement in spatial technology and better understanding of human-environment interactions. The government efforts of improving transport infrastructure in the post-independence period had helped in opening up of the rural economy. The infrastructural development, improved connectivity, exposure to market forces, increased tourism and subsequent progresses and outsider influence are some of the factors that have caused significant changes in human-environment relationships in the Himachal state of western Himalayas. The different studies have also pointed out these changes. Vishwa et al. (2013) discussed that the factors such as increase in area under cultivation and settlements, horticulture activities, tourism development, hydro-power generation and increased construction activity related to road building and infrastructure development have changed the landscape of Kullu from predominantly natural to human dominated. Negi et al. (2022) discussed that improvement in accessibility, growth in horticulture sector, tourism development, unplanned urbanization and increased inflow of population have caused tremendous land use land cover changes in the Upper Beas Valley. Negi and Irfan (2022) in their study have shown significant reduction in snow cover and forest cover while increase in barren land, agriculture/horticulture land and built-up area in the upper Kullu Valley thereby changing the land use/cover. Vatsal et al. (2023) have shown significant landscape transformation in Sainj Valley area under GHNPCA since 1980s. The area has witnessed rapid infrastructure and developmental activities owing to the increased tourism and subsequent inflow of population and resultant pressure over the natural environment. The Sainj Valley has experienced such changes prominently in the post-protected period. These results are corresponding to the findings of the present study. The protected area status and subsequent restrictions imposed have eased pressure over the core zone however resulted into intensified land use practices in the Ecozone.

Land Use/Cover Pattern in 1972

The land use/cover map of 1972 is drawn from Landsat 1 (MSS) satellite images and was subsequently divided into seven major categories (Fig.

2 and Table 2). The land use/cover map of 1972 is characterized by the predominance of forest land followed by pasture/open land. The largest part is covered by forest cover 233.32 km² comprising 57.51 percent of the total area. The forest cover in the area comprising Wildlife Sanctuary (WLS) is found to be continuous except in areas adjacent to Mashiyar panchayat where agriculture fields have taken over adjoining forest land or in high altitude areas where tree cover gives way to sub-alpine and alpine meadows. The intense agricultural activities and huge number of settlements in and around Banjar town have caused decreased forest cover in the Territorial area as compared to other parts of the Tirthan Valley.

The area under pasture/open land is 93.67 km² covering 23.09 percent of the total area. The map for the year 1972 shows that the pasture/open land in the Core zone occupies the high-altitude areas in the form of sub-alpine and alpine meadows *(thaches)*. The area is supporting high quality pastures and herbs of great medicinal value therefore had been traditional grazing and herb collection sites. These pasture lands and surrounding *thaches* have great religious significance also in the form of deities' places to which local people visit throughout the year.

In this way, these high-altitude pastures had been driving socio-cultural, religious and economic set up of the people throughout the valley and in turn had been shaped and reshaped by these operating forces. The pasture/open land covers the maximum area in the Core zone dominating in the northern and eastern high-altitude lands. The pasture/open land in relatively low lying areas of the Ecozone and Territorial areas are the most pressurized land use categories mainly surrounding villages especially during winters.

The agriculture/horticulture covers an area of 29.41 km² constituting 7.25 percent of the total area. The LULC map shows that the area comprising present day Core zone and WLS have

Table 2: Land use/cover pattern (1972-1991)

	1972		*1981*		*1991*	
LULC Classes	*Area (Km²)*	*Area (%)*	*Area (Km²)*	*Area (%)*	*Area (Km²)*	*Area (%)*
Forest cover	233.32	57.51	272.44	67.15	251.87	62.08
Pasture/Open land	93.67	23.09	60.01	14.79	84.52	20.83
Rocky/Barren land	27.12	6.68	25.87	6.38	14.85	3.66
Snow Cover	14.16	3.49	7.41	1.83	17.72	4.37
River/Water body	6.97	1.72	7.1	1.75	4.43	1.09
Agriculture/Horticulture	29.41	7.25	31.62	7.79	30.6	7.54
Settlement/Built-up	1.05	0.26	1.25	0.31	1.71	0.42
	405.7	100	405.7	100	405.7	100

Source: Computed by Authors using Landsat-1 (MSS), Landsat-3 (MSS) and Landsat-5 (TM), USGS

Table 3: Land use/cover pattern (2001-2020)

							LULC Change	
	2001		*2011*		*2020*		*1972-2020*	
LULC Classes	*Area (Km²)*	*Area (%)*	*Area (Km²)*	*Area (%)*	*Area (Km²)*	*Area (%)*	*Area (Km²)*	*Area (%)*
Forest Cover	266.33	65.65	248.81	61.33	250.33	61.70	17.01	7.29
Pasture/Open Land	65.56	16.16	69.55	17.14	65.60	16.17	-28.07	-29.97
Rocky/Barren Land	22.27	5.49	19.43	4.79	39.42	9.72	12.3	45.35
Snow Cover	10.11	2.49	21.76	5.36	6.21	1.53	-7.95	-56.14
River/Water Body	3.19	0.79	4.43	1.09	3.17	0.78	-3.8	-54.52
Agriculture/Horticulture	36.20	8.92	39.47	9.73	37.92	9.35	8.51	28.94
Settlement/Built-up	2.04	0.50	2.25	0.55	3.05	0.75	2	190.48
	405.7	100	405.7	100	405.7	100		

Source: Computed by Authors using Landsat-7 (ETM+), Landsat-5 (TM) and Landsat-8 (OLI/TIRS), USGS

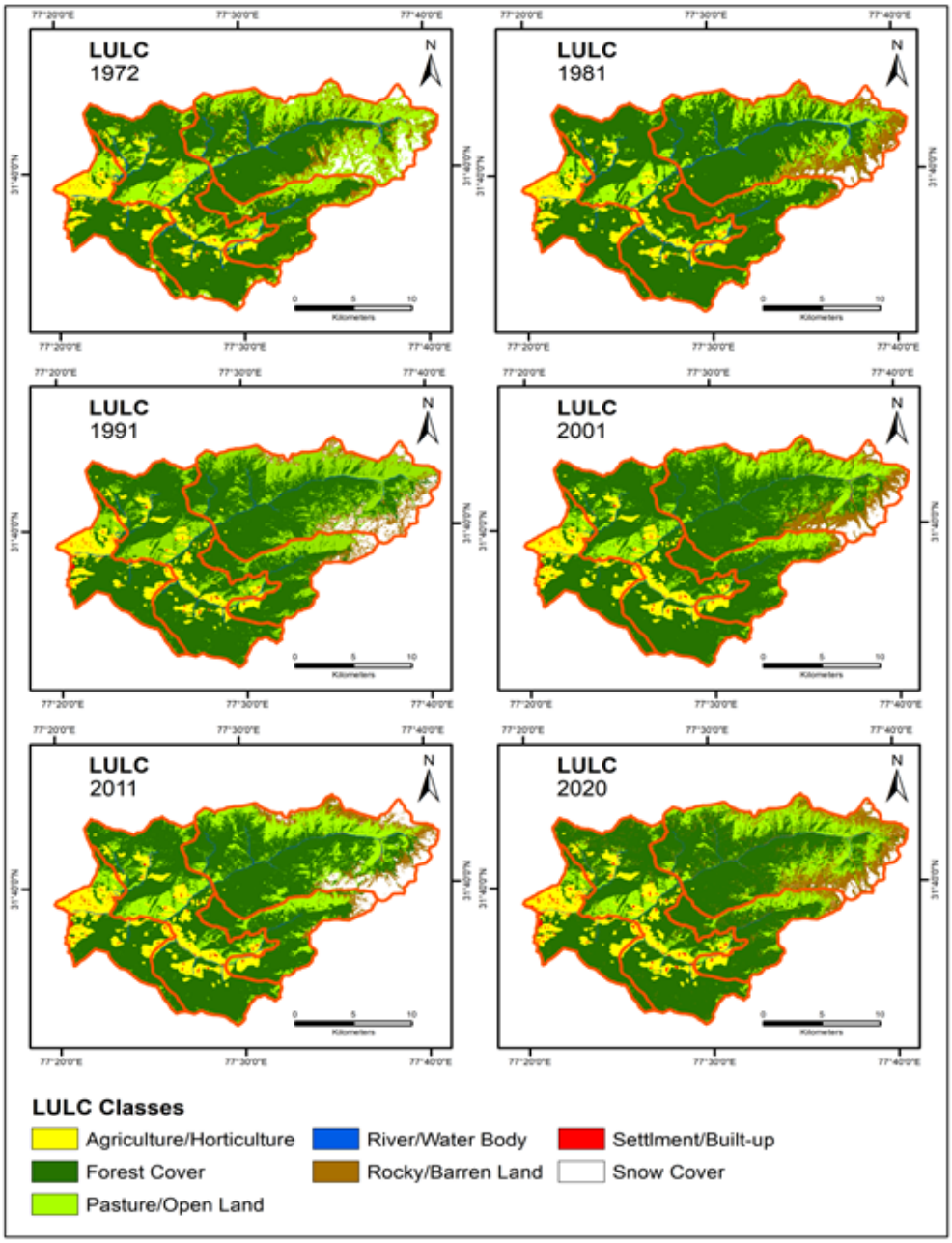

Fig. 2. Land use/cover pattern from 1972 to 2020
Source: Prepared by Authors using Landsat-1 (MSS); Landsat-3 (MSS); Landsat-5 (TM); Landsat-7 (ETM+); Landsat-8 (OLI/TIRS), USGS

always been devoid of any permanent settlement and agricultural activity even before the creation of the protected area except few agricultural lands owned by people from Dhar and Shungcha village in Rolla and Balu area which has come under park area. The area comprising the present day Ecozone and Territorial Area have the highest agricultural area. The agricultural area is mostly located on both the sides of Tirthan khad, Palachan Gad and Tirthan River. The agriculture area is more along the Palachan Gad than Tirthan khad as the former has larger number of settlements and villages near its course. Traditional crops grown were Wheat, Barley, Maize, Sariyara, Kodara, Kathu, and Millets and Vegetables etc. and agriculture was mostly subsistence in nature. The rocky/barren land (27.12 km²) and snow cover (14.16 km²) constitute 6.68 percent and 3.49 percent of the area respectively. The rocky/barren land and snow cover are found in the high-altitude areas in the eastern part. The rocky/barren land can also be seen in dispersed form on southern aspects in the north of Tirthan khad and Tirthan River. This is followed by river/water body (6.97 km²) and settlement/built-up (1.05 km²) covering 1.72 percent and 0.26 percent respectively. The Tirthan khad and Palachan Gad after originating in the eastern high-altitude areas flows westward forming Tirthan River at Gushaini. The Tirthan River system is joined by tributaries all along its course thus forming dendritic and trellis drainage pattern. The traditional settlement pattern is mostly clustered in nature and they are located at some elevation in close proximity to sources of water such as natural spring. The villages comprising clustered settlement can also be seen in close proximity to Tirthan khad, Palachan Gad, Tirthan River and along roads thus organized in linear form.

Land Use/Cover Pattern in 1981

Landsat 3 (MSS) has been used to prepare LULC map for the year 1981 as shown in Table 1 and Figure 2. The largest land cover categories are forest cover (272.44 km²) and pasture/open land (60.01 km²) covering 67.15 percent and 14.79 percent of the area respectively. The data shows that the area under pasture/open land has decreased considerably and almost the same percentage increase has been observed in the forest cover which is due to the state government efforts of plantation drive during 1970s. The snow cover is the next land use category that has shown significant change where it has reduced to 7.41 km² covering 1.83 percent of the area and majority of which is transformed into rocky/barren land covering 25.87 km² with 6.38 percent of the area mostly situated in the eastern higher reaches. This reduction in snow cover can be attributed to less amount of snowfall or much warmer summer condition resulting into melting of snow. The rocky/barren land previously dispersed all over area transformed into forest cover. Thus, the rocky/barren land had not only decreased slightly but changed spatially. The agriculture/horticulture (31.62 km²) and settlement/built-up (1.25 km²) covering 7.79 percent and 0.31 percent of the total area respectively showed slight increase in these categories. This shows that the overall environment concerning agriculture/horticulture and settlement/built-up activities remained stagnant during this period. The river/water body covering 7.10 km² of the area with 1.75 percent showed very negligible increase.

Land Use/Cover Pattern in 1991

The land use/cover map for the year 1991 prepared with Landsat 5 (TM) shows that the forest cover and pasture/open land holds the dominant position among the identified land use/cover classes. The forest cover (251.87 km²) and pasture/open land (84.52 km²) constitute 62.08 percent and 20.83 percent of the area respectively. The LULC map and subsequent data analysis illustrate that the percentage point by which forest cover declined and pasture/open land increased are almost similar and further investigation shows that the pasture land had increased at the expense of the forest cover. The similar scenario has been noticed among the rocky/barren land and the snow cover where a decline in rocky/barren land had been followed by similar percentage point increase in the snow cover and further study point towards an increase in snow cover in the eastern higher reaches and along northern boundary over the rocky/barren land. Thus, the rocky/barren land (14.85 km²) and the snow cover (17.72 km²) occupy 3.66 percent and 4.37 percent of the area respectively. The agriculture/horticulture (30.60 km²) and the settlement/built-up (1.71

km²) constitute 7.54 percent and 0.42 percent of the total area thus showing a slow gradual increase over the period. The river/water body class experienced negligible decrease.

Land Use/Cover Pattern in 2001

Landsat 7 (ETM+) satellite image has been used to prepare the LULC map of 2001. The data analysis for the period shows that the forest cover occupies 266.33 km² covering 65.65 percent of the study area thus showing small increase from the last period. The maximum change by percentage point among all the categories occurred in the pasture/open land where it is reduced by 18.96 km² (4.67%) thus covering an area of 65.56 km² constituting 16.16 percent of the study area. A close observation into the LULC map (Fig. 2) shows that the reduction in pasture/open land can be attributed to the transformation into forest cover which is more pronounced in the northern and eastern high-altitude areas. The snow cover occupied 10.11 km² covering 2.49 percent of the area thus reduced considerably where it can be seen restricted over heights in the eastern part. The rocky/barren land has started becoming visible where snow cover is absent. The rocky/barren land covers 22.27 km² constituting 5.49 percent of the area. The agriculture/horticulture (36.20 km²) and settlement/built-up (2.04 km²) covers 8.92 percent and 0.50 percent of the area respectively. The increase in the agriculture/horticulture land can be attributed to the increased focus of people over enhancing agricultural production, expansion of agriculture land and conversion from agriculture to horticulture fields. This was partially driven by restriction over entering to the park area and mainly due to the development of road networks and improved connectivity thereby prompting people to opt for agriculture as an alternative source of livelihood. This was also the period when settlements were expanding where people were moving out from clustered villages and building houses along roads thus more dispersed nature of settlements came to the fore.

Land Use/Cover Pattern in 2011

The Landsat 5 (TM) satellite image was used to prepare the LULC map of 2011, the analysis of which shows that the forest cover and snow cover are two land use/cover categories that have shown considerable changes since 2001. The decline in the forest cover to 248.81 km² covering 61.33 percent of the area raises some of the questions as to how the forest cover has declined despite restrictions imposed in the national park area which is also a matter of further exploration. A close investigation into the LULC map shows that the decline was much more noticeable in the Ecozone especially surrounding villages and pasture/open lands. This decline could be probably due to the felling down of trees in the Ecozone mainly for construction and other developmental purposes resulting from strict restriction and subsequent risk associated with entering park area for timber purpose. An investigation into the map and through multiple field visits, it has come to the knowledge that people are resorting to illegal felling of trees in the Ecozone mainly for timber purpose where maintenance and renovation of old wooden houses *(Kathkuni style)*, construction of new houses and home stays required huge amount of timber wood. Lack of road connectivity to far flung interior areas also made it difficult to procure modern construction material thereby dependency on timber brought from neighboring forest areas is high. Modern chain saw machines have also made it possible to cut down trees in a short time without getting noticed. Lack of manpower at the park administrations disposal and huge area of the Ecozone with tough terrain makes patrolling difficult and thus such activities mostly go unchecked.

The pasture/open land covers an area of 69.55 km² occupying 17.14 percent of the area. Although, the pasture/open land has experienced very slight increase but it has shifted spatially all over the area. An examination into the map shows that the pasture/open land had shrunk along the eastern and the north-eastern boundary and taken over by snow cover and mostly rocky/barren land. A shift in pasture/open land has been noticed towards the Tirthan khad on both the sides in the Core zone but the shift was more pronounced in the northern part. Another important development noticed was that the pasture/open land had become somewhat dense thus forming continuous patches especially in the WLS. The main increase in pasture/open land has been noticed in the Ecozone where it has increased over

areas which were otherwise occupied by forest cover.

The important development that has occurred is related with the snow cover area. The snow cover has increased considerably and occupying the maximum area among all the identified time periods. A thick and somewhat compact snow cover can be seen in the eastern part of the area. The agriculture/horticulture (39.47 km²) and settlement/built-up (2.25 km²) covers 9.73 percent and 0.55 percent of the area respectively, thus, showing slow and gradual increase as in all previously identified periods.

Land Use/Cover Pattern in 2020

The LULC map for the year 2020 is prepared with the help of Landsat 8 (OLI/TIRS) satellite image. The land use/cover map and subsequent data analysis shows that despite the fluctuations in the forest cover of the area since decades they still hold the dominant class position in the area where forest cover accounts for 61.70 percent of the area covering 250.33 km², thus showing very minute increase since 2011.

The pasture/open land being the second most dominant category covers an area of 65.60 km² with 16.17 percent of the area. The rocky/barren land and agriculture/horticulture covers almost similar area with 9.72 percent and 9.35 percent of the area occupying 39.42 km² and 37.92 km² areas respectively. The snow cover with an area of 6.21 km² covering 1.53 percent of the area has shown a considerable decline since the year 2011. The settlement/built-up with an area of 3.05 km² occupying 0.75 percent of the area is the least dominant land use/cover class as is the case in all other previous periods. But despite the least dominant class, this category has shown gradual increase in the area and percentage over the period of time due to increased tourism and subsequent infrastructural and developmental activities.

The rocky/barren land and snow cover have shown significant changes where rocky/barren land (39.42 km²) and snow cover (6.21 km²) occupying 9.72 percent and 1.53 percent of the area respectively. The rocky/barren land has increased considerably and the increase has been noticed in the high-altitude areas along the eastern and northern boundary where the otherwise snow cover areas are taken over by the rocky/barren land due to absence of snow cover. The rocky/barren land can be seen scattered all over the area which is an important change that has significantly increased the areas occupied by the said category. The increase in area under rocky/barren land shows the increased climatic variability in the recent past thus enhancing much warmer and drier conditions. The agriculture/horticulture (37.92 km²) and settlement/built-up (3.05 km²) covering 9.35 percent and 0.75 percent of the area shows gradual increase in their respective areas. The agriculture/horticulture area has shown slight reduction which is due to the large number of construction activities over agriculture land especially along Tirthan River. A large number of hotels, restaurants and home stays have come up over agriculture land especially between Sai

Table 4: Land use/cover transformation matrix (1972-2020)

	Forest cover	*Pasture/ OL*	*Rocky/ BL*	*Snow Cover*	*River/ WB*	*A/HL*	*Settlement/ BU*	*Total Transfer*	
								(Loss)	*Year 1972*
Forest Cover	209.76	8.25	7.50	0.01	0.22	7.42	0.21	23.61	233.37
Pasture/OL	24.69	46.10	18.23	1.73	0.07	2.68	0.07	47.47	93.57
Rocky/BL	11.77	6.50	7.00	0.90	0.02	0.83	0.02	20.04	27.04
Snow Cover	0.95	3.22	6.39	3.60	0	0	0	10.56	14.16
River/WB	2.03	0.76	0.39	0	2.76	0.92	0.14	4.24	7.00
A/HL	0.93	0.63	0.07	0	0.07	26.18	1.62	3.32	29.50
Settlement/BU	0.01	0.01	0	0	0.01	0.06	0.97	0.09	1.06
(Gain)	40.38	19.37	32.58	2.64	0.39	11.91	2.06		
Year 2020	250.14	65.47	39.58	6.24	3.15	38.09	3.03		405.70

Source: Computed by Authors using Landsat 1 (MSS), Landsat 8 (OLI/TIRS)
Abbreviations: OL: Open Land; BL: Barren Land; WB: Water Body; A/HL: Agriculture/Horticulture Land; BU: Built-up.

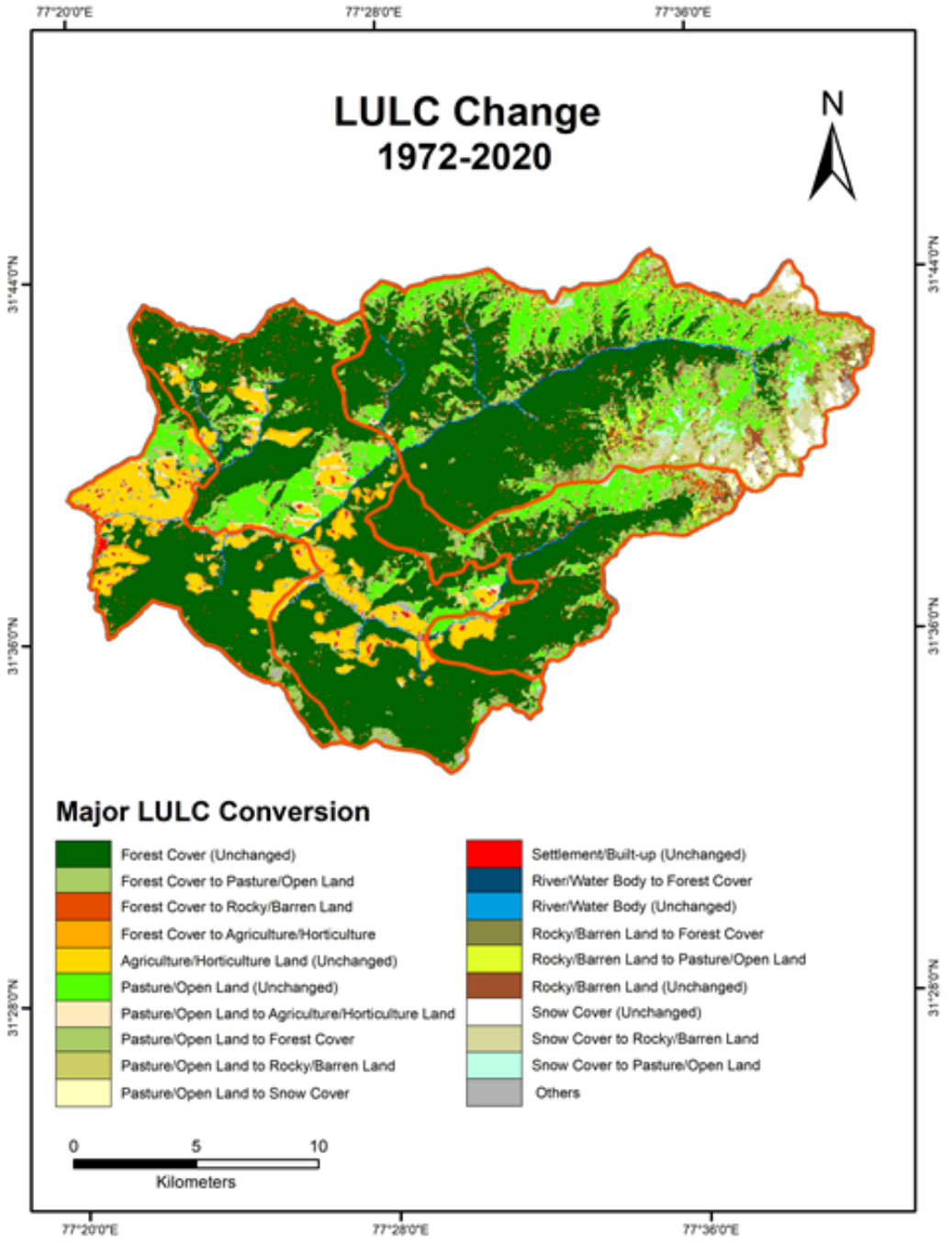

Fig. 3. Land use/cover transformation matrix (1972-2020)
Source: Prepared by Authors using Landsat-1 (MSS), Landsat-8 (OLI/TIRS), USGS

Ropa and Gushaini catering to the increased tourist demand particularly after the recognition of GHNP as World Heritage Site by UNESCO in 2014. This is also the reason for increase in the cover pertaining to settlement/built-up category in the area.

Land Use/Cover Change from 1972 to 2020

The land use/cover maps for the period 1972 to 2020 have been prepared, analyzed and discussed to provide insights into periodic changes of the different LULC classes identified in the area. The maps showing LULC change for the period between 1972 and 2020 have been used (Fig. 3 and Table 4) and subsequent change detection analysis has been undertaken to get a comprehensive picture of the changes that have taken place altogether from the period 1972 to 2020 under different identified LULC classes. The period from 1972-2020 is marked by an increase in forest cover, rocky/barren land, agriculture/horticulture and settlement/built-up and a decrease in pasture/open land, snow cover and river/water body. During the period (1972-2020), the maximum loss is experienced by snow cover which is reduced by 7.95 km² (56.14%) from 1972. The snow cover has been transformed to rocky/barren land (6.39 km²) and pasture/open land (3.22 km²) as a result of prevailing climatic variability. The river/water body has also shown remarkable reduction (3.8 km²) where it is decreased by 54.52 percent of the total area covered by river/water body in 1972. The area covered by river/water body has been transformed into forest cover (2.03 km²) followed by agriculture/horticulture (0.92 km²). The pasture/open land has shown a reduction of 28.07 km² constituting 29.97 percent of the area covered by pasture/open land in 1972. The maximum amount of pasture/open land converted into forest cover (24.69 km²) then followed by rocky/barren land (18.23 km²).

The change detection analysis from the LULC maps of the period (1972-2020) shows that maximum gain occurred in settlement/built-up class which has shown an increase of 2 km² with 190.48 percent increase from that of 1972. The maximum shift occurred from agriculture/horticulture where 1.62 km² of area transformed into settlement/built-up followed by forest cover where 0.21 km² of the forest area converted into settlement/built-up. The rocky/barren land is another category where area cover has increased for the period 1972-2020. The area covered by rocky/barren land has increased by 12.3 km² with 45.35 percent of the area covered by rocky/barren land in 1972. The agriculture/horticulture class has shown an increase of 8.51 km² with 28.94 percent from what it was in 1972. The maximum increase has been noticed from the forest class where 7.42 km² of the forest area has been converted into the agriculture/horticulture followed by pasture/open land where 2.68 km² of the area has been transformed into agriculture/horticulture sector. The further analysis for the period (1972-2020) shows forest cover as the dominant class among all the identified land use/cover categories. The subsequent change detection analysis has shown that although the forest cover has shown an increase from the period 1972 to 2020 but there have been fluctuations in the forest cover during the same period. The area covered by forests has shown an increase in alternate periods followed by alternate periods of reduction. The area covered by forest cover has increased by 7.29 percent (17.01 km²) from that of 1972.

CONCLUSION

The present study focuses over long term analysis of land use/cover change before and after the creation of Tirthan Valley as protected area. The land use/cover of the Valley prior to the protected status was influenced by unhindered access to the whole of the area. This traditional accessibility in the form of grazing, herb collection, hunting, timber and pilgrimage sites had driven the socio-cultural and economic set up of the Valley. Thus, historical land use/cover of the area have been shaped and reshaped through these traditional human-environment interactions. The subsequent declaration of the area as protected zone followed by restrictions imposed shifted the pressure over the Ecozone where most of the population resides. This phase has been characterized by focus over agriculture mainly horticulture, better infrastructural facilities, improved connectivity and increased tourism and subsequent exposure to outside forces thereby bringing socio-cultural and economic changes along with changes in the land use/cover in the area. The increased pressure in the Ecozone which spill over

to the protected zone has called for ensuring balance between conservation and development especially when the benefits of socio-economic developments have not percolated down to the rural poor. The expansion of agriculture land at the cost of forest cover, the increase in settlement/built-up land due to increase in tourism and subsequent enhanced demand for timber, ever increasing pressure over pasture land, the construction of hotels and home stays in adjacent to the river over floodplain have altogether resulted into decrease in forest cover especially around villages, increased encroachment over forest land and floodplain, reduction in pasture lands, increased fire incidence etc. These developments must be seen in combination with climatic variability and subsequent warmer conditions resulting into decline in quality of pastures, drying up of natural sources of water, increased rocky/barren land and reduction in snow cover. Such issues are posing a serious threat to the sustainability of the ecosystems and exposing fragility of human-environment relationships. This becomes all the more important in high altitude protected Himalayan landscape where establishing balance between conservation and development has become a huge challenge. An understanding of the land use/cover change and underlying forces responsible will go a long way in guiding formulating management policies and achieving conservation targets without compromising on the developmental aspects.

RECOMMENDATIONS

The protected areas have become contested grounds for conservation and development. These contestations have become more dominant in areas surrounding core zones where local/indigenous people have been dependent over neighboring resources. Such areas known as buffer/Ecozone (as in case of Tirthan Valley) have witnessed intense land use land cover changes which are in contravention to the very idea of conservation. Therefore, these areas have become center of nature conservation. The government bodies, planners, conservationists and environmentalists need to rationalise land use practices in such areas where they play a crucial role in striking a balance between preserving natural habitats and promoting sustainable development.

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