punjab geographer

A DOUBLE BLIND PEER REVIEWED JOURNAL OF APG AND KSS-ISPER INDIA

VOLUME 18 ISSN: 0973–3485 OCTOBER 2022

LANDSCAPE CHANGE ANALYSIS OF UPPER BEAS VALLEY, INDIA USING CORONA AND PLANETSCOPE IMAGERIES

Vivek Negi
Vishwa B.S. Chandel
Karanjot Kaur Brar

Abstract

The present study explores landscape change as a way of measuring the visual impressions of land transformation in the Upper Beas valley, Himachal Pradesh, India. Land change has been analysed through high resolution CORONA photographs of 1972 and PlanetScope satellite imageries for 2020. The study has used the Grey Level Co-occurrence Matrix to extract textural information from the former and supervised classification of both images using maximum likelihood classifier, which provide a comprehensive picture of changes in the area since 1970s. The analysis reveals considerable landscape changes characterized by increasing horticultural land (114.33 per cent) and built-up (311.44 per cent) area that have resulted in escalated occupancy of rural landscape for settlement expansion, commercial horticulture and tourism activities. The natural cover, on the other hand, shrunk remarkably. The forest cover has declined from 224.08 km² in 1972 to 217.72 km² in 2020 with notable fragmentation indicated by 119.73 per cent increase in forest patches and patch size reduction by 55.71 per cent. The pasture land too has decreased by 12.36 per cent; other major land cover class, i.e., barren land has faced reduction by 48.37 per cent.

Keywords: Land change, High resolution imageries, Land use/cover transformation, Himalayan mountains, Geospatial technology.

Introduction

Landscape is a dynamic entity perpetually transforming in its forms and functions following multi-scale human-environment interactions (Antrop, 2000). Landscape represents composition of space created or modified by humans that embodies tangible and intangible, material and non-material properties of land. Geographers look at it as a dynamic spatial system carved out by natural and cultural elements. This dynamism is 'an intrinsic characteristic' (Burgi et al., 2004) that produces change to keep the landscapes in transition wherein change is steadier than the stasis. Such changes, observed globally, are predominantly the result of accelerated human activities in the age of anthropocene. In recent decades, a swift transformation of mountain landscapes (Marston, 2008; Slaymaker, 2010; Patru-Stupariu et al., 2020) materialized through extensive land conversion for cultivation and urban land use (Tiwari et al., 2018) has triggered notable ecological implications. The fragmentation of natural habitats, deforestation, land conversion and degradation reduced water availability, and livelihood insecurity are few amongst many critical issues that place humans as the chief driver of landscape change.

The prime manifestation of anthropogenically driven landscape transformation echoes from perceptible land use and land cover (LULC) changes steered by developmental impulses. Consequently, land pattern is the most examined theme aimed at observing key drivers and implications on physical and cultural landscapes in mountainous regions (Chandel et al., 2013; Batar et al., 2017). To this end, geospatial technology has acted as a powerful tool to uncover the land dynamics (Fonji and Taff, 2014; Garrard et al., 2016). Satellite imageries since the first Landsat satellite in 1972 has aided sequential land change analysis (Loveland, 2012) at low to moderate resolution. Researchers often use these multi-temporal imageries to observe land use patterns; however, a reliable long-term analysis remains questionable for notable difference in image resolution. An important source of data that settles the issue of low-resolution in the early phase of satellite imaging is the declassified military intelligence photographs by the USA. These high-resolution images of 1960s and early 1970s from CORONA satellite provide opportunity to compare historical landscape (Lasaponara et al., 2018) with present day PlanetScope Nanosatellite imageries of similar resolution.

The high spatial resolution CORONA photographs enable extraction of detailed information (Song et al., 2015), however, its spectral limitation hinders image classification. Even so, efforts have been made to extract reliable information on land cover (Saleem et al., 2018; Gurjar and Tare, 2019), glacial changes (Narama et al., 2010), archeological studies (Casana and Cothren, 2008) and three-dimensional analyses (Altmaier and Kany, 2002). Information extraction from single band CORONA images is challenging due to its poor spectral resolution. However, researchers have used textural analysis that characterizes discernible texture content of high-resolution image to classify single band datasets (Caridade et al., 2008; Kupidura, 2019) using a variety of methods in which Gray Level Co-occurrence Matrix (GLCM) is the most common (Zhang et al., 2017; Mishra et al., 2018). Scholars have also used CORONA images along with Landsat (Shahtahmassebi et al., 2017), IKONOS (Beck et al., 2007), Quick Bird and EROS-B (Fuentes et al., 2018), and Orb-View (Fekete, 2020) imageries for reliable interpretation of land dynamics.

In this study, land dynamics have been compared with two points in time using historic CORONA image and contemporary PlanetScope image to establish half a century long tangible land use change in the upper Beas valley, India. The pre-existing work on land change dynamics in the Himalayan region (Gupta, 2007; Thakur et al., 2018) is primarily based on medium to low resolution images and therefore fall short of a comprehensive interpretation. This work, therefore, offers a fresh perspective on landscape transformation trajectories through high-resolution imageries.

Objectives

Major objectives of the study are:

- to analyse the aspects of land use/cover in upper Beas valley using high-resolution CORONA (1972) and PlanetScope (2020) imageries and
- to characterize the direction and magnitude of change between 1972-2020 along with causative factors observed for landscape transformation.

Study Area

The upper Beas valley is a part of Kullu district of Himachal Pradesh, India. It spreads over 990 km² between 32° 03' 10" to 32° 24' 56" N latitudes and 76° 58' 44" to 77° 23' 32" E longitudes and the elevation varies from 1358-6000 m above mean sea level (amsl). Geomorphologically, high to moderately dissected hills and valleys dominate the landscape with permanent snow-clad peaks on the north, north-west and north-east. The upper sections of valley exhibit imprints of glacial and periglacial processes, whereas fluvial processes have carved extensive river terraces and alluvial fans in the main valley floor. A dense forest cover on the valley slopes gradually terminates in the alpine pastures at higher altitudes. The valley has cool temperate climate with ample precipitation throughout the year. The gentle sloping terraces on either side of the river Beas are under intensive human occupancy. The major settlements include the only town at Manali, and large villages of Jagatsukh, Naggar, Patlikuhl, and Katrain. The settlements scattered over the landscape are surrounded by agricultural fields and orchards. The fertile soils and abundant water supply offer conducive conditions for paddy, vegetables, and fruits such as apples, plum and apricot. Owing to diverse natural resources and avenues for development, the valley has undergone considerable land use changes.

Database and Methodology

The study is primarily an interpretation of land change dynamics in upper Beas valley on the basis of satellite data of 1972 and 2020. However, to build the foundations of study, a brief interpretation of traditional land use/cover has been presented at the beginning of the discussion. This historical interpretation is based on archival records/documents written during the British period and early post-independence era. The detailed study of LULC since 1972 is based on high resolution imageries of CORONA and PlanetScope satellite systems. Corona has been a photo reconnaissance satellite of collective satellite system of the US military intelligence and its models have been called KEYHOLE (abbreviated as KH). The mission has operated between 1960-1972 with spatial resolution of panchromatic images between 12.2 meter for KH-1 to 1.8 meter in KH-4B. These datasets have been declassified in 1995. For this study, 3 tiles of CORONA KH-4B images of 31st May 1972 with a ground resolution of 1.83 m has been used to analyze historical landscape. To compare the results with contemporary land dynamics, this study has utilized PlanetScope images for the 21st May 2020. PlanetScope is a group of more than 120 high resolution satellites providing daily worldwide coverage. Geometrically, radiometrically and sensor corrected PlanetScope ortho-scene images (type 3B) have also been used. The sensor correction is based on sensor telemetry and a sensor model while orthorectification has been done using GCPs and DEMs. The images projected to UTM projection with WGS84 datum consist of three bands of RGB and one NIR, each having spatial resolution of 3 m. The study area is covered in 21 such tiles that have been mosaicked to form a single image for the entire study area.

PlanetScope imageries are orthorectified, hence can be used without pre-processing. However, CORONA images being single band grayscale without any spatial reference have been processed for geometric corrections and color balancing by using method suggested by Hamandawana et al. (2007). These images have been georeferenced using PlanetScope image and Google-earth by identifying 864 ground control points (GCPs) at road crossovers, historical buildings and isolated trees etc. Atmospheric corrections have been done via cloud masking while reference images of adjacent years have been used to interpret features underneath cloud cover. The unwanted edges of individual image have been trimmed before mosaicking three images to form a single image.

The high-resolution grayscale CORONA image (Fig. 1) allows for feature extraction based on texture analysis to identify land use/cover. The Grey Level Co-occurrence Matrix (GLCM) measure (Haralick et al., 1973) has been used with 3x3 moving window in ENVI software. A total of eight textures, viz. angular second moment, contrast, correlation, dissimilarity, entropy, homogeneity, GLCM mean, and GLCM variance have been used followed by Principal Component Analysis (PCA) for all texture indices to reduce the dimensionality. The first three PCs having maxing information have been retained and used in the classification of CORONA image. Since the single band grayscale images restrict classification to broad land use/cover classes, therefore the identification of land classes is based on training samples marked through region growing method that take existing seed locations and add neighbouring pixels to region class based on a threshold range or multiple of standard deviation of regions' pixel values.

In order to check whether classes are statistically separable, Jeffries-Matusita test has been used which showed least separability of settlement, horticulture land, river and river bed with respect to other classes. Hence, river and river bed have been extracted via image segmentation as these have not been precisely differentiable. Similarly, PlanetScope image (Fig. 2) has been processed with twenty training samples taken for each LULC class. Jeffries-Matusita test applied on these training sets has shown least separability of river bed and settlements from barren land. In mountainous areas, shadow effect leads to misclassification of non-probable classes such as agriculture or water bodies in high altitude zones or on sloping surfaces. To avoid such errors, ALOS PALSAR DEM has been used. Since two images have slightly different resolution, CORONA image has been resampled for pixel size comparable to PlanetScope image at 3 meters resolution.

Finally, the two images of 1972 and 2020 have been processed using supervised classification and Maximum Likelihood Classifier (MLC) for eight different land use/cover classes, viz. forest, barren land, horticultural land, river, river-bed, pasture land, snow-cover and built-up area. The classified images have been compared for change detection and transformation matrix computation. Land use in the study area is highly heterogenous that obscures the distinction between land under agriculture and horticulture. Hence, the classification scheme uses the dominant land use, i.e., 'horticultural land' as the representative of farming activities. To ensure reliability, image classification scheme has been followed for a rigorous accuracy assessment. The lack of historical reference data to validate the classification of CORONA image of 1972 has been dealt with the help of reference data collected through visual interpretation. The reference data for 2020 imagery has been collected and compared with google earth image. For the point

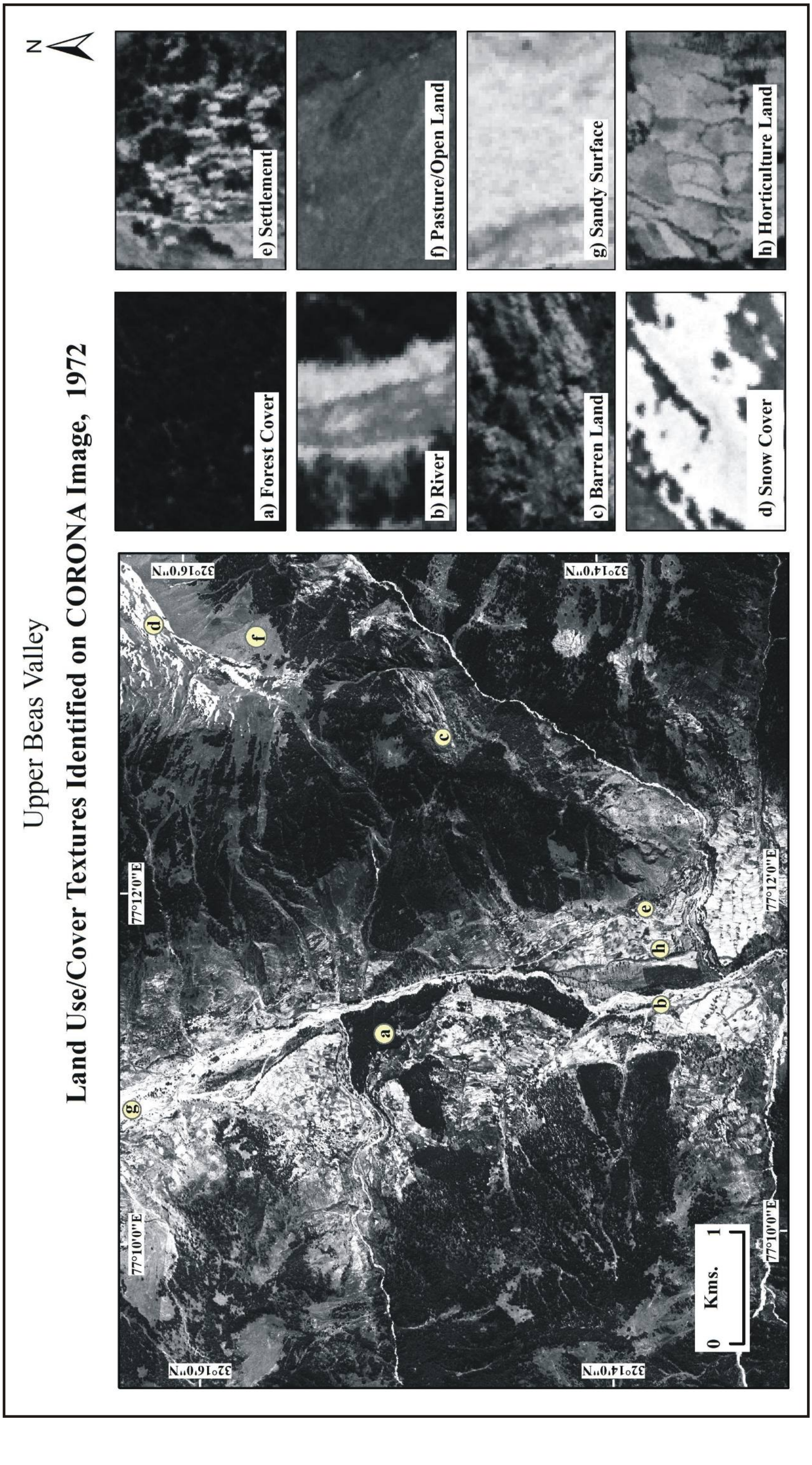
Upper Beas Valley
Land Use/Cover Textures Identified on CORONA Image, 1972
N
a) Forest Cover
b) River
c) Barren Land
d) Snow Cover
e) Settlement
f) Pasture/Open Land
g) Sandy Surface
h) Horticulture Land
77°10'0"E
77°12'0"E
32°16'0"N
32°14'0"N
0 Kms. 1

Fig. 1

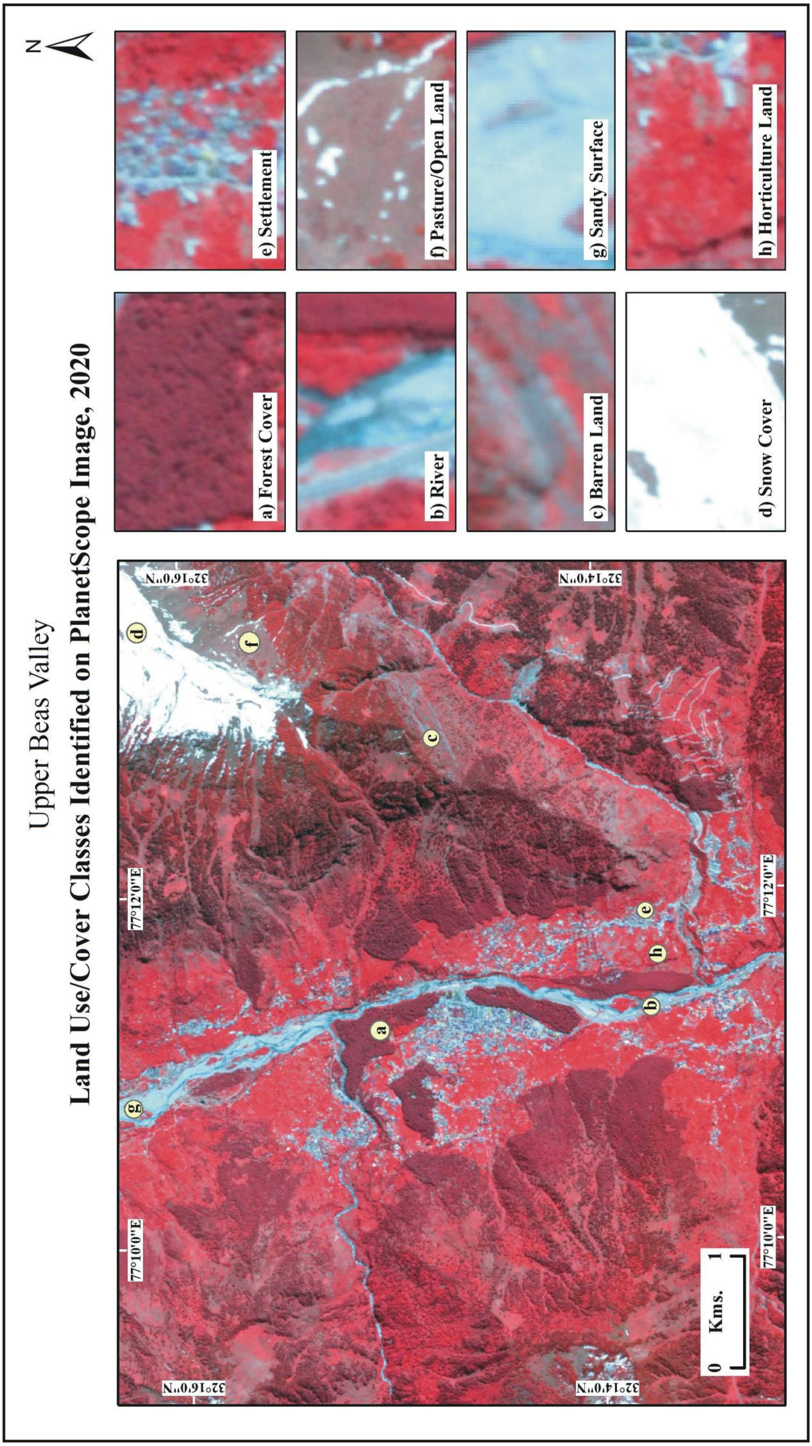
Upper Beas Valley
Land Use/Cover Classes Identified on PlanetScope Image, 2020
N
77°10'0"E
77°12'0"E
32°16'0"N
32°14'0"N
0 Kms. 1
a
b
c
d
e
f
g
h
a) Forest Cover
b) River
c) Barren Land
d) Snow Cover
e) Settlement
f) Pasture/Open Land
g) Sandy Surface
h) Horticulture Land

Fig. 2

reference dataset, stratified random sampling has been done for both the imageries. Further, the error matrix and Kappa coefficient have been calculated. The overall accuracy in the former has been 93.13 per cent with Kappa coefficient as 0.91. The accuracy for PlanetScope imagery has been 91.15 per cent with a Kappa coefficient of 0.89. Both outputs show a reliable accuracy level.

Land dynamics are complex as changes not only take place across the LULC classes but also in the composition and spatial patterns within the classes. Landscape metrics allows for such quantification of landscape patterns over time and space (McGarigal and Marks, 1995). Landscape metrics analysis has been done by using FRAGSTAT 4.2 to quantify landscape structure for the class and the landscape level interpretation. The former includes amount and distribution of single patch type while latter represents spatial patterns at landscape level. The indices have been calculated by taking into account class area (CA), number of patches (NP), largest patch index (LPI), mean patch size (MPS), total core area (TCA) and mean core area index (CAI_MN). The population data have been collected from District Census Handbooks published by the Census of India for the years, 1971, 1981, 1991, 2001 and 2011.

Results and Discussion

Land Dynamics in Pre-Remotely Sensed Imaging Era

The traditional landscape of upper Beas valley had a typical countryside outlook; forest and highland pasture land predominated the landscape, while rural settlements scattered in the valley floor had been surrounded by cultivated fields. The human occupancy on high altitudes had been limited by steep sloping lands and rugged terrain. The landscape comprising of river terraces, small and large clusters of villages, and agricultural fields had been enclosed with trees and exhibited best possible use of available land. The land utilization had noticeable zonation; where rice, wheat, maize, barley and opium had been the principal crops (Harcourt, 1871). A total of 4.17 per cent land under cultivation in 185 increased to 4.53 per cent in the Waziri Parol Valley, (present day upper Beas valley) by the end of 19th century which showed a gradual pace of land change. The area, though a secluded landscape, had responded to development impulses from other corners of the country. The early success of tea plantation in Assam led to similar experiment in the north western region in mid-19th century. The tea gardens had also been established at Gourdour and Nuggur in the upper Kullu valley (Punjab Government, 1869) but have not succeeded due to transportation costs. The valley at that time was administered by British regime and witnessed apple plantation at Bandrol village in 1870 by Captian Lee; later introduced by Mr. Banon and Mr. Duff in Manali and Mr. Donald in Dobhi area (Punjab Government, 1899); however, such developments remained confined to area under British (Bruce, 1914). The British government since 1850 had regulated resources in the valley through land decrees of ownership transfer and land-rights (Diack, 1898). As a result, wasteland had been put to cultivation, and community land and forest rights had been regularized. In the early 20th century, few hatcheries of brown trout in the upper Kullu valley had been set up in 1909 (Forbes, 1911). The construction of motorable roads (Banon, 1952) further led to a better connectivity of the valley with the outside world.

A considerable change in land ownership has been noticed in early post-independence era as British estates have been acquired by the private owners and the Indian government. The foremost amongst others have been the farming practices and fruit gardening along with the traditional agriculture that has been soon adopted by local people. In post-1960s period, the upper Beas valley has undergone development impetuses as its environment and climate favoured commercial farming of apple, apricot and vegetables. The then Punjab Government has initiated horticultural development; saplings have been planted on non-irrigated land to promote horticulture. The metalling of road by 1970s has begun to improve the connectivity to this apple growing valley (Shabab, 1996) thus, giving a fillip to horticulture-based economy and settlements expansion (Saczuk, 2000) that has further been set in motion by tourism and hydropower development.

Land Use/Cover Change in Upper Beas Valley, 1972-2020

The availability of high-resolution images of 1972 for the upper Beas valley coincides with the period when horticultural activities in this area have begun to expand. The land use/cover based on CORONA satellite photographs for 1972 depicts eight major land categories (Table 1). Snow cover has occupied the largest area (29.77 per cent) stretching along the valley slopes above 3500 m amsl. Almost equal size area has been under barren land (27.12 per cent) positioned mostly below the snow line. The valley floor and slopes along streams too has barren land and forest patches. An insignificant area (below 5 per cent) has been occupied by active river/steams. A large part of the valley in early 1970s has extensive forests (22.63 per cent) and pastures (16.77 per cent) that have extended to the valley floor along River Beas, in small river islands, and on the valley slopes above the river terraces and the alluvial fans. The high elevation areas have kail, deodar, kharsu, moru, and fir trees, while elm and oak trees dominated the valley slopes (Chetwode, 1972). A transitional zone of grasslands dotted with strips of kail pine and deodar cedar has separated settlements from the forests. At places tosh and rai trees with small thickets of horse chestnut have been found scattered aloft

Table 1
Upper Beas Valley: Land Use/Cover Change

LULC Classes	1972		2020		1972-2020
	Area (km²)	Area (per cent)	Area (km²)	Area (per cent)	Change (per cent)
Horticultural Land	32.09	03.24	68.79	06.95	114.33
Barren Land	268.53	27.12	138.64	14.00	-48.37
Built-up land	01.26	00.13	05.17	00.52	311.44
Forest Cover	224.08	22.63	217.72	21.99	-02.84
Pasture/Open Land	166.02	16.77	145.49	14.70	-12.36
Sandy surface/ River Bed	01.23	00.12	01.99	00.20	61.18
River/ Water Body	02.13	00.21	01.51	00.15	-28.88
Snow Cover	294.75	29.77	410.78	41.49	39.37
Total	**990.09**	**100.00**	**990.09**	**100.00**	**-**

Source: Compiled by Authors.

the villages. The deciduous trees have occupied the flat portion of the valley bottom; Chestnut, walnut and oak have been common (Bose, 1968). The lower valley areas along the river Beas and its tributaries have abundance of the Himalayan poplar and alder trees (Champion and Seth, 1968).

The superimposition of classified image with the digital elevation model of the area shows that nearly 49 per cent of the total forest cover has occupied slope above 45°. Nearly 40 per cent of the total forests has been detected in the montane zone (2500-3000 m), whereas the sub-alpine (3000-3700 m) and the mid-montane (2000-2500 m) zones have covered 29 per cent and 24 per cent area, respectively. The forest cover has been found present on north western, western and south western slopes. The dense forests mainly of pines have been witnessed along the Palchan-Rohtang road, Chhor nullah, Manalsu nullah, Sujain nullah and Phajloti nullah. The right bank areas along the Pakhnoj nullah, Duhangan nullah, Salfal-Phajloti nullah and Chhakki nullah have been found covered with dense deodar forest.

Satellite imageries confirm a patchy but intensive human occupancy of the valley floor between Palchan village in the north and Dobhi village in the south during early 1970s. Agriculture has been well spread over alluvial fans and terraces on either side of river Beas; the intensity has been, however, higher in the southern parts of the valley. Such land class has occupied 32.09 km² (3.24 per cent) area; the majority (58.58 per cent) of which has been on the left bank due to gentler slopes and extensive alluvial fans. These fertile and irrigated terraces locally called ropa have been mainly occupied with rice, maize and wheat crops, while area under orchards have been insignificant. The non-irrigated land too has been cultivated with coarse grains like maize, kodra, sariara, barley and buckwheat. This rural landscape has been dotted with settlements covering about 1.26 km² area; these have been located up to 2700 m amsl but majority have been situated between 1500-2000 m. The clustering of settlements has been denser on the left bank wherein house pattern has displayed parallel rows of houses one above the other. The right bank has relatively dispersed pattern of settlements. Katrain, Naggar and Hallan have been major settlements in the valley; the former is located on the right bank of river Beas whereas the other two are on the left bank. There have been numerous one or two storeyed buildings randomly distributed within agricultural fields to store agricultural produce.

The drivers of landscape transformation in the valley have been manifold. Firstly, the proliferation of tourism by 1980s has materialized with the linking of Rohtang Pass via a motorable road. However, the real impetus has been the downfall of tourism in Kashmir valley due to political instability (Gardner et al., 2002) that has led to arrival of international tourists in the valley. The following decade has further witnessed economic development via hydropower projects and ensuing infrastructural development. Such ventures have led to more investments, infrastructure augmentation, and more importantly the arrival of new ideas, skills, and human resources from the outside that have been found backing and acceptance from the local community as these have been seen mutually benefitting. Thus, the valley has opened up more to the outside world during 1990s that has offered diversified avenues of economic growth. The landscape, consequently, has been positioned on the world map and recorded the fastest growth of population and economic prosperity amongst all the districts of Himachal Pradesh between 1971-2001.

Primarily a rural landscape of pre-1970s, Kullu valley has been remodelled in past fifty years as cosmopolitan and urban in nature. The pace of change in the past two decades has been swift and led to considerable land use transformation in response to widening of highways, bridges and Rohtang tunnel construction and extension of village road networks in the valley. The information extracted from PlanetScope imageries for the year 2020 shows visible land use changes (Table 1). The natural cover displays a decline, while human use of land witnessed a record increase. The largest proportion (41.49 per cent) of the land is still occupied by snow cover (410.78 km²), while forests are stretched over 217.72 km² (21.99 per cent) followed by pastures/open land (14.70 per cent) and barren land (14 per cent). The sandy surface/river bed and active river channels occupy 1.99 km² and 1.51 km², respectively. The horticultural land accounts for 6.95 per cent area; more than two-third of it spreads over the river terraces and alluvial fans adjacent to river channels. The built-up area occupies 5.17 km² (0.52 per cent) land; a ribbon settlement pattern along major roads is the dominant linear landscape feature. However, clustering at certain locations also indicates growing size of villages and emergence of urban like characteristics.

Land change analysis for two points in time indicate significant changes in the valley. However, a clearer picture of landscape transformation emerges from the interpretation of shift in specific land classes (Table 2, Fig. 3). Change in almost every category is evident but few recorded significant changes. The snow cover increased from 294.75 km² in 1972 to 410.78 km² in 2020. This gain has been due to untimely snowfall in the higher elevation areas in April-May 2020. Snowfall being highly variable produce drastic inter annual variations and therefore does not reflect actual increase in the permanent snow cover. In fact, many researchers have established a definite reduction in the snow cover in the area (Bhutiyani et al., 2010). The minor land cover classes, i.e., area under active rivers and water bodies also have recorded a slight reduction from 0.21 per cent (1972) to 0.15 per cent (2020) that is attributed to river channelisation. However, the sandy surfaces adjacent to river has increased especially in the southern parts. The two major flood events, first in 1995 and another in 2018 explains such changes along river course that has influenced the land dynamics.

The dominant land cover classes, viz. forest, barren land and pastures show a decline. Forest cover declined from 224.08 km² in 1972 to 217.72 km² in 2020. The conversion has been mainly to open land and barren land classes alongside a substantial transfer to horticulture. This forest cover has undergone significant fragmentation even though it shows a marginal reduction of 2.8 per cent only. This decline appears to be insignificant considering the time span of fifty years; however, one may see notable change in forest dynamics from landscape change metrices (Table 3) that reveals an increase of 119.73 per cent in forest patches (32,099 forest patches in 1972 to 70,532 in 2020) with patch size reduction from 0.007 to 0.003 km² (-55.71 per cent). The increased mean perimeters-area ratio also reveals fragmentation of continuous forest patches into smaller units. Moreover, declined total core area also suggests a reduced forest

Table 2

Upper Beas Valley: Land Transformation Matrix

LULC Classes		Horticultural Land	Barren Land	Built-up Land	Forest Cover	Pasture/ Open Land	Sandy surface/ River Bed	River/ Water Body	Snow Cover	Total Transfer Area (km²)	
										Loss	Year 1972
Horticultural Land		27.66	00.07	1.41	00.80	02.12	0.02	0.01	00.00	04.44	32.09
Barren Land		08.10	84.29	1.46	10.46	38.51	0.67	0.42	124.63	184.25	268.53
Built-up Land		00.38	00.12	0.36	00.10	00.27	0.01	0.01	00.01	00.89	01.26
Forest Cover		10.48	09.38	0.39	162.99	38.85	0.42	0.27	01.31	61.09	224.08
Pasture/Open Land		22.01	25.40	1.40	42.59	63.56	0.45	0.34	10.28	102.46	166.02
Sandy surface/ River Bed		00.05	00.31	0.04	00.20	00.27	0.17	0.10	00.10	01.06	01.23
River/ Water Body		00.12	00.36	0.06	00.45	00.50	0.25	0.36	00.01	01.76	02.13
Snow Cover		00.00	18.71	0.04	00.12	01.41	0.01	0.00	274.45	20.30	294.75
Total Transfer Area (km²)	**Gain**	**41.13**	**54.35**	**4.81**	**54.72**	**81.93**	**1.82**	**1.15**	**136.33**	**-**	**-**
	Year 2020	**68.79**	**138.64**	**5.17**	**217.72**	**145.49**	**1.99**	**1.51**	**410.78**	**-**	**990.09**

Source: Compiled by Authors.

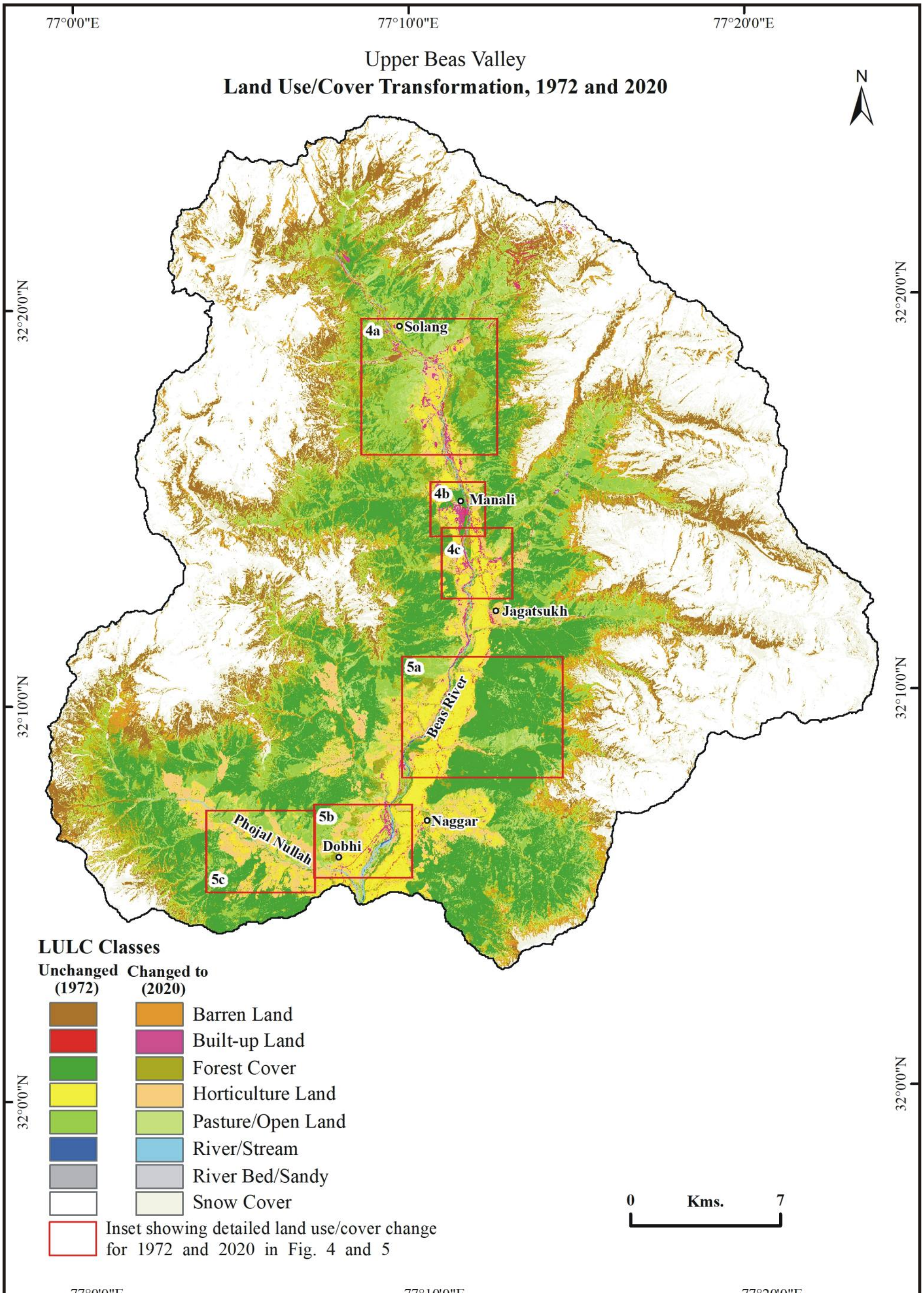
77°0'0"E
77°10'0"E
77°20'0"E
Upper Beas Valley
Land Use/Cover Transformation, 1972 and 2020
N
32°20'0"N
32°10'0"N
32°0'0"N
4a
Solang
4b
Manali
4c
Jagatsukh
5a
Beas River
5b
Naggar
Dobhi
Phojal Nullah
5c
LULC Classes
Unchanged (1972)
Changed to (2020)
Barren Land
Built-up Land
Forest Cover
Horticulture Land
Pasture/Open Land
River/Stream
River Bed/Sandy
Snow Cover
Inset showing detailed land use/cover change for 1972 and 2020 in Fig. 4 and 5
0 Kms. 7

Fig. 3

Table 3

Upper Beas Valley: Landscape Change Metrics

LULC Classes	Class Area (km^2)		Number of Patches		Largest Patch Index (per cent)		Mean Patch Size (km^2)		Total Core Area (km^2)		Mean Core Area Index (per cent)	
	1972	2020	1972	2020	1972	2020	1972	2020	1972	2020	1972	2020
Horticultural Land	32.09	68.79	16,796	22,193	00.61	2.08	00.002	00.003	07.67	19.85	0.15	0.08
Barren Land	268.53	138.64	1,45,905	89,440	16.59	2.05	00.002	00.002	21.36	01.45	0.00	0.00
Built-up Land	01.26	05.17	4,388	8,199	00.00	0.08	0.0003	0.0006	0.008	00. 59	0.04	0.30
Forest Cover	224.08	217.72	32,099	70,532	08.19	5.72	00.007	00.003	32.69	26.55	0.01	0.01
Pasture/Open Land	166.02	145.49	1,81,155	1,50,418	10.29	0.69	0.0009	00.001	03.31	06.82	0.00	0.00
Sandy surface/ River Bed	01.23	01.99	1,898	8,438	00.01	0.01	0.0007	0.0002	0.059	0.006	0.03	0.00
River/ Water Body	02.13	01.51	1,373	2,319	00.06	0.03	0.0015	0.0007	0.019	0.008	0.00	0.02
Snow Cover	294.75	410.78	21,506	25,768	11.22	38.49	00.014	00.016	134.44	250.47	0.05	0.03

Source: Compiled by Authors.

density. A discernable fragmentation of forests has materialized along the Sujain, the Kanyal and the Phojal nullahs on the right bank and the Allain, Prini, Duhangan, Kanoi, Pakhnoj, and Chhaki nullahs on the left bank.

Landscape transformation in the valley is evident from discernible shift in the usage of land towards anthropogenic activities (Fig. 4-5). It is but obvious to note an active inter-change between forests and pastures. The back-and-forth transfer between these two classes have been 17.34 per cent and 25.65 per cent, respectively. There has been significant alteration of spatial and locational characteristics of forest and pasture land. The high-altitude pastures and areas along the river Beas have seen emergence of forest patches, whereas forest cover adjacent to villages has transformed into pastures/open land. Interestingly, despite an overall decline, growth of new forest patches is evident in open land patches adjacent to the Beas River due to government initiatives. Such positive change has been witnessed in upstream areas of Beas Kund and Sarai nullah, higher reaches of Kothi, Shanag, and Goshal villages, and on the eastern slopes along river Beas in northern areas of Bahang village (Fig. 4 a-i, a-ii). On contrary, dense forest patches between Manalsu nullah, Manali town and river Beas; another around Dhungri; and along river bed and valley slopes on either side of the banks (Fig. 4 b-i, b-ii) shows an increase in forest density. The declaration of reserve and protected forests, prohibition on tree felling, and protection measures has helped raising the forest cover in recent decades. The plantation of 1.06 million saplings under various schemes further aimed at raising deodar, ban/oak and other species. A similar situation prevails in the southern parts of the valley along river Beas floodplain. However, shrinking forest cover on valley slopes of Kanoi nullah and Pakhnoj nullah (Fig. 5 a-i, a-ii) and Phojal nullah (Fig. 5 c-i, c-ii) reveals escalated tree felling and land clearance for other usages of forest land.

The change apparently is more noticeable in pastures/open land which has been reduced by 12.36 per cent as its area has declined from 16.77 per cent in 1972 to 14.70 per cent in 2020. Pastures too have been transformed to barren land (25.40 km²), horticulture (22.01 km²), built-up (1.40 km²) and forest cover (42.59 km²). These have been mainly human induced changes as common pastures adjacent to villages got encroached upon. Such conversion is discernible on the upper margins of villages situated on the valley slopes. Interestingly, substantial area under high altitude pastures too has been transformed to forests due to halting of active grazing and fodder collection activities. Consequently, land reclamation via natural succession has led to growth of forest patches in these alpine pastures. This change reflects lesser human dependence on high elevation pastures. However, escalated anthropogenic activities in the proximity of settlements have affected already limited land resource in the valley floor and adjacent hillslopes.

Of the three major land cover classes, barren land has faced maximum reduction (48.37 per cent) from 268.53 km² in 1972 to 138.64 km² in 2020. A major chunk of barren land has been transformed to other land cover classes, viz. pasture land and forest cover mainly either in the high-altitude areas or along the riverbeds. Another major shift has been to anthropogenic usages for horticulture and built-up. A considerable conversion of barren land in the northern parts of the valley has taken place along the Sarai Nullah, Halinidi Nullah,

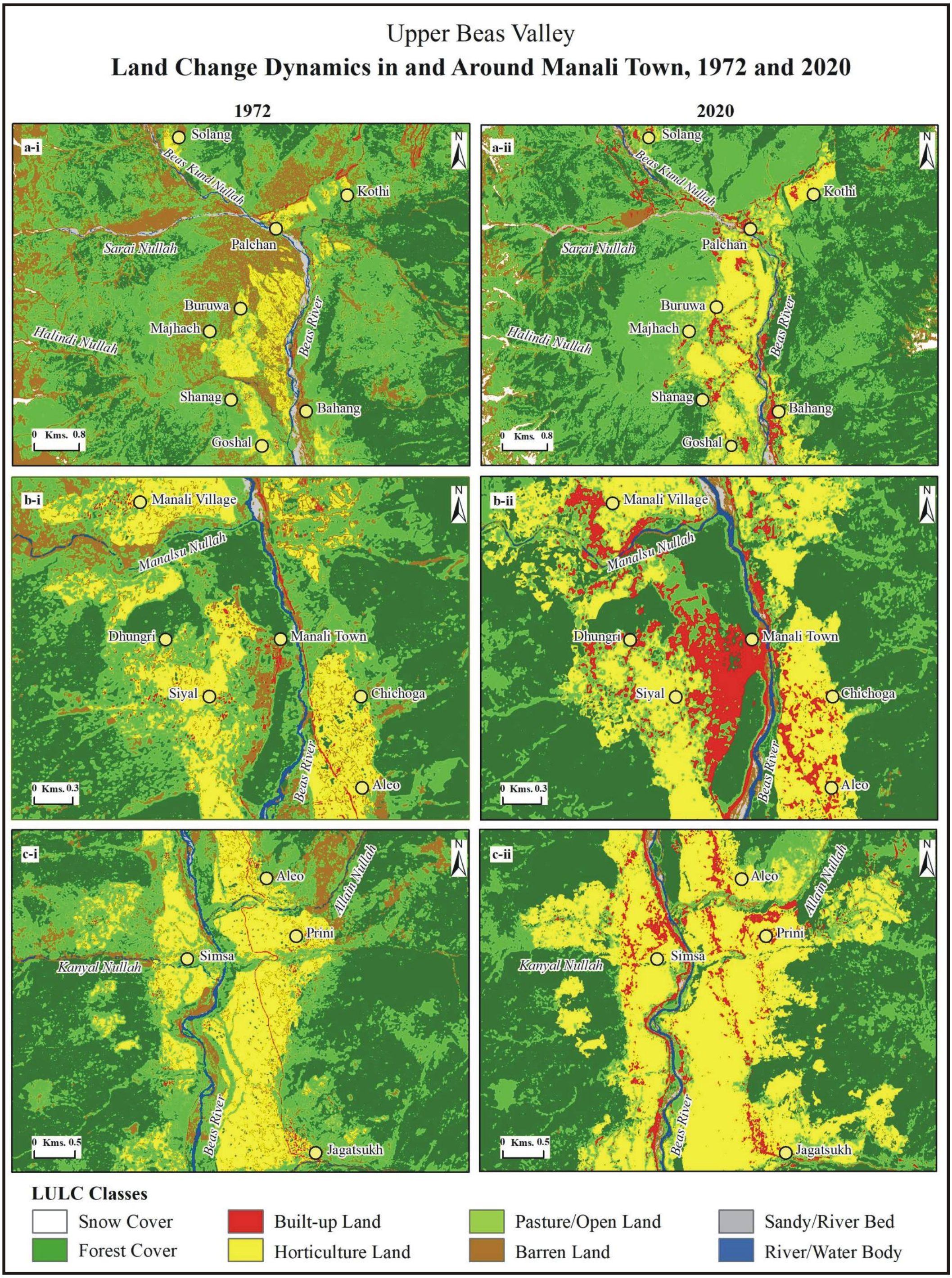
Upper Beas Valley
Land Change Dynamics in and Around Manali Town, 1972 and 2020
1972
2020
a-i
a-ii
b-i
b-ii
c-i
c-ii
Solang
Beas Kund Nullah
Kothi
Palchan
Sarai Nullah
Buruwa
Majhach
Halindi Nullah
Beas River
Shanag
Bahang
Goshal
Manali Village
Manalsu Nullah
Dhungri
Manali Town
Siyal
Chichoga
Aleo
Allain Nullah
Prini
Simsa
Kanyal Nullah
Jagatsukh
0 Kms. 0.8
0 Kms. 0.3
0 Kms. 0.5
LULC Classes
Snow Cover
Forest Cover
Built-up Land
Horticulture Land
Pasture/Open Land
Barren Land
Sandy/River Bed
River/Water Body

Fig. 4

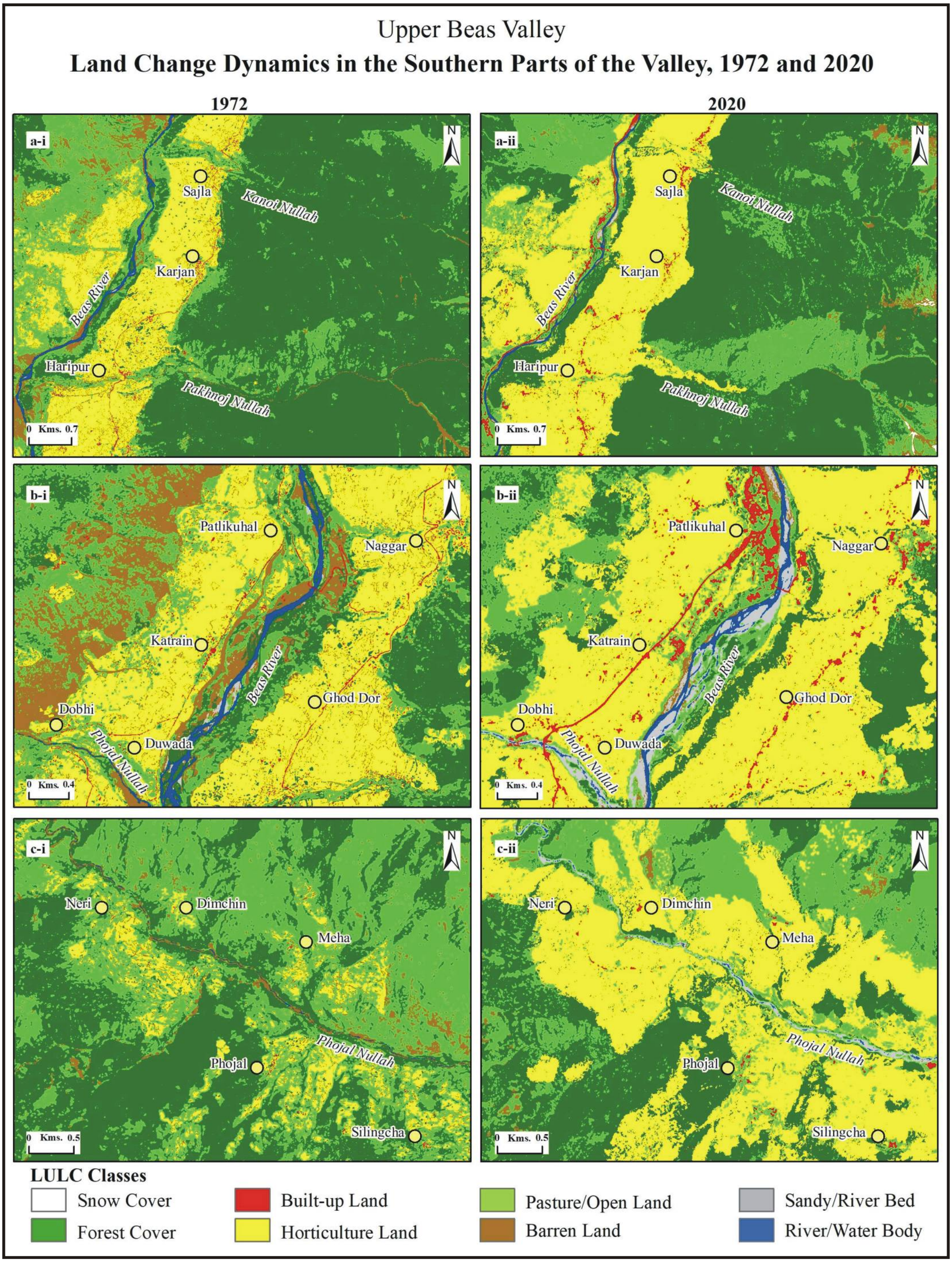
Upper Beas Valley
Land Change Dynamics in the Southern Parts of the Valley, 1972 and 2020
1972
2020
a-i
a-ii
Sajla
Karjan
Haripur
Kanoi Nullah
Pakhnoj Nullah
Beas River
0 Kms. 0.7
b-i
b-ii
Patlikuhal
Naggar
Katrain
Dobhi
Duwada
Ghod Dor
Phojal Nullah
Beas River
0 Kms. 0.4
c-i
c-ii
Neri
Dimchin
Meha
Phojal
Silingcha
Phojal Nullah
0 Kms. 0.5
N
LULC Classes
Snow Cover
Forest Cover
Built-up Land
Horticulture Land
Pasture/Open Land
Barren Land
Sandy/River Bed
River/Water Body

Fig. 5

on the outwash fan between Palchan and Burwa, and along River Beas at Bahang (Fig. 4 a-i, a-ii). A northward expansion of human occupancy is evident in and around Burwa, Palchan, Kothi and Solang villages. The valley slopes along the tributary streams have observed an increase in the pastureland, whereas the barren outwash fan is now extensively occupied for horticulture and settlements. The barren land around Manali town and its southern parts (Fig. 4b, 4c); area between Patlikuhl and Dobhi (Fig. 5 b-i, b-ii) has also seen similar changes. Such disappearance of barren land in the valley floor exhibit growing intensity of human occupancy.

Land use vis-a-vis horticulture and build-up usually exhibit a synchronous directional change in the mountainous regions. These land use classes though occupy a small proportion of the valley; their collective share increases from less than 3.50 per cent in 1972 to 7.50 per cent in 2020 which shows a remarkable growth. Horticultural land in 1972 has been 3.24 per cent that increased to 6.95 per cent recording a massive growth of 114.33 per cent by 2020. The domination of humans especially in the valley floor is evident from increased number of patches and largest patch index of horticultural land. An increase of 158 per cent in the total core area from 7.6 km² in the year 1972 to 19.85 km² in the year 2020 shows overall expansion of such land use. The expansion of such activities has taken place at the expanse of barren land, pastures and forests as accelerated growth gradually encroached upon the natural cover. The gain in horticultural area (98.66 per cent) mainly have shifted from these three land cover classes. The left-out portions of the valley floor also have been consumed for farming; a gradual expansion of existing horticultural land beside the appearance of new such patches has manifested at higher elevation slopes in interior valleys of tributary streams. Such a shift is rather discernible in the valleys of the Allain nullah, Duhangan nullah and Chhakki nullah on the left bank of river Beas and Kanyal nullah, Sujain nullah and Phojal Nullah on the right bank (Fig. 4c, 5a, b, c). An observed shift of approximately 400 m in land use activities towards the higher altitudes verify the definite occupancy of previously untenanted land under pastures/open land and the forest cover.

The built-up area has also grown in similar direction but at an overwhelmingly higher rate than the horticulture. The absolute growth appears to be very small, however, proportional change reveals a different story. The built-up area has been just 0.13 per cent in 1972 that skyrocketed by 311.44 per cent in 2020. The doubling of built-up patches, increased largest patch index and mean patch size, and growth in core area from 0.008 to 0.59 km² testify the unprecedented settlement expansion. For built-up area, the expansion has materialised mostly over barren land, pasture land, and horticultural land (Fig. 4, 5). Not only this shows encroachment of natural cover but also the transformation within the land use. The conversion of horticultural land to built-up area suggests a fundamental change in the horticulture-based economy to tourism-based service economy. As a result, swift land change in favour of built-up area became the guiding force for landscape transformation.

Land transforamtion (1972-2020) reveals massive land cover shift in favour of land use in the outwash fan area north of Manali town (Fig. 4 a-i, a-ii). The expansion of settlements and horticulture intensification took place around Solang, Palchan, Kothi, Buruwa and Bahang villages. At the same time an increase in open land on valley slopes in this area is also evident. Impressive settlement growth and horticulture area, and increased forest density around Manali town is discernable; the left bank area of Chichoga exhibit dominance of farmland and settlements (Fig. 4 b-i, b-ii). The left and the right bank areas south of Manali have also experienced similar direction of land use transformation. The settlements display a ribbon pattern and area adjacent to the river stands devoid of pastureland. The river terraces show overpowering presence of horticulture that have expanded to interiors of Prini and Kanyal areas (Fig. 4 c-i, c-ii). The southern parts of the study area has also undergone massive change as evident from the dwindling forest cover in size and density along with increased patch sizes of horticultural land. The main valley floors and river terraces are occupied for active anthropogenic activities that have gradually extended to the narrow valleys of tributary streams. The fragmentation of forests and conversion to pasture land is visible on the left bank hillslopes; the Beas River floodplain, however, shows increase in forest density (Fig. 5 a-i, a-ii). A decline in barren land on right bank hillslopes in favour of pastures and horticulture is discernable alongsides settlement grwoth around Patlikuhl and along Katrain-Dobhi highway (Fig. 5 b-i, b-ii). The valley of Phojal nullah, a right bank tribuary of river Beas, is fast changing wherein horticulture in recent decades has encroached upon pastures and forests in higher altitude areas (Fig. 5 c- i, c-ii).

Landscape change is a by-product as well as the driver of population dynamics. A change in landscape produces new economic potential that draws people inward; ideas, attitudes, and services that come with new arrivals further steer land dynamics. The upper Beas valley has experienced considerable population growth of 22.90 per cent (1971-1981), 29.60 per cent (1981-1991), 38.30 per cent (1991-2001) and 11.12 per cent (2001-2011) (Census of India, 1971, 1981, 1991, 2001, 2011). The landscape has been fundamentally rural until 1971 when Manali as a notified area committee became the first urban settlement for it has been planned to be the administrative headquarter. In the following decades, this small urban centre has been populated rapidly with a peak growth of 157.5 per cent during 1991-2001. Consequently, the conversion of horticultural land and occupancy of vacant land to the built-up area has materialised. As tourism has begun to flourish by late 1980s, roads, hotels and other construction activities have extended to river terraces. The burgeoning hotels and home stays reveals staggering land occupancy for tourism related services by the end of twentieth century. This initial occupancy of horticultural land along major roads have produced a linear settlement corridor on either side of the valley. Thereafter, such changes have manifested along the roads to the interior valleys. While tourism have had significant impact of land use change, the initiation of hydropower projects during 1990s, beginning of the Atal tunnel project in early 2000, and widening/realignment of national highway in post 2010 has emerged as compelling drivers of land acquisition, resettlements, and authorised land use changes brought out drastic changes in landscape.

Conclusions

This study has been intended to uncover the land dynamics in upper Beas valley. The analysis portrays momentous landscape transformation since 1970s as a response to human-environment interactions based on the deliberate and informed choices made by people over the time. The study has been able to overcome the problem of comparable spatial datasets for describing tangible land use changes over longer time frame. The use of declassified high resolution CORONA satellite photographs together with PlanetScope imageries successfully brings out a detailed analysis of land dynamics spanning over half a century. The Beas valley once a halting place along the historical trade route has seen multiple waves of changes since the mid-twentieth century and the period thereafter. The analysis shows significant changes in land dynamics wherein natural cover has reduced substantially to accommodate human usages of land. The transformation is noteworthy as natural cover shows areal reduction and fragmentation at higher elevations and in the valley floor. A remarkable growth of area under built-up and horticulture has materialised over land previously under forests, pastures, and barren land. Land conversion in favour of orchards and built-up in the outwash fan area north of Manali town indicate northward expansion of anthropogenic activites. The river terraces on either side of the valley and the settlements forming a linear pattern along major roads show overpowering human presence.

An active interchange within the land cover is evident. The pastures and barren land in high altitude areas and along riverbed shows new forest patches; the abandoning of timber/fuel wood and fodder collection activities in the former, and plantation initiatives in the second has contributed towards such a change. This positive change has certainly contributed in raising denser forest patches around Manali town. However, shrinking forest cover on valley slopes especially in the southern parts of the main valley and adjacent tributary valleys has materialised because of escalated tree felling and land occupancy. The forest margins and pastures adjacent to villages too have shrunk; the disappearance of barren land reveals active transgression over natural cover. Moreover, land conversion for horticulture and built-up activities have affected the hill slopes and valley floor with overwhelming human occupancy.

The evidences uncovered in this study reveal more than just land use/cover changes; a great deal intangible landscape transformation in the valley is apparent. The forces of change can be attributed to improvement in accessibility, horticultural expansion, tourism development, unplanned urbanisation and increasing inflow of population. The trajectory of land transformation in response to such forces indicate a fundamental shift in social-cultural landscape as well. The rural subsistence economy has given way to commercial ways of livelihood; the traditional agriculture stands replaced by horticulture as evidenced from vanished terraced paddy fields and an increase in area under orchards and vegetable farms. The greater engagement of people in tourism and support services has brought in significant cultural and attitudinal changes towards land management. These dimensions, however, outside the purview of this research certainly need further exploration. Nonetheless, one may notice obvious shift in human-environment interactions. The dependency of village life on forests and natural pastures has declined resulting in increasing forest cover in some areas. Such change has eased off the pressure on natural cover, however, intensified land utilisation in the interior locations negate the positive aspects of it. Moreover, human occupancy of barren land on outwash fan area and in the vicinity of river has put livelihood on active risk of flash floods and landslides. The valley floor is witness to the ravages of disasters in September 1995 and 2018, and the recent event in July and August 2022. Hence, it would not be imprudent to infer that although land transformation has led to economic prosperity, yet it has increased the fragility of this mountain landscape. To what end this may become a reality, only the time would tell.

Acknowledgements

The authors extend a sincere thanks to the University Grants Commission, India for funding the work through UGC-JRF. We also place on record the contribution of all those who helped us during our field visits to Kullu Valley.

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Vivek Negi, Research Scholar,

Vishwa B.S. Chandel, Assistant Professor
Email: vishwa.geoinvader@gmail.com
(Author for Correspondence)

Karanjot Kaur Brar, Professor,
Department of Geography
Panjab University, Chandigarh.

punjab
geographer