ORIGINAL ARTICLE

Assessment of spatiotemporal changes in land use/land cover of North Kashmir Himalayas from 1992 to 2018

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Abstract

Under changing global scenarios, assessment of land use/land cover change becomes necessary. Geospatial technologies have been used extensively in many areas of the world for generating valuable information on environmental monitoring. Kashmir valley is also witnessing large LULC changes due to the widespread lateral urbanization, favorable climate, fertile soils and improved infrastructure. This study aims to assess the LULC dynamics in North Kashmir Himalayas from 1992 to 2018 within a GIS environment. Results reveal that agricultural land, forest cover, snow and glaciers are showing a decreasing trend over the study period, while horticulture, built-up/urban area has increased over the same period. The study shows a high demand for the settlement class. Furthermore, an increase in population, climate variability and economic compulsions have been identified as major drivers of LULC change. The application of geospatial technologies to analyze LULC and related effects was clearly demonstrated.

Keywords LULC · Kashmir Himalayas · Remote sensing · Drivers · Climate

Introduction

Land use (LU) and land cover (LC) form the bedrock in describing the terrestrial environment in connection with both natural processes and anthropogenic actions (Jansen and di Gregorio 2002; Bender et al. 2005; Mendoza et al. 2010). Modifications in land use can be categorized by the complex interaction of structural and behavioral factors linked with technological capacity, demand and social relations that affect both environmental capacity and the demand, along with the nature of the environment of interest (Verburg et al. 2004). These changes are dynamic and operate at various spatial scales endlessly. The changes in LULC are ascribed to both natural factors and human actions (Sarma et al. 2008) which in turn stimulate changes that would have serious consequences on natural ecosystems (Moshen 1999; Luna and Robles 2003; Chadha 1990). LULC changes may be grouped into two broad categories such as conversion and modification. Conversion refers to the intended shift from one cover or use type to another,

while modification involves maintenance of the broad cover or use type in the face of changes in its attributes (Baulies and Szejwach 1998). LULC change has been attributed as one of the fundamental causes of global environmental change (Sala 2000). Furthermore, changes in land use are done for satisfying the needs of a growing population which are more of a short-term nature, hence contributing to the long-term loss in ecosystem services and environmental change. It is put forward that LULC change is the most significant signal of human-induced modification of the Earth's terrestrial surface. Therefore, land use is known as an important factor (Foley et al. 2005) on account of human activities such as agriculture and urbanization that have a significant impact on the environment. In the future, these ongoing changes will contribute to an increasing demand for food and energy for the growing population in the world (Schaldach 2006).

Identification of differences in the state of an object or phenomena by observing it at different time intervals involves change detection. It involves the ability to quantify temporal effects using multi-temporal datasets (Othman et al. 2013). With the provision of quantitative analysis of the spatial distribution of the variable under interest, change detection has emerged as an important process in managing and monitoring natural resources (Singh 1989;

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Yuan et al. 1999). Accurate and timely analysis of LULC change becomes necessary for understanding and assessing the environmental consequences of such changes (Giri et al. 2005). Land cover change results from the interplay of several socioeconomic, institutional and environmental factors (Lesschen et al. 2005). The LULC changes driven by anthropogenic factors have resulted into the degradation of several natural resources. Urbanization and agriculture present both direct problems of habitat conversion and indirect effects of chemical pollution and disturbance of water and nutrient cycles (Li et al. 2009). Remote sensing technology is supporting research in LULC dynamics with data sources from space that provide information to monitor and estimate changes on the surface with high temporal resolution (Badreldin and Gossens 2013).

Over the last few decades, LULC change has resulted in unproductive or less productive uses of land in the Himalayan region and is of focal concern for its sustainable development. A recent example of this is the increasing conversion of the agricultural and wastelands into horticulture and rain-fed agriculture in the Khamil catchment of Pohru watershed (Ahmed and Rashid 2009). The land use change studies in Baramulla district (J&K) reveal a remarkable decrease in forests, plantation, water body and agriculture because of the growing population, conversion of farmlands to built up, road extensions, the continuation of uncontrolled grazing activities and other allied reasons (Malik et al. 2017). Lone and Mayer (2018) in their study on LULC changes concluded that the conversion of dense forest into the sparse forest was due to the high pressure of the population. The study further revealed that built-up category was found to increase at an alarming rate in the plain areas at the cost of agricultural land. These changes in land use categories had created a food shortage in the state in general.

Kashmir Himalayas has seen massive changes in terms of population growth with improper utilization of resources, increased use of agricultural land into horticultural purposes and haphazard urbanization (Shafiq et al. 2016). North Kashmir being a part of Kashmir Himalayas has also witnessed these changes. The study area has witnessed massive changes in agricultural land, forest area, built up during the past three decades. The area under horticulture has witnessed a tremendous increase owing to greater returns as compared to crop cultivation (Ahmed and Rashid 2009). The forest cover has decreased not only in extent but also in terms of density (Kango and Qadri 1984). The LULC pattern has also changed over a period of time.

Therefore, the main objective of this work is to utilize the remote sensing and GIS technology to discern the extent of LULC changes that have happened during the past more than two decades in North Kashmir Himalayas of Jammu and Kashmir and to evaluate the major causes behind these.

Study area

North Kashmir Himalayas lies between 34° 16′–34° 40′ North Latitude and 73° 45′–75° 35′ East Longitude. The study area spans over an area of more than 8318 km^2 and attitudinally varies from 1060 to 5200 masl. The study area is enclosed on the north by Greater Himalayas and toward its south lies the Kashmir valley. North Kashmir range acts as the water divide between Jhelum in Kashmir valley and Kishenganga in Gurez valley (Raza et al. 1978). The study area has a temperate climate with distinct seasonality. The temperature varies from 9 °C in winter to 38 °C in summer with an annual rainfall of around 84 cm (Shafiq et al. 2018).

The north Kashmir comprises of three districts, viz. Baramulla, Kupwara and Bandipora. About 21% population of Jammu and Kashmir is found in North Kashmir Himalayas. The total population of North Kashmir is more than 20 lakhs (Digest of Economics and Statistics 2016). Due to the high elevational difference, most of the study area is under forest cover followed by agriculture and water bodies. The study area has recently witnessed large changes in the LULC mainly owing to the expanding population and increased urban activities (Fig. 1).

Materials and methods

Remote sensing methods were used for the assessment of LULC changes in the study area. The satellite imageries used in this study are from the United States Geological Survey (USGS) earth explorer (https://earthexplorer.usgs.gov) and National Remote Sensing Centre hosted Bhuvan (https://bhuvan.nrsc.gov.in) websites. The study area is covered by Landsat frame path row 149-36 and 149-37 of the Worldwide Reference System (WRS). Landsat images obtained for the years 1992 and 2018 and LISS III 2008 are used with a spatial resolution of 30 m and 23.5 m, respectively. The detailed information about the data is presented in Table 1.

The methodology based on supervised classification of the satellite data using maximum likelihood classification algorithm was applied for the classification of satellite images. The supervised classification includes three steps: (a) training (b) class allocation and (c) testing. In the training stage, region of interest (ROI) for different LULC classes was created using ERDAS 2014. These ROI was used to train the classifier and assign them to
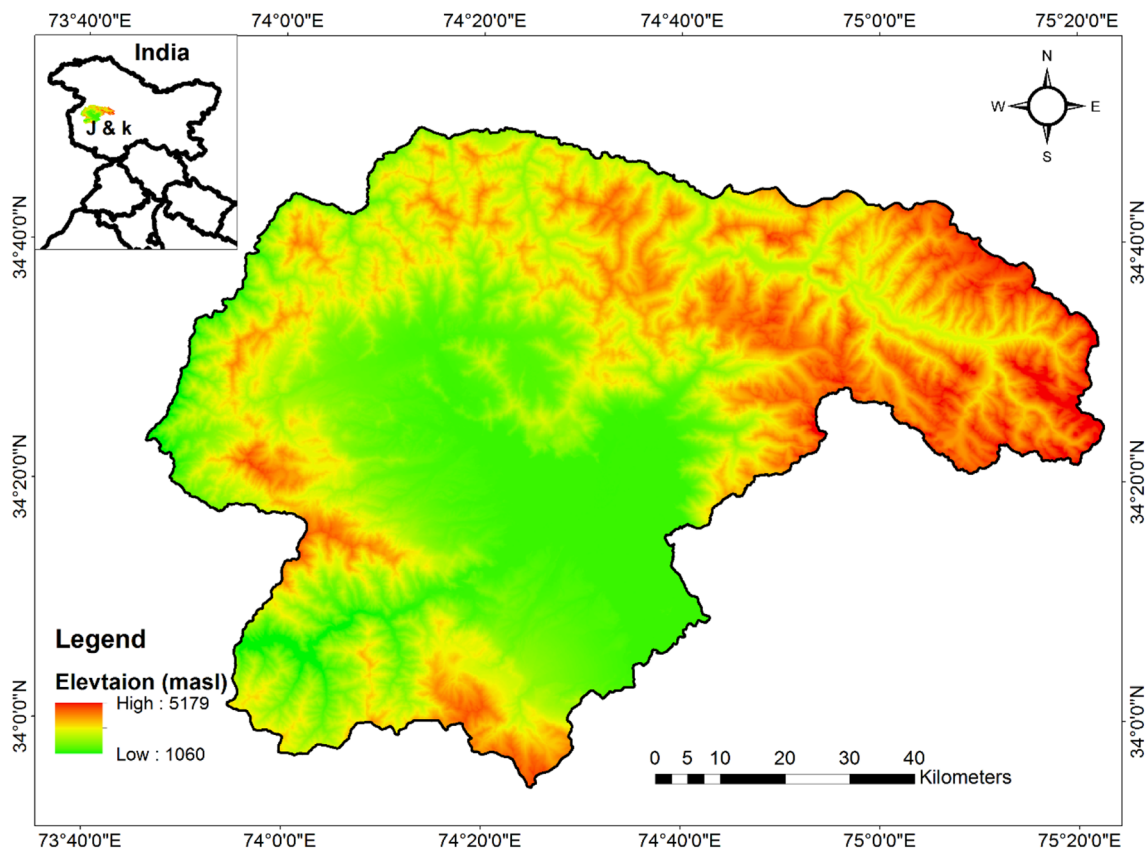
Fig. 1 Location map of the study area

Table 1 Details of satellite data used in the study

Year	Satellite/sensor	Acquisition date	Spatial resolution	Source
1992	Landsat TM	October 15, 1992	30	Earth Explorer
2008	IRS-P6 LISS III	October 3, 2008	23	ISRO Bhuvan
2018	Landsat OLI	October 22, 2018	30	Earth Explorer

matrix. The individual class accuracy was assessed using the user's and producer's accuracy (Story and Congalton 1986).

Image pre-processing and classification

Satellite image pre-processing before the change detection phenomenon is very important to establish a more direct affiliation between the acquired data and biophysical phenomena (Abd El-Kawya et al. 2011). Due to the acquisition system and platform movements, remotely sensed data from aircrafts or satellites are generally geometrically distorted. The satellite data were imported into ERDAS 2014 software in an image format for geometric correction. After these images were geo-referenced, mosaicked and subset based on area of interest (AOI). All satellite data were studied by assigning per-pixel signatures and differentiating the land area into twelve classes based on the specific digital number (DN) value of different landscape elements. The delineated classes were snow and glaciers, sparse forest, dense forest, pasture lands, built-up area, agriculture, horticulture, plantation, aquatic vegetation, water and the barren area. Each class was given a unique identity and assigned a particular color to make them separate from each other. For each of

specific classes. Furthermore, the digital terrain mode of Google earth was enabled to check for the accuracy of the classification. The LULC maps generated were tested for accuracy as they provide a guide to the quality of the map and its fitness for a particular purpose (Foody 2002). The results of the classification scheme were tested using the confusion error matrix as explained by Congalton (1991). Both the reference data and classified data were correlated and tabulated for this purpose. In addition to this, the quality of the overall performance was accessed using the overall accuracy and kappa coefficient of the error

the predetermined land cover/use types, training samples were selected by delimiting polygons around representative sites. Spectral signatures for the respective land cover types derived from the satellite imagery were recorded by using the pixels closed by these polygons. A satisfactory spectral signature is the one ensuring that there is minimal confusion among the land covers to be mapped (Gao and Liu 2010). After that supervised classification was performed by applying the maximum likelihood algorithm on the images. It is the type of image classification which is mainly controlled by the analyst as he or she selects the pixels that are representative of the desired classes. To improve classification accuracy and reduction of misclassifications, post-classification refinement was therefore used for the simplicity and effectiveness of the method (Harris and Ventura 1995). Moreover, when using a data having medium-spatial resolution such as that of Landsat mixed pixels are a common problem (Lu and Weng 2007), especially for the urban surfaces that are a heterogeneous mixture of features mainly including buildings, grass, roads, soil, trees, water (Jensen 2007). The problem of mixed pixels was addressed by visual interpretation. For the enhancement of classification accuracy and therefore the quality of the land cover/use maps produced, visual interpretation was very important. Thus, local knowledge, reference data, as well as visual analysis considerably improved the results obtained using the supervised algorithm.

Results

Visual interpretation of satellite images was done using elements of image interpretation, viz. tone, texture, pattern and association, to delineate various LULC classes using prior knowledge of the study area. The satellite images were interpreted to delineate various LULC classes, viz. built up, agriculture, plantation, dense forests, sparse forests, scrub lands, pasture lands, water bodies, aquatic vegetation, aquatic vegetation and snow and glaciers.

LULC during 1992

In the year 1992, the total snow cover area of North Kashmir, mapped from Landsat TM satellite image, was 467 km^2 which constitutes about 5.6% of the total area. The total area under water body class and the aquatic vegetation surrounding it comprises of about 0.88% and 1.1%. The perusal of Table 2 reveals that in 1992 majority of the area was under agriculture, i.e., 1515 km^2, with agricultural plantation covering 412 km^2. The area under horticulture was 160 km^2, comprising 1.92% of the study area showing less cover than plantation class. From Table 2, it is clear that land cover under forests was dominated by sparse forest (1722 km^2) followed by dense forest (1230 km^2), Scrubland (1205 km^2), and pastureland was 425 km^2. Built-up and barren lands covered an area of 124 km^2 and 891 km^2, respectively. The LULC statistics indicate that during the year 1992, there was less anthropogenic impact on the study area as higher number of natural classes dominated the study area (Fig. 2, Table 2).

Table 2 Area and amount of change in different land use/cover categories in the North Kashmir Himalayas during 1992, 2005 and 2018

| Land use class	1992		2008		2018		Change in area (1992–2008)		Change in area (2008–2018)		Change in area (1992–2018)	
	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%
Snow and glaciers	467	5.60	400	4.80	290	3.48	− 67	14.3	− 110	27.5	− 177	61.03
Water bodies	74	0.88	63	0.75	50	0.60	− 11	14.8	− 13	20.6	− 24	48
Sparse forest	1722	20.70	1758	21.13	1803	21.67	36	2.09	45	2.55	81	4.4
Dense forest	1230	14.78	1181	14.19	1134	13.63	− 49	3.98	− 47	3.97	− 96	8.4
Pasturelands	425	5.10	436	5.20	448	5.38	11	2.58	12	2.7	23	5.13
Scrublands	1205	14.48	1273	15.30	1321	15.88	68	5.64	39	3.06	116	8.78
Barren lands	891	10.71	902	10.84	927	11.14	11	1.23	25	2.77	36	1.38
Agriculture	1515	18.21	1411	16.96	1343	16.14	− 104	6.86	− 68	4.8	− 172	12.8
Horticulture	160	1.92	258	3.10	344	4.10	98	61.25	86	33.3	184	53.4
Plantation	412	4.95	358	4.30	259	3.11	− 54	13.03	− 99	27.61	− 153	59.07
Aquatic vegetation	93	1.11	102	1.22	107	1.20	9	9.6	5	4.9	14	13.08
Built up	124	1.49	176	2.11	292	3.50	52	41.98	116	65.9	168	57.5
Total	8318	100	8318	100	8318	100						
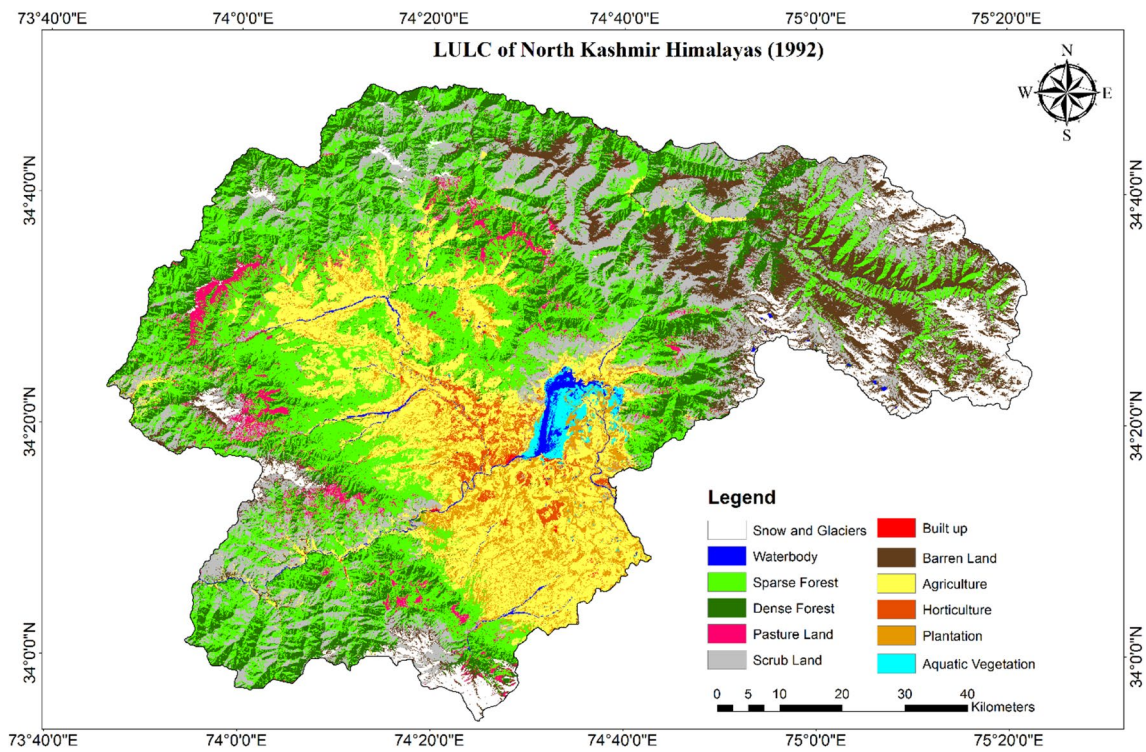
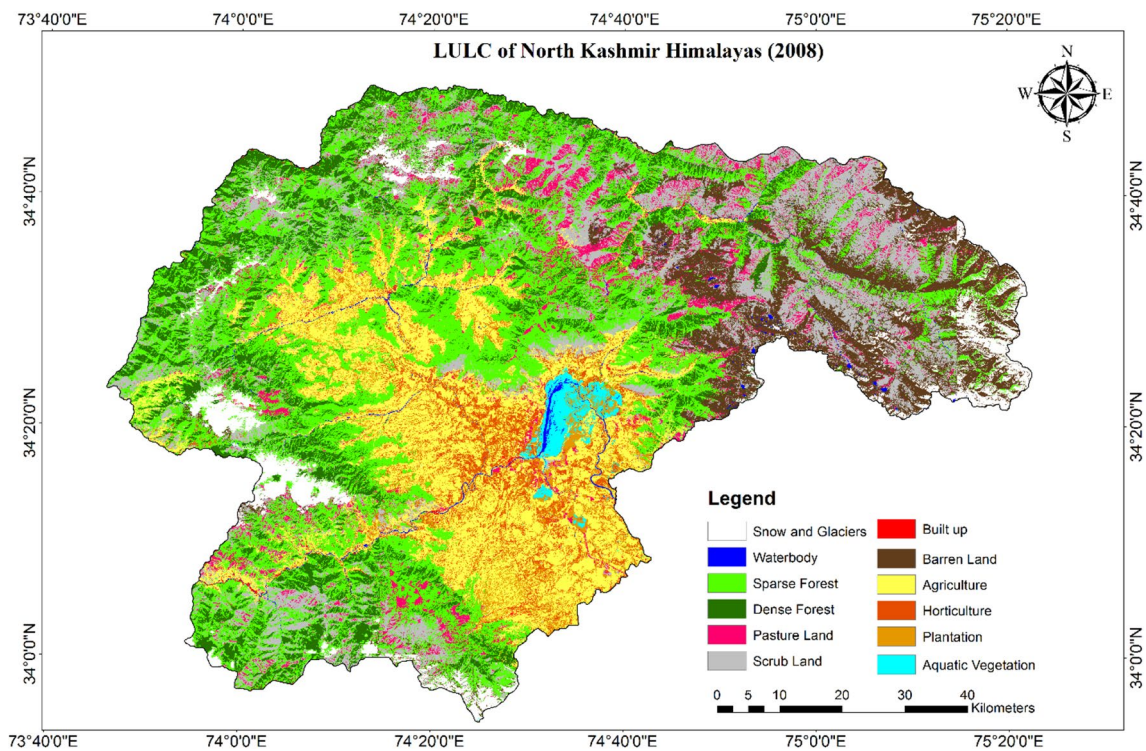**Fig. 2** Land use/land cover map of North Kashmir (1992)

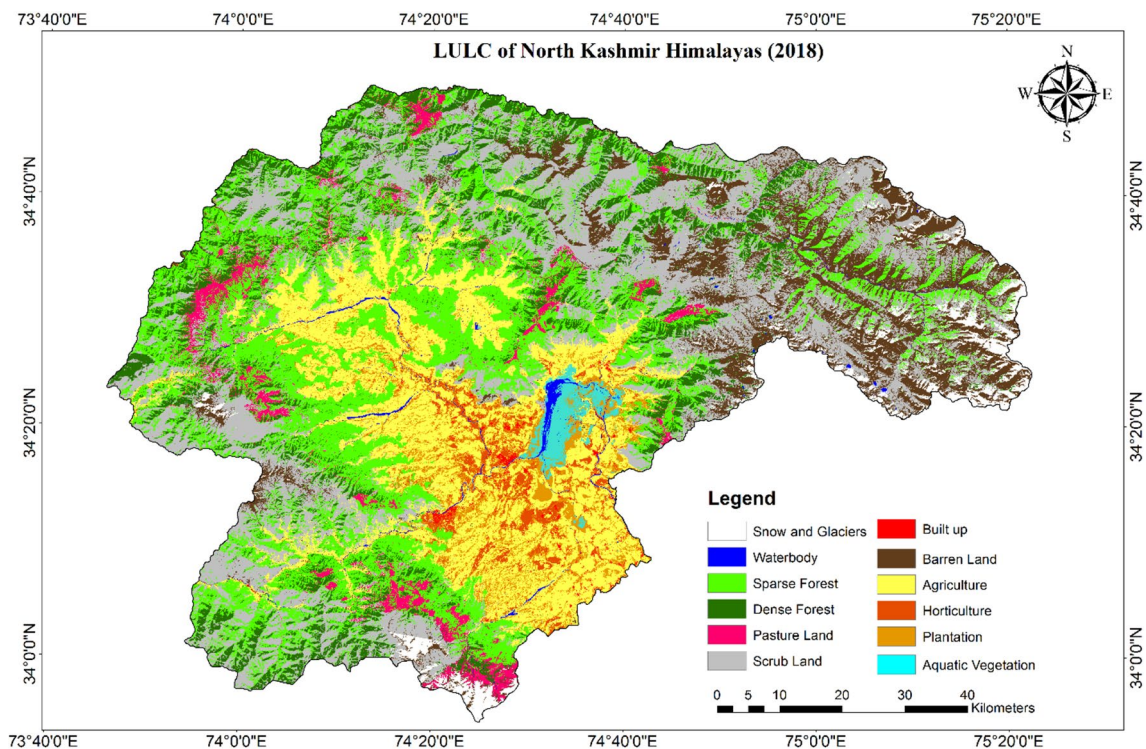**Fig. 3** Land use/land cover map of North Kashmir (2008)

LULC during 2008

In the year 2008, the total area of snow and glaciers recorded from IRS LISS III satellite image was 400 km^2 (4.8%) showing a decrease in area (Fig. 3, Table 2). The statistics also reveal that the water body reduced to 63 km^2 and aquatic vegetation surrounding it has increased to 102 km^2 comprising 0.75% and 1.22% of the total area, respectively. Although there was an increase in the area covered by sparse forests (1758 km^2), scrublands (1273 km^2) and pasture lands (436 km^2) from 1992 to 2008, the area under dense forest has decreased to 1181 km^2. The study reveals that throughout study there was a reduction in the area covered by agriculture with 1411 km^2 area in 2005, followed by plantation (358 km^2) on the one hand, while the area under horticulture and built up has increased to 258 km^2 and 176 km^2, respectively. Barren lands also showed an increasing trend in 2008 and covered an area of 902 km^2 (10.84%). LULC statistics indicate that during the period 1992–2008, changes occurred in the land use categories with the increase in the built up, aquatic vegetation, horticulture, sparse forests, pasturelands, barren lands and scrublands and decrease in the water body, snow and glaciers, dense forests, plantation and agriculture.

LULC during 2018

In the year 2018, LULC status of north Kashmir recorded from the Landsat 8 OLI/TIRS revealed that area under snow and glaciers reduced (Fig. 4) marginally from, i.e., 400 km^2 in 2008 to 290 km^2 in 2018 (3.48%). Water body class further decreased to 50 km^2 (0.60%), whereas a slight increase in the aquatic vegetation to 107 km^2 (1.2%) was recorded. The study further reveals that area under horticulture and built up increased to 344 km^2 (4.1%) and 292 (3.2%) at the expense of a decrease in agricultural land and plantation to 1343 km^2 (16.14%) and 259 km^2 (3.11%), respectively. During 2018, several classes like sparse forest, scrubland and pasture land registered further increase, i.e., 21.67%, 15.88% and 5.38% of the total area, respectively, while the area of dense forests decreased from 1181 to 1134 km^2 (13.63%). Barren land also exhibited an increase from 902 to 927 km^2 comprising an area of about 0.8%. The results of LULC during 2018 are shown in Fig. 4 and Table 2.

Land use/land cover change detection

Change analysis of features on Earth's surface is essential for a better understanding of interactions and relationships between human activities and natural phenomena. This understanding is necessary for improved resource management and improved decision making (Lu et al. 2004; Seif

Fig. 4 Land use/land cover map of north Kashmir (2018)

and Mokarram 2012). The present study was carried out to analyze the spatiotemporal changes in land use/land cover in north Kashmir from 1992 to 2018. The perusal of Table 2 shows that from 1992 to 2018, major area changes were observed in agriculture, horticulture, snow and glaciers, scrub lands, plantation and built up. Minor changes in land cover occurred in aquatic vegetation followed by barren lands, pasture lands, water bodies, sparse forest and dense forest. During the period 1992–2018, plantation showed a sharp decrease since 54 km^2 was lost from 1992 to 2005 and 99 km^2 from 2005 to 2018, which reveals that maximum loss of plantation cover was witnessed during 2005–2018. Despite being the dominant activity in the study region, agriculture also witnessed a loss in the area especially in terms of paddy land during the study period. Agriculture land decreased from 1515 km^2 in 1992 to 1411 km^2 in 2008, which registered a further decrease in the area to 1343 km^2 in 2018. This means agriculture land decreased by 172 km^2 with an annual net rate of 6.6 km^2 during 26 years. The study also reveals that the maximum decline in agriculture class had taken place from 1992 to 2008. On the one hand, agriculture and plantation are showing a decreasing trend over the period of time, while on the other hand horticulture and built up are showing an increasing trend due to their conversion. It was observed that the increase in horticulture was considerable during the period 1992–2008 (1.18%) compared to that of 2008–2018 (1%). Horticulture saw an increase of 344 km^2 with a net change of 7.07 km^2 from its previous coverage. Built-up class also registered an increase. The maximum increase was during the period 2008–2018. During this time, the class registered an additional increase of 116 km^2, depicting the demand for human settlement and other urban infrastructure as compared to 52 km^2 in 2008. Built up showed a total increment of 168 km^2 with a net change of 6.4 km^2 for 26 years. Minor changes occurred in aquatic vegetation. In 1992, 93 km^2 was under aquatic vegetation and showed a slight increase to 102 km^2 in 2008 and 107 km^2 in 2018, with a net change of 0.69%. Water body exhibited a gradual shrinkage, resulting in a decrease in the area of water spread from 74 km^2 (1992) to 50 km^2 (2018) with a net decrease of 0.09% in north Kashmir. From 2008 to 2018, an area of about 13 km^2 was reduced from water body class showing a maximum reduction in the area as compared to 11 km^2 shrinkage from 1992 to 2008. This may be attributed to the depletion of snow and glaciers during the same period. From 1992 to 2018, major changes were observed in snow and glaciers, 5.6% of the land was under snow and glaciers which reduced up to 4.8% in 2008 and further went down to 3.48% in 2018. From 2008 to 2018, maximum change in area was observed, i.e., about 110 km^2 of the area under snow and glacier was reduced as compared to 67 km^2 from 1992 to 2008. In other classes, minor changes occurred compared to previous years. Scrubland, pasture and

barren lands also registered a positive change in area from 1992 to 2018. Scrub land increased by 68 km^2 in 2008 and further showed an increase of 39 km^2 in 2018 with an annual rate of change of 4.4 km^2. Barren land increased by further 11 km^2 in 2008 and by 25 km^2 in 2018. This represents a maximum change in this class from 2008 to 2018 with a net positive change of 0.3%. The classification results revealed that during the period 1992–2008, pasture land showed an increase of 11 km^2 and from 2008 to 2018 an increase of 12 km^2, with an annual rate of 0.88 km^2. This also means that the changes in pasture lands have maintained the same rate. Dense forest saw a decrease of 49 km^2 in 2008 and 47 km^2 in 2018, showing a total decrease of 96 km^2 in forest cover and an annual rate of change of 3.65 km^2. As the negative change was observed in dense forest on the one hand, on the other side sparse forests have shown positive change during these 26 years. 1772 km^2 area was under sparse forest in 1992 which increased to 1758 km^2 in 2008 and showed a further increase of 45 km^2. Results for the period 1992–2018 suggest that the rate of change of LULC classes was high. It has been observed that the area of snow and glacier, water body, dense forest, and agriculture and plantation tends to decrease, but the area of the land use types like horticulture, sparse forest, scrub lands, pasture lands, barren lands and human settlement tends to increase.

Classification accuracy assessment

In the process of change detection analysis involving classification data, accuracy assessment becomes an essential component (Owojori and Xie 2005). Assessment of classification accuracy of 1992, 2008 and 2018 images was carried out to determine the quality of information derived from the data. A stratified random method of accuracy assessment was used to represent different LULC classes in the area. The accuracy assessment was carried out based on ground truth data and visual interpretation. The overall accuracy for the years 1992, 2008 and 2018 was 85.71%, 88.85% and 90.20%, respectively. The respective classification accuracy assessment error matrix tables are presented in Tables 3, 4 and 5. The comparison of reference data and classification results was carried out statistically using error matrices. Besides, a nonparametric kappa test was also performed to measure the extent of classification accuracy as it not only accounts for diagonal elements but all the elements in the confusion matrix (Rosenfield and Fitzpatirck-Lins 1986). Kappa is a measure of agreement between predefined producer ratings and user assigned ratings. It is calculated by a formula

$$K = \frac{P(A) - P(E)}{1 - P(E)}$$

Table 3 Error matrix table of land use/land cover of North Kashmir Himalayas (1992)

	Reference data												Row total	Users accuracy
	SG	WB	SF	DF	PL	SC	BL	A	H	P	AV	BU		
Classified data														
SG	1383	0	0	0	2	4	29	0	0	0	0	0	1418	97.5
WB	0	1176	0	0	0	0	0	0	10	0	108	5	1299	90.5
SF	0	0	405	0	2	16	0	5	12	2	0	0	442	91.6
DF	0	0	8	307	0	0	3	0	0	0	0	0	318	96.5
PL	0	0	2	0	119	1	4	0	0	0	0	0	126	94.4
SL	0	0	0	0	12	149	0	0	0	0	0	0	161	92.5
BL	0	0	0	0	0	2	120	0	0	3	0	0	125	96.0
A	0	0	0	0	0	0	0	620	14	1	0	0	635	97.6
H	0	0	0	0	0	0	0	0	137	1	0	0	138	99.3
P	0	0	0	0	0	0	0	0	2	63	0	0	65	96.9
AV	0	1	0	0	0	0	0	8	12	8	1129	2	1160	97.3
BU	0	0	0	0	0	0	0	2	0	0	0	56	58	96.6
Column Total	1383	1177	415	307	135	172	156	635	187	78	1237	63	5945	
Producers accuracy	100.0	99.9	97.6	100.0	88.1	86.6	76.9	97.6	73.3	80.8	91.3	88.9		

Overall classification accuracy in 1992 = 85.71% and kappa coefficient = 0.87

Table 4 Error matrix table of land use/land cover of North Kashmir Himalayas (2008)

	Reference data												Row total	Users accuracy
	SG	WB	SF	DF	PL	SC	BL	A	H	P	AV	BU		
Classified data														
SG	707	0	0	0	0	1	4	0	0	0	0	0	712	99.3
WB	0	137	0	0	0	0	0	1	0	0	13	0	151	90.7
SF	0	0	117	0	6	0	8	0	2	1	0	0	134	87.3
DF	0	0	31	284	0	0	2	0	0	0	0	0	317	89.6
PL	0	0	2	0	139	6	0	0	0	0	0	0	147	94.6
SL	0	0	0	0	0	102	4	0	0	4	0	0	110	92.7
BL	0	0	1	0	0	0	52	0	2	0	0	0	55	94.5
A	0	0	0	0	0	0	0	119	15	6	0	4	144	82.6
H	0	0	0	0	0	0	0	2	206	10	0	4	222	92.8
P	0	0	0	0	0	0	0	0	12	64	0	3	79	81.0
AV	0	1	0	0	0	0	0	8	2	2	860	2	875	98.3
BU	0	0	0	0	0	0	0	0	0	1	0	42	43	97.7
Column total	707	138	151	284	145	109	70	130	239	88	873	55	2989	
Producers accuracy	100.0	99.3	77.5	100.0	95.9	93.6	74.3	91.5	86.2	72.7	98.5	76.4		

Overall classification accuracy for 2005 = 88.85% and kappa coefficient = 0.72

where $P(A)$ is the number of times the k raters agree, and $P(E)$ is the number of times the k raters are expected to agree only by chance (Gwet 2002; Viera and Garrett 2005). The kappa statistics of the agreement were 0.87, 0.72 and 0.81 for the years 1992, 2005 and 2018, respectively.

Drivers of land use and land cover changes

LULC changes in the study area have been both positive and negative. There are several factors that compel the people to shift the land from one class to another class

Table 5 Error matrix table of land use/land cover of North Kashmir Himalayas (2018)

Data	Reference data												Row total	Users accuracy
	SG	WB	SF	DF	PL	SC	BL	A	H	P	AV	BU		
Classified data														
SG	735	0	0	0	0	0	2	0	0	0	0	0	737	99.7
WB	0	691	0	0	0	0	0	0	0	4	14	0	709	97.5
SF	0	0	1162	0	0	0	5	0	2	0	0	1	1170	99.3
DF	0	0	81	1182	2	0	0	0	0	0	0	0	1265	93.4
PL	0	0	0	0	263	4	2	0	0	0	0	0	269	97.8
SL	0	0	0	0	2	231	0	0	5	0	0	0	238	97.1
BL	0	4	0	0	0	0	98	7	4	0	0	0	113	86.7
A	0	4	0	0	0	0	0	799	24	1	2	8	838	95.3
H	0	0	0	0	0	0	0	2	296	4	0	2	304	97.4
P	0	0	0	0	0	0	0	1	4	49	0	2	56	87.5
AV	0	2	0	0	0	0	0	8	4	2	357	1	374	95.5
BU	0	0	0	0	0	0	0	2	0	0	0	71	73	97.3
Column total	735	701	1243	1182	267	235	107	819	339	60	373	85	6146	
Producers accuracy	100.0	98.6	93.5	100.0	98.5	98.3	91.6	97.6	87.3	81.7	95.7	83.5		

Overall classification accuracy for 2018 = 90.20% and kappa coefficient = 0.81

Classification accuracy assessment using error matrix, where *SG* snow and glacier, *WB* water body, *DF* dense forest, *SF* sparse forest, *PL* pasture lands, *SL* scrub lands, *BL* barren lands, *A* agriculture, *H* horticulture, *P* pasture lands, *AV* aquatic vegetation, *LV* low vegetation, *BU* built up

prominent among these being variability in climatic parameters, income and a massive increase in the population which has triggered the changes in the psychosocial behavior of locals. The major drivers of LULC change identified are summarized below. The drivers are grouped into climatic, demographic and economic factors.

Climatic

Recent studies on the impact of climate change on land use/land cover revealed the marked shift of climate in Kashmir valley and its effects on land use. The valley has witnessed not only a change in the magnitude of temperature and rainfall, but its distribution over the years as well. Studies conducted on climate in Kashmir Himalayas show that the annual rate of increase is 0.05 °C and 0.01 °C in mean maximum and mean minimum temperature, respectively, with a corresponding decrease of around 4.22 mm/year from 1980 to 2016 (Shafiq et al. 2018). Furthermore, the studies have also pointed out drastic changes in seasonal temperatures and precipitation in the study area (Shafiq et al. 2019). These changes have acted as a triggering factor for the land use conversion particularly toward the year 2000 around which has been seen as a year of change by Shafiq et al. 2018 in temperature and precipitation time series. The major shift in land use was also seen from 1998 to 2000 mainly owing to the changes in climatic regimes of temperature and precipitation. Temperature with a decrease in precipitation increases evapotranspiration and rapid drying

of soils, which in turn depletes the soil moisture resulting in high water demand. These changes in precipitation and temperature are changing the availability of water in the region which forced people to move from agriculture to horticulture as horticulture requires less water than agriculture which mainly is in the form of rice cultivation in the study area. Furthermore, these problems get multiplied owing to very poor water infrastructure available in the study area.

Demographic

The Himalayan region is characterized not only by ecological fragility but also by a deep and historical geopolitical sensitivity (Stone 1992). The growing anthropogenic interference due to escalating population growth has led to the adverse impact on the mountain ecosystem and biological resource base which has assumed alarming dimensions. In 1991, the total population of the study area was 13.5 lakhs which increased to 22.6 lakhs over 20 years (1991–2011), which means 11.3 lakh people were added to the total population (Census 2011). The population of Baramulla district in 2001 was 11.6 lakh and that of Kupwara was 6.5 lakh. Due to the increasing population pressure, district Bandipora was carved out from Baramulla in 2007 for administrative purposes. In 2011, the population of Kupwara reached 8.7 lakh and that of erstwhile Baramulla (Baramulla and Bandipora) reached 13.9 Lakh (Anonymous 2001, 2011). To meet the daily needs, this increase in population has its direct impacts

on the resource base of the region. Increased accessibility, population pressure, economic development and the excessive utilization of the region's resources for grazing, firewood and timber extraction have resulted in a threat to the health of this mountain ecosystem and its inhabitation (Gupta 1978). Forest clearance for agriculture driven by population growth is the primary reason of deforestation in most of the biodiversity-rich tropical forest countries (Williams 1997) as 13 million hectares of forest land is used for agricultural purposes per year (FAO 2005).

Economic

During the last century, world population has seen a significant increase putting a heavy burden on natural resources particularly affecting the LULC with more areas being devoted to non-agricultural uses. Kashmir valley has not remained aloof to these changes with a population increasing at a faster pace during the past more than three decades. With an increase in population, the sources of income have registered structural changes and high demand. In the study area, people area is transformed the land from traditional agriculture to horticulture at a much faster pace due to higher-income returns (Siddique 2007). A study by Rasool et al. 2016 in the Shopian district of Jammu and Kashmir has revealed that economic conditions have acted as the major factor which sustained the land use changes from agriculture to horticulture. The share of high value commodities concerning overall agricultural production has increased in the entire study area (Anonymous 2015). Sustained economic and income growth are fueling rapid growth in demand for high value commodities in the state. In the study area, farmers have opted to shift from agriculture to horticulture in response to increasing economic benefits in the form of profits and output from the latter as compared to the former (Rasool et al. 2016).

Discussion

Spatial analysis of the multi-temporal LULC maps of North Kashmir revealed significant changes during the 26 years from 1992 to 2018. The LULC changes were both positive and negative. In some cases, there was a shift from agricultural land to horticultural plantations particularly apple plantation. There was also the conversion of agricultural land to the built-up area. The forest area recorded a declining trend for the entire period. While at the same time, there was a positive change in some classes, e.g., due to the conversion of dense forest into the sparse forest, snow and glacier into barren and scrub lands.

Agriculture being a dominant activity in north Kashmir has got a maximum area under it. The area under agriculture

has decreased over the study period. A predominant shift was noticed from agricultural to horticulture because of economic benefit in the horticultural crops, resulting in a significant increase in horticulture plantation. This is also attributed because over the period of time, increase in temperature is observed with a decrease in precipitation (Shafiq et al. 2016, 2018, 2019; Mishra and Rafiq 2017). This resulted in increased evapotranspiration forcing people for adaptation of horticulture.

Forest cover in the study area has also registered an overall decreasing trend during the past 26 years. Forests in the study area was classified into dense, sparse and scrubland. The dense forest in the study area is transformed into a sparse forest. Shafiq et al. (2017) in their study have attributed the increased need for timber, firewood with a massive increase in population leading to increasing built-up area during the last two decades as the main cause for deforestation. Furthermore, an increase in scrubland is mainly due to a decrease in the sparse forest area which leads to more area being vulnerable to geomorphic processes of erosion and increased runoff.

The area under water bodies has also shown a decreasing trend over the entire course of the study period. The growing population and increasing built-up area in the region significantly altered the natural landscape and resulted in the loss of natural vegetation, agricultural lands and water bodies. Snow and glaciers also show a reduction in the area over a period of time. It is mainly attributed to increase in temperature (Shafiq et al. 2018) from the last few decades that glaciers are melting at a fast rate, and then, the area exposed from them has increased the area under barren lands and scrub lands.

Furthermore, the land use change in Kashmir Himalayas in general and North Kashmir in particular has been subjected to several interrelated factors. The most potent factor for triggering land use changes in the study area was found to be climate with drastic changes in temperature and precipitation. The erratic precipitation patterns showed their impact on crop production which forced farmers to change their land use pattern. This trend was further supported by an increase in population with higher economic returns in some sectors of the economy which sustained the land use change in the study area. Several studies (Rasool et al. 2016) have also shown the impact of psychosocial factors in driving the land use changes in the study area.

Conclusion

The assessment of LULC dynamics is of vital importance in assessing the global and regional ecosystem changes. LULC changes depict the direct relationship between the man and his environment. In the present study, geospatial techniques

have been used for assessing the LULC changes in North Kashmir Himalayas from 1992 to 2018. Results revealed that the study area has experienced various changes in LULC during the past 26 years. Significant positive increasing change is seen in horticulture and built-up area with a decrease in agriculture, forest area and water bodies. Agriculture which forms the backbone of the study area is being transformed into horticulture and settlement area due to the increased demand of the population. Forest land has been cleared for timber and expansion of seasonal agricultural activities besides rendering large areas of forests barren. The study found that geospatial techniques can be effectively utilized for assessing and monitoring of natural resources and aiding the land use planners for arriving at sustainable land use policies. Furthermore, the study suggests formulating a LULC policy and its strict implementation particularly for settlement and built-up area.

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