



Temporal Land-Use/Land-Cover Change Analysis in Kotla Sub-Watershed of Rupnagar District (Punjab) Using Remote Sensing and GIS

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Abstract

Land-use and land-cover (LU/LC) change is becoming a crucial component for managing the natural resources. Identification, delineation and mapping of LU/LC are very important for activities such as planning, study of earth's features and natural resource management. Remote sensing technology has proven to be an effective tool to analyze LU/LC changes at watershed level. In this study, an attempt was made to detect LU/LC changes from the year 2009 to 2018 in Kotla sub-watershed which is situated in Anandpur Sahib block, Rupnagar district of Punjab. High-resolution satellite data of IRS-P6 LISS-IV for the years 2009 and 2018 were analyzed for LU/LC mapping using visual image interpretation technique. There were total ten LU/LC classes: agriculture, built-up, canal, degraded forest, dense forest, drainage, moderate dense forest, transport, wasteland and waterbody demarcated in the study area. The overlay analysis of 2009 over 2018 was done to analyze changes in the study area over the period of 10 years. Results of study show that area under agriculture, moderate dense forest and wasteland decreased by 2.80%, 60.06% and 4.25%, respectively, and area under other LU/LC classes, i.e., built-up, degraded forest, dense forest, drainage and waterbody, was increased by 115.47%, 93.39%, 3.62%, 15.81% and 3.70%, respectively, while areas of canal and transport remain unchanged from the year 2009 to 2018. The overall accuracy and kappa statistics for classified images of 2009 and 2018 were 70.27% and 89.19% with kappa coefficient values 0.66 and 0.87, respectively. Change analysis at village level and sub-watershed level was also carried out to identify the most affected regions of the study area. Total 13 sub-watersheds are categorized as sub-watershed number 1–13. The most affected sub-watershed number is 11 which consists of villages: Kotla, Balauli, Raipur sani, Ganj pur, Mahndali khurd and Pahar pur as per LU/LC change analysis, and management practices need to be look for these villages. In this study, we also use land surface temperature algorithms and Normalized Difference Vegetation Index (NDVI) values to estimate changes in LU/LC from 2009 to 2018, where decreasing trend in the values of NDVI is estimated which is the evident of overall decrease in vegetation in the region.

Keywords Land use/land cover · LISS-IV · Kotla sub-watershed · Remote sensing and GIS · Visual image interpretation

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Introduction

Land use and land cover (LU/LC) are two terms arranged together but have different meanings, where land use refers to the use of land in different ways according to their nature and utilization by human being in terms of agricultural fields, industrial zones, residential zones, recreational areas, etc., while land cover reflects the physical appearance of land resources available on the earth. Moreover, the characteristics of the surface/subsurface of the Earth, water's surface, manmade structures, topographic and

covering soil are known as land cover (Dewangkoro & Arymurthy, 2021). It reflects the appearance such as forests, grasslands and water resources (Rawat et al., 2013; Singh et al., 2010). LU/LC is directly proportional to each other because changing in the behavior of one can affect the condition of other. The use of land influences the land-cover condition, and the transformed land cover influences the land use in such a way that they show their direct relationship with each other (Prakasam, 2010; Rawat & Kumar, 2015).

LU/LC change is becoming a very crucial component for managing the natural resources, dividing them into different categories according to their utilization and identification of changes in environmental conditions (Sushanth et al., 2019). So, identification, delineation and mapping of land cover are very important for number of activities such as planning, study of earth's features and natural resource management. Study of land cover is important for conservation planning, different uses of natural resources and their management (Chowdary et al., 2009; Rawat et al., 2013). LU/LC is changing day by day due to some activities such as deforestation, industrialization and urbanization, and these activities have big impact on environmental conditions and in the process of watershed management (Khan & Jhariya, 2016; Samal & Gedam, 2015; Satyawani et al., 2015).

Watershed is the part of land which is defined as the hydrological unit and an area that generally drains the surface water to a common outlet and used for managing the naturally available resources (Soni et al., 2015). For the conservation of precious land resources, watersheds have been known as a best planning unit. Increase in urbanization and deforestations is the big factors which influence the watershed ecosystem continuously (Sakthivel et al., 2010). The factors mentioned above are responsible for changes in LU/LC of watershed, so it is very important to manage and conserve the watershed with proper strategies. The information about watershed parameters such as size, shape, drainage pattern, topography, soil, LU/LC and their characteristics which can affect the behavior of watershed can be analyzed through geospatial technology (Chowdhury et al., 2020). Geographical Information System (GIS) is a powerful tool to manage the information which is in the form of large datasets. These technologies are time saving and cover the large area at instance of time which shows its role and importance in the field of LU/LC change detection (Pradeep et al., 2014; Bashir et al., 2018).

Satellite remote sensing data are helpful because of their large vision, real-time information as well as their repeated coverage, and they are available in the form of digital images. (Shalaby & Tateishi, 2007; Mishra et al., 2020). It is helpful in maintaining the spatial data infrastructure (SDI) which is a framework of geographic data, metadata

and tools that are interactively connected in order to use spatial data. (Butt et al., 2015). Fast and cheapest advanced techniques like remote sensing and GIS provide different tools to monitor changes in LU/LC in particular region. (Baeza & Paruelo, 2020; Kaya and Gorgun, 2020). Inspection of Earth from the space is very important to understand the impact of human's activities on natural resources over time (MohanRajan et al., 2020). So, after doing LU/LC classification, the accuracy of special data should be assessed. Accuracy assessment is the evaluation of classification with ground truth data to evaluate how well the classification represents the real world.

LU/LC classification is not completed until accuracy assessment has been performed; therefore, in the present study accuracy assessment of the resultant classified images was carried out to determine the quality of information derived from the satellite data (Rwanga & Ndambuki, 2017; Tilahun & Teferie, 2015). Producer's, user's and overall accuracy is important to evaluate in the process of accuracy assessment, where producer's accuracy generally represents how well referenced points of ground cover type are classified, while user's accuracy represents the probability that a point classified into a given class actually belongs to that class on ground. The overall accuracy is most popular and simplest way to measure accuracy, while kappa coefficient is an important technique which is used to evaluate the accuracy of error matrices statistically and value of kappa coefficient varies between 0 and 1; more the kappa value, more accurate the classification is (Thapa and Murayama, 2009; Stehman, 2013).

Several similar kinds of studies have been conducted to analyze LU/LC changes at watershed level with the advanced remote sensing approach but using low-resolution satellite data by Anees et al. (2014), Shafiq et al. (2017), Bhukhari (2019) and Mishra et al. (2020). In this particular study, high spatial resolution satellite (5.8 m) data of LISS-IV have been used by following two different approaches, i.e., visual image interpretation, NDVI and LST together to fulfill our objectives. Kotla sub-watershed was chosen as a study area to analyze LU/LC pattern and changes over time because no such work has been conducted in this region. Urbanization is one of the major factors that has come up very fast from last two decades in foothills of Punjab district. One such sub-watershed is Kotla, which is situated in Rupnagar district, Punjab. This particular region faced major problems in conversion of agricultural land into built-up due to increase in population (Census, 2020) which may lead to environmental related problems and can directly affect the overall health of sub-watershed. Another one of the major problems of this region is the overall vegetation decreasing over time which needs to be managed. NDVI and LST approach is also used to check the main cause of overall decreasing in vegetation.

Furthermore, depth analysis of LU/LC change need to be done at village level and sub-watershed level so that best and required control measures can be applied on that particular area. Therefore, to accomplish this task, timely as well as accurately monitoring of such LU/LC changes is very important. Hence, the present study was planned to evaluate the status of changes occurred in LU/LC of Kotla sub-watershed for the year 2009 to 2018. The information on the same may be helpful for planning land-use resources, watershed prioritization, urban and water harvesting planning and different hydrological studies at the sub-watershed scale. So, keeping all the above aspects in mind the present study was carried out on LU/LC change analysis of Kotla sub-watershed of Punjab with following objectives:

- 1 To generate land-use and land-cover maps using visual image interpretation for the years 2009 and 2018 of Kotla sub-watershed.
- 2 To detect the land-use/land-cover change by adopting different approaches, i.e., overlay analysis, NDVI and LST over a decade from the year 2009 to 2018.
- 3 To identify overall changes, village-level changes and sub-watershed-level changes.

Material and Methods

Study Area

The Kotla sub-watershed selected to analyze LU/LC change is situated in Sri Anandpur Sahib block of Rupnagar district, Punjab, and shown in Fig. 1. Kotla sub-watershed is a part of *Shivalik* foothills and lies between latitudes 31°11'36" N to 31°16'40" N and longitudes 76°30' E to 76°36'5" E. The study area comprises of total 17 villages (Samlah, Baddal, Balauli, Dhanera, Ganj pur, Jhinjri, Kataur, Kotla, Lakher, Mahndali khurd, Mandal Kalan, Mindhwan, Paharpur, Raipur sani, Tara pur, Thappal and Chand pur) and 13 sub-watersheds which is covering an area of 3522.55 ha (Fig. 1 of Kotla sub-watershed). Nearly half of the area in Kotla sub-watershed is covered by forest. The study area shares its boundary with Himachal Pradesh at northeast. Temperature of the study area varies from 4 °C in winter to 45 °C in summer season with average rainfall varying from 700 to 800 mm. Out of the average annual rainfall of this region, about 78% occurs during southwest monsoon. Soil texture of the study area varies from loam to silt clay loam (Rupnagar, 2020). Study area comprises portion of two main canals, i.e., Bhakra canal and Sutlej Yamuna Link (SYL) canal. The water of the natural drains of the study area drains out in the Sutlej River flowing in the Rupnagar district.

Satellite Data Acquisition

The multi-temporal satellite data of IRS-P6 LISS-IV for 25/11/2009 and 6/1/2018 were used in this study and are shown in Fig. 2. The satellite data were purchased from NRSC. Details of satellite imageries are presented in Table 1.

Image Preprocessing

Image preprocessing is one of the major steps that must be followed. It is immensely needed for establishing more direct affiliation between acquired data and the biophysical phenomena. Images were preprocessed using ArcGIS and ERDAS imagine software for mosaicking, georeferencing and sub-setting on the basis of study area.

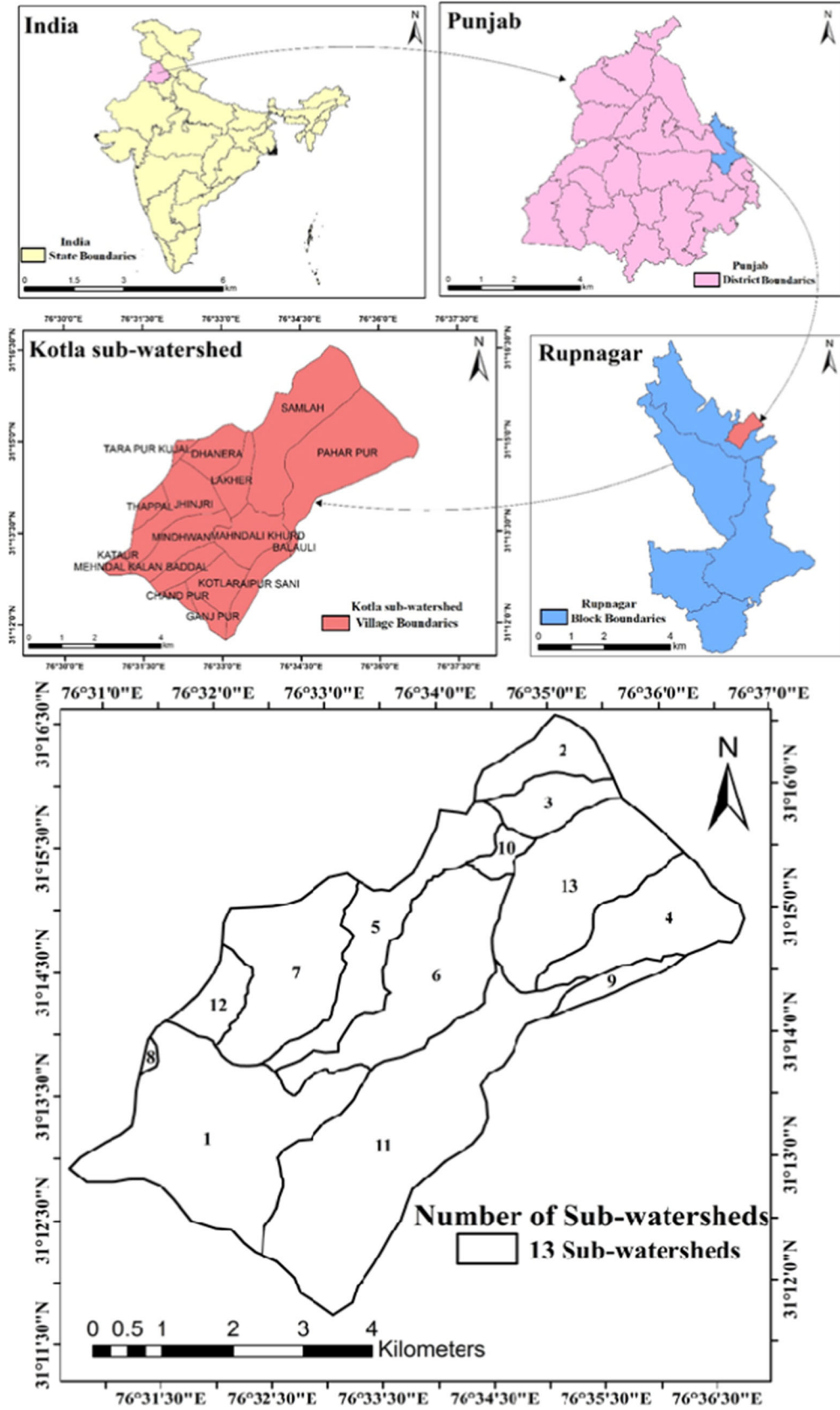
Land-Use and Land-Cover Classification

To prepare the LU/LC map, level-1 classification scheme which defines the LU/LC classes was considered. The number of LU/LC classes is chosen based on level-1 classification. Visual image interpretation technique was used to prepare LU/LC map on the basis of image interpretation elements (photo-elements) such as shape, size, tone, texture, shadow, site, association and pattern for satellite imageries as shown in Fig. 3 (Satyawani et al., 2015; Singh, 2016). All LU/LC classes were identified and digitized on 1:4000 scale. This technique is widely used for LU/LC classification in many researches since 80s and still using, and it is more accurate as compared to other techniques in order to accurate classification. Kotla sub-watershed consists of total 17 villages and 13 sub-watersheds that is why, features delineated using visual approach were the big need to define their boundaries clearly, to estimate area (ha) more accurately and to avoid mixability of features which is happened in case of supervised classification technique. Agriculture, built-up, canal, degraded forest, dense forest, drainage, moderate dense forest, transport, wasteland and waterbody are the major LU/LC classes identified in Kotla sub-watershed (Fig. 3).

LU/LC Area and Temporal Change Estimation

After preparation of LU/LC maps, basically different change detection approaches are used, i.e., overlay analysis NDVI and LST. Firstly, overlay analysis was performed to analyze changes occurred in the study area by overlaying LU/LC shapefile of 2009 over 2018. Secondly, NDVI-based change analysis was also done using raster calculator putting their standard equations in it and values were exported in the excel worksheet and tables were prepared.

Location of the Study Area



◀**Fig. 1** Location map of study area Kotla sub-watershed, Punjab, with sub-watershed regions

For LST estimation, MODIS LST product was used which is freely available at online platform. Overall changes, village-level changes and sub-watersheds-level changes were determined from 2009 to 2018 (Julien et al., 2006; Worako, 2016). Change matrix table was also prepared to clarify that which class is converted in other class and how much hectare of area is shifted from one class to other class. Figure 4 shows the flowchart of methodology adopted for LU/LC change analysis.

Accuracy Assessment of On-Screen Visual Classifications

The classification accuracy for the classified imageries of years 2009 and 2018 was assessed based on error matrix table. A point feature shape file of 111 random points was created using ArcGIS software as shown in Fig. 5a which corresponds to major areas of changes as well as other areas in the study area. Google Earth played important role in accuracy assessment process. The 111 random points were converted to KML file and overlaid on Google Earth to verify the ground truth data (Fig. 5b) of 2009 and 2018. LULC classes of the respective points were also confirmed using ground truth data where change in LULC class was verified by people residing over there. The producer's, user's and overall accuracy along with kappa coefficient

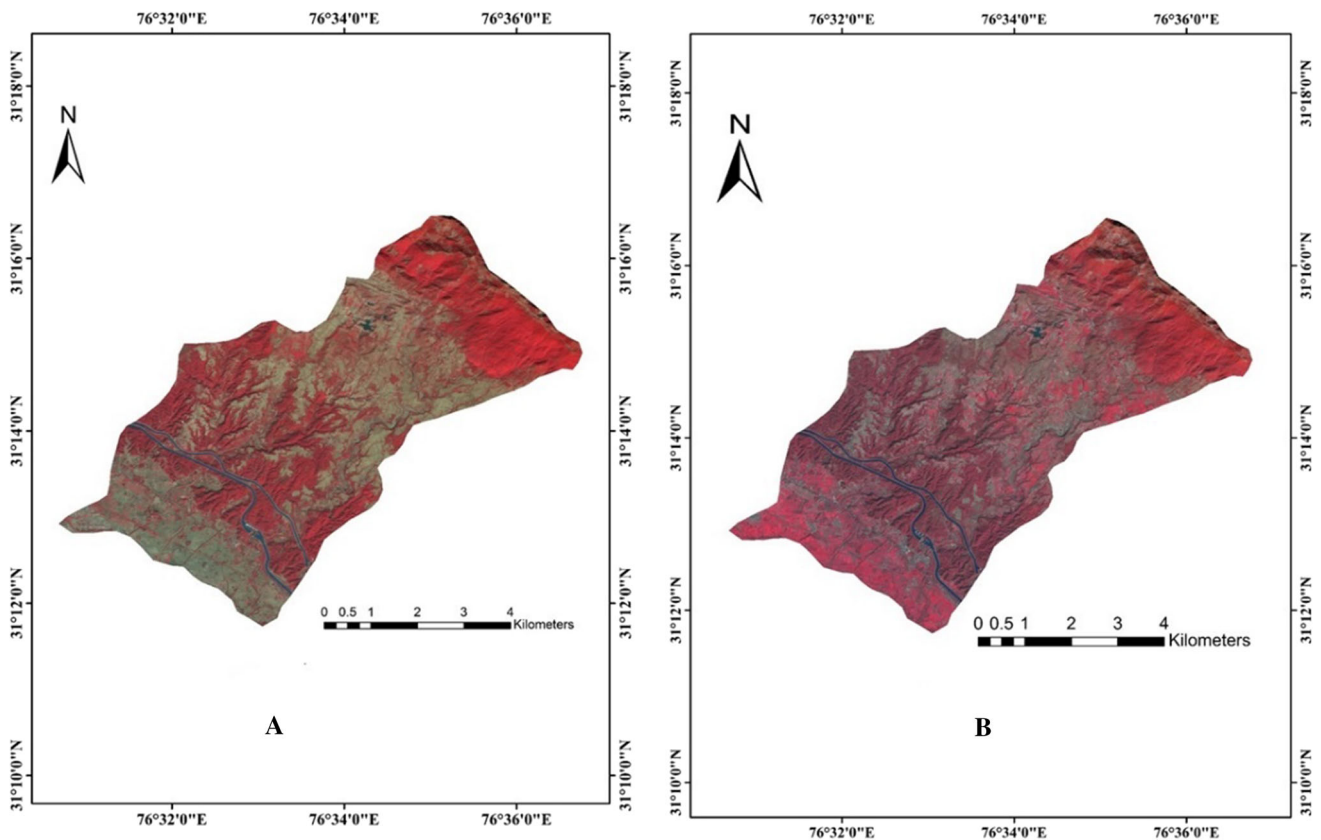


Fig. 2 False color composite of satellite images from IRS-P6 LISS-IV of Kotla sub-watershed **a** 2009 and **b** 2018

Table 1 Details of satellite data

Satellite	Sensor	Bands	Band wavelength (μm)	Resolution (m)	Swath (km)	Path/Row
IRS-P6	LISS-IV	Green (B2)	0.52–0.59	5.8	23.9–70	94/49
		Red (B3)	0.62–0.68			
		NIR (B4)	0.77–0.86			

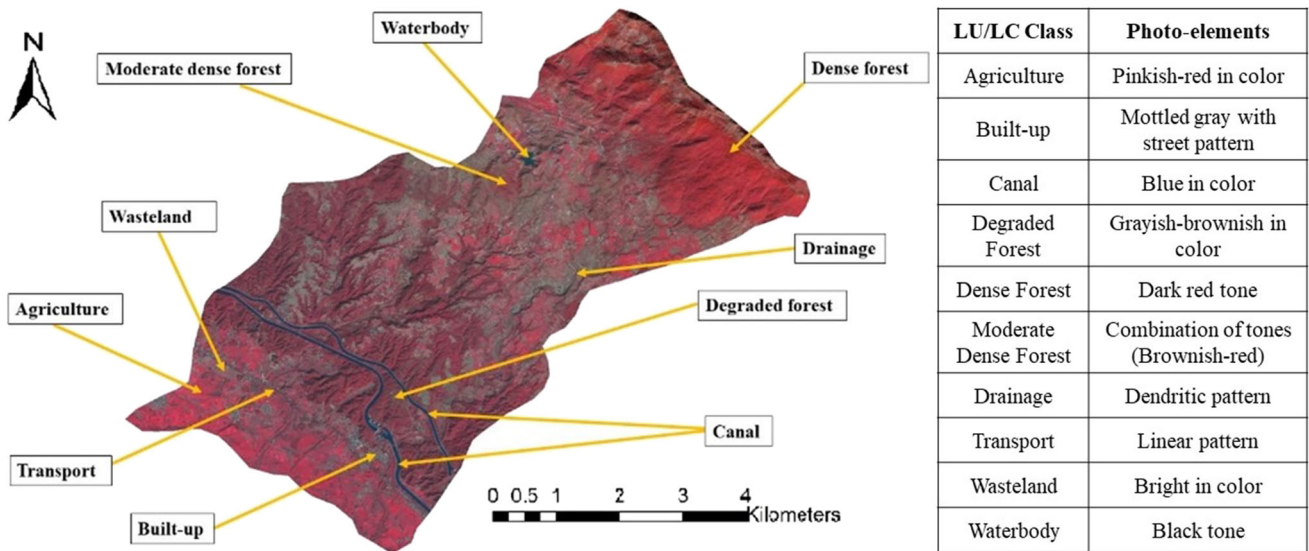


Fig. 3 Identified different LU/LC classes based on interpretation keys (photo-elements)

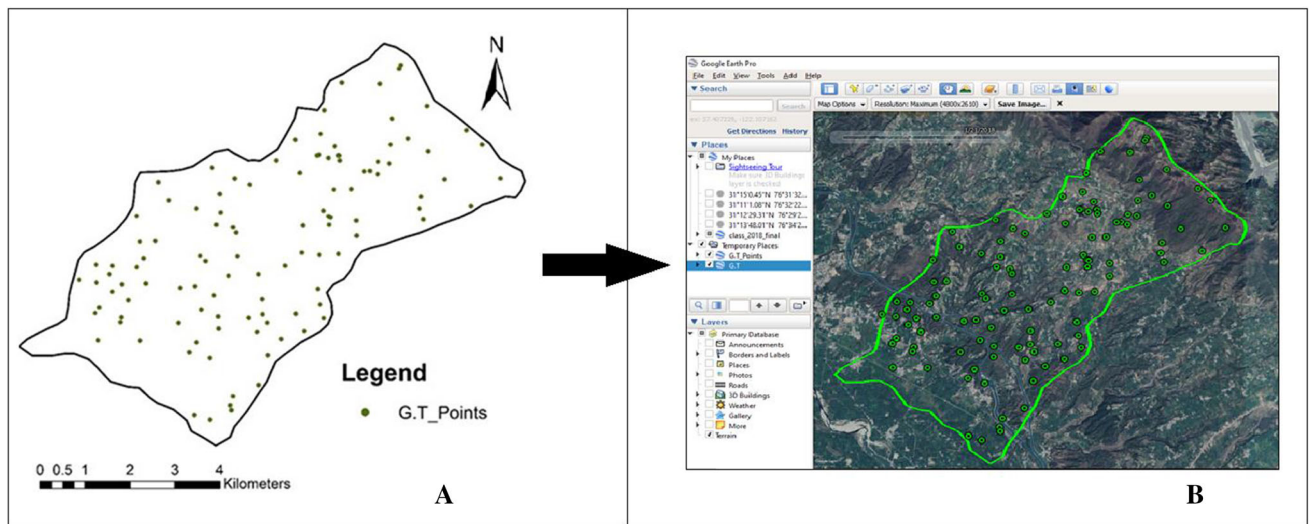


Fig. 4 a Locations of ground truth collected from study area. b Verification using Google Earth

was determined using standard equations given in Eqs. 1, 2, 3 and 4.

Producer’s accuracy (Congalton, 1991; Yuan et al., 2005)

$$\text{Producer's Accuracy} = \frac{\text{Total no. of correct points in each class}}{\text{Total no. of points used for that class (Classified Total)}} \quad (1)$$

User’s accuracy (Congalton, 1991; Yuan et al., 2005)

$$\text{User's Accuracy} = \frac{\text{Total no. of correct points in each class}}{\text{Total no. of points used for that class (Reference Total)}} \quad (2)$$

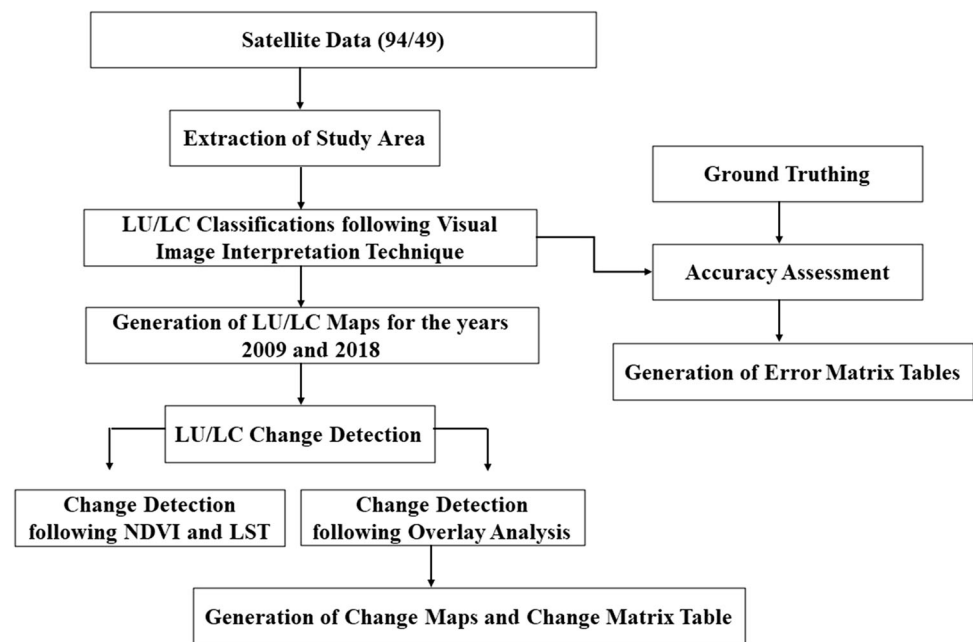
Overall accuracy (Rwanga & Ndambuki, 2017)

$$\text{Overall Accuracy} = \frac{\text{Total no. of correct points}}{\text{Total no. of selected points}} \quad (3)$$

Kappa (K) coefficient (Tilahun & Teferie, 2015)

$$\hat{K} = \frac{N \sum_{i=1}^k x_{ii+} - \sum_{i=1}^k (x_{i+} * x_{+i})}{N^2 - \sum_{i=1}^k (x_{i+} * x_{+i})} \quad (4)$$

where x_{i+} and x_{+i} are the marginal totals for row I and column I. x_{ii+} is the number of observations in row I and column I. N is the total number of observations.

Fig. 5 Flowchart of methodology

Results and Discussion

LU/LC for the Year 2009

All the identified and mapped LU/LC classes of the year 2009 are represented in Fig. 6. The percentage area under all ten LU/LC classes can be seen from the pie chart given in Fig. 7.

The statistics as presented in Table 2 shows that the majority of area in Kotla sub-watershed was covered by dense forest (1366.55 ha) and it accounts 38.79% of the total area followed by agriculture which covered an area of 1360.72 ha that accounts 38.63% of the total sub-watershed area. The other classes such as built-up, canal, degraded forest, drainage, moderate dense forest, transport, wasteland and waterbodies cover an area of 49.69 ha, 38.82 ha, 174.58 ha, 67.34 ha, 402.86 ha, 38.07 ha, 17.62 ha and 6.30 ha, respectively, which accounts 1.41%, 1.10%, 4.96%, 1.91%, 11.44%, 1.08%, 0.50% and 0.18% of total sub-watershed area, respectively (Fig. 7).

The LU/LC map of the year 2018 is shown in Fig. 8, and percentage area under all ten LU/LC classes can be seen from Fig. 9. Statistics (Table 2) shows that the major area in sub-watershed was covered by dense forest (1416.08 ha) in 2018 which accounts 40.20% of the total area in the sub-watershed, while agriculture land attained second place by covering an area of 1322.59 ha which is 37.55% of the total area. Rest of classes such as built-up, canal, degraded forest, drainage, moderate dense forest, transport, wasteland and waterbodies covers an area of 107.08 ha, 38.82 ha, 337.63 ha, 77.99 ha, 160.89 ha, 38.07 ha, 16.87 ha and 6.53 ha, respectively, which accounts 3.04%,

1.10%, 9.58%, 2.21%, 4.57%, 1.08%, 0.48% and 0.19% of the total area, respectively. The results obtained from LU/LC classification of Kotla sub-watershed from the year 2009 and 2018 are shown in Table 2.

Overall, LU/LC Change Analysis from the Year 2009 to 2018 of Study Area

There were significant changes occurred both positive (increase in dense forest) and negative (increase in built-up and decrease in agriculture land) under different LU/LC classes except canal and transport during 2009 to 2018. Area under agriculture, moderate dense forest and wasteland have been decreased in 2018, while the area under built-up, degraded forest, dense forest, drainage and waterbody was increased in 2018. Figure 10 shows changes in LU/LC of sub-watershed during the period 2009 to 2018.

The areas of major changes occurred in Kotla sub-watershed from the year 2009–2018 were calculated and are represented in Table 2. The results showed that the area under agriculture, moderate dense forest and wasteland has been decreased from year 2009 to 2018 by 2.80%, 60.06% and 4.25%, respectively (Fig. 11), with respect to year 2009. The possible causes for changes in agriculture area may be use of such land for residential/commercial purposes. The rapid growth in area under built-up which may be due to increase in population as per the census report of 2001 and 2011 with population density 2467 and 2741, respectively (Census 2020). The area under built-up, degraded forest, dense forest, drainage and waterbody has been increased by 115.47%, 93.39%, 3.62%, 15.81% and

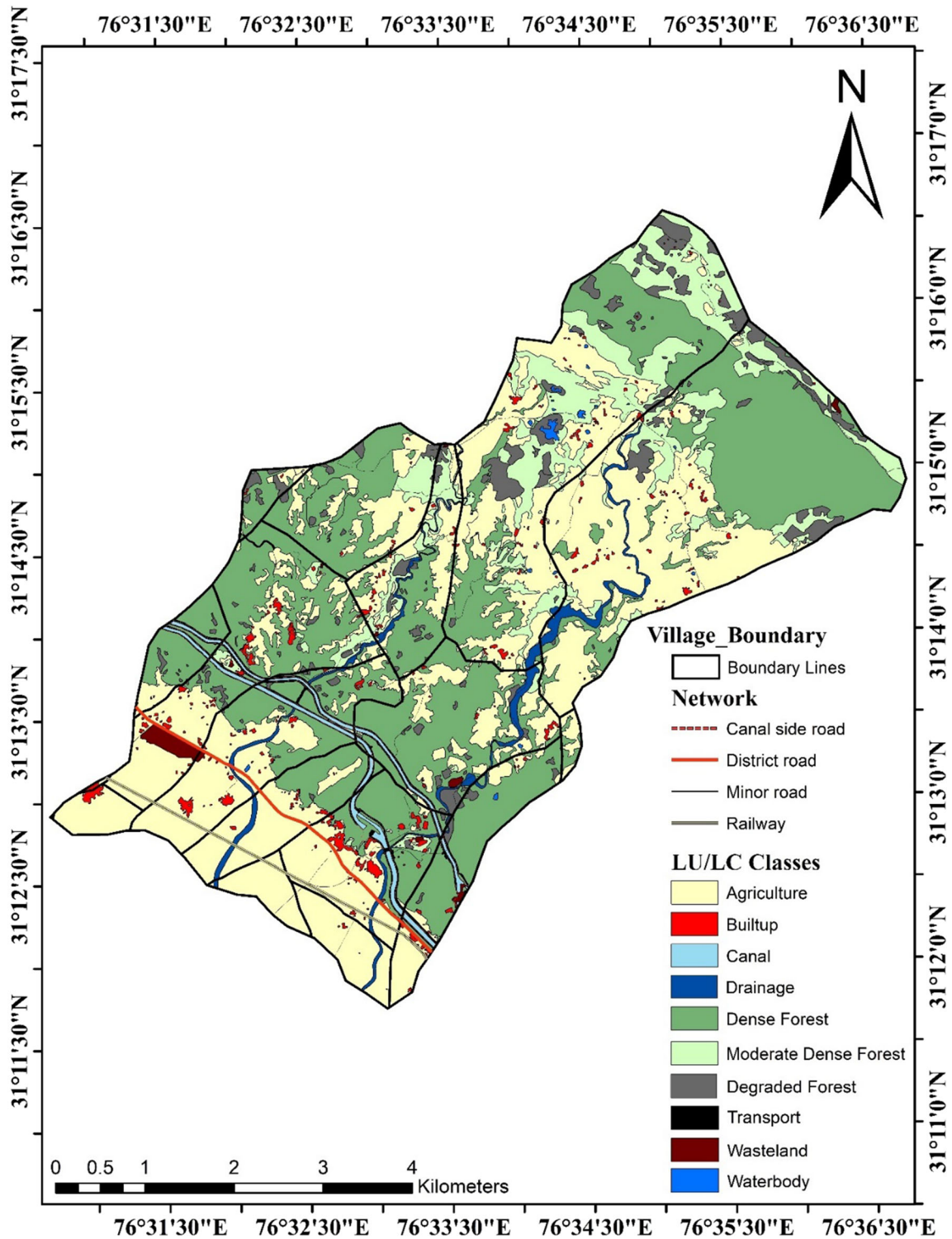
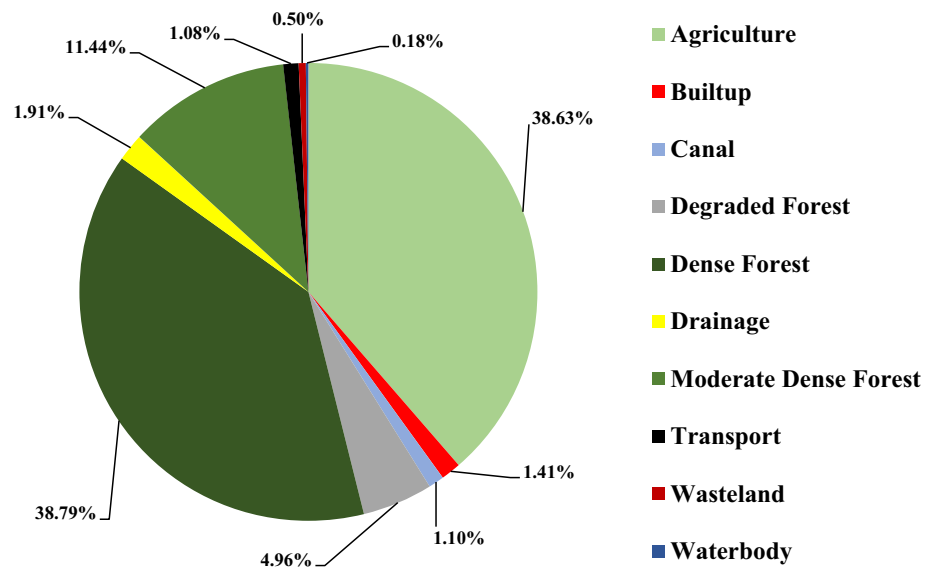


Fig. 6 Land-use and land-cover map of Kotla sub-watershed in year 2009

3.70%, respectively (Fig. 11), with respect to year 2009. In case of areas under canal and transport, both are remained unchanged from the year 2009 to 2018. Dense forest in sub-watershed increased by 3.62% from 2009 to 2018 which may be due to Greening Punjab mission started from

April 1, 2013, to increase the forest cover of Punjab during 2013–2014 to 2022–2023. The main aim of the mission is to increase forest in Punjab from 6–7% to 15% in coming 8 years (Forests, 2020). The similar type of results was obtained by Rawat et al. (2013) where the area under built-

Fig. 7 Area distribution under different LU/LC in 2009**Table 2** Overall statistical analysis of area under different LU/LC from 2009 to 2018 in Kotla sub-watershed

LU/LC Classes	Area (ha) in 2009	Area (ha) in 2018	Changed Area (ha)	Changed Area in %
Agriculture	1360.72	1322.59	– 38.13	– 2.80
Built-up	49.69	107.08	57.38	115.47
Canal	38.82	38.82	0	0
Degraded forest	174.58	337.63	163.05	93.39
Dense forest	1366.55	1416.08	49.53	3.62
Moderate dense forest	402.86	160.89	– 241.97	– 60.06
Drainage	67.34	77.99	10.65	15.81
Transport	38.07	38.07	0	0
Wasteland	17.62	16.87	– 0.75	– 4.25
Waterbody	6.30	6.53	0.23	3.70

up increased by 8.88% with decrease in agriculture land by 9.41%, by Anees et al. (2014) where area under wasteland decreased and by Shafiq et al. (2017) where agriculture has decreased to 1.04% during 2002 to 2014 which shows that built-up land replaces agricultural area.

Change matrix table (Table 3) for the year 2009 to 2018 shows that in 2009 the area under agriculture was 1360.72 ha out of which 1312.98 ha remained in the class agriculture, but the areas from other classes, i.e., 8.13 ha from dense forest and 1.48 ha from moderate dense forest, have also come into class agriculture in the year 2018. Similarly, in 2009 the area under built-up was 49.69 ha, but the area from other classes, i.e., 47.74 ha from agriculture, 1.78 ha from degraded forest, 4.23 ha from dense forest, 2.99 ha from moderate dense forest and 0.64 ha from wasteland, has also come into class built-up in the year 2018.

In 2009, the area under degraded forest was 174.58 ha out of which 120.55 ha remained in the class degraded forest, but the area from other classes, i.e., 64.12 ha from dense forest, 0.39 ha from drainage, 151.72 ha from moderate dense forest and 0.86 ha from waterbody, has also come into class degraded forest in the year 2018. Similarly, in 2009 the area under dense forest was 1366.55 ha out of which 1261.80 ha remained in the class dense forest, but the area from other classes, i.e., 35.96 ha from degraded forest, 1.90 ha from drainage, 116.05 ha from moderate dense forest, 0.14 ha from wasteland and 0.23 ha from waterbody has also come into class dense forest in the year 2018. In 2009, the area under moderate dense forest was 402.86 ha out of which 129.72 ha remained in the class moderate dense forest, but the area from other classes, i.e., 14.05 ha from degraded forest, 16.82 ha from dense forest, 0.08 ha from drainage and

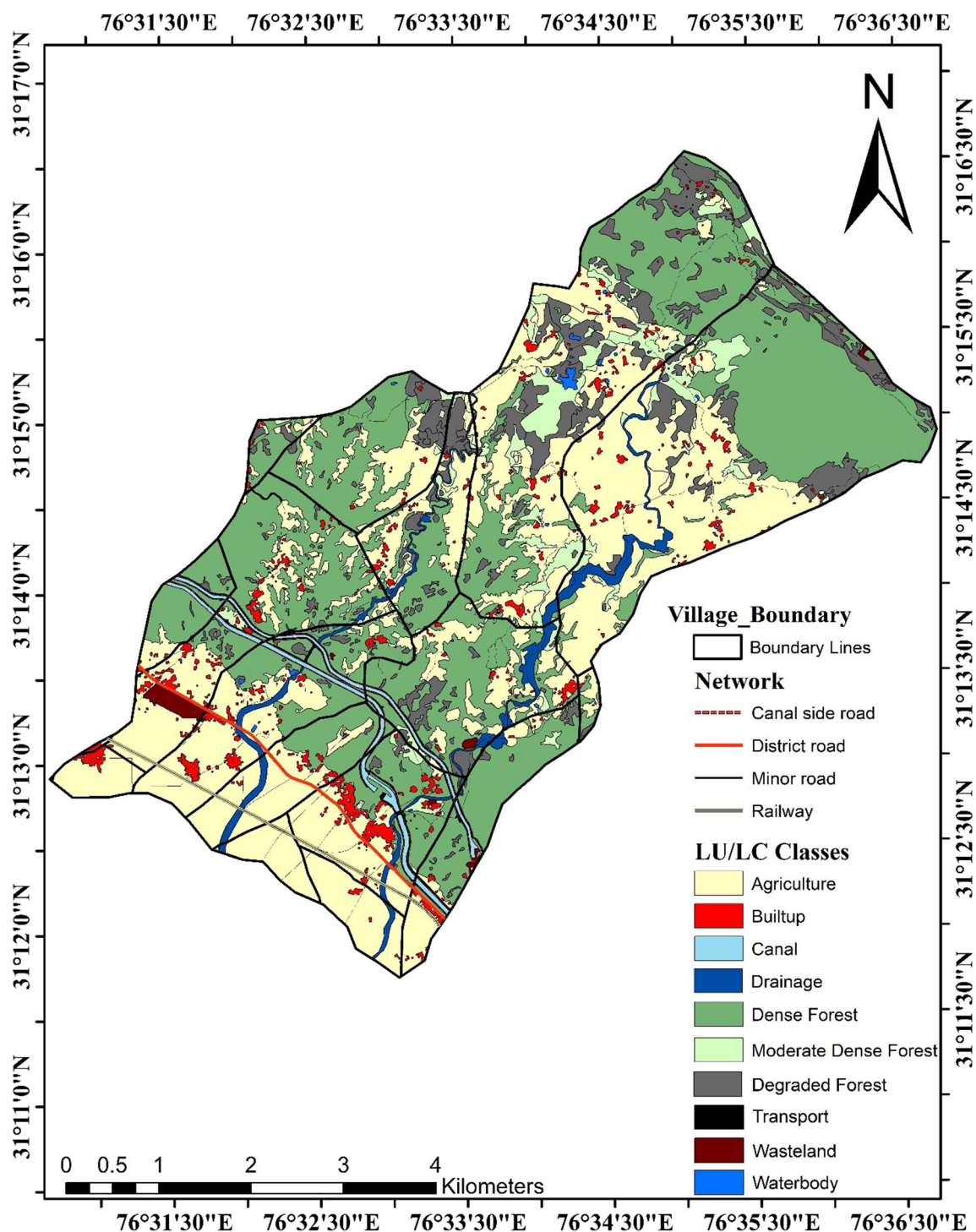


Fig. 8 Land-use and land-cover map of Kotla sub-watershed in year 2018

0.22 ha from waterbody, has also come into class moderate dense forest in the year 2018.

It has been observed that the area under canal and transport remained unchanged from the year 2009 to 2018. Similarly, same area under a particular LU/LC classes in 2009 decreased in 2018 for all the classes except built-up,

canal and transport. The gain in total area under built-up, degraded forest, dense forest, drainage and waterbody in 2018 classes was from areas under different classes of 2009. The present study was carried out in only Kotla sub-watershed of Rupnagar district. For better understanding and management of sub-watershed, change analysis was

Fig. 9 Area distribution under different LU/LC in 2018 using LISS-IV

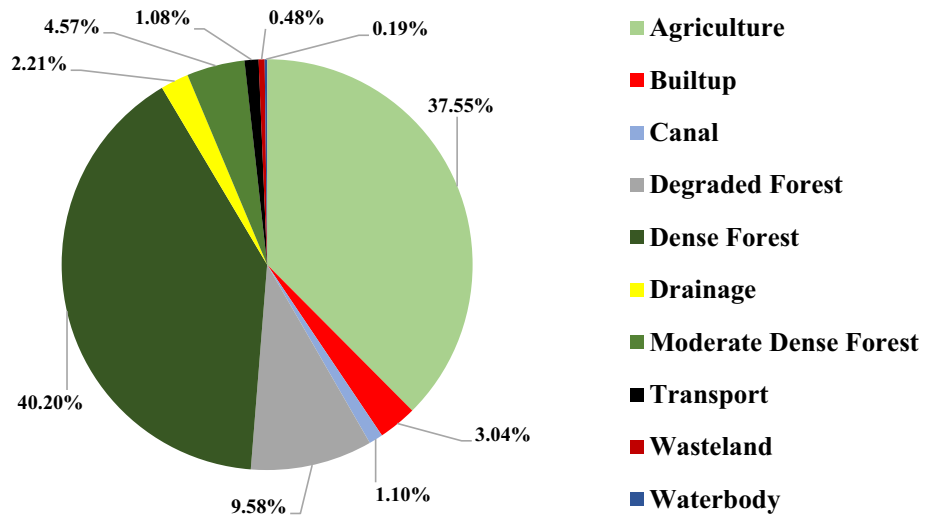


Fig. 10 Overall changes in LU/LC (2009–2018)

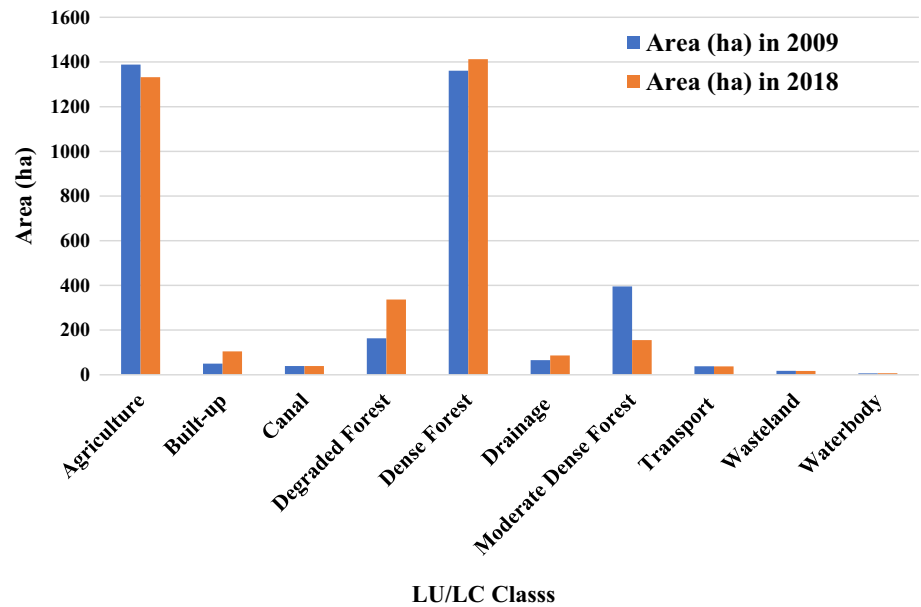


Fig. 11 Percentage of overall changes occurred in LU/LC from 2009 to 2018

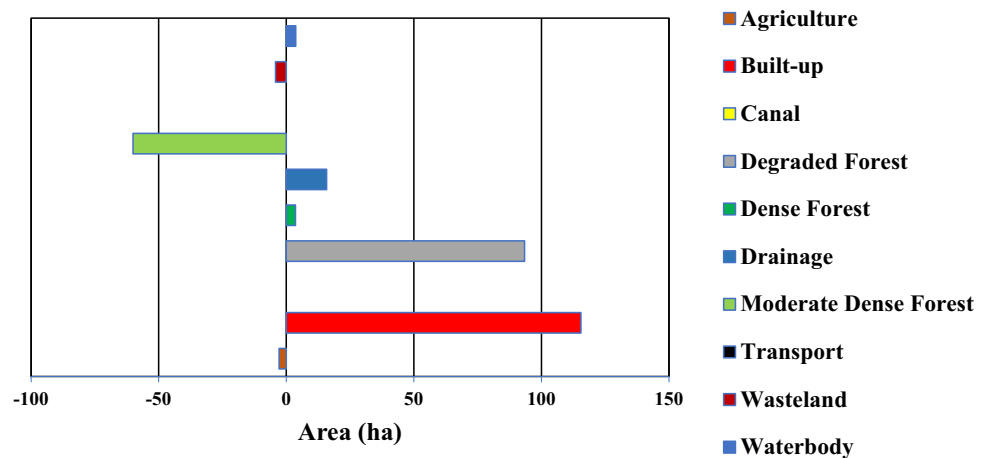


Table 3 Change matrix table for the area (ha) under different LU/LC from year 2009 to 2018 in overall Kotla sub-watershed

LU/LC Classes Year 2009	Year 2018 Agriculture	Built-up	Canal	Degraded Forest	Dense Forest	Drainage	Moderate Dense Forest	Transport	Wasteland	Waterbody	Grand Total
Agriculture	1312.98	47.74									1360.72
Built-up		49.69									49.69
Canal			38.82								38.82
Degraded Forest		1.78		120.55	35.96	1.72	14.05			0.52	174.58
Dense Forest	8.13	4.23		64.12	1261.80	10.54	16.82		0.26	0.64	1366.55
Drainage				0.39	1.90	64.98	0.08				67.34
Moderate Dense Forest	1.48	2.99		151.72	116.05	0.51	129.72			0.40	402.86
Transport								38.07			38.07
Wasteland		0.64			0.14	0.23			16.59	0.01	17.62
Waterbody				0.86	0.23		0.22		0.02	4.97	6.30
Grand Total	1322.59	107.08	38.82	337.63	1416.08	77.99	160.89	38.07	16.87	6.53	3522.55

observed at village level as well as sub-watersheds level. This will be help to identify the focus on the particular village in need for better management.

LU/LC Change Analysis from the Year 2009 to 2018 at Village Level

It has been observed that LU/LC changes analysis at village level is also important to check the most affected villages present in the region. Figure 12 shows the map representation of LU/LC changes occurred in the study area where positive changes such as conversion of degraded forest into dense forest, degraded forest into moderate dense forest, wasteland into built-up and wasteland into dense forest are represented in green shades, while negative changes such as conversion of agriculture into built-up, dense forest into degraded forest, waterbody into wasteland and dense forest into wasteland are represented in red shades. Samlah, Paharpur, Dhanera, Lakher, Jhinjri and Thappal are the villages where positive changes, i.e., conversion of moderate dense forest class into dense forest, degraded forest into moderate dense forest and degraded forest into dense forest, have been observed. In case of negative changes, conversion of agriculture into built-up and dense forest into degraded forest have been observed in villages Samlah and Paharpur.

LU/LC changes have been analyzed at village level and are shown in Table 4. It has been seen that the maximum changes are observed in village Samlah, where built-up, degraded forest, dense forest and wasteland increased by

153.73%, 108.22%, 38.62% and 2%, respectively, while the area under agriculture, drainage, moderate dense forest and waterbody are decreased by 8.85%, 0.58%, 138.51% and 0.5%, respectively. In villages such as Samlah, Baddal, Balauli, Dhanera, Ganj pur, Jhinjri, Kataur, Kotla, Mahndali khurd, Mandal Kalan, Mindhwan, Raipur sani, Tara pur and Thappal, land under agriculture is decreased by 3.77%, 4.82%, 23.35%, 13.56%, 2.58%, 5.57%, 93.61%, 4.89%, 2.73%, 3.81%, 5.16%, 6.81%, 7.84%, 19.91% and 4.96%, respectively, while area under built-up is increased by 153.73%, 178.56%, 378.36%, 127.29%, 290.37%, 73.18%, 16.29%, 81.49%, 84.53%, 171.14%, 199.49%, 109.12%, 107.05%, 183.87% and 260.07%, respectively.

Maximum loss under agriculture land is observed in village Kataur by 93.61%, while maximum gain is observed in village Paharpur by 6.99%. Similarly in case of dense forest, the maximum loss is observed in village Kotla by 11.60%, while the maximum gain is observed in the village Samlah which is 38.62%. In this analysis, degraded forest showed variations in area from 2009 to 2018 and the maximum gain in this class is observed in village Kotla by 34.45%, while maximum gain observed in village Dhanera by 237.61%. There are two LU/LC classes, i.e., canal and transport, which are unchanged from the year 2009 to 2018. This information can be utilized for urban planning, watershed prioritization, land-use planning, decision makers and natural resource management. The overall gain and loss of LU/LC at village level might be helpful to understand where management practices need to be applied.

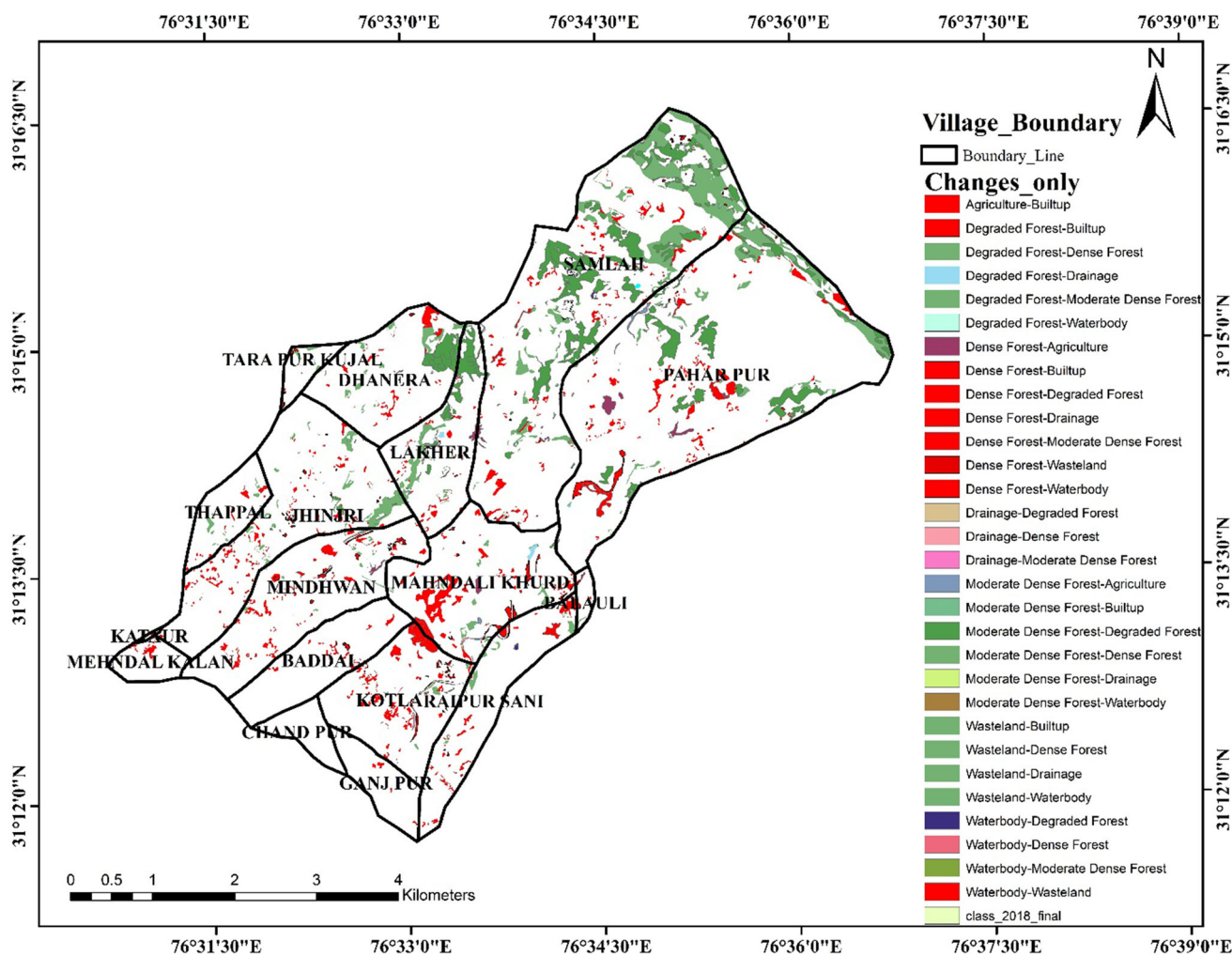


Fig. 12 Areas where major changes occurred from 2009 to 2018 at village level

Change Analysis Through NDVI and LST at Village Level

NDVI and LST values and their differences are displayed from the year 2009 to 2018 in Table 5 at village level. From the interpretation, the decreasing trend in the NDVI (up to -0.24) is observed which is the evidence of overall decrease in the vegetation in the study area, while in case of LST it shows increasing trend in the study area. Maximum NDVI values were observed in villages Samlah and Paharpur as -0.24 and minimum was observed in villages Baddal and Ganj pur as -0.07 and in case of LST, maximum value was observed in village Paharpur as $2.84\text{ }^{\circ}\text{C}$ and minimum in village Lakher as $0.2\text{ }^{\circ}\text{C}$.

LU/LC Change Analysis from the Year 2009 to 2018 at Sub-Watershed Level

The study area consists of total 13 sub-watersheds which are categorized as sub-watershed 1–13 as shown in Fig. 13.

Changes in LU/LC at sub-watershed are represented by different color combinations. It is observed that sub-watershed numbers 2, 3, 4, 5, 6, 7, 10 and 13 showed positive changes, i.e., conversion of moderate dense forest class into dense forest, degraded forest into moderate dense forest and degraded forest into dense forest. In case of negative changes, conversion of agriculture into built-up and dense forest into degraded forest have been observed in sub-watershed numbers 1, 3, 4, 7, 11 and 13.

LU/LC changes have been analyzed at sub-watershed level and are shown in Table 6. Maximum loss (13.65%) under agriculture land is observed in sub-watershed number 12 consisting of villages, i.e., Jhinjri, Tara pur Kujal and Thappal, while maximum gain (38.02%) is observed in sub-watershed number 2 consisting of Samlah village. Similarly in case of dense forest, the maximum loss (10.88%) is observed in sub-watershed number 11 consisting of villages, i.e., Kotla, Balauli, Raipur sani, Ganj pur, Mahndali khurd and Pahar pur, while the maximum gain (1034.35%) is observed in sub-watershed number 10

Table 4 LU/LC change analysis at village level

Village name	Year	Area (ha) under LU/LC Classes							
		Agriculture	Built-up	Degraded forest	Dense forest	Drainage	Moderate dense forest	Wasteland	Waterbody
Samalah	2009	234.59	6.90	66.94	174.63	4.05	229.06	0	5.14
	2018	225.74	17.51	139.39	242.07	3.47	90.55	0.02	4.57
Baddal	2009	82.55	1.33	0.29	42.71	5.94	0	0	0
	2018	78.57	3.70	0.51	42.20	7.74	0.10	0	0
Balauli	2009	8.28	0.09	0.00	5.20	0	0	0	0
	2018	6.35	0.44	1.32	5.34	0	0.13	0	0
	2018	0.11	0	0	0	0	0	0	0
Chand Pur	2009	41.18	0	0	0	0.45	0	0	0
	2018	40.88	0	0	0	0.75	0	0	0
Dhanera	2009	61.37	0.62	7.49	116.41	0	22.93	0	0.02
	2018	53.05	1.40	25.27	119.20	0	5.54	0	0.16
Ganj Pur	2009	62.03	0.26	0	0	2.40	0	0	0
	2018	60.43	1.01	0.00	0.00	3.25	0	0	0
Jhinjri	2009	124.78	8.65	7.42	157.08	1.99	14.54	12.13	0
	2018	117.84	14.98	8.98	167.18	1.98	3.91	11.79	0.04
Kataur	2009	8.69	0.85	0	0	0	0	0	0
	2018	0.56	0.99	0	0	0	0	0	0
Kotla	2009	81.53	10.39	7.02	72.10	5.26	4.22	0.43	0.04
	2018	77.54	18.86	4.60	63.73	6.37	7.88	0.59	0.10
Lakher	2009	54.62	2.22	9.66	62.63	7.45	28.81	0.37	0.06
	2018	56.11	4.11	24.15	57.63	7.52	7.70	0.00	0.11
Mahndali Khurd	2009	67.54	1.67	11.39	152.58	13.76	3.02	1.29	0.18
	2018	64.96	4.53	21.19	135.95	15.51	5.40	1.42	0.18
Mandal Kalan	2009	35.61	2.19	0	0	0	0	0	0
	2018	33.77	6.54	0	0	0	0	0	0
Mindhwan	2009	131.88	6.38	8.88	88.86	6.06	0.82	0.68	0.34
	2018	122.90	13.33	7.10	82.80	8.93	1.26	0.60	1.11
Pahar Pur	2009	315.97	5.80	42.03	321.54	19.03	99.24	0.98	0.21
	2018	338.07	14.24	87.62	323.20	20.18	35.20	0.93	0.26
Raipur Sani	2009	34.12	1.82	4.75	105.70	0.95	0.06	1.73	0.31
	2018	31.45	3.77	6.22	104.26	2.28	1.81	1.51	0
Tara Pur Kujal	2009	5.41	0.33	6.43	16.48	0	0.00	0	0
	2018	4.33	0.95	9.52	20.71	0	1.35	0	0
Thappal	2009	10.45	0.20	2.29	50.62	0	0.17	0	0
	2018	9.93	0.72	1.76	51.79	0	0.06	0	0

consisting of village Samlah. In this analysis, land use class built-up showed the maximum gain (678.87%) in sub-watershed number 12. Again, in case of canal and transport both are unchanged from 2009 to 2018.

Change Analysis Through NDVI and LST at Sub-Watersheds Level

NDVI and LST values and their differences are displayed from the year 2009 to 2018 in Table 7 at sub-watershed level. Similar trend was observed as sub-watershed-level interpretation also. Maximum NDVI values were observed in villages sub-watershed 9 as -0.31 and minimum was

Table 5 Village-wise changes based on NDVI and LST from 2009 to 2018

Village Name	NDVI			LST (°C)		
	2009	2018	Change	2009	2018	Change
Samlah	0.12	0.36	– 0.24	26.08	28.27	2.2
Baddal	0.31	0.38	– 0.07	30.97	31.64	0.66
Balauli	0.16	0.35	– 0.19	26.68	27.63	0.95
Chand Pur	0.43	0.46	– 0.03	31.67	32.27	0.6
Dhanera	0.13	0.33	– 0.2	26.47	28.13	1.65
Ganj Pur	0.36	0.44	– 0.07	29.62	30.41	0.8
Jhinjri	0.22	0.34	– 0.12	27.76	31.2	3.44
Kataur	0.16	0.3	– 0.14	26.71	29.56	2.86
Kotla	0.21	0.33	– 0.13	32	32.2	0.2
Lakher	0.11	0.31	– 0.2	29.5	30.94	1.45
Mahndali Khurd	0.15	0.33	– 0.18	26.33	29.12	2.79
Mandal Kalan	0.39	0.47	– 0.08	27.34	29.32	1.98
Mindhwan	0.26	0.35	– 0.08	31.77	33.35	1.58
Paharpur	0.15	0.39	– 0.24	26.77	29.61	2.84
Raipur Sani	0.21	0.35	– 0.14	31.71	33.13	1.42
Tara Pur Kujal	0.11	0.31	– 0.2	32.01	32.54	0.52
Thappal	0.2	0.33	– 0.14	27.4	29.1	1.7

observed in sub-watershed 1 as – 0.08 and in case of LST maximum value was observed in sub-watershed as 2.99 °C and minimum in sub-watershed 5 as 0.21 °C.

Accuracy Assessment

Accuracy assessment of the resultant classified satellite imageries, i.e., 2009 and 2018, were prepared to determine the quality of information derived from the satellite data by random sampling method. The result obtained from analysis showed the overall accuracy for LU/LC classification for LISS-IV 2009 and LISS-IV 2018 was 70.27% and 89.19%, respectively, with kappa coefficient values as 0.66 and 0.87, respectively. Tables 8 and 9 show error matrix along with producer's, user's, overall accuracy and kappa coefficient values of year 2009 and 2018. Moreover, In both the Tables 8 and 9, the bold diagonalelements indicate the numbers of sample for which the classification results agree with the reference data.

Conclusions

The LU/LC changes were investigated by geospatial technique in Kotla sub-watershed of Rupnagar district, Punjab. The comparative study using IRS-P6 LISS-IV satellite data for the year 2009 and 2018 gives the clear picture of how the sub-watershed has undergone changes during these years. The information generated in the presented study can be helpful to compare with future changes to find the impact of human interventions on the natural environment. The major changes in Kotla sub-watershed were found where area under agriculture, moderate dense forest and wasteland decreased by 38.13 ha (2.80%), 241.97 ha (60.06%) and 0.75 ha (4.25%), respectively, while there was increase in the area under built-up, degraded forest, dense forest, drainage and waterbody by 57.38 ha (115.47%), 163.05 ha (93.39%), 49.53 ha (3.62%), 10.65 ha (15.81%) and 0.23 ha (3.70%), respectively. Change analysis was also carried out at village level and sub-watershed level. In villages such as Samlah, Baddal, Balauli, Dhanera, Ganj pur, Jhinjri, Kataur, Kotla, Mahndali khurd, Mandal Kalan, Mindhwan, Raipur sani, Tara pur and Thappal, land under agriculture is decreased by 3.77%, 4.82%, 23.35%, 13.56%, 2.58%, 5.57%, 93.61%, 4.89%, 2.73%, 3.81%, 5.16%, 6.81%, 7.84%, 19.91% and 4.96%, respectively, while area under built-up is increased by 153.73%, 178.56%, 378.36%, 127.29%, 290.37%, 73.18%, 16.29%, 81.49%, 84.53%, 171.14%, 199.49%, 109.12%, 107.05%, 183.87% and 260.07%, respectively. The most affected village is Pahar pur followed by Kotla where maximum changes have been observed. In the analysis at sub-watershed level, it is observed that sub-watershed numbers 2, 3, 4, 5, 6, 7, 10 and 13 showed positive changes, i.e., conversion of moderate dense forest class into dense forest, degraded forest into moderate dense forest and degraded forest into dense forest. Similarly, in case of negative changes conversion of agriculture into built-up and dense forest into degraded forest have been observed in sub-watershed numbers 1, 3, 4, 7, 11 and 13. The most affected sub-watershed number is 11 which consists of villages Kotla, Balauli, Raipur sani, Ganj pur, Mahndali khurd and Pahar pur. There is huge population growth according to census data, i.e., 6.29 lakhs (2001), 6.85 lakhs (2011), and estimated figure is 7.25 lakhs in the year 2018 which have caused major land-use changes in the study area. The increase in the population has caused the transformation of the agriculture land into

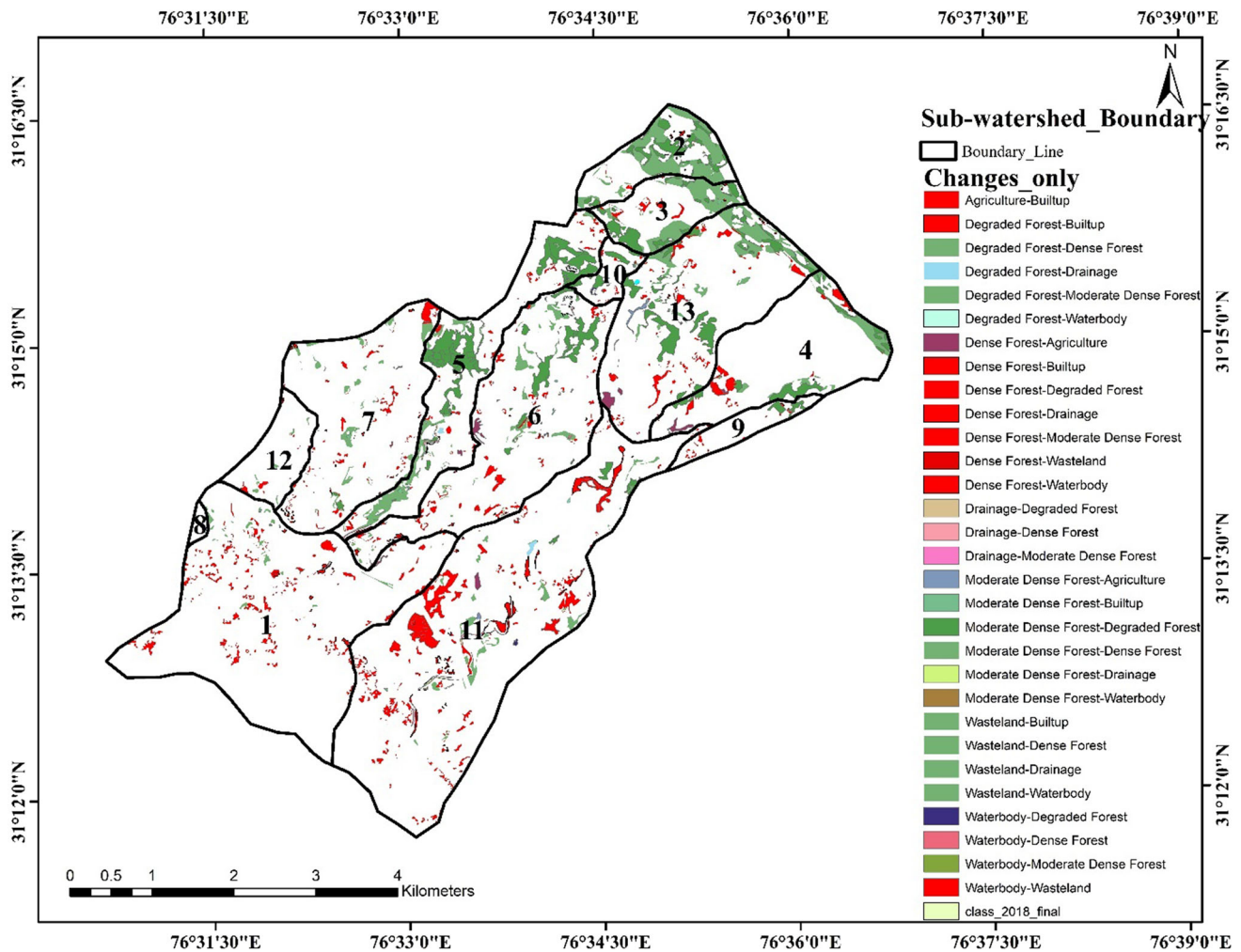


Fig. 13 Areas where major changes occurred from 2009 to 2018 at sub-watersheds level

built-up in villages such as Katur, Jhinjri, Baddal, Kotla, Ganj pur, Mindhwan, Samlah, Paharpur and Mandal Kalan which is major finding of the study, and management practices need to be look for these villages. The extracted values of NDVI in this study is the evidence for decreases in overall vegetation, and its combined use with LST helped to determine the effects for these changes due to

changes in the pattern of LU/LC. It requires suitable policies and awareness to conserve its precious land resources which is necessary for sustainable development of watersheds. The present study provides detailed information on LU/LC of sub-watershed that will be helpful for local departments and NGOs for planning village-level watershed development programs.

Table 6 LU/LC change analysis at sub-watershed level

Village name	Year	Area (ha) under LU/LC Classes							
		Agriculture	Built-up	Degraded forest	Dense forest	Drainage	Moderate dense forest	Wasteland	Waterbody
Sub-watershed 1	2009	395.67	13.04	5.87	164.72	11.09	4.18	12.71	0.34
	2018	375.13	29.81	9.95	160.47	16.10	3.77	12.13	0.99
Sub-watershed 2	2009	3.08	0.34	25.41	30.78	0	59.01	0	0
	2018	4.26	1.15	36.34	69.14	0	7.76	0	0
Sub-watershed 3	2009	1.50	0.11	20.08	52.54	0	42.38	0	0
	2018	1.43	0.63	21.15	76.33	0	5.61	0	0
Sub-watershed 4	2009	39.09	0.43	11.89	185.43	0.10	33.82	0.98	0
	2018	41.61	1.06	29.69	188.09	0.04	2.63	0.93	0
Sub-watershed 5	2009	125.49	2.70	14.41	35.86	11.20	77.85	0.38	0.84
	2018	123.54	7.10	57.91	47.17	11.38	20.47	0	1.16
Sub-watershed 6	2009	179.55	5.17	29.96	130.09	0.17	62.11	0	3.36
	2018	169.33	11.39	52.32	126.41	0.02	47.39	0.26	3.21
Sub-watershed 7	2009	101.36	7.23	13.00	218.11	0	5.28	0.09	0.25
	2018	93.17	9.61	16.28	224.31	0	1.54	0	0.17
Sub-watershed 8	2009	1.34	0	0.20	6.23	0	0	0	0
	2018	1.34	0	0	6.43	0	0	0	0
Sub-watershed 9	2009	40.40	0.84	4.38	0	0	3.29	0	0.12
	2018	38.56	2.60	7.76	0	0	0.00	0	0.12
Sub-watershed 10	2009	16.04	0.63	0	0.02	0	19.35	0	0.74
	2018	16.89	1.89	6.82	0.19	0	10.59	0	0.39
Sub-watershed 11	2009	310.94	16.16	17.68	335.70	36.52	15.22	3.45	0.53
	2018	322.60	31.58	33.81	299.18	44.30	28.04	3.53	0.29
Sub-watershed 12	2009	5.52	0.05	1.62	71.53	0	0	0	0
	2018	4.77	0.43	2.15	71.40	0	0	0	0
Sub-watershed 13	2009	140.74	2.99	30.08	135.53	8.26	80.36	0	0.12
	2018	129.97	9.83	63.43	146.97	6.15	33.09	0.02	0.20

Table 7 Sub-watersheds-wise changes based on NDVI and LST from 2009 to 2018

Sub-watershed No	NDVI			LST (°C)		
	2009	2018	Changes	2009	2018	Changes
1	0.3	0.38	– 0.08	26.8	29.11	2.31
2	0.15	0.41	– 0.27	30.19	31.35	1.16
3	0.18	0.43	– 0.25	30.99	32.23	1.24
4	0.21	0.46	– 0.25	29.88	32.87	2.99
5	0.09	0.31	– 0.22	33.06	33.26	0.21
6	0.11	0.32	– 0.21	30.72	31.61	0.89
7	0.15	0.32	– 0.17	28.22	30.7	2.48
8	0.19	0.35	– 0.16	32.83	34.06	1.23
9	0.1	0.41	– 0.31	33.12	34.25	1.13
10	0.09	0.32	– 0.23	28.76	30.67	1.91
11	0.18	0.34	– 0.16	29.83	30.63	0.81
12	0.2	0.33	– 0.14	31.66	33.71	2.05
13	0.15	0.39	– 0.23	32.2	32.65	0.45

Table 8 Error matrix table of LU/LC classification in 2009 using LISS-IV

Reference	Classified											Grand total	Producer's accuracy (%)	User's accuracy (%)
	Agriculture	Built-up	Canal	Degraded forest	Dense forest	Drainage	Moderate dense forest	Transport	Wasteland	Waterbody	Grand total			
Agriculture	12	2	1	1	5	2	2			1	23	66.67	52.17	
Built-up	6	12		2	2						22	85.71	54.55	
Canal			7								7	100	100	
Degraded forest				10	2					1	13	76.92	76.92	
Dense forest				1	16	1		1		3	22	61.54	72.73	
Drainage					1	6					7	100	85.71	
Moderate dense forest						5				1	6	50	83.33	
Transport								3			3	100	100	
Wasteland									3		3	75	100	
Waterbody										4	5	40	80	
Grand total	18	14	7	13	26	6	10	3	4	10	111			
Overall Accuracy = 70.27%														
Kappa Coefficient = 0.66														

Table 9 Error matrix table of LU/LC classification in 2018 using LISS-IV

Reference	Classified Agriculture	Built-up	Canal	Degraded forest	Dense forest	Drainage	Moderate dense forest	Transport	Wasteland	Waterbody	Grand total	Producer's accuracy (%)	User's accuracy (%)
Agriculture	22	1	2						1		26	84.62	84.62
Built-up		22									22	91.66	100
Canal			7								7	100	100
Degraded forest				9							9	75	100
Dense forest	4	1			11	1		1			18	100	61.11
Drainage						7					7	87.5	100
Moderate dense forest							6				7	100	85.71
Transport								3			3	100	100
Wasteland									2		2	50	100
Waterbody										10	10	100	100
Grand total	26	24	7	12	11	8	6	3	4	10	111		
Overall Accuracy = 89.19%													
Kappa Coefficient = 0.87													

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Declarations

Conflict of interest There is no conflict of interest.

Data availability Satellite data were procured under Rashtriya Krishi Vikas Yojana.

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