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Assessment of Spatio-Temporal Changes in Land Use and Land Cover – A Case Study of Yamunanagar District (Haryana), India

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Abstract: The present study utilises semi-automatic classification of cloud-free multispectral Landsat satellite images to find changes in land use land cover (LULC) in Yamunanagar district, Haryana (India) at decadal intervals for the years 2000, 2010 and 2020. The images are classified according to the classification scheme of the National Remote Sensing Centre, India to ensure compatibility with other global/regional LULC datasets. The normalised difference vegetation index (NDVI) is applied to separate green vegetation from other LULC features. The forest was extracted from NDVI images using the forest boundary of Yamunanagar forest division. The major changes in LULC are observed in agriculture, water, forest and built-up areas. Both, fields observed and classified LULC features showed that the presence of different LULC types can be best described qualitatively and quantitatively using satellite data. The error matrix shows an overall 88.69% accuracy is achieved in LULC features obtained from image classification. The Kappa coefficient calculated is 0.9 which is rated as almost perfect.

Key words: Remote sensing, decadal change, image classification, NDVI, error matrix.

Introduction

The land is an important part of Mother Earth and is crucial in many ways like in providing food, fuel and shelter. It serves both as a source and sink of carbon (IPCC, 2000). Regular monitoring of land is the basis for global to local applications aiming to achieve sustainable development. Technically, land cover is defined as physical and practical features on the Earth's surface, but when a financial function is added to it, it becomes land use (FAO, 2005). Land use land cover (LULC) has a significant impact on biodiversity, freshwater and energy budget (Guzha et al., 2018). Any change in land cover can adversely affect the entire ecosystem, and deforestation can lead to climate change. Therefore, technological advancement has taken shape for a scientific, systematic and temporal assessment of LULC. Remote sensing is one such technology where sensors placed on-board satellites or aircraft use reflected electromagnetic radiation in different wavelength regions to acquire information about objects and/or phenomena without being in physical contact with them (Irwin, 2001). Remotely sensed satellite images are widely used to analyse temporal changes in LULC (Navalgund et al., 2007). Satellite data provide synoptic coverage of the global land surface at different spectral, spatial and temporal resolutions and this makes them useful for studying LULC compared to other methods of remote sensing (Justice et al., 1998). The satellite images are digitally interpreted and classified to derive a piece of meaningful geospatial information using the digital image processing (DIP)

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technique (Gupta, 2017) which, in turn, is analysed using Geographic Information Systems (GIS) tools and used in many applications like in estimating temporal changes in LULC (Bajaj et al., 2023). Remote sensing and GIS are now common techniques to conduct research in areas like land cover, analysis of forest change and predicting the future scenario (Irwin, 2001). Therefore, the use of remote sensing images, digital image classification and GIS analysis in an integrated manner provides a meaningful path to many applications (El Baroudy, 2016). Shoshany (1996) investigated the advantages of remote sensing techniques in spatio-temporal distributions of vegetation cover. Normalised Differential Vegetation Index (NDVI) is among the most significant and widely used vegetation indices to measure vegetation conditions over a land area by using reflectance of red and near-infrared (NIR) bands (Huang et al., 2021).

Yamunanagar district is the largest area of highly dense forest in Haryana State and includes a wildlife sanctuary and a National Park (Forest Survey of India 2021). Agriculture and agro-forestry are the common land use practices in the district. Over a period of time, changes in LULC have been a cause of concern due to growing population pressure and industrialisation (Anuradha and Gupta, 2022; Pandey and Nathawat, 2006). Further, no specific work has been reported to date on the geospatial assessment of LULC in the district. Hence, to comprehend the concern and its related issues, it is essential to find out how changes in LULC in this region have affected the expansion trend of different land types. Therefore, the present study is undertaken to analyse the spatial distribution and changes in LULC in two decades from the year 2000 to 2020 in Yamunanagar district using remote sensing technology.

Materials and Methods

Study Area

Yamunanagar district is a north-eastern part of Haryana State (India) that lies from 29° 55′ to 30° 31′ north latitude and from 77° 00′ to 77° 35′ east longitude with a human population of 1214162 in 1756 km^2 area (Directorate of Census Operations, Yamunanagar 2011). Yamunanagar district is mainly drained by the rivers Yamuna, and Markanda and their tributaries. There are reserved, protected, and unclassified forests occupied by both deciduous and evergreen trees. The map of the study area is shown in Figure 1.

Data Acquisition

In this study, both primary (field data) and secondary data (satellite images and topographic maps) are used. The GPS-assisted field data is collected for ground verification of the classified LULC features. The cloud-free Landsat 7 ETM+ of 15 October 2000, Landsat 5 TM of 3 October 2010 and Landsat 8 OLI of 28 September 2020 of path/row 147/39 satellite images (Figure 2) having 30m spatial resolution is downloaded

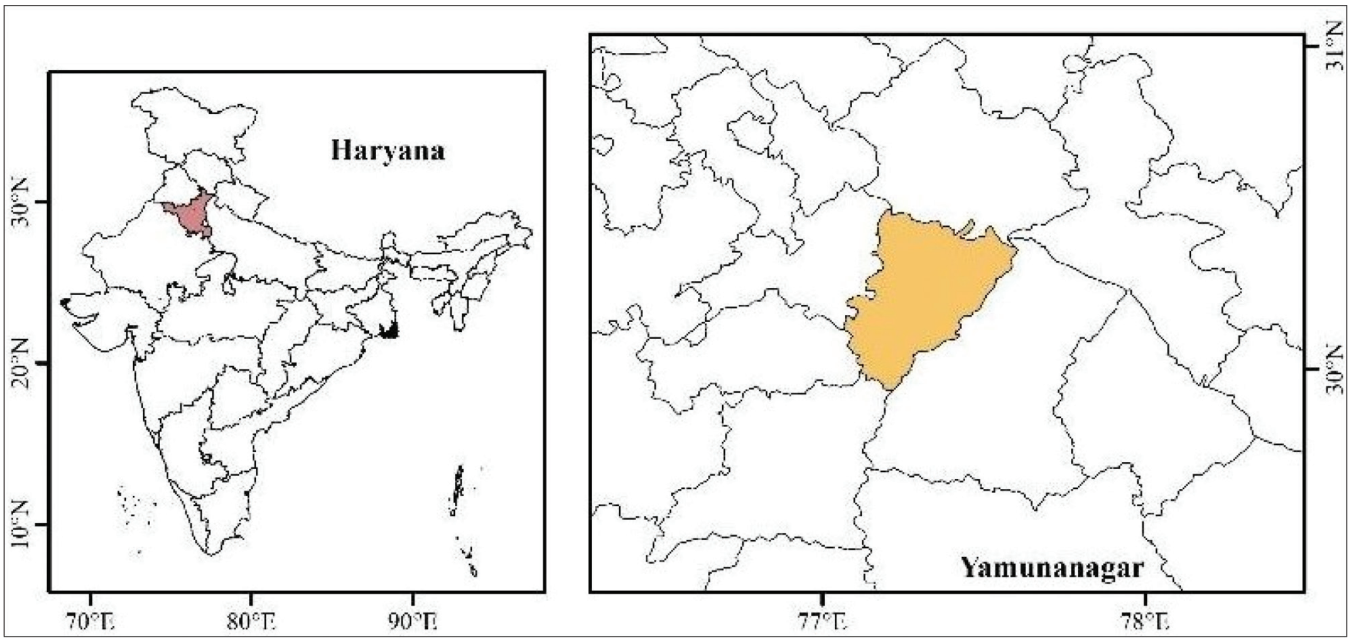
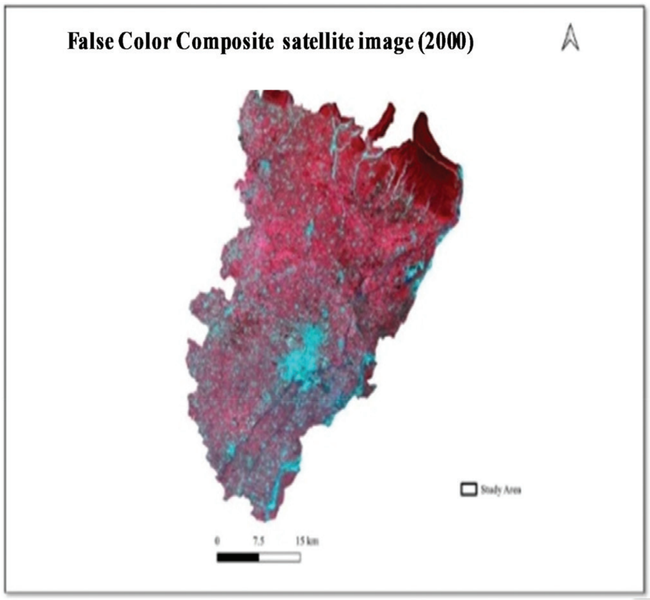
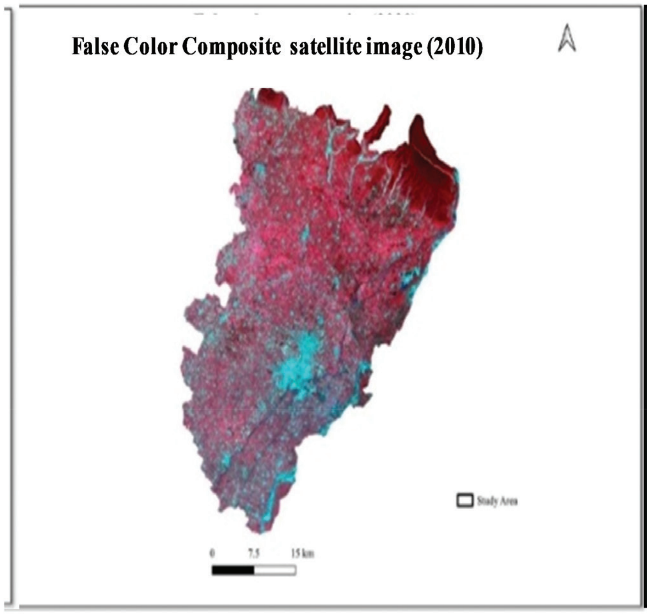


Figure 1: Location map of the study area.



2(a)



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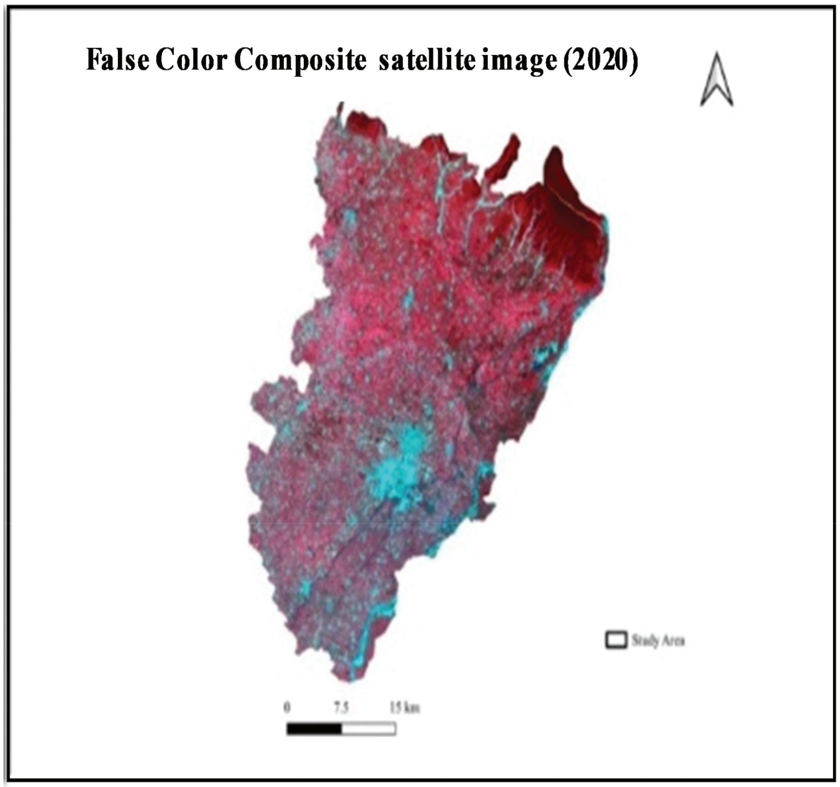


2(c)

Figure 2: Landsat False colour composite (FCC) satellite image of the years 2000, 2010, 2020.

from the United States Geological Survey (USGS), Earth Explorer data portal (USGS, 2024) and used in the mapping of LULC. The Landsat 5 image of the year 2010 is used due to the presence of scan line error appearing in all the Landsat 7 ETM+ acquired after 31 May 2003. Later, the Landsat 5 mission was decommissioned on 5 June 2013. The Landsat 8 satellite was launched on 11 February 2013 and its image is used for LULC mapping of the year 2020.

Methodology of LULC Mapping

Description of LULC Classes

In this study, the National Remote Sensing Centre (NRSC) Level-I classification scheme (NRSC, 2014) comprising seven LULC classes is used to classify satellite images (Table 1). The description of the seven LULC classes is given below:

(i) Built-up
This includes the land used for the habitat of human beings.

(ii) Agriculture
The agricultural land includes areas occupied with crops, plantations, fallow lands and current shifting cultivation.

(iii) Forest
Forest is the land with a tree able to reach a minimum height of 5m and covering a canopy of more than 10% and occupying an area of more than 0.5ha (FAO, 1998; FAO, 2000). This class includes evergreen/semi-evergreen and deciduous forests, forest plantations, scrub forests and littoral/swamp/mangrove forests.

(iv) Grass Land
It includes grasslands in the following areas: habitat, recreational, mixed built-up, utilities of public/semi-public uses, commercial, reclaimed, vegetated, industrial, transportation and dumps and ash/cooling ponds.

(v) Wetland/Water Bodies
This class includes inland wetlands, coastal wetlands, river/stream/canals, lakes, ponds, water tanks and reservoirs.

(vi) Barren Land (barren, unculturable, wasteland)
This class is described as wastelands that can be brought under vegetative cover with sincere effort and which is presently underutilised and land which is deteriorating due to lack of water and poor soil management or due to any natural causes.

(vii) Snow and Glaciers
These are the areas that remain under snow either on a temporary or permanent basis.
In our study area, snow and glaciers are not present and therefore are absent in classification results.

Visual Image Interpretation

Once the LULC classes are defined, the qualitative and quantitative information of features is visually obtained from the Landsat images using visual image interpretation elements - tone, texture, shape, size, pattern, association, aspect and shadow, and by using human knowledge. This helped in identifying LULC features on the satellite image and in observing classification accuracy.

Table 1: LULC classes (NRSC 2014)

Sr. No.	*Land use/ Land cover Classes*
i	Built-up
ii	Agriculture
iii	Forest
iv	Grass/Grazing Land
v	Wetland/Water bodies
vi	Barren/Unculturable/Wasteland
vii	Snow and Glacier

Ground Truth Strategy

Feature identification on the image is verified on the ground manually and recorded using GPS. The information on the ground is collected randomly using Trimble Juno 3-D surveying GPS having vertical and horizontal accuracy of 2-5 m and 1-3 m, respectively. The topographic maps of the 1:50,000 scale downloaded from the Survey of India portal are used as collateral information. The errors and discrepancies during the classification are corrected using ground truth/field data and other ancillary information.

LULC Classification

The visual image interpretation of satellite images and field observations showed that the LULC classes can be best described quantitatively and qualitatively by using satellite data acquired during the month of September/October due to the presence of all six LULC classes in these months. A semi-automatic classification method is used to classify multispectral Landsat images and generate LUCL maps. First, a isodata clustering-based unsupervised classification method is implemented where no prior knowledge of LULC type is required before classifying the image. The method uses the minimum spectral distance to group pixels based on similarity or difference of features (Hansen et al., 2000). It begins with random cluster means and every time the clustering replicates, the means of these groups of pixels are changed. The new spectral cluster means are used for the next iteration. The whole process continues until a maximum number of iterations has been reached or a maximum percentage of unchanged pixels (convergence threshold) has been attained between two iterations representing spectrally pure clusters of pixels forming each LULC class feature. In the second step, a manual check is performed on the features present in the classified LULC map using visual image interpretation elements with respect to features present in the image. This is further validated with ground surveyed data and Google Earth images of 0.5 m average pixel resolution. The methodology used to generate LULC information is shown in Figure 3.

Forest Cover Mapping

The forest is an important determinant in the LULC of Yamunanagar district. For this, the first NDVI method is applied to the satellite images NDVI, a numerical indicator, is obtained by estimating the difference in two-pixel values present in visible and NIR bands at the same location and 'normalising' the difference by dividing by the sum of the two-pixel values (of two bands) and thus separating vegetation from other LULC features (Tucker, 1979). In the next step, forest cover is extracted out of the total green vegetation obtained above using the forest boundary of Yamunanagar forest division.

Accuracy Assessment

The classification accuracy is defined as the extent to which the thematic map corresponds to the reference classification (Olofsson et al., 2013). The accuracy is calculated as an error matrix which includes producer's accuracy, user's accuracy, composite accuracy and Kappa statistics (Congalton, 1991). The minimum accepted interpretation accuracy in the detection of LULC features from remote sensing images is prescribed as 85% (Anderson et al., 1976) and the Kappa coefficient above 0.8 is considered almost perfect (Landis and Koch, 1977).

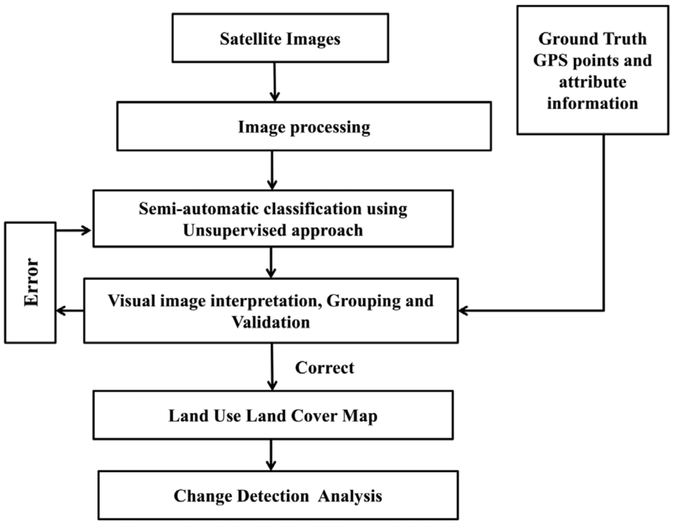


Figure 3: Methodology flow-chart used in LULC analysis.

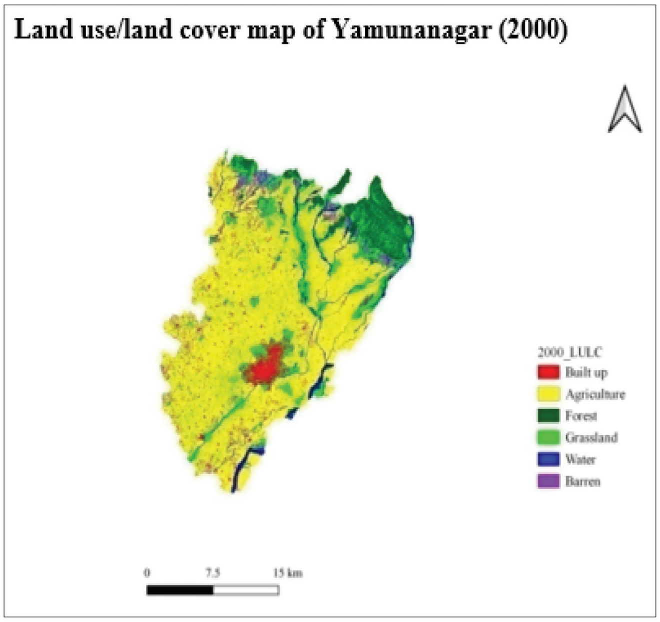
Results and Discussion

LULC Mapping

Pandey and Nathawat (2006) in their study and our ground survey revealed that land in the Yamunanagar district is mostly used for growing crops and for agro-forestry purposes. A fair presence of reserved and protected forests is also witnessed. Figure 4 and Table 2 depict the spatial extent of LULC present in the year 2000, 2010, and 2020. The result indicates that in the year 2000 the agricultural area occupied the largest fraction (60.3%) followed by grassland (16%). Although agriculture still occupied the largest fraction in year 2020, it was reduced to 46.1%. The ground survey revealed that it was mainly due to anthropogenic activities.

Table 2: Land use/land cover area (ha) and percentage (%) estimated from the multispectral satellite images of the year 2000, 2010 and 2020

Class ID	*Class name*	*2000*	*2010*	*2020*
1	Built-up	4825.8 (2.8%)	7906.68 (4.6%)	10540.53 (6.1%)
2	Agriculture	104108.58 (60.3%)	78505.56 (45.5%)	79642.71 (46.1%)
3	Forest	11459.79 (6.6%)	14143.05 (8.2%)	14930.19 (8.6%)
4	Grass Land	27611.19 (16.0%)	55911.69 (32.4%)	53319.78 (30.9%)
5	Water	8114.31 (4.7%)	10195.29 (5.9%)	6578.73 (3.8%)
6	Barren-unculturable-wasteland areas	16531.47 (9.6%)	5988.87 (3.5%)	7639.2 (4.4%)



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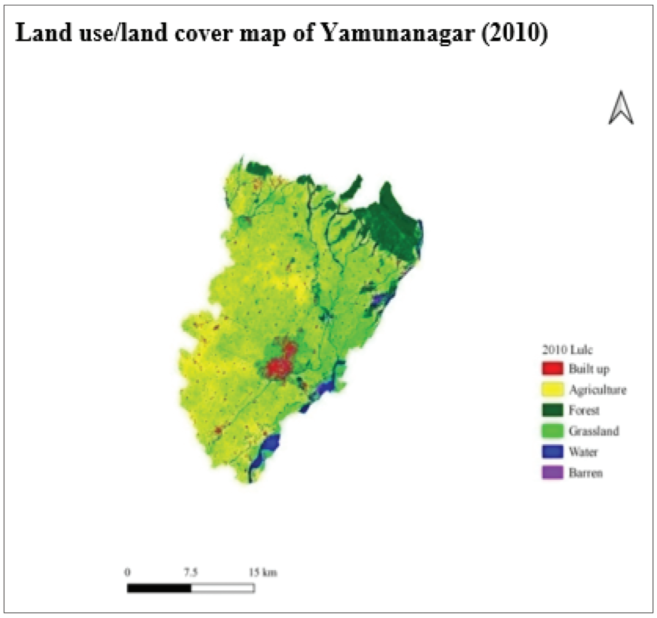

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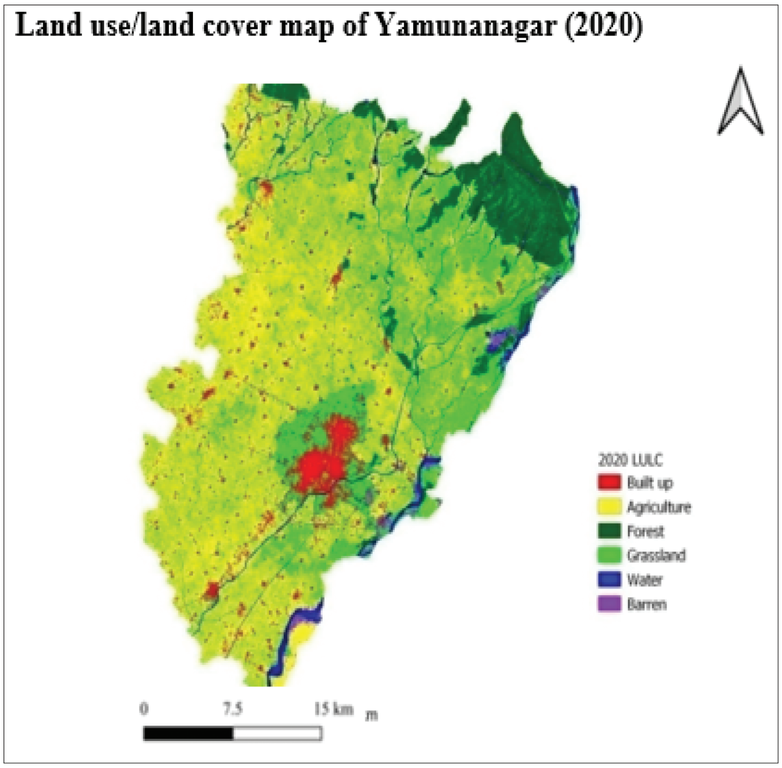
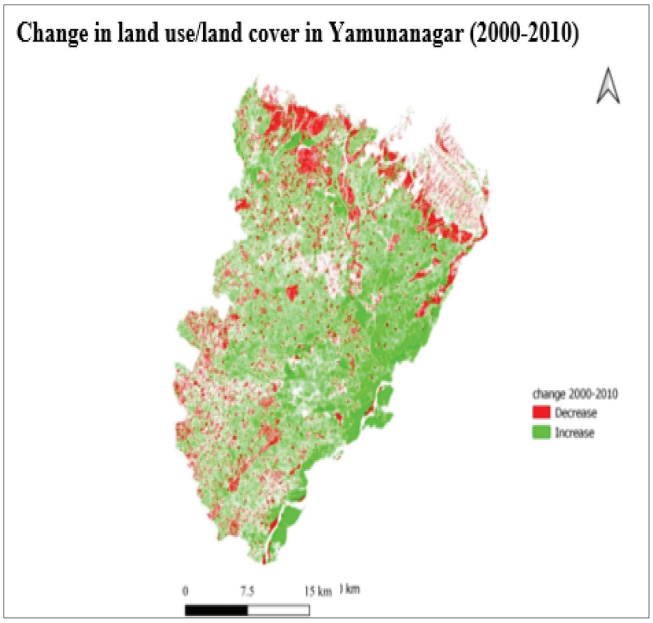


4(c)

Figure 4: LULC map of Yamunanagar district (year 2000, 2010, 2020).

Decadal Changes in LULC

The decadal changes in different LULC classes during the year 2000-2010, year 2010-2020 and finally during year 2000-2020 were obtained using GIS change detection tools. Figure 5 and Table 3 show an overall spatial change that took place over two decades in all the LULC categories. The result shows an enhancement of 5715 ha of built-up land which is generally caused by growing urban sprawl, industrialization and other land uses (Bajaj et al., 2023; El Baroudy, 2016; Navalgund



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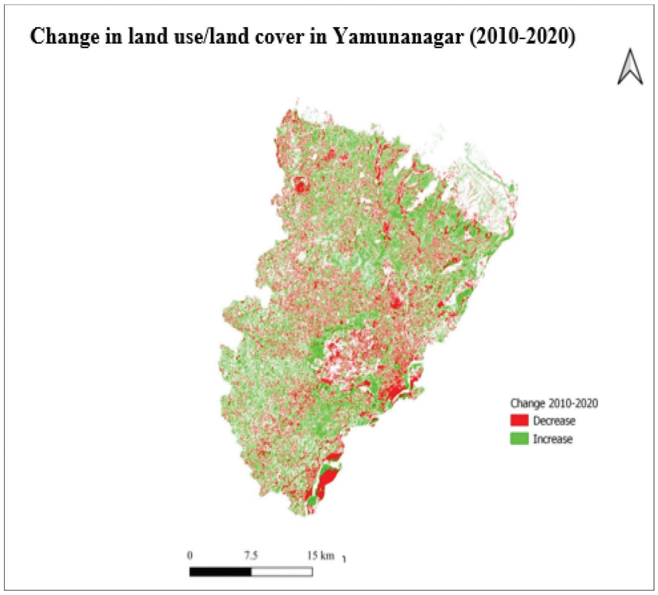

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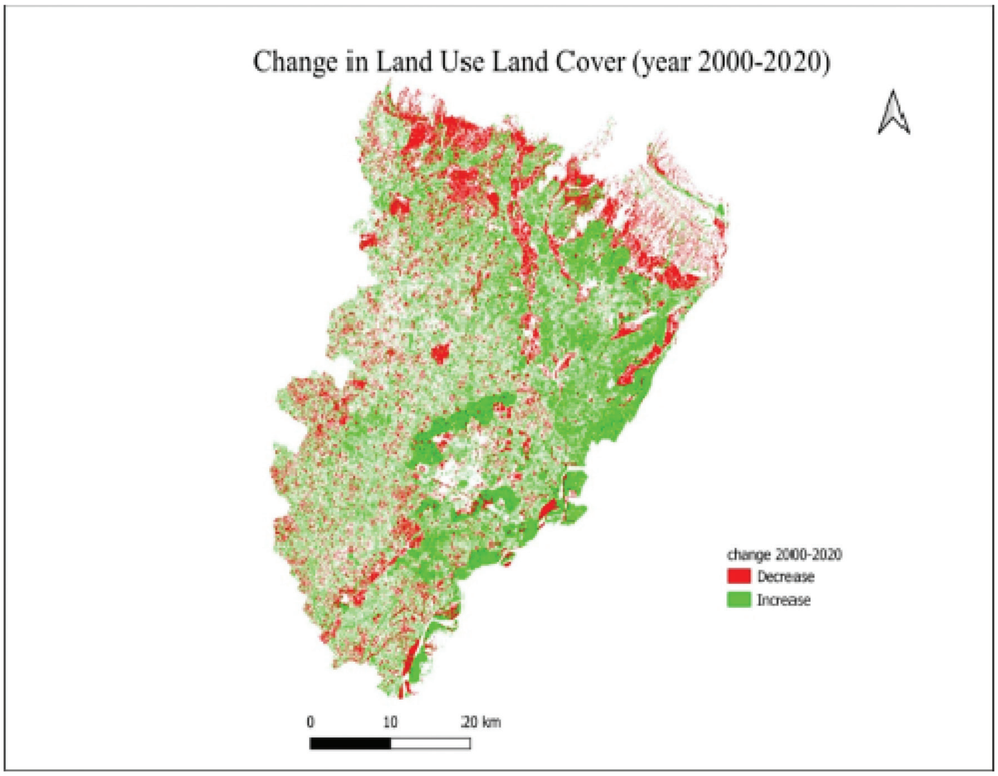

5(c)

Figure 5: Map showing an overall increase and decrease in LULC taken place in two decades in Yamunanagar district.

et al., 2007; Skidmore et al., 1997). The result in Table 3 shows a gradual increase in forest cover between year 2000 and 2020. The ground survey shows that it was an outcome of reforestation and afforestation activities implemented by the State Forest Department. The change detection indicates a two-fold increase in grassland area between year 2000 and 2010. The ground survey revealed partly it was due to the conversion of barren-unculturable-wasteland areas and partly due to a change in the course of the river/stream that has left

Table 3: Change in Land use/land cover area in hectare (ha) and percentage (%) estimated from the multispectral satellite images between the years 2000-2010, 2010-2020 and 2000-2020. (The negative sign shows a decrease in area)

Class ID	*Class Name*	*2000-2010*	*2010-2020*	*2000-2020*
1	Built-up	3080.88 (63.84%)	2633.85 (33.31%)	5714.73 (118.42%)
2	Agriculture	-25603.02 (-24.59%)	1137.15 (1.45%)	-24465.87 (-23.5%)
3	Forest	2683.26 (23.41%)	787.14 (5.57%)	3470.4 (30.28%)
4	Grass Land	28300.5 (102.5%)	-2591.91 (-4.64%)	25708.59 (93.11%)
5	Water	2080.98 (25.65%)	-3616.56 (-35.47%)	-1535.58 (-18.92%)
6	Barren-unculturable-wasteland areas	-10542.6 (-63.77%)	1650.33 (27.56%)	-8892.27 (-53.79%)

moist open areas - a suitable ground for the growth of herbs and shrubs.

Yamunanagar is a hub of timber and wood industries. The increasing population causes pressure on resources for basic livelihood and income. Figure 6 provides major regions of the study area where spatiotemporal changes have been observed in LULC during the period of year 2000-2020. The path of stream change can easily be seen in Figure 6 which has also caused land conversion and erosion of cultivated areas along the river bed. The ground survey revealed that the erosion of the river bed in Kalanour beat has led to boundary margin and tenure disputes between the fringe community and the forest department. Some of the prominent changes in

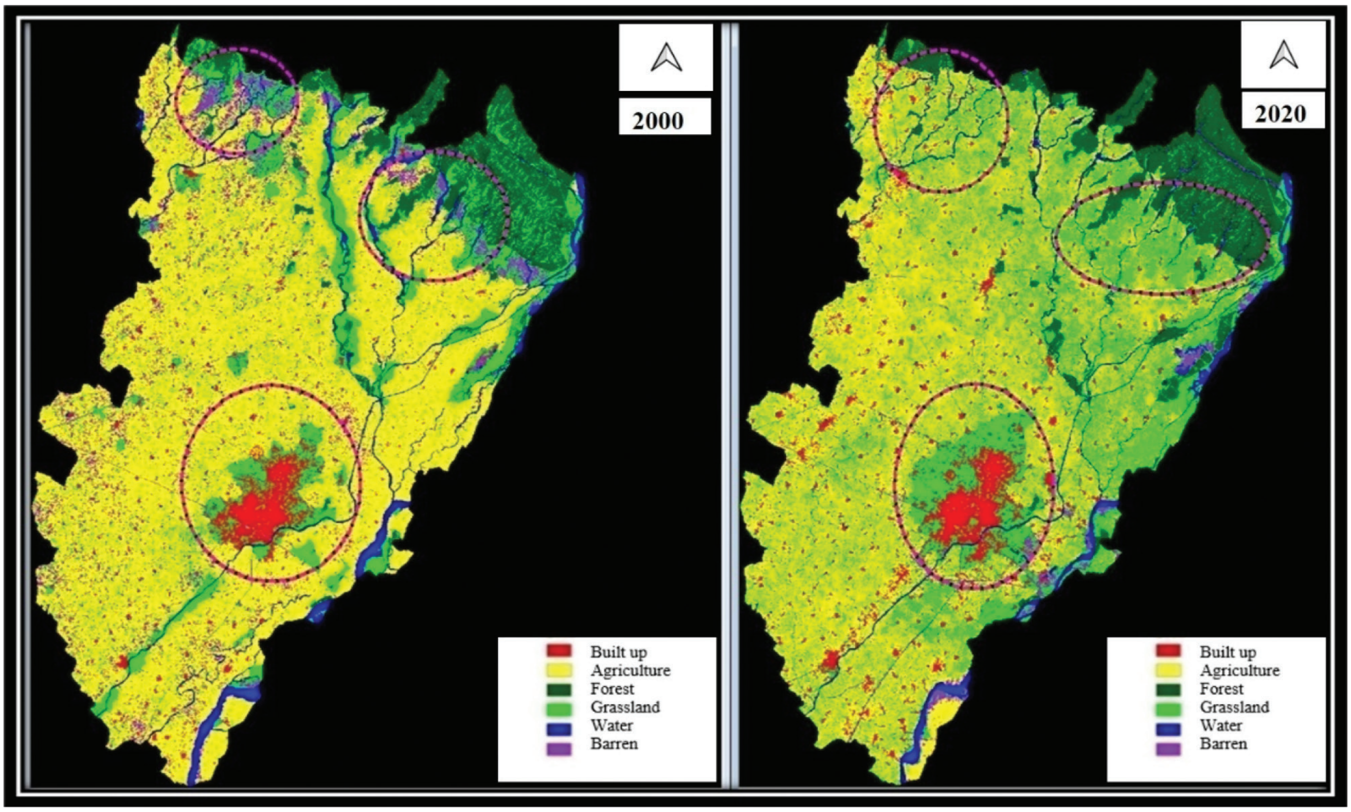

Figure 6: Map highlighting changes in LULC between year 2000 and 2020 in Yamunanagar district.

LULC are highlighted in Figure 6 and are encircled in the LULC map of the year 2000 and 2020 which also depict an expansion in built-up and grassland area.

Performance Analysis of Image Classifier

GPS-based ground truthing (locations are overlaid on the satellite image and shown in Figure 7) and interaction with the local population, forest officials and other stakeholders (Figure 8), both helped in the accuracy assessment. These classified LULC pixels obtained from pixel-based Landsat 8 OLI image classification of the year 2020 are compared to ground-measured reference points collected during the field survey and assisted with Google Earth satellite images of the year 2020. Table 4 shows the result of an error matrix calculated to find the LULC classification accuracy. The highlighted diagonal elements of the error matrix represent areas that were correctly classified. The result shows that an overall 88.69% of pixels are classified precisely and the Kappa coefficient obtained is 0.9, both indicating a strong accuracy/positive correlation between the classified LULC map and the ground reference information.

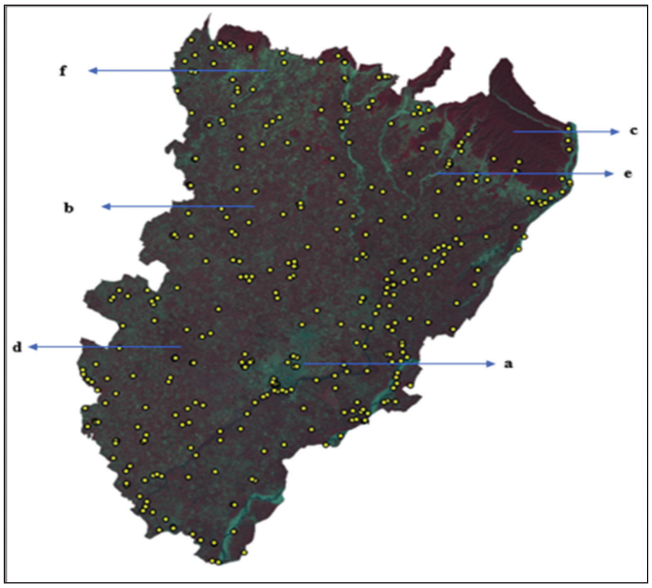

Figure 7: Image showing different LULC types in FCC satellite image with ground truth data overlaid on it; (a) built-up, (b) agriculture, (c) forest, (d) grass land, (e) water and (f) barren.

Figure 8: Field photographs.

Table 4: Error Matrix of LULC classification results based on 2020 Landsat 8 OLI image classification

Class Name		*Reference Pixels Count*							*User Accuracy*
		Built-up	*Agriculture*	*Forest*	*Grassland*	*Water*	*Barren*	*Row Total*	
Classified Pixels Count	Built-up	1390	31	0	2	0	0	1423	97.68
	Agriculture	0	2199	0	20	0	0	2219	99.10
	Forest	0	0	10115	0	0	0	10115	100
	Grass Land	53	526	736	380	0	0	1695	22.42
	Water	0	11	77	0	774	0	862	89.79
	Barren	14	179	60	6	0	398	657	100
	Column Total	1457	2946	10988	408	774	398	16971	
Producer Accuracy		95.40	74.64	92.05	93.14	100	100	**92.54**	**84.83**

Overall accuracy: 88.69%; Kappa Value: 0.9

Conclusions

The field survey reveals that dissemination of knowledge of research output and raising awareness programs is necessary for land management in Yamunanagar district. At present, this study fulfills the gap by collecting ground data, field knowledge and reporting spatial changes in LULC over two decades using satellite images. The Constitution of India empowers the Central and State Governments to enact laws for the preservation and conservation of natural resources and for this, The Forest (Conservation) Act, 1980, amended in 1988 and 2023, The Environment (Protection) Act, 1986, the provisions under EIA Notification, 2006 and other acts are constantly helping. A Government initiative for scientific training of manpower up to block level and research for constant monitoring of LULC can pave the way forward. In addition to this, the management of land can be rationalised through pilot plans and policies to include local participation, actions, granting land rights and land tenure. In India, zoning creates the legal framework, outlines permissible land uses, and distinguishes between various land use categories. The zoning enables the State Government to control and manage the land to ensure its compatible uses. However, to minimise the adverse impact of urbanisation on land cover, a policy of environmentally measured zonation for residential, commercial and industrial development is required to control pollution and management of land effectively. In the end, the authors have the opinion that scaling up this study into policy can enrich the sustainable growth of the region.

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