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Land use land cover and change detection of Rahuri Tehsil using remote sensing and GIS

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Abstract
Geospatial big data is currently received overwhelming attention and is currently the hotspot platform to cater to big data processing for Remote Sensing and GIS. Mapping land use and land cover (LULC) is important for efficiently analysing, monitoring, conserving, and planning resources. Remote sensing data is extensively utilized to research terrestrial features in less time, at a lower cost, and with greater accuracy, and GIS provides an appropriate platform for data analysis. The objective is to evaluate the feasibility of RS and GIS as a free cloud-based platform by performing a classification of Rahuri tehsil from Landsat composites of three different years (2011, 2015, and 2019). The best-categorized findings were then imported and further processed using commercial software (SAGA GIS) to quantify the changes over time. The eight-year period shows massive changes in various parameters. The cropland decreased in all three years. The cropland contributed about 48731.31 ha, i.e., 45.906% of the total area in 2011; this was reduced to 41880.96 ha in 2015, which was further reduced to 37490.13 ha, i.e., 39.45% in 2019, almost by 10%. The total increase in barren land is 5.02% from 2011 to 2015 and 5.12% from 2015 to 2019. In 8 years, the overall increase in barren land is 10.14%, with the decline in agriculture and water bodies being the primary reasons for this increase. The fallow land shows little change, with few differences. The build-up is considered an increasing parameter in all three years; it increased from 1.53% to 2.509% in eight years. Water bodies decreased in all three years, from 4689.54 ha in 2011 to 3738.69 ha in 2015 and further to 3150.9 ha in 2019, i.e., almost by 1.45% in eight years. On the other hand, GIS has performed quite effectively and quickly in terms of time and processing complexity of various datasets with minimal human engagement and intervention.

Keywords: Classification, land cover (LC) changes, change- detection, remote sensing, SAGA GIS

Introduction

Climate change is becoming a problem and the hottest topic on the entire globe. Extreme warming caused by human emissions of greenhouse gases and the subsequent large-scale changes in weather patterns confronts climate change. Land use/land cover data is crucial for selecting, planning, and implementing management methods to fulfil the growing demand for basic human requirements and the welfare of the world's population. Remote sensing technology attempts to give precise spatial data to assist decision-makers in formulating regional planning.(Singh and Khanduri 2011; Cao *et al*. 2011; Saing *et al*. 2021) [11, 3, 10].

Land use refers to the human activity or economic function associated with a certain region of land (Haque and Basak 2017) [6]. Cropland, forests, wetlands, pasture, roads, and urban areas are all instances of land cover types. As a result, accurate information on LULC is critical for implementing multiple developments, planning, and land use plans to meet the growing need for fundamental human requirements. Indeed, multi-temporal RS datasets were appropriately processed and expanded, allowing for the mapping and identification of landscape changes, resulting in an effective effort toward sustainable landscape planning and management (Dewan and Yamaguchi 2009) [4]. Long-term satellite data collections are extremely important in continuing investigations, especially in the field of Change Detection. It aids in recognising changes between two (or more) dates that are not typical of normal variance (Jayakumar and Arockiasamy 2003; Aher *et al*. 2017) [8, 1]. The process of detecting changes in aerial images taken over multiple time periods that cover the same geographic area is known as change detection. Change detection is useful in various areas such as agriculture, urban expansion, and landscape changes (Solaimani *et al*. 2010; Hegazy and Kaloop 2015; Tewabe and Fentahun 2020) [12, 7, 13]. Rapid changes in land use and cover, particularly in developing countries, are sometimes characterised by widespread urban expansion, land degradation, or the diversion of arable land to shrimp farming, resulting in tremendous environmental costs (Hegazy and Kaloop 2015) [7].

In this present study, an investigation has been carried out in Rahuri Tehsil of Ahmednagar District, Maharashtra to detect the land utilization and land cover changes. In recent decades, the area has become well-known for numerous agricultural operations and the export of various agricultural products. This aggressive human activity is thought to have affected land use/land cover patterns, potentially affecting the environment. The effort is being done to better understand this aspect of transformation. The case study's aims are as follows:

1. To generate the LULC map of Rahuri region by using RS and GIS techniques.
2. To estimate the area covered by various land use and land cover of Rahuri Tehsil region.
3. To perform change detection in SAGA GIS

Materials and Methods

Study area description

The investigation was carried out for the region of Rahuri Tehsil of Ahmednagar District, the agro-climatic region of Maharashtra in the western province of India. The major crops grown in the study area are cotton, onion, soybean, sugarcane, groundnut, sorghum, and maize. The region has an average elevation of 511 meters (1676 feet). As per the 2001 Indian census, Rahuri had a population of 34,465. There are approximately 96 villages in Rahuri Tehsil. The area covered in this investigation is about 1058.58 sq.km. Climatically, the region falls under the semi-arid and sub-tropical zone with an average annual rainfall of 566.5 mm. The distribution of rain is uneven, coupled with frequent droughts. The rainy days vary from 15 to 45 in different years. The annual mean maximum and a minimum temperature range between 33 to 43 °C and 10.10 to 22.9 °C, respectively. The annual mean pan evaporation ranges from 3.7 to 12.4 mm-day^{-1}. The annual mean wind speed ranges from 3.2 to 13.09 km-hr^{-1}. The annual mean maximum and minimum relative humidity range from 59 to 90 percent and 21 to 61 percent, respectively. The climate of Rahuri is hot and dry. 89% of annual rainfall in the central part during southwest monsoon rainfall is received from June to September, with 37 rainy days out of 122 days having daily rainfall (r >= 2.5) (Guhathakurta *et al*. 2020) [5].

Location of study area

The area for the study is in the Maharashtra region bounded by latitudes 19°6' N to 19°36' N and longitude 74°24'E to 74°48'E. The boundary map of the study area is depicted in Fig 1.

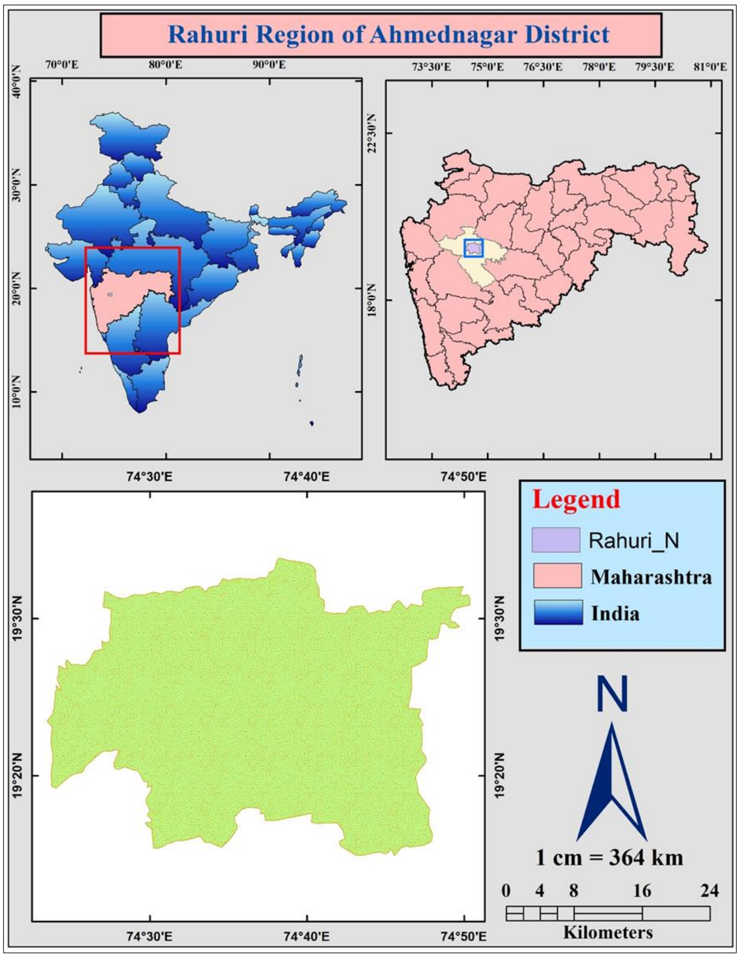


Fig 1: The location map of Rahuri Tehsil

Data Acquisition

Dataset

In the present study, two satellite datasets have been used to create a LULC map of study area *viz.* Landsat 5 TM and Landsat-8 OLI data product downloaded from the Earth Explorer. The satellite data utilized in the study is acquired from different satellites and sensors which was further utilized in the form of geo-coded False Color Composite (FCC). All the satellite images were brought under UTM projection 43N and datum WGS 84. Google Earth Images was used for image interpretation and defining different classes of LULC. The land sat data of Rahuri region were acquired for three time periods *viz.*, 2011, 2015 and 2019 from USGS Earth Explorer (https://earthexplorer.usgs.gov) while shape file of Rahuri was download from Diva GIS. The shape file was further brought under Universal Transverse Mercator projection in zone 43 and later the satellite imageries were clipped with the boundary of Rahuri. The satellite data product with general description of sensor and utilized bands are represented in Table 1.

Table 1: Satellite product and utilised bands

Sr. No	Specification	Landsat 5	Landsat 8
1	Spectral Band Used (µm)	0.45-0.52 (Blue)	0.452-0.512 (Blue)
		0.52-0.60 (Green)	0.533-0.590 (Green)
		0.63-0.69 (Red)	0.636-0.673 (Red)
		0.76-0.90 (NIR)	0.851-0.879 (NIR)
2	Total no. of bands	4	11
3	Resolution (m)	30	30
4	Swath Width (km)	-	185
5	Revisit time (days)	-	16

Software utilised

The ArcGIS 10.5, ERDAS IMAGINE 2015, SAGA GIS and Google Earth Pro was used for image processing and analysis. Esri's ArcGIS is a geographic information system (GIS) software for dealing with maps and geographic information. It is used for creating and compiling geographic data, analyze mapped information, share and discover geographic information, use maps and geographic information in a variety of applications, and manage geographic information in the database. ERDAS IMAGINE is a remote sensing and raster graphics editor application created by ERDAS, Inc. It is primarily intended for processing geospatial raster data and lets the user processing of geospatial raster data and lets the user prepare, display, and enhance digital images for use in GIS or CAD software. It has a toolbox that allows the user to execute a variety of actions on an image and create answers to geographical inquiries.

Post processing of dataset

The presented methodology was used to generate land use land cover maps from two different satellite images, and to detect changes in classified maps. The detailed procedure for classification is represented in Fig. 2. Satellite images spanning three years (2011, 2015, and 2019) were utilized to classify LULC. The downloaded file size was high due to the inclusion of zipped files containing more than ten bands of the same location. The (.tif) file comprises graphics and a text file once entirely extracted. Each image has similar name as the original file expect the number at the end denoting bands such as B1, B2, and B3. The '.tif 'file of respective bands were loaded in Arc Map 10.5 software for primary processing. All satellite images are brought under UTM projection (43N) and datum WGS 84. For LULC classification red (R), blue (B), green (G) and near-infrared (NIR) spectral bands were used. Those four spectral bands were stack and merged into a single multispectral image. The extent of the Rahuri tehsil was clipped from the multispectral band. The same procedure was followed for the remaining raster datasets for other satellite imagery. The supervised classification techniques method was the classification of each feature. The extracted data were analysed statistically, and ground truth was verified in a GIS environment.

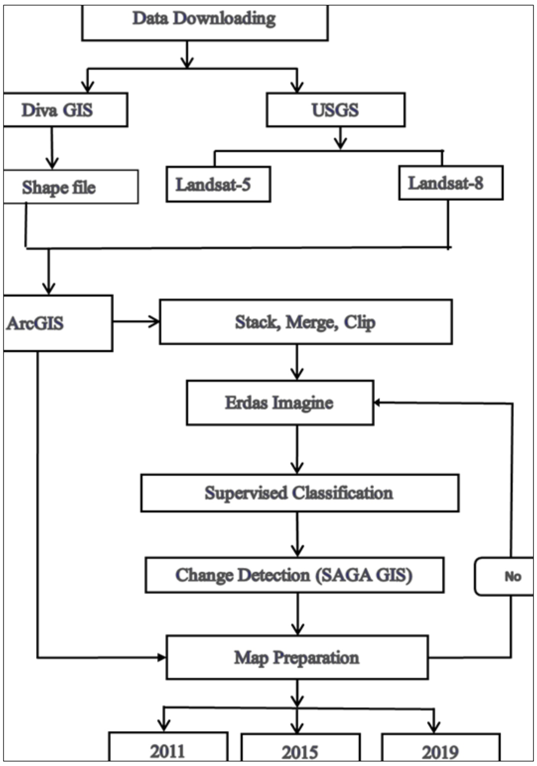


Fig 2. Flow chart depicting involved during LULC Mapping by Supervised Classification

For land use land cover classification red, blue, green and near-infrared spectral bands were used. This was done in the image analysis tool, the raster is loaded and bands (1, 2, 3, 4) and (2, 3, 4, 5) of Landsat-5 and Landsat-8 respectively were selected for layer stack and composition of an image as shown in Fig 2. The created FCC clearly represent the decrease in water bodies and cropped area as proceeded from 2011 to 2019.

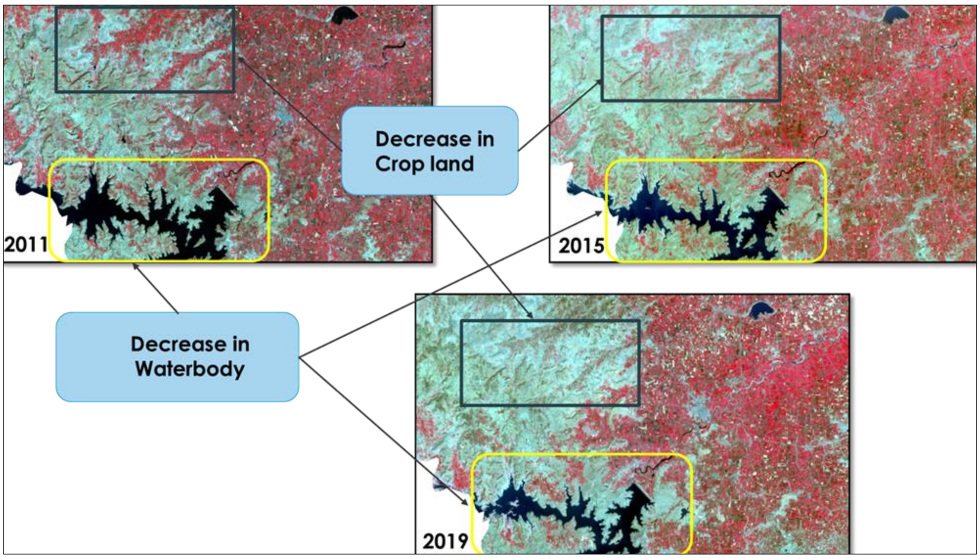


Fig 3: FCC Images depicting changes over study area

Image classification scheme

In this study, the USGS Level I, LULC classification methodology was applied. The research area was divided into five categories. Table 2 contains a thorough overview of the classes. Each class was created based on texture, tone, and colour (Radhakrishnan *et al*. 2014; Vivekananda *et al*. 2020) [9, 14]. In image classification, these classes were allocated to pixels

Table 2 Image classification details

Sr. No	Class	Description
1	Built-up	Land covered by concrete, including low-, medium, and high-density road networks; residential, industrial, and commercial buildings; educational institutes; transportation; open-roof concrete structures; other human-made structures; and solid waste landfills.
2	Fallow and	Land characterized by no cropped area following a distinct pattern and colour
3	Cropped land	Areas characterized by a high density of grasses, herbs, and crops, including parks and regularly till ed, planted croplands.
4	Barren land / Other lands	Areas with or without sparse vegetation that are likely to change or be converted to other users in the future. This category includes land without crops, land with barren rock, and sand areas along rivers/stream beaches
5	Water	Areas covered by water, including rivers, reservoirs, ponds, lakes, and streams.

Results

The study was done to achieve the primary objective of detecting land use land cover and changes in Rahuri Tehsil for the years 2011, 2015, and 2019. In general land use land cover of an area depicts an idea of overall areal utilization of resources, natural or cultural. Supervised classification of images interpreted; water bodies (lakes, reservoirs, stream, and rivers), built-up (buildings and other man-made structures. Residential, commercial services, industrial area, mixed urban or built uplands), barren land (Bare ground, bare exposed rocks, strip mines, quarries, and gravel pits), vegetation (crops field, forest, Shrubs) and fallow land (harvested field). The results coming from the study here described indicates that urbanization has considerably modified the LC of the study area, with significant land conversions. Urbanization is a complicated diffusion process that is altering rural landscapes differently in location and at different sizes (Brahmabhatt *et al*. 2000; Solaimani *et al*. 2010) [2, 12]. The statistical distribution of LULC and change detection of Rahuri region area is shown in below Table 3 and Fig. 4 and 7.

Table 3: The area under each LULC class in the 2011, 2015, and 2019 data sets and change in the area of each LULC class over 10 years (in Hectare and percentage)

Sr. No.	Land use categories	Area in Hectare			Percentage		
		2011	2015	2019	2011	2015	2019
1	Barren Land	21618.09	26950.95	32388.93	20.36	25.39	30.51
2	Crop Land	48731.31	41880.96	37490.13	45.91	39.45	35.32
3	Fallow Land	29490.84	31512.15	30459.78	27.78	29.69	28.69
5	Built up	1624.41	2071.53	2664.27	1.53	1.95	2.51
4	Water bodies	4689.54	3738.69	3150.9	4.42	3.52	2.97
Total		106154.2	106154.2	106154.2	100	100	100

It was clearly depicted that Barren Land is increased from 21618.09 ha to 32388.93 ha in a span of 8 years. The total percentage of increase in barren land was 5.02% from 2011 to 2015 and 5.12% from 2015 to 2019. The overall increment in barren land is 10.14% in a span of 8 years. The main reason for this is the decrease of Cropland and water bodies. The Cropland contributed about 48731.31 ha i.e., 45.91% of the total area in 2011 this reduced to 41880.96 ha in 2015 which further ultimately reduced to 37490.13 ha i.e., 39.45% in 2019 by almost 10%. Eventually, the change in reduction is reduced between 2015 and 2019. Built-up is increasing parameter in all three years, it increased from 1624.41 ha to 2071.53 ha in 2015 and further to 2664.27 ha in 2019. Whereas water bodies are decreased from 4689.54 ha in 2011 to 3150.9 ha in 2019. Fallow land showed little variation with minimalistic changes. The changes in 2011, 2015 and 2019 are clearly detected in maps as shown further.

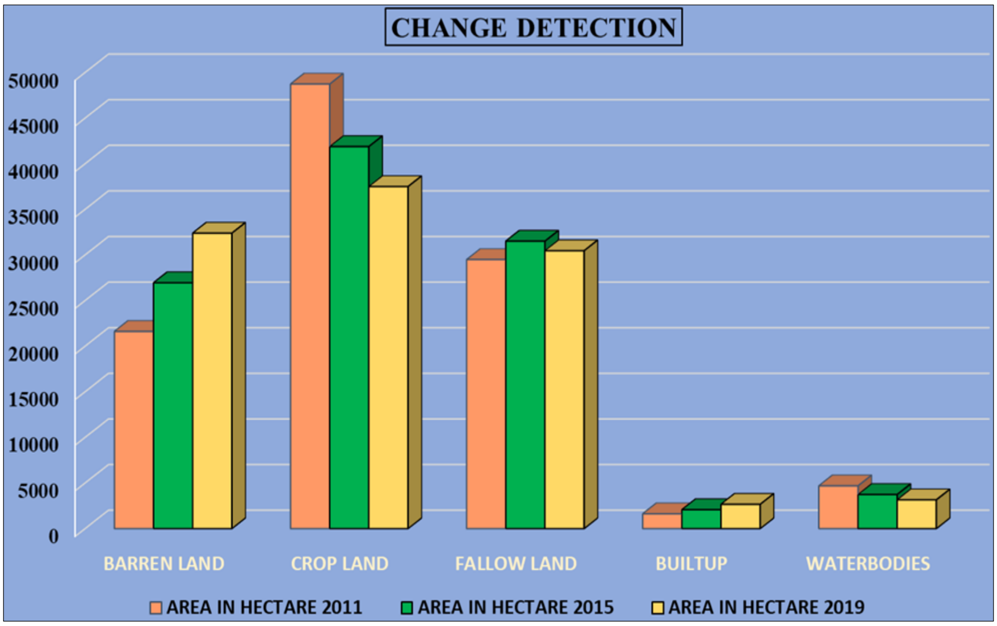
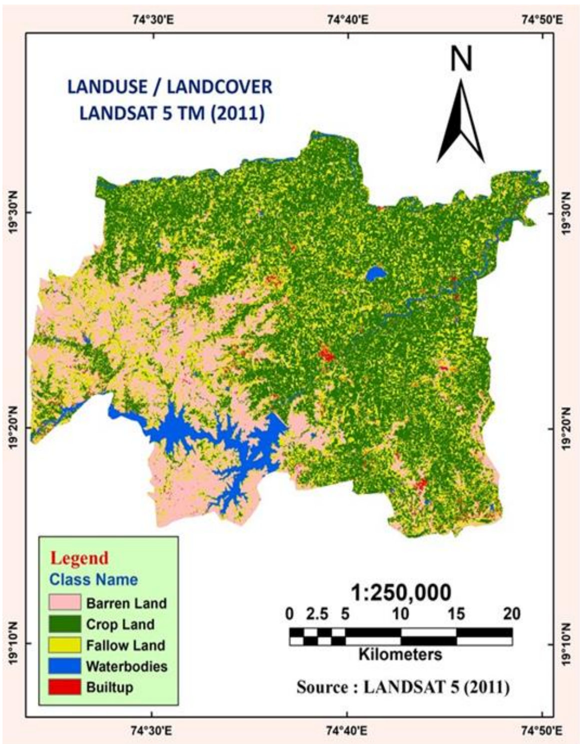


Fig 4: Graphical representation of land use land cover during 2011, 2015, and 2019

Change Detection

SAGA GIS was used for detecting change in various land parameters as change of water bodies, barren land, built-up, cropland, fallow land, etc among themselves. The change in one parameter is subsequently reflected in another and is clearly seen through map. The change in SAGA GIS were more specific that they clearly define the change of single pixel over time to any other class. These changes can be further exported in excel for further analysis. Considering Fig. 7 and 8, it is depicted that Fallow land is mostly changed to barren land in span of 4 years i.e., 2011 to 2015 and 2015 and 2019.



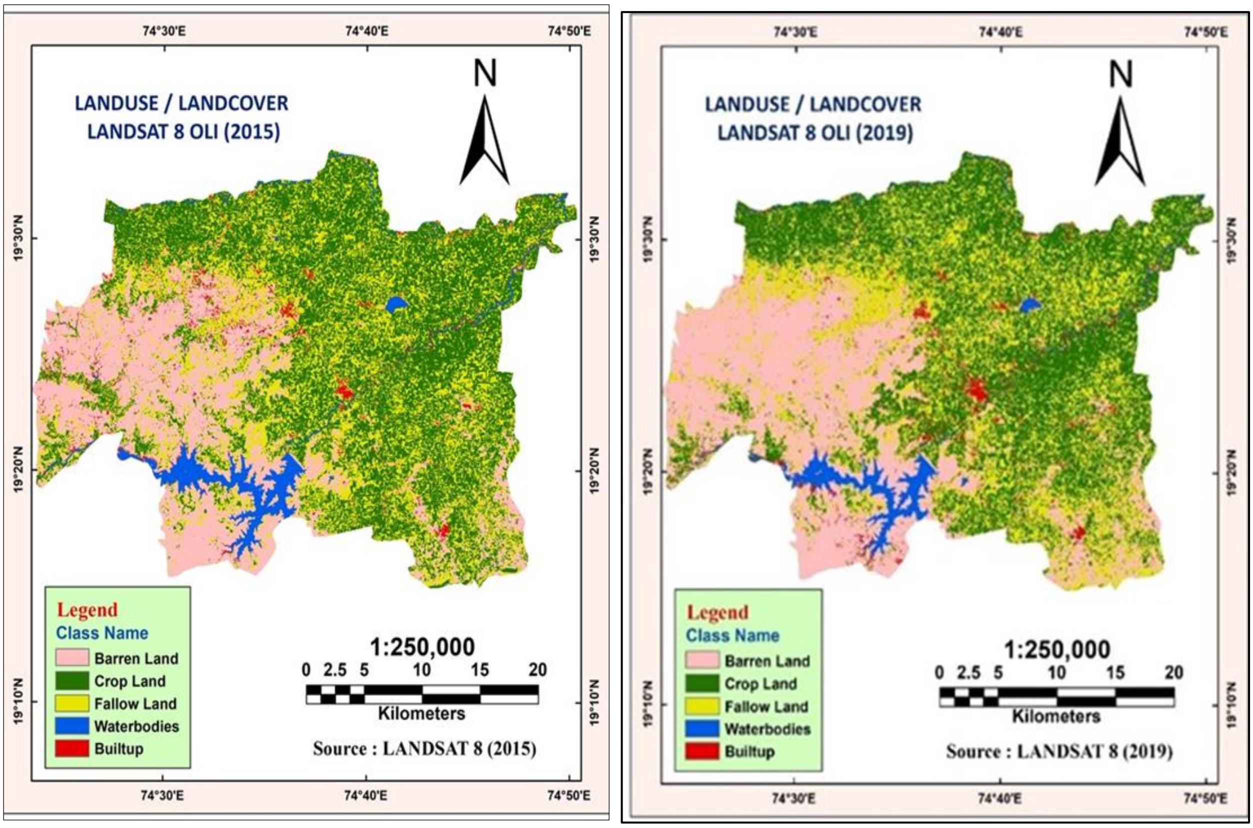


Fig 5: LULC changes during three time periods (a) 2011, (b) 2015, and (c) 2019

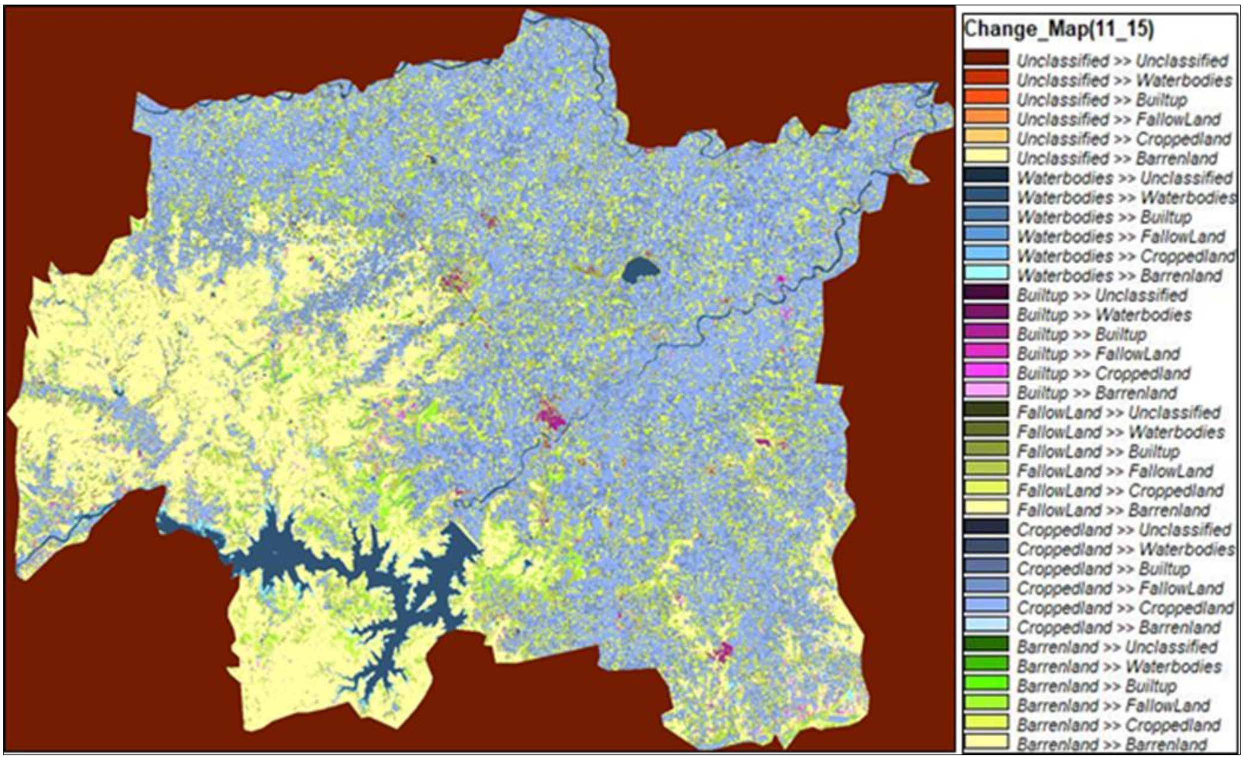


Fig 6: Change Analysis during 2011-2015

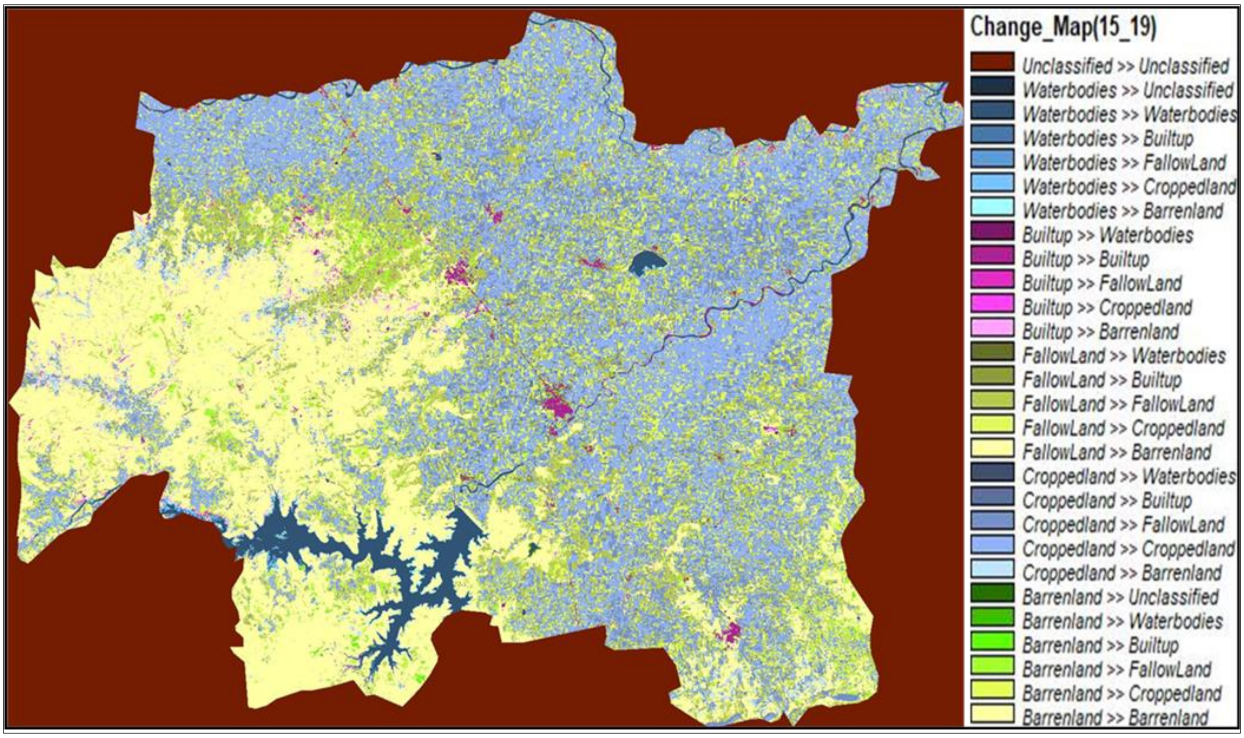


Fig 7: Change Analysis during 2015-2019

Conclusion

The use of remote sensing and GIS tools was beneficial in determining the degree of LULC change that occurred in Rahuri Tehsil over an 8-year period. The study conducted in one of the fast-growing economically regions of Ahmednagar district (Maharashtra) advocates that multi-temporal satellite imagery plays a vital role in quantifying spatial and temporal phenomena, which is otherwise not possible to attempt through conventional mapping. It is depicted that Barren land is increased by 10.14% in eight years whereas cropland and water bodies are decreased by 10% and 1.45% respectively. The water body of land use classes is acknowledged as an ecologically sensitive part that includes the Mula River, Pravara River, and a few small and medium type wetlands. According to land use statistics, the loss of the water body is 950 ha during 2011-2015 and 588.69 ha in 2015-2019. This type of modification is occurred due to outward urban expansion and spreading out of agricultural activity. The study area experienced a notable increase in the built-up area that implies an unplanned spatial growth of Rahuri town. This rapid growth of the urban areas is not only confined to the municipal boundary, but it also takes place in the surroundings of the town. The built-up land increased by 447.6 ha from 2011-2015 and further by 592.74 ha from 2015-2019. The map of land use land cover shows a vast part of the study area is covered by the agricultural field. In 2011, this land-use class covers about 45.90% out of total area. The loss of the agricultural field was 6850.35 ha in 2011- 2015 and 4390.83 ha of 2015-2019. To overcome this most part of the barren land should be bought under cultivation practices in order to maintain balance. Water bodies should be used judiciously and effectively.

In this regard, satellite remote sensing and Geographic Information System (GIS) can provide up-to-date spatial information of urban land use land cover that helps to build model base monitoring cell, to give a picture of the urban growth. The model further can be used for taking future decisions to carry out proper urban re-modelling and management plans for urban planning authorities.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The authors did not receive support from any organization for the submitted work.

Data Availability

The dataset supporting this study's findings is available on request from the corresponding author, Shubham Gade. The dataset is not publicly available as it contains information that could compromise the research participant's privacy and consent.

Code Availability

No code is available for the present study.

Compliance with Ethical Standards

This article does not contain any studies with human participants or animals performed by any authors.

Consent to Participate

Informed consent was obtained from all individual participants included in the study.

Consent to Publish

The participant has consented to the submission of the article to the journal.

Conflict of Interest

The author declares no conflict of interest.

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