



# A Spatio-temporal Study of Land Use Land Cover Change Detection Using GIS and Remote Sensing Techniques

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## Abstract

Land resources in India are under severe pressure and it is widely believed that marginal lands are being brought under cultivation. The extent of such changes needs to be known for better land use planning decisions. The present study illustrates the spatio-temporal dynamics of land use land cover of Nagjhari watershed in Bhatkuli block of Amravati, Maharashtra. Multi-temporal high resolution of Sentinel and Landsat satellite data were used to identify the significant positive and negative Land use land cover changes over a decade of 2007 to 2017. From 2007 to 2017, the 'habitation' class increased by 34% due to increasing population pressure. There was a decrease in 'wasteland' by 10.3%, while the area under 'agriculture' decreased by approximately 4.7% because of the increased area under 'habitation' and 'water body' at Nagjhari watershed. The biggest change occurred in land use class 'water body' increased sharply from 2013-17 by 62.7 per cent due to consequence of state policy of watershed development that was implemented after 2014. The forest class recorded maximum loss (18.3%) due to increasing population maximum land converted into habitation. The study shows overall classification accuracy as 85.46% and kappa coefficient (K) of 0.85. Kappa coefficient indicated that land use land cover assessment from remote sensing data show the best accuracy. These finding will help in deciding land use policy for future and its impact on land management of the watershed.

**Keywords:** Land use land cover, geospatial techniques, remote sensing, GIS

## 1. Introduction

Increased population and human activity increases the demand on limited water resources and agricultural land, forest, urban land uses and industries. With the population growing, lands under cultivation can no longer provide the needs of people and therefore, more lands are needed to be cultivated which in long terms will results in a decrease in quality and quantity of natural resources (Fatahi et al., 2000; Patil et al., 2010; Ram et al., 2014). Land use land cover (LULC) changes refer to (quantitative) changes in the areal extent (increases or decreases) of a given type of land use and land cover respectively. The spatial and temporal information on LULC could be used by ecosystem, hydrological, and climate modeling as well as by policy makers for assessing the impacts of LULC on regional climate, water resources, and biogeochemical

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cycles in terrestrial ecosystems (Tian et al., 2014). A complex set of interactions between biophysical and socioeconomic variables drive the LULC changes (Yesuph and Dagneu, 2019). These changes are known to impact ecology (forest services, biodiversity, climate, water quality, habitat of wildlife etc.), environment (carbon sequestration, oxygen levels), food security (crop production) and livelihood (source of living) of human population.

LULC are driven by change in multi scale interacting driving factors such as biophysical conditions of the land, demography, technology, affluence, political structures, economy and people's attitudes and values. These driving factors vary with geography and time; therefore LULC is also heterogeneous both spatially and temporally. Hence improved representation of both spatial and temporal dimensions of LULC is crucial for better understanding human influence on the natural environment (Bishaw, 2001; Khalkho et al., 2014). LULC is driven by complex proximate (direct) causes based on local level decision and underlying (in-direct) driving forces at regional and national level (Lambinet al., 2001; Patangray et al., 2017). The underlying driving forces influencing the proximate causes were categorized into biophysical, economic, technological, demographic, institutional and cultural factors (Geist and Lambin, 2002; Duraisamy et al., 2018). These factors vary with scale and are often simplified as 'cause-consequence relationships' at the different scale. National scale studies may influence decisions at the state level but can only be effective at influencing finer scale decisions if they are coupled with large scale analysis (DeFries et al., 2012). The dominance of one driving forces at a taluka level may or may not be emphatic at district level. For example Govindaprasad and Manikandan (2014) observed that there is evidence showing agricultural land conversion has become a serious issue in the country but the extent and intensity varies across different states. Thus it is essential to understand the change and operating factors at lower level for aggregation at broader level. The objective of the present study is to estimate and examine the finer scale land use land cover analysis over the last decades using satellite imagery in the Nagjhari watershed located in semi-arid region of India; to identify the hotspots of LULC and investigate driving forces that cause change.

## 2. Materials and Methods

Nagjhari watershed covers an area of about 14823.7 ha falling in Amravati district, Maharashtra state. The study area lies between latitudes 20° 48' 30" N to 20° 55' 0" N and longitude 77° 36' 30" E to 77° 47' 30" E. The location map of the study area is shown in Figure 1. The climate of the study area is tropical and it experience three seasons 1) hot weather from March to June 2) rainy season from July to October and 3) winter season from November to February. The average annual rainfall (1998 to 2017) in the study area is 850 mm and average temperature is 35.04°C, while mean relative humidity is 52%. The watershed falls under cretaceous-palaeocene age

of basaltic region of Deccan trap (Sahyadri hill group) which is predominant water bearing formation. The relief of the area varies between 278 to 475 m above mean sea level. Most of the soil in the watershed is clay texture soil. Agriculture is the major livelihood in the Nagjhari watershed. Crops are cultivated in two seasons namely *kharif* (July to October) and *rabi* (October to March). Cotton, soybean, pigeon pea and green gram are the important crops of the *kharif* season, while the main crops of *rabi* season are wheat and chickpea (Figure 1).

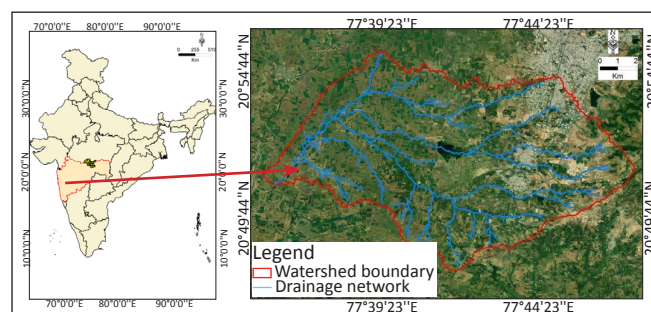


Figure 1 :Location map of the Nagjhari watershed

### 2.1. Data collection

Satellite data, physical data and ancillary data were used in the present study. Physical data included cadastral map of each village in the watershed and revenue records of land holdings, crops grown during the last decades, population details etc. Survey of India (SOI) toposheet on 1:50,000 scale (55 H/9) was used to collect topographical information. This toposheet was used as base map for location of sample areas, ground truth sites and planning for traverse routes in the field and other details. Ancillary data included ground truthing for the land cover/use classes and topographic maps. The ground truth data were in the form of reference data points collected using Geographical Positioning System (GPS). Satellite data for the three different years on the other hand consisted of multi-spectral data acquired by Sentinel and Landsat satellite for the month of October provided by open sources. Specifications of the satellite data and satellite image of Nagjhari watershed acquired for change analysis area given in Table 1 and Figure 2 to 4.

Table 1: Details of remote sensing data used for the study

Satellite	Spatial Reso- lution	Month of acqui- sition	Path/ Row	Season	Top sheet No.
LANDSAT-5	30 m	Oct., 2007	145/45	<i>Kharif</i>	55 H/9
LANDSAT-8	30 m	Nov., 2013	145/45	<i>Kharif</i>	55 H/9
Sentinel-2	10 m	Nov., 2017		<i>Kharif</i>	55 H/9

### 2.2. Classification assessment

The delineated classes were agriculture, habitation, forest cover, wasteland and water body (Table 2). For each of the pre-determined land use land cover type, training samples were selected by delimiting polygons around representative

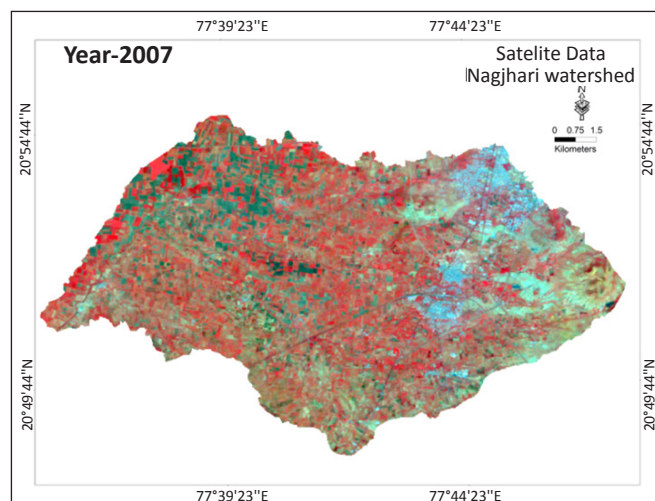


Figure 2: Satellite data of Nagjhari watershed (Temporal data-2007)

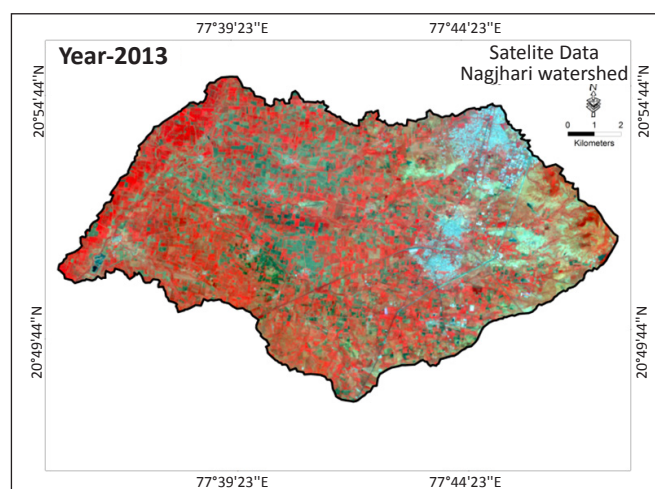


Figure 3: Satellite data of Nagjhari watershed (Temporal data-2013)

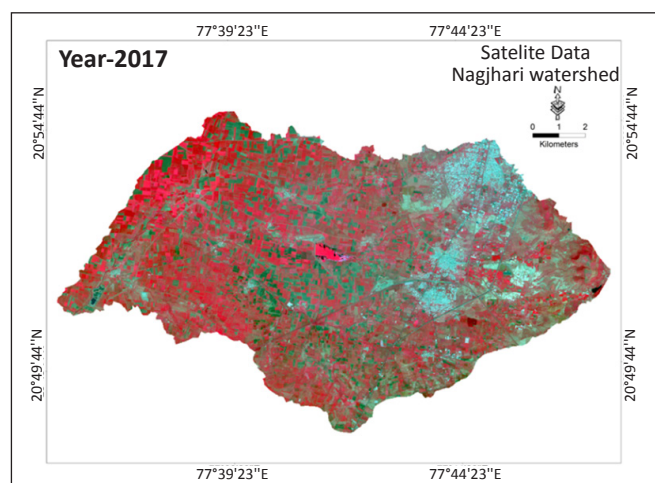


Figure 4: Satellite data of Nagjhari watershed (Temporal data-2017)

Table 2: Land use land cover classes description

Sl. No.	Class name	Description
1.	Agriculture	Crop fields and fallow lands
2.	Forest cover	Mixed forest lands
3.	Wasteland	Land areas of exposed soil and barren area due to anthropogenic influence
4.	Habitation	Residential, commercial, industrial
5.	Water body	River, open water, lakes, ponds and reservoirs

sites. The maximum likelihood algorithm was used for supervised classification, which is mainly controlled by the analyst to select the pixels that are representative of the desired classes.

### 2.3. Accuracy assessment

The accuracy assessment for the supervised classification of LULC was done for 2007 to 2017 image by using ArcMap 10.4 and Google Earth. Near about 506 points were generated randomly for 2007 to 2017 classified LULC images. The accuracy assessment was carried out using 506 points, based on ground truth data, Goggle Earth pro and visual interpretation. The comparison of reference data and classification results was carried out statistically using error matrices. It is also known as confusion matrix or contingency matrix. Such matrix shows the cross tabulation of the classified LULC and the actual LULC according to the results of sample site observations.

## 3. Results and Discussion

Land use land cover maps of Nagjhari watershed for the year 2007 to 2017 area statistics are shown in Table 3 and Figure 5 to 7. Agriculture is the major land use in this watershed with an extent of 76 percent of total geographical area. Total population of the watershed is 49087 (43% of taluka and 1.6% of district population) as reported by Census of India report (2011). During the first phase (2007-13) habitation emerged as the most important land use with an increase of 338.32 ha. The change occurred predominantly in agricultural lands in the periphery of Amravati city due to rapid urban growth. Rest of the watershed witnessed marginal increase in habitation area. Amravati city and Badnera town were separated by a distance of 670 m in 2007. The two settlements merged to form a continuous entity over 1850 ha area by 2013 with conversion of agriculture, wasteland and forest land to habitation class. The growth in habitation area was significantly low (2.2%) during 2013-17 as against 34% growth in earlier period. The expansion outside settlement area closeted by railway tracks was likely arrested by lack of connectivity. The 69.9 ha forest land was lost to habitation and 19.4 ha wasteland was brought under vegetation/afforestation. All these changes have occurred around the two urban settlements in the watershed,



Table 3: Land use land cover distribution of watershed (2007, 2013 and 2017)

LULC class	2007		2013		2017	
	Area (Ha)	Area (%)	Area (Ha)	Area (%)	Area (Ha)	Area (%)
Agriculture	11301.64	76.2	10861.81	73.2	10773	72.6
Fallow land	378.91	2.5	459.54	3.1	473.11	3.1
Waste-land	352.13	2.3	292.67	1.9	262.46	1.7
Forest cover	987.75	6.6	807.14	5.4	835.33	5.6
Water body	44.59	0.3	43.06	0.2	70.05	0.4
Habi-tation	1758.68	11.8	2359.47	15.9	2411.51	16.2
TGA	14823.7	100	14823.7	100	14823.7	100

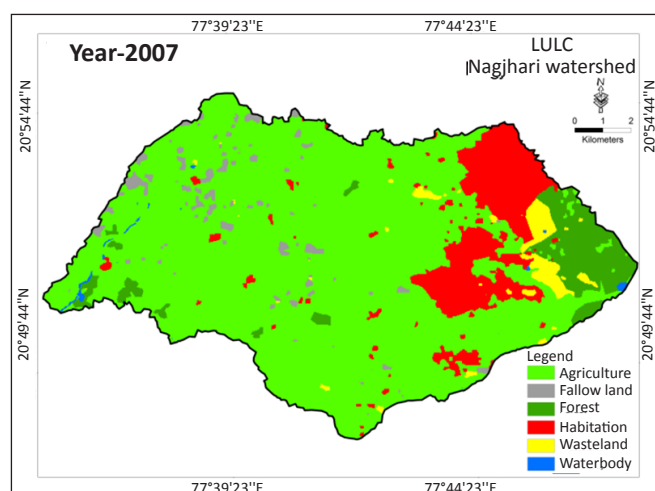


Figure 5: Land use land cover of Nagjhari watershed in year 2007

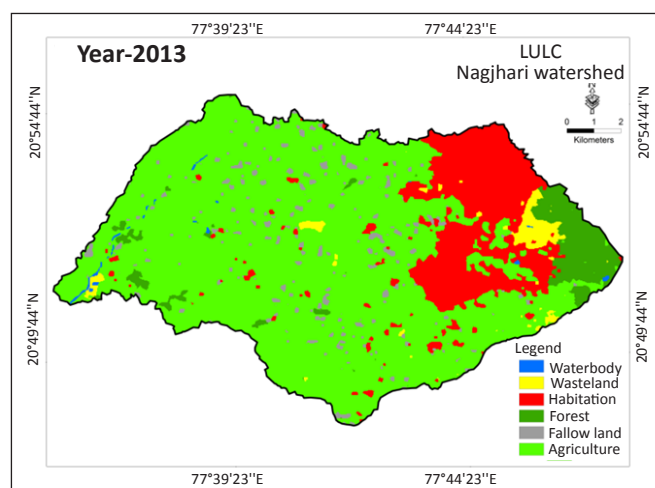


Figure 6: Land use land cover of Nagjhari watershed in year 2013

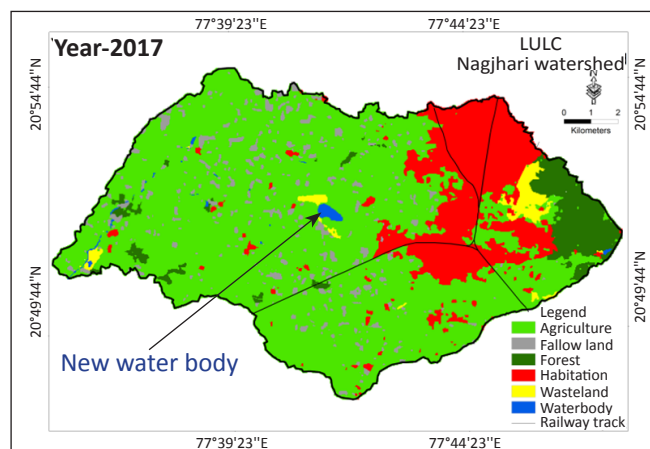


Figure 7: Land use land cover of Nagjhari watershed in year 2017 indicating influence of urbanization.

Among all the period considered, the area under water bodies declined by 3.4% during 2007-13, but later increased sharply by 62.7% (2013-17) as a consequence of state policy of watershed development that was implemented vigorously after 2014. The water bodies primarily consisted of reservoirs, lakes, ponds and water harvesting structures. The fallow land area has steadily increased during all the period. Interestingly the increase is well spread throughout the watershed underscoring the problems caused by sodicity. The watershed is located in Purna valley area. Soils of this valley including Bhatkuli have low level of sodicity (ESP 4.8-11.1) but severely restricted hydraulic conductivity. High amount of smectitic clays leads to increased bulk density (Kadam et al., 2013) resulting in hard and compact soil structure. During field visits, numerous interactions with the farmers confirmed that the farmers are increasingly abandoning crop cultivation during *kharif* season and the trend is likely to continue.

The LULC changes were both positive and negative. In some spots, there was a shift from agriculture land to water bodies, which are considered here as positive change in agriculture land. On other side agriculture land converted into habitation land implying negative change. The forest land was positive change due to conversion of open forest/scrub into agriculture land.

### 3.1. Accuracy assessment

There are 509 points selected for checking the accuracy assessment of LULC map. Accuracy assessment or validation was an important step in the processing of remote sensing data which determines the information value of the resulting data to a user (Tilahun and Teferie, 2015; Rwanda and Ndambuki, 2017). The overall accuracy of the LULC for years 2007, 2013 and 2017 was 90.56%, 87.62% and 85.46%, respectively. Looking into individual class, agriculture, forest, wasteland and water body show the better product accuracy while fallow land and habitation show lower product accuracy. In same way agriculture, habitation, and water body represent good user's accuracy then fallow land and wasteland. The

error matrix for the assessment of LULC classification in 2017 represent in Table 4. In the present study kappa indices were estimated as 0.85 in year 2017, show the perfect match between the classified and reference data. Kappa index between 0.81 to 1 denotes almost perfect match between

the classified and reference data in the classification system (Yang and Lo, 2002; Vliet et al., 2011; Lekha and Kumar, 2018). The accuracy assessment indicated that land use land cover assessment from remote sensing data use in Arc Map show the best accuracy.

Table 4: The error matrix for the assessment of LULC classification in 2017

Classified Data	Agriculture	Fallow land	Forest	Habitation	Waste land	Waterbody	Total	Users Accuracy
Agriculture	323	12	3	10	1	1	350	92.28
Fallow land	8	14	0	1	0	0	23	60.86
Forest	2	0	23	0	0	0	25	92
Habitation	0	0	0	57	0	0	57	100
Wasteland	19	0	2	13	9	0	43	20.93
Water body	1	0	1	0	0	9	11	81.81
Total	353	26	29	81	10	10	509	
Product accuracy	91.5	53.8	79.3	70.3	90	90		
Overall accuracy	85.46							
Kappa index	0.85							

#### 4. Conclusion

This study provides a description of the finer scale LULC pattern and locations of significant change, which is a valuable source of information for explaining regional level changes and it is useful for predicting future land use development in the Nagjhari watershed. The conventional records and remote sensing data provide high resolution data for better assessment of LULC. The LULC changes provided a glimpse to the issues and drivers operating at different level of land management requiring specific policy measures within the ambit of subnational goals.

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