International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-6, April 2020

Land use Land Cover Monitoring and Change Detection of Tinsukia, India

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Abstract*: *This study is driven towards land use land cover (LULC) mapping and LULC change detection in Tinsukia district, India. LULC mapping and change detection provides land planner and environmental scientists a better understanding of the land surface processes occurring in a given landscape so that they can come up with a strategy for sustainable development keeping degradation of natural environment from anthropogenic activities at bay. This study utilized remote sensing data products and software's for LULC mapping and LULC change. Landsat data has been utilized in ENVI for the classification of LULC and LULC change detection during the period 1991-2020. The LULC classification was achieved through Maximum Likelihood Classification (MLC) which is a widely preferred classificatory method. Image change detection was achieved through ENVI thematic change workflow. On top of that ArcGIS version 10.2 was used for preparing all map layouts. Results reveal that the study area has undergone significant changes in its LULC pattern. Substantial increases were recorded in agricultural area (862.4 sq. km to 1186 sq. km), built up area (473.4 sq. km to 699.5 sq. km) and waterbodies (81 sq. km to 146.7 sq. km). A declining trend was evident in degraded vegetation (772.2 sq. km to 274.3 sq. km) and barren land (798.8 sq. km to 641 sq. km). In the short study period, the study area already seems to be changing in its LULC pattern due to anthropogenic activities. The steady increases to the agricultural land and built up area (BUA) is a potential threat to the LULC balance and it may have manifold impacts to LULC dynamics in the future if proper land utilization policy is not adopted.

Keywords*: *LULC, Change detection, Landsat, ENVI, MLC, Thematic change, BUA

I. INTRODUCTION

Rapid population growth has accounted for tremendous changes in the global LULC pattern (Lambin et al., 2000; Owojori and Xie, 2005; Ao et al., 2017) and LULC changes are considered as one of the core global environmental concern in recent times (Guan et al., 2011; Halmy et al., 2015).

Revised Manuscript Received on April 30, 2020.
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Most changes in LULC is recorded as conversion from natural vegetation and waterbodies to agricultural land and built up areas (Singh et al., 2016; Mohanta and Sharma, 2017; Silva et al., 2019). These changes can affect the land surface processes and often have have manifold effects on temperature, precipitation, ecosystem, soil health and habitable environment (Ogle et al., 2017; Viana et al., 2019). Thus, the study of LULC change is relevant as it is related to a wide array of disciplines such as climate change, hydrology, ecology, vegetation monitoring and many more (Carlson and Arthur, 2000; Kogan, 2001; Arnfield, 2003; Voogt & Oke, 2003; Rogan and Chen, 2004).

In recent years, remote sensing data products have been used extensively in LULC studies. Satellite data can provide data for a large area in different times, making it possible to study the temporal and spatial changes in LULC. Currently, a series of satellite sensors such as Landsat, MODIS, Sentinel are in operation which provide free optical datasets (Tran et al., 2017). These datasets are suitable for large scale LULC monitoring. Further, using satellite data makes it possible to analyze and quantify changes in LULC through change detection algorithms. While numerous studies have been carried in different parts of north east India (Lele et al., 2008; Sharma & Saikia,2018; Pawe & Saikia, 2018) and Bhutan (Sharma et al., 2017), the Tinsukia and upper Assam area has evoked negligible research interest.

In this study, LULC mapping and LULC change detection of the Tinsukia district, of Assam, India has been carried out using geospatial technology. Landsat datasets have been utilized for the mapping of LULC and LULC change detection during the period 1991-2020 in ENVI 5.3. The LULC of the study area is mainly governed by anthropogenic activities as agricultural land occupies majority of the study area. The LULC balance in the study area is slowly changing due to unplanned development and inadequate resource utilization policies. Hence, LULC studies can help planners and policy makers to come up with better policies for future sustainable development.

II. STUDY AREA

The selected study area is the Tinsukia district, Assam India and it lies in the easternmost part of Assam (Buragohain, 2011). Tinsukia district extends from $27^0 23^/$ N to $27^0 48^/$N and $95^0 22^/$ E to $95^0 38^/$E covering an area of 3799 sq. km. As most parts of Assam, Tinsukia district enjoys high rainfall and humidity owing to its sub-tropical location (Gogoi, 2012). Topographically, the study area is covered mostly by plains with occasional hilly areas in its southern and northern parts.

The study area has an altitude of 147 metre above mean sea level. Tinsukia district is very rich in terms of natural land cover and a healthy amount of the total area comes under vegetation cover making the study area very significant in terms of biodiversity (Gogoi, 2012). The Brahmaputra river flows in the northern parts of the study area, keeping the land fertile, hence agricultural activities are predominant and lot of area comes under agricultural fields. As for settlement, the study area does not yet have very high pressure from built-up areas, however in the study period (1991-2020) there has been a steady increase in built-up areas which may pose threat to the LULC balance if adequate land use planning is not adopted.

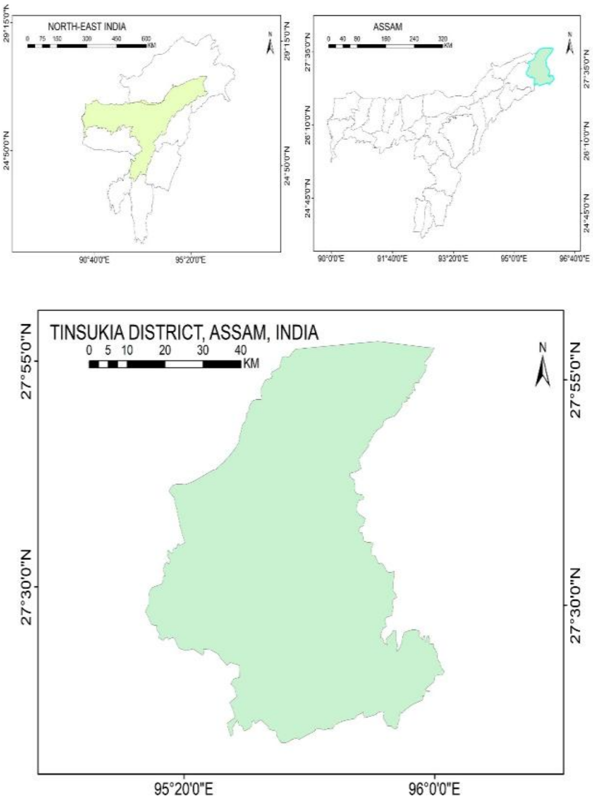

Fig. 1. Location of the study area

III. DATABASE AND METHODOLOGY

Landsat images has formed the base for the study. Landsat Thematic Mapper image of 1991 and Landsat OLI (Operational Land Imager) image of 2020 has been utilized for LULC classification and change detection. These datasets have been downloaded from http://earthexplorer.usgs.gov for free of cost. These datasets have been imported to ENVI 5.3 for LULC classification and LULC change detection. A detailed explanation of the adopted methodology is given in the following section.

Table-I: Satellite data used in the study

Sensors	Date	Path /row	Spatial resolution	source
Landsat 5 TM	1991-02-06	134/ 41	30	earthexplorer.usgs.gov
Landsat 8 OLI	2020-02-06	134/ 41	30	earthexplorer.usgs.gov

A. Image pre-processing

Radiometric calibration and atmospheric correction of all Landsat scenes has been carried out using ENVI 5.3. Radiometric calibration enables the user to convert the image digital numbers (DN) to spectral units, thus enhancing the image quality. On top of that, the fast line of sight atmospheric analysis of spectral hypercubes (FLAASH) module has been utilized for removing the atmospheric attenuations present in the image. A region of interest (ROI) consisting the extent of the study area has been created to mask out the study area from the whole Landsat scene.

B. LULC mapping

For LULC detection and mapping, the maximum likelihood classification (MLC) algorithm was preferred. MLC is a widely preferred classificatory method (Mosammam et al., 2016; Sharma et al., 2017) which seeks to classify each pixel of the image based on the highest probability assuming that probability of one pixel belonging to all classes are same (Richards, 1999; Rawat and Kumar, 2015). Seven classes have been taken into consideration for LULC mapping, e.g. sand, dense vegetation, waterbody, degraded vegetation, agriculture, barren land and built-up.

C. LULC change detection

LULC change detection and mapping has been performed using the change detection workflow in ENVI 5.3. The change detection workflow in ENVI allows to identify and quantify the difference between two classified images of two different dates. Two classified images of Tinsukia district of 1991 and 2020 acted as input files for the change detection analysis. A change detection map and change statistics was achieved through the process. The change statistics file comes in the form of a change matrix table where statistics of each class for the two dates (initial LULC image and later LULC image) is cross tabulated.

IV. RESULTS AND DISCUSSIONS

A. LULC status for the year 1991 and 2020

2 raster datasets have been prepared to understand the LULC distribution and pattern in the study area. The spatial and temporal LULC pattern is illustrated in fig. 2. The results obtained from the classification of satellite imageries reveals that for the year 1991 about 23% (862.4 sq.km) area of Tinsukia district was under agricultural land, 21% (798.8sq. km) was under barren land, 20% (772.2 sq.km) under degraded vegetation, 17% (661.8 sq.km) was under dense forest, 13% (473.4 sq.km) was under built-up area, 4% (150.8 sq.km) was under sandbar and 2% (81.01 sq.km) was under water body.

During the year 2020 the area under these categories was found about 31% (1186 sq.km) under agriculture, 20% (740.8 sq.km) under dense forest, 18% (699.5 sq.km) under built-up area, 17% (641 sq.km) under barren land, 7% (274.3 sq.km) under degraded vegetation, 4% (146.7 sq.km) under waterbody and 3% (111.9 sq.km) under sandbar.

International Journal of Innovative Technology and Exploring Engineering (IJITEE)
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Table-II: Class types of the land use land cover classification and their description

Class name	Description
Sand	Sandy areas in river bars and islands
Dense vegetation	Healthy vegetation cover
Waterbody	Natural and artificial waterbodies
Degraded vegetation	Moderately healthy vegetation, semi-natural and artificial vegetation cover
Agriculture	Agricultural fields, tea gardens
Barren land	Fallow lands
Built-up	Impervious surfaces

B. LULC changes from 1991-2020

The results showed that there has been a marked change in the LULC during the study period of 29 years. There has been an increase in the agricultural land use by 8% during the year 1991 and 2020 accounting for an area of 323.6 sq.km. Built-up area has also increased from 13% to 18% during the year 1991 to 2020 with a percentage increase of 5% accounting for an increase in area of 65.7 sq.km. it is also evident from the study that dense forest has also increased by 3% with an increase in area of 79 sq.km. However, there has been a decline in the degraded vegetation from 772.2 sq.km in the year 1991 to 274.3 sq.km in 2020 and the decrease

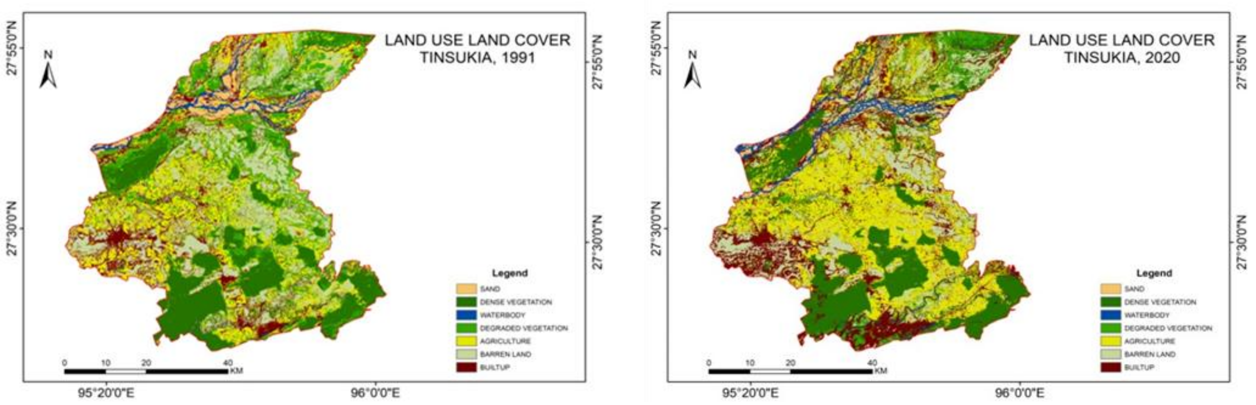

Fig. 2. Land use land cover of Tinsukia district in 1991 and 2020

Table-III: Area and amount of change in LULC categories in Tinsukia district (1991 to 2020)

LULC categories	1991		2020		Change 1991 to 2020	
	Area in km^2	%	Area in km^2	%	Area in km^2	%
Dense forest	661.84	17	740.87	20	79.03	3
Degraded vegetation	772.2	20	274.34	7	-497.86	-13
Agriculture	862.44	23	1186.06	31	323.62	8
Barren land	798.81	21	641.04	17	-157.77	-4
Built-up	473.41	13	699.5	18	226.09	5
Water body	81.01	2	146.76	4	65.75	2
Sandbar	150.82	4	111.94	3	-38.88	-1

percentage is calculated to be -13%. The barren land has also decreased from an area of 798.8 sq.km to 641 sq.km during the period of 1991 to 2020 with a decrease percentage of 4%.

The sandbar in the study area has slightly decreased in area from 150.8 sq.km in 1991 to 111.9 sq.km in 2020 which accounts for a percentage change in -1%.

Table-IV: LULC change matrix of Tinsukia district

Landuse categories	Year 1991 →						
Year 2020 ↓	Agriculture	Barren land	Built-up	Dense vegetation	Degraded vegetation	sand	water
Agriculture	59.1	22.7	25.1	7.6	37.6	15.1	13.9
Barren land	4.64	57.3	10	0.6	10.2	6.4	3.5
Built-up	18.9	12.1	43.9	6.7	16.9	24.7	21.7
Dense vegetation	8	0.3	3.4	79.5	16.3	0.4	0.4
Degraded vegetation	6.2	5.7	6	4.3	13.3	5.4	7.2
sand	1.2	0.6	4.6	0.4	2.5	23.2	20.5
Water bodies	1.7	1.1	6.7	0.5	2.9	24.6	32.6
Class total	100	100	100	100	100	100	100

A change detection matrix (Table 2) was prepared which reveals that:

i) About 4.6% area of agricultural land has been converted into barren land, 18.9% area under built-up, 8% area under dense forest, 6.2% area under degraded vegetation, 1.2% and 1.7% under sand and water bodies respectively.

i) About 22.7% area of barren land has been converted to agriculture, 12.1% area under built-up, 5.7% area under degraded vegetation whereas, 1.1%, 0.6% and 0.3% area under water bodies, sand and dense forest respectively.

ii) About 25.1% area of built-up land has been converted to agricultural land, 10% area under barren land, 6% and 6.7 % area under degraded vegetation and water bodies, whereas, 4.6% and 3.4% of area under sandbar and dense forest respectively.

iii) About 7.6% of area under dense vegetation has been converted to agricultural land, 6.78% of area under built-up, 4.3% area under degraded vegetation and 0.6%, 0.5% and 0.4% area under barren land, water bodies and sandbar respectively.

iv) About 37.6% of area under degraded vegetation has been converted to agricultural land, 16.9% area under built-up, 16.3% area under dense forest, 10.2% area under barren land whereas, 2.9% and 2.5% area under water bodies and sandbar respectively.

v) About 15.1% of area under sandbar has been converted to agricultural land, 24.7% area under built-up, 24.6%area under water bodies, 6.4% area under barren land, 5.3% area under degraded vegetation and 0.44% area

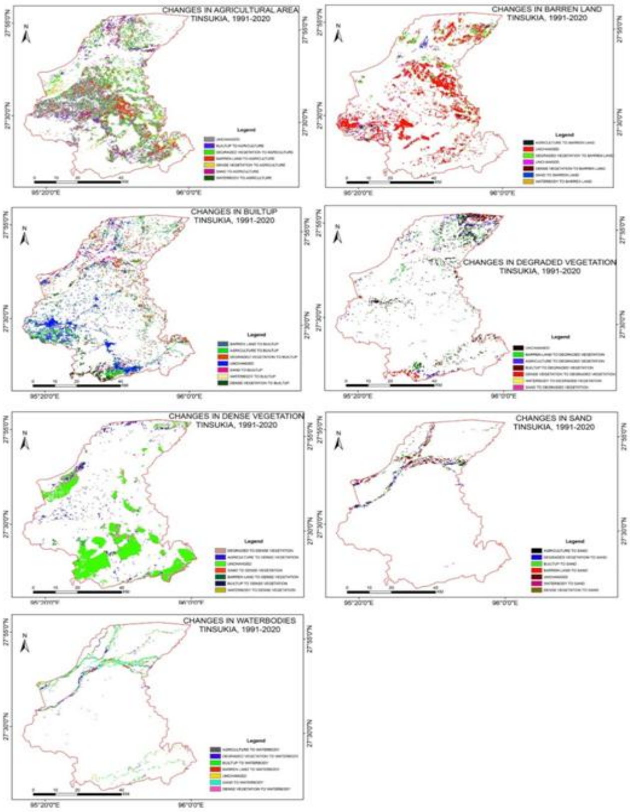

Fig. 3. Changes in LULC classes in Tinsukia district under dense forest.

vi) About 13.9% area under water bodies has been converted to agricultural land, 21.7% area under built-up, 20.5% area under sandbar, 7.2% area under degraded vegetation, 3.4% area under barren land and 0.4% area under dense forest.

V. CONCLUSION

In this study, LULC pattern, distribution and changes have been quantified using remote sensing datasets and methodologies. Seven land categories namely agricultural land, built up area, waterbody, dense vegetation, degraded vegetation, sand and waterbodies were taken into consideration for the LULC classification.

In 1991, the study area exhibited a healthy LULC pattern enjoying a substantial amount of natural cover with minimal pressure of modification in LULC from anthropogenic activities. However, in the recent past (2020) there has been notable changes in LULC pattern. Notable changes were recorded in agricultural area, built up area and degraded vegetation cover. Evidently, agricultural land increased from 862.4 sq. km to 1186 sq. km, built up area increased from 473.4 sq. km to 699.5 sq. km. Consequently, the amount of vegetation cover has taken a hit with a decrease from 772.2 sq. km in 1992 to a mere 274.3 sq. km in 2020. Such changes in LULC pattern will have manifold effects on LULC dynamics and land surface processes and may soon pose threats to local climates, surface runoff patterns, habitable environment and biodiversity. Hence, policy makers must come up with better land reformation policies before LULC dynamics gets disturbed beyond repair.

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