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Analysis of Land-use and Land-Cover Change Detection Using Geospatial Technology of Biswanath District of Assam, India

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ABSTRACT

Land-use and land-cover dynamics is a fundamental issue that has transformed the terrestrial environment across the globe owing to both natural and anthropogenic causes. This has led to the degradation of natural resources and therefore land-use studies have become prominent to understand the driving forces responsible for the unbalance occurring over the landscape. Based on the rate of change of LULC, the present paper aims to quantify the LULC status of Biswanath district in Assam over 20 years from 2000 to 2020 using geospatial technologies wherein the supervised classification with maximum likelihood classifier is performed.The entire region is classified into seven major classes and the dominant class is agricultural land. However, the significant net loss and gain are marked in the agricultural land, tea garden and forest categories. On the other hand, a negligible change is observed in vegetation and sandbar classes. The overall classification accuracy for the classified map of 2020 is calculated as 81.43% with overall kappa statistics at 0.812 that can be acceptable. Thus, the results of the present study would support and enhance the decision and policymakers to implement and formulate strategies for proper land-use planning to achieve sustainable development of the existing resources.

Keywords: Land-use, Land-cover, Geospatial, Sustainable, Spatio-temporal..

INTRODUCTION

The land-use land-cover (LULC) changes over time is a common occurrence globally that affect the ecosystem services, sustainability, communities as well as biodiversity (Kogo *et al.* 2019). The Earth's terrestrial surface is undergoing rapid land-use and land-cover change (LUCC) due to various anthropogenic activities as well as natural phenomena (Mishra *et al*. 2020). Constant alteration of the land-use might be the most ecologically significant anthropogenic impact on the global environment with serious implications of habitat loss and maintenance of biodiversity (Vitousek 1994, Wimberly and Ohmann 2004). The alarming growth of the human population, expansion of urban centers, scarcity of land, the need for more production, technological development are the main reasons responsible for the LULC changes in the present world (Barros 2004). This has developed into a major issue becoming an additional irreplaceable observation feature across the sphere (Gadrani *et al.* 2018, Cheruto *et al.* 2016) and is considered as a

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central component in current strategies for managing natural resources (Kaul and Sopan 2012).

Thus, it is necessary to have sufficient and updated information concerning land-use and land cover status of a certain area to prepare integrated plans for optimal utilization of natural resources, environmental monitoring as well as maintaining the ecological health (Chaudhary *et al*. 2008). In earlier, to detect LULC changes, the data were generated through various ground survey methods which were not only costly and time-consuming, but also unfeasible for monitoring dynamic changes over a short period accompanied by subjectivity and time constraints. But with the development of geospatial tools and techniques, a drastic change occurred in landscape mapping, modeling and monitoring in recent decades (Kushwaha and Oesten 1995). It is noteworthy that both Remote Sensing (RS) and GIS have long been recognized as indispensable and powerful tools in determining LULC changes at different spatial scales and the combined use of remote sensing and GIS has proved to be an accurate and cost-effective method to detect LULC changes (Twisa and Buchroithner 2019) more accurately.

Moreover, the digital change detection method has been also widely used for determination and description of the widespread changes in LULC patterns based on multi-temporal remotely sensed data because of its ability to quantify the uncharacteristic changes between two or more periods (Hassan *et al.* 2016, Lu *et al.* 2004). Several techniques have been used for change detection to identify the modifications by using various methods viz., image differencing, post-classification comparison, vegetation index differencing and principal components analysis (Lu *et al.* 2004). Keeping this in backdrop, the present paper is an endeavor to quantify the spatio-temporal changes of land-use and land-cover patterns of Biswanath District in Assam for the years 2000 and 2020 using geospatial techniques.

MATERIALS AND METHODS

Study site

The study site is one of the major administrative districts of Assam, India, located between the mighty river of the Brahmaputra and the Himalayan foothills of Arunachal Pradesh. Its latitudinal extension is 26°30' N to 27°00' N and longitudinal extension is 92°16' E to 93°43' E covering an area of about 1415.18 sq km. The study site is bordered by Arunachal Pradesh in the north, Brahmaputra River in the south, Lakhimpur District in the east and Sonitpur District in the west. The topography of the district is largely plain and apart from the Brahmaputra, many other small tributaries flow through the district viz., Ghiladhari, Burhigang, Behali, Burhoi, Moroni, Kharoi. The district falls in the sub-tropical climatic region and enjoys monsoon type climate. It experiences hot and humid summer with an average temperature of 29° C, cold and dry winter with an average temperature of 16 ° C. The study site has a rich biodiversity with evergreen and deciduous forest but the vegetation types and its floristic composition is largely influenced by the climatic condition of the area. It is covered mostly with moist deciduous forest, semi-evergreen forest, riverine forest, grassland as well as agricultural land.The total population of the Biswanath District is 6,12,491 with a density of 560 per sq km (Census of India 2011). Agriculture is the major source of livelihood in the rural areas of the district. Unprecedented increase in the human population of the area for the last few decades led to the loss of forest, habitat influencing the land use pattern of the district enormously (Fig. 1).

Data acquisition

The study is conducted analyzing Landsat 7 (Enhanced Thematic Mapper plus) and Landsat 8 (Operational Land Imager) images for two different years over 20 years (Table 1). The spatial resolution of Landsat 7 and Landsat 8 is 30 m respectively.

Pre-processing

The geospatial approach usually involves the usage of satellite images of multiple periods for quantifying the LULC changes in any area (Tsegaye *et al.* 2020). In the present study, Landsat 7 and Landsat 8 data have been selected for the periods of 2000 and 2020

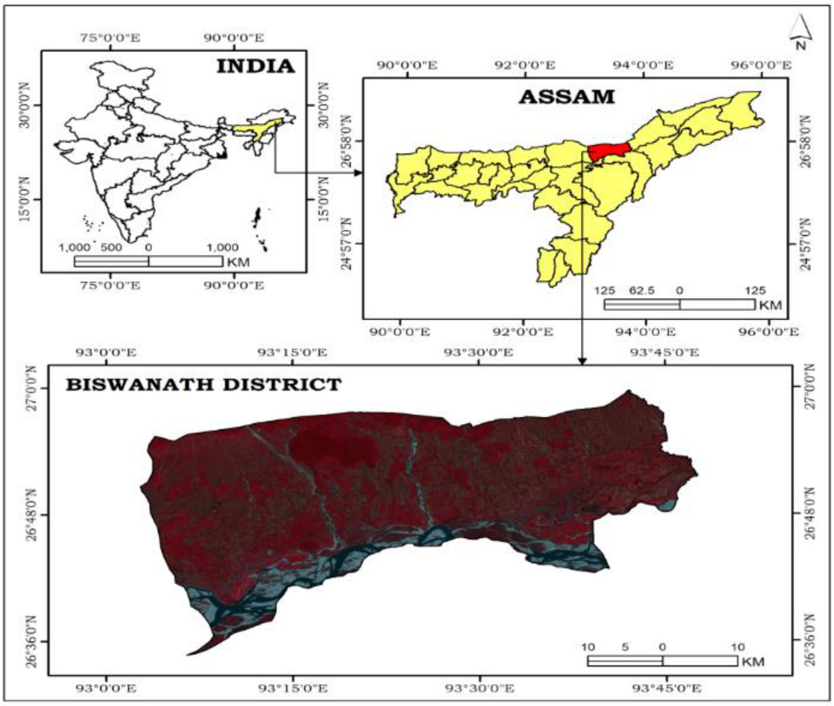

Fig. 1. Map of the study site.

respectively. For change detection analysis, image pre-processing is very important to establish a more direct relationship between the acquired data and physical phenomena (Abd El-Kawy *et al.* 2011, Hassan *et al.* 2016). The imageries composing of varied bands are superimposed to form a single multispectral image datas et through layer stacking (Al-Saady *et al.* 2015) and standard false-color composite (FCC) is created for LULC mapping.

LULC classification scheme

The information regarding LULC can be obtained from the multiband raster imageries through the process of image interpretation and classification (Liu and Yang 2015). All imageries are studied by assigning per-pixel signatures and differentiating the land area into seven classes based on specific Digital Number (DN) value of different landscape elements (Hassan *et al.* 2016). The defined classes are agricultural land, forest, tea garden, vegetation, mixed built-up area, water bodies and sandbars. A unique identity is provided to each class by assigning a particular color to make them separate from each other. Training samples are selected by delimiting polygons around representative sites to each of the predetermined land-use types. After that supervised

Table 1. Description of the spatial data sources.

Satellite	Sensor	Year	Spatial resolution
Landsat 7	Enhanced Thematic Mapper Plus (ETM+)	2000	30 m
Landsat 8	Operational Land Imager (OLI)	2020	30 m

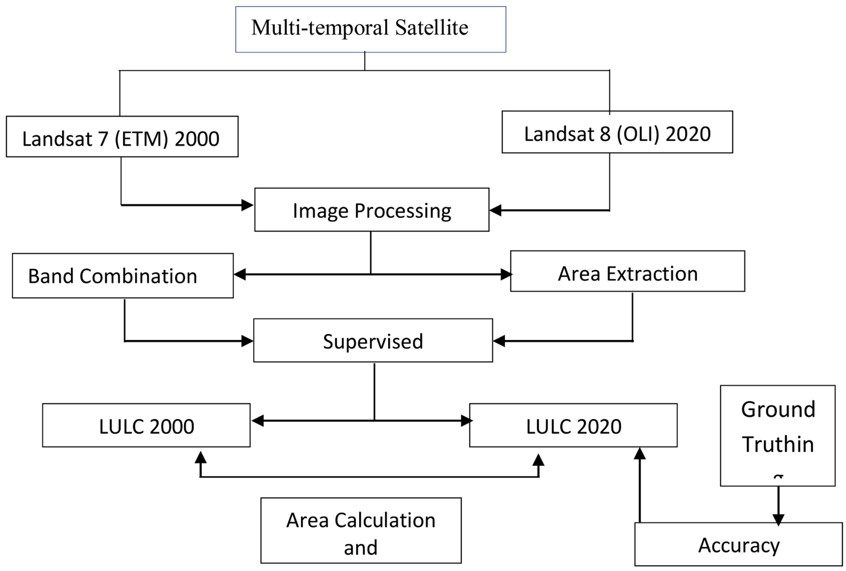

Fig. 2. Methodological flowchart.

classification method is performed by applying a maximum likelihood algorithm on the images. It is one of the major types of image classification that is mainly controlled by the analyst as he selects the pixels that are representative of the desired classes. Besides, ground verification of the study area through field observation and visual interpretation is also carried out.

Accuracy assessment

Accuracy assessment is very necessary for individual classification, if the classification data is to be used in the change detection process (Akinwale and Xie 2003, Hassan *et al.* 2016) and it is executed to omit certain error probability (Al-Saady *et al.* 2015). To perform this task, a stratified random sampling design is applied to describe the individual andcover classese xisting in the study area. Moreover, ground verification is also performed only for the year 2020 through the Kappa coefficient method by calculating users, producers and overall accuracies.

LULC change detection

Post classification comprising the change detection technique is key to all types of LULC studies as it detects the differentiation in terms of magnitude and nature for all landcover categories observed over a certain period (Kafi *et al.* 2014). A change matrix is executed to quantify the fundamental alteration that has taken place between 2000 and 2020 (Fig. 2).

Table 2. Area coverage under different LULC classes.

LULC class	2000 (Area in km^2)	2000 (Area in %)	2020 (Area in km^2)	2020 (Area in %)
Agricultural Land	1039.49	58.21	862.29	48.29
Forest	228.01	12.77	145.64	8.16
Tea Garden	74.07	4.15	237.63	13.31
Mixed Built-up	21.04	1.18	64.12	3.59
Vegetation	137.74	7.71	107.74	6.03
Waterbodies	121.03	6.78	176.27	9.87
Sandbar	164.37	9.2	192.06	10.75

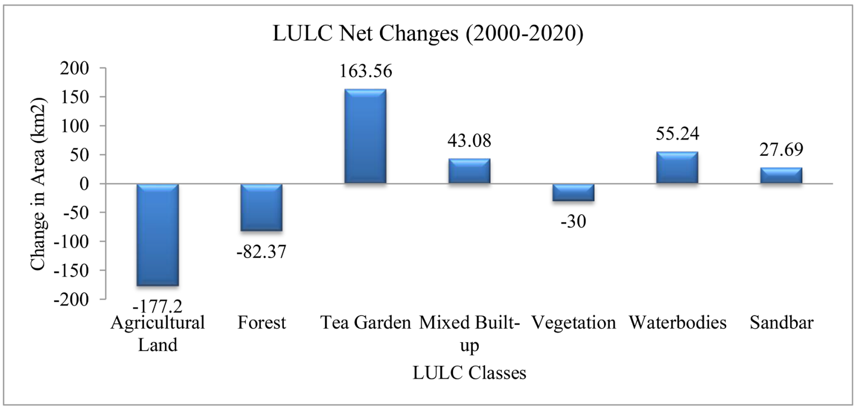

Fig. 3. LULC Net Changes between 2000 and 2020.

RESULTS AND DISCUSSION

LULC dynamics between 2000 and 2020

Biswanath District have been witnessing substantial changes in land-use land-cover during the last two decades. The entire area has been classified into seven major classes for identifying the change detection viz., agricultural land, tea garden, vegetation, forest, sandbars, water bodies and mixed built-up for the years 2000 and 2020 which are displayed in the Figs. 3-5. The areas occupied under the respective categories are represented in Table 2. The results showed that during 2000, the agricultural area had the largest share of the total LULC categories assigned which is 58.21% (1039.49 km^2) of total land area. Similarly, area covered by other categories are as 12.77% (228.01 km^2) in forest, 9.20% (164.37 km^2) in the sandbar, 7.71% (137.74 km^2) in vegetation, 6.78% (121.03 km^2) in waterbodies, 4.15% (74.07 km^2) in tea garden and only 1.18% (21.04 km^2) in mixed built-up area. On the other hand, in 2020, the agricultural land occupied 48.29% (862.29 km^2), 13.31% (237.63 km^2) by tea garden, 10.75% (192.06 km^2) by sandbar,

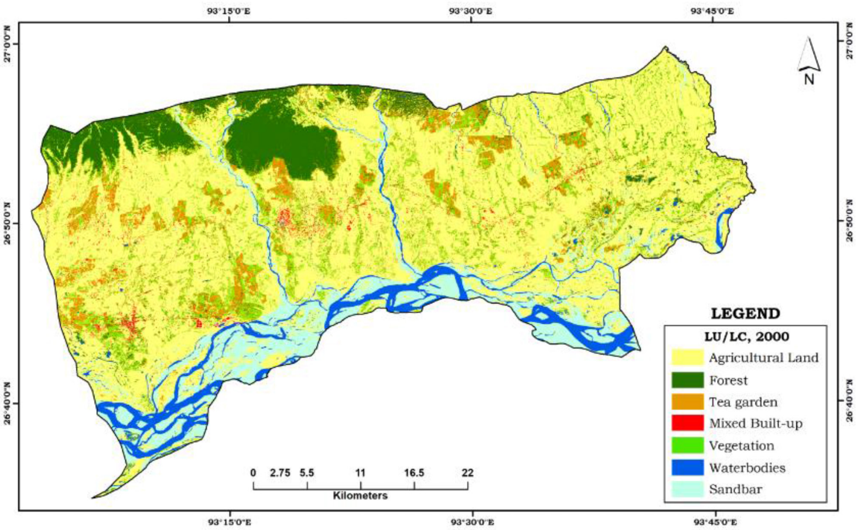

Fig. 4. LULC map of 2000.

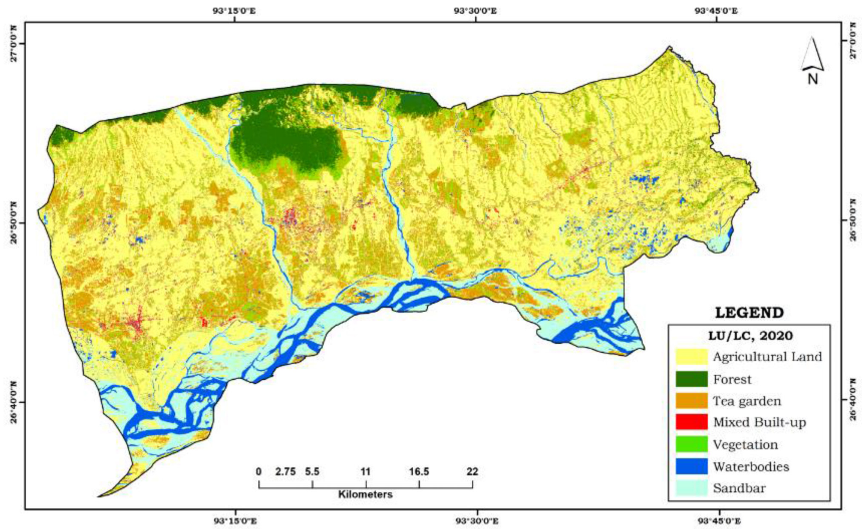

Fig. 5. LULC map 2020.

9.87% (176.27 km^2) by waterbodies, 8.16% (145.64 km^2) by forest, 6.03% (107.74 km^2) by vegetation and 3.59% (64.12 km^2) by mixed built-up area.

Amongst all identified classes, agricultural landforms the largest in the study site and has recorded the highest changes during the study periods. It has reduced from 58.21% (1039.49 km^2) in 2000 to 48.29% (862.29 km^2) in 2020 which is about an area of 177.2 km^2. The main reason for this change is tremendous shift in the land-use practice from crop cultivation to tea plantations in the district. Moreover, a significant proportion of agricultural land was lost due to the expansion of the built-up area during this period. Dense forest cover also declined remarkably during the study period due to the rapid population growth in the district. It was 12.77 % (228.01 km^2) in 2000 and decreased to 8.16% (145.64 km^2) in 2020. The area under open forest cover is also declining due to the rapid growth of small scale rural tea plantation and built-up area. Mainly the rural people of the region cleared open forest areas and started tea plantation from the mid of the 1st decade of the 21st century leading to tremendous deforestation in rural areas. As per the present study, the open forest area reduced from 7.71% (137.74 km^2) in 2000 to 6.03% (107.27 km^2) in 2020.

The land cover occupied by the tea garden is rapidly growing in the study area for the last two decades. In 2000, the area covered by the tea garden was only 4.15% (74.07 km^2) of the total land area of the

Table 3. Error matrix table of LULC classified image 2020.

LULC class	Agricultural land	Forest	Tea garden	Mixed built-Up	Vegetation	Waterbodies	Sandbar	Classified total
Agricultural land	23	0	3	0	1	0	0	27
Forest	0	25	4	0	2	0	0	31
Tea garden	3	2	23	0	3	0	0	31
Mixed built up	0	0	0	19	2	0	1	22
Vegetation	4	3	0	5	22	0	0	34
Waterbodies	0	0	0	0	0	30	0	30
Sandbar	0	0	0	6	0	0	29	35
Reference total	30	30	30	30	30	30	30	210

Table 4. Producer's and user's Accuracy assessment of 2020 classified image.

LULC class	Reference total	Classified total	Number correct	Producer accuracy	User accuracy
Agricultural land	30	27	23	76.67	85.19
Forest	30	31	25	83.33	80.65
Tea garden	30	31	23	76.67	74.19
Mixed built-up	30	22	19	63.33	86.36
Vegetation	30	34	22	73.33	64.71
Waterbodies	30	30	30	100	100
Sandbar	30	35	29	96.67	82.86

Table 5. .Change detection during the study periods.

LULC class	2020 Area in km^2 Agricultural land	Forest	Tea garden	Mixed built-up	Vegetation	Waterbodies	Sandbar	Grand total 2000
Agricultural land	**790.56**	0.03	134.17	34.01	1.41	64.05	15.26	1039.49
Forest	51.15	**136.92**	29.59	1.06	9.29	0	0	228.01
Tea garden	0.01	0	**71.49**	0.31	2.26	0	0	74.07
Mixed built up	0.43	0.08	0.07	**20.44**	0.02	0	0	21.04
Vegetation	9.54	8.41	2.31	8.18	**94.39**	0	14.91	137.74
Waterbodies	3.08	0.07	0	0	0.21	**109.01**	8.66	121.03
Sandbar	7.52	0.13	0	0.12	0.16	3.21	**153.23**	164.37
Grand total 2020	862.29	145.64	237.63	64.12	107.74	176.27	192.06	**1785.75**

district, but in the year 2020, it rose to about 23.32% (237.63 km^2). A total of 163.56 km^2 area has increased under tea plantations during the study period. This category gained most of its area from rice cultivation, *rabi* and *kharif* cultivable land because of its higher economic returns. The small scale tea plantation of the district was started in the mid-1990s and at present, the rural landscape of the district, especially that of the Biswanath sub-division, is characterized by the presence of a large number of small scall tea garden (Sharma and Barua 2017). The built-up area is also expanding noticeably in the district which are mainly encroaching the agricultural land, wetland and forest area. The growing built-up have adversely affected the environmental quality of the area, especially when it expands along roads and peripheral zones (Kuchay and Bhat 2014). During the study period, the built-up area of 43.08 km^2 has increased. Another two important land-use classes viz., water bodies and sandbar are also rising significantly during this period. Water bodies have increased from 6.78% (121.03 km^2) in 2000 to 9.87% (176.27 km^2) in 2020. On other hand, the sandbars have increased by 9.2% (164.37 km^2) in 2000 to 10.75% (192.06 km^2) in 2020. This alteration is the result of significant morphological changes of the rivers flowing through the district.

Accuracy assessment

Accuracy assessment index is a crucial part of the classification process as it quantitatively determines the extent of correspondence between ground data and the real world to check its accuracy and reliability (Rwanga and Ndambuki 2017). For this, an error matrix table is produced that represents the individual classes of LULC classified image for the year 2020 (Table 2). On the other hand Table 3 presents the user's and producer's accuracy along with the kappa coefficient. Moreover, the overall accuracy from the classified map of 2020 is computed as 81.43% with overall kappa statistics as 0.812 that can be acceptable (Table 4).

Land cover change detection

The changes witnessed in the region among the identified classes have been further detected through post-classification comparision approach (Yesuph and Dagnew 2019). This technique is concerned with generating "from-to" maps to detect the changes in each individual LULC category (Erasu 2017). The cross-tabulation matrix signifies that a major portion of agricultural land is converted to tea garden (134.17 km^2), water-bodies (64.05 km^2) and mixed-built up (34.01 km^2). Similarly, a significant part of forest cover have also been transformed mainly to agricultural land class while vegetation cover is converted basically to sandbars (14.91 km^2) and agricultural land (9.54 km^2). Thus, the matrix table (Table 5) representing the individual classes and their conversion to other classes are vividly described along with their respective areas.

CONCLUSION

The land-use land-cover changes are detected by the remote sensing satellite images with different spectral, spatial as well as temporal resolutions. This study shows the array of land-use land-cover changes between 2000 and 2020 in the Biswanath District of Assam, India. The identified land-use classes have shown the substantial change pattern of the study area. The LULC categories such as mixed built-up, tea gardens, water bodies and sandbars revealed an increasing trend whereas the agricultural land, forest, as well as vegetation cover, revealed a declining trend from 2000 to 2020. Most of the landuse are unplanned and are a result of anthropogenic activities causing multifarious damages to the environment. Therefore, this work might provide an input to the policymakers as well as the Government in understanding the scenario of LULC changes for formulating some eco-friendly land-use policies in future by enhancing the landuse planners to relocate the resources in resource deficit areas.

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