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Change detection analysis using Landsat images on Balurghat Municipality, West Bengal, India

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Abstract

The major focus of the current study is a spatio-temporal analysis of land use and land cover changes in Balurghat Municipality, West Bengal, using remote sensing and geographic information systems (G.I.S.) from 1990 to 2020. The primary goals are to identify changes in land use and land cover and to look at the key influences and how they affect the dynamics of the landscape. The Landsat images of the study area are classified into five categories with the help of GIS software and Google verified and validated by the process of accuracy assessment. An image has been classified digitally with the help of the Supervised Image Classification method under Maximum Likelihood Classification techniques which also helps to identify the transformation of land from vegetation cover to built up area.
Keywords: *Change detection, Transformation of land, Supervised Image Classification, Maximum likelihood classification, Land use and Land cover.*

Introduction

The land is a product of nature and it is an example of three-dimensional dynamic complex bodies. A part of land developed through the interaction of lithology, structure, drainage, climate, vegetation, and the geomorphological processes operating through time. As a result, different types of landforms have evolved in different parts of the earth (Roy& Shaikh, 2021). Top most solid layer of earth surface which is known as land and Land cover is the biophysical state of the earth's surface particularly immediate surface (Turner et al., 1995). Land cover refers to the natural vegetative cover types that characterize a particular area. These are generally a reflection of the local climate and landforms, though they too can be altered by human actions. Therefore, land use change may involve either Conversion from one type of use to another, or, Modification of a certain type of land use. We have already noted that Land Use describes human uses of the land, or immediate actions modifying or converting land cover and includes such broad categories as human settlements, protected areas and agriculture. The land use change may involve either (a) conversion from one type of use to another or (b) modification of a certain type of land use (Briassoulis, 2002, Roy& Shaikh, 2021). Changes in Land Use and Land Cover have significant impacts on local physical environmental conditions and economic and social welfare. A landscape is a natural arrangement on interrelated tracts of land which is very complicated in nature, the study of landscape dynamics it is very much relevant for land use land cover planning management (De & Jana, 1997). Recent research on land use and land cover change detection has drawn attention of many researchers (Liang et al. 2002; Ayele et al. 2016).Change detection has a significant process for managing and monitoring natural resources and urban development mainly due to the provision of quantitative analysis of the spatial distribution based on a temporal scale. There are a lot of available techniques that serve the purpose of detecting and recording differences and might also be attributable to change (Singh, 1989). Remote Sensing (RS) and Geographic Information System (GIS) are now providing new tools for advanced ecosystem management. The collection of remotely sensed data facilitates the synoptic analyses of Earth – system function, patterning, and change at local, regional and global scales over time; such data also provide an important link between intensive, localized ecological research and regional, national and international conservation and management of biological diversity (Wilkie & Finn 1996, Patra &Gavsker,2021). Balurghat is the headquarter of the Dakshin Dinajpur district but in 60 years ago it had been a mere village, in the historical context of the partition of India and East Pakistan(1971), overnight made its appearance as a town and today it has been turned into a Class-I urban centre of district. Due rapid urbanization, still different problems such as population growth, dramatically changed land cover and land use pattern, urban environmental degradation and gaps are related to the development, don't use any kind statistical based and satellite image based study on urban growth and landscape dynamics of this town are (Kundu,2018).

Objectives:

The present study focused on the following major objectives-

a) To examine the pattern of population growth.
b) To identify the land use and land cover change detection.
c) To identify major land use and land cover problems and provide some probable solutions.

Study area

The name of the town Balurghat has been probably derived from 'BALUKAKIRNAGHAT' meaning a 'ghatfull of sand' (Roy, 2000). The study area is Balurghat municipality under Balurghat community development block of South Dinajpur district. Balurghat, Khadimpur, Bongi, Narayanpur, Barargunathpur, part of Hosseinpur, and Dakra are all included in the Balurghat municipal area. It is lies between 25°12’29’’ N to 25°16’17’’ N and 88°44’48E to 88°47’27’’ E (Figure1). The study area had 151,299 people living there as of the 2011 Census, covering an area of just under 10.74 sq. km. 23wards are available in this municipality and river Atreyee runs across the city, dividing it into disproportionate halves. On the eastern bank of the river is where the city's vital administrative, cultural, and entertainment units are located. The border between India and Bangladesh is 3 km away from the township (Kundu,2018).

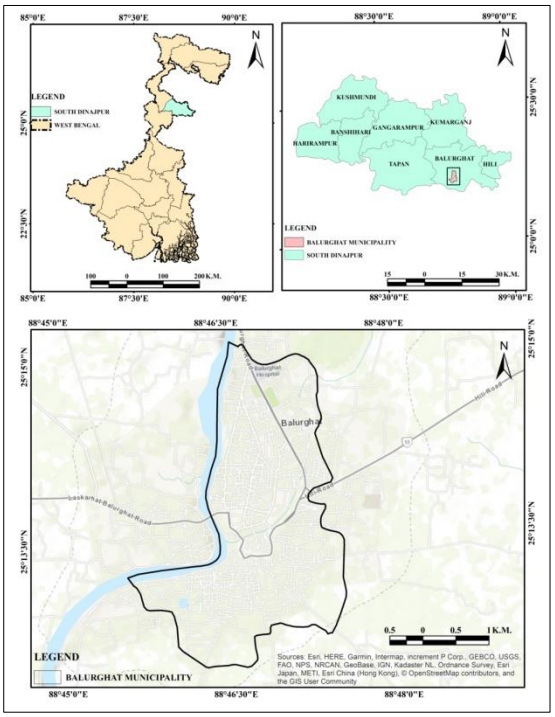

Figure1.Map of study area

Materials and methods

This research is based on cloud free, error free satellite images from USGS data archive on various dates (Table1). For the improving the image accuracy, satellite images should be preprocessed before using. GIS mapping techniques, cartographic techniques and various statistical analyses have been done to fulfill our research objectives. Arc GIS 10.2 and QGIS 2.18 have been used for location map, supervised image classification with maximum likelihood algorithm and transformation of land characteristics. MS-Excel (07) and Power Bi software have been used for statistical calculation and cartographic techniques. Figure 2's flow chart illustrates the approach used in the current study.

Supervised Image Classification

The goal of image classification is to classify all of the pixels in digital image into various landuse and landcover classes. There are two forms of classification, depending on how the computer and interpreter interact during the process. When an analyst has extensive expertise of the field, supervised classification—one of the two main approaches of picture classification—is typically selected. The analyst performs these classifications using a three-stage method that includes training, classification, and output. The analyst chooses training sites to reflect regions with well-known cover kinds throughout the training phase. In this process, the analyst selects training pixels that are representative of the desired land use classes. In the present study, for each class around 25 training samples are taken into account. The sample selection sites from various landuse and land cover categories are shown in Table 1.The classification stage is the second step in supervised classification; it involves categorizing a variety of spectral bands into precise categories of land use and land cover. The output stage is the final outcomes of the image which are presented, visualized, and interpreted using output products. In this research supervised image classification method has been adopted to demonstrate the change detection over a 30-year period. In this classification five different landuse and landcover features have been identify to validate our research goal. Each and every image is independently classified in a supervised classification method with the help of a maximum likelihood algorithm using Arc GIS (10.2) software.

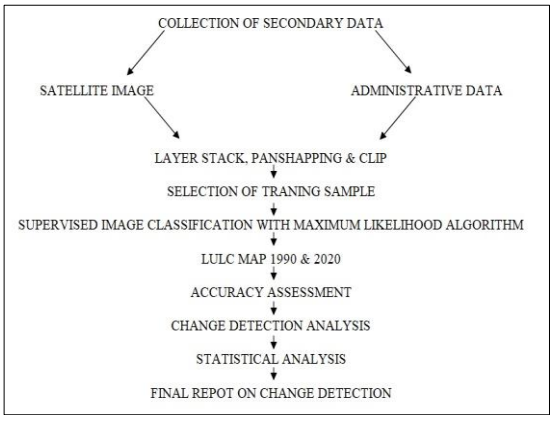

Figure 2.Flowchart of methodology

Table 1: Secondary Data source of this research

SPATIAL DATA	DATA	DATA SOURCE	DATE OF ACQUISITION
SATELLITE IMAGE	Landsat 5 TM	USGS Earth Explorer	30.01.1990
	Landsat 8 OLI/TIRS	PATH : 138/ ROW:48	20.02.2020
ADMINISTATIVE AREA	Village Shape file	https://sedac.ciesin.columbia.edu	01.07.2022
NON SPATIAL DATA	South Dinajpur District Census Hand Book,2001 & 2011		
	District Statistical Hand Book South Dinajpur 2014		

Source: *Prepared by author, 2022.*

Table 2: Land use and land cover classes of the study area

LANDUSE AND LAND COVER CLASS	DESCRIPTION
Waterbody	Rivers, Canals, Ponds.
Sand	Riverian Sands.
Vegetation area	Deciduous Forest Lands,Gardens, Mixed ForestLands, Roadside or Riverside vegetation areas etc.
Open space	Stadium, Play Ground, Park, Recreational spot and Project area under construction, permanent or current fallow.
Builtup area	Residential,Commercial and Services lands.

Source: *Prepared by author, 2022.*

Accuracy Assessment

The term 'accuracy' is often used to indicate the measure of correctness of a derive map which can be tested by using an error-matrix. Remote sensing studies have been focused on accuracy assessment as a key component. It is necessary to gather some in-situ data or a priori knowledge about specific features before comparing them to the classification map produced by remote sensing in order to quantitatively evaluate classification accuracy. Consequently, comparing two classification maps is required to evaluate classification accuracy. 1) The map obtained from remote sensing, and 2) real map. The presumed genuine map may be from on-the-ground research or, more frequently, from the interpretation of remotely sensed data collected at a greater scale or resolution. The most popular method for determining accuracy is error matrix analysis (Khorram et al. 2013). The change detection process relies heavily on individual classifications.

Table 3: Status of Kappa (Rwanga, 2017)

VALUE OF KAPPA	STATUS OF KAPPA
< 0	Poor
0 – 0.2	Slight
0.21 – 0.4	Fair
0.41 – 0.6	Moderate
0.61 – 0.8	Good
> 0.81	Very good

Source: *Prepared by author, 2022 & Das &Sahu, 2020*

As a result, a thorough examination of accuracy must include a report on overall accuracy, user accuracy, and producer accuracy, all of which were examined using the Kappa coefficient (Table3).

Statistical Calculation

Correlation analysis is a statistical analysis which allows researchers to explore the degree of association within independent and dependent variables (Schober&Schwarte, 2018; Senthilnathan, 2019).

$$\mathbf{r} = \frac{\sum(X\mathrm{i}-\bar{\mathrm{x}})(\mathrm{Yi}-\bar{\mathrm{y}})}{\sqrt{(X\mathrm{i}-\bar{\mathrm{x}})^2\sum(\mathrm{Yi}-\bar{\mathrm{y}})^2}}$$

Where, 'r' is the Pearson's product moment correlation coefficient, 'x_i' is values of x variable in a sample,'$\bar{x}_i$' is mean values of x variable, y_i is the value of y variable in a sample and '$\bar{y}_i$'is mean values of y variable.

Scatter plots were created by using regression analysis to demonstrate the pattern of transformation of land from the year 1990 to 2020. Pearson's product-moment correlation coefficient (PPMCC) has been used to measure the direction and strength of the relationship between two variables and regression analysis established the functional relationship between independent (x) and dependent (y) variables (Zhao, 2013). Linear regression is used to ascertain the impact of several numbers of independent variables like X1, X2,X3…Xi on a single dependent variable y Symbolically.

$$y = \beta_0 + x_1 \beta_{1+\ldots} x_p \beta_p + \varepsilon$$

Where, 'β' reflects how much x effects on yand 'Ɛ' is the error term.

Results and discussion

Population Growth

The political reasons for the country's split in 1947 and in 1971 as a result of the Bangladesh war are the key factors that led to the formation of Balurghat Town. This area was first incorporated in East Pakistan by British attorney Sir Radcliff. Later, Radcliff was forced to reverse his choice as a result of the persistent efforts of Mr. Satindranath Basu and Dr. Sushil Ranjan Chatterjee. So, three days later, on August 18, 1947, Balurghat experienced the taste of independence and it was designated as the administrative centre of the West Dinajpur District. Previously a little settlement patches were converted into Balurghat municipality status in 1951 at a small room of the "1928 Club" by Notification No. M1M-40/50 (1) dt. 24th May, 1951 with a population of 18,121 and an area of 6.37 sq. km. The Municipality began operations formally on June 18, 1951, with five wards operating under a nominated authority (Kundu,2018). The population data are collected from census handbook of South dinajpur district showing the continuous population growth in Balurghat municipality from 1951 to 2011 and r2 value showing the population growth over time.

According to Census (2011), present Municipality has 23 wards with 10.74 sq.km total area and total population is 1, 53279. The town is primarily an administrative town having overall population density 6213 persons per sq km. According to census highest decadal growth rate had been recorded in the year 1971, which was 148.48% due to independence war of Bangladesh. **Figure 3** line graph illustrates the continuous flow of population growth.

Infrastructural development is the major threshold area on which developments depends upon in an area (Arif, 2018). It is one of the most significant pull factor for the migrate people. The phenomenon of urbanization therefore occurs on an area and involves links and nodes to create a total system (Sharma, 2012). We are classified urban service basic on their functionality in to six categories such as administrative sector, educational sector, health sector, transport sector, market and recreational sector. The degree of urbanization generally refers to the relative or absolute number of people who live in places defined as urban (Kundu, 2013).

$$\text{Degree of urbanization} = \frac{Urban\ Population}{Total\ Population)} * 100$$

$$= (153279/248907)*100 = 61\%$$

The rate of urbanization is 61 percent, which is significantly greater than India's rate of urbanization. Due to a lack of adequate urban infrastructure, Balurghat is getting increasingly crowded and congested.

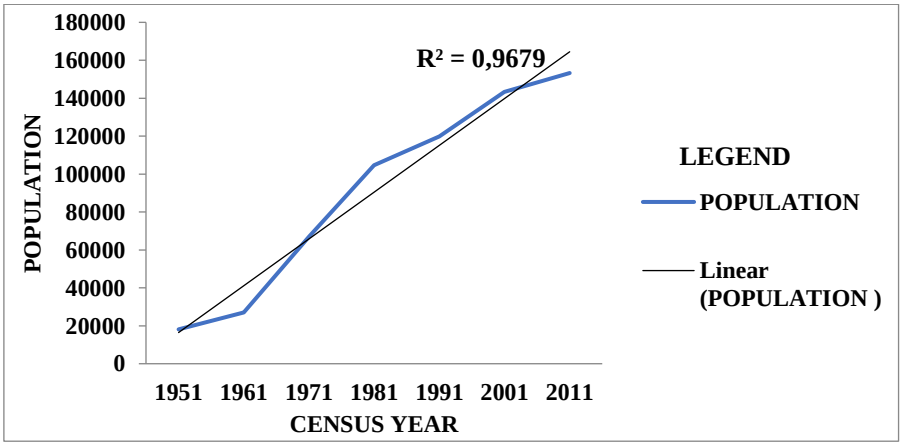

Figure 3: Population Growth of Study Area from 1951 to 2011

Land use and Land cover Change

Detection of changes in the land use / land cover involves use of at least two period data sets (Jenson, 1996). Therefore, spatial changes including surface organization of the land use and land cover and their inter-relationship with a focus on direction and spread are well explained (Patra and Gavsker, 2021). A substantial portion of the research region is revealed to be urban in nature, with little in the way of greenery or open space (Figure4)

Land use and Land Cover Classification 1990

Land use land cover classification was done in the study area under the supervised classification method using maximum likelihood algorithm. On the basis of the number of pixels, the area of each class was calculated

(Das & Sahu, 2020). Based on the land use land cover map of 1990 the area and percentage of areas as classified are water bodies 2.88 % (0.31 Sq.Km.), sand 0.93%(0.1Sq.Km.), vegetation area 33.79 % (3.63Sq.Km.), open space 16.79 % (1.8Sq.km.) and built up area 45.62% (4.9 Sq.Km.). The dominated land use class was built up area and main land cover type was vegetation cover.

Land use and Land Cover Classification 2020

In other hand based on the land use land cover map of 2020 the area and percentage of areas as classified are water bodies 4.18 % (0.45Sq.Km.), sand 1.86 %(0.2 Sq.Km.), vegetation area 14.05 % (1.51 Sq.Km.), open space 18.43 % (1.98 Sq.Km.), and built up area 61.45% (6.6 Sq.Km.). The dominated land use class was built up area and main land cover type was vegetation cover. In case of spatio temporal change it is very indicated that most part of the vegetation cover and open space are transform into or built up area.

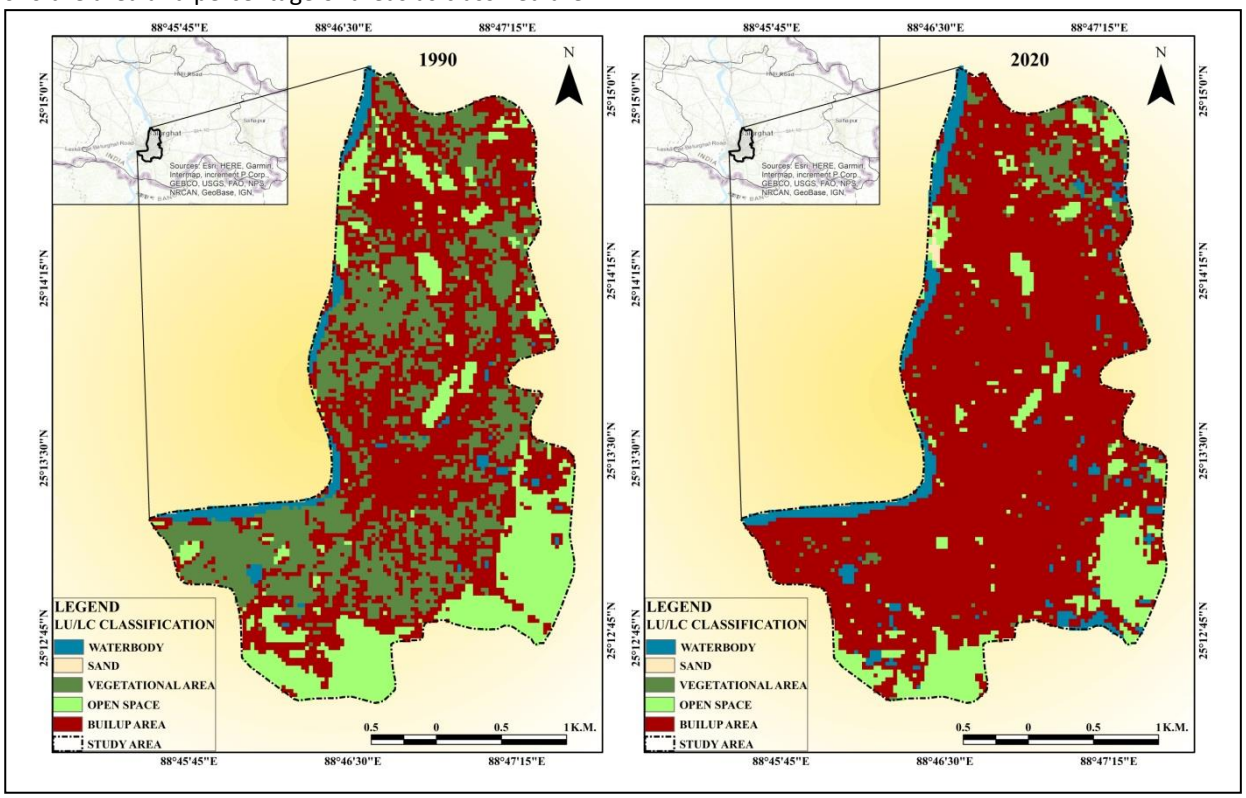

Figure 4: Land use and Land cover map of the study area from 1990 to 2020

Accuracy Assessment:

Accuracy assessment is one of the most crucial stages of the research to confirm our work with genuine earth. Kappa coefficient analysis is one of the most helpful approaches to determine the accuracy evaluation of a study. For the accuracy assessment random sampling method has been used over 100 samples, collected samples are compared between Google Earth image and Landsat images and Table 4 are represent the kappa value which was express the level of accuracy of our research (Kaimais& Patidar,2016). According to Rwanga's (2017) classification (Table 3) the values of kappa are under good to very good scale.

Table4:Summary of Accuracy Assessment from 1990 to 2020

LU/LC CLASSIFICATON TYPE	1990		2020	
	USER'S ACCURACY	PRODUCER'S ACCURACY	USER'S ACCURACY	PRODUCER'S ACCURACY
WATERBODY	0.78	0.88	0.8	0.94
SAND	0.8	0.75	0.82	0.87
VEGETATION	0.76	0.76	0.8	0.92
OPEN	0.8	0.85	0.85	0.85
BUILUP	0.92	0.81	0.92	0.81
OVERALL ACCURACY	**0.815**		**0.881**	
KAPPA	**0.769**		**0.834**	

Source: Prepared by author, 2022

Change detection

Boriah et al., (2008) have performed a new change detection technique for the landcover change detection, especially for remote sensing data. An important aspect of change detection is to determine, which is actually changing to what extent, in other words to check, which landuse class is changing. The outcome results will reveal both the desirable and undesirable changes along with relatively stable categories overtime. This information works as a vital tool in management decisions (Opeyemi, 2006). In this section the attempt is made to check the trend, rate and magnitude of changes in land use / land cover of study area. Table 5 and Figure 5 are representing the spatial change over study area.

Table 5: Summary of Accuracy Assessment from 1990 to 2020

LU/LC CATEGORIES	1990		2020		Area Change		VALUE OF R SQUARE
	Area	%	Area	%	Area	%	
WATERBODY	0.31	2.88	0.45	4.18	0.14	1.3	**0.826**
SAND	0.1	0.93	0.2	1.86	0.1	0.93	**0.89**
VEGETATION COVER	3.63	33.79	1.51	14.05	-2.12	-19.74	**0.858**
OPEN SPACE	1.8	16.79	1.98	18.43	0.18	1.64	**0.79**
BUILTUP AREA	4.9	45.62	6.6	61.45	1.7	15.83	**0.811**

Source: Prepared by author, 2022

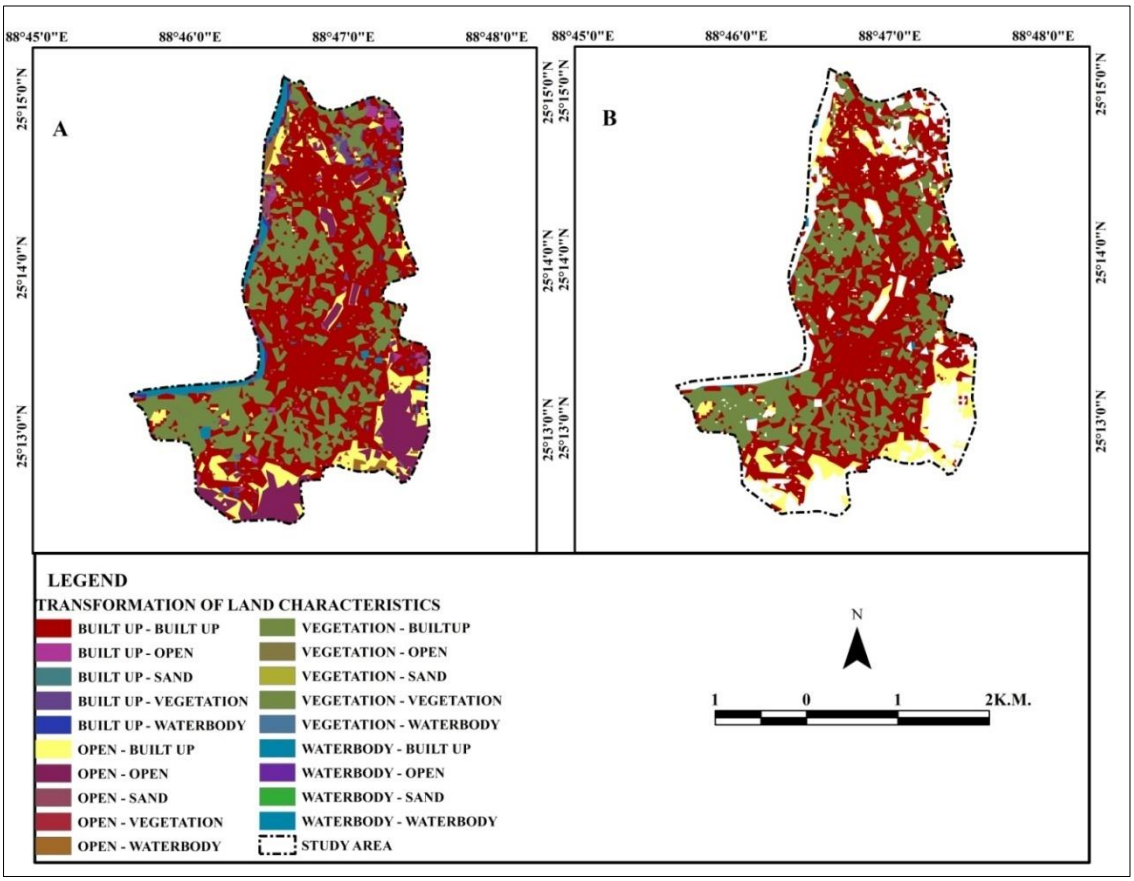

Figure 5: A. Change Detection of land characteristics of the study area from 1990 to 2020 and B. Expansion Built up area

- **Water body**

A river called River Atreyee flows from north to south direction in this region and there are many lakes, ponds and tanks etc have been found. In 1990 the water bodies hold 0.31 sq.km areas which were almost 2.88 % of the total area. But in 2020 the water bodies hold 0.45 sq.km areas which were almost 4.18 % of the total area. So it's clear that from 1990 to 2020 total areas of water bodies continuously increasing nearly 1.3% and the r2 value of water body is 0.826 which indicates the rate growth of water body within this time (Table 5 and Figure 6).

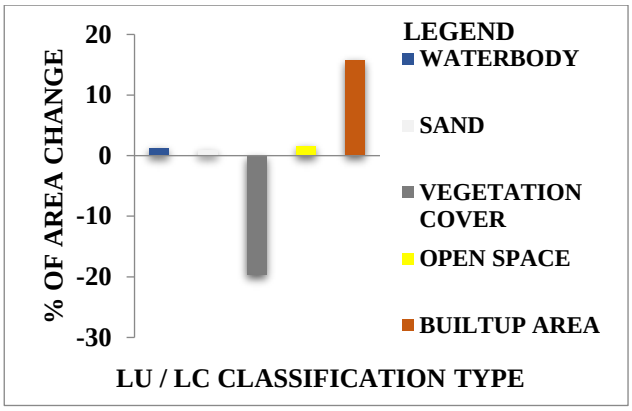

Figure6: Change detection of the study area from 1990 to 2020

- **Sand**

Sand area mainly found in the river floodplain. Sand covered 0.1 sq. km in 1990, or roughly 0.93 percent of the total area but in the 2020 sand holds 0.2 sq.km areas which were almost 1.86 % of the total area. Therefore, it is evident that total sand areas was increased by roughly 0.93 percent between 1990 and 2020, and the r2 value 0.89, so it is shows the pace at which sand will expand during this period (Table 5 and Figure 6).

- **Vegetation cover**

North Eastern, South and South Western parts of the region are covered by dense forest (Figure4). In 1991the vegetation cover was 3.63 km2 areas, about 33.79 % of the total area. But the area decreased to 1.51 km2 (14.05%) in 2020. Hence it's clearly analyzed that from 1990 to 2020 the amount of vegetation cover continuously decreased nearly 19.74 percentage of area. Also the r2 value of vegetation cover is 0.858 which indicates the rate of extensive declining of vegetation cover within this time (Table 5 and Figure 6).

- **Open space**

Stadium, Play Ground, Park, Recreational spot, Project area and under construction area etc are categorized as open area in LULC map. Generally this natural open area has been converted into urban sector and few of them remain static. This area experience a little change with an aerial extent of 1.8 km2 in 1990 which was 16.79% of the total area and 1.98 km2 (18.43%) in 2020. Value of r2 open area is 0.79 indicating the low positive value and showing its significant level of complexness according to time (Table 5 and Figure 6).

- **Builtup area**

An urban sector's area are includes residential, commercial, and other administrative buildings. Accordingly the area included under built up area was 4.9 km2 in 1991 which was 45.62 % of the total area and in the year 2020 the area is 6.6 km2 (61.45%) of the total area respectively. The transformation and growth of built up areas mainly from eastern to south eastern part of the municipality area (Figure 4). Value of r2 built up area is 0.811 is the indication of highly positive development of built up area within time and roughly 15.83 percentage area had been take a positive change(Table 5 and Figure6).

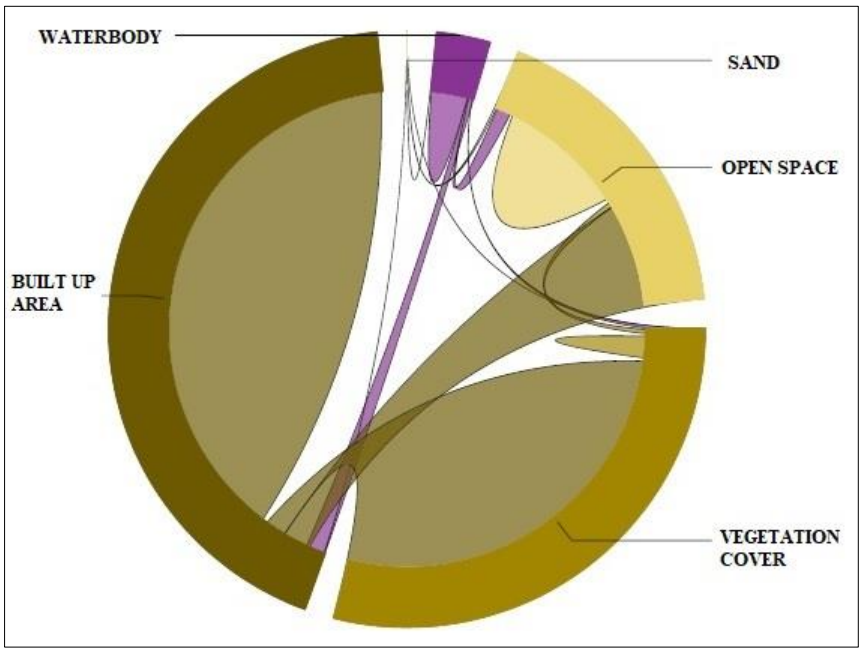

Figure 7: Transformation of land characteristics of the study area from 1990 to 2020

Figure 7 is useful for determining the rate of change, whereas Table 5 and Figure 6 primarily aid in identifying the region of change during the course of the research. The primary land characteristics have shifted from vegetation cover (2.44%) and open space (0.63%) to built-up area.

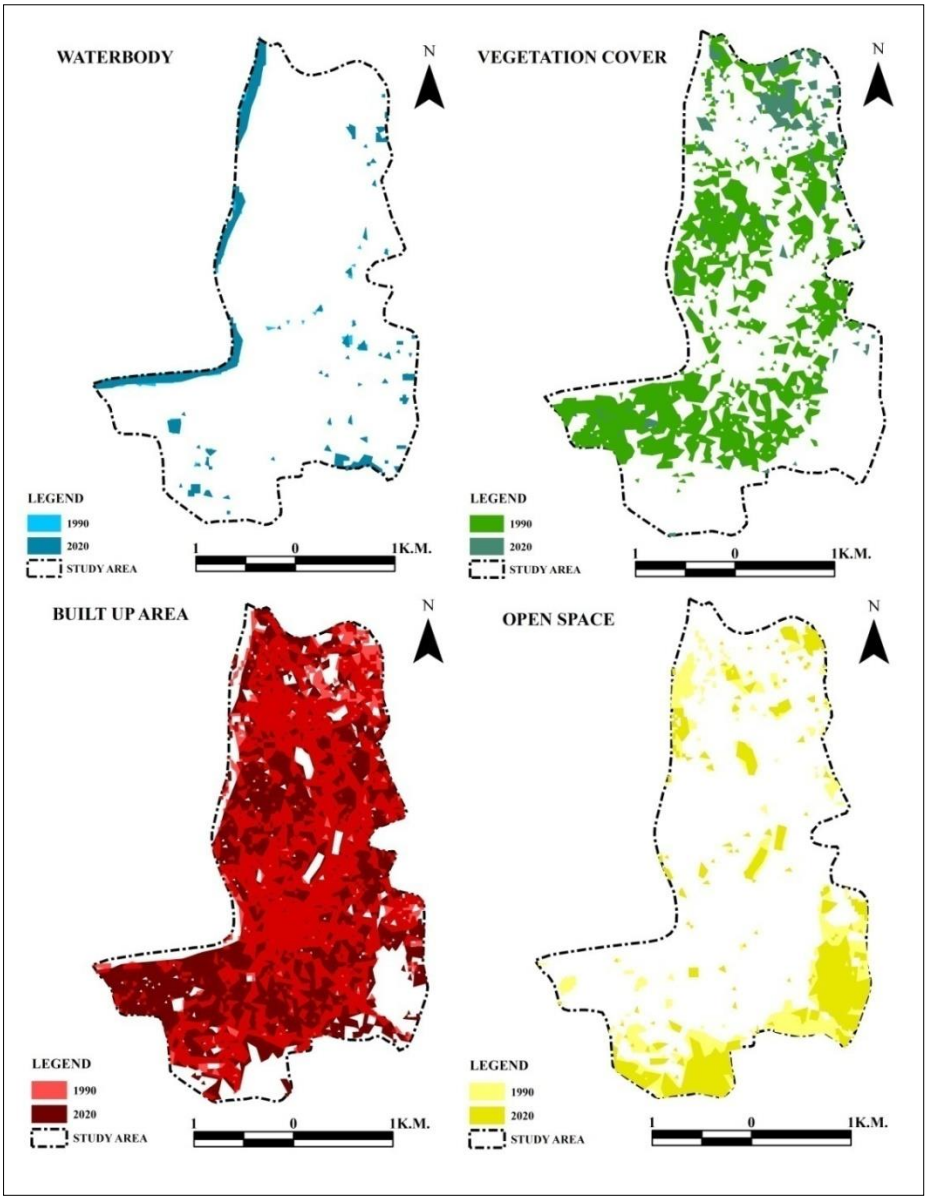

Figure 8: Spatial distribution of land characteristics of the study area from 1990 to 2020

The spatial transformation of each significant land use and land cover characteristic over the study area is plotted in Figure 8. Positive changes have been discovered in land use and land cover elements such water body (1.3%), open space (1.64%), and built-up areas (15.83), while negative changes have been recorded in vegetation cover (almost 19.74%).

Major problem associated with land use and land cover changes

•Clearing of forest areas in some parts of Balurghat city has increased the level of carbon-di-oxide is what is called greenhouse gas. It causes a general rise in temperature. It is also observed that due to concretization of the open land the area is now becoming heat islands.

•Water logging in the rainy season is one of the most important problems in the town as a result of unplanned rapid urbanization.

•Construct residential apartment is major crime to encroaching of water bodies in my study area.

•Land is one of the most precious natural resources on the planet. Due to the sprawling and unplanned growth the fetching of ground water increased and it affects the soil character of the land. Due to the improper management system the soil gets polluted and it affects the soil health and microbial statues of the soil, and the quality of soil is degraded over time.

•Overcrowding refers to the situation in which more people are living within a single dwelling. It is observed from the current study that, the central portions (Ward No.4, 6, 9, 11, 12, 14 &17) have over crowded rather than others.

•Transport plays an important role in economic growth and globalization, but has a deteriorating impact on the congestion, particularly in portions where there are encroachments. Most of the traffic in Balurghat is made up with slow moving vehicles.
•Solid waste is the waste matter which is generated by domestic, commercial, industrial healthcare, agricultural activities etc and accumulates in study area. It is another burning issue in study area.

Probable solution

•The new underground drainage system should be made to control the hygienic condition of the environment

environment. Many areas of the study area have traffic

•The system of collection and management of solid wastes should be improved.
•Urban sprawl and expansion of the city should be controlled.
•Large scale afforestation programmes should be undertaken by the Balurghat municipality.
•Proper manage the urban wetland to check the water scarcity in summer and urban flood.
•New automatic traffic system should be made to control the traffic system.
•One way transportation system should be made to control the overcrowding.

Picture Plate1: Major problem associated with land use and land cover changes

A. Soil pollution &degradation; B. Slum &overcrowding; C. Water logging; D. Traffic congestion; E. Urban waste and F. Drainage problem

Conclusions

This study pinpoints the fundamental issue and suggests some potential solutions. It mostly focuses on change detection from 1990 to 2020. With the use of satellite images and statistical measurements, supervised image classification, accuracy assessment and Pearson's Product Moment Correlation coefficient(r) are used to detect the current situation. It is vital to note that changes in land use and land cover, as well as prompt corrective actions, are crucial for the best and most sustainable use of land resources and the prevention of additional unfavorable degradation. According to the research, Balurghat municipal policy makers should be concerned about future urban growth and create a detailed strategy for environmentally friendly constriction. The study also projected that Land use and land cover change detection can improve the overall urban health and environment and there is further scope for research in this arena to look into population growth, correlation among NDVI, NDWI and NDBI, Land surface temperature and solid waste management program etc. This may be further studied in relation to overall

biophysical and human-induced changes in the region

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Author contribution

Conceptualization, methodology, writing – original draft, ML. The author has read and agreed to the published.

Conflicts of interest

The author declare no conflict of interest.

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