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A STUDY ON DETERMINING LAND USE/LAND COVER CHANGES IN DHAKA OVER THE LAST 20 YEARS AND OBSERVING THE IMPACT OF POPULATION GROWTH ON LAND USE/LAND COVER USING REMOTE SENSING

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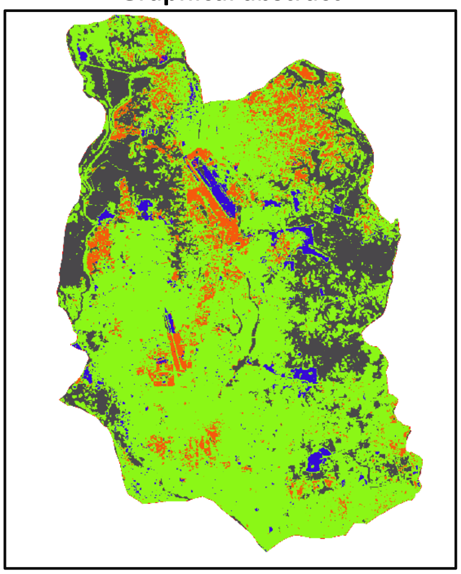
Graphical abstract



Abstract

Land use is an important factor in understanding how human activities change the environment. Changes need to be monitored and identified in order to maintain a sustainable and conducive environment in any city. Dhaka, the capital of Bangladesh, is one of the most densely populated megacities in the world with an area of 306.4 km^2. This study has highlighted how land use has changed as a result of rapid urbanization in Dhaka city in the last 20 years and the relationship of population with these land uses. Land use has been reviewed during the previous 20 years by creating a map of LULC using various GIS and remote sensing techniques using Landsat 5 ETM + images from 2001 and 2011 and Landsat 8 OLI images from 2021.The change in land use has been classified into four categories for the purposes of this study: built-up area, vegetation, water body, and bare soil. After analysis an accuracy assessment has been done in this study to keep LULC's classified maps accurate and transparent. In the time period from 2001 to 2021, the amount of build-up area and bare land in Dhaka city has increased by 27% and 2% respectively. On the other hand, the amount of vegetation has decreased by 29%, the amount of water body is constant. Although the area of Dhaka city did not increase at the same time, the population increased by about 11.04 million. The findings of the study reveal and present a clear illustration of Dhaka's urban growth during the previous 20 years.

Keywords: Land Use/Land Cover change, Remote Sensing, Supervised Classification, Urbanization, Dhaka City

1.0 INTRODUCTION

Land use and land cover (LULC) are dynamic, with significant environmental and socioeconomic repercussions. The pathways and rates of change vary with space and time and are linked to the interaction of human activities and biophysical circumstances in a given area (Kabir, 2011). In recent decades, developing countries have seen a significant increase in urbanization. If done correctly, urbanization can have a lot of positive effects. However, widespread urbanization has largely negative consequences (IOPscience, 2019). Land Use Land Cover (LULC) change detection assists policymakers in understanding the dynamics of environmental change in order to attain sustainable development. As a result, LULC feature identification has arisen as a significant study element, necessitating the development of a proper and accurate approach for LULC categorization (Sinha et al., 2015). LULC provides a clear idea of an area. LULC gives a clear idea about the amount of water in an area and the quality of water (Griffith et al., 2002).

Bangladesh has been a developing country for a long time. Bangladesh is experiencing urbanization, which is one of the issues that emerging countries face. Dhaka, Bangladesh's capital, has suffered the worst. Dhaka must bear the strain of a large population in addition to urbanization. With a land area of 147,000 km^2, Bangladesh is one of the world's most densely populated countries. It is primarily an agrarian country that has recently experienced rapid urbanization and economic transformation. In Bangladesh, urbanization is one of the most pressing development issues (Kabir, 2011). Dhaka became the capital of the then-East Pakistan after the Indian subcontinent was partitioned into India and Pakistan in 1947. Bangladesh became an independent country in 1971, and Dhaka was retained as the capital. Dhaka has been the center of administrative, social, educational, and cultural activities since then (Dewan & Corner, 2014). As almost every sector of Bangladesh is heading towards Dhaka, it has affected the normal life of the people. At present most of the rural people of Bangladesh want to live in Dhaka. A misconception has taken root in the minds of these people that living in Dhaka will improve their financial structure. As a result, the population of Dhaka, the capital of Bangladesh, has grown at an alarming rate. Currently, approximately 47,400 people live on each square kilometer of Dhaka's land, which is residence to 17.4 million people(Amin, 2018). Dhaka is experiencing a lot of issues as a result of the city's failure to be built according to a specified urbanization. In this city, unplanned urbanization and transportation congestion are on the rise. In this city, the rate of increase in environmental pollution is likewise on the rise. In addition to growing water logging, air pollution, and deforestation, a variety of socioeconomic problems are on the rise in this region. Dhaka, the capital of Bangladesh, was named third least livable city in the EIU's Global Liveability Ranking 2019 and second worst in the 2018 index (Alam, 2021).

It will not be easy to get Dhaka out of its current predicament. Only a well-thought-out long-term strategy can improve the situation in Dhaka. The main objective of this research is to highlight the changes in land use of Dhaka city in the last 20 years. The research also provides an idea of the relationship between population and change. The entire work of spatial - temporal change in land of Dhaka has been completed with the assistance of remote sensing and GIS, both of which are extremely powerful and effective tools.

2.0 METHODOLOGY

The main goal of this study is to examine how land use has changed in Dhaka. In the last 20 years, Dhaka's land use has shifted dramatically. To see the idea of this change, there are a few steps to follow. This study's methodology is depicted in Figure 1 below.

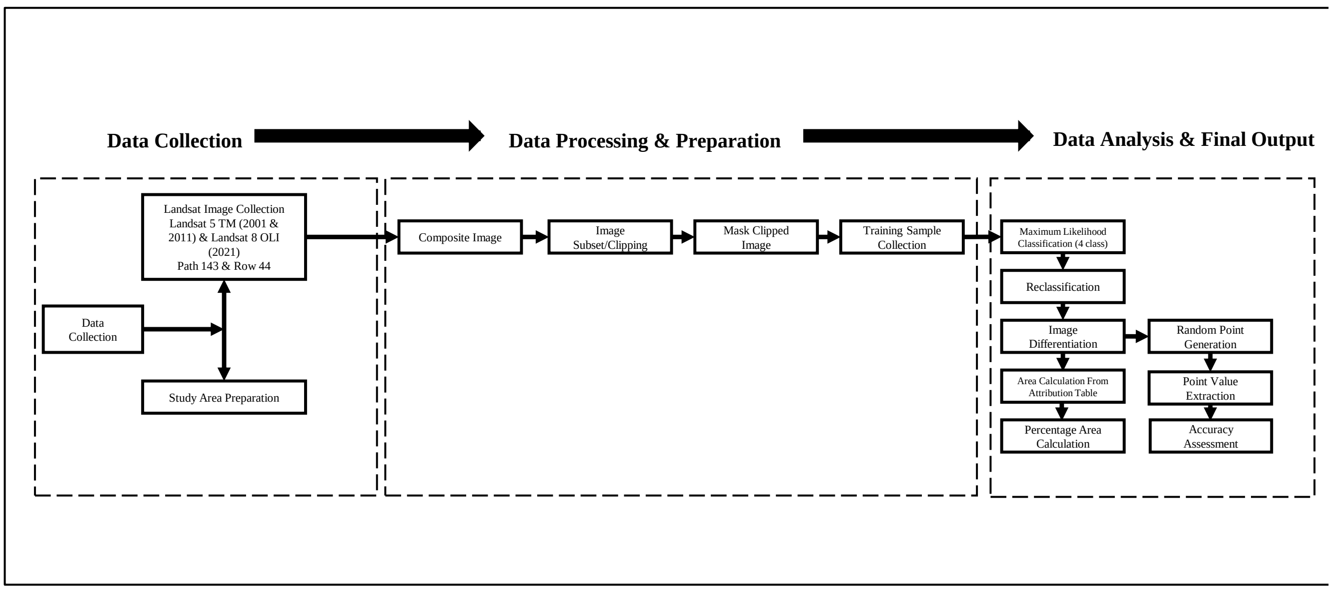


Figure 1: Methodology Flow Chart of Study

In this study, the observation compares the percentage of land use calculated from the classified images of three different years in identifying changes in the rapidly changing urban land use of Dhaka. The Landsat Images used in the study are from Landsat 5 TM+ and Landsat 8 OLI sensors, dated January 2001, January 2011, and January 2021, respectively, and retrieved from USGS Earth Explorer.

Images from the Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) have a spatial resolution of 30 meters for Bands 1–7 and 9. The new band 1 (ultra-blue) wavelength is excellent for coastal and aerosol research. The new band 9 is beneficial for detecting cirrus clouds. Band 8 (panchromatic) resolution is 15 meters. Thermal bands 10 and 11 are collected at 100 meters and are effective for delivering more precise surface temperatures. The approximate size of the scene is 170 km north-south by 183 km east-west (106 mi by 114 mi). The equipment on Landsat 9 (due for launch in mid-2021) are enhanced versions of Landsat 8. Landsat 4-5 Thematic Mapper (TM) pictures are made up of seven spectral bands with spatial resolutions of 30 meters for Bands 1–5 and 7. Band 6 (thermal infrared) spatial resolution is 120 meters, although it is resampled to 30-meter pixels. The approximate size of the scene is 170 km north-south by 183 km east-west (106 mi by 114 mi) (USGS, 2022).

Landsat 5 TM bands 1–7 (resolution 30m) and Landsat 8 OLI bands 1–7 (resolution 30m) are used to create a composite image for the classification method. In this study. From 2001 to 2021, the supervised classification technique was used for LULC mapping in the studied area. Using a supervised classification approach, four LULC classes were identified: Water Body, Build

Up Area, Vegetation, and Bare Soil. After supervised classification, its validity has been verified by accuracy assessment method which is an essential component of any classification project. This measures up the classified image to another source of data generally considered accurate and often ground truth information. Ground truth data is collected in the field, but it is time-consuming and costly. Interpreting high-resolution imagery, which is used in this study, can also generate ground truth data (ESRI, 2022).

2.1 Study Area

The study area Dhaka (shown in Figure 2), Bangladesh is located at 23.777176 latitude and 90.399452 longitude. Dhaka is in the Cities location category in Bangladesh, with gps coordinates of 23° 46' 37.8336" N and 90° 23' 58.0272" E (Lat Long, 2022). Four rivers run through Dhaka: the Balu on the east, the Tongi Khal on the north, the Turag on the west, and the Turag-Buriganga on the south (Hadiuzzaman et al., 2006; Rahman et al., 2022). The land is flat, partially flood plain, partly alluvial terrace, and is commonly referred to as the Pleistocene Modhupur terrace (Miah & Bazlee, 1968). The city is located on the Ganges Delta's lower reaches, with a total size of 306.38 square kilometers (118.29 sq. mi). The land is flat and close to sea level, with tropical vegetation and damp soils. Due to severe rainfall and cyclones, Dhaka is vulnerable to floods throughout the monsoon season (Hough, 2004). The city is surrounded by large mangroves and tidal flat habitats due to its location on the Ganges Delta's lowland plain (Murray et al., 2014).

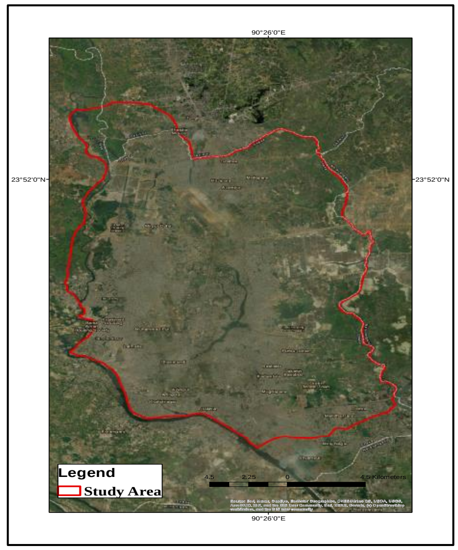


Figure 2: Map of Study Area

2.2 Data Collection

Landsat 5 TM images from January 2001; Landsat 5 TM images from January 2011 and Landsat 8 OLI images of rows 44 and 137 with the cloud cover less than 10% and spatial resolution 30mX30m covering were downloaded using Glovis from the United States Geological survey website (https://earthexplorer.usgs.gov) is shown in Table 1.

Table 1: Satellite Image with their sensors, path/raw, acquisition dates and resolution

Satellite	Sensor	Path/Row	Acquisition Date	Resolution
Landsat 5	TM+	137/44	06/02/2001 02/02/2011	30m
Landsat 8	OLI	137/44	12/01/2021	

The population figures of Dhaka city for 2001, 2011 and 2021 have also been used in this research (shown in Table 2). This data is taken from the World Population Review site. This website is available at this link https://worldpopulationreview.com/world-cities/dhakapopulation

Table 2: Population of Dhaka with respect to Year

Year	Population (Million)
2001	10.7
2011	15.3
2021	21.7

2.3 Data Porcessing And Preparation

Radiometric or geometric corrections are applied to the collected images before they are processed. Correcting the data for sensor irregularities and unwanted sensor or atmospheric noise, as well as converting the data to accurately represent the reflected or emitted radiation measured by the sensor, are all part of radiometric corrections (Al Mamun, 2013).

Later, for data processing, first the Landsat images had to be converted into composite images. Later, the study area of this research was clipped from the composite image. The class that will be divided with the help of different bands has been found out and specified. Each class is given a specific name so that it can be easily identified. It is possible to create various FCC images using the basic colors red, green, and blue (RGB) in ArcGIS (Eastman, 2009). These FCC images are useful for distinguishing between different cover types or ground objects such as build Up Area, Water Body, Vegetation etc. With band combinations, the training sample selection process is simple, allowing for better class selection in study.

2.4 Data Analysis

After the image has been pre-processed, the data is ready for the consecutive classification process, which includes Maximum

Likelihood Classification, differentiation of the classified image, area and percentage of area calculation.

2.4.1 Maximum Likelihood Classification

The Maximum Likelihood Classification tool's algorithm is based on two principles:

1. Each class's cells sample in a multidimensional space that is normally distributed.
2. Bayes' decision-making theorem

When assigning each cell to one of the classes represented in the signature file, the tool of Maximum Likelihood Classification takes into account both the variances and covariance of the class signatures. With the assumption that a class sample's distribution is normal, a class can be defined by the mean vector and the covariance matrix. Given these two characteristics for each cell value, the statistical probability for each class is computed to determine the cells' membership in the class. When the EQUAL option for A priori probability weighting is used, each cell is assigned to the class with the highest probability of being a member (ESRI, 2022). Prior to classification, a signature file (gsg format) is created from the training samples collected during the image processing phase.

By selecting the maximum probability classification from the Classification toolbar and inputting the signature file, all cells in the output raster will be classified, with the weight of equal probability of each class attached to their signature (Ahmed et al., 2020). The classified image (masked study area) were then reclassified individually into four land classes (shown in Table 3). The following five land use/land cover classes are described in details below:

Table 3: Land classification names with description

No	Land Classification Name	Description
1	Water Body	River, Pond, Open Water , Lake, Permanent Wetland, Seasonal Wetland
2	Build Up Area	Residential Building, Commercial Building, Industrial Building, Roads, Urban and Other
3	Vegetation	Forest, Mixed Forest, Scrub, Crop Fields, Vegetable Lands
4	Bare Soil	Sand fill, Active Excavation Area, Landfill Sites, Under Construction Area

2.4.2 Area And Percentage Area Calculation

After distinguishing the classified images, the four classes are combined into one image. Each image field is calculated from the pixel count given in the table of its image properties. A new field is created in the attribute table for the area calculation and the following formula is then used to calculate the area using the field calculator.

$$Area = \frac{count\ of\ pixel * Cell\ Size\ (X\ \&\ Y)}{1000000} \quad (1)$$

The pixel size for Landsat 5 and 8 images is 30m*30m. After that, the area is converted to kilometers. After calculating the area of the individual class, the data is taken in a Microsoft Excel work file. And for the three dates mentioned, the area percentage of each class has been calculated. The formula used to complete the work is provided below.

$$Area\ Percentage = \frac{Land\ Use\ Area}{Total\ Area} \text{x } 100 \quad (2)$$

The results are contrasted to a graphical depiction to demonstrate the changes in land usage that occur over time.

2.4.3 Accuracy Assessment

The purpose of accuracy assessment is to ensure that the classification process is transparent. In the study area, a dataset containing some random points was created for this purpose. Google Earth was used to identify these points for those years. The results of Google Earth are then compared to Raster's results. It is identified as accurate if the values of the two places are equal.

$$Accuracy\ (\%) = \frac{Number\ of\ Points\ with\ similar\ values}{Total\ Random\ Points} \text{x}100 \quad (3)$$

The output data was used to create error matrices for two separate years, allowing us to generate a number of accuracy metrics from our data, such as User and Producer accuracy, using the following formulas:

$$User\ Accuracy\ (\%) = \frac{Total\ Numbers\ of\ Accurate\ pixels}{\text{Total numbers of pixel actually classified}} \text{x}100 \quad (4)$$

$$Producer\ Accuracy\ (\%) = \frac{Total\ Numbers\ of\ Accurate\ pixels}{\text{Total numbers of reference pixel}} \text{x}100 \quad (5)$$

3.0 ANALYSIS RESULTS

This study is primarily based on a series of Landsat satellite images that were used to assess spatial-temporal changes in Dhaka over the previous 20 years using land use and land cover mapping. Every 10 years intervals, i.e. land usage of 2001, 2011 and 2021, and land cover maps were created using the highest probability classification algorithm by supervised classification method, following a step-by-step classification and measurement approach. The software ArcGIS 10.2.4 was used to detect land cover changes. Identify land use changes using a 4 classification system. Water Body, Build Up Area, Vegetation, and Bare Soil are the names of four classes.

3.1 Changes In Land Use And Land Cover Identification In Dhaka City Within 20 Years

The quantity of built-up land in Dhaka city has risen the most in the last 20 years, according to the photographs obtained from this study. During this time, the amount of vegetation has decreased the most. The amount of water has remained unchanged in these 20 years. The amount of bare soil has increased somewhat in these 20 years. Figure 3 shows land cover map for 2001, Figure 4 shows land cover map for 2011 and Figure 5 shows land cover map for 2021

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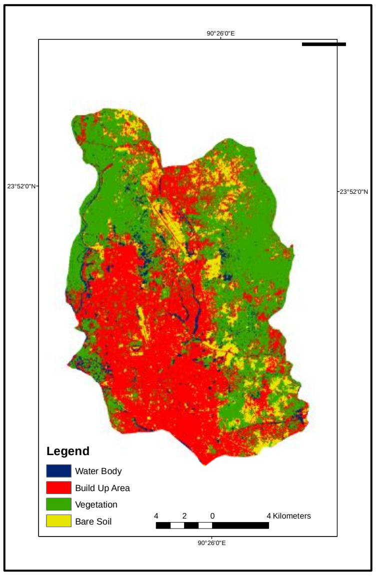

Figure 3: Land use/land cover map of 2001

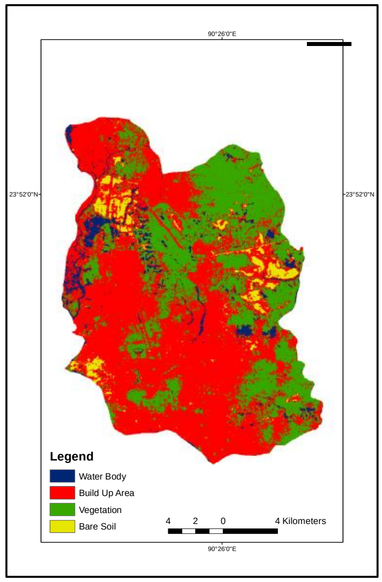

Figure 4: Land use/land cover map of 2011

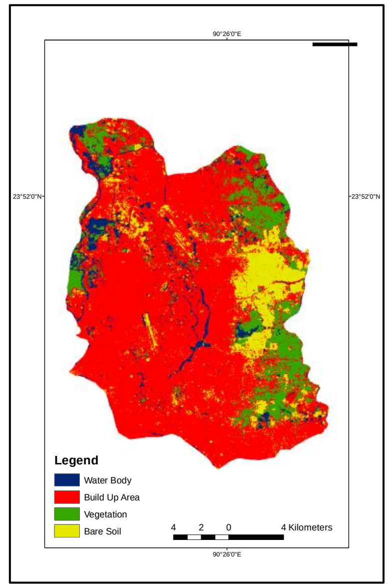

Figure 5: Land use/land cover map of 2021

If we look at the classification system used in this study, we can observe that every class in Dhaka has changed over the last 20 years. Table 4 showed the area and percentage of land cover classes at ten-year intervals (2001, 2011, and 2021) and Table 5 showed land cover changes from 2001 to 2021. The figures 3, 4 and 5 showed graphical representation of the percentage of area changes of 2001, 2011, and 2021

Table 4: Land cover/land use labels with areas of 2001, 2011 & 2021

	2001		2011		2021	
Classification Labels Name	Sum of Area (km^2)	Percentage of Area	Sum of Area (km^2)	Percentage of Area	Sum of Area (km^2)	Percentage of Area
Bare Soil	64.005	21%	59.18	19%	69.42175	23%
Build Up Area	119.050	39%	143.631	47%	200.693	66%
Vegetation Land	107.808	35%	90.592	30%	19.83	6%
Water Body	15.537	5%	12.997	4%	16.45525	5%

Table 5: Land cover/land use labels with areas differences

	2001		2021		
Classification Labels Name	Sum of Area (km^2)	Percentage of Area	Sum of Area (km^2)	Percentage of Area	Percentage of Area increase or decrease
Bare Soil	64.005	21%	69.42175	23%	2%
Build Up Area	119.050	39%	200.693	66%	27%
Vegetation Land	107.808	35%	19.83	6%	-29%
Water Body	15.537	5%	16.45525	5%	0%

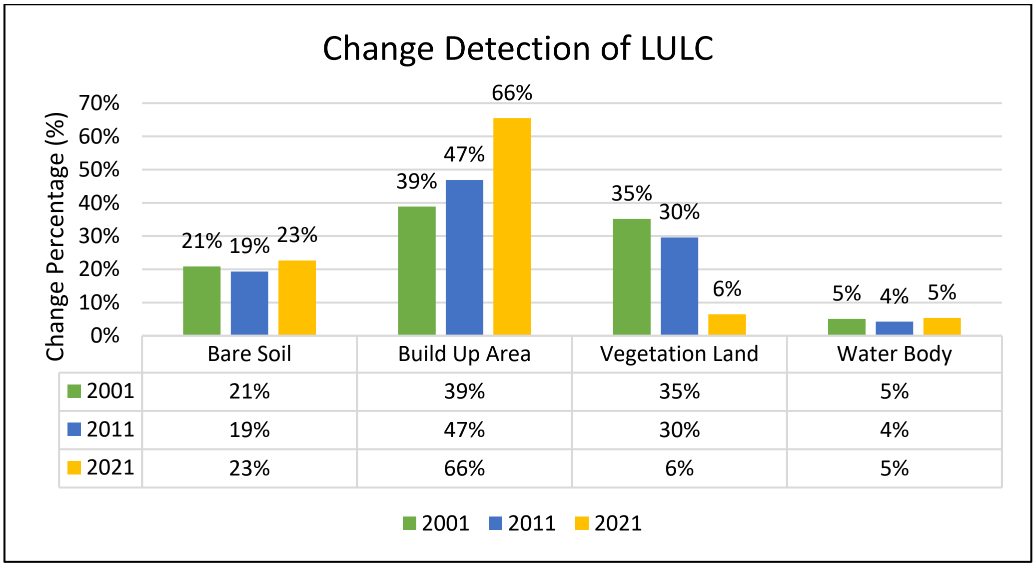

Figure 6: Change detection of LULC

Dhaka's water body was 15.537 square kilometers in 2001, representing for 5% of the city's total area. In 2011, it had 12.997 square kilometer, representing for 4% of Dhaka's total area. In 2021, the number of water bodies in Dhaka city totaled 16.455 square kilometer, representing for 5% of the city's total area (shown in Figure 6). It is observed the amount of water in Dhaka city has been constant over the last two decades. But the amount of water body in Dhaka city was gradually reducing due to unplanned urbanization and canal occupation the period of 2001 to 2011. Subsequent recovery projects have been able to reduce this reduction.

In the previous 20 years, Dhaka's built-up area has expanded the most. Between 2000 and 2021(shown in Figure 6), the built-up area rose by 27%. This result demonstrates the impact of urbanization on Dhaka. There is currently a built-up area covering 66% of Dhaka's total area.

In the previous 20 years, the amount of vegetation in Dhaka has declined the maximum. As the amount of vegetation in Dhaka city has declined, so has the amount of agricultural land. During this time, these agricultural land were essentially turned into built-up areas. There has also been deforestation, which has aided in the expansion of the built-up area. In the last 20 years, vegetation has decreased by 29%, which means that 27% of Dhaka city area has been converted into build up area in the last 20 years. At the same time it is seen that the amount of bare soil has increased by 2%. Increasing the amount of bare soil indicates increasing of infrastructural development and constructional activities. On the other hand, as a result of these kinds of development, agricultural land is generally reduced to a large extent.

3.2 Changes In Land Use With Population

The population and land use have a strong affiliation. The amount of built-up area is often viewed to rise as the population grows. Furthermore, as the world's population grows, there is a need to develop a human habitation system, for which arable land serves as a construction site. As a result of population growth, the amount of bare soil also increases. In the case of Dhaka city, the relationship between land use and population is shown in Table 6 and Figure 7.

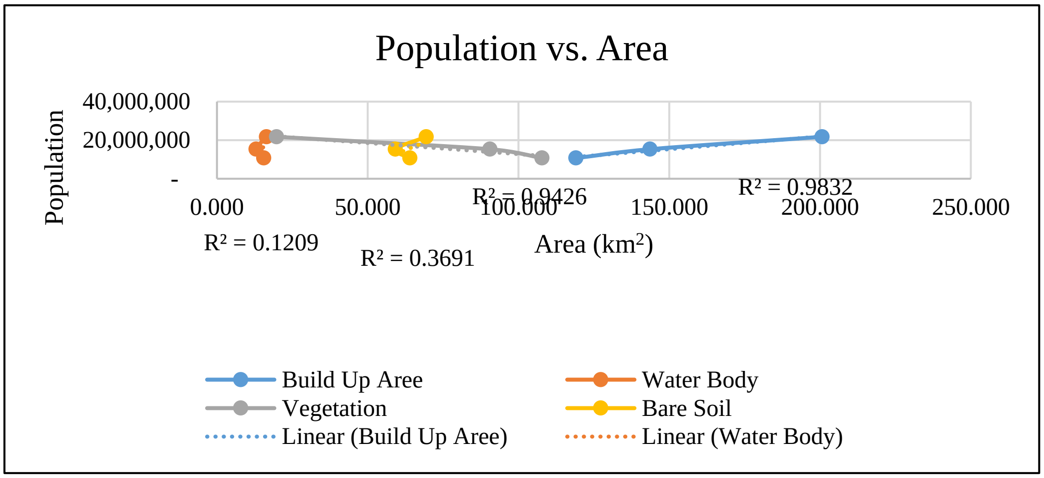

Figure 7: Population vs. Year graph of Dhaka

Table 6: R^2 values of classification class

Classification Name	R^2
Water Body	0.3691
Built Up Area	0.9832
Vegetation	0.9426
Bare Soil	0.1209

When we look at the R^2 values in each classification, we can observe that Build Up Area and vegetation have the highest R^2 values. R^2 value of Build Up Area is 0.9832 and R^2 value of vegetation is 0.9426. On the other hand, the R^2 value of water body is the poorest in this classification. Because the Built-Up Area has changed significantly over the last 20 years, the R^2 value of the built-up area is found good. This result is also observed in vegetation. The value of vegetation decreased drastically over the 20 years. This decrease rate gives vegetation a good R^2 value.

3.3 Accuracy Assessment

The following Table 7, Table 8, and Table 9 show the error matrix for three separate years, including User accuracy and Producer accuracy determined from equations 4 and 5.

Table 7: Classification accuracy of user and producer of 2001

Land cover class	1-Water	2-Build Up Area	3-Vegetation	4-Bare Soil	Total points	User Accuracy
Water Body	7	1		1	9	78%
Build Up Area	2	9		1	12	75%
Vegetation	2	1	12	3	18	67%
Bare soil	1	2	3	15	21	71%
Total	12	13	15	20	60	73%
Producer Accuracy	58%	69%	80%	75%		

Table 8: Classification accuracy of user and producer of 2011

Land cover class	1-Water	2-Build Up Area	3-Vegetation	4-Bare Soil	Total points	User Accuracy
Water Body	8	0	1	1	10	80%
Build Up Area		16		1	17	94%
Vegetation	3	2	13	3	21	62%
Bare soil		1	1	25	27	93%
Total	11	19	15	30	75	82%
Producer Accuracy	73%	84%	87%	83%		

Table 9: Classification accuracy of user and producer of 2021

Land cover class	1-Water	2-Build Up Area	3-Vegetation	4-Bare Soil	Total points	User Accuracy
Water Body	18				18	100%
Build Up Area		19		1	20	95%
Vegetation	3	2	14	3	22	64%
Bare soil			1	28	30	93%
Total	21	21	15	32	90	88%
Producer Accuracy	86%	90%	93%	88%		

Total Accuracy of Classified Landsat Images was calculated using Equation 3 for the years 2001, 2011, and 2021.

For the year 2001, the total number of random points generated was 60, with all points falling within the research area.

$$Accuracy\ (\%) = \frac{43}{60}\ \text{x}\ 100 = 71.67\%$$

For the year 2011, the total number of random points generated was 75, with all points falling within the research area.

$$Accuracy\ (\%) = \frac{62}{75}\ \text{x}\ 100 = 82.67\%$$

For the year 2021, the total number of random points generated was 90, with all points falling within the research area.

$$Accuracy\ (\%) = \frac{79}{90}\ \text{x}\ 100 = 87.78\%$$

4.0 CONCLUSION

This study discusses the results of land use change in Dhaka which is Capital of Bangladesh during a 20-year period (2001-2021). Using The maximum likelihood classification, LULC map of different three years were made. The data from that map was then evaluated in several ways. Basically, some of the information from this research is very important, which we need to take seriously. The important points are-

- In the last 20 years, the built-up area of Dhaka has risen dramatically. At the same time, the city of Dhaka's population has grown. The quantity of built-up area has expanded to accommodate a big number of people in this city, posing a threat to Dhaka. Natural disasters, such as earthquakes, can cause chaos on the city. Individuals must be evacuated and gradually removed from Dhaka for ensure security of people.
- The amount of vegetation in Dhaka has decreased alarmingly in the last 20 years. There is no substitute of vegetation to keep the city in balance. So the amount of trees in this city needs to be increased through massive afforestation.
- Dhaka's population expansion must be slowed. Civic amenities have been questioned as Dhaka's population has grown over the previous 20 years. People who are planning to head Dhaka should be advised not to do so. Only by developing every divisional city in the same way as Dhaka will the flow of people towards Dhaka be halted.

Dhaka has experienced irreversible harm in the last 20 years. In this city, there is no longer any environmental balance. Now the task is to make Dhaka livable. To find out what else has changed in Dhaka, further extensive investigation is required. This requires both remote sensing and hands-on investigation and research.

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