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Predicting Blue-Green-Grey Space Changes in Chittagong City Corporation Area Based On CA-Markov Model

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Abstract: *Using remote sensing and a Geographic Information System (GIS), this study examines the land use change in the Chittagong city corporation region from 2000 to 2020. It then uses a Cellular Automata Markov model to forecast the likelihood of future land use patterns for 2030.In this study, land use classification is defined as follows: Blue represents water bodies, Green indicates vegetation cover, and Grey signifies built-up areas and there is another category the other open spaces, those are classified using the maximum likelihood supervised classification. Three sets of multi-temporal Landsat images taken in 2000, 2010 and 2020, where one image from the Landsat 8 Operational Land Imager (OLI) and two from the Landsat 5 Thematic Mapper (TM). The analysis revealed that from 2000 to 2020 Built up area and vegetation cover increased respectively 13% and 6% where other open spaces and water body decreases 18% and 1% respectively.*

Keywords: Land use, GIS, LULC, Change detection, Change prediction, Supervised classification.

Background of the Study

The rise in the percentage of people residing in urban areas is known as urbanization. It explains how people migrate throughout a country from rural to urban locations, giving rise to new towns and cities. In addition, the features of urbanization include the creation of jobs, industrialization, modifications to living standards, and the accessibility of social services. Changes to the Earth's surface caused by human activity are referred to as land use/land cover (LULC) changes. "Land cover" pertains to the physical attributes of the Earth's surface, encompassing elements like soil composition, vegetation coverage, water bodies, and other discernible natural features. Conversely, "land use" refers the multifarious ways in which land is employed.

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For instance, activities like agriculture, salt production, urban development, forestry. Around the world, a number of reputable Models for Change Detection are used to analyse historical land use trends and apply those trends to predict the future. The Markov model is a notable participant in this field, particularly when combined with CA Markov. In recent decades, the urban population of Bangladesh has rapidly increased, rising from 14.1 million in 1981 to 22.5 million in 1991 to 31.1 million in 2001 to 42.11 million in 2011, similar to other developing countries. Sustainable development in Bangladesh is significantly impacted by the strain that population growth has on the environment and its resources.

With a share of 19.7% of the urban population in our country, Chittagong is the second-largest metropolitan area in Bangladesh. There have been significant changes in hilly regions due to shifting farming on the slopes of hills, the removal of hilly forest and the cutting and conversion of hills into plain land for habitation and other facilities. The city has experienced substantial land use changes and grown in all directions over the past forty years in an unplanned and chaotic manner.
As a result, it leads to a rise in the amount of land consumed as well as changes in the land usage through time. In agricultural lowlands and hilly regions, housing projects are frequently started both with and without approval, resulting in the careless filling, leveling, subdivision, and selling of plots without any guidelines for the supply of facilities or infrastructure.

This study examines how Chittagong City Corporation's land use pattern changed between 2000 and 2020, primarily in the Blue (water bodies), Green (vegetation cover), and Grey (built-up) areas. It uses the CA-Markov model to forecast these land use dynamics for 2030. Using GIS and EDRISI SELVA software, this study sought to identify the temporal variations in land use and land cover. The concepts of cellular automata and Markov Chain modelling are applied in many scientific fields, and the model has broadened its influence with the development of remote sensing and Geographic Information System technologies as well as an exponential rise in computational and modelling capacity. The combination of the Cellular Automata Markov model is regarded as effective for simulating land use changes with the capability of modelling and forecasting alterations. The utilization of a composite cellular automata Markov chain model has enhanced capabilities in generating a more refined dynamic pattern of land use change (Mondol et al. 2016). Researchers in

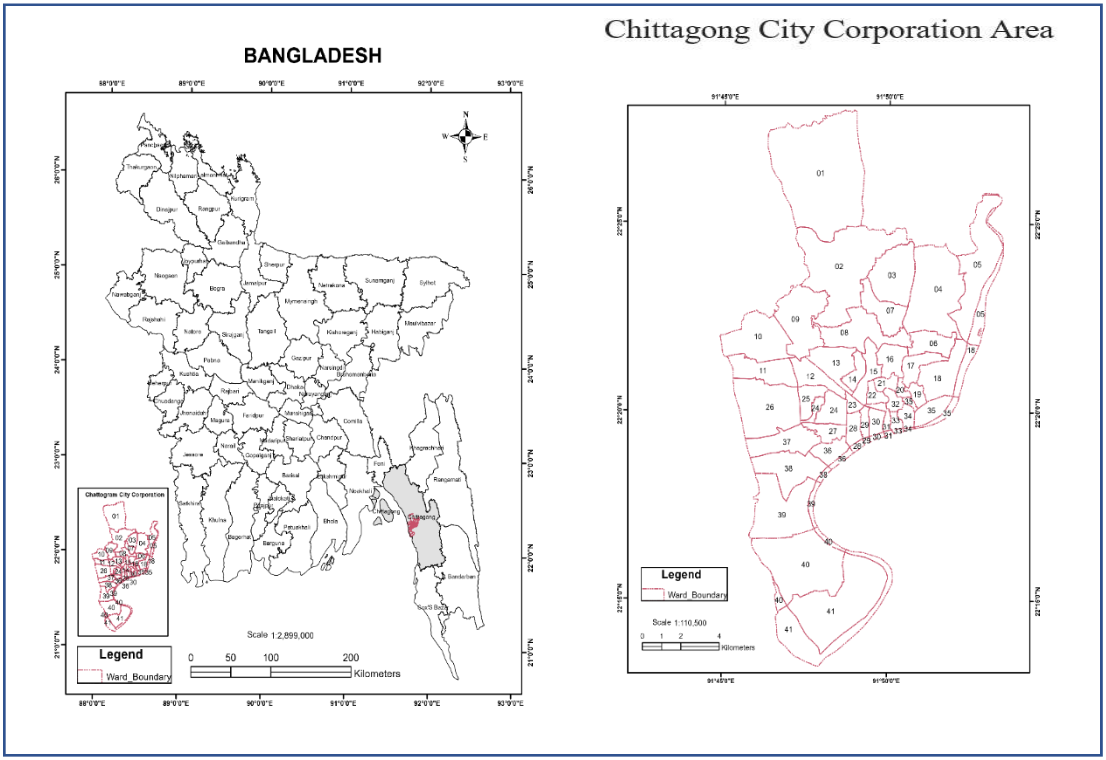


Figure 1: Chittagong City Corporation Area Location in the Context of Bangladesh

Sources: Created by Authors, 2025.

Bangladesh have employed the CA-Markov model to study a range of topics pertaining to environmental dynamics, urban growth, and land use change. The CA-Markov model has been used to forecast how different environmental circumstances may affect the composition and assemblage of mangroves in the Bangladesh Sundarbans (Mukhopadhyay et al., 2015). Thus, using the CA-Markov model to forecast the future Blue-Green-Grey areas in the Chittagong City Corporation region may be appropriate for the current study.

Materials and Methods

Study Area

Chittagong division is located in the South-eastern part of Bangladesh which includes the Chittagong district as an administrative area. Chittagong has more geographical diversity than any other district in Bangladesh because of the hills, the sea, the valleys, and the forests. Not only is Chittagong City the administrative centre of the district, it is also the second-largest city in Bangladesh. It is located on the right bank of the river Karnafuli between 22°14' and 22°24' N latitude and 91°46' and 91°53' E longitude. There are 41 wards in the city, with a total population of 3,227,246, as of the 2022 Census. The Chittagong City Corporation spans 42694.393 acres in total. There were 41 wards among them. The larg est area, covering about 6000 acres, is South Pahartali and the smallest area, covering only 100 acres, is Dewan Bazaar Ward.

Satellite Image Data

Remote sensing images from the United States Geological Survey (USGS) Earth Explorer were collected to detect changes in land cover, built-up area, and water body during the winter. These images have the best visibility and the least amount of cloud cover, making them ideal for image analysis. To identify changes over a 20-year period, three-year images were gathered at 10-year intervals. Images for 2000, 2010, and 2020 were gathered based on their availability. The downloaded images are the 30m pixel size that were obtained from row code 45 and path code 136.

Meta Data of Collected Landsat Images

Table 1: Collected satellite images and their characteristics.

Year	Landsat	Sensor	Acquisition date	Path/row	Cloud cover	Resolution
2000	Landsat 5	TM	11/11/2000	136/45	4%	30
2010	Landsat 5	TM	23/11/2010	136/45	4%	30
2020	Landsat 8	OLI	20/12/2020	136/45	4%	30

Sources: USGS and Compiled by Authors, 2025.

Land use Maps Preparation and Change Detection

Numerous academics in Bangladesh have studied land use and land cover (LULC extensively, particularly with the use of remote sensing and GIS techniques). Correction and augmentation of satellite images are required for a better understanding of the image's numerous features. Both geometric correction and radiometric correction are necessary for proper satellite image analysis. Nevertheless, every satellite image utilized in this study was captured at Level 1, meaning that the information has already been orthorectified and no data processing was required for geometric correction (Srivastava et al., 2012).At first, collected satellite images are transformed to Universal Transverse Mercator (UTM) within zone 46-N Datum World Geodetic System-84. After that, the composite band application is used to combine satellite images. Then, the Chittagong city corporation area is extracted from the composite file by using extract by mask tools of Arc toolbox in ArcGIS. A supervised classification method has been applied in this investigation. Constructing structure by using the band composition of the images, the digital polygon has calculated the signature value. These pictures have a DN value for their signature value. Signature development refers to the pixel reflectance value. In this work, the maximum likelihood parametric rule was taken into account for image classification. A supervised classification uses polygons (training samples) that represent separate sample areas of the various land use classifications that need to be identified. The classification is done using the following four categories: built up Area, vegetation cover, water body and other open spaces. The investigation began with the use of the maximum likelihood classification in ArcMap 10.6.1 to categorise satellite imagery, including urban, vegetation, and aquatic land cover. Maximum Likelihood (ML) is one of the widely used algorithms in supervised classification to classify images (Jensen, 2005). Detailed land cover maps of three crucial years, 2000, 2010, and 2020, are investigated to highlight urban and environmental changes.

Following the creation of land use maps in 2000, 2010, and 2020, we utilized the post-classification comparison technique to identify areas of change. To assess changes in land use, we calculated the area (in sq. km) and percentage of change for each land use type. Each class's area change was divided by its area in the base year, and the result was multiplied by 100 to calculate the percentage change. Using 2000, 2010, and 2020 data, the IDRISI Selva software was used to model and predict 2030 Land Use/Land Cover (LULC) data.

Accuracy Assessment

The assessment of accuracy is essential for the classification of remote sensing images. Kappa-based indices and total accuracy are commonly used to evaluate accuracy and show the feasibility of a classification method. The accuracy of land use and land cover mapping is frequently illustrated using a confusion matrix that is derived from the Kappa. The generated kappas used in this study are the producer accuracy, user accuracy, total accuracy, and kappa coefficient. "True" positive ratings for a class are determined by the accuracy of the producer. False negative ratings are determined by the accuracy of the user. Furthermore, the true positive ratings for the entire thematic map are determined by the overall accuracy.

Accuracy Assessment Formula

Users accuracy = $\frac{Number\ of\ Correctly\ classified\ Pixels\ in\ each\ category}{Total\ nuimber\ of\ Classified\ Pixels\ in\ that\ cattagory\ (The\ row\ total\ )}\ x\ 100$…….(1)

Producers Accuracy = $\frac{Number\ of\ Correctly\ Classified\ Pixels\ in\ each\ category}{Total\ number\ of\ reference\ Pixels\ in\ that\ category\ (The\ column\ Total)}\ x\ 100$………..(2)

Overall Accuracy = $\frac{Total\ number\ of\ Correctly\ Classified\ Pixles\ (Diagonal)}{Total\ number\ of\ refernce\ Pixels} x100$………..(3)

Kappa Coefficient = $\frac{(TSxTCS)-\sum(Column\ total\ x\ Row\ total)}{TS^2-\sum(Column\ total-Row\ total)}$ x 100…………………….. (4)

Table 2: Accuracy assessment of land use classes in the year of 2000,2010 and 2020.

Land use	2000		2010		2020	
	PA	UA	PA	UA	PA	UA
Vegetation cover	100%	100%	100%	80%	81.81%	90%
Built up area	100%	70%	100%	80%	81.81%	90%
Water body	90%	90%	90%	90%	100%	100%
Other open spaces	69.23%	90%	64.28%	90%	100%	80%
Overall Accuracy (%)	87.5%		85%		90%	
Overall Kappa Statistics	83.33%		80%		86.66%	

* PA = Producer’s accuracy and ** UA = User’s accuracy

Sources: Created by Authors, 2025.

A summary of the accuracy evaluation results is given in the table. An appropriate level of accuracy is indicated by a coefficient value of 0.80 or higher than 80%. With kappa values of 0.83, 0.80, and 0.86, the overall accuracy rates for the years 2000, 2010, and 2020 were determined to be 87.5%, 85%, and 90%, respectively, based on the data that was supplied.

Future Prediction of Land Use through CA-Markov Model

CA-Markov is a combination of two models: Cellular Automata and the Markov model. The geographical and temporal pattern of Land Use/Land Cover (LULC) change can be simulated by the CA-Markov model. The CA-Markov model is also one of the planning tools for analysing the temporal changes and spatial distribution of LULC.This model comprehensively describes the dynamics of LULC, forest cover, urban development, plant growth, and watershed management modelling. A spatial continuity component and information of the anticipated geographical distribution of transitions are provided by CA (Cellular Automata), which integrates Markov chain land use predictions. The first point of reference for the change scenario is the basic land use map. Simply put, a Markov chain model shows how land usage varies over time, from present periods to future ones, in order to predict future changes. A Markov chain model essentially offers a framework for illuminating the progression of LULC from the present period to future periods, allowing the anticipation of impending changes. The mathematical expression used to determine the anticipated trajectory of altered land use is represented by equation (1). The composition and distribution of land cover types will change over time, and this equation is essential for assessing and predicting these changes.

S (t, t+1) = Pij x S(t) ………………………………………………………… (1)

S(t) denotes the state of the system at time t and S (t + 1) denotes the state of the system at time t + 1. The transition probability matrix in a state is determined using the formula following:

$$= \|p_{ij}\| = \left\| \begin{matrix} p_{1,1} & p_{1,2} & \cdots & p_{1,N} \\ p_{2,1} & p_{2,2} & \cdots & p_{2,N} \\ \cdots & \cdots & \cdots & \cdots \\ p_{N,1} & p_{N,2} & \cdots & p_{N,N} \end{matrix} \right\|$$

PN is the state $(0 \leq P_{ij} \leq 1)$ probability of any given time; Pij is the chance of changing from the current state (i) to another state (j) in the future; and P is the transition probability. The likelihood of a low transition will be close to zero, whereas the probability of a high transition will be close to one. In the

Markov model, certain land use patterns are divided into discrete groups and then observed for a predetermined amount of time in the past. Markov Chain calculates precisely how much land would be expected to change between the most recent date

and the anticipated date. The output of this method is a matrix called a transition probabilities file that tracks the likelihood that each land cover class will change to each other class. A transition matrix is then created by synthesizing and representing these observations. Using matrix-based computations, the transition probability matrix is utilized to determine the likelihood of moving to later time periods. However, a

Results and Discussions

Land use of Chittagong City Corporation Area in 2000

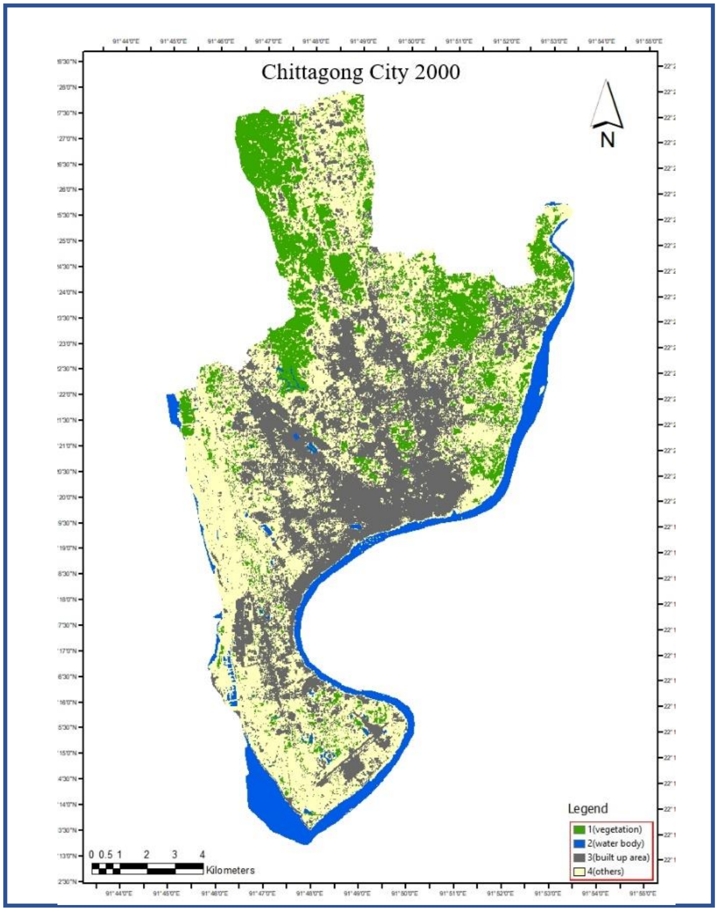


Figure 2: Land use map of Chittagong City Corporation Area in 2000

(Sources: Classified by Authors,2025

Land use of Chittagong City Corporation Area in 2010

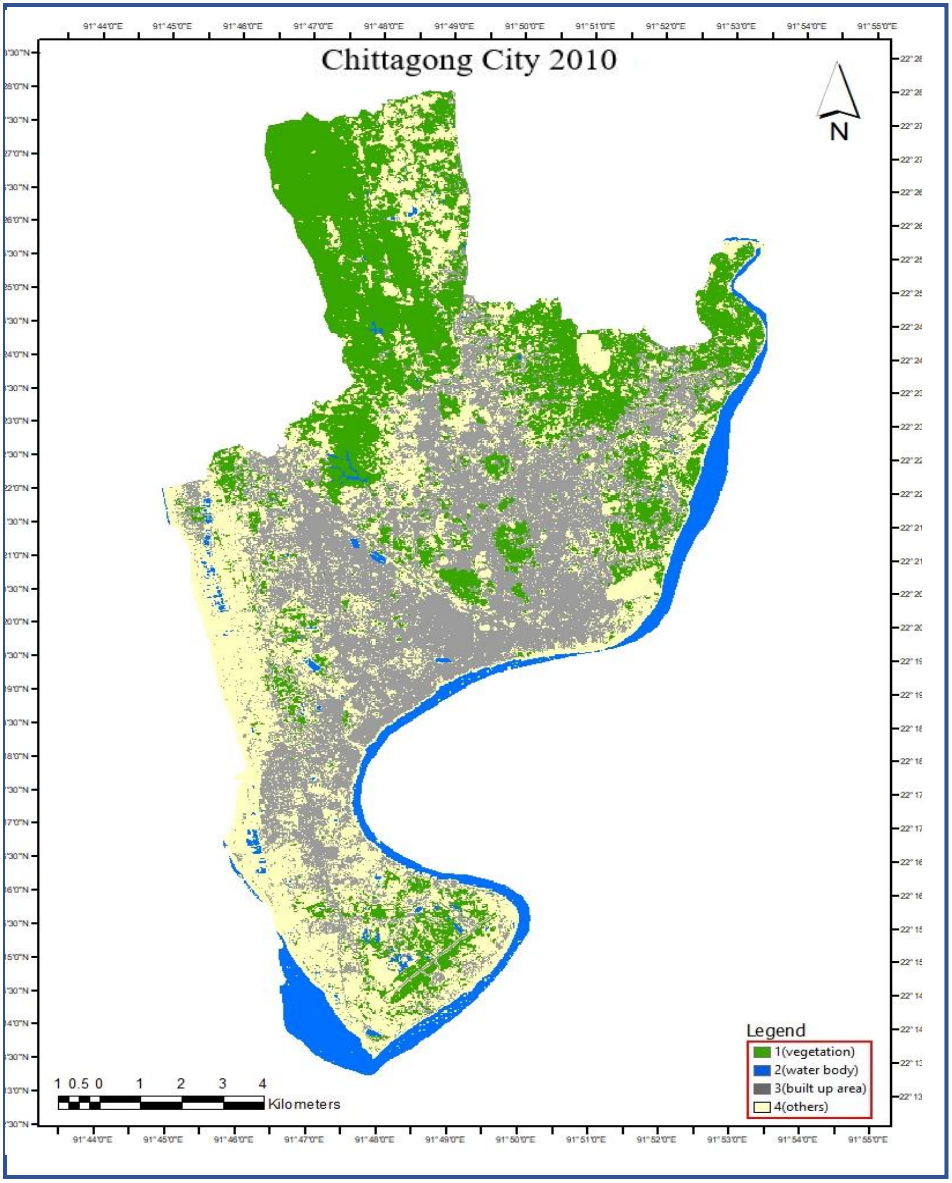


Figure 3: Land use map of Chittagong City Corporation Area in 2010
(Sources: Classified by Authors,2025)

Land use of Chittagong City Corporation Area in 2020

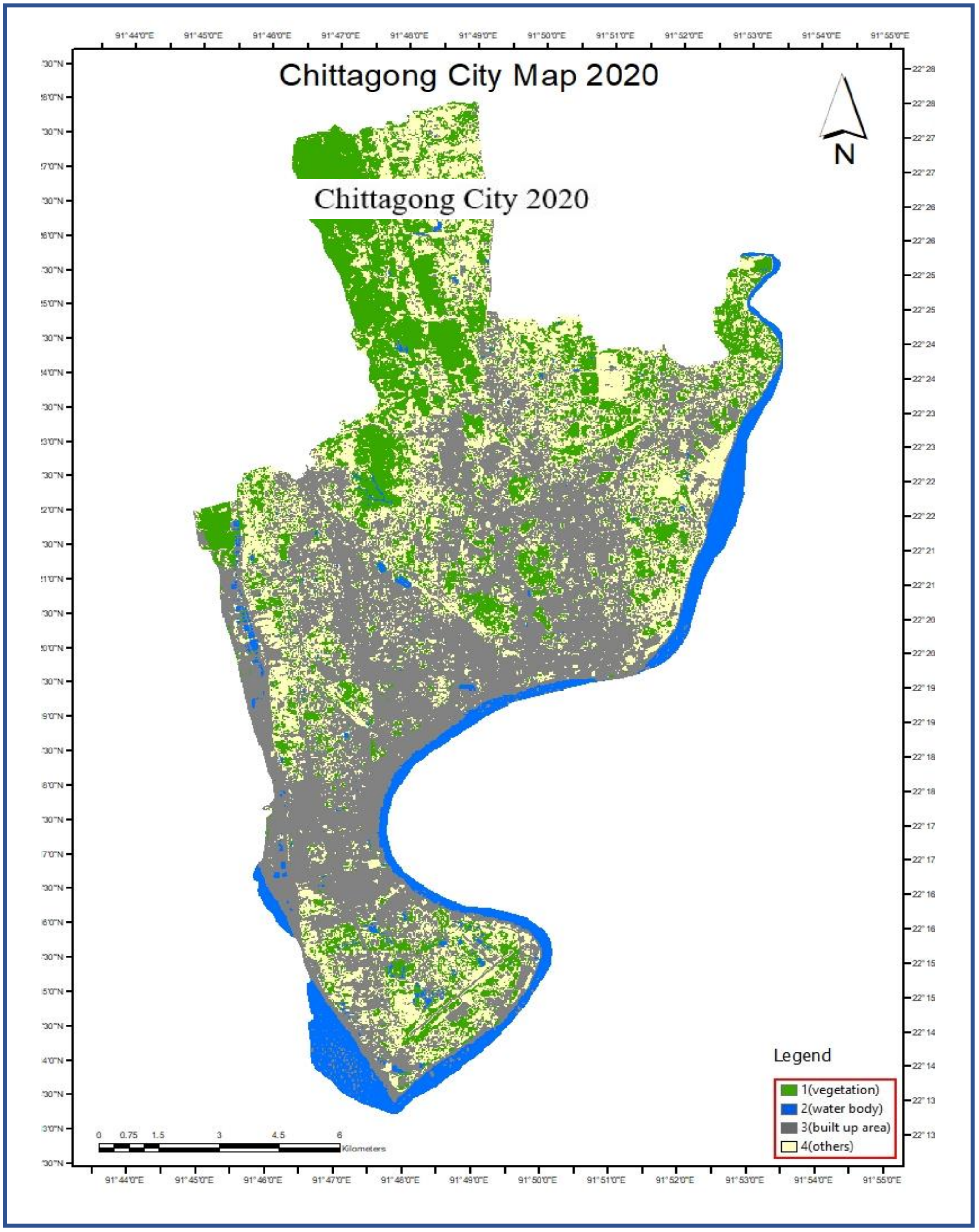


Figure 4: Land use map of Chittagong City Corporation Area in 2020
Sources: Classified by Authors,2025)

projected land use map for 2030 using the same land use classes was created as part of this study to forecast the future land use of the Chittagong city corporation region.

Here we presented the land use maps for the years 2000,2010, and 2020 which is generated from Landsat image analysis, while Table 3 is for the area distribution of land use types in square kilometres and their percentages.

Table 3: Land use of Chittagong city corporation area for the year 2000, 2010 and 2020 and their change detection

Land use class	Year				Changes from 2000 to 2010		Increase /decrease	Year 2020		Changes from 2010 to 2020		Overall Changes from 2000 to 2020	
	2000		2010										
	Area (sq. km)	%	Area (sq. km	%	Area (sq. km)	%	+/-	Area (sq. km)	%	Area (sq. km)	%	Area (sq. km)	%
Vegetation cover	33.12	18	51.44	28	18.32	10	+	44.28	24	7.16	-4	11.16	+6
Built up area	54.25	29	59.06	32	4.81	3	+	77.02	42	17.97	+10	22.77	+13
Water body	14.42	8	13.18	7	1.23	1	-	13.54	7	0.36	0	0.88	-1
Other open spaces	82.39	45	60.58	33	21.81	12	-	49.39	27	11.19	-6	33	-18

Sources: Calculated by the Authors using the maps that were created in Figure 2,3, and 4.

This study showed that it is possible to employ multitemporal images to investigate changes in land use, particularly the trends of the established category. Using the highest likelihood supervised categorization for each image, the post classification comparison change detection method was applied. The results showed notable changes over the preceding 20 years (2000-2020), with the built-up LULC category experiencing a significant gradual growth and the majority of LULC classifications experiencing a considerable drop in their respective areal extents. According to the preceding table for year of 2000, Chittagong has many open spaces in different parts which is seen in map of 2000 year that included the area named hathazari, pahartoli, chatgaon, bakalia, halishahor, patenga the majority of the study area is the other open spaces, accounting for 82.39 sqkm, 45% of the entire region. Also, according to the preceding table for year of 2010, the majority of the study area is other open spaces, accounting for 60.58 sq km, 33% of the entire region. However, the other open spaces were decreased more than 12% (21.81 sq.km) in between 2000 to 2010. And According to the preceding table for the year of 2020, where the others open area is 49.39 sqkm, or 27%. From the year of 2010-2020 the above table shows that the other open areas decreased 6%.

In addition, from the figure 2,3,4 and table 3 for the map of the year 2000 the built-up area (grey space) is 54.25 sq.km which is indicating 29% of total land area, the kotwali, khulshi panchlaish and the bandar is seen as the majority of built up area. And the 2010 map are showing the built-up area is 59.06 sq. km which is 32%. From the year of 2000-2010 the built-up area (grey space) increased 3%.and that was spreading to the area of bandar and chatgaon. And According to the preceding table for the year of 2020, where the majority of the study area is built up area, accounting for 77.03sq km .42% of the entire region, From the year of 2010-2020 the above table shows that the built-up area increased 10%.

From the figure 2,3,4 and table 3 for the map of the year 2000 the Vegetation cover is 33.12 sqkm, or 18% of the entire study region where the hathazari chatgaon are prominent for green area and the 2010 map are showing the vegetation cover is 51.44 sqkm, or 28% .From the year of 2000-2010 the above table shows that the area of vegetation cover (green space) increased 10% which was spreading to the area of hathazari. According to the preceding table for the year of 2020, where the vegetation cover is 44.28sq km which is 24% of the entire region, From the year of 2010-2020 the above table shows that the area of vegetation cover (green space) is decreased 4%.

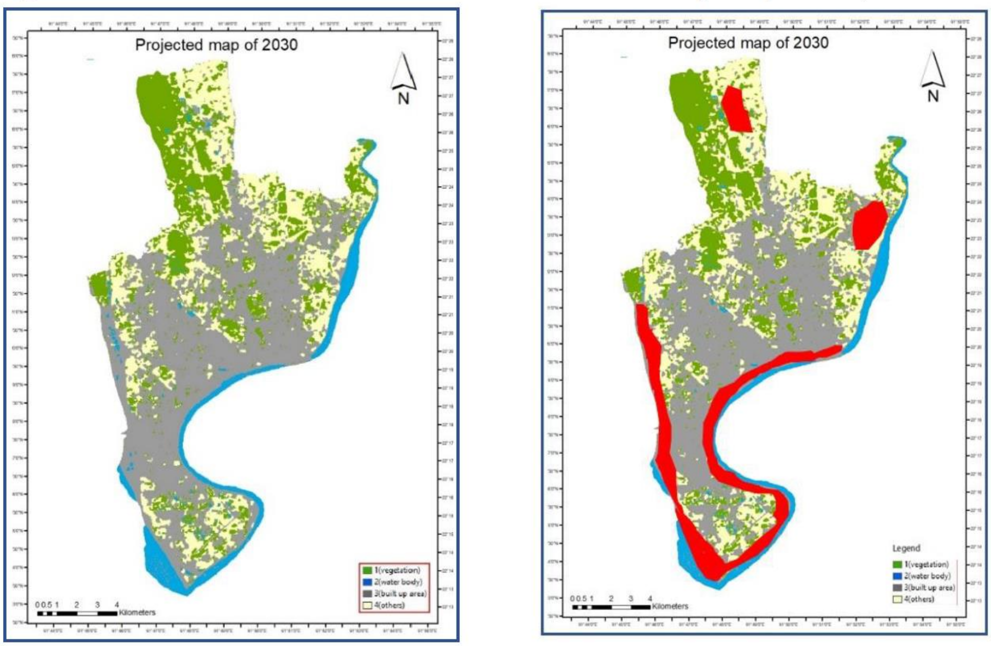
From the figure 2,3,4 and table 3 for the map of the year 2000 the remaining area is 14.42 sqkm or 8% which is existing as water body. Water body (blue space) is scatterly staying all over the region mainly halishahar khulshi and patenga. the 2010 map are showing the water body is 13.18 sqkm or 7%, that is decreased the 1% ratio of previous water body. According to the map for the year of 2020 the blue area is 13.55 or 7% which is cover as water body. From the year of 2010-2020 the above table shows that the area of water body is almost same as before.

The above table describe modifications in land utilization dynamics during 2000 to 2020. The built-up area increasing gradually rapidly and the open spaces are decreasing rapidly as well. The vegetation cover increased in a certain time then decreasing gradually and the water body remaining almost same as before.

Prediction of land use change in 2030

The land use classes that were utilized in the 2000, 2020, and 2010 maps are still included in the projected map for 2030. Figure 5 shows the Chittagong City Corporation Area's projected land use map for 2030 as well as the area's growth trend over the previous 30 years. The computed value of each land use for that study year is displayed in Table 4, along with the likely changes from 2020 to 2030.

Figure 5: Sources: Compiled by Authors, 2025.



Projected map of Chittagong City Corporation Area ■ Growth Trend of Chittagong City Corporation Area

Table 4: Land use of Chittagong city corporation Area in 2020 and 2030, and

Land use class	Year				Changes from 2020 to 2030		
	2020		2030				
	Area (sq. km)	%	Area (sq. km)	%	Area (sq. km)	%	Increase /decrease (+/-)
Vegetation cover	44.28	24	38.68	21	5.62	3	-
Built up area	77.02	42	86.63	47	9.62	5	+
Water body	13.54	7	13.55	7	0.04	0	+
Other open spaces	49.39	27	45.06	25	4.33	2	-

Calculated Change Prediction from 2020 to 2030

Sources: Calculated by Authors, 2025.

The chart shows that 86.63 sqkm, which is 47% of the total area, will cover with build-up area in 2030. Additionally,45.06 sqkm or 25% of the study area will remain as open spaces, 38.67 sqkm of study area or 21% of the total area will remain as vegetation cover, and the rest 7% area or 13.54 sqkm area will remain as water body.

The Figure 5 shows that the study revealed the built-up area will be dramatically increase in Chittagong city corporation in 2030. The majority of built up area will be found in Patenga, close to the harbour. Since the majority of the workers first resided in the residential and commercial zones close to the port and began to develop around the dock area, this contributed to the development of Chittagong's downtown. Because of that the open spaces are gradually decreasing in the map of 2030.

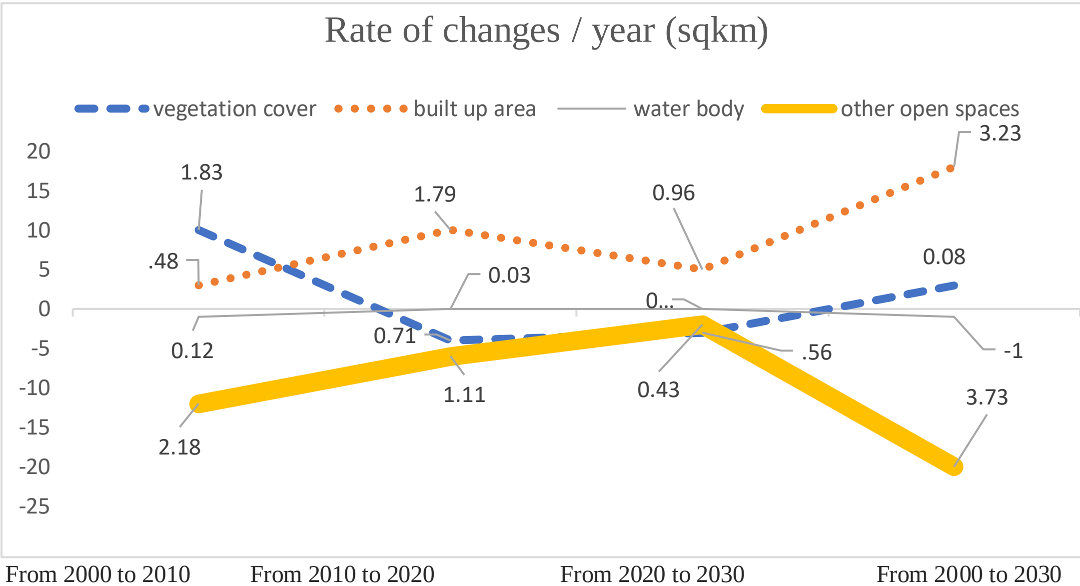


Figure 6: Graphs Illustrating Chittagong City Corporation's Annual Land Use Change Patterns (sq.km) from 2000 to 2030.
Sources: Compiled by Authors, 2025.

The analysis discovered that built up area has been extended from 54.25 sq. km. in 2000 to 77.02sqkm in 2020 with a net increase of 22.77 where the predicted area is 86.63 sq.km. in 2030, with a net increase of 32.38 sq.km. from 2000 during the 30 years. Another condition in vegetation is 33.12sqkm in 2000 to 44.28sqkm in 2020. with a net increase of 11.16 sqkm where the predicted area is 38.67sqkm and the decrease in other open spaces is 82.39 sqkm in 2000 to 49.39 sqkm in 2020 with a net decrease of 33 sqkm where the predicted area is 45.06 sqkm in 2030, with a net decrease of 37.33 sqkm from the 2000 during 30 years. Water body has also remained almost the same as before as 2000, water body is 14.41 sqkm where 13.54 sqkm in 2020 and the predicted area is 13.54sqkm.

The rapid evolution of land use in recent times poses significant challenges to researchers and decision makers in the areas of sustainable land management and planning. Various factors have contributed to this evolution.

Conclusion

Urbanization, or the concentration of population in cities and the resulting rise in the percentage of the population living in urban areas, brings with it both advantages and disadvantages. Chittagong's current infrastructure may be strained by the city's rapid urbanization, which could result in problems like poor public transportation, congested roads, and difficulties delivering basic services. The loss of green spaces and deforestation could be exacerbated by urban expansion. Chittagong is vulnerable to cyclones and flooding, among other natural disasters. Without adequate infrastructure development and planning, rapid urbanization may make people more susceptible to natural disasters. Local food production may be impacted by the conversion of agricultural land into residential or industrial zones as a result of urban area expansion. Sustainable urban planning, infrastructure development, environmental conservation, and community engagement would all be part of the effort to lessen these threats. Data on changes in built-up areas, green spaces, and vegetation can provide by LULC analysis. Assessing the environmental effects of urbanization, such as problems with deforestation, biodiversity loss, and microclimate changes, is made easier with the help of this information. Urban area growth can be tracked with the use of LULC analysis. This is essential for controlling population growth, guaranteeing a sufficient supply of housing, and stopping urban development from encroaching on environmentally delicate areas. Frequent LULC analysis yields baseline data for long-term comparison. This temporal analysis is useful for identifying patterns, evaluating the success of policies that have been put into place, and modifying future planning strategies as necessary.

In conclusion, LULC analysis is a useful method for comprehending how Chittagong City's land use is changing. It promotes responsible decision-making, environmentally friendly urban growth, and the general welfare of the populace.

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