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Research Article

FACTORS OF LAND COVER CHANGE OF DHAKA CITY THROUGH GEOSPATIAL TECHNIQUES

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ABSTRACT

This research provides a comprehensive investigation of the underlying issues of Dhaka City Corporation (DCC) in the context of rapid urban population growth and increasing residential demand. The study employs sophisticated methods for site selection and spatial pattern detection. To classify the satellite imagery, the study utilizes the Maximum Likelihood (ML) supervised classification approach spanning 58 years (1972, 1980, 1990, 2000, 2010, 2020) for identifying historical land use and land cover changes and investigate their causative factors. The results of the study show that housing company/organizational impact accounts for 25.86% of the changes in Dhaka, followed by transportation infrastructure (17.24%) and government (15.52%). Additionally, it is found that 37.50% of transformational activities are done by the government, while private developer companies are responsible for 25%. Settlement (48.08%) is the most formed land cover, whereas Barren Land (24.62%) and Agricultural Land (23.72%) are the most transformed. The study has significant implications for government, legislators, and researchers to take decisions about large-scale studies in urban areas in future.

Keywords: *Post Classification, Change Detection, Area of Consideration, LULC, CAOTCEY, Urbanization.*

Introduction

Since 1960, 32% of global land area has been altered by land use change, four times more than long-term land cover change (Winkler *et al.*, 2021). Although management influences urbanization, few scholarly researches have been conducted on geospatial management and development (Hersperger *et al.*, 2018). By analyzing human-natural interactions, early and accurate identification of earth surface changes enhances resource management (Asokan and Anitha, 2019). Urbanism is expanding with industrialization. Land use maps containing information and analysis can bring benefit to policymakers of developing nations (Addae and Oppelt, 2019). Hence, the barrier connecting investigation on spatiotemporal management and

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land alteration could be overcome (Hersperger *et al.*, 2018). Researchers must therefore identify illicit infrastructure. Numerous experts in remote sensing investigate land use and urbanization highlighted the significance of urban land use change. Academics have conducted study on urbanization, urban heat island, land surface temperature, rainfall & precipitation, demography, and socioeconomic function (Huang and Lu, 2018; Pramanik and Punia, 2020; Cai *et al.*, 2016; Karakuş, 2019).

Prior studies show that human and environmental variables aggravate land use and land cover (LULC) changes. Organizational factors also affect LULC changes in metropolitan areas where people actively invest in infrastructure. BBS (Bangladesh Bureau of Statistics) data indicates that GDP has increased, which encourages people to purchase a house or apartment. Dhaka North and South City are the most urbanized among the twelve city corporations in Bangladesh.

Most researchers identified changes in land use and land cover utilizing cognitive methods. In light of the pressing concerns surrounding urbanization and territorial expansion in Dhaka, this study aims to bridge the knowledge gaps regarding the driving forces behind these trends. By focusing on community-level perspectives and examining changes since 1972, this research offers valuable insights into how to address the social, economic, and environmental challenges posed by urbanization and territorial expansion. This study provides a unique contribution to the existing literature on land use/land cover in Dhaka city, as it focuses on identifying the motivation factors driving urbanization and territorial expansion, with a particular emphasis on disparities among communities. Unlike previous studies on Dhaka City (Uddin *et al.*, 2014; Ashraful *et al.*, 2015; Dewan *et al.*, 2012; Trotter *et al.*, 2017; Rahman *et al.*, 2018; Mamun *et al.*, 2013; Dewan and Yamaguchi, 2009; Imran *et al.*, 2021), which examined river encroachment, monitored land use/cover changes, and investigated the status of land use/cover, this study is distinct in its focus and approach. Although some of the previous studies also explored the drivers of land use change, none of them examined the motivation factors that drive urbanization at the community level. We enhanced the classification of change types to aid law enforcement in decision-making. The findings have the potential to facilitate both urban planners and government officials in addressing the underlying reasons for the city's geographical growth.

Materials and Methods

The most used methods of land cover and land use change detection is satellite image classification. We have also used satellite images to identify the land covers and post-classification change pattern techniques. In addition to that we conducted field survey on the factors of land cover change.

Study Area

The North and South parts of Dhaka City Corporation (DCC) were georeferenced and digitized to constitute the research area (Fig. 1). In 1983, Dhaka had 3,444,147 inhabitants and 400 square kilometers.

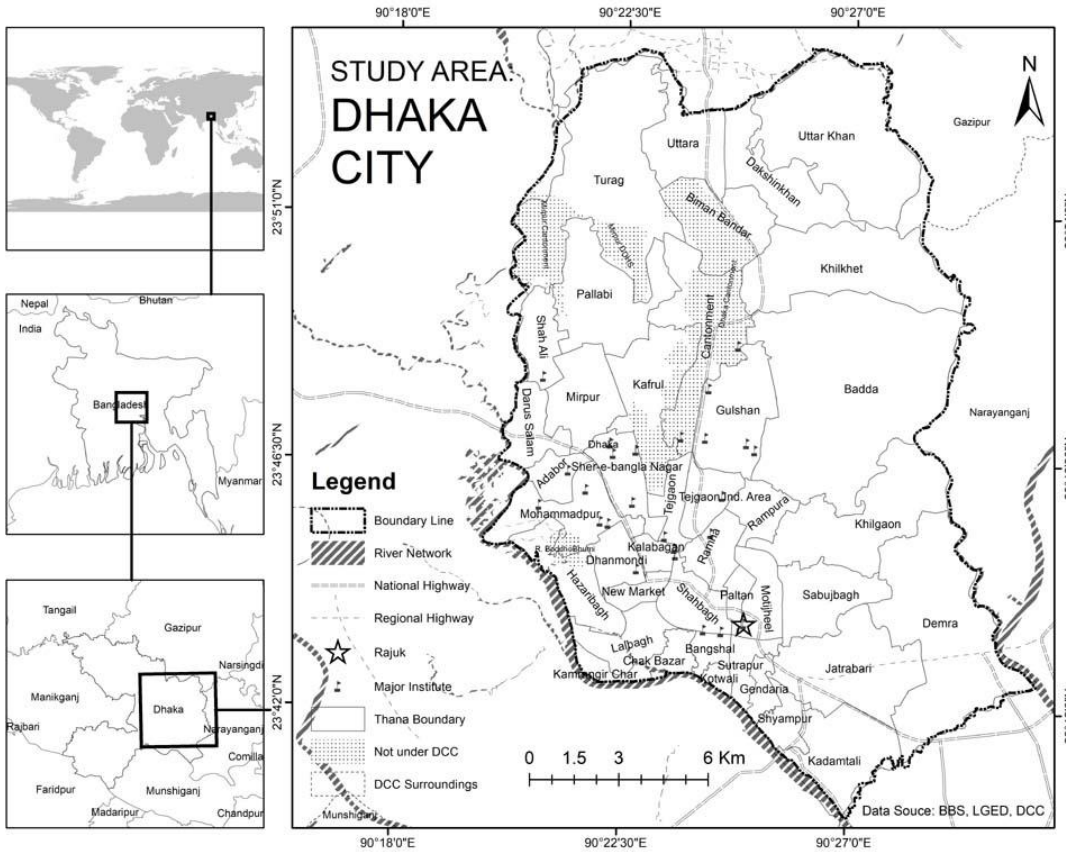

Fig. 1. Study Area.

The City Corporation was established in 1983 and entrusted with the responsibility of governing the city. It has now 75 wards. Four rivers (*Buriganga, Turag, Balu* and *Shitalakshya*) flow close to the city, producing urban flooding. Central and southern areas of the city are heavily developed, while its outskirts are lowlands. The Dhaka region experiences winter (November to February), pre-monsoon (March to May), and monsoon (June to October) (Imran *et al.*, 2021). Due to excessive rainfall and river overflow, it is vulnerable to monsoon flooding. The city suffered disastrous floods in 1988, 1998, and 2004 (Dewan and Yamaguchi, 2009).

Materials and Data Acquisition

Supervised classification, post-classification change detection and established methodologies are utilized in this study (Fig. 2). This method uses change detection to analyze sorts of change patterns and make reconnaissance survey decisions. From arid land to habitation, agricultural land to habitation, agricultural land to a water body etc are identified through image classification. The USGS land use and land cover classification system permits more specific groups (Lillesand and Kiefer, 1999). It can be further sub-divided and each entity belongs to one land class (Janssen and Bakker, 2000).

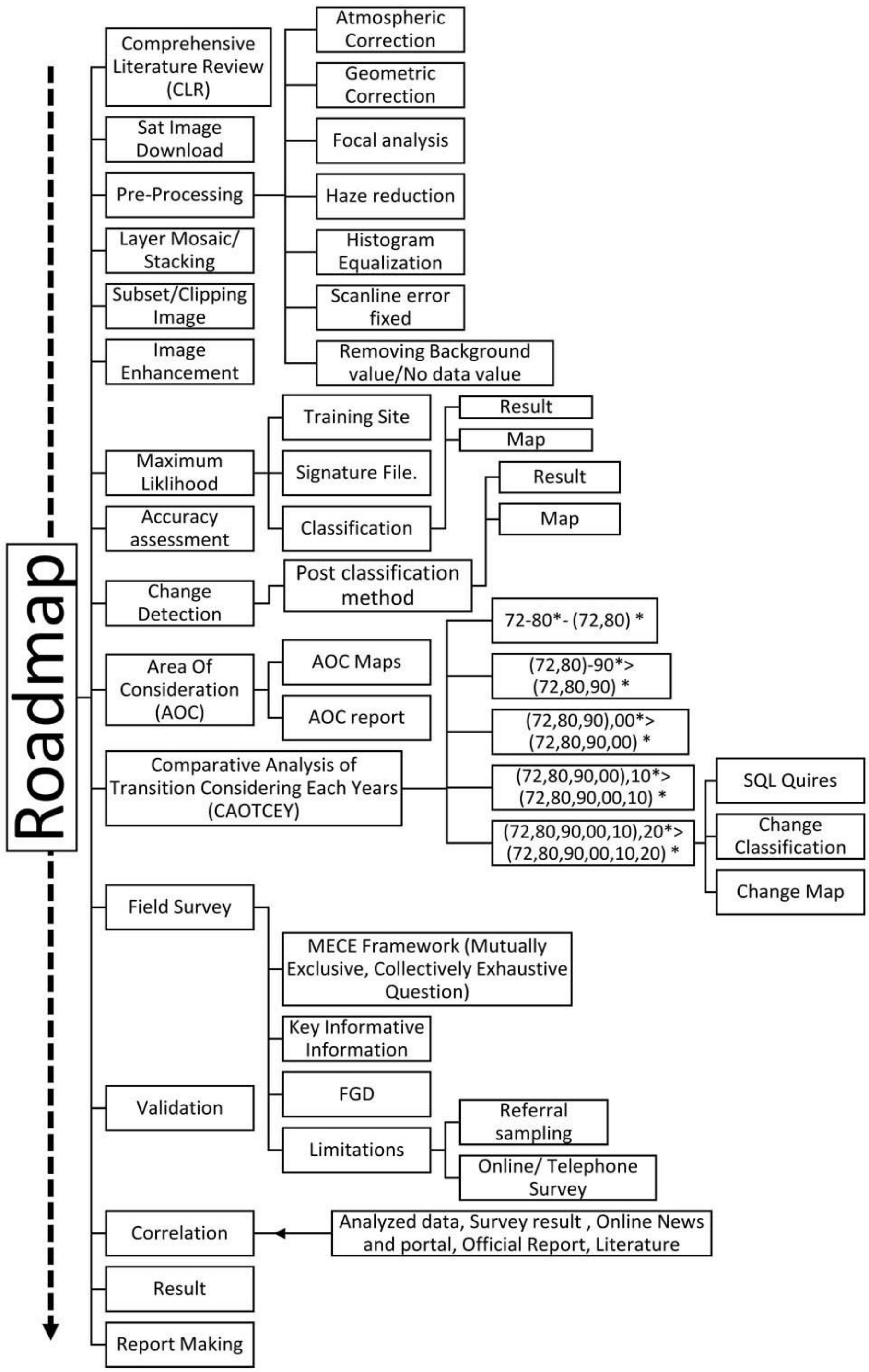

Fig. 2. Streamlining the Process of Investigation: Research Roadmap.

The research acquired 180 multiple responses from 43 locals in a field survey to analyze reasons of land cover changes. The fluctuating factors of cause and motivation are diverse and interesting. Multiple factors can reshape a location, which makes it challenging and intriguing to collect data for this study. The positioning of an area may have the greatest impact on its profitability. This research paper utilized two distinct approaches, namely the Area of Consideration (AOC) and the Comparative Analysis of Transition Considering Each Year (CAOTCEY), to evaluate changes in land use within a specific geographical area. The AOC method employed a meticulous and adaptive technique that integrated raster and vector data model to examine land use changes from 1972 to 2020, with a particular focus on the periods of 1990 to 2020, for the purpose of conducting a comprehensive field survey. In contrast, the CAOTCEY method was designed to identify and compare changes that occurred over multiple years, ranging from 1972 to 2020, and was focused on identifying transitions between 1972 and 1980 to establish an appropriate level of alteration for the year 1990. The results obtained from this analysis were then used to reconcile changes with the year 2000. Ultimately, the final CAOTCEY results spanned from 1972 to 2020 and considered a total of six years (Fig. 3).

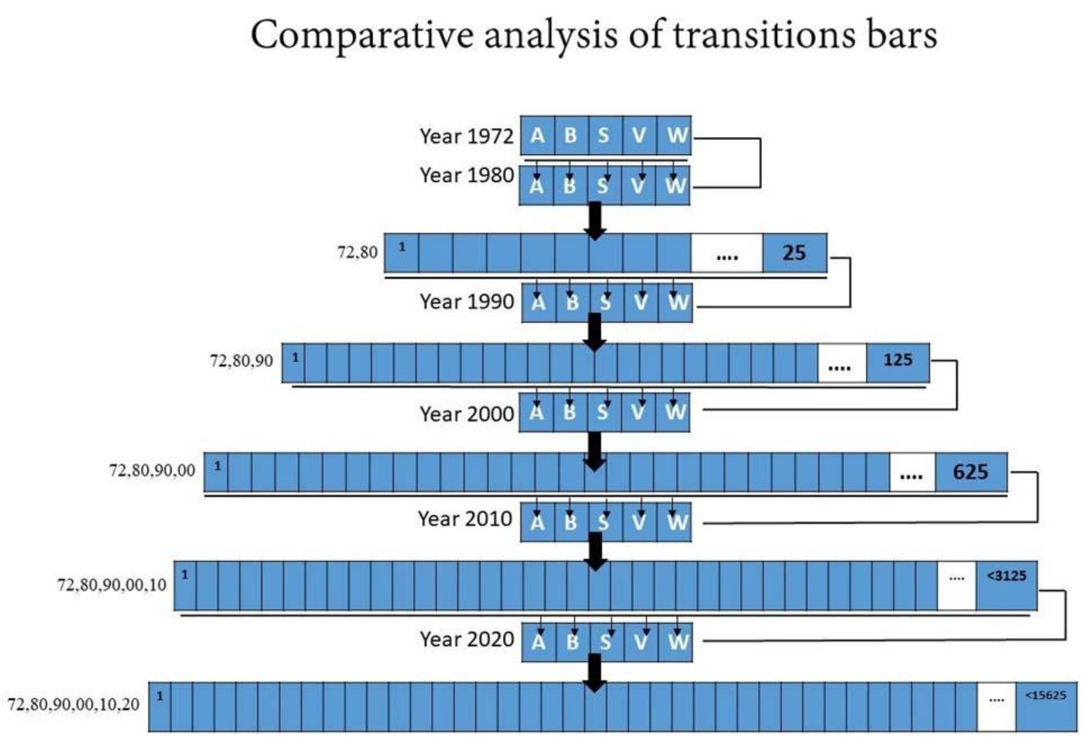

Fig. 3. Comparative Analysis of Transition Bars.

Digital Image Processing

It is an important tool for categorizing and analyzing images in various applications, such as remote sensing and geography. In this study, satellite images from different years were collected and analyzed to determine changes in land cover. The study used a combination of pre-processing techniques, such as seed pixel selection, and Gaussian Maximum Likelihood Classification (MLC) for image classification. After classification, the study used post-classification change detection to determine the changes in the land cover over time.

To rationalize data collection and analysis, the study used a comprehensive and well-integrated database, which consisted of raster and vector data. The study used a modified version of the from-to-change method to determine the changes in the land cover among different years. The results were divided into four basic groups to understand the changes separately: no change, permanent change, transitional change, and Substantial change. To measure the accuracy of the results, the Kappa Coefficient formula was used, which compares the reference data with an autonomous classifier and a random classifier. In order to compile ground-truth data of several years, this research used hand-held GPS for field-accuracy evaluations. The use of a comprehensive and well-integrated database, combined with the post-classification change detection method, allowed a more accurate analysis of the changes in land cover.

Results and Discussion

Land cover change patterns has been identified on several maps by using remote sensing and GIS techniques. The statistics of each land cover classes, and change amount has also been calculated and presented on graphical and tabular format.

Area changes of land cover

The area of Agricultural Land decreased from 82 sq.km in 1972 to 39 sq.km in 2020. In contrast, the area of Settlement increased from 39 sq.km in 1972 to 135 sq.km in 2020. The vegetation cover decreased from 53 sq.km in 1972 to 48 sq.km in 2020 (Table 1). The area of Barren Land and Waterbody has remained relatively stable with slight deviations over the years. According to the land cover change analysis, a total of 43 square kilometers of farmland were lost between 1972 and 2020, with corresponding areas being converted into barren land, Settlement, vegetation, and waterbody at a rate of 4.10%, 12.9%, 5.02%, and 1.69%, respectively (Table 2). However, to create the 96 square kilometer rising trend in the settlement, 12.95% of agricultural land, 15.90% of barren land, 6.18% of vegetation, and 5.05% of a water body were converted.

Table 1. Dhaka City's LULC of different Land Class, 1972-2020

Features	1972 (sqkm)	1980 (sqkm)	1990 (sqkm)	2000 (sqkm)	2010 (sqkm)	2020 (sqkm)
Agricultural Land	82	91	120	79	49	39
Barren Land	76	68	25	41	34	37
Settlement	39	58	58	70	106	135
Vegetation	53	43	54	69	79	48
Waterbody	33	22	24	21	12	19

Population growth and urbanization have had an impact on Land Use and Land Cover (LULC) changes in the Dhaka metropolitan area. Agricultural land has declined over time, whilst the rate of human settlement has consistently risen since 1980, beckoning rural laborers and resulting in the establishment of townships. The growth in human settlement has led to a sharp decline in other land cover types, such as barren land and vegetation. The water reservoir has likewise been steadily declining. The development of *Hatirjheel* lake has contributed to the decarbonization of the city however the removal of trees for the Metro Rail project will have a consequence. Meanwhile, the project's construction may prove helpful in the long run. The finding shows that the conversion of wetland habitats to other types has been expanding.

Validation of Classified Image

The classification accuracy for images from 1972 to 2020 deviates from 71.70% and 97.50%. The overall kappa values for the classifications range from 0.64 to 0.97, indicating a degree of agreement with training dataset that is marginal to satisfactory (Fig. 4).

Table 2. Classification accuracy

Year	**Overall Accuracy**	**Kappa Value**
2020	88.35%	0.85
2010	90.18%	0.87
2000	81.55%	0.77
1990	97.50%	0.97
1980	76.74%	0.70
1972	71.70%	0.64

For the year 2020, the classifier exhibited especially high accuracy for classes such as settlement (96.15%) and moderate accuracy for classes such as Agricultural land (92.31%) and bare Land (91.30%). The classifier's capacity to retain a high level of accuracy across time, demonstrates its temporal stability.

This research indicates that the accuracy of image classification for historical remote sensing images is inferior to that of more current images. This is likely owing to the reduced quality of previous satellite images, which hinders the classifier's ability to reliably recognize and categorize features. Our research employed additional data sources, such as ground-based observations or chronological maps, and implemented photographic enhancement techniques, such as thresholding and atmospheric correction, to circumvent this constraint.

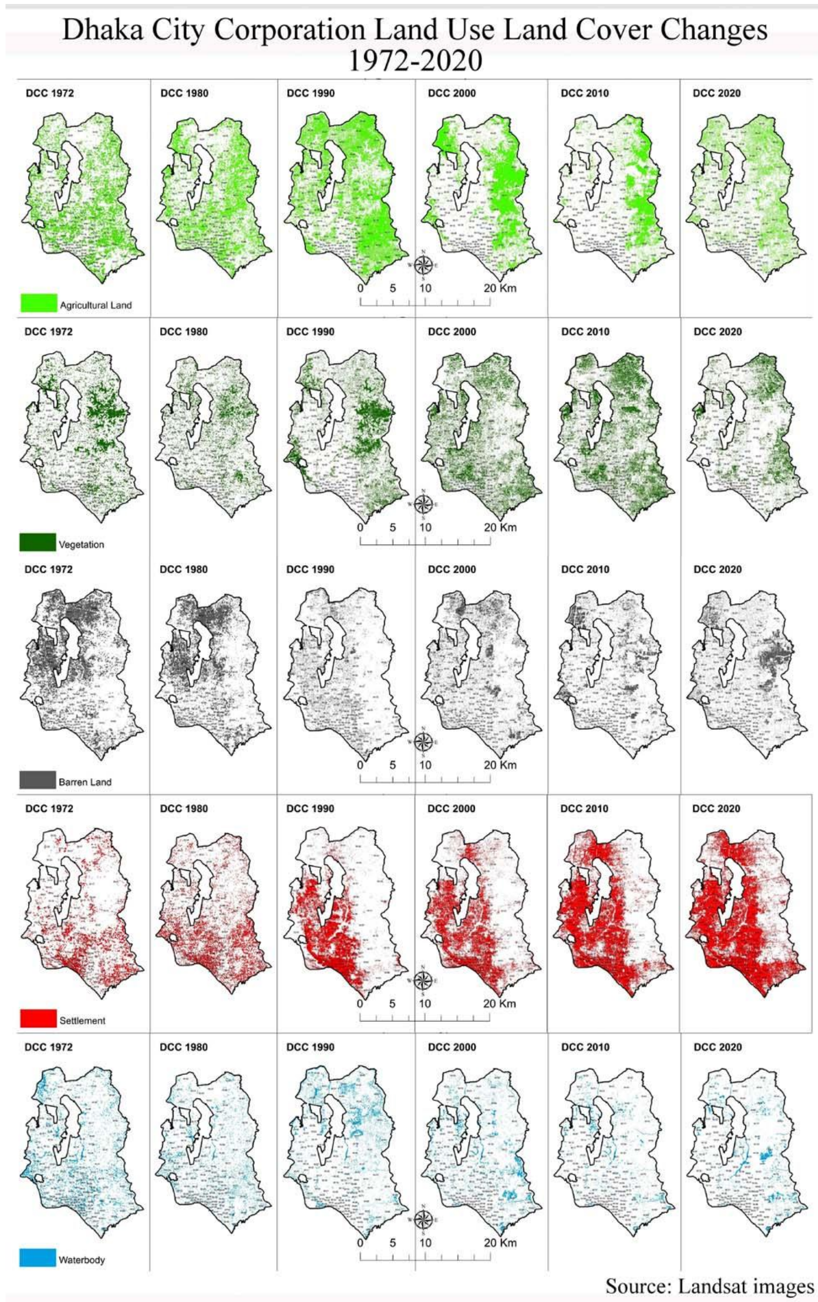

Fig. 4. Tracing the urban transformation: A glimpse into Dhaka city's Land Use and Land Cover Changes from 1972 to 2020.

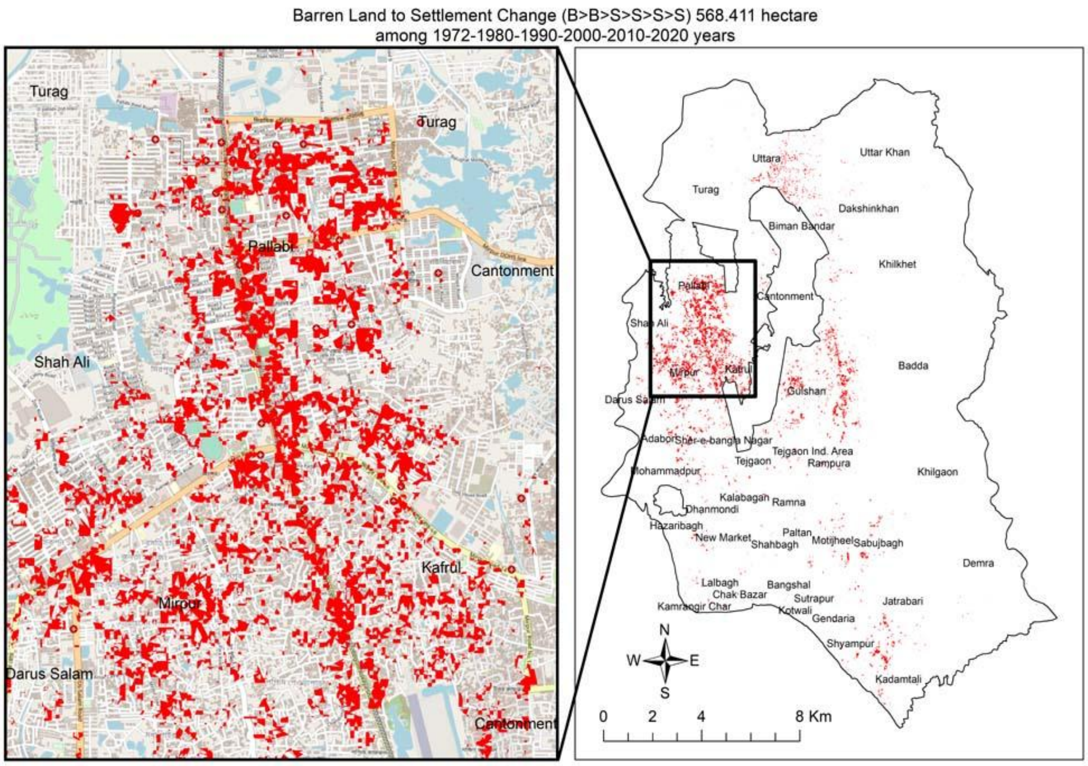

Fig. 5. Decoding the growth story of Dhaka through linear pattern changes.

Growth Pattern

This Change detection result (Table 2) fluctuates from year to year, with Agricultural land (29.64%) and Barren (27.55%) Land experiencing the most changes and settlements experiencing the most formation (48.08%). The diagonal cells indicate that there has been no change in that class. The value in the column represents the year 2020, whereas the value in the row represents the land cover percentage in 1972. Historical image analysis objectives determine the formation of land cover groups. Towards this objective, which is specifically articulated in the CAOTCEY strategy, significant changes could be witnessed. The land cover class with the least amount of change is waterbodies, represented by 10.86%, whereas vegetation cover is changed by 18.26%. The majority of changes in the Barren Land category have been turned to Settlement (15.90%), followed by Agricultural Land (4.8%). The Waterbody category has been converted predominantly to Settlement (5.05%) and Agricultural Land (2.09%).

Table 3. LULC Change Detection: 1972 to 2020 Results (%)

	Land class 2020						
	Land Class Name	**Agricultural Land**	**Barren Land**	**Settlement**	**Vegetation**	**Waterbody**	**Grand Total**
Land Class 1972	Agricultural Land	5.87	4.10	12.95	5.02	1.69	**29.64**
	Barren Land	4.81	2.93	15.90	3.27	0.63	**27.55**
	Settlement	2.37	0.88	8.00	1.74	0.70	**13.69**
	Vegetation	3.89	4.33	6.18	2.52	1.33	**18.26**
	Waterbody	2.09	1.42	5.05	1.37	0.93	**10.86**
	Grand Total	**19.04**	**13.66**	**48.08**	**13.92**	**5.29**	**100.00**

Comparative analysis of transition considering each years (CAOTCEY) result

This methodology is a sequential procedure for post-classification change detection. On the map (Fig. 5) it is seen that the evolution of the barren land is represented by the gray zone. It was the same in 1972 and 1980. Henceforth, it became a settlement area in 1990 and continued to be so until 2020. As a result, this change pattern was classified as a 568.411 ha permanent change area.

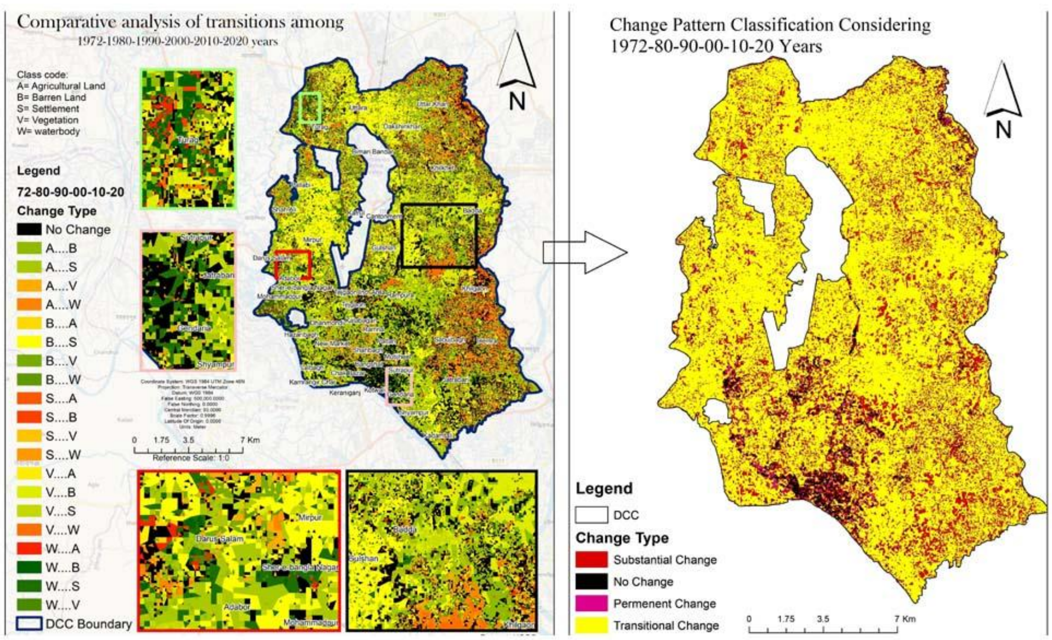

Fig. 6. Quantifying the Types of Transformation Over the Years.

In order to classify different growth patterns stemming from a given land cover, a thorough study was performed during land cover change map production (Quader *et al.*, 2017). As a logical consequence, four types of change have been found in this research for the Dhaka City Corporation region. It is found that the substantial change (Fig. 6) occurs in 46 sq.km indicating significant land use changes such as urbanization and industrialization. This type of alteration could have tangible effects on the environment, economy, and local populations. No change considers different intervals where land functioning has not changed, which is 7 sq.km. Permanent change is considered where transformation occurs after two-to-three-time intervals in 9 sq.km, resulting from human activities like urbanization, industrialization, or infrastructural development. Transitional change is surprisingly infrequent which is insightful (in 216 sq.km). It indicates that land use changes in this area are dynamic and it could be changed again in the upcoming years. In any change detection approaches, it is crucial to highlight that the method is dependent on the quality and accuracy of the training dataset, as well as the parameters and methodologies utilized for the investigation.

Temporal Validation

GIS technology has the potential to enhance planning processes through the integration of novel models and tools, as well as by leveraging the full spectrum of GIS capabilities. This can provide a more precise analysis, leading to superior strategic decision-making (Yaakup & Sulaiman, 2006).

AOC	Change (Ha)	Area							
AOC1	1007.988	Adabor	Darus Salam	Kafrul	Mirpur	Pallabi	Shah Ali	Sher-e-bangla Nagar	Turag
AOC2	711.406	Biman Bandar	Dakshinkhan	Turag	Uttar Khan	Uttara			
AOC3	427.866	Badda	Khilkhet						
AOC4	349.743	Badda	Cantonment	Gulshan					
AOC5	254.980	Turag	Uttara						
AOC6	166.025	Kalabagan	Motijheel	New Market	Paltan	Ramna	Shahbagh	Tejgaon	
AOC7	151.919	Badda	Khilgaon	Rampura					
AOC8	118.200	Badda	Khilkhet						
AOC9	110.434	Gendaria	Jatrabari	Kadamtali	Shyampur				
AOC10	103.736	Dhanmondi	Hazaribagh	Mohammadpur					

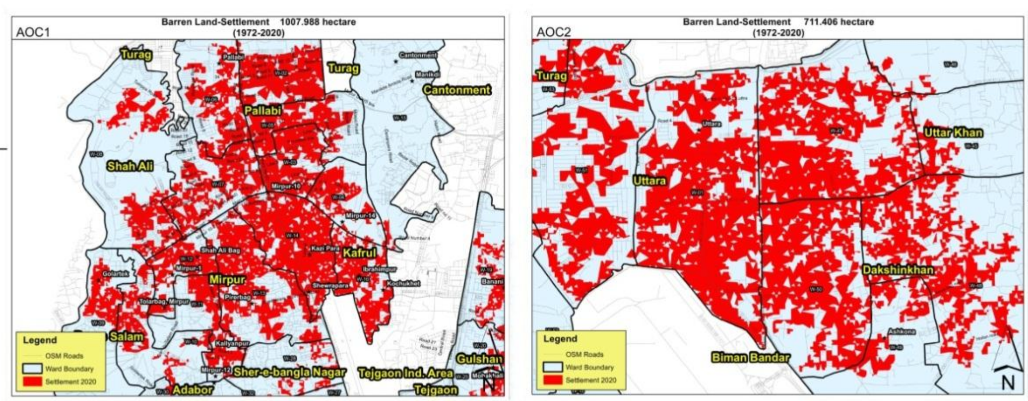

Fig. 7. Depicting the Extent of the Field Work: Area of Consideration Table and Mapping.

As illustrated in Fig. 7, a comprehensive analysis of land area variations across DCC regions between 1972 and 2020 reveals that AOC1 and AOC2 underwent the most substantial changes, with an increase of 1007.988 and 711.406 hectares, respectively, while AOC10 had the least change. The disparity in the degree of transformation was notable, with AOCs 5-1 experiencing changes ranging from 254.980 to 1007.988 hectares, indicating a significant alteration in land use among those areas. Conversely, AOCs 10-6 demonstrated more moderate changes, ranging from 103.736 to 166.025 hectares. The comparison underscores the criticality of utilizing the full range of GIS tools and techniques for precise analysis and informed urban planning decisions.

Post Classification Evidence

The transformation of Dhaka city has been significantly influenced by the housing sector being the primary motivating factor, accounting for 25.86% of the changes (Fig. 8-9). Private housing companies and developers have played a pivotal role in shaping the city's landscape and demographics. The improvement of transport infrastructure has facilitated connectivity and accessibility within the city, resulting in the growth of businesses and industries, contributing to 17.24% of the changes. Additionally, government initiatives, including the creation of special economic zones and public-private partnerships, have encouraged investment and development in various sectors, accounting for 15.52% of the changes. The growth of markets and shops has also played a role, accounting for 13.79% of the changes, while socio-cultural structures such as parks, religious buildings, and playgrounds have contributed 8.86%. The government has played a significant role in the transformations, being responsible for 37.50% of the changes, while private developers have been responsible for 25% of changes. In terms of micro-level analysis, several neighborhoods in Dhaka, including *Adabor*, *Darus Salam*, *Pallabi*, *Kafrul*, and *Mirpur* regions, have experienced the most significant changes (Fig. 8-9).

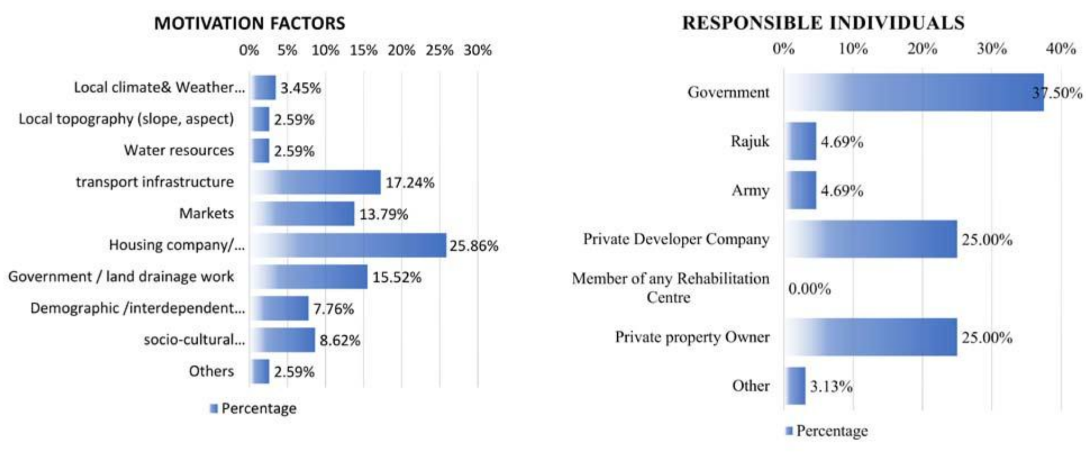

Fig. 8. Motivating factors and responsible individual result statistics.

There is a concern that housing companies are causing environmental degradation in Dhaka. The Bangladesh Environmental Lawyers Association (BELA) has initiated legal proceedings against housing companies for purportedly converting farmland and wetland into a residential development. In 2005, the Supreme Court declared the *Nandonik Housing* project (previously known as *Modhumoti*) unlawful as it was involved in grabbing land located in floodplains identified on the 1997 Master Plan for Dhaka City (Siddiqui, 2020). The Real Estate and Housing Association of Bangladesh (REHAB) has responded to the matter by noting that they may only take action against members who break their guidelines.

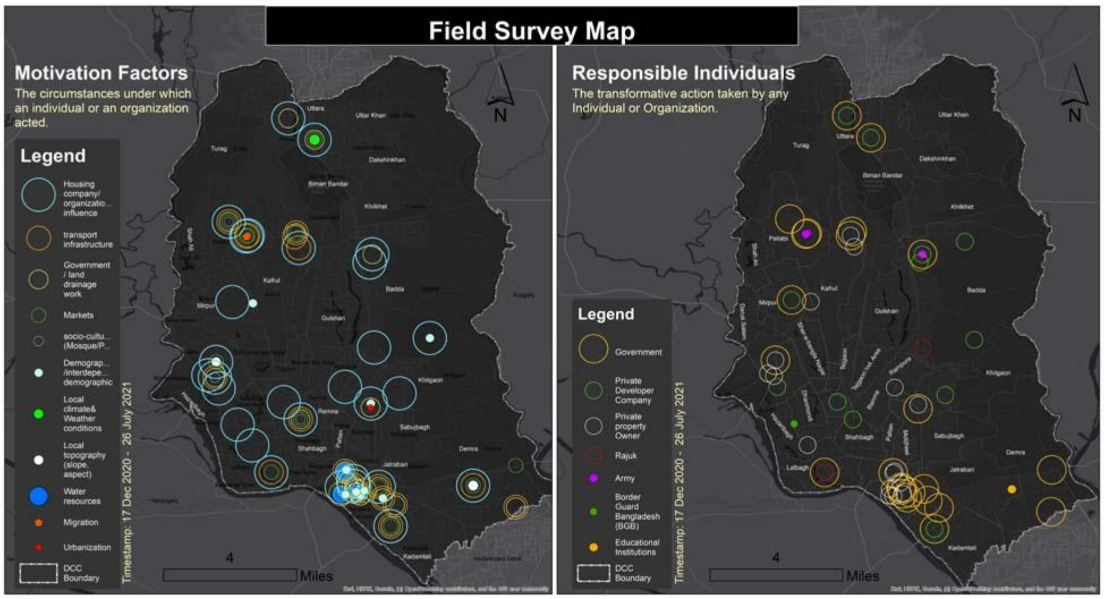

Fig. 9. Comprehensive Overview of the Field Survey Results.

Following the terrorist attack that occurred in July 2016, the Ministry of Housing and Public Works cautioned property owners in areas such as *Gulshan*, *Banani*, and *Dhanmondi* against the use of residential dwellings for commercial activities. Alternatively, they were advised to ensure that their properties are complied with the building code and the initial design specifications (Mamun, 2017). The Department of Environment (DoE) and Rapid Action Battalion (RAB) investigated the project area and found that *Ashiyan Lands* had illegally seized land, buildings, and even cemeteries from local inhabitants to develop plots. They illegally grabbed government-owned *khas* land and wetlands. The company was initially allowed to construct 43 acres of land for their project by *Rajdhani Unnoyan Kartripakkha* (RAJUK) and the Dhaka district administration in 2005, but they enlarged the area to over 1,197 acres, 30 times of its initial size, utilizing political influence (Karim, 2020).

The city underwent major transformations between 2010 and 2015, although urbanization had already begun before then. The distribution of underdeveloped plots by RAJUK has led to a situation where owners of uninhabited land are compelled to either construct buildings or utilize their land, due to the pressing need for residential purposes. The housing sector plays a major role in the transformations of Dhaka, with the government and private developers contributing to the changes. The city has faced challenges in terms of environmental issues and illegal acquisitions, but the government and other organizations have taken steps to address these issues.

Conclusion

Urban expansion in Dhaka is evident through the increasing trend in settlement and decreasing trend in other land covers. According to the analysis of land use and land cover (LULC) change, urban settlement area has expanded by 246.15% from 1972 to 2020. This growth in construction activity between 1979 and 2000 has also led to a decrease in water bodies by 42.42%. Despite being the most prevalent of the five land cover groups, agricultural land has decreased by 52.44% from 1972 to 2020. Rapid population expansion and the inadequate implementation of land resettlement protocols resulted detrimental effects on the indigenous ecological ecosystems and caused a diverse range of environmental deterioration.

Our research, which uses remote sensing and GIS techniques, can help officials in Dhaka to identify areas with change factors that require improved planning and sustained development. While there may be existing plans for the city, our study can complement and inform these plans by identifying factors that need to be revised or improved due to environmental degradation resulting from rapid urbanization and loss of natural ecosystems.

Our research has highlighted certain factors that are contributing immensely to the land use changes, such as housing development, transport infrastructure, markets, and government work cumulatively constituting nearly 72% of the total change factors. This has led to rapid urban growth with negative consequences for the unplanned expansion of the city's built-up areas. Based on this information, strategic decisions can be made on how to manage and plan for different types of land use change in the region. For example, areas with substantial change could be targeted for conservation or mitigation efforts to minimize negative impacts on the environment and communities. Areas with no change could be designated as natural preserves or protected areas. Areas with permanent change could be targeted for urban development or infrastructure planning. Areas with transitional change could be closely monitored for further changes and managed accordingly.

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