Spatiotemporal Changes of Wetlands over Gazipur District Bangladesh: A GIS-Based Analysis

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ABSTRACT

Gazipur District has undergone rapid urbanization, resulting in significant loss of wetlands and natural ecosystems. This study analyzes land use and land cover changes from 1988 to 2024 using remote sensing and GIS. Landsat imagery (TM, ETM+, and OLI) was classified using the maximum likelihood supervised classification method. The analysis showed that built-up areas have increased more than threefold while agricultural land and wetlands declined by 93.5% and 59%, respectively, representing proportional reductions relative to their original areas. The most substantial changes occurred between 1995 and 2015, driven by Dhaka's urban expansion and limited enforcement of land-use regulations. Wetland loss was most severe near industrial zones and major highways, particularly along the Dhaka–Mymensingh road. These transformations have caused notable ecological impacts, reduced flood buffering capacity, diminished groundwater recharge, and loss of biodiversity. The study demonstrates the utility of GIS and remote sensing for monitoring land transformation and provides critical insights to support sustainable urban planning and wetland conservation in rapidly developing regions.

1. INTRODUCTION

Wetlands operate as one of Earth's most intensive habitats, which supply numerous ecological benefits that encompass water filtering and flood management, and groundwater refilling, and serve as ecological habitats for different plant and animal forms [1].Wetland systems around the world endure serious threats from activities created by humans, but rapid urban sprawl remains the primary threat.

Developing nations like Bangladesh experience specific pressure due to population increase and unregulated infrastructure growth that threatens the natural state of wetlands [2]. Gazipur District, located directly north of Dhaka, illustrates these challenges. Covering an area of approximately 1,818 square kilometers, between 1999 and 2023 the built-up zone in Gazipur expanded nearly 300% of its original area by transforming agriculture fields and wetlands into concrete structures [3]. The rapid growth of Gazipur stems from Dhaka urban expansion as well as the establishment of more than 3,000 industrial units including tanneries, garments and dyeing industries. The construction activities along with industrial establishment have caused both major land conversion and severe environmental damage by creating pollution and interfering with natural water flows. When wetlands degrade or disappear from these areas, essential ecosystem services are lost, and the landscape undergoes substantial alteration. Wetlands play a critical role in flood buffering, water storage, filtration, and they provide fish and aquatic plants that are vital to rural livelihoods [4].

This research adopts a remote sensing and GIS-based approach to analyze LULC dynamic in Gazipur district over 36 years, from 1988 to 2024. This period was selected because reliable, clear satellite imagery prior to 1988 was not available, and it aligns with the major phases of urban growth in Gazipur District. The primary objective is to evaluate the rate and pattern of change in four key land categories: wetlands, vegetation, agricultural land, and built-up area. Landsat satellite images from the USGS Earth Explorer platform were used to derive land cover classifications using the supervised Maximum Likelihood Classification method in ArcGIS. The selection of this method ensures a high degree of classification accuracy and is well-suited for heterogeneous landscapes such as Gazipur [5].

Most existing LULC studies in Gazipur utilize satellite imagery over relatively short periods, often under two decades, thereby constraining insights into long-term urban expansion and wetland degradation trends. The findings of this study not only contribute to the

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academic understanding of land transformation in peri-urban Bangladesh but also have practical implications. In the face of climate change, urban heat islands, and water scarcity, the conservation of wetland ecosystems becomes even more urgent. Policymakers, city planners, and environmental regulators must leverage geospatial data to implement sustainable urban planning strategies that prioritize ecological balance. These might include zoning regulations to protect remaining wetlands, the creation of green buffers, and the integration of nature-based solutions in infrastructure development [6].

The primary goal of this study is to:

(1) Account for spatiotemporal variations of wetlands, agricultural, vegetation, area of built-up, from 1988 to 2024 over the region;

(2) Identify spatial patterns of land cover conversion;

(3) Provide geospatial insights towards the environmental conservation and sustainable urban development.

2. STUDY AREA

The research territory consists of Gazipur district which faces the northern border of Dhaka Bangladesh while situated between 23°50′ N to 24°20′ N latitude and 90°10′ E to 90°40′ E longitude (shown in Fig. 1). The bordering regions of this district include Mymensingh and Kishoreganj to the north along with Narsingdi to the east and Tangail to the west followed by Dhaka–Narayanganj to the south [7][8].

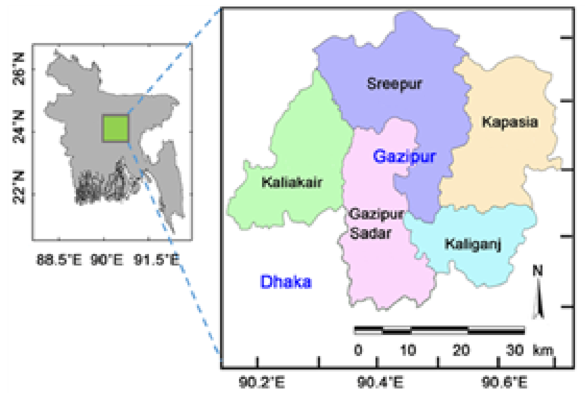

Fig. 1: Study Area [9]

The Shitalakkhya river, Turag river and the Balu river create fundamental geographic limits while the Dhaka–Mymensingh Highway maintains excellent road connections to Dhaka city. The current total population of Gazipur has reached 4.2 million while maintaining a population density of 2.100 inhabitants per square kilometer following its continuous transition to an urbanized industrial city [10]. Population growth in this region continues to rise because its industrial area successfully supports over 3,000 industries that concentrate on textile, garment and dyeing facilities [10]. Gazipur City Corporation operates as the largest metropolitan council in Bangladesh while controlling the urban development process of the city. Urbanization together with industrial development presents substantial pressure on the biodiverse Vawal Pargana forest which used to thrive abundantly. The district climate exhibits wide temperature ranges from 12.7°C to 36°C and receives an average annual rainfall of 2,376 mm according to BBS (2024). The current climate allows multiple diverse wetlands to exist throughout history. The district possessed numerous lowland wetlands (haors and beels) and agricultural areas that developers transformed through time into urbanized zones.

3. METHODOLOGY

Remote Sensing were employed in combination with GIS to examine extensive Land Use and Land Cover transformations within Gazipur District from 1988 up to 2024. The method retrieves satellite data for analysis through a sequence of procedures that starts with data collection then moves to image formatting and classification operations before executing spatial land transformation assessments.

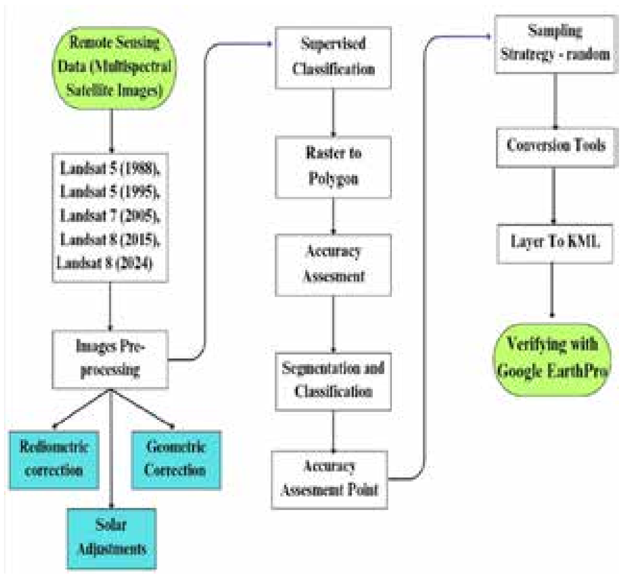

Fig. 2: Methodology Flow Chart

The methodological framework (Fig. 2) operates its steps to guarantee precision while providing consistent results that are strongly connected to the environmental dynamics' analysis across the span of decades.

3.1. Satellite Data Acquisition

Multi-temporal satellite data used to extract Land Use and Land Cover (LULC) information were obtained from the USGS Earth Explorer platform. To maintain spectral and temporal consistency, the study incorporated data from Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), and Landsat 8 Operational Land Imager (OLI), as summarized in Table I. Satellite imagery was selected from the dry season months of December through January for five reference years: 1988, 1995, 2005, 2015, and 2024, ensuring phenological consistency across datasets. All datasets were projected into the Universal Transverse Mercator (UTM) coordinate system (Zone 46N) at a 30-meter spatial resolution to support harmonized spatial and analytical assessments.

3.2 Preprocessing

Satellite imagery preprocessing measures maintained the integrity and multi-temporal consistency of images from 1988 and 1995 up to 2005 and 2015 and 2024. The methods applied to the data increased the precision and steadiness of Land Use/Land Cover classification information for the area of Gazipur.

Table I: Specification of Satellite Image Acquisition

Satellite	Sensor	Date	Band Number	Path/row	Cloud Cover	Spatial Resolution (m)
Landsat 5	TM	2-1-1988	7	137/43	<5	30
Landsat 5	TM	21-11-1995	7	137/43	<3	30
Landsat 7	ETM	10-12-2005	7	137/43	<10	30
Landsat 8	OLI	12-11-2015	11	137/43	<2	30
Landsat 8	OLI	4-11-2024	11	137/43	<2	30

Radiometric correction was applied to convert raw digital numbers (DN) into top-of-atmosphere (TOA) reflectance, minimizing atmospheric and sensor-related effects. Initially, DN values were transformed into TOA radiance using scaling factors provided in the Landsat metadata file, following the USGS standard procedure:

$$L_\lambda = M_L \times Q_{CAL} + A_L$$

where, L_λ represents TOA spectral radiance, M_L and A_L are the band-specific multiplicative and additive rescaling factors, and Q_{cal} is the quantized calibrated pixel value. Subsequently, radiance was converted to TOA reflectance to account for solar irradiance and acquisition geometry:

$$\rho\lambda = \frac{L_\lambda \, x \, d^2 \, x \, \pi}{ESUN_\lambda \, x \, cos(\theta_s)}$$

where, ρ_λ denotes TOA reflectance, d is the Earth–Sun distance in astronomical units, $ESU\,N_\lambda$ is the mean solar exoatmospheric irradiance, and θs is the solar zenith angle.

To further reduce atmospheric scattering (haze), the Dark Object Subtraction (DOS) method was employed, wherein the minimum reflectance value identified from dense water bodies was subtracted from all pixels in the corresponding band [11]. This combination of conversion and correction steps ensured radiometric consistency across sensors and acquisition dates. Geometric correction ensures all images are accurately aligned in a common coordinate system, so that each pixel corresponds to the same ground location across years.

Solar angle adjustment was applied to correct for varying illumination conditions, using the cosine of the solar zenith angle recorded in the metadata. The normalized reflectance (ρ corrected) was calculated as [12]:

$$\rho_{corrected} = \frac{\rho\lambda}{cos(\theta_s)}$$

where, $\rho_{corrected}$ = reflectance normalized to standard illumination.

3.3 Supervised Classification

Land cover was classified into four categories: wetlands, agricultural land, vegetation, and built-up areas as shown in Table II. The Maximum Likelihood Classification (MLC) algorithm operated as part of supervised classification through ArcGIS to classify LULC. A substantial number of training samples for each land cover class were acquired according to field-based expertise and high-resolution imagery checks. Through the use of training sample spectral signature, the methodology classified land types effectively for precise separation.

Table II: Land Cover Classification

SN	Class	Details
01	Wetlands	Water body like lake, pond, canal, including rivers, water reservoirs, and streams.
02	Vegetation	Trees, natural vegetation, mixed forest, gardens.
03	Built-up	Residential, commercial, industrial area, land covered with concrete.
04	Agricultural	Agricultural lands, crop fields, barren land

3.4 Accuracy Assessment:

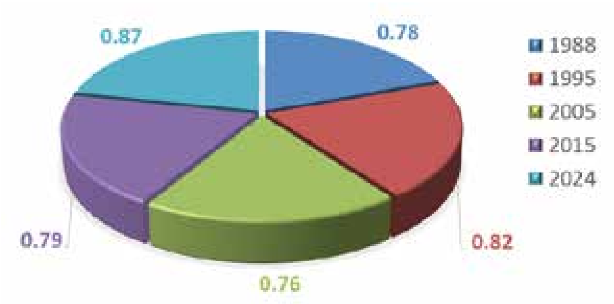

Fig. 3: Kappa value

The LULC classification results underwent validation through accuracy assessment which used random stratified method and confusion matrices processed using 100 reference points generated automatically. The reference data acquisition process involved field validation along with high-definition Google Earth Pro Map. Confidence in the classified outputs increased because the classification accuracy rate across all studied years stayed 0.76-0.87, Fig. 3 shows more details.

4. RESULTS AND DISCUSSION

Landsat images were used to create supervisory classification-driven LULC maps of Gazipur district from (1988-2024). The research examined four main land use and land cover types including wetlands, vegetation, agriculture, and built-up area in 36 years.

4.1 Wetlands Changes

The total wetland area declined from 221.19 sq.km in 1988 to 89.75 sq.km in 2024, marking a 59.4% loss over the study period (shown in Fig. 4). The sharp decline occurred between 2005 and 2015, where wetlands area decreased by 40.87%, largely attributed to rapid peri-urban expansion, land encroachment, and possible sedimentation of natural wetlands. The loss of these areas compromises hydrological stability, increases urban flood vulnerability, and leads potential risk for aquatic and terrestrial species. These findings align with earlier studies on wetland degradation 6.25% between 1989 and 2009 in Mirzapur Union and Dhaka's peripheral zones [13], directing a shared pattern of ecological pressure due to unregulated urbanization.

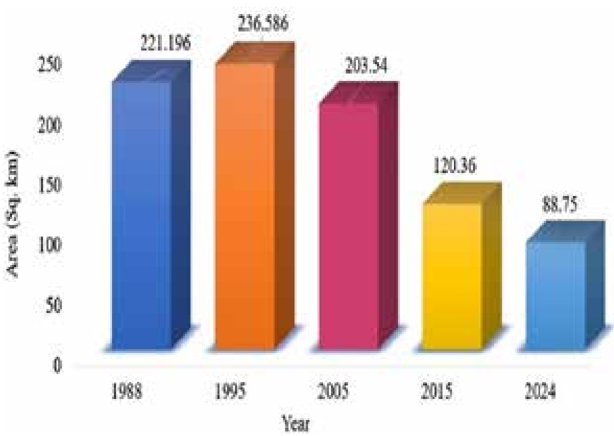

Fig. 4: Degradation of wetlands

4.2 Built-up Area Expansion

As shown in Fig. 5, the built-up areas increased more than threefold, growing from 242.17 sq. km in 1988 to 826.50 sq. km in 2024. The most rapid expansion occurred between 2005 and 2015 (60.86%), coinciding with rapid industrialization, real estate development, and infrastructure in the Gazipur–Tongi corridor and along the Dhaka–Mymensingh Highway. Similar conversion pattern was also noted in earlier articles [14], which reported cropland and forest zones transformed into built-up and homestead areas.

4.3 Agricultural Land Decline

Agricultural land witnessed a reduction of over 93%, from 901.65 sq.km in 1988 to 60.51 sq.km by 2024. The most significant declines were recorded during 1995–2005 (−31.73%) and 2015–2024 (−86.45%), reflecting direct conversion into built-up areas. The similar outcome was also found in previous study on Gazipur [14]. This trend poses serious risks to food security, undermines rural livelihoods.

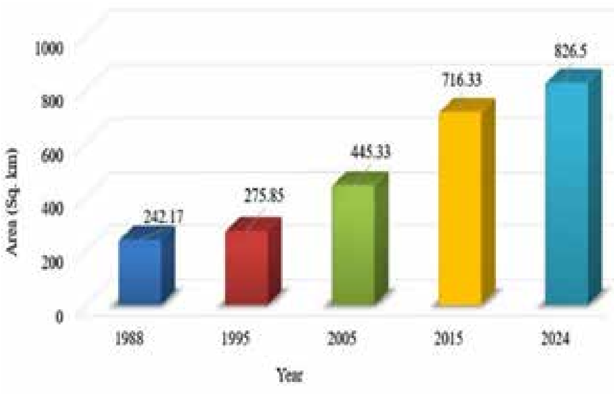

Fig. 5: Urban Expansion in Gazipur District from 1988 to 2024

4.4 Vegetation Cover Changes

Vegetation cover increased from 452.57 sq.km to 841.82 sq.km in terms of between 1988 and 2024, but the most significant increment was in the most recent decade (2015–2024) of 57.24%. The trend is explained by these environmental improvement-oriented projects like the urban greening projects and afforestation initiatives. Land cover reduction due to the destruction of forest and unregulated land use conversions during some periods between 1995 and 2005 led to vegetation cover ceasing to cover 13.31 sq.km of the land area.

The analysis shows how the urban expansion caused a systematic move of agricultural and wetland areas into the urban territories, while uncontrolled urban growth served as the most important factor. Research data aligns with earlier research [2][3][5]. Dhaka fringe area needs urgent sustainable land use planning in combination with wetland conservation especially in fast expanding areas like Gazipur.

5. CONCLUSION

The current research studies the land-use and land-cover change of Gazipur District during the last 36 years, which can be explained by the rapid development of urbanization on the one hand and the excessive growth of industrial enterprises on the other. The discussion shows that there is a more than doubling of built-up areas and a decreasing of wetland and cropland by 59 % and 93.5 respectively. This pattern results in undermining the ecological resilience of the district and weakening flood control abilities, groundwater storage capacity, and biodiversity to maintain native species habitat.

Class	Area (Sq.km)					Change %			
	1988	1995	2005	2015	2024	1988-95	1995-05	2005-15	2015-24
K Value	0.78	0.82	0.76	0.79	0.87				
Wetlands	221.192	236.586	203.54	120.36	89.7546	6.959565	-13.9679	-40.8667	-25.4282
Vegetation	452.573	449.39	548.2	535.36	841.8158	-0.7033	-13.3097	-2.34221	57.24294
Agriculture	901.6451	856.708	621.51	446.51	60.51215	-4.9833	-31.7299	-28.1572	-86.4478
Built-up Area	242.17	275.846	445.33	716.35	826.4975	13.90593	61.44153	60.85824	15.37621

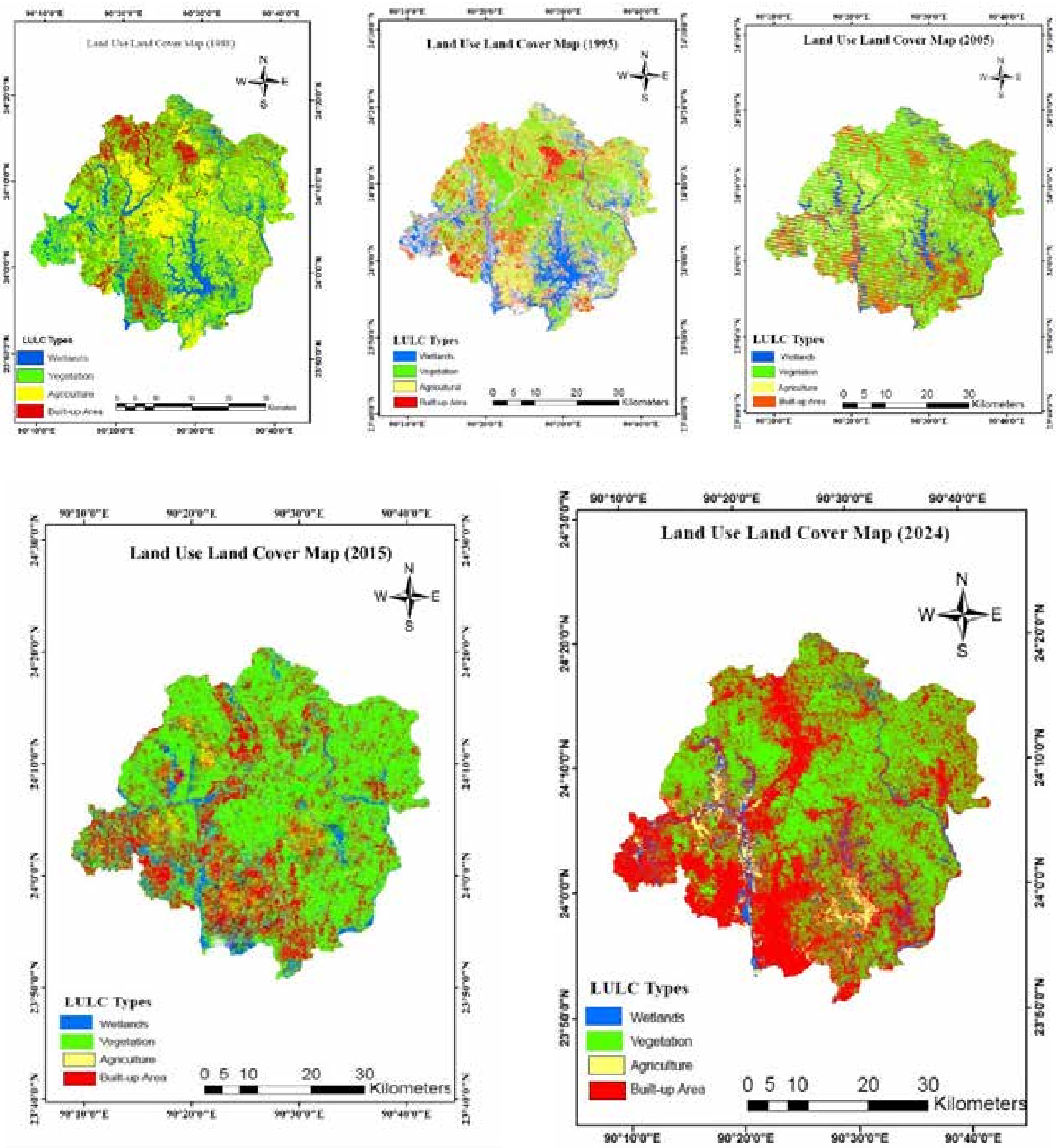

Fig. 6: Land Use Land Cover (LULC) Classify Map in (A) 1988, (B) 1995, (C) 2005, (D) 2015 and (E) 2024

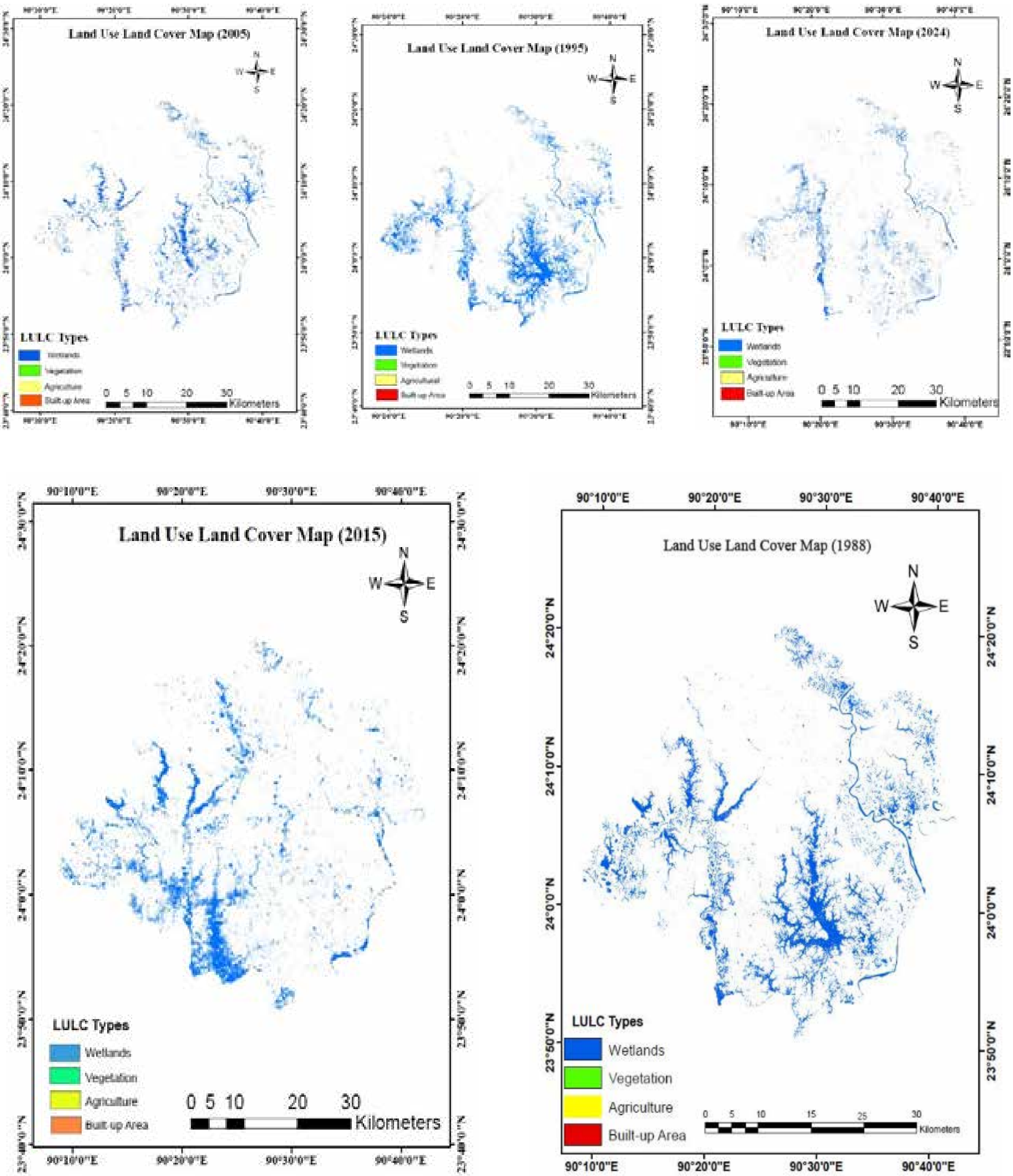

Fig. 7: Land Use Land Cover (LULC) Classify of Wetlands in (F) 1988, (G) 1995, (H) 2005, (I) 2015 and (J) 2024

Ongoing research has established that the use of geospatial monitoring in urban planning and environmental management is inevitable. Especially in the areas of swift peri-urban expansion, it is essential to ensure that the existing wetlands remain intact and that the new development anchors the nature-based solutions, thus maintaining the balance of nature.

The study presents policymakers and city planners with empirical data that they can use in the development of law and spatial plans of protecting wetland systems. In particular, the results indicate the need to use zoning rules, create green buffers, and encourage sustainable land-use patterns. Such proactive actions are pertinent to reduce further the degradation of wetland systems, as livelihoods and the reduction of the disasters risk rely on such systems in the face of the ongoing urbanization in Bangladesh.

Overall, this research contributes to a deeper understanding of long-term land cover dynamics and provides actionable evidence to inform sustainable urban development and wetland conservation policies

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