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Dynamics of Land Use and Land Cover Changes in Dhunat Upazila using Remote Sensing and GIS between 2000 and 2024

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Abstract: *Land use and land cover (LULC) changes significantly impact environmental sustainability, resource management, and land-use planning. This study analyzes the spatial and temporal dynamics of LULC changes in Dhunat Upazila, Bangladesh, between 2000 and 2024 using Landsat 5 TM (2000) and Landsat 8 OLI (2024) satellite imagery. Supervised Classification with the Maximum Likelihood Classification (MLC) method and Post-Classification Comparison (PCC) were applied to detect LULC transitions over time. The findings reveal a substantial reduction in agricultural land (-14.86 km²) and barren land (-4.96 km²), while vegetation (+16.82 km²) and water bodies (+2.99 km²) expanded. The accuracy assessment reported an overall accuracy of 81.5% (2000) and 84.2% (2024), with kappa coefficients of 81.34 and 84.42, ensuring classification reliability. The primary drivers of LULC transformation include agricultural expansion (22.30%), urbanization (18.70%), riverbank erosion (14.20%), and deforestation (12.40%). These changes indicate a shift towards increased vegetation cover and water body expansion, influenced by conservation measures, hydrological shifts, and socio-economic transformations. The study underscores the need for sustainable land-use policies, adaptive agricultural strategies, and afforestation programs to enhance ecological resilience in riverine floodplains.*

Keywords: Land Use, Land Cover, Remote Sensing, GIS, Dhunat Upazila

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Introduction

Over the past two to three decades, Bangladesh has been experiencing a growing land crisis. Alongside the decline in agricultural land, the area of water bodies is also decreasing steadily (Ahmed & Hasan, 2019). Where once almost every household had some fallow land areas where no agricultural or other activities were carried out now there is hardly enough land available even for constructing a house, let alone preserving fallow land (Rahman et al., 2022). In this context, agriculture-based economic systems, residential construction, agricultural expansion, and river navigability are increasingly under threat (Verburg et al., 2011; Uuemaa et al., 2009).

Although the topic of land use and land cover (LULC) is frequently discussed in various media and by experts across the country, no focused research has yet been conducted on the landform changes specifically within Dhunat Upazila. Most of the landform changes in this region are directly or indirectly related to rivers. Since the sources of the major rivers flowing through Bangladesh originate in India or China, and approximately 90 percent of the river basins lie outside the country, Bangladesh has limited control over its river systems (Dewan & Yamaguchi, 2009; Islam et al., 2020).

In such a situation, the development of a permanent and effective land management framework requires a thorough understanding of the types and characteristics of landforms, the causes behind their transformation, and the external and internal factors that drive these changes (Haque & Khan, 2021). Every research has some limitations. While high-resolution imagery is ideal for accurate land use and land cover change detection, this study utilizes Landsat images, which have a spatial resolution of 30 meters (Lu & Weng, 2007; Roy et al., 2014). Consequently, it is not possible to claim with complete certainty that all land use categories have been classified with absolute accuracy.

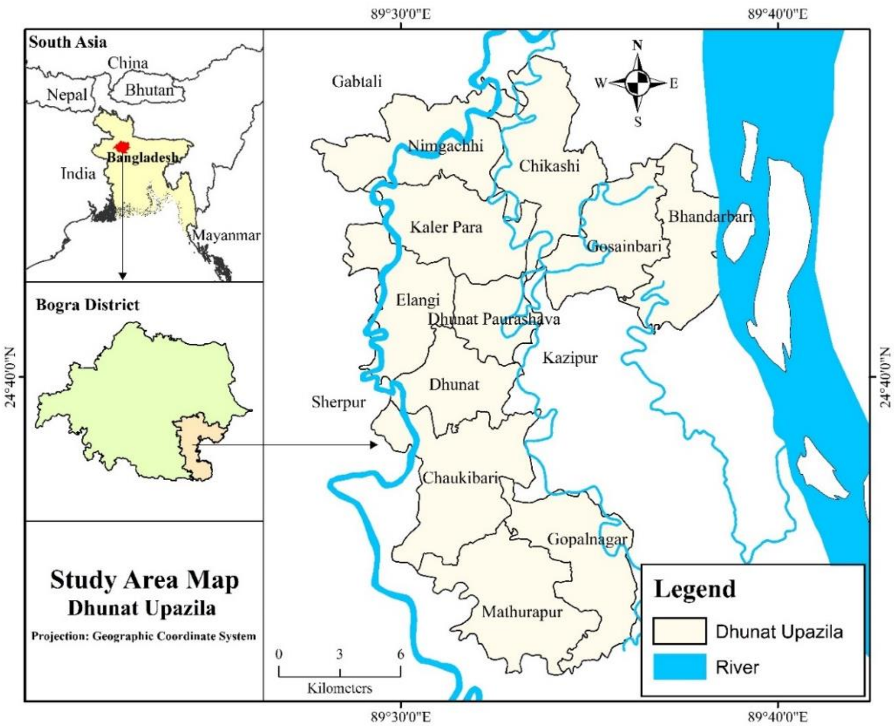
Nevertheless, despite these limitations, it can be concluded that the findings of this study offer valuable insights. The relevant authorities can use these results to implement timely and informed measures for land management in the area—steps that will play a vital role in promoting sustainable land use and development (Hassan et al., 2017).

This study aims to analyze the spatial and temporal trends of land use and land cover (LULC) changes in Dhunat Upazila between 2000 and 2024, identifying the key drivers influencing these transitions. The objectives of this research are:

1. To classify and analyze LULC distribution in Dhunat Upazila for 2000 and 2024;
2. To detect and measure LULC transformations between 2000 and 2024; and
3. To examine the key factors influencing LULC transformations

Study Area

Dhunat is one of the upazilas of Bogura district, which is known as the gateway to North Bengal. The police station established in 1962 was converted into an upazila in 1983. It was named after the administrative center of the upazila, Dhunat. It was converted into a municipality in 2001. The upazila, which consists of one municipality and ten union parishads, has an area of 247.73 square kilometers. It is located between 24°32' - 24°48' north latitude and 89°28' - 89°40' east longitude.



Map 1: Study area map of Dhunat Upazila.

The Jamuna River, one of the three main rivers of Bangladesh, flows through this area. Although tubewells are one of the main sources of drinking water, the people of the area depend on the river for daily life. The area along the river is one of the most important for agricultural work. Every year, a large amount of silt is deposited during the monsoon, which plays a supportive role in producing more crops. However, due to river erosion, agricultural land, roads and homes are constantly facing threats. It is very important to know the causes and types of LULC changes in this agriculturally dependent area.

Data and Methodology

The research methodology is very important for every study. Landsat images were used for this study, which were collected from the USGS Earth Explorer platform. Landsat 5 TM images for the year 2000 and Landsat 8 OLI images for the year 2024 were used. Both images were collected between December and January, when cloud cover is low. As a result, all images have less than 5% cloud cover. Standard preprocessing techniques, including geometric correction, were applied for better performance (Chander et al., 2009; Roy et al., 2014).

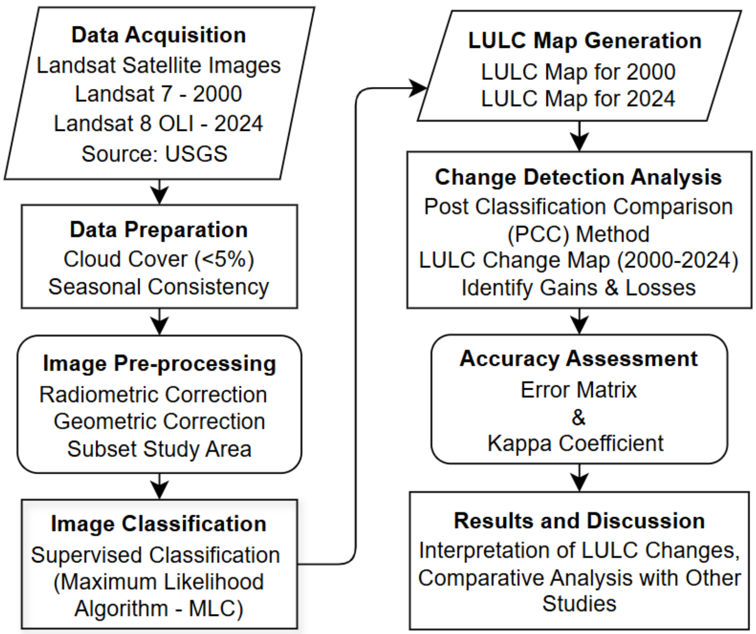


Figure 1: Data processing approaches, tools and techniques

Figure 1 shows the data collection method, data preparation, image pre-processing, image classification, LULC map generation, change detection analysis and accuracy assessment process. Along with this, remote sensing and GIS technology have been used in a systematic framework to determine the correct classification of the landforms of the study area.

Land Use and Land Cover (LULC) Classification

Land Use and Land Cover (LULC) classification is the process of categorizing the Earth's surface into distinct classes based on how land is used and what covers it. In this study, the LULC was divided into four categories using the Maximum Likelihood Classification (MLC) algorithm; Agricultural Land, Homestead Vegetation, Barren Land and Water Bodies. While the OBIA method is more commonly used for high resolution images, MLC gives better results for medium resolution images (Hussain et al., 2013).

LULC Change Detection Method

LULC changes between 2000 and 2024 were analyzed using the Post-Classification Comparison (PCC) method. PCC is widely known worldwide for reducing the effects of atmospheric changes and for pixel-by-pixel comparisons with multi-temporal datasets (Nguyen et al., 2021).

The following formula was used to calculate the percentage of LULC change:

$$\text{LULC Change}(\%) = \left(\frac{A_2 - A_1}{A_1}\right) \times 100$$

Where:

- A_1 = LULC area in 2000
- A_2 = LULC area in 2024

This equation has been used to quantify landscape-level change, particularly the expansion or reduction of land cover types in a specific region.

Accuracy Assessment

The error/confusion matrix and Kappa coefficient were used to assess the accuracy of the LULC classification. Various data were used for verification using ground-truth points; such as Google Earth, field surveys and supporting GIS datasets. The accuracy was found to be 81.5% for the year 2000 and 84.2% for the year 2024. The Kappa coefficients were 81.34 and 84.42 respectively, which are globally accepted for such research.

The Kappa coefficient (κ) was computed using the following equation:

$$\kappa = \frac{P_o - P_e}{1 - P_e}$$

Where:

- P_o = Observed accuracy (diagonal values in the confusion matrix ÷ total observations)
- P_e = Expected accuracy (based on chance)

To ensure the effectiveness of the supervised classification and post-classification comparison (PCC) method, a high kappa value is desirable, with a strong correlation between the classified and reference data.

Accuracy Assessment Results

The results of Accuracy Assessment depend on the type of image used. In case of high-quality image, the confidence level is higher while in case of medium resolution image, the confidence level is comparatively lower. Here, 30-meter resolution Landsat image has been used for Accuracy Assessment, in this case if the result level is 80-85 then it has global acceptance. Detailed results of each LULC class are shown in Table-1.

Table 1: Accuracy Assessment for 2000 and 2024 Classifications

LULC Category	**2000 (Landsat 5 TM)**		**2024 (Landsat 8 OLI)**	
	Producer's Accuracy	User's Accuracy	Producer's Accuracy	User's Accuracy
Agricultural Land	79.45%	81.36%	82.15%	83.76%
Vegetation	82.67%	84.12%	85.23%	87.45%
Barren Land	76.98%	78.42%	80.87%	82.58%
Water Bodies	85.32%	83.74	86.94%	84.68%
Overall Accuracy	81.5%		84.2%	
Overall Kappa	81.34%		84.42%	

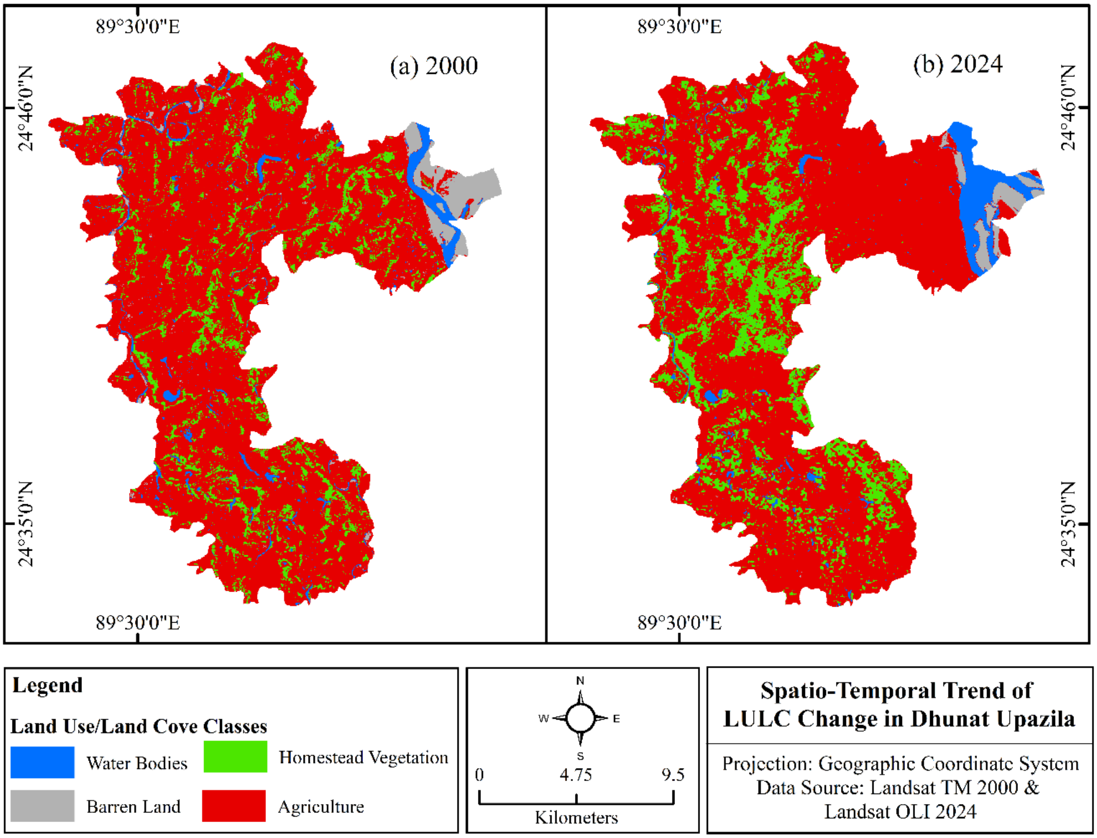
Results

During the monsoon season, a large volume of sediment is deposited with water from upstream to downstream, and at the same time, bank erosion occurs as a result of excessive flow of water. Therefore, it is essential to understand the changes in LULC in this area.

LULC transformation assessment techniques, its causes, and their driving forces change over time. Consequently, this section discusses the reasons for these changes in the last 24 years.

LULC Distribution in 2000 and 2024

It is possible to determine which types of LULC have changed, where the change has occurred, and by how much it has changed by knowing the amount of each type of LULC in each year between 2000 and 2024.



Map 2: Spatio-Temporal Trend of LULC Change in Dhunat Upazila (2000-2024)

Figure 2 illustrates the significant change in LULC over the past 24 years. Agricultural land occupied the largest area in 2000. The area of other land was relatively small. Vegetation was 26.99, barren land was 9.39 and water bodies were 8.93 sq km. A different picture emerged in 2024, where agricultural land decreased by 6.02%, while vegetation increased by 6.78%. Water bodies increased by 1.2% despite a 2% decrease in barren land.

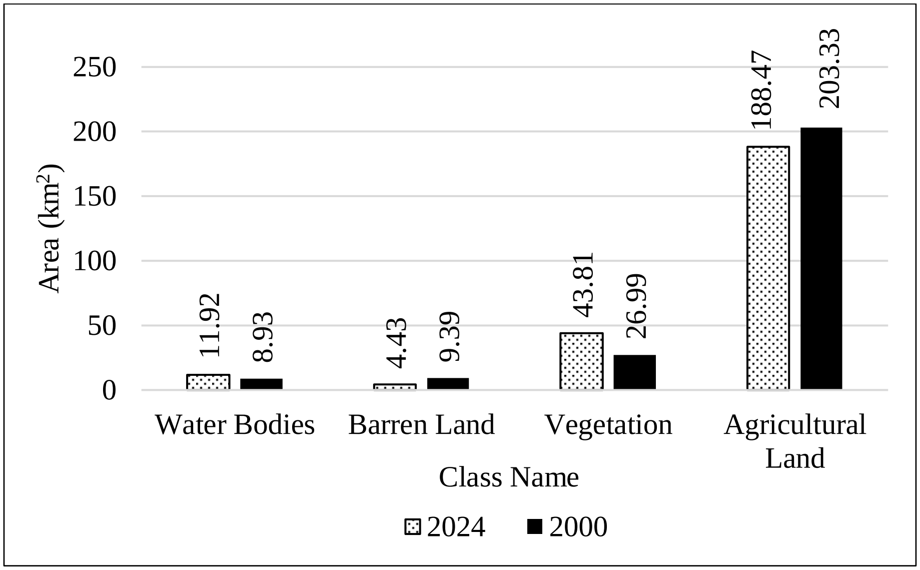


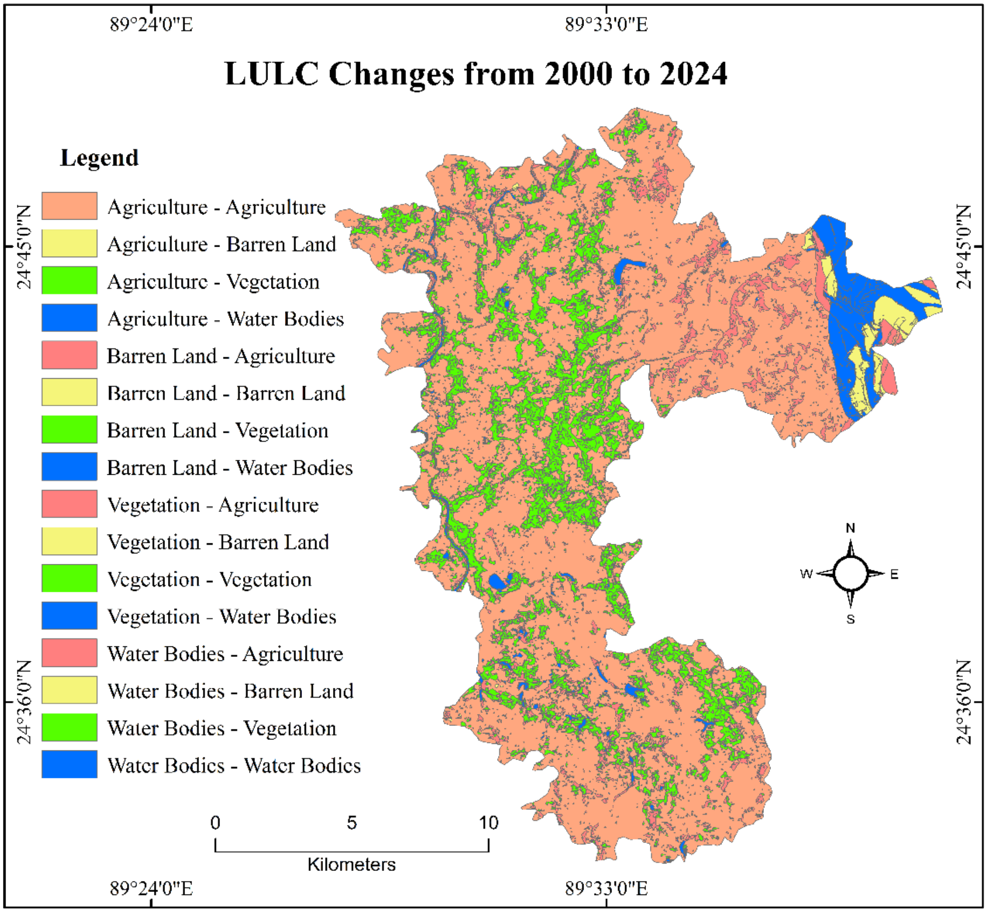
Figure 2: Comparison of Areal Extent of LULC Classes Between 2000 and 2024

This indicates that the majority of the changes have been caused by natural factors, such as seasonal floods, changes in river courses, river erosion and sediment accumulation, etc. In the study area, these changes are also influenced by human-made factors, including agricultural expansion, urbanization, and deforestation.

LULC Dynamics from 2000 to 2024

In this section, all LULC types are analyzed according to their transformation into different types. A land use plan for this area can only be developed by gaining knowledge of the changes in the specific LULC.

Map 3 indicates that the changes in land use and land cover (LULC) are not limited to a simple decrease in agricultural land or an increase in vegetation. While agricultural land has decreased in some areas due to river erosion, settlement expansion, or urbanization, it can also be observed that new agricultural land has emerged in certain regions as a result of sediment deposition by the river. Therefore, it cannot be stated definitively that the four types of LULC are consistently increasing or decreasing. In reality, the transformation of LULC in such areas is an ongoing and dynamic process.



Map 3: LULC Change Transitions in Dhunat Upazila (2000-2024)
Source: USGS

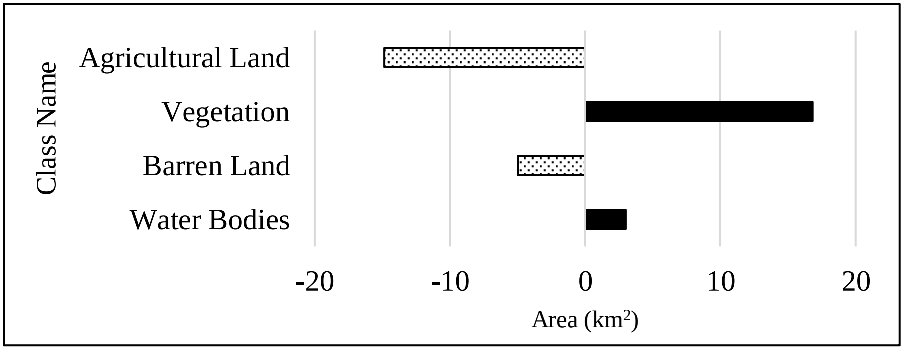


Figure 3: Changed Areal Distribution of LULC Classes between 2000 and 2024

Figure 3 illustrates that among the four types of LULC, the areas covered by vegetation and water bodies have increased by 16.82 and 3 square kilometers, respectively. In contrast, agricultural land has decreased by 14.85 square kilometers, and barren land by 4.96 square kilometers. Based on this analysis, it can be concluded that these increases and decreases are primarily the result of urbanization, settlement expansion, river erosion, road construction, agricultural expansion, and deforestation.

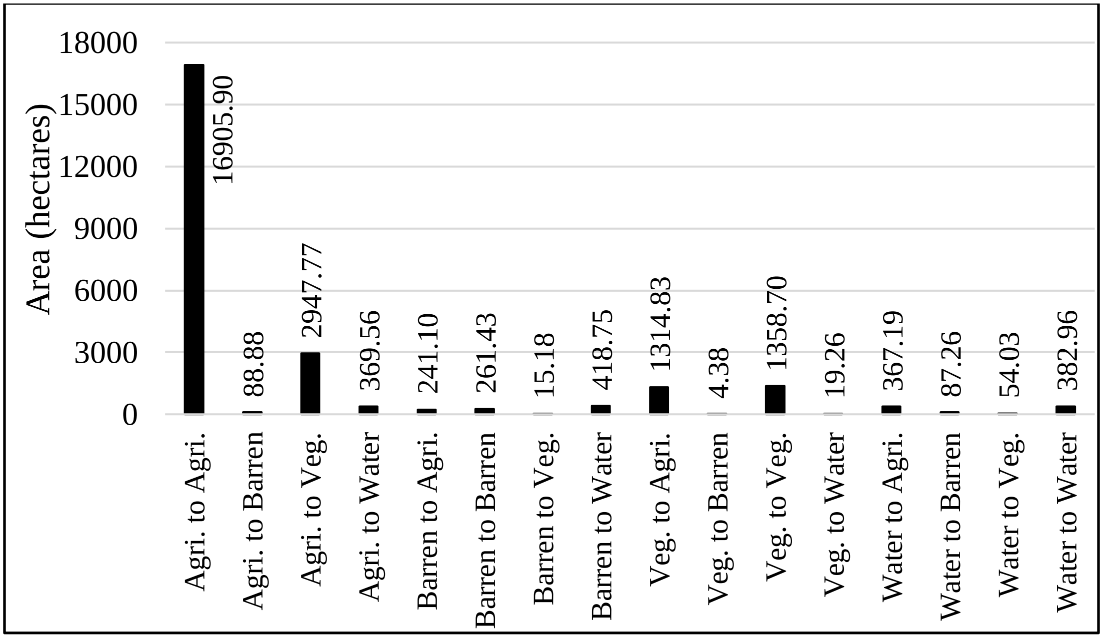
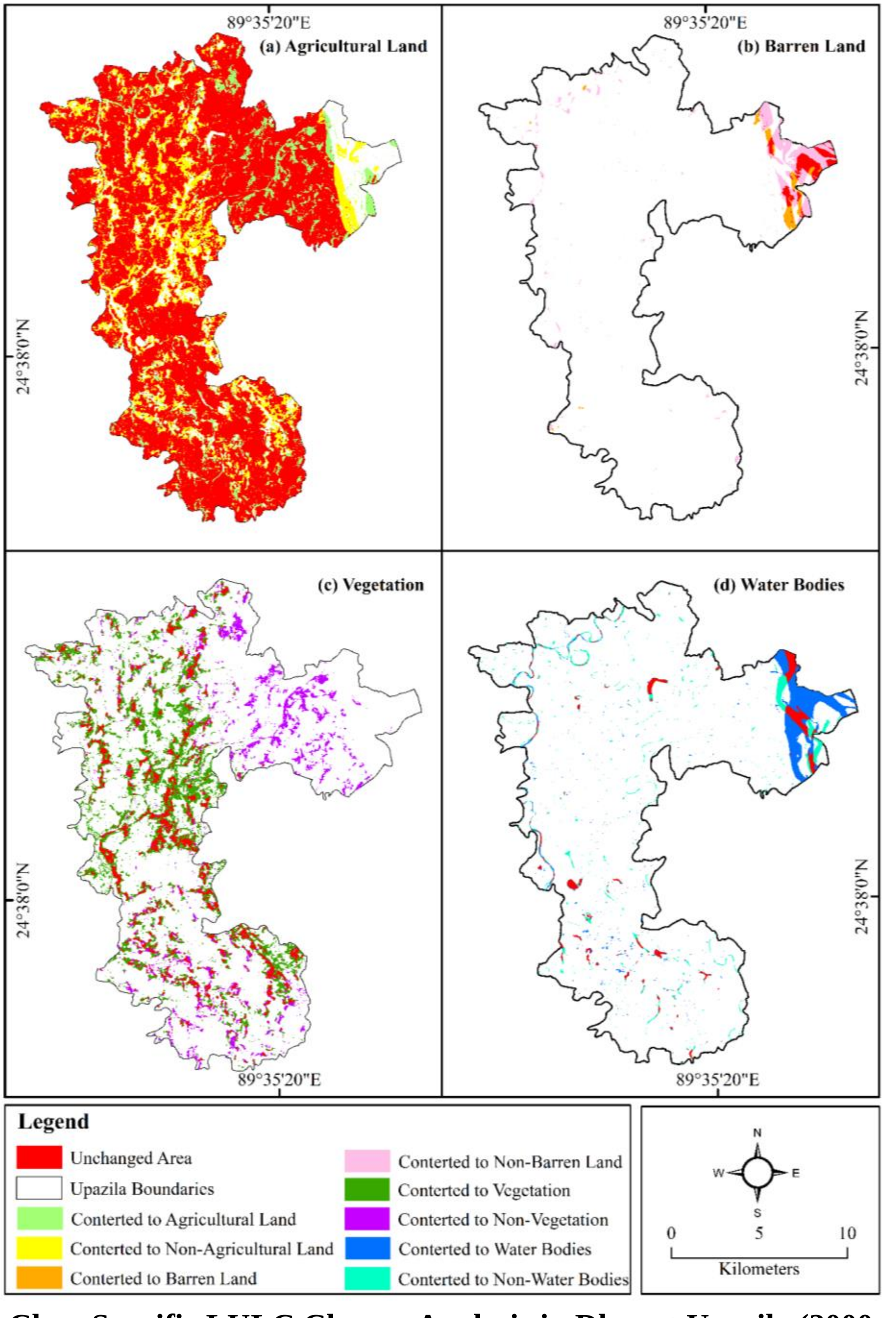


Figure 4: LULC Change Detection in Dhunat Upazila between 2000 and 2024

The image clearly demonstrates that all types of land have undergone changes and transformations. For instance, agricultural land has been converted into vegetation, and vice versa; similarly, barren land has transformed into water bodies, and water bodies into barren land. This represents a typical example of landform change.

Class-Wise LULC Change Detection

A category-based analysis was conducted to determine the extent of changes in specific land categories agricultural land, vegetation, barren land, and water bodies over the past 24 years. The nature of these changes is illustrated in Map 4, while their proportions are presented in Figure 5.



Map 4: Class-Specific LULC Change Analysis in Dhunat Upazila (2000-2024)

One notable observation across all four LULC categories is the presence of unchanged land within each type. Among them, agricultural land exhibits the highest proportion of unchanged area, accounting for approximately 76.3 percent.

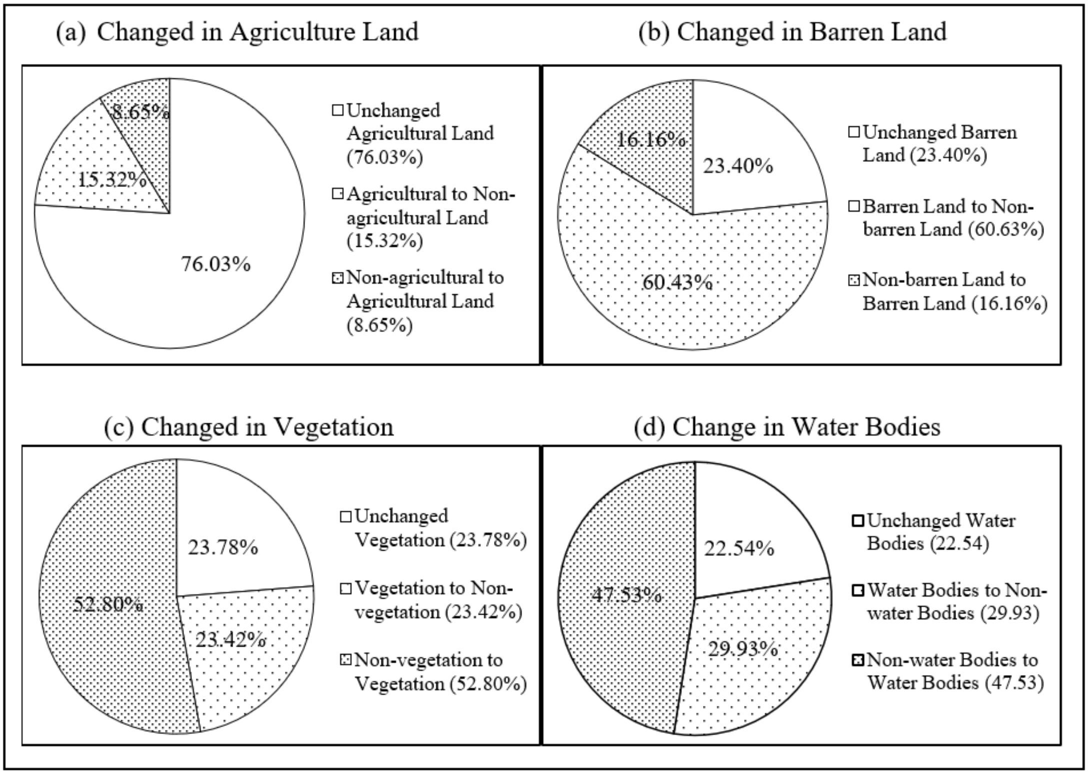


Figure 5: Class-Wise Proportional Changes in LULC Categories between 2000 and 2024

Although transitions from one category to another are evident in all land types, the highest rate of change is observed in barren land, with approximately 60.63 percent transformation. A similar pattern is seen in the conversion of other land types into different categories. While all categories have experienced varying degrees of change, the greatest amount of change is noted in vegetation.

Factors of LULC Change Detection in Dhunat Upazila

Although natural processes are the primary drivers of landform change, in many cases, these changes are also influenced by human-induced factors. As the population continues to grow in this densely populated country, the demand for food and agricultural production inevitably increases. Consequently, the expansion of agricultural land is considered one of the key human-induced drivers of landform change.

Table 2: Human-Induced Drivers of LULC Change in Dhunat Upazila

Factors of LULC Change	Percentage (%) of Respondents
Agricultural expansion	22.30%
Urbanization and settlement growth	18.70%
Deforestation and land clearing	12.40%
Riverbank erosion	14.20%
Sand deposition and flooding	6.80%
Road and infrastructure development	5.60%
Conversion of barren land to agriculture	5.90%
Industrial activities	5.30%
No significant change	6.70%
Other factors	2.10%

Most of the individuals from whom data were collected in the study area have grown up in rural environments. Therefore, the insights regarding human-induced causes are highly credible and grounded in lived experience. Moreover, the findings derived from the analysis of Landsat imagery closely align with the data obtained directly from field surveys. These issues must be taken into serious consideration when formulating policies aimed at promoting socio-economic development, environmental conservation, climate stability, and effective land management for the benefit of the people in this region.

Discussion

The findings of this study reveal significant spatial and temporal LULC changes in Dhunat Upazila from 2000 to 2024, aligning with regional and global trends observed in floodplain ecosystems. The substantial decline in agricultural land (-14.86 km²) and expansion of vegetation (+16.82 km²) and water bodies (+2.99 km²), as shown in Map 3 and Figure 3, reflect a complex interaction between geomorphological processes and socio-economic activities. The reduction in agricultural land is primarily attributed to riverbank erosion, sediment deposition, and shifting cultivation practices. Similar trends have been reported in the Jamuna basin of Bangladesh, where hydro-morphological changes have led to declining farmland and increased community reliance on alternative land uses (Rahman et al., 2022). In the Ganges-Brahmaputra delta, recurring floods and channel migration have resulted in cropland loss and wetland expansion (Ahmed & Hasan, 2019), which mirrors the patterns observed in Dhunat.

Vegetation cover experienced the highest rate of transformation, with 52.80% of non-vegetated areas turning into vegetation. This highlights ecological recovery in certain parts of the region, possibly due to reduced pressure or land abandonment. Despite the decrease, agricultural land remains the most extensive land use class. However, 76.03% of agricultural land remained unchanged, suggesting stability in some zones, while other parts are under threat from settlements, erosion, and non-agricultural conversions.

The class-wise analysis (Map 4a and 4d) and pixel-based transition matrix (Figure 4) reveal major intra-category shifts such as Agriculture to Vegetation and Water to Agriculture. These findings underscore the ongoing land-use reconfiguration caused by land scarcity, settlement expansion, and erosion-prone geomorphology. Table 2 provides insights from field-based perception surveys, highlighting that agricultural expansion, urbanization, and erosion are perceived as dominant LULC drivers. These socio-environmental pressures are not isolated; similar factors have driven LULC change in Chittagong region, Bangladesh (Mandal et al., 2020; Rahman & Akhter, 2020).

Human-induced factors such as agricultural expansion (22.3%) and urbanization (18.7%) were highlighted by field respondents as major transformation drivers. These insights are consistent with earlier work by Islam and Rashid (2020), who demonstrated how rural-to-urban land conversions in Bangladesh escalate due to housing demands and population pressure.

The study applied Maximum Likelihood Classification (MLC) and Post Classification Comparison (PCC) techniques to Landsat 5 TM and Landsat 8 OLI imagery. The classification achieved overall accuracies of 81.5% (2000) and 84.2% (2024), with kappa coefficients of 81.34 and 84.42, which confirms the reliability of the LULC maps (Congalton et al., 2019). The findings emphasize the urgent need for sustainable land management, conservation strategies, and adaptive planning, especially in a floodplain context like Dhunat, where both natural processes and human activities are constantly reshaping the land.

Conclusion

This study presents a comprehensive spatiotemporal analysis of LULC changes in Dhunat Upazila between 2000 and 2024, using Landsat imagery and GIS-based techniques. The results show a clear transformation from agriculture and barren land to vegetation and water bodies, driven by riverine dynamics and human activities. The reduction in cropland and expansion of green and aquatic areas highlight both environmental vulnerability and opportunities for sustainable restoration. The class-wise change detection and transition matrix underscore the spatial complexity of land reallocation. Major drivers such as agricultural expansion, settlement pressure, and erosion necessitate integrated planning interventions. This research not only fills a knowledge gap in rural floodplain LULC dynamics but also emphasizes the importance of high-resolution satellite monitoring, stakeholder-driven policy, and climate-resilient land management strategies to ensure long-term ecological and socio-economic sustainability.

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