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Analysing the Impact of Land Use and Land Cover Changes on Ecosystem Service Values in Tangail Municipality, Bangladesh

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Abstract: In the last few decades, rapid urbanisation has led to Land Use Land Cover (LULC) change, which has had a significant impact on the environment, ecosystem and its key goods and services around the globe. Ecosystem Service (ES) provides a wide range of benefits and advantages to communities and local economies. Land Use and Land Cover (LULC) changes have led to rapid alterations in composition, structure, and ecosystem functions, thereby reducing their capacity to provide essential services. Economic evaluation of ecosystem services is very crucial. Ecosystem Service Values (ESVs) are not given as much consideration in urban planning and policymaking, despite the fact that it is well known in the literature that urban ecosystems significantly contribute to human well-being in cities. Using ArcGIS 10.8.1, the LULC changes were computed for Tangail municipality between 2005 and 2023, based on LULC data computed from the Landsat imagery. The Benefits Transfer Approach (BTM) is used to calculate the changes in ESV associated with LULC changes. The research aims to analyse LULC change and assess its impact on ESV at the municipal level, providing a better understanding of how spatial patterns affect ESV. The results show a continuous reduction in ESV during the study periods. Between 2005 and 2023, due to the increase in built-up area, the area increased by about 46.66%. The ESV in Tangail Municipality has decreased from 3.02 million USD to 1.63 million USD during the same period. This study provides valuable insights that can aid in managing land resources and developing plans to mitigate the decline in ESV, ensuring sustainability and long-term ecosystem conservation at the municipal level.

Keywords: *Urbanization, Land use land cover change, Ecosystem service values, Benefit transfer approach*

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1. Introduction

Ecosystem Services (ES) provide a wide range of benefits that individuals may receive for their overall health, social, and economic welfare, either directly or indirectly, and are immensely valuable and advantageous to communities, local economies, and families (Boyd & Banzhaf, 2007). It also contributes to the preservation of Earth's life-supporting circumstances (Deal et al., 2012). A well-functioning ecosystem offers various advantages to human health, including nutrition, construction materials, disease prevention, climate regulation, medicines, fresh and clean water, air, and soils, as well as a cultural and spiritual landscape (Daily, 2017). To improve urban public health, resilience, and life quality, as well as integrate urban areas with the biosphere and reduce ecological debt and footprint, urban ecosystem services are essential (Elmqvist et al., 2013). These benefits include the provision of fresh air, water purification, waste treatment, pollination, noise reduction, and the availability of food and water supplies, as well as the control of the heat island effect in urban areas and climate regulation (Baró et al., 2014). In addition to ensuring urban sustainability, a robust ecosystem can contribute to achieving sustainable development (Pan et al., 2021). Ecosystem Service Values (ESV) is a method for valuing an ecosystem and its main products and services in terms of monetary value (Sannigrahi et al., 2019). Nowadays, ESV is widely used in the modern policy agenda and scientific research (Braat & De Groot, 2012). Economic evaluation of ecosystem services has become increasingly crucial for understanding the various benefits that ecosystems provide. (Guo et al., 2001).

One of the significant human activities that drives the dynamics of urban ecosystem services is the change in Land Use and Land Cover (LULC), which has resulted in rapid changes in composition, structure, and ecosystem functions, reducing their ability to provide essential services (Rahman & Szabó, 2021). Changes in LULC directly cause changes in ecosystem services (Belay et al., 2022). Compared to the past, the LULC transformations in each area have accelerated due to urbanisation, sprawl, and the subsequent expansion of settlement land in both urban and rural areas. Urban ecosystem services are impacted by the geographical distribution of LULC change in urban areas in numerous ways (Rahman & Szabó, 2021). The consequences of land use and land cover conversion (LULC) on ecosystem services vary with time and location (De Groot et al., 2010). To coordinate urban growth that serves the urban economy, ecology, and society, it is crucial to monitor the state of urban ecosystem services and understand how changes in LULC influence human well-being in cities (Arunyawat & Shrestha, 2016).

Global studies emphasise the connection between land use changes and urban ecosystem services. Chengdu, in China, is mentioned by Lin et al. (2018) as a case where the built-up area land proportion was 51.86% and the agricultural land was 18.16% respectively in 2018. On the other hand, Shrestha et al. (2022) indicated that over the last 30 years, Kathmandu Valley's ESV has sustained a loss of 20.60% due to urban sprawl and forest depletion. Similar findings were reported by Estoque & Murayama (2012), who recorded a decrease in ESV in agricultural and forest spatial expansion replacement in the city of Baguio, Philippines. R. Sharma et al., (2019) have documented that in India, the Chandigarh settlements increased by 104.61%, while there was a decrease of 2.54% in ESV from 1990 to 2020. Similarly, Talukdar et al., (2020) point out that built-up areas in India expanded by 29.14%, while waterbodies shrank by 15.81% over the period since 1999. In Ethiopia, however, over a period of 35 years, Assefa et al. (2021) reported an expansion of built-up areas by 216.24% and a reduction of 75.71% in wetlands, which resulted in a loss of ESV worth $8.9 million. Athukorala et al. (2021) reported that from 1997 to 2017, the total ESV of Muthurajawela Marsh and Negombo Lagoon in Sri Lanka decreased by 33% as mangrove and marshland were lost due to urban expansion. Najmuddin et al. (2022) found that the total ESV of Afghanistan has decreased from $161 billion to $152.27 billion from 2000 to 2020. Zeng et al. (2024) reported that Poyang Lake Basin in China's ESVs are negatively impacted by landscape fragmentation, with the highest value in woodlands. The regional ESV can be sustained by retaining woodlands, conserving water bodies, and maintaining a balanced urban land use. K. Sharma et al. (2024) have documented that, in Nashik, India, from 2017 to 2023, the overall ESV declined by $ 9.6 million. A study on the Eastern Himalayan region by Dutta & Verma (2023) found that, due to afforestation, the total ESV increased by $618 million from 1992 to 2020.

Bangladesh is a densely populated nation that relies heavily on agriculture and is among the most susceptible to climate change and catastrophic disasters (Mondal, 2019). However, Numerous studies have shown that in recent decades, the country has seen extraordinary LULC changes because of rapid urbanisation, sea level rise, economic growth, natural disasters, and climate change. Bangladesh registered changes in ESV related to LULC changes, resulting in a loss of $105.34 million for the Meghna River Estuary (Hoque et al., 2020) and $1.06 billion in freshwater services due to wetland depletion (Huq et al., 2019). Total ESV for overall Bangladesh has been calculated by (Hasan et al., 2023), which explores that during 2020, total ESV surpassed $350 billion. The Southwest region is estimated to have a value of around $160 billion, whereas the North Central region is valued at less than $10 billion. All these studies highlight the need for balanced land-use strategies to prevent the negative impacts of the changes in LULC.

From existing literature, it was found that most of the studies have been conducted in fully urbanised areas or coastal areas. No related research has been done in growing municipalities like Tangail that are in a transition phase toward full urbanization. Mamun et al. (2019) found major changes in LULC types in their research; however, their study does not reveal the impact of these changes on the ESV of Tangail Municipality. The ecological significance and varied land use patterns offer several land cover types, including agricultural land, urban development, and natural landscape, which differ from fully urbanised or coastal areas. Aiming to fill this gap, this research is particularly significant in demonstrating how urbanisation leads to land conversion and decline in ecosystem services from its earliest stages, providing essential information that can be useful for planning and sustainable development in Tangail municipality. It is of great importance to understand the consequences of LULC change alongside ecosystem service values in growing municipalities like Tangail, experiencing rapid development, and learning more about ecosystem services and operating as a global agenda item for local communities.

Scientific studies on ES may encourage policymakers to work towards preventing ecosystems from further degradation. According to Rahman & Szabó (2021), the rapid development in Bangladesh leads to a decline in Dhaka's ecosystem service values due to the conversion of green spaces, waterbodies, and agricultural land, resulting in waterlogging, pollution, and food security issues. Due to the proximity of Tangail district to Dhaka, it is experiencing metropolitan expansion and faces challenges like rapid urbanisation, which led to a significant land use change in Tangail municipality (Mamun et al., 2019). It is a critical study area, as it contributes significantly to the country's food supply, with a substantial amount of agricultural land and vegetation. Mamun et al. (2019) have found that agricultural land and water bodies were converted into built-up areas, and vegetation also declined, posing environmental risks due to population growth and unplanned development. Growing factories and industries in municipal areas, such as Yarn Dyeing, Paper Mill, and other factories in the Tartia BSCIC area, discharged pollutants into the Louhajang River (Tazvir, 2021). All these problems together may make the municipality unlivable and greatly hamper the food supply. The research aims to quantify the LULC change in Tangail Municipality and estimate the value of Ecosystem Service Values resulting from Land Use and Land Cover change, which contributes to long-term ecological conservation and prevents haphazard growth.

2. Materials and Methods

2.1 Study Area

Tangail Municipality is in Tangail Sadar Upazila. Tangail Municipality was built along the former Dhaleshwari River in the Southern part of Tangail Sadar Thana. The Lohajang River spans the Tangail Municipality. Tangail Municipality is bordered by Sakhipur and Basail Upazilas on the west; Ghatail and Kalihati Upazilas on the north; Nagarpur Upazila on the south; and Sirajganj District on the east, and the total area is 33.80 sq km. According to the Census Year 2011, 167412 populations are living in the area with a gross density of 21 people per acre. The annual population growth rate is 2.6%. This is an “A type” municipality (Bangladesh Bureau of Statistics 2011).

Tangail experiences a tropical environment. Right here, the ordinary temperature level is 25.5 ° C. Annually, about 1872 mm of precipitation falls (Tangail Climate: Weather Tangail & Temperature by Month, Retrieved January 30, 2024). The increasing population in the Tangail Area endangers the location's biodiversity, ecosystem, and basic environment.

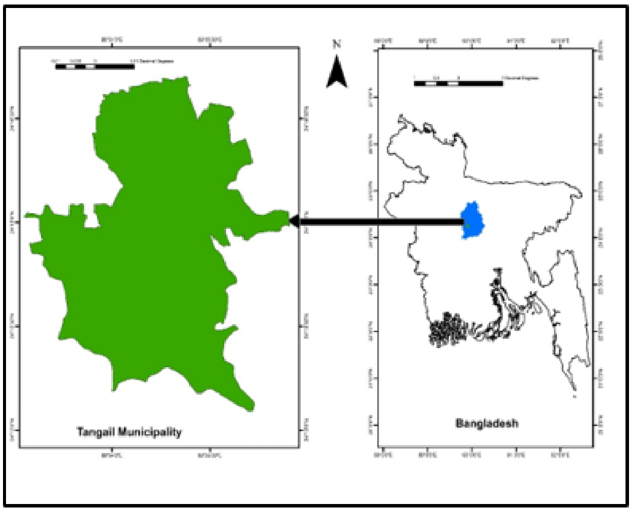

Figure 1: Study Area

2.2 Data Collection

This research intends to value the services provided by ecosystems based on changes in LULC. Because of that, the secondary data used in this study is LULC, which originated from satellite imagery. Time series information from Landsat 4/5 and Landsat 8/9 is used in this study. To obtain the data, the 137/43 path/row of the Landsat satellite TM OLI-TIRS images, which provide a resolution of 30 x 30 meters. Accessed on November 28, 2023, the United States Geological Survey (https://earthexplorer.usgs.gov/) provided Landsat imagery for the following years: 2005, 2010, 2015, 2020 and 2023. Landsat data were selected for the months of January, February and March in each year because images with significantly less cloud cover were readily available during this season. Additionally, there was no rain during this season, this makes sure the actual existence of waterbodies.

Table 1: Landsat Data

ID	Landsat Series	Resolution	Bands	Sensor	Date Acquired
LT05_L2SP_137043_20050217_20200902_02_T1	Landsat 5	30*30 m	1-5, 7	TM, MSS	2005/02/17
LT05_L2SP_137043_20100130_20200825_02_T1	Landsat 5	30*30 m	1-5, 7	TM, MSS	2010/01/30
LC08_L2SP_137043_20150317_20200909_02_T1	Landsat 8	30*30 m	1-7	OLI, TIRS	2015/03/17
LC08_L2SP_137043_20200211_20200823_02_T1	Landsat 8	30*30 m	1-7	OLI, TIRS	2020/02/11
LC08_L2SP_137043_20230203_20230209_02_T1	Landsat 8	30*30 m	1-7	OLI, TIRS	2023/02/03

Image Processing

Following a methodical procedure, the satellite imagery was processed by compositing multiple bands, exporting a shape file, and clipping the imagery to the shape file that represented the research area. Spectral signatures of items in the imagery were analysed using ArcGIS 10.8.1 software to do geospatial analysis. False colour composites were produced by combining certain band combinations. The five broad LULC classifications were recognised as part of the classification strategy utilised in the study. This classification process was based on the examination of the spectral signatures displayed by the numerous objects found in these classes. The maximum likelihood method was used to classify the images. Ground truthing and Google Earth observation were used to assess the accuracy of the LULC classification. The training data was made up of imagery taken at various times from Google Earth. The best training sites were determined using these images and gather training area/pixels for five different types of LULC. Approximately 100 training samples in all were gathered.

The study effectively categorized and measured different land cover classes using supervised category approaches.

LULC Classification and Map Preparation

In ArcGIS 10.8.1, Supervised classification was utilized to categorize Landsat imageries into five broad LULC groups. The LULC classifications are: (a) Agricultural Land; (b) Waterbody; (c) Vegetation; (d) Built-up Area; and (e) Barren Land. Table 1 supplies the definitions for numerous LULC classes. These LULC categories were chosen using the biome kinds that are considered while establishing the ecosystem value. After classifying LULC groups, maps were prepared in ArcGIS 10.8.1 with legend, north arrow, and grid. Maps were prepared for the years 2005, 2010, 2015, 2020 and 2023 and locations for those LULC types were computed in sq km.

Table 2: Land Use and Land Cover Types

LULC Types	Description
Agricultural Land	Orchards, Gardens, Nurseries, Groves, and Other Agricultural Land.
Waterbody	Pond, River, Canal, Lake, and Wetland
Vegetation	Gardens. Mixed forest, Trees, Grasslands, Natural Vegetation etc.
Built-up	Rural and Urban settlement, Commercial, Industrial, Residential area, and other Man-made structure.
Barren Land	Construction site, Bare soil, Fallow land, Open space

Source: (Rahman & Szabó, 2021)

Accuracy assessment

Accuracy assessment is a vital part of any kind of LULC classification because maps always have misclassified pixels and errors. A classification map cannot be applied without knowledge of the errors and assessment of accuracy (Gumma et al., 2019). It compares the classified image to an additional information source that is thought to be exact. Ground truth data can be derived from high resolution imagery.

The produced map of this research was evaluated for accuracy assessment using Google Earth Platform. Classified images were compared to the relevant land cover on Google Earth to assess accuracy. 100 random points were created in the map through ArcGIS by using the Accuracy Assessment points tool and the select sampling techniques. In this research random sampling strategy was used. Then, the created points were compared to the image of Google Earth, and the data table was updated, and then a confusion matrix table was created. From which it can easily find the User accuracy and Kappa coefficient. The level of Kappa coefficient impacts research reliability since it determines the extent of compliance between the classified map and the ground truth data. High Kappa (0.8-1) shows strong agreement, moderate Kappa (0.4-0.79) shows moderate reliability but calls for more investigation, while low Kappa (0-0.39) indicates strong uncertainty towards findings.

Table 3: User accuracy and Kappa coefficient for classified image

Year	User Accuracy (%)	Kappa Coefficient
2005	76.21	0.67
2010	80.21	0.71
2015	86.00	0.79
2020	83.83	0.75
2023	84.00	0.76

2.3 Calculation Procedure

Land-use dynamic index

To comprehend the changes in LULC over time, equation (1) was used to calculate the land use dynamic index.

$$K = \frac{A_j - A_i}{A_i} x \frac{1}{T} x\ 100\% \ldots\ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

(Hao et al., 2012)

Here K is the land use dynamic index for a single LULC types, A_i is the initial area of specific LULC types, A_j is the final area of specific LULC types and T is the study period.

Assigning Values of Ecosystem Services

The ecosystem service evaluation model proposed by (Costanza et al., 1997) is regarded as the reliable technique to calculate the ESV. They determined 17 ecosystem services from 16 biomes to determine ESV. Making use of the Benefits Transfer approach (BTM), they estimated global economic values for those ecosystem services based on existing literary works and original computations. Since this approach has been made use of by numerous research internationally to analyze ecosystem Service, the model presents one of the most comprehensive collections of initial estimation for ecosystem service evaluation.

To get the ESV for each of the five LULC groups in Tangail, the five categories of LULC were compared with 16 biomes identified in Costanza et al. (1997). The most appropriate biome for each and every classification was appointed as the proxy for that LULC types in this study as Rahman & Szabó, (2021) used in their study which was conducted in local context of Bangladesh, such as 'agricultural land' for 'cropland' biome, 'water body' for 'wetland', 'vegetation' for 'tropical woodland', 'built-up area' for 'urban', 'barren land' for 'desert'. Many of the waterbodies in the research area are rivers and wetlands.

Therefore, 'wetlands' were designated for 'waterbodies' instead of lakes as Rahman & Szabó (2021) used these proxies in their research. Although the LULC groups and equivalent biomes do not perfectly match, their use has been verified as possible in several other studies (Tolessa et al., 2017).

Table 4: Biome equivalents for the five LULC categories and the corresponding values

Types of LULC	Biome	ESV Coefficient (US$ $ha^{-1}\, yr^{-1}$)
Agricultural Land	Cropland	92
Waterbody	Wetland	14,785
Vegetation	Tropical Forest	2,007
Built-up	Urban	0
Barren Land	Desert	0

Source: (Costanza et al., 1997, Rahman & Szabó, 2021)

Ecosystem Service Values

To estimate ESV, equation (2) was used. Area was converted from sq km to ha.

$$ESV = \sum(A_k x\, VC_k) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

(Kreuter et al., 2001)

Here, ESV is the overall calculated Ecosystem Service Value, A_k is the area of single LULC types in ha and $VC_k(US\$ha^{-1}yr^{-1})$ is the Value coefficient where k is the each LULC category.

Change Rate of Ecosystem Service Values

The change rate in ESV for every type of LULC determined through the following equation (3)

$$ESV_{cr} = \frac{ESV_j - ESV_i}{ESV_i} x \frac{1}{T}\, x\, 100\% \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

(Hu et al., 2008)

Here, ESV_{cr} is the change rate of ESV for a single type of LULC, ESV_i is the initial ESV, ESV_j is the final ESV and T is the study period.

Elasticity of ESV Respond to LULC Change

Elasticity calculation is necessary to comprehend how modifications in LULC types affect the total ESV. Song & Deng (2017) developed an elasticity indicator. The percentage change in ESV as a function of the percentage change in LULC can be measured using following equation (4).

$$EEL = \frac{\frac{ESV_j - ESV_i}{ESV_i}\, x\, 100\%}{LCP} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

(Song & Deng, 2017)

Here EEL is the elasticity of ESV respond to LULC change, ESV_i is the total initial Ecosystem Service Values, ESV_j is the total final Ecosystem Service Values, LCP is the percentage of land conversion.

Analysis of Sensitivity

There are discrepancies in the value coefficient and the dependable representation of biomes in various LULC classes affect the overall ESV. The coefficient level of sensitivity (CS) is the process of confirming the accuracy of the equivalent value coefficient and the dependable representation of biomes in various LULC classes. The following equation (5) was used to compute CS.

$$CS = \frac{\frac{ESV_j - ESV_i}{ESV_i}}{\frac{VC_{jk} - VC_{ik}}{VC_{ik}}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

(Hu et al., 2008)

Here, ESV_j is the calculated Total ESV with the actual value coefficient for each LULC type, and ESV_i is the ±50% adjusted Ecosystem Service Value. VC_i is the initial Value coefficient, VC_j is the final Value Coefficient and K is the specific LULC Type. To determine the adjusted ESV and CS, the value coefficient associated with each LULC category was adjusted by ±50 %. The approximated ESV is inelastic relative to the value coefficient if CS is less than 1, and flexible relative to the value coefficient if CS is more than 1.

3. Results and discussion

3.1 Land Use Land Cover of Tangail Municipality

The LULC types of Tangail Municipality for the period from 2005 to 2023 are presented in Figure 2. The LULC map is presented in the figure in five-year intervals. Figure 2 illustrates that built-up areas are spatially dispersed in the central part of the municipality. Over the past 18 years, the built-up area has expanded in the entire municipality through the alteration of vegetation and agricultural land. There was a big quantity of vegetation and agricultural land in the municipality. However, with time, they were transformed into built-up areas. Large quantities of vegetation are transformed into built-up areas. There are still considerable number of agricultural lands towards the municipal boundary. In 2005, a significant portion of the municipal area was covered with vegetation and agricultural land, which was converted into a built-up area by 2023. Most of the agricultural land and vegetation in the central part of the municipality have been replaced by built-up areas over the past 18 years. In 2005, there was a high amount of vegetation. In 2010, the water bodies in the study area increased and later decreased due to the conversion of built-up areas or barren land. Most of the land converted into built-up areas was agricultural land and vegetation. Most of the water bodies have been transformed into barren land and subsequently used for built-up areas or agricultural purposes. From the figure, since 2015, urbanisation has been occurring in the municipality. Built-up areas have grown haphazardly.

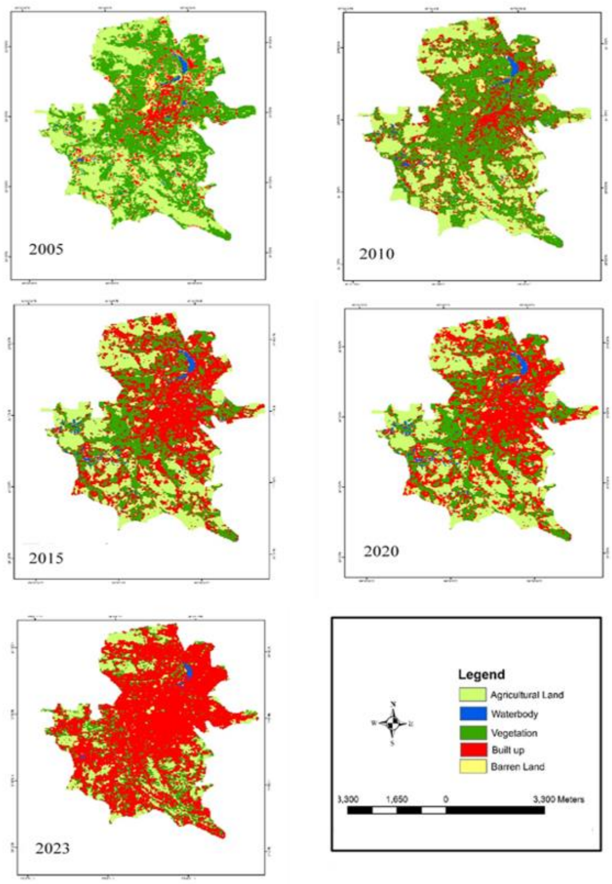

Figure 2: Land Use Land Cover Map of Tangail Municipality

Areas of various LULC, such as agricultural land, waterbody, vegetation, built up area, and barren land, have been determined from the LULC map generated by ArcGIS 10.8.1. In Figure 4 shows the trends of Land use and land cover change of Tangail Municipality.

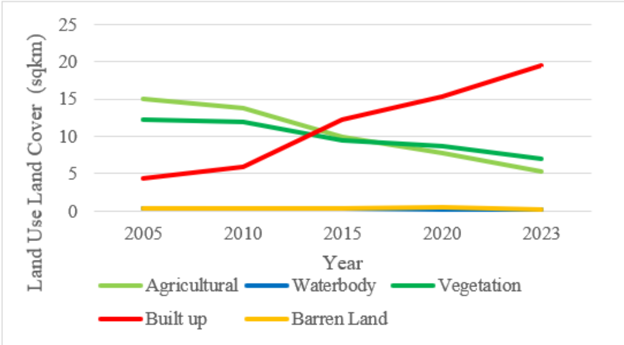

Figure 3: Trend of Land Use Land Cover change

Figure 3 reveals three trends of LULC changes of Tangail Municipality during the period from 2005 to 2023. Firstly, the agricultural land and vegetation show a significant decrease; secondly, built-up areas exhibit an increasing trend during the study period. Waterbody and Barren land show the least adjustment. This shows that there was a significant fall in agricultural lands and vegetation in the study area over the last 18 years and probably similar cases in other urban areas as well. In 2005, the dominant LULC class was Agriculture, which occupied an area of 15.03 sq km and decreased to approximately 13.78 sq km, 9.92 sq km, 7.78 sq km, 5.44 sq km in 2010, 2015, 2020, and 2023 respectively. The waterbody allotted the least amount of area, which measures 0.30 sq km in 2005 and has an area of 0.41 sq km, 0.31 sq km, 0.21 sq km, 0.19 sq km in the following years. In 2023, the largest amount of the area was given to built-up area which expands to 19.404 sq km. Nevertheless, other than in 2005 and 2010, the dominating LULC type constituted by built-up area having an area of approximately 4.445 sq km, 5.90 sq km, 12.301 sq km, 15.49 sq km, and 19.404 sq km and Barren land shows an unstable trend by having area of 0.34 sq km, 0.42 sq km, 0.36 sq km, 0.45 sq km and 0.22 sq km in 2005, 2010, 2015, 2020 and 2023 respectively. Particularly, the reason behind this was the flow of migrated people who built new houses in the municipality. Eventually, both the increasing population and economic development caused a decrease in the city's agricultural land and vegetation (Mamun et al., 2019).

Land Use Land Cover Change Dynamic Index

Using equation (1), the LULC changes dynamic index has been calculated to comprehend the change rate of various LULC types in the different study periods and has been presented in Table 5.

Table 5: LULC change dynamic index K (%)

LULC	2005-2010	2010-2015	2015-2020	2020-2023	2005-2023
Agricultural	-1.66	-5.60	-4.31	-10.02	-3.54
Waterbody	7.34	-4.88	-6.45	-3.17	-2.04
Vegetation	-0.64	-4.02	-1.77	-6.45	-2.39
Built up	6.54	21.69	5.18	8.74	18.85
Barren Land	4.53	-2.73	5.00	-17.03	-1.96

Table 5 presents the values of k, where a decline is indicated by a (-) sign and a positive sign indicates a rise in LULC changes. From Table 5, agricultural land, vegetation and waterbody and barren land decreased by 3.54%, 2.04% and 2.39%, 1.96% from the duration 2005-2023. On the contrary, the built-up area increased by 18.85% during the period from 2005 to 2023. It can be seen that barren land decreased by 17.03%, which is the highest possible rate from 2020 to 2023, and vegetation decreased by 0.64%, which is the lowest value during the period from 2015 to 2020. The built-up area increased by 21.69%, the highest rate recorded during the period of 2010-2015. The table reveals that, from the period of 2005-2023, only the built-up area was enhanced, while other LULC types, such as agricultural land, water bodies, vegetation, and barren land, were reduced.

3.2 Spatial Distribution of ESV of Tangail Municipality

In this study, the ESV of Tangail Municipality is quantified for each LULC type based on Equation (2), the Ecosystem Service Value coefficient in Table 3, and the area of different LULC categories. The unit of land area has been converted into hectares from square kilometres since the unit of value coefficient of Ecosystem Service is in $US\$ha^{-1}yr^{-1}$. The result has been converted to USD million. Figure 4 shows the spatial distribution map of ESV of Tangail municipality for the years 2005, 2010, 2015, 2020, and 2023. The figure reveals that in 2005, the total ESV was higher throughout the municipality except in the central part. About 33.80 sq km of the total area had 3.02 million $US\$ha^{-1}yr^{-1}$. The higher value of the ESV was the result of the presence of vegetation, followed by water bodies and agricultural land. Although the total area of agricultural land is higher than that of the other two types of LULC, due to the low value coefficient of this category, its contribution to ESV is lower. The expanding built-up area in the central part of the municipality led to a decline in the total ESV in 2005. Due to the increase in water bodies in 2010, the total ESV for 2010 is larger than the total ESV for 2005. The contribution of water bodies is larger than that of other LULC types; as a result, an increase in water bodies increases the total ESV. From 2015, the ESV considerably decreased, resulting from the transformation of vegetation into built-up areas. Only about 1.63 million USD ESV contains by the municipality in 2023.

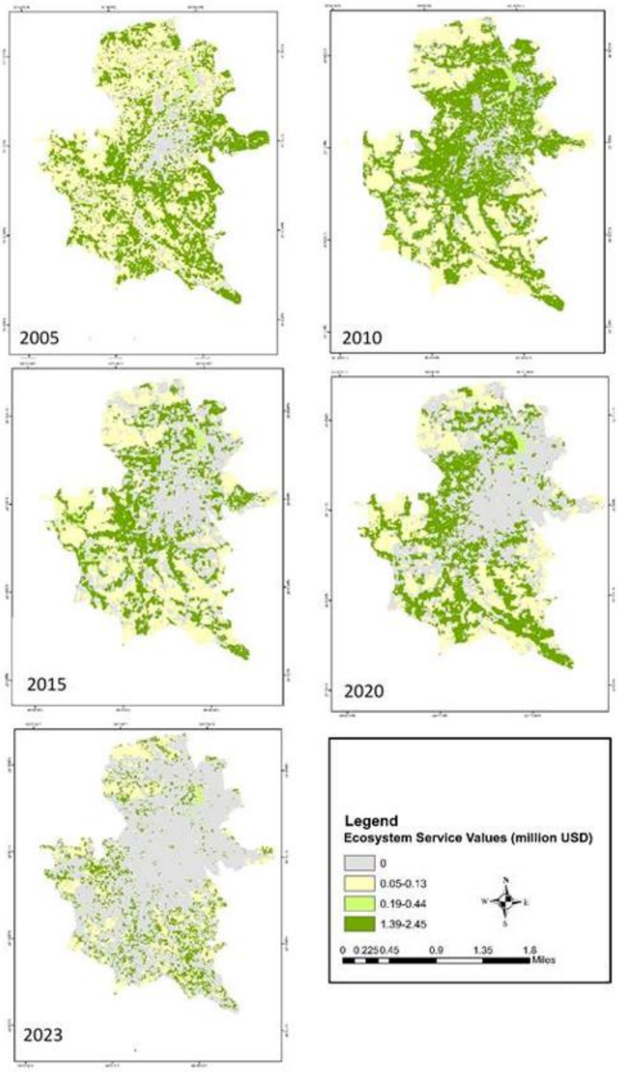

Figure 4: Spatial Distribution of ESV in Tangail Municipality

A trend of total ESV in Tangail Municipality during 2005 to 2023 has been shown in Figure 5.

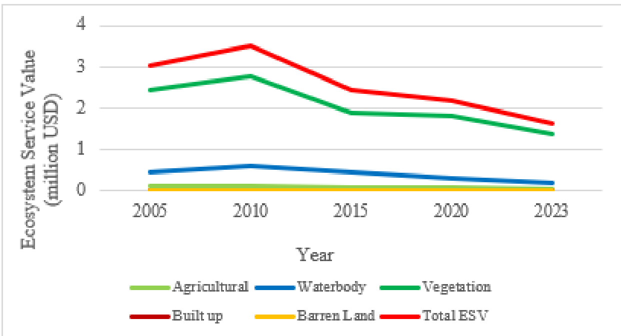

Figure 5: Trend of total ESV in Tangail Municipality during 2005-2023

Figure 5 indicates the declining trend of total ESV, which has been shown by a downward curve. Only agricultural land, waterbody and vegetation contributed to the ESV. Built-up and Barren land make no contribution to the ESV, as their value is 0. Vegetation has the most contribution as the value coefficient of vegetation is higher than other types of LULC, followed by water bodies and agricultural land. Although the value coefficient of water bodies is the highest, a smaller number of water bodies in the study area added less value to ESV. The LULC types that contributed most to the ESV showed a declining trend. Between 2005 and 2010, the total ESV increased due to the expansion of water bodies, and the decline in the rate of agricultural land and water bodies was very low. During this period, changes in the water body may be attributed to seasonal variations. Further waterbody decreases as people filled it up with trash or other solid objects (Mamun et al., 2019). A sharply decreasing trend in ESV has been observed in the period from 2010 to 2015, primarily due to the significant decline in agricultural land, water bodies, and vegetation. The water body and agricultural land were reduced due to their gradual transformation into a settlement or human development area as the population grew over the previous few decades (Mamun et al., 2019). As vegetation contributed significantly to the total ESV in this municipality, the distinctive change process of vegetation production dominates the overall ESV change process. According to the results, the total calculated ESV of Tangail Municipality were 3.02, 3.09, 2.45, 2.19, and 1.63 million USD in 2005, 2010, 2015, 2020, and 2023, respectively. According to equation (3), the change rate (%) of ESV was calculated to comprehend the yearly change of ESV.

Table 6: Change Rate (%) of ESV for different LULC

LULC	2005-2010	2010-2015	2015-2020	2020-2023
Agricultural	-1.54	-5	-4.44	-9.52
Waterbody	7.27	-4.67	-6.52	-3.23
Vegetation	-0.65	-3.97	-1.79	-6.55
Built up	0	0	0	0
Barren Land	0	0	0	0

The rate of change of ESV for various LULC types from 2005 to 2023 is displayed in Table 6. The values' negative (-) sign indicates that the ESV has decreased. Changes in ESV for built-up areas and barren land were absent because they do not have any Value Coefficient. From 2005 to 2023, the ESV generated from waterbodies, vegetation, and agricultural land decreased annually by 3.41%, 2.02%, and 2.40%, respectively.

Impact of LULC Change on ESV

Equation (4) has been used to compute the elasticity of ESV to comprehend the influence of changes in LULC and presented in Figure 6.

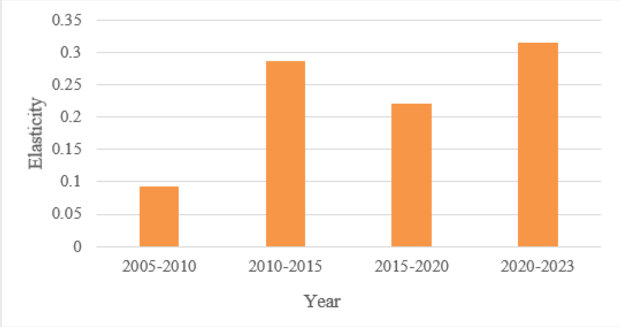

Figure 6: Elasticity of ESV due to LULC change

The elasticity of ESV in relation to LULC changes has been determined to comprehend the effect of LULC changes on the overall ESV and their connection. According to the figure, the ESV's elasticity in response to changes in LULC was 0.09, 0.29, 0.22, and 0.31 in the following periods: 2005-2010, 2010-2015, 2015-2020, and 2020-2023, respectively. According to the elasticity analysis, during the study period, a 1% change in LULC would result in changes to the total ESV of 0.09%, 0.29%, 0.22%, and 0.31% (Figure 6). There was an upward trend in the elasticity of ESV from 2005 to 2015, followed by a downward trend from 2015 to 2020, and then an upward trend from 2020 to 2023. The rise in the elasticity trend suggests that over time, ESV is getting more susceptible to LULC changes. The years 2020-2023 saw the highest ESV elasticity as in that period each type of land use changed significantly, which impacted ESV most. Agricultural land, waterbody and vegetation have been transformed into built-up areas. The elasticity of ESV indicates how sensitive it is to the changes in LULC. The sensitivity of ESV to LULC change increases with increasing elasticity values. The greater ESV elasticity value between 2020 and 2023 suggests the biggest change in the ESV response to LULC change.

Analysis of Sensitivity

To comprehend the reliability and robustness of the result, a sensitivity analysis has been done through equation (5). The result is presented in Table 7.

Table 7: Sensitivity Coefficient (CS) for a value adjustment Ecosystem Coefficient

Adjusted Value Coefficient	2005	2010	2015	2020	2023
Agricultural	0.05	0.04	0.04	0.03	0.03
Waterbody	0.15	0.19	0.19	0.15	0.16
Vegetation	0.81	0.76	0.78	0.82	0.81
Built up	0	0	0	0	0

Barren Land	0	0	0	0	0

The value of CS must be less than 1 for the calculated ESV to be reliable and robust. The ecosystem service value coefficient was perfectly assigned, and generally, the ESV calculation was inelastic with respect to the coefficient value if the value of CS is consistently less than one. Table 7 demonstrates that the CS value of the research was less than 1, indicating that the estimation of the total ESV was inelastic with respect to the value coefficient that Costanza et al. (1997) provided in Table 4. The CS for vegetation (0.50) is higher than Agricultural land and waterbody in 2010. Because vegetation contains a high value coefficient, and the total area of vegetation is also larger than the other two types. The CS for waterbody (0.32) in 2023 is the lowest as its total area is smaller than agricultural land or waterbody. It suggests that the predicted ESV is more affected by changes in the ecosystem value coefficient. However, the sensitivity analysis demonstrated the robustness and reliability of the estimated ESV derived from the value coefficient.

From the findings of the study some recommendations can be provided.

- Built-up area increased throughout the study period is about 18.69% at Tangail Municipality. Vegetation has decreased from 37.82% to 21.51% for Tangail Municipality. Agricultural land shows the highest decrease in the study area than other LULC types. So, it is a very important task to conserve Agricultural land, vegetation, and waterbody to conserve environment, food security, habitat for animals, conservation of biodiversity and climate regulation. Sustainable urban planning, green infrastructure, and integrated regional planning may be helpful to conserve valuable resources.
- Analysis shows that the ESV of vegetation contributes to the total ESV most in the study area. In 2010, Tangail Municipality consisted of approximately 11.85 square kilometres of vegetation, which contributed to the highest ESV of 2.78 million USD. Therefore, it is a crucial task to protect vegetation for a healthy ecosystem. Integration of tree plantation in policies and master plans may be a useful option. Waterbody also makes a significant contribution to the total ESV, as value coefficient is larger than that of other LULC types. In Tangail municipality, only 0.64% of the water bodies contribute 26.15% to the total ESV. A decrease in the water body could have a substantial effect on total ESV. Therefore, waterbody conservation, preventing pollution, and ensuring sustainable waterbody management are of utmost importance.
- Implementation of a sustainable Land use plan and establishing zoning regulations in the master plan, such as the National Land Use Policy 2011, by balancing development with the reduction of conversion of valuable agricultural land, vegetation and water bodies, will help in the conservation of the ecosystem. Ensuring the proper application of policies related to environmental protection, water bodies, and agricultural land, such as the Bangladesh Water Act 2013, the Environment Conservation Rules, 1997, the Bangladesh Environment Conservation Act 1995, the Wetland Conservation Act 2000, and the Bangladesh Environment Conservation Rules 2023. Integrate land use policy with other relevant policies such as water management, biodiversity conservation etc. to achieve a sustainable masterplan which will help in protecting agricultural land, vegetation, and waterbody as well as protection of Ecosystem and thus Ecosystem service values will be increased.

4. Conclusion

Ecosystem Service Values has been estimated based on Land Use Land Cover change at municipal level. Results indicate that changes in land use patterns caused variations in total ESV of the study area. In the municipal area a substantial decrease in ESV was determined. This resulted from a substantial increase in built-up area. Results revealed that the vegetation contributed to the ESV to a greater extent, followed by waterbody. Built-up areas have expanded in the central parts of the Tangail Municipality. Agricultural land and vegetation that contribute to the ESV are in the peripheral part of the municipality. The sustainable land use plan of a municipal area is greatly impacted by the valuation of ecosystem services (ESV), which also has an extensive impact on human well-being. The welfare of people will be more affected by the loss of vegetation, agricultural land, and water bodies. Large scale increase of the built-up area at the expense of agriculture, vegetation, and water bodies will have a negative impact on the climate and cause other issues like urban heat islands. Therefore, in order facilitate in the decision-making process regarding the land use plan and master plan of an area, it is necessary to examine at how ecosystem services react to variation in LULC. Agricultural land, water bodies, and vegetation contribute largely to the ESV of an area, so it is important to conserve these. The integration of tree plantation into policies and master plans, as well as the conservation of agricultural land and water bodies, and the prevention of pollution, could be important tasks. Further, the findings of this study will support planners and policymakers in creating a sustainable land use plan. By taking necessary steps and improving current condition, Tangail municipality can become a model for other municipalities, ensuring sustainability and long-term ecosystem conservation at the municipal level.

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Conflict of Interest

The authors declare that there are no conflicts of interest.

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