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Land Cover Change using GIS and RS Techniques of the Padma River Floodplain in the Three Adjacent Districts in Bangladesh

Research Article

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ABSTRACT

Bangladesh is a nation characterized by its reliance on river systems for various aspects of its socio-economic and geographical features. The region experiences a significant number of natural disasters every year as a result of the existence of the river. The region undergoes regular riverbank erosion as a result of the continuous changing of river channels. This study aimed to assess the changing of the Padma River and its impact on land use and land cover in the three adjacent districts of Munshiganj, Madaripur, and Shariatpur. Geographic Information System (GIS) along with remote sensing (RS) techniques were employed to analyze data collected between 1988 and 2023. Best results in detecting land-use/land-cover type and identifying erosional impact were achieved using K-means cluster unsupervised image classification. The accuracy of image preprocessing and classification was separately evaluated using the kappa coefficient. For the years 1988, 1993, 1998, 2003, 2008, 2013, 2017, and 2023, the findings indicated an overall accuracy of 86.36%, 83.32%, 87.1%, 85.43%, 87.3%, 87.92%, 88.42%, 90.06% and a kappa coefficient of 83.02%, 83.32%, 86.66%,85.37%, 87.78%, 87.29%, 87.91%, 86.59% respectively. Arable land accounted for 56.40 percent of the overall accreted land area (26340.06 ha), whereas cropland accounted for just 5.99 percent (2798.10 ha) based on long-term river channel migration results. In 35 years, arable land (23661.21 ha) suffered the most erosion (55.42%), followed by inland water (3351.53 ha), which suffered the least (7.15%). The implementation of an embankment inside the research area is proposed as a potentially efficacious strategy for mitigating riverbank erosion in this particular region. The government may implement long-term rehabilitation projects to support individuals who have been displaced by bank erosion and are now landless.

Keywords: *Land cover change, River morphology, Channel pattern, Erosion, Accretion*

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1. Introduction

Rivers had a substantial influence on the livelihoods and societal dynamics of individuals residing in Bangladesh. Rivers exhibit a significant amount of sensitivity to environmental circumstances. Alluvial channels have the capacity to adapt and reconfigure themselves at various rates in response to changes induced by water and sediment inputs, active tectonic processes, and human activities over different spatial and temporal dimensions (Heitmuller, 2014; Sinha and Ghosh, 2012). Any alterations, whether they arise from natural processes or human activities, have the potential to disrupt the existing balance of changing equilibrium (Petts and Gurnell, 2005; Winterbottom, 2000). According to Yang (1999), the potential consequence of this phenomenon is the occurrence of channel instability, which can subsequently lead to alterations in both channel structure and pattern. Changes in the frequency, magnitude, and depth of inundation are crucial for Bangladesh (Am et al., 2003; Mirza). According to Guppy and Anderson (2017), water is the basis of the world. Half of the world's population depends on rivers as their primary source of water (freshwater) for survival and other essentials like commerce, transport, and resource discovery. (Kummu et al., 2011; Fang et al., 2018). Rivers' physical features and ecology are vulnerable to the effects of LULC change caused by the growing demand for water worldwide. The effects of LULC change on a river basin have been studied from various aspects (Chin, 2006).

The alteration of the Earth's terrestrial surface due to human activity is widely referred to as Land Use Land Cover (LULC) change on a global scale. The alteration of land by human activities for the purpose of obtaining sustenance and other necessities has been a longstanding practice for thousands of years. However, it is important to note that the current magnitude, intensity, and pace of land use and land cover change (LULC) exceeds those observed in previous eras. Therefore, the study and analysis of land use and land cover (LULC) changes are of great significance in understanding the current global scenario of change. The data about these changes is crucial in providing essential input for decision-making in managing the environment and ecological planning for the future (Zhao et al., 2004; Dwivedi et al., 2005; Erle & Pontius, 2007; Fan et al., 2007). RS technologies emerged as the most effective means of acquiring and updating information related to the prevailing circumstances and dynamic alterations in land use and land cover (LULC) over extended durations from the Earth's surface. Hence, within the context of land use and land cover (LULC) classification, the depiction of cultural attributes, urban regions, vegetative areas, and cultivated land is provided (Akinci et al., 2013). Land use assessments are gaining significance across different fields, including urban development, environmental research, operational strategy, and agricultural management. Land Use and Land Cover (LULC) data also hold significant importance as an input for simulations. Furthermore, they are closely associated with formulating policy measures and mitigating the detrimental impacts of climate change (Disperati et al., 2015).

The process of bank erosion is primarily determined by river dynamics. Bank erosion is complicated and difficult to control (Schwarte et al., 2011). Lateral migration is a process that can result in cataclysmic changes on a local or regional scale (Hickin and Nanson, 1975). River dynamics translate into fluvial hazards while impacting the ecology and commerce of floodplain inhabitants (Das et al., 2012). In 2007, the Bangladesh Water Development Board (BWDB) showed that floods eroded 140 km of riverbanks completely and another 1345 km partially (Islam,2009). There are numerous negative effects of bank erosion, including the loss of land and the resources it generates, the destruction or loss of infrastructure, and poor water quality (Piégay et al., 2005). The loss of land as a result of river erosion and the consequent relocation of the population has severe socioeconomic consequences. Since 1973, major rivers such as the Jamuna, the Ganges, and the Padma have eroded approximately 1,590 square kilometers of flood plains, rendering 1.6 million people destitute

(CEGIS, 2009). Consequently, a significant proportion of slum inhabitants in large urban and metropolitan areas are victims of riverbank erosion (Haque and Zaman, 1989). This subset of migrants is referred to as "floating populations" without a defined occupation or social standing (Elahi et al., 1991). Bank erosion is a natural hazard, and the river's dynamic character alters the LULC of its surrounding basin, which has become a natural occurrence in recent years (Debnath et al., 2017). It is a one-of-a-kind study that demonstrates both channel migration and land cover variations of the Padma River at a particular location. Several studies have been conducted on the Padma River, but none of them are shown in the same frame.

Therefore, the purpose of this paper is to evaluate the changes in the Padma River's fluvial morphology and land cover in the study area. This research aims to determine the land cover changes along the Padma River in the districts of Munshiganj, Madaripur, and Shariatpur using remote sensing and GIS to find the most changed land use classes. And the specific objective of the study is- to calculate the eroded land area and the accreted land area of the three adjacent districts of Padma River. Consequently, the channel morphology of the Padma River is the result of a complex interaction between channel dynamics and sedimentproperties in the study area.

2. Materials and Methods

The three adjacent districts Munshiganj, Madaripur, and Shariatpur were selected as study area because these districts cover distinct length of Padma River from both sides. Major reasons behind the selection of these districts as study area is—these districts are located on the bank of Padma River. River bank shifting and channel migration is very rapid in this area and finally majority portion is being eroded and newly deposited. Satellite data underpin this investigation.Freeware USGS (earthexplorer.nasa.gov) and LGED satellite images and maps were used. Seven satellite images from 1988, 1993, 1998, 2003, 2008, 2013, 2017 and 2023, were acquired to analyze Land Cover Change and calculate the eroded and accreted land area over 35 years.

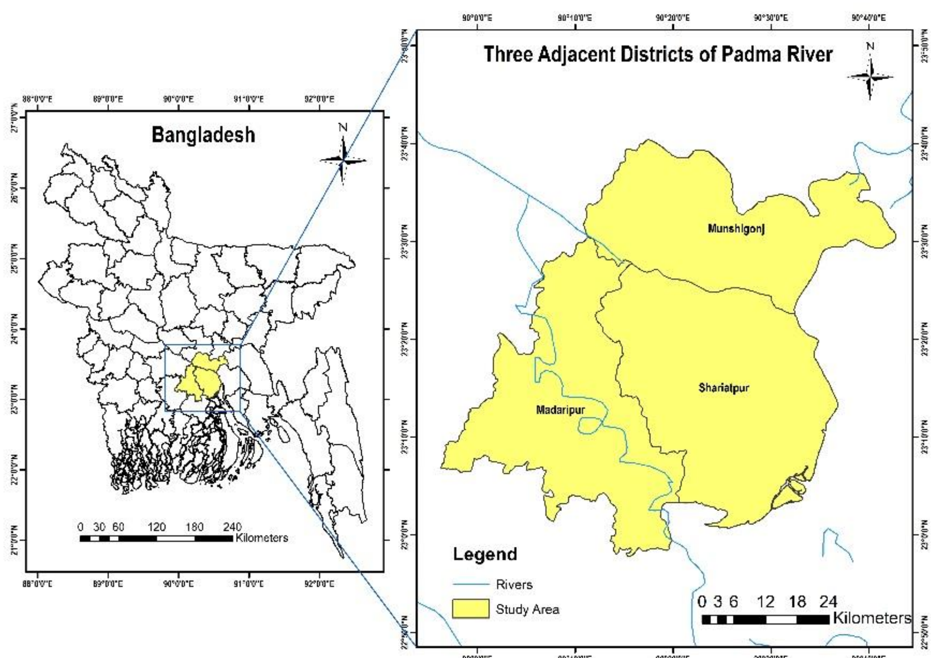


Fig. 1: Study Area

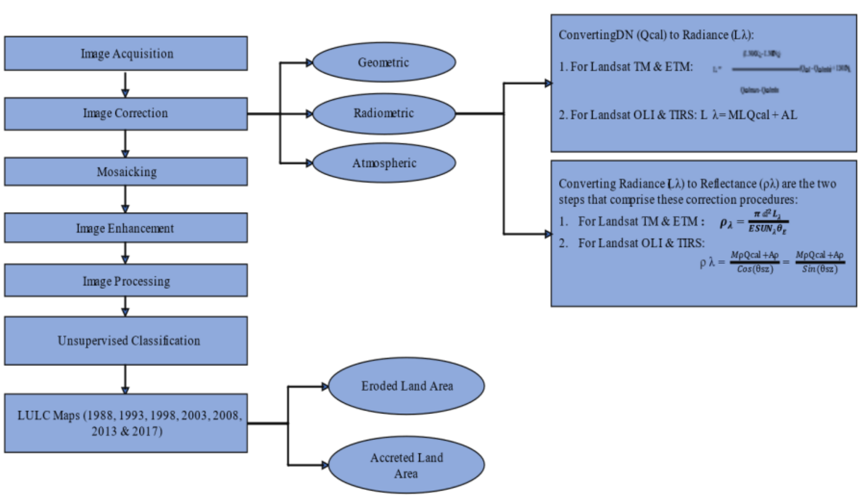
Table 1. The Selected Satellite Images Details

Satellite ID	Sensor ID	Path/Row	Acquisition Date	Spatial Resolution	Quality	Cloud Coverage
Landsat 5	TM	137/44	19-02-1988	30 meters	9	1
Landsat 5	TM	137/44	15-01-1993	30 meters	9	0
Landsat 5	TM	137/44	14-02-1998	30 meters	9	0
Landsat 5	TM	137/44	19-01-2003	30 meters	9	0
Landsat 5	TM	137/44	24-11-2008	30 meters	7	0
Landsat 5	OLI & TIRS	137/44	24-12-2013	30 meters	9	0.08
Landsat 8	OLI & TIRS	137/44	03-12-2017	30 meters	9	0.02
Landsat 8	OLI & TIRS	137/44	23-12-2023	30 meters	9	1

The images used in this study belong to Landsat Collection 1 Level 1. The processing level designations have changed for Collection 1 Level-1 data products.

Landsat Level-1 Processing Levels		
Pre-Collection	**Collection 1**	**Description**
L1T	L1TP	Radiometrically calibrated and orthorectified using ground control points and digital elevation model (DEM) data to correct for relief displacement. These are the highest quality Level-1 products suitable for pixel-level time series analysis.
L1GT	L1GT	Radiometrically calibrated and with systemic geometric corrections applied using the spacecraft ephemeris data and DEM data to correct for relief displacement
L1G	L1GS	Radiometrically calibrated and with only systemic geometric corrections applied using the spacecraft ephemeris data

Flow Chart of the work:



Raw image preprocessing includes atmospheric correction. Image classification was developed after preprocessing. After classification, the true color image is composited. Classification validity was assessed with random sampling. Vegetation Cover maps for each yearly image were created after preprocessing and accuracy evaluation. Attribute-focused area computation was rendered. Change detection was analyzed pre- and post-change detection. Key change locations were determined using multiple methods.

Following **Software's and Tools** are used in this research, Erdas Imagine 2014, Environment for Visualizing Images (ENVI); Version: 5.3, Arc GIS; Version: 10.7, ArcMap, Surfer; Version: 14, Google Earth Pro, Microsoft Office 2019: Word, Excel.

3. Results

3.1 Land Cover

For the analysis of land cover change, the extant landscape of the study area was divided into five classes, based on the Landsat image, as follows: Vegetation, Water, Arable land, Crop land, and Fallow land. The Table 2 provides an in-depth overview of the land cover classes.

Table 2. Explanation of the study's categorization of land uses

Land Cover Classes	Description
Vegetation	Scattered plantation including home stead area.
Waterbody	Open water features such as rivers, natural lakes etc.
Arable land	Area where crops would be harvested.
Crop land	Area where crops are harvested.
Fallow land	Surface without vegetation.

The constant movement of the Padma River has significantly changed the land use classification of its historically migrated flood plain. Details are shown in Table 3.

Table 3. Different land covers area in hectares

Land Cover	1988	1993	1998	2003	2008	2013	2017	2023
Vegetation	115951.40	104234.93	75247.49	140175.94	118057.06	83972.82	131328.79	129234.99
Arable land	150725.65	140853.40	166374.6	118772.97	139377.06	52323.25	131234.49	65151.15
Crop land	27411.14	38594.98	33919.08	20588.42	41122.37	120702.58	42564.32	77284.77
Fallow land	9642.30	19185.81	23076.76	16715.40	2873.44	49713.75	3633.33	28024.22
Water body	25636.45	26498.21	30750.60	33115.79	27938.34	22656.15	20607.76	35325.45

In 1988, the study region exhibited the highest amount of arable land, measuring 150725.65 hectares, while the lowest amount of fallow land, totaling 9642.30 hectares, was seen. The data indicates a significant decrease in vegetation between the years 1988 and 1998, followed by a subsequent return in the subsequent years leading up to 2017. In contrast, arable land demonstrates variations without displaying a uniform long-term trend. The area of land dedicated to crop cultivation exhibits substantial fluctuations over time. The data exhibits a progressive progression from 1993 to 2013, afterwards followed by a decrease. The extent of fallow land, which refers to uncultivated land that is temporarily left unused, experienced a significant decline between the years 1993 and 2013, indicating a trend towards more intense land utilization. Nevertheless, there has been a notable spike in the year 2017, which could perhaps suggest alterations in land management practices or be a manifestation of agricultural cycles. The surface areas of water bodies have exhibited a consistent level of stability over the course of time, with little fluctuations seen. Nevertheless, the observed rise in the period between 2013 and 2017 could potentially suggest alterations in water management practices or modifications in the techniques employed for measuring water levels. One notable trend observed in the dataset is a major increase in the extent of cultivated land between 2013 and 2017, afterwards followed by a decline in 2023.

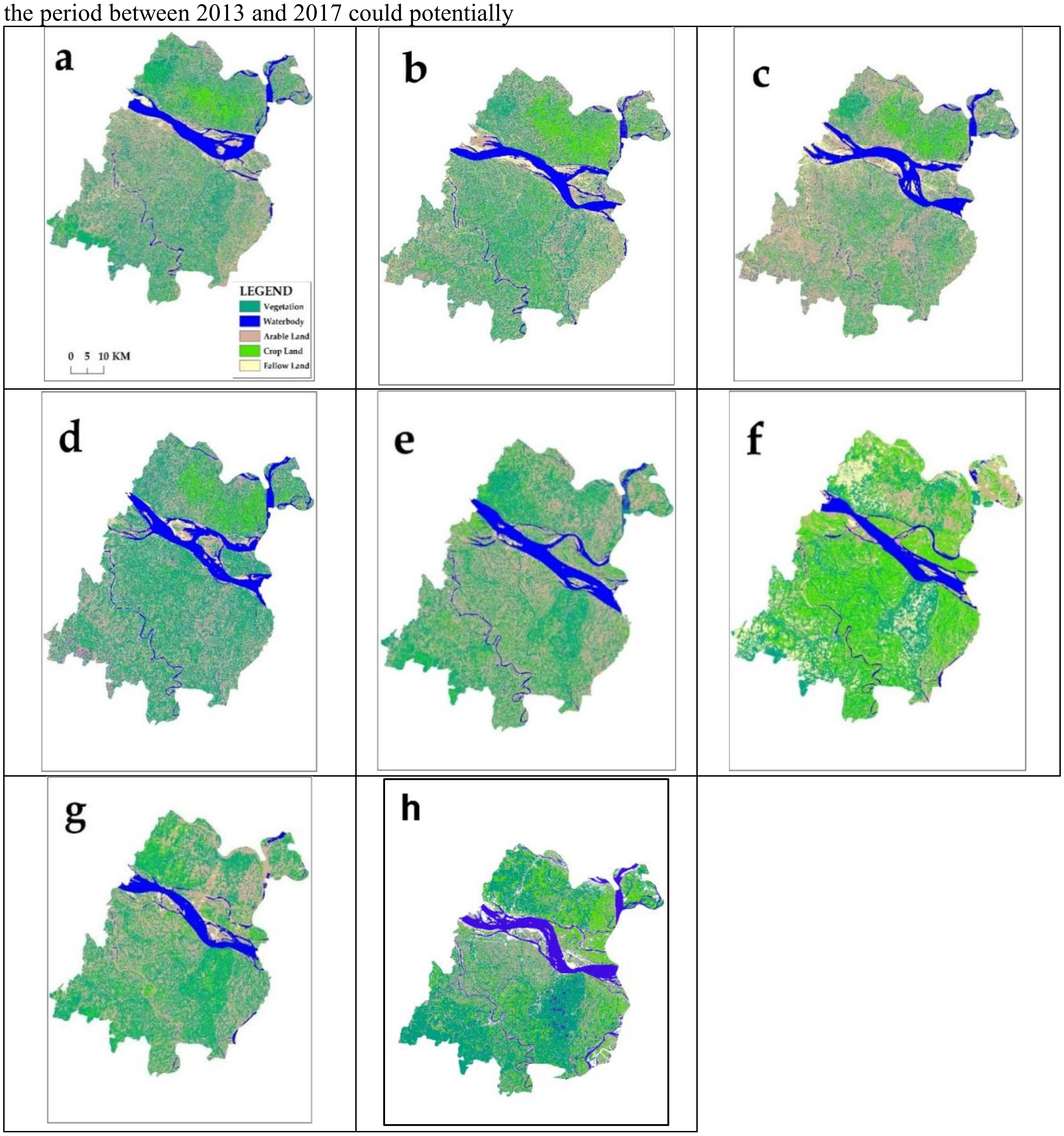


Fig. 2: Land Cover a) 1988, b) 1993, c) 1998, d) 2003, e) 2008, f) 2013, g) 2017, h) 2023

In the year 2003, the total area of vegetated land reached a maximum of 140,175.94 hectares, surpassing previous records. Since 1998, there has been a significant decrease in the amount of arable land and cropland, with a reduction of about 50% to 118,772.97 hectares and 20,588.42 hectares, respectively. The area of fallow land and aquatic bodies experienced a significant growth, rising from 16,715.40 hectares to 33,115.79 hectares.

From 2003 to 2008, the amount of farmland nearly tripled to 41122.37 ha. The most arable land was 139377.06 ha, and the least waste land was 2873.44 ha, which is a lot less than in previous years. The amount of vegetation land and water dropped to 118057.06 ha and 27938.34 ha, respectively. In 2013, there were 120702.58 ha of cropland, which is almost three times as much as in 2008. Fallow land went up to 49713.75 ha, which was the most ever. From 2008 on, the amount of land that could be used for farming fell by half, to 52323.25 ha. 83972.82 ha of land with plants and 22656.15 ha of water were lost. From 2013 to 2017, the amount of crop land shrunk by almost three times, to 42564.32 ha. The land with vegetation was 13132.79 ha, and the land that could be cultivate was 131234.49 ha. Last year, 3633.33 hectares less of land was left empty. From last year, the amount of water bodies dropped to 20607.76 hectares.

3.2 Land Use and Land Cover Analysis

In order to evaluate the accuracy of the classification, a confusion matrix was employed, which encompassed measures such as overall accuracy, user's accuracy, and producer's accuracy. The process of classification cannot be considered as fully accomplished until its correctness has been evaluated by the utilization of the well-established Kappa statistics (Forkuor & Cofie, 2011).

3.3 Overall Accuracy

The confusion matrix can be summarized with this degree of precision. It is determined by dividing the number of unconfused pixels by the number of confused pixels (the diagonal values). For trustworthy land cover classification, (Anderson, 1976) suggests a minimum accuracy value of 85%. Individual opinions about what constitutes sufficient accuracy for a given task can vary widely (Geremew, 2013).

3.4 Kappa Coefficient (KC)

Kappa is a statistical measure of how closely two sets of data classifications match one another. And put to use in determining a model's predicted efficacy by evaluating its correlation with data collected from field surveys (Moriasi et al., 2007).

The results showed that overall accuracy in the study area was 86.36%, 83.32%, 87.1%, 85.43%, 87.3%, 87.92%, 88.42%, 90.06% and kappa coefficient of 83.02%, 83.32%, 86.66%,85.37%, 87.78%, 87.29%, 87.91%, 86.59% for the years 1988, 1993, 1998, 2003,2008, 2013,2017 and 2023 respectively.

3.5 Newly Accreted Land Area

The Padma River's land cover altered significantly between 1988 and 2017. A large number of lands were vegetated, cropped, fellow, or arable. Tables 4 and 5 indicate annual land accretion.

Table 4. Accreted land covers area in hectares

Accreted Area	1988-1993	1993-1998	1998-2003	2003-2008	2008-2013	2013-2017	2017-2023
Vegetation	1121.52	144.36	1857.30	1941.01	186.03	705.08	377.89
Arable land	5642.84	2515.04	5560.67	4395.72	3491.49	4734.25	4519.35
Crop land	232.92	42.75	100.35	667.01	1425.73	329.32	1138.33
Fallow land	2624.58	3210.05	2056.03	869.42	1159.14	1212.61	957.49
Inland water	593.30	485.65	610.31	899.58	449.65	1256.44	437.54

The Padma River gained the most land with vegetation between 2003 and 2008, with 1941.01 ha, or 23.93% of the total, and the least, with 144.36 ha, or 2.47%, between 1993 and 1998. The amount of land with vegetation was high from 1998 to 2003 (19.53%) and low from 2008 to 2013 (3.06%). From 1988 to 2017, 5955.33 hectares (12.75%) of land that can grow vegetation were added. As additional vegetation grow, the people who live in the study area get more land to build on.

The most arable land was accumulated between 1988-1993 (5642.84) and 1998-2003 (5560.67) ha. In 1993-1998, 2515.04 hectares (43.10%) represented the smallest area. In 2008-2013, there were only 3,491.49 hectares of arable land, the most of any land cover category. From 2008 to 2013, it occupied 57.47% of the land. In 35 years, 26340.06 hectares were added to the land area. The greatest amount of land that was accreted was 56,40%. Typically, accreted cropland was low. In 1993-1998, 0.73 %, or 42.75 hectares, represented the lowest area covered by forest. In the period between 1998 and 2003, 100.35 hectares, or 1.05%, exhibited a low cover. The most land accreted between 2008 and 2013 was 1,425.73 hectares, or 23.47 percent of the total land accreted. The total amount of accreted agricultural land was 5.9 percent, or 2798.10 ha.

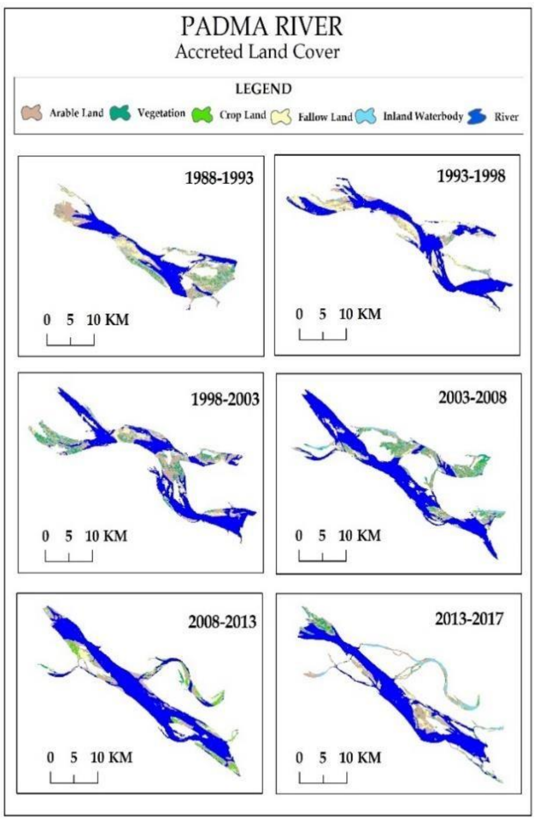


Fig. 3: **Accreted Land Cover**

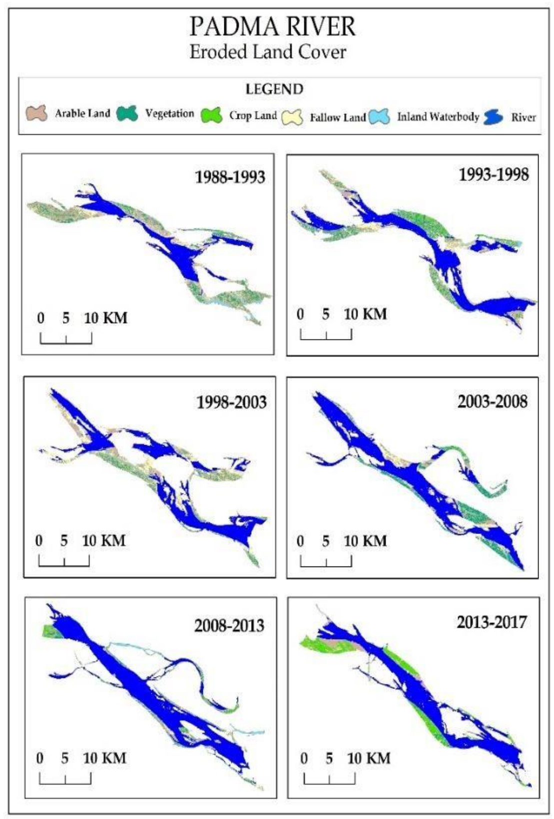


Fig. 4: **Eroded Land Cover**

Table 5. Accreted land cover area (in Percentage)

Accreted Land	1988-1993	1993-1998	1998-2003	2003-2008	2008-2013	2013-2017	2017-2023
Vegetation	11.50	2.47	19.53	23.93	3.06	9.50	12.75
Arable land	57.89	43.10	58.48	54.21	57.47	63.78	56.40
Crop land	2.39	0.73	1.05	8.23	23.46	4.43	5.99
Fallow land	26.93	55.01	21.62	10.72	19.07	16.34	23.83
Inland water	6.08	8.32	6.42	11.09	7.40	16.93	9.19

The "Arable land" category saw the biggest growth in accreted area from 1988 to 1993. This shows that a lot of land was reclaimed or added to agricultural fields during that time. The amount of "crop land" changes over time. During 2003-2008 and 2008-2013, the amount of "crop land" grew a lot, which suggests that farming habits or land use changed. "Inland water" also shows changes in the area that has been accreted. The amount of new land added to each group as a percentage of the total land area shows how important these changes are. "Fallow land" has always had the highest percentage of accreted land, which shows that this category has changed a lot, probably because of changes in how farming is done.

3.6. Eroded Land Cover

Padma River bank erosion and accretion continued for 35 years. The river bank erodes as one side accretes. River bank erosion erodes the research area's land cover type. See Tables 6 and 7

Table 6. Eroded land covers area in hectares

Eroded Area	1988-1993	1993-1998	1998-2003	2003-2008	2008-2013	2013-2017	2017-2023
Vegetation	1985.38	2063.5	980.67	2575.17	1109.28	251.82	342.32
Arable land	6195.63	4947.93	4816.61	3112.40	2330.72	2257.91	2039.49
Crop land	431.38	874.20	350.92	223.56	551.44	2864.62	673.93
Fallow land	1722.20	2117.33	3330.93	1867.74	664.85	361.72	412.47
Inland water	638.12	594.29	646.40	515.53	703.28	253.89	296.31

In 2013–2017, 4.55% of vegetated land was degraded. 2575.17 hectares covered 33.59% of land in 2003-2008. Among them, 21% of degraded land is vegetated—8965.84 acres.

Table 7. Eroded land cover area (Percentage)

Eroded Area	1988-1993	1993-1998	1998-2003	2003-2008	2008-2013	2013-2017	2017-2023
Vegetation	19	20.76	10.43	33.59	23.66	4.55	9.09
Arable land	59.29	49.80	51.25	40.60	49.71	40.81	54.18
Crop land	4.12	8.79	3.73	2.91	11.76	51.78	17.90
Fallow land	16.48	21.31	35.44	24.36	14.18	6.53	10.96
Inland water	6.11	5.98	6.87	6.72	15	4.58	7.87

The data values show how much erosion has happened to each type of land over different time periods. Both "Vegetation" and "Arable land" can be eroded to different degrees. "Arable land" is especially prone to erosion, especially between 1988 and 1993 and 1993 and 1998. Erosion happens on "crop land" at different times, but a lot of it happens between 2013 and 2017, which could mean that it's hard to protect the soil in these places. "Fallow land" and "Inland water" also show different levels of erosion, which suggests that both uncultivated land and water areas are being affected.

4. Discussion

The Padma River erodes and build up land, so the land area of Munshiganj, Madaripur, and Shariatpur changes over time. During the years 1988–1993 and 1993–1998, the land area declined because the rate of erosion was higher than the rate of accretion. During the years 1998–2003, 2003–2008, 2008–2013, 2013–2017, and 2017–2023, the land area grew. The most damaged time period was from 1993 to 1998 when 4,100.09 ha of land were lost. And most dumping took place between 2013 and 2017 when 706 ha of land was added. The rate of growth was lowest from 1998 to 2003 when only 109.80 ha of land was added. From 1988 to 2017, 42,689.59 ha of land were lost in the study area, and 46,694.46 ha of land were added. At a rate of 33.54 ha per year, the amount of land lost over these 35 years was estimated to be 972.94 ha.

The continuous monitoring of land percentages affected by accretion and erosion may be used as a valuable tool for researchers to assess the efficacy of conservation efforts, detect evolving patterns, and anticipate forthcoming issues. The integration of these findings across several domains has the potential to facilitate more informed decision-making processes that prioritize the preservation of the environment as well as the welfare of human beings. Through the utilization of the knowledge acquired from the analysis, various stakeholders can collaborate in order to establish a future that is more sustainable for our landscapes and ecosystems.

5. Conclusions

In a span of 35 years, the type of land that grew the most was arable land, with 26340.06 ha, or 56.40%, and the type that grew the least was cropland, with 2798.10 ha, or 5.99%. In 35 years, the type of land that eroded the most was also fertile land, with 23661.21 ha, or 55.42%. The type of land that eroded the least was inland water, with 3351.53 ha, or only 7.85%. The analysis of these changes in land cover is important for figuring out how sustainable the area as a whole is. Conservation of the environment and the growth of agriculture are two important goals that need to be kept in balance. Sustainably using land, planting trees, and managing water well are all important for keeping the ecosystem in order and providing for future generations. To learn more about these changes, it is important to look at the things that cause buildup and erosion, like how land is used, how crops are grown, how the weather is, and how infrastructure is built. An embankment might be the best way to stop riverbed erosion in the study area. The government can start long-term projects to help the people who lost their land because of bank erosion get back on their feet.

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