

Shift in cropping systems following riverbank erosion: from paddy to short-duration crops in Bangladesh?

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Abstract: Bangladesh, a riverine country with vast floodplains is highly vulnerable to riverbank erosion threatening agriculture and livelihoods. This study investigates shifts in cropping practices in response to riverbank dynamics in *Alokdia Mouza*, a *char* land along the Jamuna River. Therefore, Digital Shoreline Analysis System (DSAS) and multiple statistical analyses were applied to examine riverbank shifting along with cropping patterns through Landsat satellite imagery from 2015 to 2025 at five-year intervals. Besides that, the study conducted a household questionnaire survey with 68 respondents (90% confidence level, 10% margin of error) and seven FGDs involving local farmers and community representatives using random sampling techniques, which supported the development of the crop calendar. The results revealed highly dynamic riverbank changes between 2015 and 2025 with maximum erosion rates recorded were -38.88 m/year (WLR), -5174.52 m (NBM), -956.04 m/year (EPR), and -451.87 m/year (LRR), while the maximum accretion rates were 73.44 m/year (WLR), 649.26 m (NBM), 71.61 m/year (EPR), and 73.44 m/year (LRR) respectively. Statistical analysis including Pearson Correlation, Mann-Whitney *U* test, Transition Matrix, Analysis of Variance (ANOVA) test indicate a transition in cropping patterns from long-duration to short-duration crops from 2015 to 2025 which accompanied by a notable expansion of uncultivated land. The results also reveals the erosion and accretion prone areas have led to more short-duration crops and increased fallow land in the study site. These findings offer valuable insights for sustainable agricultural management and erosion mitigation in Bangladesh's riverine *char* lands.

Keywords: Riverbank shifting, Cropping system, Crop calendar, DSAS, Bangladesh.

1.0 Introduction

Agriculture dominated country, Bangladesh lies within one of the world's largest deltas (Ganga-Brahmaputra and Sundarbans), crisscrossed by thousands of rivers and rivulets (Nasim et al., 2017). The land is enriched with fertile alluvial soil (Faisal et al., 2022). The

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soil and environment are well suited for different kinds of crops all over the year (Ali et al., 2003). About 60.52 % of its total land is arable (World Bank, 2022). However, this inherently riverine and alluvial setting makes much of Bangladesh low-lying, highly dynamic, and extremely vulnerable to fluvial processes such as flooding, sedimentation, and riverbank erosion (Faisal et al., 2022).

In particular, riverbank erosion is one of the most prevalent natural disasters in Bangladesh (Baqee, 1997). Almost 2,400 km river bank line including 283 locations, 85 towns and growth centres are vulnerable to river bank erosion in Bangladesh (Islam and Rashid, 2011). As a braided downstream river, the Jamuna exhibits unstable banks and experiences the highest rates of bank line shifts (Rahman et al 2013). It has been evidently observed that changes in the proportion of erosion and accretion differ in different points of Jamuna River (Pahlowan et al., 2015). The highest eroded area, spanning over 3.82 km², occurred between 1995 and 2005, while the highest accreted area, covering 6.15 km², was observed between 1995 and 2015 (Abdeen et al., 2023). During 1973 to 2015 erosion and accretion along the Jamuna River was 88,462 ha and 16,315 ha respectively (CEGIS, 2015). It has been estimated that tens of thousands of people are displaced annually by river erosion in Bangladesh, possibly up to 100,000 (Rahman, 2010). Communities living along riverbanks are particularly vulnerable, often losing their homes, farmland, homestead gardens, and livelihoods, coupled with alterations in river flow and ecological imbalance (Alam et al., 2016). The processes of riverbank erosion and accretion give rise to chars, which are riverine islands or newly accreted lands within floodplains. *Char* lands cover approximately 1.723 thousand km², representing about 1.2% of Bangladesh's total territory (Sarker et al., 2003), and support an estimated 6.5 million people, or roughly 5% of the national population (Islam et al., 2014). These lands are highly fertile, making them attractive for agricultural activities. However, *chars* are naturally unstable, as many emerge, persist for a limited period, and are subsequently eroded, causing significant disruption to cultivated land (Sarker et al., 2003).

Traditionally, *char* land agriculture in Bangladesh has been dominated by paddy due to its suitability for flooded and low-lying soils (Hussain, 2017). Particularly *Aman*, a long-duration crop requiring four to five months to mature and increasing rates of riverbank erosion and land uncertainty have made its cultivation less viable (Sultana, 2013). Consequently, farmers in erosion-prone *char* areas are reportedly shifting toward short-duration crops which allow earlier harvesting and reduce the risk of land loss (Gardner et al., 1999). Understanding such changes is crucial as shifts in cropping patterns affect crop calendar, income cycles, food security, and broader land use planning, reflecting the significant influence of river dynamics on agricultural practices (Rutten et al., 2014).

In recent years, the integration of numerical models with remote sensing data and GIS tool has gained considerable attention for monitoring riverbank erosion (Raj et al., 2019). Nevertheless, most researchers applied the traditional technique and manual overlapping method to calculate river bank erosion and accretion (Hasanuzzaman et al., 2023). These methods are highly prone to human bias and error (Ashraf et al., 2018; Jana, 2020). With the advancement of modern scientific methods, automated techniques have emerged that minimize human error and enhance the reliability of riverbank monitoring (Manfreda et al., 2024). Through an in-depth analysis of the existing literature, it can be confidently stated that DSAS model is the only statistical-based automated tool currently available for calculating riverbank erosion and accretion (Khallaghi et al., 2022; Schielen et al., 2017; Hasanuzzaman et al., 2023). In addition to utilizing the DSAS model to quantify riverbank erosion and accretion rates in the study area and integrates multiple statistical analyses (Pearson Correlation, Mann-Whitney *U* test, Transition Matrix, Analysis of Variance (ANOVA) test) to examine how much shifts in cropping systems in erosion-affected areas, focusing on the transition from traditional long-duration paddy to short-duration crops in erosion-prone areas. Therefore, the main objectives of the study are (1) to examine the river bank shifting using DSAS Model; (2) to identify shifts from traditional paddy cultivation to short duration crops through RS and local people perceptions; and finally, (3) to make relation between riverbank shifting and changes of agricultural practices in the study site.

2.0 Methodology

2.1 Selection of the study area

The study was conducted in *Alokdia Mouza*, a *char* land located in Teota Union of Shibaloy Upazila, Manikganj District, Bangladesh. This area lies along the Jamuna River one of the most erosion-prone rivers in the country and has experienced frequent and severe riverbank erosion over recent decades. *Alokdia Mouza* covers an area of approximately 201 hectares and is geographically situated between 23°50'45.49"N and 23°54'26.64"N latitudes and 89°42'41.67"E and 89°45'55.58"E longitudes (Fig. 1). The local climate presents additional challenges for agriculture with an average annual temperature of 28.55 °C slightly above the national average and annual rainfall of about 70.26 mm (Halder, 2015). Agriculture forms the backbone of the local economy with the majority of households either directly or indirectly dependent on farming for their livelihoods. The main crops cultivated in *Alokdia Mouza* include Boro rice, maize, sesame, black gram, peanut, potato, tomato, mustard, and various pulses.

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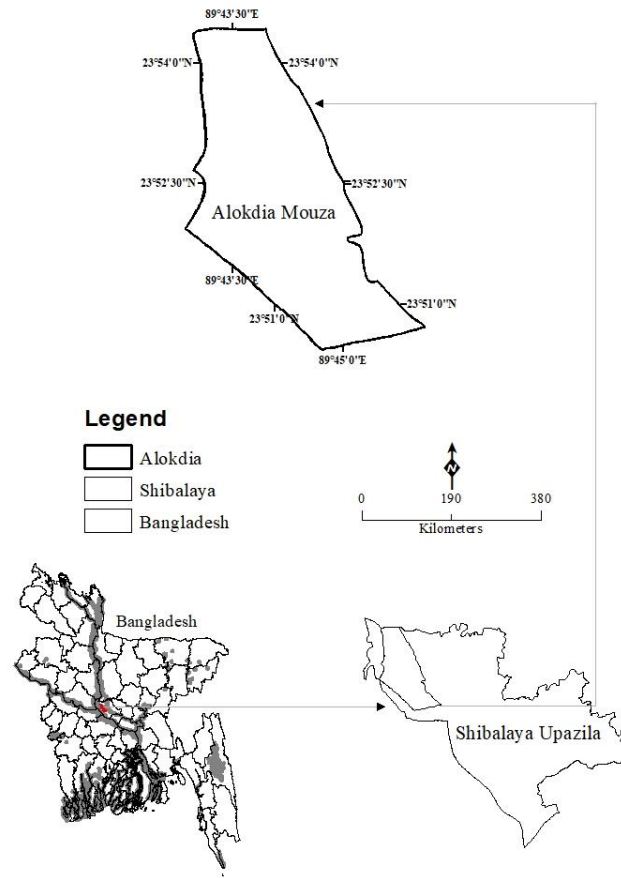


Fig. 1. Study area map of Alokdia Mouza, Manikganj, Bangladesh

Source: Compiled by author, 2025

2.2 Data source

2.2.1 Local people perceptions

Primary data were collected through a random household survey comprising 28 questions across four thematic areas: (1) Riverbank Erosion and Agricultural Land Loss, (2) Riverbank Erosion Impacts on Agricultural Productivity, (3) Changes in Cropping Patterns, and (4) Adoption of Short-Duration Crops. A total of 68 households were surveyed using random sampling to ensure balanced representation from both erosion-affected and non-affected zones. Additionally, seven FGDs (each FGD consists 7 to 8 farmers) were conducted with local farmers and community representatives to gather qualitative insights on erosion trends, cropping pattern shifts, and adaptive strategies. The integration of both quantitative and qualitative methods provided a comprehensive understanding of the relationship between riverbank erosion and changes in agricultural cropping systems within the study area.

2.2.2 Satellite images

Secondary data were carefully compiled from various sources, including government organizations, national and international journals, books, and satellite datasets. Specifically, OLI satellite images for the years 2015, 2020, and 2025 were obtained from the United States Geological Survey (USGS) (Table 1). These years were selected based on image availability, minimal cloud cover, and a five-year interval to capture temporal changes. Images acquired between November and January were prioritized, as this period typically provides cloud-free conditions. All satellite images were projected in Universal Transverse Mercator (UTM) Zone 45 North using the WGS84 datum. For riverbank erosion trend analysis, EarthExplorer was used to download the images, and ArcGIS 10.8 software was employed for geospatial processing and analysis.

Table 1. Details of the different satellite imagery used in the present study

Sl. No	Image Acquisition Date (mm/dd/yyyy)	Sensor Type	Image Resolution (m)	Cloud Cover
1	12-21-2015	Landsat 8 – OLI	30	15%
2	12-18-2020	Landsat 8 – OLI	30	15%
3	1-14-2025	Landsat 8 – OLI	30	15%

Source: Compiled by author, 2025

2.3 Bankline extraction

Riverbank lines are among the most dynamic features in fluvial landscapes, as they can shift significantly within short periods due to erosion and deposition processes. Various methods for extracting the river body from Landsat imagery have been developed using ArcGIS software. In this research, the Modified Normalized Difference Water Index (MNDWI) was used which is based on the principle that water exhibits higher reflectance in the green band and lower reflectance in the near-infrared (NIR) band. Xu (2007) modified the traditional Normalized Difference Water Index (NDWI) by replacing the NIR band with the mid-infrared (MIR) band, improving the detection of open water features particularly in areas with built-up land by efficiently reducing background noise. The optimal threshold values for MNDWI are generally lower than those for NDWI, indicating that using zero as a default threshold often yields more accurate water extraction results with MNDWI compared to NDWI (Xu, 2007). The MNDWI values range from -1 to +1, where higher reflectance represents waterbody and lower reflectance represents built-up land in the SWIR band results. For the Landsat OLI sensor, Xu's MNDWI is calculated as follows:

$$MNDWI = \frac{Green - SWIR}{Green + SWIR}$$

Where, *Green* is green band for OLI is band 3 and *SWIR* is reflectance of the SWIR band for

OLI is band 7 (Li et al. 2013; Xu 2006).

2.4 Bankline change analysis in DSAS model

This study employed the Digital Shoreline Analysis System (DSAS) version 5.1 to quantitatively assess riverbank erosion and bankline shifting. DSAS is a freely available extension of ArcGIS designed to compute statistical changes in riverbank line delineation (Thieler et al., 2009). Although originally developed for coastal shoreline change analysis, the tool has also been effectively applied in fluvial environments, demonstrating its suitability for examining riverbank dynamics and channel migration (Yunus et al., 2009). To utilize DSAS for this purpose, the software requires river polylines as an input of various time periods along with user-defined baseline, following the procedures outlined by Thieler et al. (2009) and Yunus et al. (2015). The DSAS tool defines the river banks using user-defined baseline data and the baseline is established by generating a buffer polygon (1km) from a reference river profile, taken as 2015 in this study which is then converted to a line shape and manually refined for accuracy. Furthermore, DSAS automatically generates transects perpendicular to the baseline at specified intervals. This tool operates by simulating transects from a hypothetical baseline located at a specified distance from the most recent shoreline of the study area and then subsequently calculate the convergence of each shoreline with each transect (Brooks and Spencer, 2010). For this study, transects were cast at 100-m intervals for the river stretch. A total of 140 transects were generated across the study area for detailed analysis. Using the DSAS tool, parameters such as Net River Migration (NRM), End Point Rate (EPR), Linear Regression Rate (LRR), and Weighted Linear Regression (WLR) were computed to quantify the horizontal changes of riverbanks and assess the rates of change over time. The riverbank erosion and accretion rates were categorized into ten classes, and the corresponding ranges of Weighted Linear Regression (WLR) are presented in Table 2 (Natesan et al., 2015).

Table 2. Classifications of bankline based on erosion (negative value) and accretion (positive value) rates estimated from Weighted Linear Regression (WLR) analysis.

S. No	Classification	Rate of riverbank change (m/yr)
1	Very high erosion	$-38.9 < \text{to} \leq -3.0$
2	High erosion	$-3.0 < \text{to} \leq -2.0$
3	Moderate-high erosion	$-2.0 < \text{to} \leq -1.0$
4	Moderate erosion	$-1.0 < \text{to} \leq -0.5$
5	Stable	$-0.5 < \text{to} \leq 0.5$
6	Moderate accretion	$0.5 < \text{to} \leq 1.0$
7	Moderate-high accretion	$1.0 < \text{to} \leq 2.0$
8	High accretion	$2.0 < \text{to} \leq 3.0$
9	Very high accretion	$3.0 < \text{to} \leq 73.5$
10	Null	Not available

Source: Compiled by author, 2025

2.4.1 Rate of change statistics in DSAS model

DSAS quantifies riverbank changes using multiple statistical measures. The formulas for these statistical parameters are provided below table 3.

Table 3. Statistical parameters of DSAS model.

Statistics	Description	Formula	Source
Net Bankline Movement (NBM)	Enumerates the actual distance between the oldest and the youngest shoreline for each transect laid perpendicular to the bankline.	$\{d_{2025} - d_{2015}\}m$	DSAS 5.0 User Guide, 2018
End Point Rate (EPR)	Calculated by dividing NBM with the time elapsed between the oldest and the most recent bankline.	$\left\{ \frac{d_{2025} - d_{2015}}{t_{2025} - t_{2015}} \right\}$	Dolan et al. 1991; Crowell et al. 1997
Linear Regression Rate (LRR)	Quantifies the long-term rate of riverbank movement by fitting a least squares regression line through all riverbank positions intersecting each transect over time.	$L = b + mx$ Where L is the distance (m) from the baseline, x is the time interval (years), m represents the slope (m/year) and b is the y-intercept.	Dolan et al., 1991; Crowell et al., 1997
Weighted Linear Regression (WLR)	A variation of standard linear regression that assigns greater weight to more reliable data points when determining the best-fit line.	$W = 1/e^2$ Where W is weight e is shoreline uncertainty value	DSAS 5.0 User Guide, 2018

Source: Compiled by author, 2025

2.5 Uncertainty calculation

The positional uncertainties of the riverbank were collected from the Bangladesh Water Development Board (BWDB) for the years 2015, 2020, and 2025, with values of 9.6m, 9.24m, and 9.44m respectively. To estimate the total uncertainty (U_{total}) of riverbank change between 2015 and 2025, the calculation followed the equation (Thieler et al., 2009):

$$U_{total} = \frac{\sqrt{U_{2015}^2 + U_{2020}^2 + U_{2025}^2}}{T}$$

Where, (U_{2015}) , (U_{2020}) and (U_{2025}) represent the positional uncertainties (in meters) of each respective year, and TTT is the time interval between the first and last years (in years).

2.6 Statistical analysis

Pearson Correlation Analysis measures the strength and direction of the linear relationship between two continuous variables, ranging from -1 to 1 (Janse et al. 2021). A value of 1 indicates a perfect positive relationship, -1 a perfect negative relationship, and 0 no linear relationship. In this study, it was used to quantify the association between erosion rates and changes in cropping patterns within erosion-affected areas, serving as a supporting statistical method alongside other analyses.

The Mann-Whitney U test, also known as the Wilcoxon-Mann-Whitney test, is a non-parametric statistical test used to evaluate the significance of differences between two independent groups. The test produces the U statistic, which represents the sum of ranks assigned to one of the groups, adjusted for the sample sizes. This statistic is then converted into a p -value to assess significance. The test statistic U is computed through the following formula (Chicco et al., 2025):

$$U = n_1 n_2 + \frac{n_1(n_1 + 1)x^2}{2} + R_1$$

Where n_1 , n_2 are the sample sizes of the two groups and R_1 is the sum of ranks in the first group.

Transition Matrix Analysis is a statistical method that examines changes or transitions in crop type over time. Represented as a square matrix, it displays the probabilities or frequencies of moving from one state (crop type at time t) to another state at a later time (crop type at time $t+1$). Each row corresponds to the initial state, and each column corresponds to the subsequent state, with matrix values indicating transition likelihoods or counts.

Analysis of Variance (ANOVA) Test is a statistical method used to determine whether there are significant differences between the means of three or more independent groups. It compares the amount of variation between group means to the variation within groups, using an F-test to assess if observed differences are likely due to real effects rather than random chance. In this study, ANOVA was employed to test whether erosion rates differ significantly among identified spatial crop change hotspot zones. By comparing mean erosion rates across these multiple hotspot groups, ANOVA helped reveal if riverbank erosion intensity varies systematically with cropping system transformations. Computed as:

$$F = \frac{MST}{MSE}$$

Where, F represent ANOVA coefficient, MST is the Mean sum of squares due to treatment and MSE is the Mean sum of squares due to error.

3.0 Results and Discussion

3.1 Bankline change

The outcome from the DSAS models clearly stated that the riverbank in the study area was highly dynamic and experienced substantial changes from 2015 to 2025. To better understand the changes of riverbank erosion, the riverbanks were visualized at 5-year intervals. For more detailed interpretation, the area was divided into three sectors (a, b, c) running north to south and WLR estimated the rates of erosion and accretion (Fig 2).

In this study, the DSAS analysis initially utilized 140 transects to assess riverbank changes. However, due to missing or null data, the number of transects analyzed varied depending on the statistical method applied (NBM, EPR, LRR, and WLR). For Weighted Linear Regression (WLR) analysis based on 88 transects shows an average bankline change rate of 8.77 m/year with a standard deviation of 31.52 m/year indicating substantial variability in channel movement. Out of all transects, 39 (44.3%) exhibited erosion while 49 (55.7%) showed deposition suggesting that accretion slightly dominates over erosion within the study period. The maximum accretion rate was 73.44 m/year at in Sector (c) with an average accretion rate of 31.32 m/year, whereas the maximum erosion rate of -38.88 m/year occurred at Transect 76 in Sector (a), with an average erosion rate of -19.55 m/year.

Net Bank Movement (NBM), out of 140 transects, 125 yielded usable data. The results revealed an average NBM of approximately -36.80 m, with a high standard deviation of 304.54 m, indicating that the majority of bankline changes were erosion-dominated, though there was considerable variability among transects (Table 3). The maximum accretion of 649.26 m occurred at Transect 130 in Sector (c), representing areas of notable land gain, whereas the maximum erosion of -554.04 m was observed at Transect 16 in Sector (a), highlighting zones experiencing severe bankline retreat (Fig. 2A).

Table 3 Statistical result of NRM, EPR and LRR along the riverbank

Statistics	Parameters			
	Average	Standard deviation	Maximum	Minimum
NRM (m)	-36.80	304.54	649.26	-554.04
EPR (m/year)	-12.31	44.63	71.61	-110.93
LRR (m/year)	8.77	31.52	73.44	-38.88

Source: Compiled by author, 2025

The result of End Point Rate (EPR) of the same 125 transects disclose that an average bankline change of -12.31 m/year, reflecting a predominantly erosional trend across the study area. The standard deviation of 44.63 m/year indicates strong spatial variability in erosion and accretion among transects (Table 3). The maximum accretion rate of 71.61 m/year occurred at Transect 130 in Sector (c), while the maximum erosion rate of -110.93 m/year was recorded at Transect 16 in Sector (a), marking a hotspot of severe land loss

(Fig.2B). Regression results from DSAS for Linear Regression Rate (LRR), based on 88 transects, indicate an average channel migration rate of 8.77 m/year, with a standard deviation of 31.52 m/year (Table 3). The maximum accretion rate of 73.44 m/year was recorded at Transect 130 in Sector (c), while the maximum erosion rate of -38.88 m/year occurred at Transect 76 in Sector (a). The peak accretion and erosion points were thus identified at Transect 130 (Sector c) and Transect 76 (Sector a), respectively, suggesting that while certain sections experienced rapid accretion, others underwent significant erosion (Fig 2C).

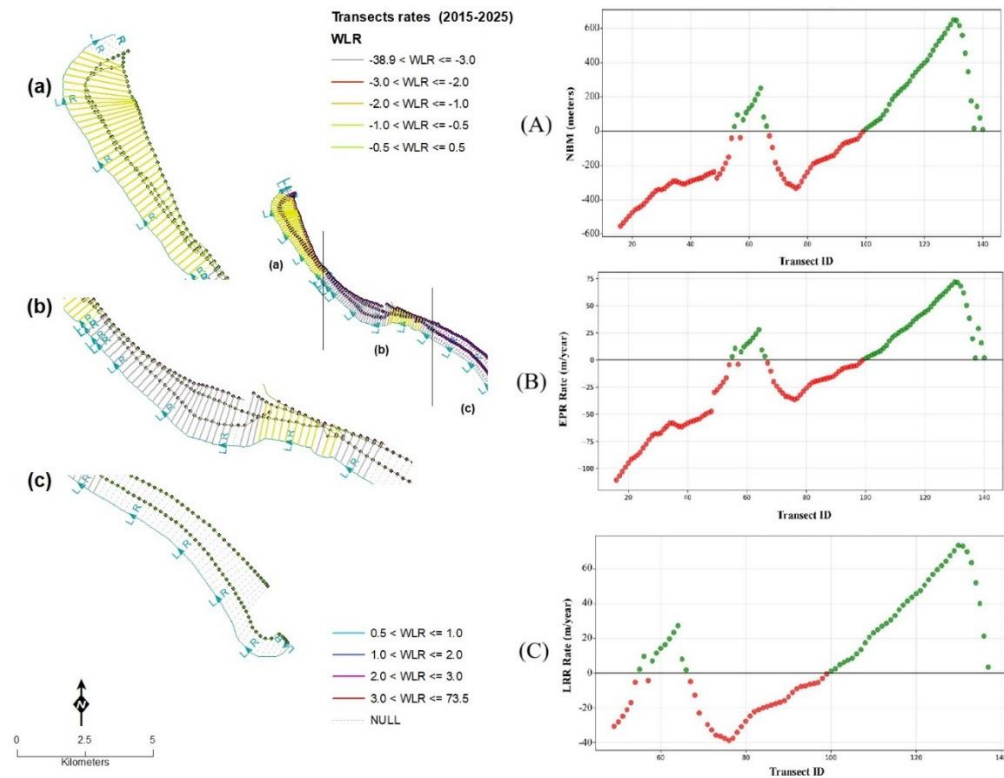


Fig. 2. Estimations of different degrees of erosion and accretion at a, b, c sectors between 2015 and 2025 from WLR and graph representing A (NBM), B (EPR), and C (LRR) calculated corresponding to 140 transects for the study area. Red points indicate erosion (negative values); green points indicate accretion (positive values).

Source: Compiled by author, 2025 using DSAS model.

3.2 Shifts in cropping system

3.2.1 Shifts in crop planting and harvesting timeline

The crop calendar presented in Fig. 3 was developed based on community surveys and focused group discussions, particularly with participants over the age of 40, who provided detailed recollections of farming practices from the past 5 to 10 years. This calendar provides a comprehensive visualization of current (2025) cropping cycles and highlights

temporal shifts in planting and harvesting over the past decade. It captures the monthly timing and duration of planting and harvesting for major crops and visually compares cropping cycles between 2015 and 2025 reflecting both traditional and current agricultural practices in the study area. The calendar illustrates the current (2025) planting and harvesting months for thirteen major crops including *Boro rice*, *IRRI rice*, maize, mustard, sesame, black gram, millet, pumpkin, peanut, potato, tomato, bottle gourd, chili, and cauliflower. In comparison, crops in 2015 were mainly *Aman rice*, *Boro rice*, black gram, potato, and peanut. This transition from predominantly long-duration crops in 2015 to shorter-duration crops in 2025 reflects changes in cropping systems chiefly driven by riverbank erosion.

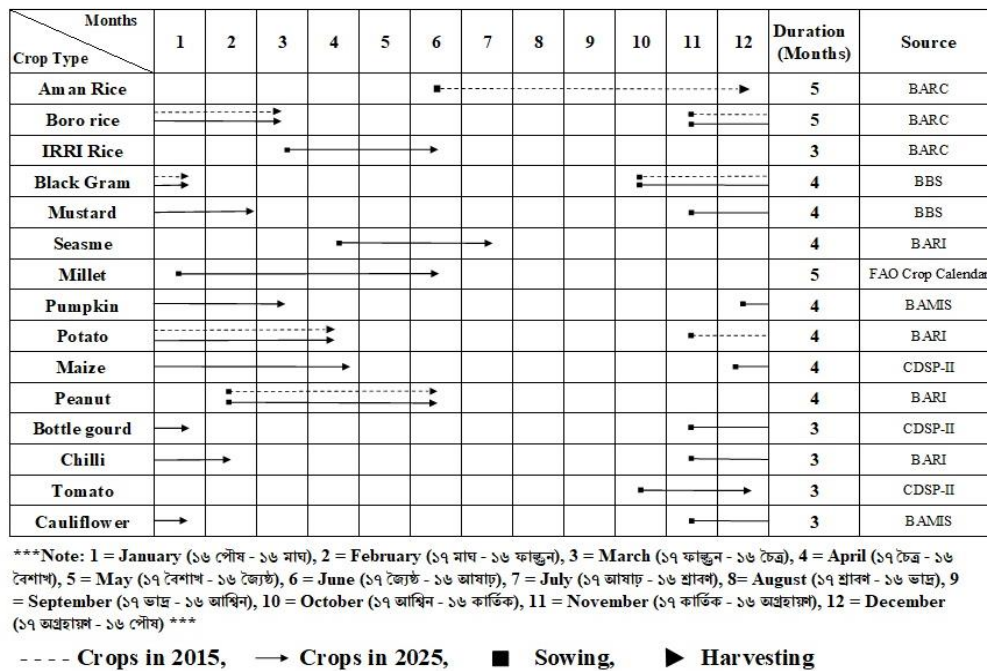


Fig. 3 Crop calendar for study site demonstrating the shift in cropping systems following riverbank erosion from the year 2015 to 2025.

3.2.2 Analysis of crop duration, transitions, and change hotspots

To assess temporal changes in crop duration between 2015 and 2025, the Mann-Whitney U test was applied to 140 transects in the study area. The analysis revealed that 129 transects (92.14%) experienced changes in crop duration over the decade. The Mann-Whitney U statistic was 367 with a p-value of 0.507, indicating that the observed shifts in crop duration were not statistically significant at the 0.05 level. In 2015, most transects were dominated by long and medium-duration crops, with fewer areas allocated to short-duration crops or left uncultivated. By 2025, there was a notable decline in long and medium-duration crops, alongside a substantial increase in short-duration crops and a pronounced expansion of uncultivated land. These trends reflect farmer's adaptive

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strategies to riverbank erosion, including shifting from long-duration paddy to shorter-duration, more resilient crops. The no crop category has become increasingly dominant, highlighting significant agricultural abandonment as land stability declines (Fig. 4a).

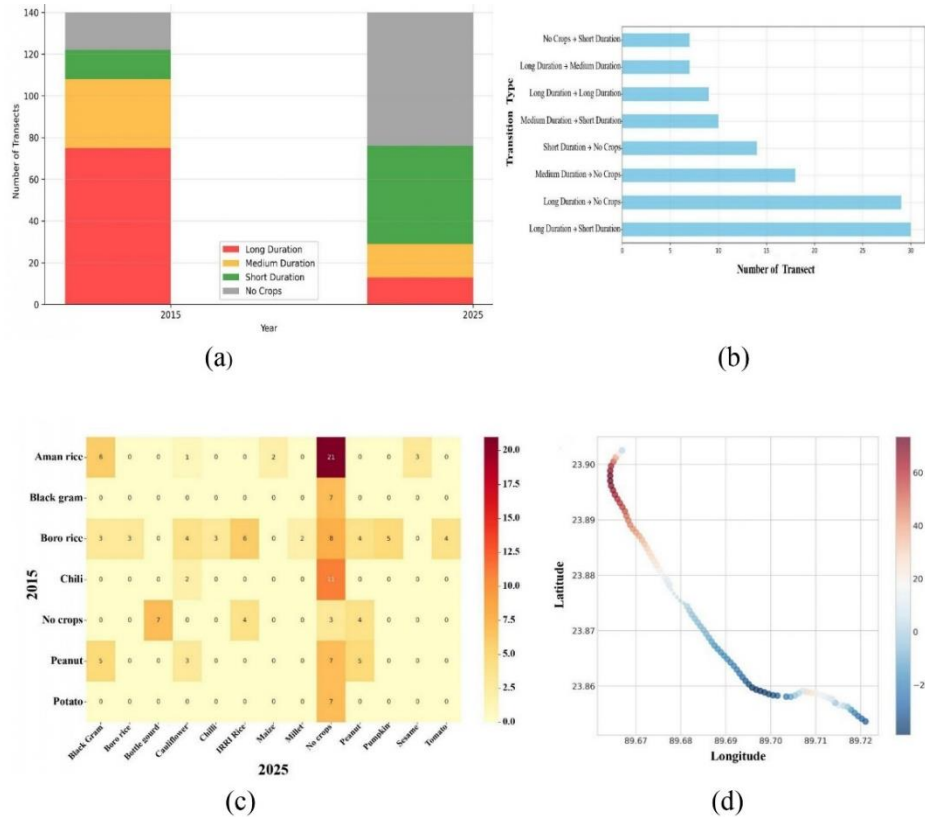


Fig. 4 Illustrates crop dynamics between 2015 and 2025, including (a) Crop duration, (b) Crop transitions, (c) Transition heat map, and (d) Change hotspots.

Source: Compiled by author, 2025.

Through the transition matrix analysis, we examined crop transition and generated a transition heatmap as shown in Fig. 4b which illustrates the most common crop duration transitions. The analysis reveals that the most frequent transitions occurred from long-duration crops to short-duration crops and from long-duration crops to uncultivated land, each recorded in approximately 30 transects. Additionally, medium-duration and short-duration crops often transitioned to uncultivated land, indicating a gradual abandonment of agriculture due to ongoing land instability and erosion pressures. Conversely, a small portion of previously uncultivated land has been reclaimed for short-duration cropping, reflecting localized adaptation efforts by farmers. However, sustained long-duration cropping remains relatively uncommon, as evidenced by the limited number of transitions that stayed within the long-duration category. Besides, the crop transition heatmap for 2015–2025 shows the specific transitions of crop types over the decade within the study

area, with rows representing crop types in 2015 and columns representing crop types in 2025 (fig. 4c). In 2015, *Aman* rice covered several transects, but by 2025, most had transitioned to uncultivated land (no crops, 21 transects), with some shifting to *IRRI* rice or *Boro* rice. Only a small number of transects remained under *Aman* rice, reflecting a sharp decline in long-duration cropping due to erosion and land instability. Black gram plots showed almost complete abandonment, with seven transects transitioning to uncultivated land. *Boro* rice areas exhibited more diverse transitions: while a few remained *Boro* rice (3 transects), others shifted to *IRRI* rice, bottle gourd, millet, pumpkin, or no crops (8 transects), indicating a combination of adaptive strategies and land abandonment. Chili plots largely became uncultivated (11 transects), with only a few remaining as chili (2 transects), highlighting high abandonment rates even for short-duration crops. Previously uncultivated land was occasionally reclaimed for crops such as *Boro* rice, *IRRI* rice, peanut, or potato (4-7 transects), showing limited but targeted adaptation efforts. Peanut areas mostly transitioned to uncultivated land (7 transects) or remained peanut (5 transects), while some were converted to other crops like bottle gourd or cauliflower, indicating partial adaptation amid dominant abandonment. Potato cultivation was entirely lost in the affected transects, with all seven plots shifting to uncultivated land by 2025. The matrix underscores that ongoing erosion prompted widespread agricultural abandonment and localized shifts toward more resilient or opportunistic crops, highlighting a significant disruption of traditional cropping patterns across the region. Fig 4d shows erosion rates vary significantly between the hotspot zones, confirming a strong spatial relationship between high erosion areas and substantial changes in cropping patterns. The northern section of the mapped area exhibits the highest erosion rates, corresponding to more intensive crop system disruptions or land abandonment. The southern section shows predominantly accretion or lower erosion rates, indicating relatively stable or expanding land.

4.0 Conclusion

Riverbank erosion remains one of the most critical environmental challenges in Bangladesh, continuously reshaping landscapes and influencing the livelihoods of river-dependent communities. The integration of field-based socio-economic data, satellite imagery, DSAS modeling, and statistical analyses revealed a strong relationship between riverbank dynamics and shifts in local cropping systems. Erosion and accretion zones indicated a slightly dominant accretion trend from 2015 to 2025. These geomorphic changes have significantly influenced agricultural practices, driving a transition from long-duration crops to short-duration crops and contributing to a noticeable expansion of fallow land. Such transformations reflect the growing challenges of maintaining agricultural sustainability and food security in erosion-prone regions. Overall, the findings highlight the urgent need for integrated land management, erosion control, and livelihood diversification strategies to enhance community resilience. Promoting sustainable crop planning and strengthening community-based adaptation can play a vital role in mitigating the socio-economic impacts of riverbank erosion in Bangladesh's vulnerable char lands.

References

- Abdeen, M., Rayhan, K., Hasan, S., Zishan, N., & Anwar, S. (2023) Study of Erosion and Accretion of Jamuna River Using GIS and Remote Sensing Technology.
- Alam, G. M. (2016). *An assessment of the livelihood vulnerability of the riverbank erosion hazard and its impact on food security for rural households in Bangladesh* (Doctoral dissertation, University of Southern Queensland).
- Ali, A. M. S. (2003). Farmers' knowledge of soils and the sustainability of agriculture in a saline water ecosystem in Southwestern Bangladesh. *Geoderma*, 111(3-4), 333-353.
- Ashraf, M., & Shakir, A. S. (2018). Prediction of river bank erosion and protection works in a reach of Chenab River, Pakistan. *Arabian Journal of Geosciences*, 11(7), 145.
- Baqee, A. H. M. A. "Coping with floods and erosion in Bangladesh charlands." (1997): 38-52.
- Brooks, S. M., & Spencer, T. (2010). Temporal and spatial variations in recession rates and sediment release from soft rock cliffs, Suffolk coast, UK. *Geomorphology*, 124(1-2), 26-41.
- Chicco, D., Sichenze, A., & Jurman, G. (2025). A simple guide to the use of Student's t-test, Mann-Whitney U test, Chi-squared test, and Kruskal-Wallis test in biostatistics. *BioData Mining*, 18(1), 56.
- Crowell, M., Douglas, B. C., & Leatherman, S. P. (1997). On forecasting future US shoreline positions: a test of algorithms. *Journal of Coastal Research*, 1245-1255.
- Dolan, R., Fenster, M. S., & Holme, S. J. (1991). Temporal analysis of shoreline recession and accretion. *Journal of coastal research*, 723-744.
- Faisal, B. R., & Hayakawa, Y. S. (2022). Geomorphological processes and their connectivity in hillslope, fluvial, and coastal areas in Bangladesh: A review. *Progress in Earth and Planetary Science*, 9(1), 41.
- Gardner, C. M., Laryea, K. B., & Unger, P. W. (1999). *Soil physical constraints to plant growth and crop production* (Vol. 11). Rome, Italy: Land and Water Development Division, Food and Agriculture Organization.
- Genz, A. S., Fletcher, C. H., Dunn, R. A., Frazer, L. N., & Rooney, J. J. (2007). The predictive accuracy of shoreline change rate methods and alongshore beach variation on Maui, Hawaii. *Journal of Coastal Research*, 23(1), 87-105.
- Halder, P. G. (2015). *Study of impact on surrounding livelihoods due to riverbank erosion: a case on Shibalaya's Jamuna Bank of Manikganj* (Doctoral dissertation, BRAC University).
- Hasanuzzaman, M., Bera, B., Islam, A., & Shit, P. K. (2023). Estimation and prediction of riverbank erosion and accretion rate using DSAS, BEHI, and REBVI models: evidence from the lower Ganga River in India. *Natural Hazards*, 118(2), 1163-1190.

- Hasanuzzaman, M., Islam, A., Bera, B., & Shit, P. K. (2024). Quantifying the riverbank erosion and accretion rate using DSAS model study from the lower Ganga River, India. *Natural Hazards Research*, 4(4), 550-561.
- Hussain, S. G. (2017). *Identification and Modeling of Suitable Cropping Systems and Patterns for Saline, Drought and Flood Prone Areas of Bangladesh*. Climate Change Unit, Christian Commission for Development in Bangladesh.
- Islam, M. F., & Rashid, A. B. (2011). Riverbank erosion displacees in Bangladesh: need for institutional response and policy intervention. *Bangladesh Journal of Bioethics*, 2(2), 4-19.
- Islam, M. R., & Hossain, D. (2014). Island char resources mobilization (ICRM): changes of livelihoods of vulnerable people in Bangladesh. *Social indicators research*, 117(3), 1033-1054.
- Jana, S. (2020). Micro-level coastal vulnerability assessment in relation to post-Aila landscape alteration at the fragile coastal stretch of the Sagar Island, India. *Regional Studies in Marine Science*, 33, 100908.
- Khallaghi, S., & Pontius Jr, R. G. (2022). Area method compared with Transect method to measure shoreline movement. *Geocarto International*, 37(20), 5963-5984.
- Li, L., Lin, P., Yu, Y., Wang, B., Zhou, T., Liu, L., ... & Qiao, F. (2013). The flexible global ocean-atmosphere-land system model, Grid-point Version 2: FGOALS-g2. *Advances in Atmospheric Sciences*, 30(3), 543-560.
- Manfreda, S., Miglino, D., Saddi, K. C., Jomaa, S., Eltner, A., Perks, M., ... & Rode, M. (2024). Advancing river monitoring using image-based techniques: challenges and opportunities. *Hydrological Sciences Journal*, 69(6), 657-677.
- Pahlowan, E. U., & Hossain, A. T. M. S. (2015). Jamuna River Erosional Hazards, Accretion & Annual Water Discharge—A Remote Sensing & Gis Approach. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 40, 831-835.
- Rahman, M. (2013). Morphological stability of a dredged channel for river training: a case study along the braided Jamuna river.
- Rahman, M. R. (2010). Impact of riverbank erosion hazard in the Jamuna floodplain areas in Bangladesh. *Journal of Science Foundation*, 8(1-2), 55-65.
- Raj, N., Gurugnanam, B., Sudhakar, V., & Francis, P. G. (2019). Estuarine shoreline change analysis along The Ennore river mouth, south east coast of India, using digital shoreline analysis system. *Geodesy and Geodynamics*, 10(3), 205-212.
- Rutten, M., Van Dijk, M., Van Rooij, W., & Hilderink, H. (2014). Land use dynamics, climate change, and food security in Vietnam: a global-to-local modeling approach. *World Development*, 59, 29-46.

- Sarker, M. H., Huque, I., Alam, M., & Koudstaal, R. (2003). Rivers, chars and char dwellers of Bangladesh. *International Journal of River Basin Management*, 1(1), 61-80.
- Sarker, S., & Rahman, M. M. (2016). Trend analysis of bank erosion of Jamuna River and migration impact: A case study on Teota union of Shibhalaya Upazila. *Journal of Bangladesh Institute of Planners*, 81-93.
- Schielen, R. M., & Blom, A. (2017). A gravel-sand bifurcation: a simple model and the stability of the equilibrium states. In *RCEM2017 Back to Italy: 10th Symposium on river coastal and estuarine morphodynamics*.
- Sen, S., Varma, S., & Sahu, B. P. (Eds.). (2022). *The archaeology of early medieval and medieval South Asia: contesting narratives from the Eastern Ganga-Brahmaputra Basin*. Taylor & Francis.
- Sultana, S. (2013). Identification and prediction of suitability of selected climatic parameters on major crops of Bangladesh.
- Thieler, E. R., Himmelstoss, E. A., Zichichi, J. L., & Ergul, A. (2009). *The Digital Shoreline Analysis System (DSAS) version 4.0-an ArcGIS extension for calculating shoreline change* (No. 2008-1278). US Geological Survey.
- Xu, H. (2006). Modification of normalised difference water index (NDWI) to enhance open water features in remotely sensed imagery. *International journal of remote sensing*, 27(14), 3025-3033.