

PREDICTING RIVERBANK STABILITY OF A FLASHY RIVER USING THE ROM AND BANCS MODELS: A CASE STUDY OF THE SURMA RIVER IN SYLHET, BANGLADESH

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ABSTRACT

Riverbank erosion is a persistent geomorphological issue for riverine countries like Bangladesh. The Surma River, located in northeastern Bangladesh, has experienced significant riverbank erosion in recent years, largely attributed to increased upstream flow. In 2024, flash floods along the Surma River submerged around 75% of Sylhet District, particularly Sylhet City, resulting in considerable infrastructure damage and heightening concerns regarding urban expansion. Therefore, this study predicts the stability of the Surma River bank by using the ROM scale assessment (based on soil texture) and the Bank Assessment for Non-point Source Consequences of Sediment (BANCS) model, which combines the Bank Erosion Hazard Index (BEHI) and Near-Bank Stress (NBS) indices. Eighteen locations across four sites in Sylhet City were examined to evaluate site characteristics, including bank height, bankfull height, bank angle and protection, vegetation attributes (e.g., root depth and density), surface, protection, bank material adjustment, and bank material stratification. In addition, soil samples were collected for the laboratory-based geotechnical analysis. Laboratory analysis reveals that riverbank sediments are primarily composed of silt (~60%), suggesting low cohesion and high susceptibility to detachment. The ROM scale assessment yielded values between 3.62 and 48.52, with most values concentrated in the critical erodibility class. The computed BEHI scores, varying from 20.30 to 29.73, suggest a moderate risk of erosion. The NBS ratings indicate a low to moderate erosion propensity, with scores ranging from 1.13 to 1.81. These findings offer valuable insights into the riverbank stability of the Surma River in Sylhet City, which could aid future development and planning, especially for flood risk management.

Keywords: Riverbank erosion, Surma River, Stability prediction, BANCS model, Moderate erosion

1. INTRODUCTION

Riverbank erosion, a fluvial process, involves the removal of sediment from the riverbank and its fall into the river because of the hydraulic action of flowing water. According to Florsheim et al. (2008), this natural process is essential for maintaining sediment supply and facilitating ecological functions of a fluvial system. In a riverine country like Bangladesh, riverbank erosion poses a major challenge, frequently leading to significant damage to infrastructure and permanent loss of valuable agricultural land, which affects the communities that live near the riverbanks. Florsheim et al. (2008) highlight the eco-geomorphological significance of riverbank erosion, arguing it is not solely a destructive perspective; rather, it is a vital element of river dynamics, which controls the eco-geomorphological processes and shapes the fluvial systems.

Although engineering interventions have long been implemented to protect human infrastructure, they unintentionally disrupt the ecological and geomorphological processes. Sediments eroded from the riverbank frequently redeposit within the channel, promoting the formation of features like riffles in areas where the flow velocity is low. As a result, the local hydraulics and sediment transport routes can be altered, potentially impairing channel stability. More generally, riverbank erosion enriches geomorphic diversity by creating erosional landforms through scouring and depositional features through sediment accretion, thus promoting a dynamic equilibrium within riverine environments (Florsheim et al., 2008). On the other hand, construction of dams and barrages on river systems has resulted in sediment entrapment upstream, consequently diminishing downstream sediment flux (Alexander et al., 2012). This reduced downstream sediment supply eventually hampered the delta-building processes by restricting long-term morphological evolution.

The Surma River is an integral part of the Surma-Meghna river system and plays a crucial role in the hydrological and geomorphological processes of northeastern Bangladesh. It originates at the India-Bangladesh border, where the Barak River, which itself originates in the Mao Sangashanga region of Manipur, India, bifurcates into two main branches: the Surma and the Kushiya Rivers (Chowdhury, 2021; Chowdhury & Murshed, 2021). After flowing southward through the Naga-Manipur region of Assam, the Barak River enters Bangladesh and continues through Zakiganj, Kanaighat, Beanibazar, Sylhet Sadar, and South Surma Upazilas. The Surma then splits into two branches: its northern branch flows through Bishwanath and Chhatak in Sunamganj, while its southern branch converges with the Kushiya near Azmiriganj in northeastern Sylhet, near the Kalni River. Further downstream, the Surma and Kushiya merge and form the Meghna River (Chowdhury, 2021; Chowdhury & Murshed, 2021). This river is recognized as one of the country's largest river systems.

Sylhet City, located along the Surma River, is experiencing escalating impacts from riverbank erosion. Erosion is often coupled with sediment deposition and degradation of riparian zones, which eventually poses a persistent risk for both the urban populace and landholders. The collapse of unsupported banks, the instability of embankments, and the gradual retreat of the riverbanks have emerged as significant local issues. Specifically, intense rainfall and recurrent flooding are exacerbating bank failure and embankment damage, making the situation worse and resulting in considerable losses in agricultural production and infrastructure (Tingsanchali & Karim, 2005).

Over the last few decades, approximately 13,000 km of flood and river embankments have been repaired in Bangladesh. However, these earthen embankments and adjacent riverbanks continuously face annual erosion, breaches, and gradual retreat (Ali et al., 2021; Islam & Hossain, 2020). Such erosion contributes to river widening and channel expansion (Adnan et al., 2019). However, these ongoing effects, in turn, contribute to regional stagnation, preventing affected communities from achieving sustainable development. Therefore, scientific studies are needed in this area to develop an appropriate management plan.

However, it is challenging to distinguish between natural streambank erosion and anthropogenically induced erosion due to altered watershed hydrology or sediment loading (Belletti et al., 2015; Lykousis

& Chronis, 1989). The Bank Assessment for Non-point source Consequences of Sediment (BANCS) model is a frequently used method to assess riverbank erosion potential. BANCS predicts streambank erosion rates by combining the Bank Erosion Hazard Index (BEHI), which measures bank erodibility and stability, with Near-Bank Stress (NBS), which represents near-bank shear stress when the stream channel is at bankfull stage (Bigham et al., 2018).

This study uses the BANCS method to assess streambank erosion hazard along a specific section of the Surma River, about 12 km long, between Upashahar and Tukurbazar. The main goal of this research is to provide practical, site-specific guidance for stream management, aiming to reduce ongoing bank erosion in the study area.

2. METHODOLOGY

2.1 Study area and sample collection

To assess riverbank erosion hazard, the entire Surma River reach within Sylhet City was examined in detail. Eighteen sampling stations from four representative sites were taken under study along the Surma River bank, as illustrated in Figure 1. The photographs of the four representative sites: Kanishail, Temukhi, Tukurbazar, and Upashahar are presented in Figure 2. At each sampling station, the wetted depth of the river was measured at 5 m intervals across the channel to obtain representative cross-sections. Soil samples were also collected from the selected stations. Then, geotechnical soil characterization tests, including sieve analysis, hydrometer analysis, compaction testing, and the direct shear test, were carried out to evaluate key geotechnical properties and the textural classification of the collected samples.

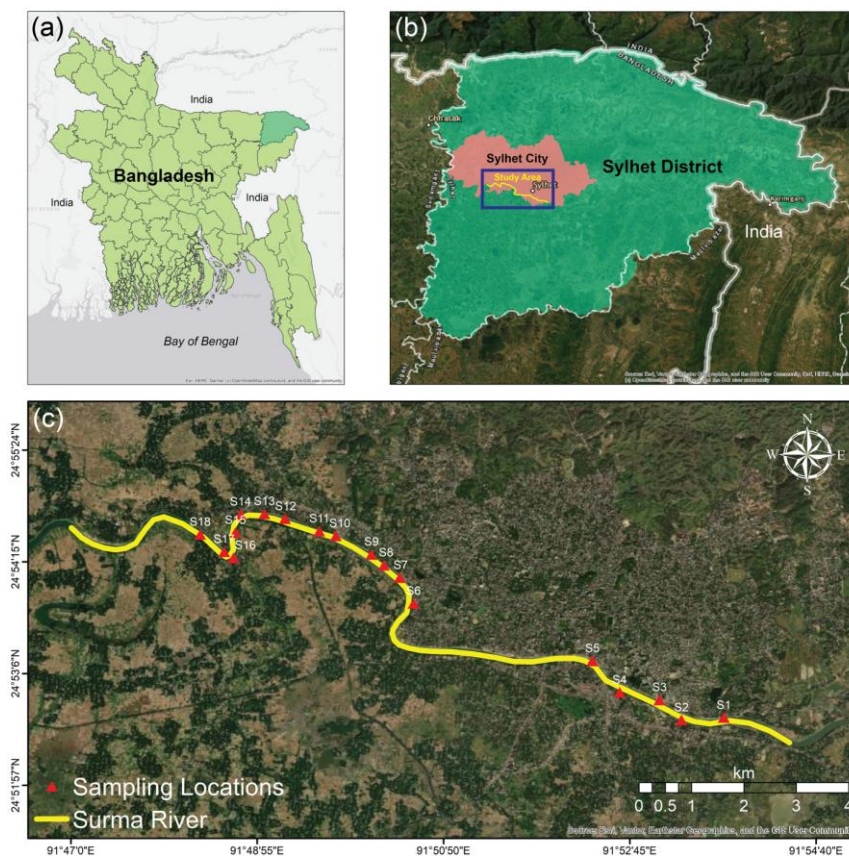


Figure 1: Study area map: (a) Location of the Sylhet District in the northeastern part of Bangladesh, (b) location of Sylhet City within the Sylhet District with the study area indicated by a blue box, and (c) soil sample collection stations along the Surma River in Sylhet City.



Figure 2: Photographs of the soil sample collection sites: (a) Kanishail, (b) Temukhi, (c) Tukerbazar, and (d) Upashahar.

2.2 Soil erodibility

Erodibility denotes the vulnerability to erosion. Soil erodibility is a measure of the soil's capacity for erosion, which can be evaluated using numerous indices. Among these, the advanced and improved soil erodibility index known as the EI_{ROM} (or "ROM") scale was employed in this study. This new equation preserves Bouyoucos' original principle (Bouyoucos, 1962) by evaluating soil texture based on the relative proportions of sand, silt, and clay. The ROM relationship is presented in Eq. (1) following Roslan and Mazidah (2002).

$$EI_{ROM} = \frac{\%Sand + \%Silt}{2(\%Clay)} \quad (1)$$

2.3 Bank erosion potential using BANCS model

BANCS integrates BEHI and NBS for erosion prediction (Bigham et al., 2018). The BEHI, developed by Rosgen (2001), offers a standardized methodology for evaluating streambank conditions and potential risk for erosion and was used in this study. This index incorporates various riverbank characteristics, such as bank height, bankfull height, bank angle and protection, vegetation attributes (e.g., root depth and density), surface, protection, bank material adjustment, and bank material stratification. By assessing the point values for these attributes, BEHI generates a comprehensive score that can be used to assess stream bank conditions across wide areas and prioritize eroding banks for corrective measures (De Rose & Basher, 2011). The modified BEHI erosion potential can be determined after calculation using the BEHI values as shown in Table 1. The level of shear stress at the riverbank by hydraulic action was calculated by NBS rating based on the NBS value shown in Table 2.

Table 1: Bank Erosion Hazard Index (BEHI) ratings values (adopted from Rosgen, 2001).

BEHI category	Value/ score	Bank height/ bankfull height	Root depth/ bank height	Root density (%)	Bank angles (°)	Surface protection (%)	Total Score
Very low	Value	1.0-1.1	1.0-0.9	100-80	0-20	100-80	5-9.5
	Score	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9	
Low	Value	1.1-1.19	0.89-0.5	79-55	21-60	79-55	10-19.5
	Score	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9	
Moderate	Value	1.2-1.59	0.49-0.3	54-30	61-80	54-30	20-29.5
	Score	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9	
High	Value	1.6-2.0	0.29-0.15	29-15	81-90	29-15	30-39.5
	Score	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9	
Very High	Value	2.1-2.8	0.14-0.05	14-5.0	91-119	14-10	40-45
	Score	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0	
Extreme	Value	>2.8	<0.05	<5	<119	<10	46-50
	Score	10	10	10	10	10	

Table 2: Near-Bank Stress (NBS) ratings worksheet (based on Rosgen, 2009).

NBS rating	Radius of curvature/ bankfull width ratio	Pool slope/ average water surface lope ratio	Pool slope/ riffle slope ratio	Near-bank maximum depth/ bankfull mean depth ratio	Near-bank shear stress and bankfull shear stress ratio	Velocity gradient
Very low	>3.00	<0.20	<1.00	<1.00	<0.80	<0.50
Low	2.21–3.00	0.20–0.40	1.00–1.50	1.00–1.50	0.80–1.05	0.50–1.00
Moderate	2.01–2.20	0.41–0.60	1.51–1.80	1.51–1.80	1.06–1.14	1.01–1.60
High	1.81–2.00	0.61–0.80	1.81–1.00	1.81–2.50	1.15–1.19	1.61–2.00
Very high	1.50–1.80	0.81–1.00	1.01–1.20	2.51–3.00	1.20–1.60	2.01–2.40
Extremely high	<1.50	>1.20	>1.20	>3.00	>1.60	>2.40

3. RESULTS AND DISCUSSIONS

3.1 Textural composition of riverbank materials

Table 3 presents the textural composition of soil samples collected from the Kanishail, Temukhi, Tukerbazar, and Upashahar sites. The riverbank materials in the study area are predominantly silty and sandy, with silt contents ranging from 41.79% to 80.81%. Sample-12 demonstrates the highest silt content, whereas Kanishail (Sample-5) exhibits the lowest. Sand content fluctuates between 16% and 55.35%, indicating the existence of coarser zones along the bank, especially in the Kanishail and Tukerbazar sites.

On the other hand, the clay content is relatively low across all samples (1.02%–12.14%), which implies that the bank soil has limited cohesive properties. The soil samples of Kanishail are primarily sandy silt, while the Temukhi soils are predominantly silty and silty loam, with silty sand being the most

common texture in the Tukerbazar samples. This textural composition suggests moderate to high susceptibility to erosion, given that silty soils are more easily detached and transported when subjected to hydraulic stress, in contrast to clayey soils. The substantial presence of silt and a minor contribution of clay content indicate that the Surma River banks are especially vulnerable to erosion caused by fluvial processes and flash floods, thereby influencing the BEHI and NBS ratings derived from the subsequent analysis.

Table 3: Soil textural composition (sand, silt, and clay) of samples collected from the four representative sites.

Sampling sites	Sample	Textural compositions		
		Sand (%)	Silt (%)	Clay (%)
Kanishail	Sample-1	51.06	43.58	5.36
	Sample-2	39.12	54.84	6.04
	Sample-3	41.92	57.06	1.02
	Sample-4	19.26	76.85	3.89
	Sample-5	55.35	41.79	2.86
Temukhi	Sample-6	29.60	68.43	1.97
	Sample-7	20.00	68.16	11.84
	Sample-8	18.00	69.86	12.14
	Sample-9	35.00	63.18	1.82
	Sample-10	31.00	64.66	4.34
Upashahar	Sample-11	25.00	72.15	2.85
	Sample-12	16.00	80.81	3.19
	Sample-13	27.00	70.77	2.23
	Sample-14	30.00	66.85	3.15
	Sample-15	28.00	68.77	3.23
Tukerbazar	Sample-16	42.63	54.78	2.59
	Sample-17	46.79	51.13	2.08
	Sample-18	43.02	54.22	2.76

3.2 Erodibility from the ROM scale assessment

The erodibility of the Surma River banks at the 18 selected locations, based on the ROM scale, is presented in Table 4. The findings reveal substantial spatial variability in erosion potentiality across four sites, with ROM values ranging from 3.62 to 48.52, corresponding to moderate to critical erodibility classes. Das and Deka (2020) investigated riverbank erosion in the lower Brahmaputra floodplain of Assam and reported ROM values between 2.8 and 16. In contrast, within the study region, most locations fall within the critical category, suggesting a high vulnerability of the riverbanks to erosion. In the Kanishail site, ROM values varied from 7.78 to 48.52, with Sample-3 and Sample-5 exhibiting critical conditions, indicative of loose and non-cohesive soil. Temukhi shows considerable erodibility in most samples, particularly Sample-6 and Sample-9, classified as critical. Conversely, Samples-7 and Sample-8 are classified as moderate, likely reflecting minor textural variations attributable to localized depositional processes.

The remaining two sites, Upashahar and Tukerbazar, exhibit critical erosion susceptibility, thus indicating a consistently elevated erosion risk. The dominance of silty soils with low clay content reduces cohesion and compromises the structural integrity of the bank materials in both sites. The

observed elevated ROM values are consistent with the highly erodible soils found along the Surma River's bank, supporting the previously discussed dominance of silty composition. Overall, these findings suggest that inherent soil erodibility plays a crucial role in bank failure at this scale, increasing susceptibility to erosion during hydrodynamic events, including high-flow conditions and flooding.

Table 4: Erosion potential of the collected samples according to the ROM scale.

Sampling sites	Sample	El _{ROM}	Erodibility class
Kanishail	Sample-1	8.38	Very high
	Sample-2	7.78	High
	Sample-3	48.52	Critical
	Sample-4	11.45	Very high
	Sample-5	17.35	Critical
Temukhi	Sample-6	24.88	Critical
	Sample-7	3.72	Moderate
	Sample-8	3.62	Moderate
	Sample-9	26.97	Critical
	Sample-10	11.02	Very high
Upashahar	Sample-11	17.04	Critical
	Sample-12	15.17	Critical
	Sample-13	21.92	Critical
	Sample-14	15.37	Critical
	Sample-15	14.98	Critical
Tukerbazar	Sample-16	18.81	Critical
	Sample-17	23.54	Critical
	Sample-18	17.62	Critical

3.3 BANCS scale assessment by BEHI and NBS indices

Analysis of the BEHI and NBS ratings suggests that the Surma River banks exhibit moderate potential for erosion across the sampling locations (Table 5). BEHI scores range from 20.29 to 29.73, signifying a relatively consistent moderate erosion hazard. This consistency implies that, although the bank materials are not extremely weak, they are sufficiently unstable to erode under moderate hydraulic forcing. Majumdar and Mandal (2020) evaluated BEHI and NBS values for the Pagla and Ganga Rivers in West Bengal and reported BEHI scores of 26–31 and NBS ratings of 1.2–1.9. Similarly, the NBS rating observed in the Surma River demonstrates variability, ranging from 1.13 to 1.81, thereby indicating low to high erosion potential. Sample-5 (Kanishail) exhibited the highest NBS value of 1.81, suggesting a localized area of increased hydraulic stress, probably due to flow concentration and channel curvature. Conversely, Sample-14 shows the lowest NBS value (1.13), which suggests a relatively stable bank section with minimal shear effects from the flow. Overall, most evaluated locations exhibit low to moderate NBS ratings, implying an inconsistent and uneven distribution of hydraulic energy along the riverbank.

The combined analysis of BEHI and NBS data suggests that bank erosion along the Surma River is influenced by both geotechnical and hydraulic factors. While most parts of the study area show moderate susceptibility, certain segments experience heightened erosion pressure. Consequently, this pattern highlights the need for site-specific management strategies, particularly in areas with high NBS and moderate BEHI values, with the aim of reducing outward lateral bank retreat and promoting long-term riverbank stability.

Table 5: BEHI scores and NBS ratings, and their erosion potentiality at 18 sampling locations.

Sampling Sites	Sample	BEHI score	Erosion potential	NBS rating	Erosion potential
Kanishail	Sample-1	20.29	Moderate	1.71	Moderate
	Sample-2	20.30	Moderate	1.56	Low
	Sample-3	21.07	Moderate	1.51	Moderate
	Sample-4	27.90	Moderate	1.34	Low
	Sample-5	22.37	Moderate	1.81	High
Temukhi	Sample-6	20.50	Moderate	1.19	Low
	Sample-7	22.30	Moderate	1.46	Low
	Sample-8	21.70	Moderate	1.49	Low
	Sample-9	23.10	Moderate	1.36	Low
	Sample-10	24.60	Moderate	1.50	Moderate
Upashahar	Sample-11	25.10	Moderate	1.48	Moderate
	Sample-12	29.30	Moderate	1.28	Low
	Sample-13	22.63	Moderate	1.62	Moderate
	Sample-14	24.90	Moderate	1.13	Low
	Sample-15	23.70	Moderate	1.24	Low
Tukerbazar	Sample-16	29.73	Moderate	1.64	Moderate
	Sample-17	28.64	Moderate	1.64	Moderate
	Sample-18	28.39	Moderate	1.64	Moderate

4. CONCLUSIONS

This investigation evaluated the riverbank stability of the Surma River banks in Sylhet City using the ROM soil erodibility scale (based on soil texture) together with the BANCS framework, which integrates the bank stability indicators (BEHI and NBS). The principal findings lead to the following conclusions:

- The riverbank soils are primarily silty, with silt contents spanning from 41.79% to 81.81%, sand content between 16% and 55.35%, and clay contents ranging from 1.02% to 12.14%. These characteristics indicate that the soils are mainly the non-cohesive type and susceptible to erosion. Locations with high silt and low clay content, including Upashahar (80.81% silt, 3.19% clay) and Kanishail (76.85% silt, 3.89% clay), demonstrated the greatest vulnerability to erosion.
- The ROM index exhibited considerable variability, ranging from 3.62 to 48.52. Upashahar and Tukerbazar consistently fell within critical erosion categories ($EI_{ROM} = 17.62-23.54$). Kanishail displayed localized extreme values, peaking at 48.52, while Temukhi's EI_{ROM} values are comparatively moderate and fluctuating between 3.62 and 26.97.
- BEHI values spanned from 20.29 to 29.73, thereby suggesting a moderate erosion potential. NBS ratings, ranging from 1.13 to 1.81, indicated low to moderate hydraulic stress, with only Sample-5 classified as high (NBS=1.81).
- The combined indices reveal that critical erosion zones are correlated with high silt and low clay soils, implying that textural composition is the principal determinant of the Surma River banks' instability.

In summary, the study reveals moderate to critical erosion potential along the Surma River, with Upashahar and Tukurbazar identified as the most susceptible zones, requiring immediate bank stabilization and sediment management strategies.

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DECLARATION OF USE OF AI

The language of the manuscript was corrected using Grammarly (AI based grammar correction tool). Later, the revised manuscript was checked with Turnitin software for identifying plagiarism and/or similarities.

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