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A Case Study of Rahmatkhali Riverbank Erosion: Comparison Among Riparian Management, Coir Logs and Geo Bags

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Abstract
Riverbank erosion is a global concern. Due to its geological position, Bangladesh is particularly more vulnerable to this issue. The techniques for riverbank protection in Bangladesh heavily rely on physical infrastructure-based solutions. In addition to posing a threat to dwellings, riverbank erosion also endangers hydraulic structures. The bank line of Rahmatkhali River in Lakshmipur Sadar Upazila along the Rahmatkhali regulator has been facing significant erosion for the last few decades. This erosion has put the Rahmatkhali regulator at a high risk of becoming unserviceable subsequently. The geospatial analysis on LULC using Google Earth data and Landsat multi-temporal image data over two decades shows that there is a change in vegetation and a major shift in bank line of the study area. Thus, a case study has been done comparing three riverbank protection methods: riparian management, coir logs and geo-bags for the study area. Riparian management is a natural protection method using riparian vegetation to stabilize stream banks. Coir logs made of coconut fiber, and synthetic bags, filled with sand, called geo-bags are also natural erosion control devices used to stabilize and protect stream-banks. In contrast to the study area, the report presents a discussion in favor of riparian management as a more practical and sustainable approach as compared to the other two methods.

Keywords: *Riverbank erosion; Geospatial analysis; Riparian management; Coir logs; Geo bags*

1 Introduction

Riverbank erosion affects millions of people by causing damage and loss to valuable crops, animals' habitats, housing, and farms every year. Since Bangladesh is located in one of the largest river deltas of the world, riverbank erosion is among the most drastic environmental disasters in terms of yearly damage. About 283 locations with around 2400 kilometers of riverbank line in Bangladesh are at risk of riverbank erosion (Islam and Rashid, 2012), which results in the loss of approximately 8700 hectares of land each year, affecting around 200,000 people by damaging their homes and/or agricultural land (Freihardt & Frey, 2023). The unpredictable bank-line shifting not only affects the rural floodplain population but also erodes significant hydraulic structures. Rahmatkhali regulator, located near Moju Chowdhury Hat in Lakshmipur Upazila, is one of those structures that are at a high risk due to bank-line shifting. A vast area of the bank of the Rahmatkhali River is eroding fast. However, there are ways to discern an explanation and protect the bank line. The most common techniques are channelization, sediment trapping, and bank stabilization. The first two are mostly structural solutions. Some of the most used structural protections in Bangladesh are groynes, spurs, revetments, guide bunds, etc (Sarker et al., 2011). Yet we need to establish a more effective and resilient solution that will help to stabilize and strengthen the riverbank. Riparian buffers, geotextile bags, coir logs are some of the options that are being adapted in riverbank protection. While geo bags and coir logs have been demonstrated in Asian countries like Bangladesh and India, riparian management is already an established solution for riverbank protection in countries with some of the world's largest river basins like the USA, Canada, Australia, and Brazil (Pedraza et al., 2021). Hence, the paper focuses on estimating the bank-line shifting and analyzing the erosion accretion of the study area with the help of GIS. Riparian management is helpful to protect the riverbank and combat the perennial and intermittent streams (Verry et al., 1999). Our objective is to assess the vegetation rate based on the Normalized Difference Vegetation Index (NDVI) analysis.

This will guide us to demonstrate a case study on how riparian buffer can be more cost-effective and resilient than using geo bags or coir logs as a sustainable riverbank protection solution.

2 Study Area and Methodology

2.1 Study Area

The river of our concern is Rahmatkhali River, which is situated in Lakshmipur Sadar, Bangladesh. The study area is 3.54 sq.km, of which Rahmatkhali River covers approximately 0.38 sq.km. The river in the study area is separated into two sections. One is upstream of the Rahmatkhali regulator; the other is downstream of it, which meets the Meghna River further downstream. The upstream of the river to the regulator is the main point of our interest, which covers around 0.22 sq.km of our study area. The bank lines are of around 2 km and were portrayed on Google Earth Pro during dry period, December to March.

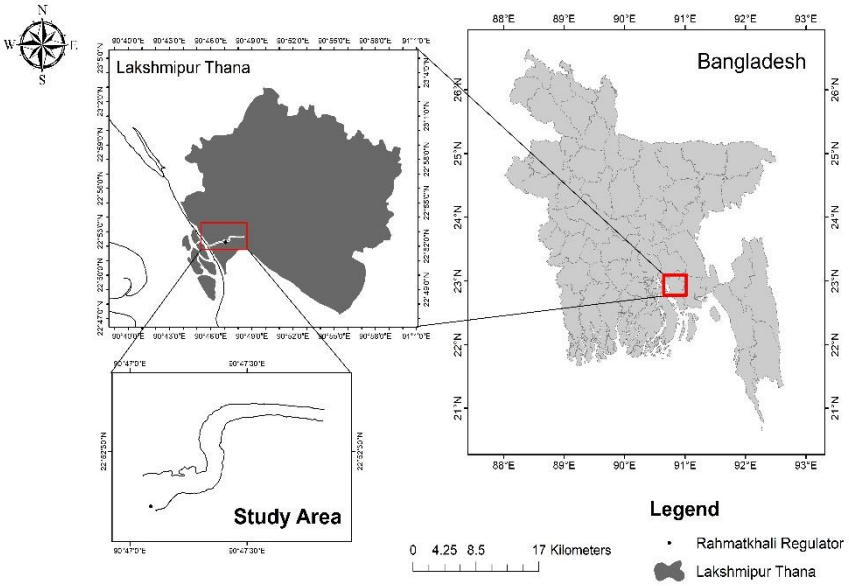

Figure 1. Study Area

2.2 Data Collection and Software used

For this study Landsat-8 and Landsat-5 data are used which are collected from U.S. Geological Survey (USGS) earth explorer. The analysis of the changes has been completed with Google Earth Pro and GIS

2.3 Erosion-Accretion Analysis

In order to execute long-term and short-term analysis on erosion-accretion, the illustration was done on Google Earth Pro from 2006 to 2022 on the Rahmatkhali River up to Rahmatkhali regulator. The coordinate system on the study area was WGS 1984 UTM Zone 46N.

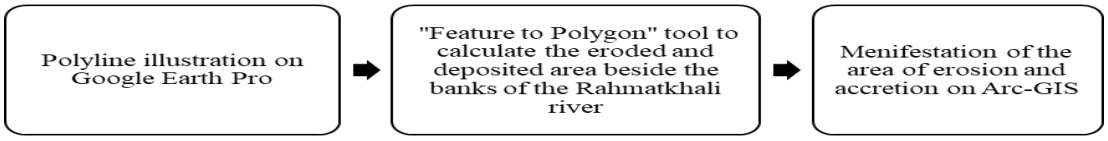

Figure 2. Long-term analysis

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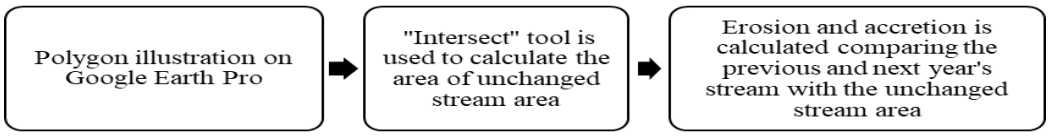

Figure 3. Short-term analysis

2.4 NDVI Analysis

All of the remotely sensed data used in this study to calculate the NDVI of the study area coordinated as (22°53'26.80"N,90°49'9.40"E),(22°52'43.95"N,90°46'50.53"E),(22°51'49.63"N,90°47'13.01"E),(22°52'14.35"N, 90°49'18.03"E) were obtained from the U.S. Geological Survey (USGS). The data used in this project spans 16 years and has a resolution of 30 m and 30 m. After calculating NDVI, areas of vegetation (by percentage) are compared in Figure 6.

Figure 4. NDVI Analysis

2.5 Site Observation and Field Survey

The preliminary observation of the site gave significant ideas about the unprotected right bank on the upstream of the regulator, which has been eroding for years. The riverbank shows signs of erosion along its edges. There are visible signs of soil slumping and undercutting. The exposed sections of the bank exhibit bare soil, indicating the lack of stabilization measures. There are different ranges of trees. Some dominant tree species are Betel Nut, Coconut and other abundant fruit trees, which are mainly seasonal fruits. The trees appear to be of varying ages and sizes, creating a somewhat uneven canopy cover.

It is crucial to take an immediate approach by introducing the erosion control measures among the native people. Feasibility checks with comprehensive analysis and development of an appropriate management plan have been discussed here further.

Figure 5. Site Observation on May 2023

3 Result and Discussion

3.1 Short-term and Long-term Analysis of Erosion-Accretion

The short-term & long-term bank shifting and erosion-accretion for Rahmatkhali River are calculated for a time-period from 2006 to 2022. The analysis is illustrated in Figure 7. The highest erosion is found to be about 7 hectares on right bank towards the Rahmatkhali regulator. On the Char Ramani Mohan near the regulator, the bank shifted from the left to right due to huge accretion rate on the left bank as well as erosion on right bank during these years as shown in the Figure 8. Bangladesh being a riverine country faces erosion-accretion & bank line shifting significantly. The negative impact of riverbank erosion is severe as it causes significant damages to infrastructures and inhabitants as (Halima & Maria, 2021) showed. The results of this study showed that if not taken measures near the Rahmatkhali regulator on the Char Ramani Mohan, it might face severe outcome as the morphology of the channel is changing gradually.

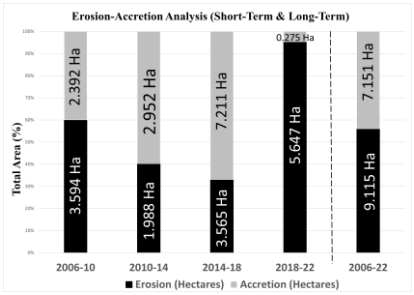

Figure 6. Short-term & Long-term NDVI Analysis

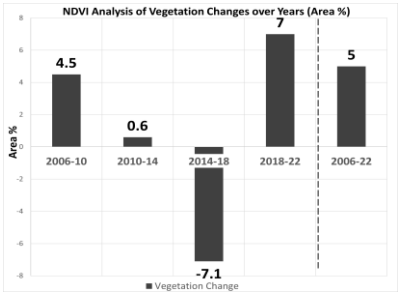

Figure 7. Short-term & Long-term Erosion analysis

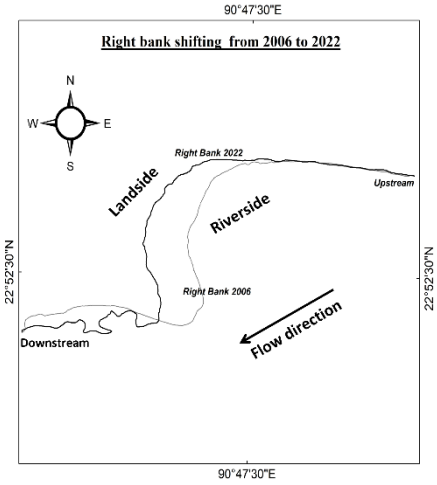

Figure 8. Right Bank shifting

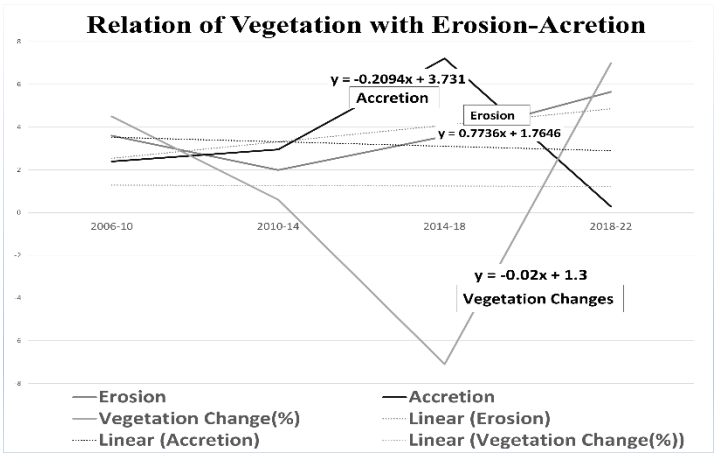

Figure 9. Relation of Vegetation with Erosion-Accretion

3.2 Vegetation Analysis

From the normalized time series of vegetation and erosion-accretion plotted over 2006 to 2022 (Figure 9), the trend lines of accretion and vegetation shows a slight downward slope indicating a decline in accretion correlates with the decline of vegetation. Simultaneously, as erosion increases, vegetation shows a decline.

3.3 Feasibility Check: Coir Logs

Coir logs are made of 100% natural interlaced coconut fibers held together with biodegradable netting. The coir logs are placed at the edge of the bank secured by wooden pegs, usually on alternate sides of the logs. The length of each coir log does not exceed 3-4 meters, which is around 10 feet (Santha, 2006). The logs can be used as single row or staked (Morris et al., 2008). These logs can also be molded and adjusted to conform to the contour of the bank-line. Coir logs present themselves as a valuable natural solution due to the abundant availability of coconut fibers in Lakshmipur, which serves as a prominent hub for coconut husk trading (Miah et al, 2005). As coir logs naturally decompose in the environment, there is no need for manual demolition of the remnants.

To determine whether coir logs are appropriate for the Rahmatkhali riverbank, factors such as proper assessments of the site and the framework for restoration needs to be considered. Since the logs are biodegradable, these have a relatively short lifespan, typically ranging from 2 to 4 years, depending on the moisture conditions. The moisture content varies from 10% to 12% at 65% humidity and 22% to 55% at 95% humidity. The greatest retaining strength is observed during the dry season (Pillai & Vasudev, 2001). Therefore, the longevity of these logs depends on the weather conditions. As a result, the area needs a regular installation and maintenance for its restoration. Coir logs have a low buoyant weight, which lacks stability unless appropriately anchored. However, coir logs can never be a permanent solution in terms of susceptibility.

3.4 Feasibility Check: Geo Bags

Geo bags, woven/ non-woven geotextile sand containers, are filled with locally available sand and stitched manually on site to form a bag. Given the fineness of the locally available sand, the most suitable geotextile material is non-woven (Oberhagemann & Hossain, 2011). The design formula for the establishment of geo bags is primarily focused on withstanding the vertically-averaged velocity, without considering the local shear stresses acting on the bag. This approach is based on the understanding that, for braided rivers, such as the study area, depth averaged velocities cannot accurately describe the shear stresses acting on the bags. It has been observed from geo-bag installation in the Brahmaputra, that geo bags are installed in one to three layers with a combination of 78 kg and 126 kg bags, depending on the scale of the riverbank (Oberhagemann & Hossain, 2011). While the bags are initially soft, the sand undergoes a consolidation process over several months, leading to a hard as concrete texture (Oberhagemann & Hossain, 2011). Although geo-bags are an economic option, for this approach, they are not sustainable. Geo bags are indeed susceptible to physical damage if they are left exposed to direct solar radiation in open air for extended periods. It appears that the use of UV-stabilized polypropylene, as opposed to regular polypropylene staple fiber, in geo bags is not widespread in Bangladesh. This will add an extra manufacturing cost, which is relatively insignificant when compared to the extended lifespan of the installation. When sand-filled geo bags are deposited solely underwater or covered with sand after placement along riverbanks, they have the potential to endure for a considerable period, ranging from 10 to 50 years whereas if the bags are left exposed in the open air or partially exposed to both air and water, their lifespan is significantly reduced, often lasting no more than two

years. It is a common practice in Bangladesh to dump geo bags in the sun. Dumping of geo bags in a haphazard manner can also compromise the stability and cause failure. The field survey conducted at various working sites has identified several failure modes associated with geo-bags. Some of those failure modes are sliding, partial filling, overtopping, unstitching, washing out, improper dumping and others (Hossain & Hasan, 2016). The woven bags from Bangladeshi jute also cannot be adapted because the absorption capacity of the subcontinental jute-geo bags is 2.75. These stay damp for several days following absorption, which will eventually the bank protection vulnerable even in dry weather condition (Islam et al., 2013). Apparently, geo bags are cost efficient but they lack durability over time.

3.5 Feasibility Check: Riparian Management

Riparian management is the practice of vegetation in a three-dimensional organized approach within the interface between terrestrial environment and aquatic environment. It has been promoted as an effective method of bank stability and to restore stream ecosystem. The effects of vegetation can be differentiated into two categories: mechanical effects, which pertain to physical actions, and hydrologic effects, which relate to water cycle processes. While soil exhibits strength under compression, it tends to be weak under tension. On the other hand, the fibrous roots of trees and herbaceous species are resilient under tension but lack strength under compression. Consequently, when roots infiltrate soil, it forms a composite material that possesses enhanced strength. There is a nonlinear, inverse correlation between root diameter and strength, which means that smaller roots provide a higher level of strength per unit of root area. Apart from the stabilizing impact resulting from root reinforcement, vegetation enhances bank stability through two additional mechanisms. Firstly, it intercepts rainfall that would have otherwise infiltrated into the bank, and secondly, it extracts soil moisture for transpiration (Simon & Collison, 2002). Moreover, riparian vegetation management holds significant value for biodiversity and ecosystem processes. Establishment of broadleaved species and increased tree size variation would aid the process of ecosystem functioning of the riparian zone as well as develop a more stable riverbank protection structure for the future. The creation of these openings, while ensuring the preservation of the surrounding vegetation, contributes to the provision of shade to streams and riparian zones (Hasselquist et al., 2021). Given the correlation between vegetation and Erosion-Accretion analysis, riparian management emerges as the best choice for riverbank protection.

3.6 Implementation Requirements for Riparian Management:

Zoned buffer strips, comprising separate areas of trees and grassy or herbaceous vegetation, are most effective riparian buffer management in safeguarding small-scale riverbanks. The buffer zones consist of native plants and grasses. Clearly defined zones of grass and trees are expected to yield better results compared to a buffer where the two components are mixed together (Cole et al., 2000).

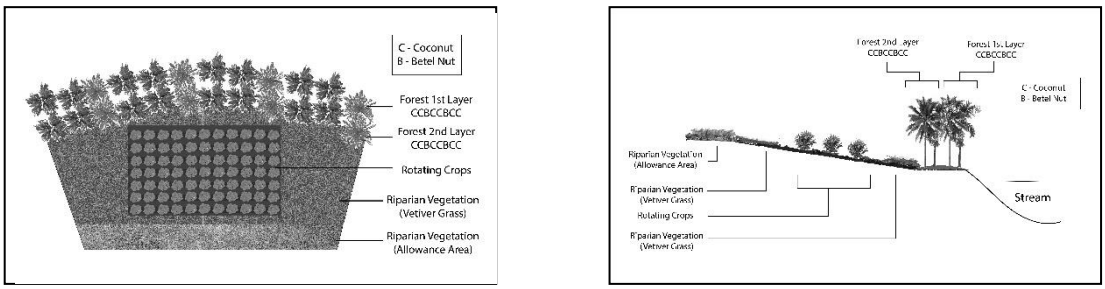

Figure 10. Framework of Riparian Management

For the study area, the recommended approach includes three distinct vegetation zones, which are:

- Zone-1: A narrow strip of permanent Betel Nut and Coconut trees in two or three layers in an order mentioned in the Figure, immediately adjacent to the watercourse to stabilize riverbanks and to provide inputs to freshwater systems. This is the nearest zone from the riverbank.
- Zone-2: A wider zone of native rotating crops such as potatoes, chilies, and other cash crops that may be cropped to generate additional income. Furthermore, incorporating Vetiver grasses along the boundaries is a cost-effective option, especially in tropical countries like India and Bangladesh (Islam et al., 2013). This specific zone serves the purpose of nutrient filtration and offers stability to steep slopes.
- Zone-3: A narrow zone of dense grass, or functionally similar vegetation. This zone plays a crucial role in assimilating nutrients and binding dissolved pesticides, ensuring their effective management and minimizing their impact on the stream. This is the farthest zone from the stream.

4 Conclusion

Rahmatkhali regulator has been in threat for many years due to rapid bank line shifting in this region. To combat the shifting, implementation of Choir logs, Geo-bags and Riparian management have been taken into consideration. Implementation of choir logs proved unfeasible due to its short service life and Geo-bags showed critical failures. Meanwhile from the relation of erosion-accretion with vegetation gives a positive nudge towards the success of Riparian Management to combat bank line shifting in this area.
Implementing Riparian Management can be a pivotal asset for local agriculture, in addition to safeguarding the Rahmatkhali regulator. This study is directed towards local governments and engineers, with the goal of shielding the regulator and the community's assets from the impacts of riverbank erosion.

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