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# A Review on Sustainable River Training Strategies in Bangladesh

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## Abstract

Rivers play an important part in Bangladesh's socioeconomic and ecological fabric. The country has significant issues connected to riverbank erosion, floods, and sedimentation due to its enormous river network. River training techniques emerge as key interventions in this setting for successfully managing and mitigating these difficulties. River training encompasses a variety of strategies aimed at managing river behavior, preserving ideal channel alignments, and safeguarding sensitive locations. The purpose of this research paper is to investigate and underline the relevance of river training in Bangladesh. It dives into several aspects of river training, such as erosion control, flood management, sediment transport, and ecological stability. The research investigates the role of various sustainable interventions used in river training. This study aims to add to the understanding of efficient river management techniques in Bangladesh by assessing the significance of river training. It underlines the need for holistic approaches that take into account ecological sustainability, community resilience, and long-term socioeconomic growth. The main findings of this paper show that in terms of its low cost, long lifespan & environmental friendliness may be a soft bio-engineering method such as vetiver along geo-jute as an alternative to rigid or hard structures is the most sustainable approach among all. The research findings can help politicians, engineers, and environmental practitioners participating in river training projects make more informed decisions and promote sustainable river management practices.

***Keywords:*** *Bio-engineering; River Training; Slope protection; Vetiver; Sustainable management*

## 1 Introduction

In this paper we review studies on sustainable river training strategies in Bangladesh. Figure 1 illustrate the overall framework of this paper. In section 2, it introduces all the eco-friendly defense strategies that can frequently use, section 3 presents overall discussion about all the eco-friendly strategies indicating pros and cons and finally section 4 indicates the conclusion about the overall study work. In the section 1, we cover the introduction part and the overall use and novelty of this paper.

Bangladesh, a country with many rivers and a vast coastline, is prone to natural calamities because of its unusual geographical position. As the first line of defense against cyclonic storm surges and floods, embankments, river banks, and other hydraulic structures sustain the most damage. Most of the land is inundated for 4 to 6 months of the year, which loosens the earthen slopes and causes erosion. The following are the primary reasons for river bank erosion: (1) low water levels flow during the dry season (causes siltation on the river bed); (2) high flow during the wet season (causes bank erosion). (3) Alluvial soil (prone to erosion); and (4) concentrated flow of water towards the bank (Das et al., 2014). The preservation of appropriate slopes is one of the key maintenance difficulties of rural roads, bridge approaches, and embankments in Bangladesh (Islam, 2019). Engineers play important roles in poverty alleviation in many ways, e.g. by designing, planning, and implementing infrastructures. It was critical to recognize that no structure is ever completely fixed in this morphologically evolving world. Bangladesh has fought for years to protect itself from the threat of an ever-expanding river corridor (Oberhagemann et al., 2020). It is extremely difficult to build cost-effective and sustainable infrastructure alongside these massive waterways due to a variety of factors. River training has been practiced in Bangladesh since the 1960s although

the process is quite expensive. BWDB has built 1695 flood control structures, 4310 km of drainage canals, and 5695 km of embankments, including 3433 km in coastal areas (Zaman et al., 2016). Because they are the first line of defense against storm waves and floods, river banks, embankments, and other hydraulic structures suffer the most damage. Hence, safeguarding these embankments is essential (Schroeder, 2014). Mattress along the bank line, revetment with boulders or concrete, permeable spurs, guide bunds, palisade fences, gravel drains, masonry walls, geo-bags other slope protection techniques are currently in use (Shrestha et al., 2012). Unfortunately, state funding for embankment protection in Bangladesh is insufficient, limiting rigid structural protection measures to only the most severe portions and failing to cover the entire length of the river bank or shoreline and embankment (Islam, 2019). The plantation of vegetation, which is widely accepted soft bio-engineering method such as vetiver along geo-jute as an alternative to rigid or hard structures (Islam et al., 2013) with this method The authors of this study hope to add accurate knowledge about various river training tactics, as well as make recommendations regarding the most eco-friendly and sustainable strategies for dealing with a critical problem like riverbank erosion, both in traditional and low-cost approaches. So that a developing country like Bangladesh may afford it and make the best use of this technology. Because of its economic effectiveness and sustainability, it can be used by the government as well as locally, which can substantially minimize losses.

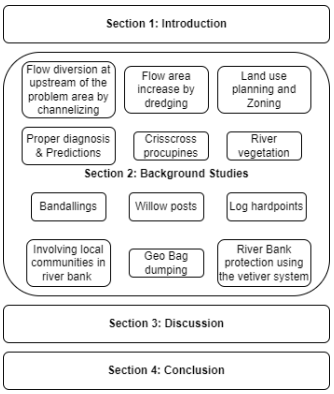


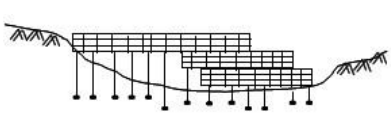

Figure 1. The Structure of this paper

## 2 Background Studies

The bank protection measures have been classified as structural, non-structural, and biological measures but Sustainable river training refers to environmentally friendly and socially responsible practices to manage and modify rivers in a way that maintains their natural functions, enhances their ecological health, and minimizes negative impacts on surrounding ecosystems and human communities. It involves the use of various techniques and approaches to shape, control, and manage rivers while considering the long-term sustainability of the riverine environment. Bioengineering approaches use live vegetation and natural materials to stabilize riverbanks and reduce erosion, replicating natural processes to produce resilient ecosystems and the most sustainable. By strengthening the bank with plant roots, these strategies absorb water energy and diminish erosive pressures, assuring long-term stability. Furthermore, bioengineering fosters biodiversity, provides habitat possibilities, improves water quality, and improves the river system's ecological health. The following defense strategies are frequently used:

### 2.1 Crisscross porcupines

Crisscross is a river training technique that involves the strategic placement of wooden or concrete structures resembling porcupine quills in a crisscross pattern. Figure 2 shows these structures dissipate the energy of the flowing water, enhance sediment deposition, and promote channel stability by redirecting the flow and reducing erosion risks.



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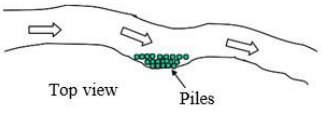


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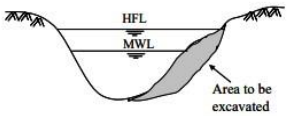


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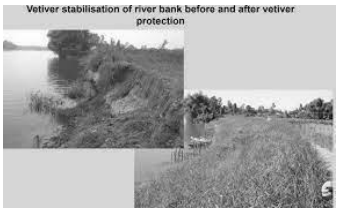
Figure 2. Crisscross porcupines (Islam, 2008), Figure 3. Willow posts (Islam, 2011), Figure 4. Flow area increase by dredging. (Islam, 2008)

### 2.2 Willow posts

Through the methodical construction of posts to support eroding banks, this approach controls stream bank erosion. It reduces the speed of the floodwater near and on the eroding bank. Figure 3 shows In order to stop bank erosion and restore riparian zones, huge willow cuttings (10 to 30 cm dia; 2 to 4 m long) have been planted extensively in the United States. Along the stream bank, from the water's edge landward, willow posts are positioned using 3-5 rows that are roughly spaced 1 m apart. (Watson et al., 1997; Shields et al., 1995).

**2.3 River Bank Protection using the vetiver system**

A perennial grass called vetiver grows two meters high and three meters below the surface of the earth. It has a robust, vertical root system that is thick and powerful (Hengchaovanich and Nilaweera, 1996). It may grow in both xerophytic and hydrophilic environments. Each blade of the leaves, which emerge from the base of the clumps, is long, thin, and gritty. The leaf is 6 to 12 cm in diameter and 45 to 100 cm long. Whether they are primary, secondary, or fibrous roots, they all extend vertically deep into the earth rather than horizontally. The vetiver grass system has a maximum horizontal extension of 50 cm. There are several uses for vetiver grass, including the rehabilitation of mine dumps, slope stability, wind and water barriers, seepage management, cow feed, essential oil, and fragrance manufacturing, fabric for rope and clothing, and water treatment (Roongtanakiat et al., 2007). Vetiver grass is an ancient plant that originated in South India. V. nigritana and V. nemoralis are similar species that originated in Africa and Southeast Asia, respectively. These species lack all of the properties of Vetiveria zizanioides and should not be used as the foundation of vetiver grass technology (Grimshaw, 2006). Bangladesh is in an ideal position in this regard since it has an enormous supply of vetiver and it is a labor-demanding approach. Locals are using this strategy without understanding which grass species to use. Until 2008, just a few studies on vetiver had been undertaken in Bangladesh. Vetiver is widely accessible in Bangladesh. Vetiveria zizanioides is the most ideal species for vetiver systems for slope protection and other possible uses. It has been discovered that vetiver thrives in both sandy and clayey soils, as well as saline and polluted soil. It has also been demonstrated that vetiver can grow in several geographical zones of Bangladesh. This implies that vetiver has a high potential for usage in slope protection and land reclamation in Bangladesh. In the haor districts, the village island slope is well preserved by vetiver grass sown in the holes of CC blocks. The soil anchoring and block nailing technology used for embankment protection should be vetiver grass based. The use of vetiver in conjunction with geo-jute was proven to be beneficial in providing land protection in river bank erosion-prone areas of the country's northern districts. Figure 5 shows the drastic changes of river bank before and after vetiver protection.

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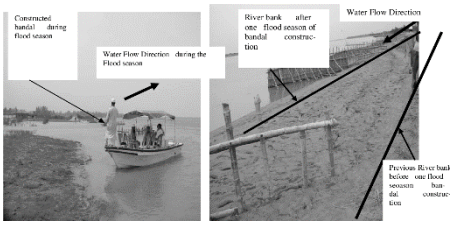



(6)

Figure 5. River Bank Protection using the vetiver system (Vetiver.org), Figure 6. Stabilization of river bank with the aid of bamboo bandalling structures. (Rahman, L., & Osman, S. (2011)).

**2.4 Bandallings**

Figure 6 shows this technique used in river training, involves the strategic placement of large rocks or boulders along the riverbank to dissipate water energy and prevent erosion. This practice stabilizes the riverbank, maintains the desired channel alignment, and redirects the flow of water. Additionally, it promotes the formation of secondary currents, facilitating natural sediment deposition and creating valuable habitats for aquatic organisms. This phenomenon plays a crucial role in preserving ecological balance and improving the overall health of the river ecosystem.

**2.5 Bank vegetation**

It plays a crucial role in river training as it acts as a natural barrier, safeguarding against erosion by mitigating the impact of flowing water. The roots of these plants firmly bind the soil, ensuring the stability and integrity of the riverbank. Additionally, bank vegetation effectively regulates sediment transport by slowing down water flow, allowing sediment particles to settle and minimizing deposition in the river channel.

**2.6 Log hardpoints**

They are made up of log bundles that are 20 meters long and sunk 10 meters into the bank. To prevent scour, around 25 tons of stones are put around the toe of the structure. (Shofiul, 2008). It strategically placed along riverbanks can help prevent erosion by absorbing the energy of flowing water and can act as a barrier that slows down the water's velocity and minimizes the impact on the riverbanks.

**2.7 Flow area increase by dredging**
It is done in the channel's shallow areas to expand the flow area and decrease flow velocity. (Shofiul, 2008). Figure 4 shows the mechanism of this process.

**2.8 Flow diversion at upstream of the problem area by channelizing**
Dredging via pass channels re-channelizes the issue area's upstream approach, and flow is managed in the midstream channel. By directing water away from the problematic zone, this technique helps reduce erosion, minimize flood risks, and protect infrastructure. It enables controlled water flow, preventing further damage.

**2.9 Geo bag dumping**
Geo bags are strong, breathable containers that are filled with dirt or sand and used to protect riverbanks from erosion and level slopes. These bags offer a versatile and sustainable solution that maintains structural integrity while allowing for plant growth. Geo bags are inexpensive, simple to deploy, and efficient in halting bank erosion. Figure 7(a) shows how Geo bag dumping can be use for river training and 7(b) shows failure problems of geobag revetment. This figure was taken for field study in Jamuna River.


(a) (b)

Figure 7. (a) Geo Bag Dumping for river training (b) Failure in geobag revetment (1 = pullout; 2 = slump; 3 = dislodgement of top bag; 4 = slide; 5 = physically damaged) (Akter, A., et al., 2009)

**2.10 Land-use Planning and Zoning**
Proper land-use planning and zoning restrictions are critical for preventing encroachment and ensuring that human settlements and infrastructure are positioned safely away from the river. This helps to lessen the danger of riverbank erosion and flooding.

**2.11 Involving local communities in river bank**
Preservation efforts develop a sense of ownership and responsibility. River conservation is made more important by awareness campaigns and education initiatives, which promote sustainable behaviors.

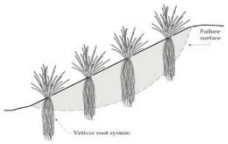
**2.12 Proper Diagnosis & Predictions**
In river training, proper diagnosis and prediction are critical for recognizing instability reasons, making educated decisions, and limiting hazards. Through precise evaluation and long-term planning, they enable focused interventions, vulnerability assessment, and cost-effective resource allocation, enabling sustainable riverbank management and protection.

**3 Discussion**
In an emergency, geo-bags, require very little time from sand filling to dumping. The largest sand-filled geo-bags provide 1.3 times as much volume and 4.5 times as much surface area protection per unit of cost as the largest CC blocks, depending on both volume and land surface covering. From an economic standpoint, sand-filled geo-bags outperform CC blocks (Hossain, M. M. and Hasan, M. Z. 2016). If geo-bags are dropped outside where they may be directly struck by sun radiation, they will become physically destroyed in a matter of days. Geo-bags loaded with sand can endure for 10 to 50 years if they are solely dropped under water or covered with sand after being placed on river banks, but if they are thrown in the open or partially submerged in both water and air, they may only live for two years. Geo-bag dumping in the heat and rain is a widespread practice in our nation. Geo-bags are exposed to the open air even though they were submerged during the monsoon when the water levels in the rivers decrease. Additionally, it is impractical to cover the geo-bags with sand after setting them on the level field, which reduces their lifespan. Geo-bags are anticipated to perform significantly better than CC blocks in all regards if it is possible to ensure that they are shielded from sun radiation or only dropped under water (Chen, G. Li. Y. and Tang, X. 2008). But geo-bags, have a danger of physical damage, being washed out, unstitching, or individual settling.

Due to the expense of building materials and labor, methods including crisscross constructions, wooden piling, and log hardpoints may have greater initial prices. However, over time, their long-term advantages, such as stability and erosion management, may make them cost-effective. Bank vegetation and willow posts may be reasonably inexpensive and have a number of ecological advantages. Flow area expansion by dredging and flow diversion techniques can be expensive depending on the degree of channelization or dredging needed. In the long term, zoning and land-use planning can save money by reducing the potential harm from unsuitable growth. These approaches' durability is affected by a variety of elements, including the project's size, quality of materials, maintenance procedures, and local hydrological conditions. If built using sturdy materials and kept up properly, some techniques, such as crisscross constructions, wooden piling, and log hardpoints, can last for a very long time. To preserve the long-term survival of willow posts and the vegetation along banks, constant inspection and maintenance are necessary. If correctly planned and performed, flow area augmentation through dredging and flow diversion techniques can have long-lasting impacts.

The Local Government Engineering Department (LGED) discovered through a vetiver grass trial study that vetiver grass plantation was successful in safeguarding the road slope for more than 100 years. Because of its unique properties, several nations are successfully adopting naturally growing vetiver grass (Vetiveria zizanioides L. Nash) to preserve embankment slopes and river banks (Truong et al., 2002; Grimshaw, 2006; Man et al., 2011). For improved performance, regular maintenance is necessary. Compared to other systems, the vetiver system is less expensive and more environmentally friendly. This approach may be used without the need for specialized tools or laborers with particular training. However, this system has to be maintained on a regular basis. When compared to other, traditional slope protection options, the vetiver system is 10 to 15 times less expensive vetiver grass and geo-jute are much less expensive as a means of protecting slopes. In- situ, shear test reveals that, the shear strength and effective soil cohesion of vetiver rooted soil matrix are respectively 2.0 times and 2.1 times higher than that of bared soil (Zaman et al., (2016)). It has been shown that vetiver plantations boost the slope's stability by 50%. Finally, it may be claimed that geo-jute and vetiver grass plantations are economical and Bangladesh needs a long-term, environmentally friendly solution to prevent rain-cut erosion on its slopes. It can grow in any sort of soil, including sands, shales, gravels, and even soils that are poisonous to metal, independent of its fertility, pH, or salinity. It can grow in a variety of climates and is known to do so in regions with temperatures ranging from -9 to +50 degrees Celsius and average annual rainfall between 200 and 6,000 millimeters. It is a climax plant, thus it will survive even if drought, flood, pests, disease, fire, or other hardship kills all surrounding plants and shields the land from the next set of rainfall. So it can be said that it is the most sustainable for river training. On the other hand, plant protection of soil is a low-cost option that can safeguard the slope for a long time. It also helps to reduce soil erosion and recharge subsurface water. The chosen geo-jute has a water retention capacity of 375% of its dry weight. It helps to keep soil moisture from evaporating throughout the dry season. As a result, it promotes the growth of plants. However, during the rainy season, it aids in the prevention of soil erosion. It also aids in the growth of plants. Geo-jute is helpful in growing vetiver throughout the year. The vetiver roots' rapid, Figure 8(a) shows and vast development forcefully binds the soil. Its roots are also quite strong. According to estimates, planting vetiver grass along a slope will decrease erosion and boost safety by 50%. It also enhances groundwater recharge, reduces water pollution, lowers the risk of floods, and increases economic advantages to the communities. Rainfall-runoff is conserved to the tune of 4.70 x 105 mm3/m2. Long-lasting protection for the slope can be achieved with vetiver. To improve the effectiveness of the vetiver system, regular maintenance is necessary (Islam, 2013). It is also not a grass that is used for grazing. It is a sustainable type of plant. It has roots and lengthy leaves. High tensile strength allows its roots to securely grasp the earth. On the exposed surface, geo-jute is spread with vetiver, which principally aids in reducing soil erosion. As a result, it can be claimed that using vegetation, such as vetiver, with or without geo-jute is a viable solution for protecting slopes in Bangladesh. So with the help of all the discussions, we have we can tell Figure 8(a) shows the most sustainable and cost-effective approach in terms of river training strategies in Bangladesh.

8(a)



8(b)

Figure 8: (a) Just after planting the vetiver grass along with Jute Geo-Textile (JGT) (b) Cross section of vetiver grass on the embankment showing large root depth. (Zaman et al., (2016)).

**4 Conclusion**

Bangladesh is prone to flooding and erosion, making sustainable river training essential for mitigating risks, preserving ecosystems, and ensuring the well-being of local communities. Our review demonstrated Different sustainable strategies in terms of river training across the world. Briefly, the findings can be stated as-

- Traditional soil erosion control measures include wood revetments, geotextiles, geo bag dumping, and other strategies which are motioned here that are costly and, in some situations, ineffective. Geo-bag revetment can be failed due to washing out of bank materials and bag tearing. Failure can occur due to improper dumping, or unstitching geo-bags. Much more costly and needs more maintenance than the vetiver system.
- Given Bangladesh's existing socioeconomic conditions, vetiver grass planting and the deployment of jute geotextile (JGT) in embankment slopes are decided to be the optimum techniques for improving embankment solidarity.
- Vetiver grass with Geo Jute, the application of this technology doesn't require any specialized tools or highly trained personnel. It is highly resilient to climate change and most cost effective and sustainable in terms of Bangladesh.

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