APPLICATION OF VETIVER (VETIVERIA ZIZANIIOIDES) AS A BIO-TECHNICAL SLOPE PROTECTION MEASURE – SOME SUCCESS STORIES IN BANGLADESH

Mohammad Shariful Islam

Professor, Department of Civil Engineering
Bangladesh University of Engineering and Technology (BUET), Dhaka-1000, Bangladesh
E-mail: msharifulislam@ce.buet.ac.bd, msharifulbd@gmail.com

Abstract

Bangladesh, a country of many rivers and a very long coastline, is frequented by natural disasters due to its unique geological location. As the embankments, river banks and other hydraulic structures act as the first line of defense against natural disasters like cyclonic storm surges and floods, they experience the most severe damage. Protection of embankments is, therefore, of paramount importance. The cost of protecting embankments is high, and the national budget for such works is never sufficient which confines rigid structural protection measures to the most acute sections, never to the full length of coastline and embankment. Many countries are effectively using naturally grown vetiver grass (Vetiveria zizanioides L. Nash) to protect embankment slopes. But unfortunately, only a few researches were carried out in Bangladesh for evaluating the effectiveness of vetiver plant in slope protection. To this context, laboratory studies, numerical analyses and field trials have been conducted to evaluate the effectiveness of vetiver plant in slope protection. It has been found that vetiver is available in almost all the parts of Bangladesh. The available vetiver species is Vetiveria zizanioides. Local vetiver can grow in silt and clayey soils. Vetiver is also found to grow in heavy metal contaminated soil and saline soil. Vetiver is found to be effective in uptaking heavy metals and removing salinity. A device has been developed to determine in-situ shear strength of the vetiver rooted soil matrix. It is found that vetiver root enhances the shear strength and deformation capacity significantly. Direct shear tests conducted on reconstituted samples showed that soil samples containing 9% root have maximum strength and deformation capacity. Both analytical and finite element analyses showed that vetiver plantation increases the factor of safety of slope stability significantly. Vetiver roots enhance the bearing capacity of both the dense and loose grounds. Field trials conducted in three different geographic locations (coastal zone, flood plain and Barind Tract zone) has shown that vetiver plantation is effective in slope protection against rain-cut and wind-induced erosion. It was also proven that vetiver grass can grow in different soil and geographic conditions of Bangladesh. Success in field trials has given confidence to the local people and government agencies in the country. Large-scale field trials are being undertaken with the cooperation of Government agencies and NGOs for extending and popularizing the use of vetiver in Bangladesh.

Keywords: Erosion, geo-jute, heavy metal, slope stability, salinity

1. Introduction

Bangladesh is frequented by natural disasters due to its unique geological location. The geological formation of the country, a low lying delta formed by recent deposits in the flood plains of the Ganges-Brahmaputra-Meghna river system, with hundreds of
tributaries, distributaries and water bodies, pose a big challenge for construction and maintenance of road and embankments. River bank and Haor island erosion as well as coastal and road embankment failure happens continuously throughout the country. Embankments, river banks and other hydraulic structures act as the first line of defense against storm surges and floods. Protection of embankments is, therefore, of paramount importance. The cost of remediating these problems is high, and the national budget for such works is never sufficient which confines rigid structural protection measures to the most acute sections, never to the full length of coastline and embankment. For example, cyclone ‘Sidr 2007’ affected 2,290 km of embankment in 15 districts. Total damages were estimated to be US$71 million by the Bangladesh Water Development Board. The damages to the polder infrastructure in the worst affected districts was estimated at US$40 million, which is about 58% of the total amount (DMB, 2008).

Current practices of slope protection are: mattressing along the bank line, revetment either by boulders or concrete, permeable spurs, guide bunds, palisade fences, gravel drains, masonry walls, geo-bags, etc. These are expensive and in many cases not effective to protect the embankments during their design life (Islam et al., 2010). Photographs in Figure 1 present damage of embankment and costly protection measures of embankments using concrete blocks and geo-textiles. Tree plantation is a cost effective and environment friendly method to protect embankment. But due to high wind and storm surge during cyclones, trees are either uprooted or fall down cutting off the transportation system of affected areas and boost the sufferings of the affected peoples.

Many countries are effectively using naturally grown vetiver grass (Vetiveria zizanioides L. Nash) to protect embankment slopes and river banks for its special attributes (Troung, 2000; Truong et al., 2002; Grimshaw, 2006; Man et al., 2011). Vetiver grass is an ancient grass with its center of origin in south India. Other related species such as V. nigriflava and V. nemoralis have origins in Africa and Southeast Asia, respectively. These species do not have all the characteristics of V. zizanioides and are not recommended as a base component of vetiver grass technology (Grimshaw, 2006). To this context, Bangladesh is in an advantageous position as it has an abundant supply of vetiver as well as it is a labor intensive technique. However, local people are practicing this method without following the correct grass planting technique.

So far a few researches were conducted on vetiver in Bangladesh. These are mainly related to vetiver availability and potential uses of vetiver (Rahman et al., 1996; Uddin, 2000; Islam, 2000; Thomas et al., 2002; Huq, 2006; Islam et al., 2008; Bhuiyan et al., 2008). Moula and Rahman (2008) investigated the optimum number of tillers per clump for the proper propagation of vetiver grass. It was revealed that propagation of vetiver clump with double tillers is optimum. Moula and Rahman (2009) presented the seed germination potential of vetiver grass. Their study revealed that the seed of a wild variety of Vetiveria zizanioides L. Nash is one of the potential methods for its propagation. These initial studies recommended field trials for investigating the efficacy in slope protection and erosion control.

Thomas et al. (2002) presented the trials of vetiver grass on 28 km of embankment project built on the Kangsha River in Netrokona District under Dampara Water Management Project (DWMP) in 2000. DWMP demonstration sites proved that the vetiver grass provides outstanding protection against erosion while also being a sustainable supply of fodder and thatch. Islam (2003) presented the use of vetiver in controlling water borne erosion with particular reference to Bangladesh coastal region through Coastal Embankment Rehabilitation Project (CERP). Vetiver was introduced in
18 coastal polders and 87 km of earthen embankments where half a million vetiver tillers were planted from 1999 to 2003. Vetiver was also planted in different types of low-cost toe-protection trials. Success was achieved where initial protection and watering could be ensured. Human and animal interferences, seasonal variations in soil moisture content, sea water level variation, salinity, threat of washing away by cyclones or tidal surges were found as limiting factors.

He suggested that a systematic approach is required to make others understand the importance of the vetiver grass technology and a gradual expansion of the system to solve the problem of erosion. He commenced the Bangladesh Vetiver Network in July 2003.

Although several studies such as CERP have made a breakthrough introducing half a million tillers in the field in disseminating the importance of vetiver grass technology to government officials, NGO workers, and grassroot level communities, there is still a long way to proceed for Vetiver System (VS) to be adopted by government agencies in Bangladesh. With more research and development, vetiver grass can play a very important role in slope protection and poverty alleviation in Bangladesh.

Interest for vetiver grass technology in Bangladesh increased significantly in recent times. Although, some studies have been conducted in this area, there is no integrated approach to study on vetiver. The author feels that systematic scientific study is necessary for developing the vetiver system and confidence of the policymakers. Research is needed to be undertaken in institutes like Bangladesh University of Engineering and Technology which has multi-disciplinary arrangement/laboratory facilities and faculties including geotechnical, structural, environmental, transportation, water resources engineering, as well as flood management and disaster research institutes. Institutional research which will involve the faculties (who are involved in decision making of different projects of Bangladesh) and students (future leaders) with the collaboration of implementing agencies (both government and NGO) are required for sustainable development of the technology.

It was felt necessary to focus on the following issues: (1) exploration of vetiver availability and growth characteristics of vetiver in Bangladesh, (2) properties of local vetiver (leaf, shoot and root), (3) determination of safety of vetiver grass protected slope, (4) field trials for determining the efficacy under different soil (saline, non-saline, contaminated soil) and geographic condition (flood plain and coastal zone), (5) heavy metal extraction from industrial waste contaminated soil, (6) salinity removal and (7) dissemination of the technology to local people, academia, engineers, NGOs, government agencies and policymakers.

A few studies have been conducted by the author on the performance of vetiver system in slope protection, phytoremediation of heavy metals, salinity removal, earth wall
stabilization, etc. since 2008. Research findings are presented in different international journals and conferences held in Bangladesh, Japan, Malaysia, South Korea and USA. Vetiver availability in Bangladesh, shear strength of vetiver rooted soil and the cost of the vetiver system were presented in Islam and Arifuzzaman (2010), Islam et al. (2010), Islam et al. (2011), and Islam et al. (2013a). Factor of safety of vetiver planted slope was presented in Islam et al. (2013b). Effect of vetiver root in bearing capacity and stability of the slopes estimated by numerical analyses was presented in Islam and Hossain (2013). Growth characteristics of vetiver root and shoot, efficacy of vetiver (with and without geojute) in protecting road embankment slope in flood plain and pond bank slope protection in Barind Tract was presented in Islam et al. (2013b and 2013c). Effectiveness of vetiver in salinity removal, growth characteristics of vetiver in saline zone, efficacy in shrimp farm dykes protection in coastal zone was presented in Islam et al. (2013c and 2014).

This paper summarizes the findings of previous laboratory tests, field tests, numerical analyses and field trials conducted by the author during the last 5 years in collaboration with partners at home and abroad. Recent findings, ongoing research activities and future research plan on vetiver are also discussed.

2. Researches Conducted in the Current Study

Study was conducted in different geographic locations of Bangladesh. Figure 2 represents the locations of the selected areas for studying different parameters. Vetiver species were collected from Kuakata (coastal zone), Pubail (flood prone area), Haor area (lowland) and
Porsha (drought and earthquake prone zone). In-situ shear tests were conducted in Kuakata and Pubail. For studying the phytoremediation of heavy metals using vetiver, contaminated soil was collected from Buriganga River in Dhaka (flood prone area). Field trials were conducted in Keraniganj (flood prone area), Godagari (Barind Tract zone), Kaliganj, Nildumur, Baliapur, and Bashkahl, Satkhira (saline zone, marked on the map as ‘Satkhira saline zone study area’). Earth wall stabilization was conducted in Porsha. Extended field trials are ongoing in 12 districts of coastal area (marked on the map as ‘CCRIP study area’) and 5 districts of Haor area (marked on the map as ‘Haor study area’).

2.1 Vetiver availability in Bangladesh

In the current study, field survey was undertaken to explore the vetiver availability and for identifying vetiver type in Bangladesh. Vetiver grass was collected from different places such as flood plain (Pubail), coastal region (Kuakata) and Haor area. Bangladesh has an abundant supply of vetiver grass. It is commonly found in almost all the districts of Bangladesh as also stated by Rahman et al. (1996) and Thomas et al. (2002). Thomas et al. (2002) mapped available places of vetiver in Bangladesh and they found that vetiver grass is available in 85% of the total land. Figures 3a, 3b and 3c present naturally grown vetiver grass in Kuakata, Pubail and Haor area, respectively. Soil of Kuakata and Haor area is silty sand (SM) while the soil of Pubail is silty clay (CL). It means that vetiver can grow in both types of soils. The massive root system of the vetiver found in Pubail is presented in the Figure 3b. Root length of one year old vetiver was found to be 1.5 m. Countrywide study is yet to be done to have a clear profile of availability and uses of vetiver.

![Line of vetiver grass used by local people for village protection](image)

**Figure 3.** Local vetiver: (a) Kuakata (coastal zone), (b) Pubail (flood plain) and (c) vetiver in Haor area (low land) (Hoque, 2013)
2.2 Growth characteristics of the local vetiver in different soils

Growth characteristics of local vetiver were studied in the ground of BUET premises with a heavy metal contaminated soil collected from the Buriganga River bed and a saline soil. Findings of this study are described below.

A comparative study on the growth of vetiver collected from different sources has been conducted at BUET premises (silty clay) during the period January-June 2014. Growth of local vetiver (from Pubail) was compared with that of vetiver collected from Assam, India and Thailand. It took 2-3 months to grow green leaves of the grasses after plantation. It was found that among the planted vetiver grasses, the vetiver collected from Pubail grew best. Photos 4a-4c in Figure 4 show the vetiver planted at BUET premises. It is interesting to note that vetiver has been found to grow even in a concrete dumping yard full of concrete debris resting on reinforced concrete pavement. The vetiver plant, grown without any ground contact, essentially demonstrates that vetiver can grow and survive even in very harsh conditions.

![Figure 4. Comparative study on the growth of vetiver (Vetiveria zizanioides) at BUET premises: (a) local vetiver from Pubail, Gazipur District, (b) vetiver from Assam, India, (c) vetiver from Thailand and (d) vetiver plant grown in concrete dump yard at BUET campus.](image)

The capital city Dhaka stands on the bank of Buriganga River. The bank of this river is the center of many economic activities, which includes numerous industries (e.g. textile, tannery, machine shops, etc.), a busy river port and other commercial enterprises. Lack of legislative action and awareness has resulted in the discharge of heavy pollution loads from city’s industrial units and dumping from combined sewer lines containing a huge volume of toxic wastes directly into the river from these riverside establishments without any prior treatment. Of all the chemical pollutants, heavy metals, being non-biodegradable, can be concentrated in the food chain and they can impart toxic effects at distant points far away from the point of generation. Vetiver was planted in tubs in contaminated soil collected from the bank and bed of Buriganga River. Liquid limit and plasticity index of the soil are 46% and 23%, respectively. Silt and clay content of the soil was 92% and 8%, respectively. Heavy metal concentration of the soil was found to be Pb = 23-47 mg/kg, Cr = 116-167 mg/kg, Cu = 33-44 mg/kg, Ni = 23.1 mg/kg, Zn = 120-455 mg/kg. Small clumps of vetiver that have been separated out and had the tops and roots trimmed were planted in the tubs from December 2013 to November 2014 (Fig. 5a). It was found that local vetiver can grow in industrial waste contaminated soil (Fig. 5b). Roots and shoots grew 150 cm and 39 cm, respectively, in 49 weeks. The results of heavy metal extraction tests by atomic absorption spectrophotometer (AAS) flame on vetiver samples
showed that both vetiver roots and shoots consumed Pb, Cr, Cu, Ni and Zn as also described by Roongtanakiat and Chairoj (2000). Extensive studies are being conducted to investigate the effectiveness of vetiver plants in heavy metal uptake from industrial waste contaminated soil in comparison with locally available Indian mustard (Brassica juncea) and marigold (Tagetes patula).

Even though Bangladesh is a small country, it has 750 km long coast. Fifty-three percent of the coastal areas are affected by salinity which causes unfavorable situations that restrict the crop production and vegetation throughout the year. It is important to investigate whether the vetiver grass grow in saline soil as indicated by Rahman et al. (1996). To this context, vetiver grass was planted in alluvial soil ($G_s = 2.49$, sand = 84%, silt = 4%, clay = 12%) in clay pots of the size of 250 mm in diameter and 200 mm in depth. The plantation was done in the dry season from December 2013 to April 2014. Average relative humidity was 42-50% and rainfall occurred hardly two or three times during this period. After 5 months of regular watering on alternate days, these grasses grew well, having a root length of about 1.0 m. Thus grown vetiver was then replanted in saline soil ($EC = 4.8$ to 12.5 $ds/m$). It was found that vetiver grass survived and further grew in the saline soil (Fig. 5c). However, the higher the salinity, the lower the vetiver growth was observed. Vetiver was also found effective in salinity removal as also stated by Truong (2002). The detail of the salinity removal was presented in Islam et al. (2014).

2.3 Strength of vetiver-rooted soil

For proper stability analysis of embankments slope protected by vetiver grass, it is essential to know the strength of the vetiver-rooted soil matrix (soil permeated with vetiver root). Despite extensive use of vetiver in slope protection, very few quantitative studies (Hengchaovanich and Nilaweera, 1996; Mickovski and Van Beek, 2009) were carried out to determine the shear strength of vetiver-rooted soil. Using the new device developed (Fig. 6a) in this research, in-situ shear strength of the vetiver-rooted soil matrix has been determined in two regions of Bangladesh (coastal and flood plain regions, Fig. 2). Laboratory direct shear tests have also been conducted on reconstituted unreinforced and vetiver-rooted soil samples having the density and moisture content similar to that of the field conditions (Figs. 6b and 6c). Detail of sample preparation, test method and results are presented in Islam et al. (2010) and Islam et al. (2013a). In-situ shear strength has been compared with that of the reconstituted samples. Failure pattern of both rooted soil and unrooted soil is presented in Figure 7. Shear stress vs horizontal deformation graph is presented in Figure 8. In spite of low root depth, direct in-situ shear tests showed that vetiver root enhances the shear strength and deformation capacity significantly. Similar results were reported by Mickovski and Van Beek (2009). Laboratory tests on reconstituted soil samples (Fig. 6c) showed that both the average cohesion and angle of internal friction of vetiver root mixed soil samples are higher than those of the
unreinforced soil samples. Consequently, the peak shear stress of rooted soil is higher than that of the unreinforced soil which confirms high potentiality of the vetiver-rooted soil in the case of absorbing disturbing forces than that of the unreinforced soil. The 9% rooted soil sample produces higher peak shear stress than that of the 6% and 12% rooted samples. It means that root content in the soil mix has a significant effect on the strength. Tests are being conducted to compare the strength of vetiver-rooted soil with that of rooted soil of other plants.

Figure 6. (a) Test set-up for in-situ shear test, (b) vetiver root mixed soil and (c) reconstituted soil sample prepared with vetiver root

Figure 7. Failure plane of (a) unreinforced block sample, and (b) vetiver-rooted block sample

Figure 8. (a) Shear stress vs. horizontal deformation graph for the block sample from coastal zone (Kuakata) and (b) shear stress vs. horizontal deformation graph for the block sample from flood zone (Pubail) (\(w_n\) = natural moisture content; D = test depth from existing ground level; \(\sigma_n\) = applied normal stress; FRBS = field rooted block soil samples; FUBS = field unreinforced block soil samples)
2.4 Slope stability analyses

**Analytical method:** Bishop method was used to estimate the stability of the bare slope. Stability of the vetiver planted slopes was estimated by the method described by Coppin and Richards (1990) using the parameters obtained from the laboratory and field tests. Analyses showed that factor of safety of bare slope and rooted slope are 1.66 and 2.90.

**Finite Element method:** The effectiveness of vetiver root on the stability of slopes and bearing capacity of the reinforced ground is evaluated by finite element analyses using elastoplastic subloading $t_{ij}$ model (Nakai and Hinoko, 2004) with the cooperation from Nagoya Institute of Technology, Japan. Figure 9a shows the finite element mesh used for the analysis and Figure 9b shows the displacement vectors of the Pubail soil with reinforcement. It is revealed from field tests that the shear strength of vetiver-rooted soil matrix is higher than that of the unreinforced soil. The reinforced soil with vetiver root also shows ductile behavior. The numerical analyses simulate the results of the in-situ shear tests very well. Effectiveness of vetiver root in geotechnical structures—strip foundation and embankment slope has been evaluated by finite element analyses. It is found that the reinforcement with vetiver root enhances the bearing capacities of the grounds and stabilizes the embankment slopes. Detailed analyses are available in Islam and Hossain (2013). The reinforcement with vetiver roots enhances the bearing capacities for both dense and loose grounds. Even in sandy ground (Kuakata soils) the vetiver roots significantly increase the bearing capacity of the ground. During flooding (rising water level), the displacement of the ground is curbed in the reinforced ground where reinforcing is done with vetiver roots, because the reinforcement restricts the lateral flow of the slope ground (Fig. 9b). Reinforcement with vetiver roots causes a significant reinforcing effect in the Pubail and Kuakata grounds. The vetiver root enhances the bearing capacities of the grounds and stabilizes the embankment slopes. Hence, from the FE analyses it is also revealed that vetiver plantation can be a low-cost, eco-friendly and sustainable technology for embankment protection.

**Figure 9.** (a) Finite element mesh for slope stability analyses, and (b) displacement vectors of Pubail soil with reinforcement (unit in m)

2.5 Field trials

Field trials were undertaken in three different geographic locations of Bangladesh to investigate the efficacy of vetiver plants in protecting the slopes against erosion. These trials were also useful in disseminating the technology to the local people, NGOs and government agencies. Vetiver installation guidelines for planting vetiver along the road side for flood plain and dykes for coastal zone have been prepared.
2.5.1 Road embankment in the flood plain

Road embankment construction is a big challenge due to the scarcity of suitable soil from nearby green fields which are used mainly as agricultural land. Nowadays, dredge fill soil is mainly used. But such soil is silty sand which is easily erodible by rainfall and wave action. A 100 m stretch of mild sloped road side of a District Road under Roads and Highways Department (RHD) at Keraniganj near Dhaka (Fig. 2) was selected for the study. The stretch is near the bridge approach which needed to be repaired every year as it was damaged by heavy rainfall. RHD and Jute Diversification Promotion Centre (JDPC) cooperated in the field trial. A total of 40,000 vetiver tillers collected from Pubail, 40 km away from the site, were used. Before planting, geo-jute (700 gsm) was laid on the slope. The photograph in the Figure 10 shows the road side before and after vetiver plantation. Performance was found satisfactory during the first rainy season while subsidence occurred in front of the retaining wall in the other side due to heavy rainfall. Officials of Local Government Engineering Department (LGED), RHD and JDPC visited the site on 21st September 2012 and they were satisfied with the performance. It is found that the vetiver grass plantation with geo-jute laying costs only US$1.45/sqm, which is 1/5th of the cost of masonry wall construction. Plantation of vetiver along with the use of geo-jute can be a cost-effective, sustainable and eco-friendly method for erosion control of slopes. It is observed that shoots and roots grew up to 170 cm and 55 cm, respectively, in one year. The growth of roots is smaller than that of other places. A similar result was also reported by Islam (2003).

![Figure 10. Keraniganj site: (a) before vetiver plantation, (b) vetiver planted at the slope, and (c) grown vetiver after 10 months](image)

2.5.2 Pond slope protection in the Barind Tract zone

![Figure 11. Pond bank stabilization in Godagari: (a) pond condition before vetiver application, (b) pond condition after vetiver application, and (c) grown vetiver plant at the site](image)
A field trial was made to protect a pond slope from erosion in the Barind Tract zone in Godagari, Rajshahi (Fig. 2). The periphery of the pond was about 122 m. The pond is used for bathing and household purposes. There was almost no vegetation around the side slope of the pond except some banana trees (Fig. 11a). The side slope’s soil of the pond was highly erodible. In the rainy season, the top soil washes away by runoff which causes the pond water to be muddy. In the dry season, the top soil is blown away from the bank by the wind. Vetiver grass was planted on three sides of the pond bank in June 2010 and the growth of its roots and shoots was monitored until November 2010. At first cow-dung was mixed with the bank soil. Vetiver slips were collected from a road side in Shirajganj where LGED used vetiver to protect the road from wave action. Well rooted slips were planted at 15 cm apart to ensure a close hedge within 6 months. It was found that the roots grew up to 25 cm and the shoot grew up to 80 cm in 6 months. Figures 11a and 11b show the condition of the pond before and after vetiver plantation. Figure 11c shows the grown vetiver at the site in 6 months after planting.

2.5.3 Protection of dykes in saline zone

![Figure 11a](image1)
![Figure 11b](image2)
![Figure 11c](image3)
![Figure 11d](image4)

Figure 12. (a) Shrimp pond dykes (without any vegetation), (b) vetiver planted at the front of WAB office in Kaliganj, (c) grown vetiver at Baliaapur (moderate saline zone), and (d) grown vetiver in the Bashkahli area (strongly saline zone).

Shrimp cultivation is the main earning source of the people in the coastal belt. For shrimp cultivation, ponds are dug side by side. These ponds are separated by common dykes around each pond. Slopes of these ponds are also maintained for hassle free cultivation. Cropping time is all year round except from November to January. During these 3 months farmers refurbish their ponds as they become dry. In the region, floods occur during rainy season (July to August) on a regular basis. The whole area becomes flooded and the pond boundaries go under water. Flood causes damages to the dyke
boundaries of the shrimp ponds. Very often farmers engage themselves in boundary deciding arguments. As the coastal area is affected by salinity, little vegetation grows there (Fig. 12a). For investigating the performance of vetiver to protect dykes in the saline zone, at first vetiver grass was planted in the office garden of the WAB Trading Int. (Asia) Ltd. (a shrimp farm) located at Kaliganj (EC = 1.57 ds/m) with the cooperation of GIZ, Germany. This was also done to build the confidence of local people and also to train them about vetiver cultivation.

After that vetiver was planted in other three locations of saline zone: Baliapur (moderately saline: EC = 3.93 ds/m), Nildumur (moderately saline: EC = 4.19 ds/m), and Bashkhali (strongly saline: EC = 12.37 ds/m). The study was started in the summer on 10 May 2013 in Kaliganj and Baliapur. The study at Nildumur and Bashkhali was started during the rainy season on 23 August 2013. Performance and growth was monitored until June 2014. It was observed that vetiver grew in all the three regions. However, the growth in the strong saline zone was found to be the least. WAB has adopted the technology for planting vetiver in other shrimp farming dykes for green covering (Sarder, 2014). Again, in the Baliapur (saline zone) shoots were maintained up to 130 cm and cut down for maintenance. The roots grew up to 30-50 cm depending on the salinity level. The growth of roots is lower than that of the non-saline zone. Figure 12 presents the growth of vetiver in different saline zones.

2.5.4 Ongoing field trials/projects

Coastal Zone: Recently, a 3-year research subproject titled ‘Investigation of Climate Resilient Slope Protection of Embankments’ under the project ‘Coastal Climate Resilient Infrastructure (CCRIP)’ of LGED funded by the International Fund for Agricultural Development (IFAD, UN) has been initiated. The main objective of this project is to investigate the effectiveness of vetiver grass as a sustainable, environmentally safe and economically feasible anti-erosion cover of embankments/dykes adapted to local conditions of flooding and saline water, thereby making road embankments more climate resilient. The author is leading the research team. The CCRIP covers 12 districts of the south-western coastal areas (Fig. 2) which are classified into three categories based on soil characteristics and local disasters (embankments of soft-soil zone, embankments subject to wave action and embankments in saline zone). In this project, a botanist, a hydrologist, a transport specialist, and geotechnical engineers will work together along with LGED engineers. Under this project, preparatory works for 36 trials of vetiver plantation have been started. A model study involving 8 cases for investigating the efficacy of vetiver in rain-cut erosion and wave action has also been started at BUET focusing on the Bangladesh situation.

Haor Area: A major problem for people living in Haor island villages is that their small islands are continuously eroded by wind-induced wave action. The erosion of the villages in the Haor areas is probably one of the most severe natural calamities faced by people of the country. A 5-year supplementary project ‘Climate Adaptation and Livelihood Protection (CALIP)’ of IFAD, UN funded ‘Haor Infrastructure and Livelihood Improvement Project (HILIP)’ has been initiated recently by LGED for making trials for village mound protection and upazilla/union road slope protection in five selected districts of Haor area of Bangladesh (Fig. 2). Under this project, bio-technology using vetiver grass as a protection measure for village mound protection, canal bank, beel-bank, and upazilla road slope instead of hardcore expensive measures is introduced by Hoque (2013) with the cooperation from the author. Field level activities of the project have already been started.
2.5.5 Earthen wall stabilization using vetiver straw

‘CARITAS, Bangladesh’ is implementing a 5-year project in Bangladesh ‘Development of Affordable House Design and Construction in Different Geographic Regions of Bangladesh’, which is funded by ‘CARITAS, France’ and ‘CARITAS, Luxemburg.’ The main objective of the project is to develop disaster resilient rural houses for different geographic locations of Bangladesh using local building materials. BUET, Bangladesh and CRATerre-ENSAG, France are developing the designs of rural houses. The author is the leading member of the BUET team. Under this project, an area in Porsha has been selected (Fig. 2). In this area, people construct very thick earthen walled houses (1 m thick). The area is in a drought and earthquake prone zone. To improve the earthquake resistance, stabilized earthen blocks were prepared mixing locally available vetiver straw (Figs. 13a and 13b). From the laboratory tests conducted at BUET, it was found that vetiver straw is effective in improving the ductility, tensile strength and toughness of earthen blocks which are necessary for making earthquake resilient house (Islam and Hossain, 2013). Figure 13c shows a house constructed in early 2013 with vetiver straw (2% by weight) stabilized blocks. This technology is well-accepted by the local people and is adopted by them in building new houses using vetiver straw stabilized earthen block/wall.

![Figure 13](image)

**Figure 13.** (a) Vetiver straw to mix with soil, (b) author instructing local people about block making, and (c) constructed house made with vetiver straw stabilized earthen wall in 2013

3. Conclusions

River bank and Hoar island erosion as well as embankment failure are common disasters in Bangladesh. Bioengineering using vetiver is a proven technology. Laboratory study, field tests, numerical analyses and field trials have been conducted for more than last 5 years. The following are the findings of the study:

1) Vetiver is available in most parts of Bangladesh. The available species is *Vetiveria zizanioides*, which is the most suitable vetiver system for slope protection.

2) It is found that vetiver can grow in both silt and clay type of soils; in also saline soil and even in heavy metal contaminated soil. Vetiver is also found to be effective in uptaking heavy metals and salinity removal. It means that vetiver has strong potential to use for slope protection and land reclamation in Bangladesh.

3) Houses built with stabilized earthen blocks with vetiver straw have been found to be resilient to earthquakes. This technology has been well-accepted by the local people.

4) Direct in-situ shear tests and laboratory tests on reconstituted samples showed that vetiver root enhances the shear strength and deformation capacity of soil significantly.

5) Both the analytical and numerical analyses showed that vetiver plantation increases the safety of slopes. Vetiver root also enhances the bearing capacities of the ground.

6) Field trials for a road embankment in the flood plain, dykes in the coastal zone and pond slope protection in the Barind Tract zone proved that vetiver plantation is effective in controlling erosion. It is also proven that vetiver can grow in different
geographical locations and soil conditions of Bangladesh. Upon the success of field trials, a project has recently been started in collaboration with LGED to protect village mounds, road slopes, canal banks, and *beel*-banks in the Haor areas using vetiver.

7) An extended project (CCRIP) has been initiated for conducting model studies and field trials for embankment slope protection using vetiver in 12 coastal districts of Bangladesh. Effectiveness of vetiver in wastewater purification and arsenic removal has been started at BUET.

Upon successful completion and continuation of the research works, this community-based, environment friendly, sustainable biotechnology has initiated a positive move towards embankment protection, land reclamation and other potential uses of vetiver.

Acknowledgements

The author is grateful to BUET for providing the financial support and necessary facilities for conducting the research. The author is also grateful to WAB Trading Intl. (Asia) Ltd. and GIZ, Germany for their support in the field trials conducted in the saline zones and also providing vetiver planting materials from India. HRH Princess Maha Chakri Sirindhorn, the Patron of TVNI, on His Majesty the King of Thailand’s behalf, gifted some vetiver saplings to the Government of Bangladesh. Some of these saplings were planted in BUET premises for this study. Ital-Thai Ltd. of Thailand helped BUET in acquiring these saplings. The author is grateful for the provision of vetiver from Thailand.

Dr. Matiur Rahman, Ex-Director, National Herbarium, Bangladesh is also acknowledged for classifying the vetiver grass. The author acknowledges the presence of Prof. N. Tanaka, Saitama University, Japan for participating in the first field test in Kuakata in Bangladesh. The cooperation and encouragement of Dr. Paul Truong for this study at different levels is highly appreciated and gratefully acknowledged. Finally, the author is grateful to the students of BUET who have participated in the different stages of the research.

References


Hoque, M.S. 2013. Project design report for Climate Adaptation and Livelihood (CALIP): Scaling up and Innovation Adapting Activity in Haor Infrastructure and Livelihood Improvement Project (HILIP) funded by IFAD, UN, implementing Agency-LGED, GoB.


Islam, M.S. and Arifuzzaman. 2010. Performance of vetiver grass in protecting embankments on the Bangladesh coast against cyclonic tidal surge. The 5th National Conference on Coastal and Estuarine Habitat Restoration, USA.


Author’s Biography: Dr. Mohammad Shariful Islam is a Professor at the Department of Civil Engineering, Bangladesh University of Engineering and Technology (BUET). Dr. Islam earned his PhD from Saitama University, Japan. He also conducted two years JSPS postdoctoral research at the same university in Japan. He was awarded ‘Dr. Rashid Gold Medal’ and ‘Sharfuddin Gold Medal’ for his best academic performance in MSc Engg. at BUET. He was awarded ‘Best Paper Award in Civil Engineering’ in the 7th CUTSE Conference held in Malaysia in 2012, ‘1st Prize Award’ in the ICETCESD-2011 held in 2011 in Bangladesh, ‘Certificate of Appreciation’ in 6th Asian Young Geotechnical Engineers Conference held in India in 2008, ‘Best Paper Award’ in the 5th Asian Young Geotechnical Engineers Conference held in Taiwan in 2004, ‘Excellent Presentation Award’ in the 56th Annual Conference of the Japan Society of Civil Engineers (JSCE) held in Japan in 2001.