CLIMATE RESILIENT SLOPE PROTECTION FOR COASTAL REGIONS OF BANGLADESH USING BIO-ENGINEERINGTECHNIQUES

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ABSTRACT

One of the major maintenance challenges of rural roads, bridge approaches and minor embankments in Bangladesh is protection of respective slopes. Almost whole of the country remains inundated for 4 to 6 months of the year that loosen the earthen slopes resulting in erosion of the slopes. The traditional engineering solutions for this problem have been application of concrete blocks, palisade, sand bags, stone revetments, geo-textile, etc. that not only increases cost of construction and maintenance but is often found ineffective and unsustainable. Studies in many countries around the world has revealed that embankment stability can also be gainfully augmented by using bio-engineering techniques and can provide for long-term sustainable low-cost and maintenance free solution for slope protection. It has been widely recognized that plant root systems can improve the soil shear strength significantly. The technique envisages the use of appropriate vegetation with minimum artificial human intervention resulting in economic and ecological benefits. In this regard, a comprehensive field study on vegetative slope protection is being conducted in different parts of the coastal region under the 'Coastal Climate Resilient Infrastructure Project (CCRIP)'. Vetiver grass (*Vetiveria zizanioides,* locally known as *binna grass*) has been selected for its special attributes and easy availability throughout the country. Effectiveness of vetiver grass against rain-cut erosion and tidal wave in coastal zones of Bangladesh has been examined using model study and field trials. This paper presents three case studies of vetiver plantation in slope protection against rain-cut and wave-induced erosion. It has been found that the vetiver based bio-engineering technique can provide an effective and environment-friendly solution for embankment slope protection.

Keywords: Bio-engineering, embankment protection, vetiver, salinity, sustainability.

INTRODUCTION

Most of the traditional practices to protect embankments against erosion in Bangladesh are expensive and sometimes their performances are quite unsatisfactory with respect to their costs. Recently, around the world the bio-engineering techniques have widely gained popularity for embankment/slope protection (Hengchaovanich, 1998; Truong et al., 2002; Islam et al., 2014). These techniques are being increasingly favored to control soil erosion in general and for slope protection in particular. Vetiver grass (*Vetiveria zizanioides*, locally known as *binna grass*) has already been used in more than 100 countries around the world to curb soil erosion. Most developed and developing countries like Australia, Brazil, China, India, Kuwait, Malaysia, Spain, Thailand, USA and Zimbabwe use vetiver for erosion protection works (Islam et al., 2013a; Islam et al., 2013b; Suleiman et al., 2013; Islam, 2015; Parshi, 2016). However, efficacy of such systems has not been scientifically studied in Bangladesh perspective. Local Government Engineering Department (LGED) is one of the largest departments of Bangladesh Government and has constructed about 3,05,000 km of rural road. More than 50% of these roads are constructed on embankments. These embankments need to be protected from erosion and damage for overall structural stability and sustainability of roadway pavements. Henceforth, LGED seeks for cheaper, appropriate and effective protection measure for its vast road network infrastructures. To study the potential of bio-engineering as climate resilient slope protection measure in the coastal areas of Bangladesh, an action research project entitled "Investigation of

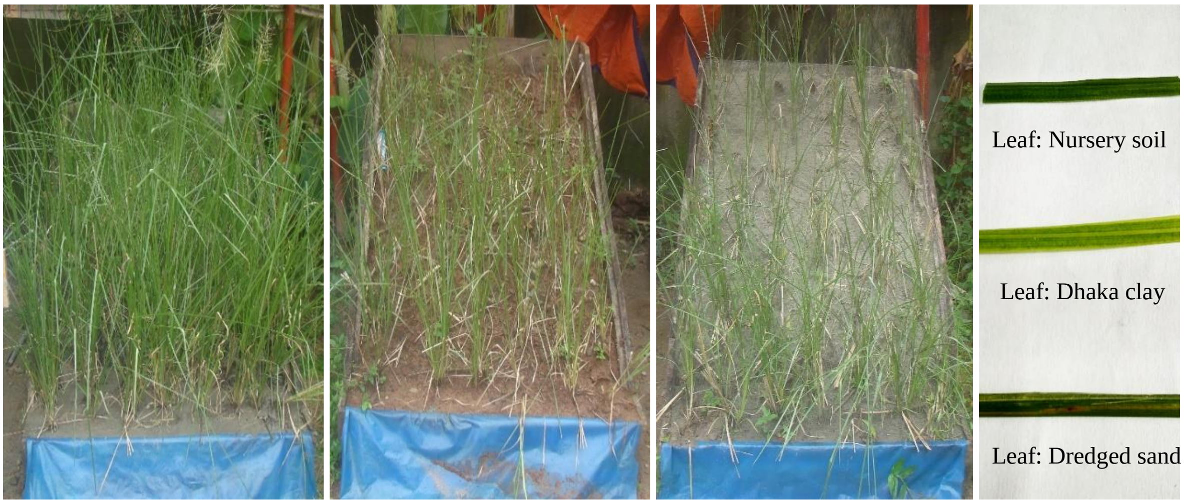
Climate Resilient Slope Protection of Embankments" was awarded to the Department of Civil Engineering, BUET by LGED in 2014. The project has started in July 2014 and the research activities of the project is planned to be carried out over a period of 36 months. The CCRIP intervention covers a total of 12 districts of the south-western coastal areas: Gopalgonj, Madaripur and Shariyatpur (Dhaka Division); Khulna, Bagerhat and Sathkhira (Khulna Division); Barisal, Patuakhali, Barguna, Jhalokathi, Bhola and Pirojpur (Barisal Division). Main objective of the study is to identify suitable plant species that would provide for a sustainable, environmentally safe and cost-effective anti-erosion cover for embankments/dykes/village and market mounds etc. to be adapted to local conditions of inundation and saline water, thereby making rural communication as well as community infrastructures more climate resilient and sustainable.

METHODOLOGY

Vetiver grass has been selected for its inherent special attributes and easy availability throughout the country. To determine the efficacy of vetiver grass in stabilizing road side slopes against rain-cut erosion and flood, at first the model (dimension: 180 cm ×100 cm × 130 cm containing different soils and with varying slopes) studies have been conducted at BUET premises. Vetiver grass was collected from a local natural source located in Pubail, Gazipur area. Then they were planted in cow dung mixed soil in poly-bags and nurtured for three months in an open place where these plants got enough sunlight and rainfall. Then healthy grown up plants were planted in grid, triangular and row patterns in the model slopes. Growth and performance of vetiver in slope protection are being monitored at 2-3 months' interval. At the beginning of dry season (winter) the shoots were trimmed and the plants were watered regularly. Figs. 1a-1c represent the condition of model slopes three months after plantation. Fig. 1d presents the close view of leaves of vetiver grown in different kinds of soils. For the model study, three types of soils namely: dredged sand, Dhaka clay and nursery soil were filled in six wooden slope models. The gradation curve of these soils has been presented in Fig. 3a. The general description of the models is presented in Table 1. After the model study, the field trials have been conducted in the selected coastal zones to study the performance of vetiver based protection measures under field conditions. Under CCRIP project so far field trial has been conducted in nine districts namely: Barisal, Khulna, Satkhira, Sariatpur, Patuakhali, Madaripur, Gopalganj, Pirojpur and Bagerhat. In this paper, findings of the field trials conducted at Barisal, Madaripur and Satkhira sites have been presented. Fig. 2a shows the districts under CCRIP project. All the selected roads were newly upgraded. Then the embankment slopes of these sites were prepared getting help from the members of labor contracting society (LCS). The selected vetiver tillers were planted at 30cm apart along the slope and perpendicular to the slope. The typical road section and plantation pattern are presented in Fig. 2b and

Table 1: Description of the models

Model name	Source	Type of soil	Plantation	
			Pattern	Spacing
M1	Dredged material	Silty sand	Grid	15 cm c/c
M2	Dhaka clay	Red silty clay	Grid	15 cm c/c
M3	Nursery	Sandy silt with organic content	Triangular	15 cm c/c
M4	Nursery	Sandy silt with organic content	Row	10 cm c/c
M5	Nursery	Sandy silt with organic content	Row	15 cm c/c
M6	Nursery	Sandy silt with organic content	Row	20 cm c/c
M7	Nursery	Sandy silt with organic content (Salinity: 10 to 12 ds/m)	Grid	25 cm c/c



(a) (b) (c) (d)

Fig. 1 Photographs showing the growth of vetiver in model slopes after three months of plantation: (a) nursery soil (leaf: dark green), (b) red clay (leaf: light green with multiple yellow strips), (c) dredged sand (leaf: dark green with single yellow strip in the middle) and (d) close view of leaves

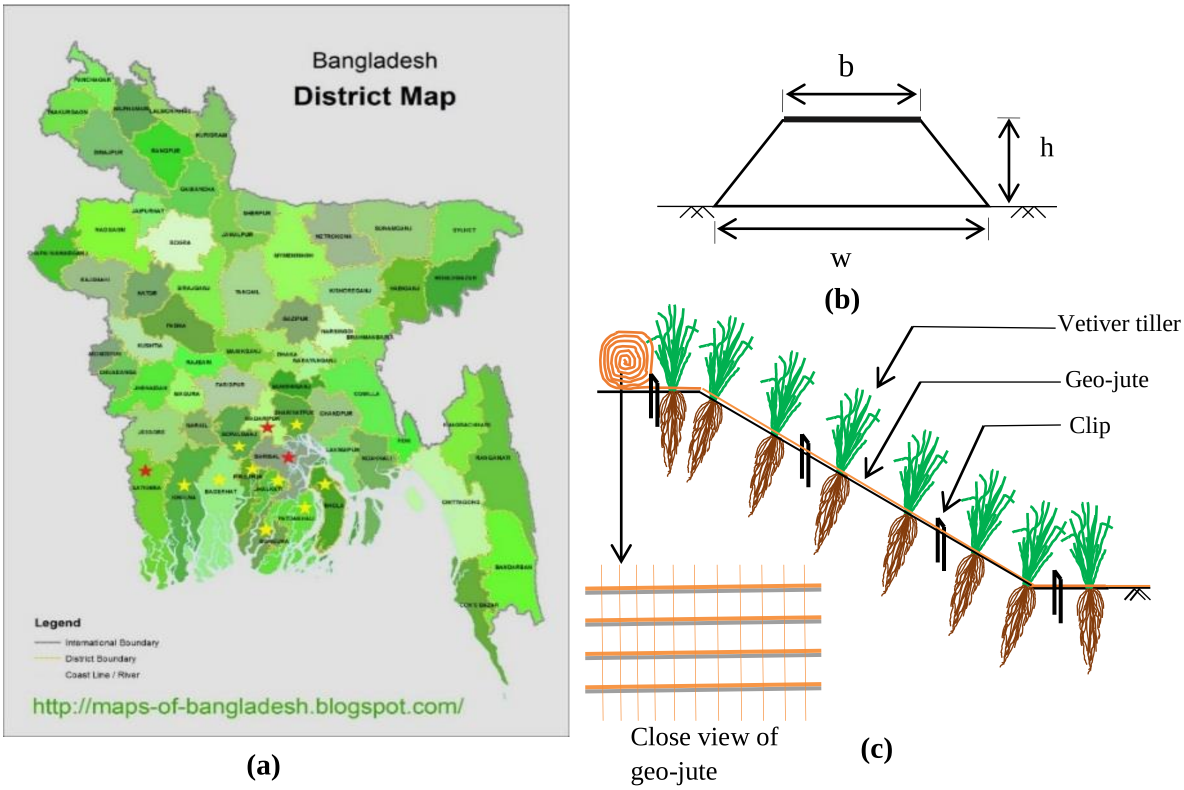
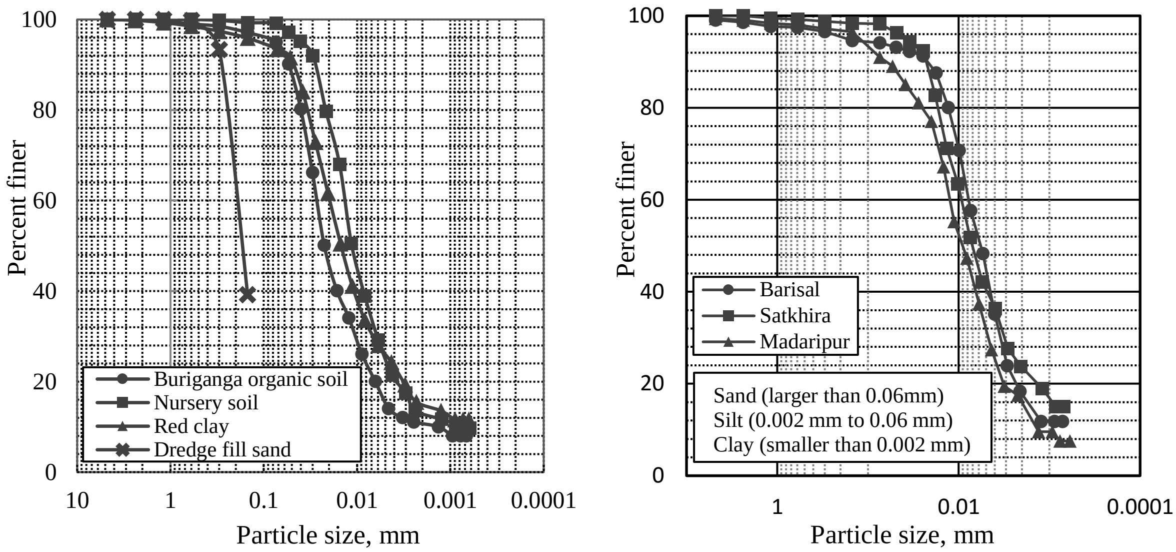


Fig. 2 (a) Study areas of CCRIP, (b) typical road section of LGED (top width: b, bottom width: w, height: h) (LGED, 2005) and (c) Schematic diagram showing vetiver plantation scheme

Fig. 2c, respectively. After completion of vetiver plantation, proper nursing and monitoring (that includes watering, measurement of root, shoot growth, erosion of the road embankment) was made at regular basis. The first trial was conducted at Barisal and then at Satkhira. These two trials were conducted in August, 2015. The trial in Madaripur was conducted in January, 2016. All of these roads are village road. A brief description about the selected field trial sites is stated in the Table 2. Fig. 4 states the condition of the field trial sites (including topography) at the time of plantation. Soil sample from each site was collected and index properties and grain size of the soil samples were determined. From the gradation curves shown in Fig. 3b, it is clear that, soil in these sites are basically clayey silt with 70-75% silt, 15-25% clay and 2-10% sand. The field trial sites were monitored closely and performance data were acquired on a regular basis.



(a) **(b)**

Fig. 3 Gradation curves for: (a) soils used for model and (b) soils collected from field trial sites

Table 2: Location, geometry of road embankment, traffic and climatic conditions of field trial sites

Site Name	District	GPS	Length of road (km)	b (m)	h (m)	w (m)	Traffic condition	Temp (°C)	Rainfall (mm)
Babuganj	Barisal	22.84° N, 90.29° E	2.3	4.4	2.4	11.4	Both motorized and non-motorized	25.9	2184
Rajoir	Madarip-ur	23.23° N, 90.07° E	5.0	4.0	2.43	11.2	Both motorized and non-motorized	33.8	1350
Asashuni	Satkhira	22.57° N, 89.19° E	2.13	5.5	2.13	11.2	Non-motorized	35.5	1710

(a) **(b)** **(c)**

Fig. 4 Photographs showing the site just after vetiver plantation: (a) Barisal (surrounded by wet land) (b) Madaripur (surrounded by green field with a small nearby canal) and (c) Satkhira (river *Morichop* flowing alongside creating wave action)

RESULTS AND DISCUSSIONS

With a view to investigating performance of the vetiver grass in protecting slope of road embankment, the field visits were made regularly in the intervention site areas. During filed visits as part of the plans monitoring process, the growth progress of both root and shoot were measured. Also it was keenly observed whether there was any damage to the road embankment slope occurred due to rain-cut or sliding. From the model studies, it has been found that vetiver growth is the best in nursery soil as compared to that of Dhaka clay and dredged sand (Fig. 1). Performance of vetiver grass against rain cut erosion of slopes has been found satisfactory in the model study. However, some part of the upper portion of the sand model eroded in the first few weeks of plantation. In these different types of soil, the color of the vetiver leaf has been found to be different (Fig. 1d). From Fig. 5, it was observed that after 24 weeks, roots grew up to 32 cm in Barisal, whereas in Madaripur the root grew up to 50 cm within the same span of time in spite of being planted in winter. This prodigious/accelerated growth in Madaripur was mainly due to proper nursing particularly during the dry season. In both Barisal and Madaripur, inflorescence has been observed which indicates maturity of vetiver grass. The growth of vetiver grass in Satkhira has been found to be poor, only a meager number of planted tillers did survive at this site with adverse climatic condition (Fig. 6c). The main reasons behind the poor growth in Satkhira intervention area have been identified as mainly due to the salinity as well as the improper time of plantation i.e., just after monsoon. In order to find a solution for growing vetiver in saline soil, vetiver was planted in a wooden slope that contained saline soil (sea salt mixed with nursery soil) with different alternative conditions. It was found that vetiver can be grown in saline soil adding organic fertilizer and ensuring proper watering. Moreover, it has revealed that the proper time of plantation would be well before the full monsoon period.

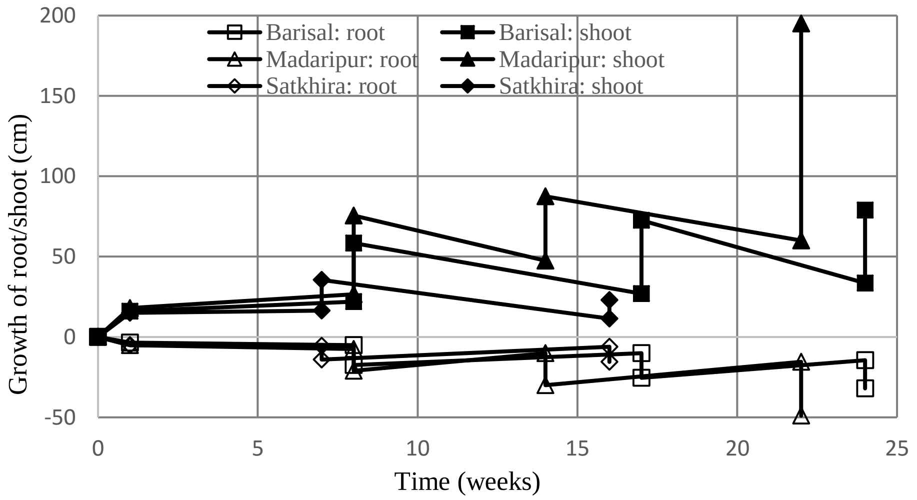


Fig. 5 Root and shoot growth of vetiver grass in the field trial sites

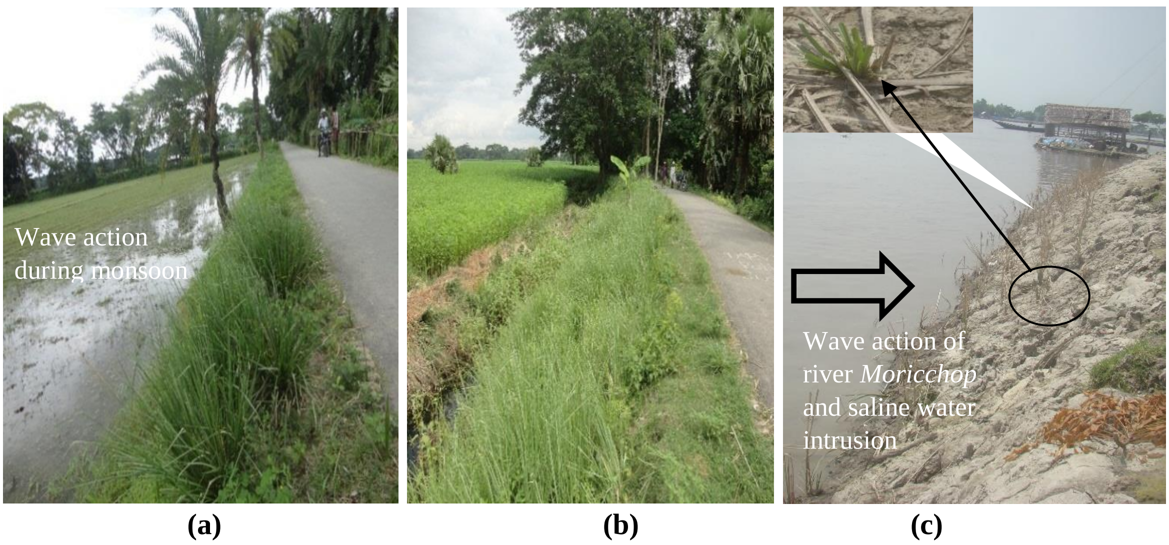


Fig. 6 Photographs showing: (a) Barisal site condition after 42 weeks, (b) Madaripur site condition after 20 weeks and (c) poor growth of vetiver in Satkhira site after 20 weeks

CONCLUSIONS

Bio-technology in contrast to current practices of embankment and slope protection around the world is more sustainable, practical and efficient. The data acquired from the field trials made in the intervention sites and model studies conducted at BUET premise, have revealed that the vetiver based slope protection measure is an effective method in protecting the slope of road embankment from rain-cut erosion. It is also found that to protect embankment slopes from erosion, these grasses need to be planted well before the monsoon period i.e. during May-June. Besides, proper nursing and monitoring need to be ensured until the plants grow quite well. It may take six weeks to eight weeks for vetiver to grow. It is also observed that to have better growth performance and survival rate, the vetiver grass should be planted at least six weeks before the monsoon starts. With this plantation arrangement, it is expected that the plants will get enough monsoon rainfall and grow very quickly and thereby would be ready for protecting slope from erosion more effectively. Even if the plantation is done in winter, proper nursing and watering can result in positive output. From the study, it is clear that vetiver plantation holds a good prospect for protecting slopes in different geographic setting with various soils and climatic conditions. Though, the growth rate of vetiver roots and shoots were found to be widely varied with soil conditions i.e., soil type, nutrient content, salinity and climatic conditions. It is recommended that if an embankment is constructed with sandy soil, the soil should be covered with geo-jute for ensuring the protection at the early stage. For saline zone, it is suggested that the plantation should be made on soil properly mixed up with cow-dung/fly ash and most importantly watering should be made regularly and vigorously for better growth and performance.

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