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STUDY ON GROWTH OF VETIVER GRASS IN TROPICAL REGION FOR SLOPE PROTECTION

Mohammad Shariful Islam[1], B. A. M. Shahriar[1] and Hossain Md. Shahin[2]
[1]Department of Civil Engineering, Bangladesh University of Engineering and Technology, Bangladesh
[2]Department of Civil Engineering, Nagoya Institute of Technology, Japan

ABSTRACT: River bank erosion and embankment failures happen continuously throughout Bangladesh. From a strictly economic point of view, the cost of remediating these problems is high, and the state budget for such works is never sufficient. This confines rigid structural protection measures to the most acute sections. General reasons of embankment failure are erosion due to rain splash, wave action, overtopping of storm surge. Faulty design, poor maintenance and poor construction also cause failure. The use of cement concrete blocks, stone revetments, geo-bags, and plantation etc. are commonly used for protection of embankment in traditional practices. These materials are expensive and sometimes are not effective to protect the embankments and river bank for an expected design life. On the other hand, slope stability can be augmented by using bio-engineering techniques. Vetiver grass (*Vetiveria zizanioides*) is being used as an efficient bio-technology for slope protection in many countries, for its special attributes like longer life, strong and long finely structured root system and high tolerance of extreme climatic condition. A few steps have only been taken recently to employ this technique for slope protection purposes in Bangladesh. This paper presents three case studies of vetiver plantation in slope protection against rain-cut and wind-induced erosion. It is found that vetiver grass grows in different soil and climatic conditions of Bangladesh and it is effective for slope protection. Prospect of vetiver plantation in protecting *haor* low-land is also discussed.

Keywords: Bio-technology, Erosion, Low-land protection, Salinity, Vetiver

1. INTRODUCTION

Bangladesh is a small riverine country located in South East Asia. In total, it has 700 rivers including tributaries which have a total length of 24,140km. It also carries two months of monsoon period in a year. As a result, embankment failure due to erosion and bank breaching is very common phenomena in this country. Embankment failure is a big setback for transportation sector of Bangladesh. High cost of land in this over populated country forces to economic design of road embankment which is often failed by the wave action of heavy tidal force.

Bangladesh managed to construct about 7,555km of embankment including 4,000km of coastal embankments during the last few decades. It protects about 24% of total land area and 39% of net cultivation area. These embankments are constructed to protect land from tidal inundation, but cannot prevent overtopping of cyclonic surges and tidal bores. In addition, due to increased agricultural production, these embankments provide good road communication and contribute in the growth of the overall socio-economic condition at the coastal zone. Coastal region of Bangladesh is about 700km long. To protect such long length of embankment against natural calamity and erosion, every year government of Bangladesh has to allocate huge amount of money in its annual budget. So, cheaper maintenance and construction cost of embankment would be a great relief for Bangladesh.

Cultivation and export of shrimp is very successful in the coastal region and it contributes 4% of National GDP every year [1]. For shrimp cultivation, ponds are dug side by side. These ponds are separated by common dikes around each pond. Slopes of these ponds are also to be maintained for hassle free cultivation [2]. Cropping time is all round the year except November to January. During these three months farmers refurnish their ponds as it becomes a dry season. In Satkhira region, flood occurs during rainy season (July to August) in a regular basis. The whole area becomes flooded and pond boundaries go under water. Flood causes damages to the dikes boundary of the shrimp ponds. Very often farmers engage themselves in boundary deciding argument [3].

During monsoon season, basin type low lands of north eastern part of Bangladesh (called "*Haor*") become flooded every year under water of 2 to 6m. Erosion in these areas is the main cause of loss of home for a good number of people every year.

The common causes for embankment slope failure in Bangladesh are heavy rainfall, wave action from river, and inadequate protection of slopes against overtopping of storm surge. Protection against these types of failures can be divided into three categories, such as –i) structural, ii) non-structural and iii) biological protections. Among the structural protections revetment, guide bunds, boulders and brick mattressing are common, while dredging, channelization geo-bag dumping etc. are common in non-structural protections. Biological protections refer to bank vegetation, wooden pilling, willow post,

bandalling and crisscross porcupines [4]. Most of these are expensive solutions against desired design life for the protection.

Now–a-days, bio-engineering technique is becoming popular in some countries. As Bangladesh could be one of the most affected countries for global warming [5], implementation of bio-technology would be the best solution against global warming. Moreover, it is cheaper than typical structural solutions that are provided for slope protection. Vetiver grass (*Vetiveria zizaniodes*) is being used as an efficient bio-technology for slope protection purpose in many countries. The special attributes of vetiver is that it can grow on sites where annual rainfall ranges from 200mm to 5000mm [6]. It can survive in temperature ranging from 0˚C to 50˚C. It grows on highly acidic soil types (pH ranges from 3.0 to 10.5) and also tolerant to high content of Al, Mn, As, Cd, Cr, Ni, Pb, Hg, Se and Zn in the soil. The saline threshold (EC) of vetiver is 7.8 dS/m. However, in soil with EC values of 10~20 dS/m, the yield of vetiver is reduced by 10%~50% [7]. Its roots are very strong with a diameter of 0.66 ± 0.32mm having a high tensile strength of around 85.10 ± 31.20 MPa. It is also found that vetiver hedges can survive even for more than 100 years [8].

Recently, few efforts have been made to investigate the effectiveness of vetiver in slope protection in Bangladesh [9, 10]. In this paper, efficacy of vetiver grass to protect road embankment, shrimp pond sides in saline zone and pond slope in *barind tract* zone has been presented. Finally, possibility of vetiver application in *haor* low-land protection is discussed.

2. DESCRIPTION OF STUDY AREAS

Trials are made in three different geographic regions of Bangladesh. Possibilities of using the developed method are also proposed for *haor* village protection. Road embankment slope, pond slope in *barind tract* and saline zone were selected for field trials. General descriptions, climatic data, and soil characteristics of the sites are given below.

2.1 Keraniganj Site

A road embankment named as Konakhola-Kholamura-Hazratpur-Itavara-Hemayetpur under Roads and Highway Department of Bangladesh was selected to investigate the effectiveness of vetiver at road side slope. The site is situated at Keraniganj under Savar Upazilla, Dhaka. Total length of the road is 23.01km and average width is 3.80m. The chainage of the field trial is 17+700m to 17+800m. Annual Average Daily Traffic of the road is 71.38. Temperature and humidity of this area ranges between 14°C and 34°C and between 45% and 79%, respectively. Average annual rainfall is 1875mm.

Specific gravity of the slope soil is 2.70. Sand, silt, and clay content are 10%, 80% and 10%, respectively. Mean grain size, D_{50} and coefficient of uniformity, C_u of the soil are 0.048mm and 7.5, respectively. It is seen that the soil is sandy silt. It seems that the soil is erodible.

2.2 Rajshahi Site

A pond was selected to evaluate the growth and effectiveness of vetiver grass to control erosion of pond bank soil. The pond is situated at Godagari Upazilla in Rajshahi District. The region consists of *Barind tract*, *Diara* and *Char* lands. Annual average temperature ranges between 11.2°C and 37.8°C. Average annual rainfall is 1862mm.

Specific gravity of the slope soil is 2.64. Sand, silt and clay content of the soil are 13%, 75% and 12%, respectively. Mean grain size, D_{50} and coefficient of uniformity, C_u is 0.016mm and 7.4, respectively. According to percentage of contents the soil is sandy silt. It seems that the soil is erodible as well.

2.3 Satkhira Site

Satkhira is a district of south western part of Bangladesh under Khulna division. It is close to Bay of Bengal. Being coastal district, salinity is a key feature for soil and water of this district. The annual average maximum and minimum temperatures are 35.5°C and 12.5°C respectively. The annual rainfall is 1710mm. Most of the population is involved with shrimp cultivation in this district. Plantation was done in two areas.

Plantation Area-1 was a plane land and part of a well maintained garden. Specific gravity of the soil is 2.64. Sand, silt and clay content are 2%, 97%, and 1%, respectively. Mean grain size, D_{50} and coefficients of uniformity, C_u are 0.025mm and11.87, respectively. It is to be noted here that this plantation area is not a slope. However, this trial was employed to compare the growth in the same region.

Plantation Area-2 was a slope of a shrimp pond. The soil of this site is organic soil with organic content of about 10%. Specific gravity of the soil is 2.52. Sand, silt, clay content are 3%, 88%, and 9%, respectively. According to the percentage of the contents the soil is classified as CH. D_{50} and C_u are 0.022mm and 9.56, respectively. Liquid limit and plasticity index of the soil are 63 and 38, respectively. pH level of the soil varies between 6.2 and 8.4.

Cation exchange capacity is 14.2 to 25.5 m.e%. Na, K, Ca and Mg content ranges are 0.5 to 0.6, 0.2 to 1.2, 6.3 to 16.2 and 2.8 to 11.4 m.e%, respectively.

Contents of P, Zn and Cu ranged between 12 to 24, 0.1 to 0.8 and 0.08 to 0.30 ppm, respectively. Saline content of three ponds near the Plantation Area-2 are given in Fig. 1. Salinity is the highest in March.

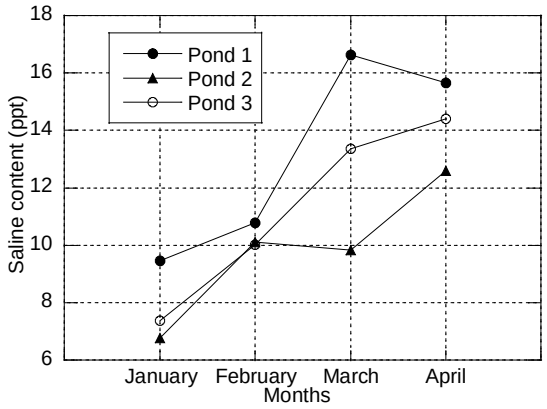

Fig. 1 Variation of salinity content of water of the ponds with time at Plantation Area-2.

2.4 *Haor* Area

Haor is a basin type low land area in the north eastern part of Bangladesh. This zone contains about 400 *haors* and *beels*. The *haor* basin is a remote and difficult access area that is flooded every year during monsoon. The climate of the area is subtropical monsoonal with an average annual rainfall of 4,000mm. Temperature varies between 26°C and 31°C. The surface soil of the area is mainly composed of yellowish grey silts which are highly erosion prone and problematic from filtration point of view.

Index and physical properties of the soils from Keraniganj (Site-1), Rajshahi (Site-2), Satkhira (Plantation Area-1: Site-3; Plantation Area-2: Site-4) are presented in Table 1. It is seen that soil from Keraniganj and Rajshahi are sandy silt. Soil of the Plantation Area-1 of Satkhira is mainly silt while the soil from Plantation Area-2 is organic clay.

3. FIELD TRIALS

3.1 Application in Road Embankment

Field trial was conducted at the Keraniganj site for a road slope. Before vetiver plantation, site was prepared by plucking out unwanted grasses and leveling the soil bed. Then geo-jute was placed over the soil bed using fixing pins at a fixed interval. 700gsm geo-jute was used in this plantation purpose. After that, vetiver grass was planted at an interval of 20cm c/c both in horizontal and vertical direction using a stick for making hole in the ground through geo-jute in October 2011. These vetiver grasses were collected from a place called 'Pubail' which is nearby Dhaka city. Watering was done for 1 month on a regular basis. Detail about this trial is presented in Islam et al., 2013 [10].

The growth of shoot and root was monitored regularly. Figure 2 presents the site view and vetiver shoot & root after 52 weeks. Figure 3 shows the shoot and root growth with time. It can be seen that root grew up to 52cm at the end of 52nd week while length of shoot was grew up to 180cm. It is found that although both the shoot and root lengths increased with time the rate of growth became slow after 40weeks. No sort of geo-jute was found at the site after 52 weeks which indicates that geo-jute is totally bio-degradable to environment. In the opposite side of the vetiver plantation, a thick masonry wall was constructed for protecting the slope from rain-cut erosion.

Table 1 Index and physical properties of soils

Site	G_s	Sand (%)	Silt (%)	Clay (%)	PI (%)	OC (%)
Site-1	2.70	10	80	10	-	-
Site-2	2.64	13	75	12	-	-
Site-3	2.64	2	97	1	-	-
Site-4	2.52	10	3	88	38	10

Note: G_s: specific gravity, PI: plasticity index, OC: organic content

(a)

(b)

Fig. 2 Growth of vetiver grass at Keraniganj site after 52 weeks of plantation: (a) view of the site and (b) close view of shoot and root.

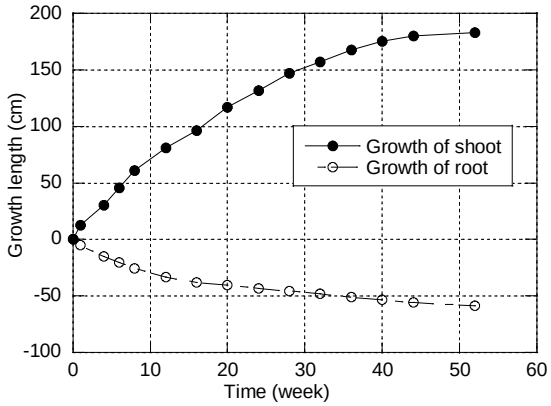

Fig.3Growth of vetiver shoot and root with time at Keraniganj site.

Some parts of the wall were damaged due to the rain water pressure while the vetiver plantation part perfectly worked. Cost of the vetiver plantation is 4 times lower than that of the masonry wall construction [10]. Vetiver grass increases the factor of safety of the slope from 1.7 to 2.8 [10].

3.2 Application in Pond Slope

3.2.1 Trial in barind tract zone in Rajshahi

Field trial was made to protect a pond slope from erosion in the *barind tract* zone. The periphery of the pond was about 122m. 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. Side slope's soils of the pond were highly erodible. In rainy season, top soil is washed away by runoff which causes the pond water muddy. In dry season, the top soil is flown away from the bank by wind. The slope of the pond is not uniform. The slope at the top, middle and lower portion is 1:1.5, 1:2 and 1:3, respectively.

Vetiver grass was planted in three sides of the pond bank in June 2010 and growth of its root and shoot were monitored until November 2010. At first cow-dung was mixed with the bank soil. Vetiver collected from 'Shirajganj' was planted according to the contour line shown in Fig.4. Spacing of planted vetiver grass was 15cm both along the slope and transverse to the slope direction (Fig. 4). Well rooted slips were planted at 15cm apart to ensure a close hedge within 6 months of plantation. It was found that the root grew up to 25.4cm and shoot grew up to 80cm in 6 months. Figure 5 shows the condition of the pond before and after vetiver plantation. Water of the pond was turbid before the vetiver plantation. But water became clear even in rainy season after the vetiver plantation. It proves that the application of vetiver was effective to protect the erosion and migration of soil particles from the top and bank of the pond during rainy season and winter (dry season).

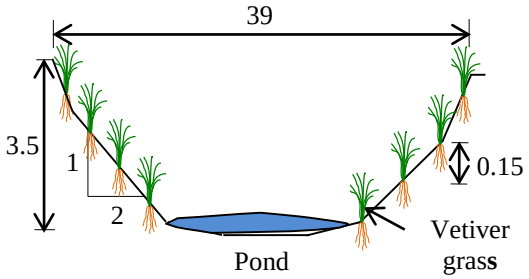

Fig. 4 Schematic diagram showing the plantation of vetiver grass along the pond slope (dimensions are in meter)

(a)

(b)

Fig. 5 Pond conditions: (a) before vetiver plantation and (b) after 6 months of vetiver plantation at the Rajshahi site.

3.2.2 Application in saline zone

At Satkhira, two places were chosen for the plantation program. Plantation Area-1 was a garden

with an area of 100 square meter and Plantation Area-2 was a side slope of a shrimp pond of about 100 square meter of plantation area which is 35km away from the Plantation Area-1. Vetiver grass collected from 'Pubail' site was also planted in these two areas.

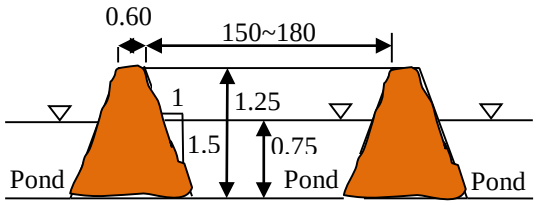

Fig. 6 Schematic diagram of a typical shrimp pond at Satkhira (all the dimensions are in meter)

For Plantation Area-1, soil bed was watered and ploughed using a garden hoe. After that, vetiver grass was planted in square grid of 30.5cm^2. Root of the grasses was inserted at least 7.5cm below the soil surface. Watering was done two times every day.

On the other hand, for Plantation Area-2, which was a slope of a shrimp pond, vetiver grass was planted at 30.5cm distance both in along the slope and transverse to the slope direction. Here, it is to be mentioned that no geo-jute was used in the slope area. Watering was done from the shrimp pond itself to make the grasses habituated with the saline condition. Fig. 6 shows a typical section of shrimp pond.

After plantation, growth of the shoots of vetiver are monitored weekly. It is to be noted here that salinity content of ponds become very high during March to April and plantation work was done in May, 2013. Plantation during high saline content period would help us to monitor vetiver's sustainability against hostile soil condition.

Condition of the root and shoot after 45 days for both plantation areas is presented in Fig. 7. Growth of root and shoot with time has been presented in Fig. 8. The growth in the Plantation Area-2 is less than that of the Plantation Area-1. This might be due to high salinity of the water and soil in this area. However, it is clear that vetiver grass can grow even in the saline zone. Similar results were obtained in Fiji where vetiver grown in high saline zone (Truong et al., 2002).

Comparison of vetiver roots and shoot growth in different areas that is Keraniganj, Rajshahi and Satkhira is presented in Fig. 9. Growth of both the root and shoot are different for different soils and climatic conditions. The growth is different even in the same area. It is seen that in all the cases both the root and shoot grow with time.

3.3 *Haor* Village Protection

In the *haor* areas, masonry wall, revetment stone bamboo etc. are used for protecting the villages from the wave action. Comparative cost analyses for the typical slope protection measures that are used in *haor* areas are made. Unit costs are taken from the rate schedule 2011 of Public works Department (PWD) [11]. It is found that among the four solutions 'Total vegetation protection' type of protection system is less costly and very easy for construction. In general, a 300mm layer of stone is placed over geo-textile. Vertical and horizontal anchors are also used to attach with ground.

(a)

(b)

Fig. 7 Growth of vetiver shoot at Satkhira site in 45 days at (a) Plantation Area-1, (b) Plantation Area-2

It is a hard solution and costs about US$ 19.55 per square meter slope protection. Another hard type protection system is 'Masonry wall protection system'. Its construction cost for per unit square meter is US$38. This solution is found as the most costly solution among them. Another two protection measures are proposed. One is vetiver grass with revetment and another is vetiver grass without revetment. Protection including revetment stone costs US$9.53 per square meter and vetiver plantation costs only US$ 4.7 per square meter.

4. FINDINGS AND RECOMMENDATIONS

Bio-technology in contrast to current practices of embankment and slope protection around the world is

more sustainable, practical and efficient. Field trials have been made in three different geographical locations of Bangladesh. The main findings are:

1) Vetiver plantation works very well on the slope of road embankment which protects the slope from rain-cut erosion and sliding. This proves that vetiver plantation grows suitably in a sub-tropical climate condition having sandy soil.

2) Vetiver grass also grows well in *barind tract* zone and works very well against rain-cut erosion and wind induced erosion to protect pond slope.

3) Even in high saline zone area, vetiver plantation is a suitable solution to protect the side slopes of shrimp ponds from flood and wave actions.

4) From the study it is clear that vetiver plantation is suitable for protecting slopes in different geographic areas with different soils and climatic conditions. However, the growth of vetiver roots and shoot varies in different areas. These are due to the differences in soil type, nutrient content, salinity and climatic conditions.

5) From comparative cost analysis it is found that vetiver application is about 8 times cheaper than the masonry wall protection and about 5 times cheaper than the revetment stone slope protection system. Thus vetiver grass plantation for slope protection could be a sustainable, green and cheaper bio-engineering solution.

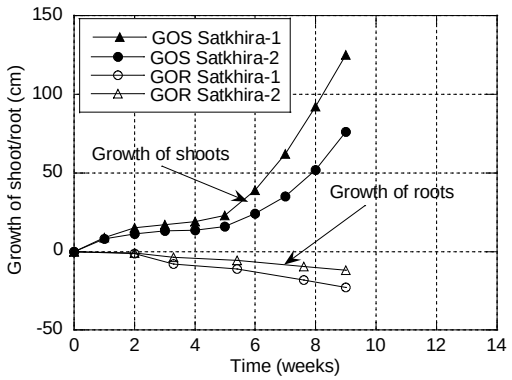

Fig. 8 Growth of vetiver shoot and root with time

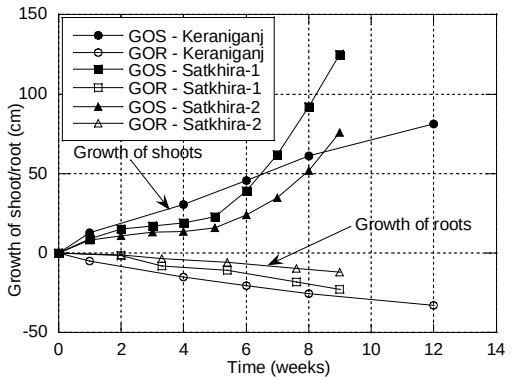

Fig. 9 Comparison of vetiver growth

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Corresponding Author: Mohammad Shariful Islam