Title: VETIVER SYSTEM – THE GREEN TOOL AGAINST EROSION

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Abstract:
Vetiver Grass Technology is a well established system for protection of soil slopes from erosion. It is used for this purpose in over 100 countries throughout Asia, Africa and the Americas, where it is a low cost, environmentally sustainable and community friendly solution. The Vetiver system was introduced to Assam in the beginning of the year, 2009 with the formation of Eastern Vetiver Network, India. This paper is a description of three demonstration bioengineering projects- one to stabilize hill slope, one to stabilize a big bridge approach and the other to protect against the severe erosion of the Brahmaputra river in the North-East Indian state of Assam.
All the three projects were designed, supervised and monitored by the author.
A vulnerable slope on the eastern face of the Chunsali hill along the Noonmati- Kharghuli road at Guwahati was chosen for the hill slope project. This location was a perennial problem during the monsoon.
For the bridge approach project, the approaches to the Doria bridge in Majuli- the largest river island was chosen because the soil was silty sand, typical of the flood plains of Assam. Majuli is notorious for erosion and it is very difficult to control erosion without costly measures. Another problem in Majuli is the unavailability of rocks locally for the conventional protection works with rocks.
For the river bank protection, a stretch of Brahmaputra riverbank was chosen. This was chosen because the river bank retreated by about 1 km from 1998 and the Govt. of Assam decided to apply the Geosynthetic mattress on that stretch. This offered a good opportunity for comparison also.
The full process of stabilization including propagation of the plants in a nursery, dressing slopes, planting onto the slopes and maintenance is described. The condition of the slopes before planting, during growing period, and after the monsoon season in 2010 is described.
In all the projects only local manpower was used. The labourers engaged gained enough skill to work elsewhere.
The demonstration project confirms that the Vetiver system can be used in Assam to control erosion on hill slopes / bridge approaches/ high embankments and river bank. The vetiver system can be used alone or in combination with traditional engineering approaches currently used in the region. This system will bring in a paradigm shift in the erosion control regime of a poor state like Assam through its economy, environment friendliness and community involvement.
The success of these projects established the Vetiver system as self evident and spurred interest in the system throughout India and in Nepal.

Key words: Bioengineering, slope stabilization, erosion control

1.0 Introduction

Soil erosion is one of the largest environmental issues facing the earth today, and the North Eastern region of India, with heavy rainfall, is particularly affected. Erosion devastates infrastructural activities- landslides, erosion by river and flood water take heavy toll of developed infrastructure.

From an engineer's perspective sustainable asset management has posed as a gargantuan task because of soil erosion. Traditional hard engineering is now found to be inconsistent with the three pillars of sustainability- economy, social and environmental.

Hard engineering interventions to prevent erosion have been attempted over decades in the region, incurring large financial and environmental costs, and with limited success. This in combination with limited State budgets makes finding an alternative, low cost, environmentally sustainable solution imperative. One such method that shows considerable promise is Vetiver grass. The following three demonstration bioengineering projects were taken up to show the efficacy of the Vetiver system

1. Hill slope stabilization – Chunsali hills, Guwahati
2. Bridge approach / road embankment protection- Doria bridge, Majuli
3. River bank protection – Afala, pitting the Vetiver system against the mighty Brahmaputra.

2.0 The Options for Erosion Control

2.0.1 Traditional "Hard" Engineering Structures and Climate change- need for a change towards bioengineering.

Traditional "hard" engineering structures that aim to directly reduce erosion include concrete and stone rip-rap, stone filled gabion baskets, and masonry walls.
These traditional engineering systems involve use of stone, cement and steel- each with high energy embodiment, Also because none of these materials are available locally at the sites of concern, they all need to be transported over large distances. This makes these methods both costly and environmentally damaging. The energy footprint of hard engineering is very high contributing to the global warming. The mining involved also devastates the environment. Hence the environmentally conscious engineers and development consultants are looking for a green solution. Vetiver, a C4 plant, has stood up as an excellent tool in this context.

2.0.2 Vetiver Grass Technology

Vetiver, a plant promoted to help conserve soil and water for agriculture by the World Bank in the 1980's and 1990's (Greenfield 1989 and National Research Council 1993), evolved in the late 1990's to become an important soil bioengineering tool. The benchmark experiments on vetiver root strength in 1996 were an important step towards its wider acceptance. The experiments confirmed a mean tensile strength of some 75MPa at 0.7- 0.8mm root diameter (Hengchaovanich and Nilaweera, 1996). The roots of vetiver grow rapidly and can achieve a depth of 3m in one year. Vetiver can grow in adverse soil conditions and extreme climatic conditions (Truong 1996). The vetiver system has become a field tested, economical, environment and community friendly, sustainable system for erosion control on slopes and in drainage systems.

2.0.3 Effect of Vetiver grass on erosion control.

The occurrence of erosion can be briefly described as comprising of the following three phenomena:

1. Sub aerial preparation – Vetiver canopy dissipates rain drop energy and reduce Wind erosion
   -Stems reduce run-off erosion by spreading the flow and decreasing the run-off velocity

2. Particle entrainment - Submerged canopy and stems reduce near-bank flow velocity, damps turbulence, dissipates wave energy
   - The root system physically restraints soil particle, provides an apparent cohesion which increases critical shear stress.
3. Mass failure - The root system increases drainage and permeability which results in a decrease of excess pore pressures, tensile strength of the roots hinder crack forming and hinder pushing off aggregates of soil

2.0.4 Why Vetiver plant?

The ideal plant for use in bioengineering should have the following qualities:

- long, strong and abundant root matrix.
- ability to grow as a dense hedge
- very quick growth
- ability to grow almost everywhere
- High biomass below ground, low biomass above ground
- should be non invasive so that the local ecology is not disturbed
- Should be perennial and permanent
- It should exhibit xerophytic and hydrophytic characteristics if it is to survive the forces of nature.
- It should not compete with the crop plants it is protecting.
- It should be free of pests and diseases.

Vetiver is perhaps the only plant with all the above qualities.

2.0.5 Slope stability and root strength:

Shallow slips of 1-1.5 m, comprise the majority of problems faced by most people after slope formation, especially in regions with prolonged and high rainfall. This problem still arises despite the fact that slope analysis might have shown a slope to have adequate overall factor of safety. To tackle this problem, engineers conventionally rely on the use of ‘hard’ or ‘inert’ material such as mortared riprap, shotcrete or the like to seal off the slope to prevent water infiltration that is deemed to be the cause of the slippage in the first place. However, not in all cases they succeed.

An alternative solution, as mentioned in the Introduction, is to resort to vegetation, in this case vetiver, to help strengthen the surficial 1-1.5 m layer that is prone to slippage. How vetiver roots help in the strengthening the outer zone is explained diagrammatically below (fig 3):

When vetiver roots interact with the soil in which it is grown, a new composite material comprising roots with high tensile strength and adhesion embedded in a matrix of lower tensile strength is formed. Vetiver roots reinforce a soil by transfer of shear stress in the soil matrix to tensile inclusions. In other words, the shear strength of the soil is enhanced by the root matrix (Styczen and Morgan, 1995). As mentioned in the introduction, vetiver roots are very strong with high mean tensile strength of 75 MPa or approximately 1/6th of strength of mild steel. When the dense and massive root networks act in unison, they resemble the behavior of soil nails normally used in civil engineering works. With its innate power to penetrate through hardpans or rocky layers, the action of vetiver roots is analogically likened to ‘living soil nails’ by the Hengchaovanich .

Fig. 1 : The Root

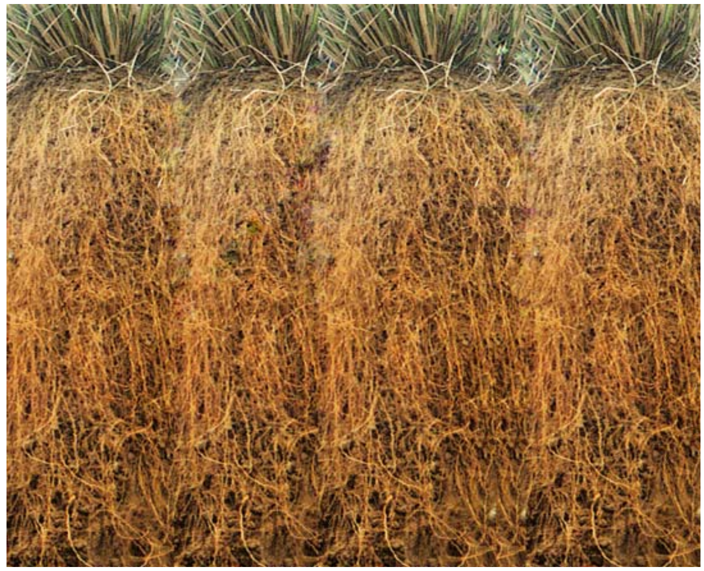
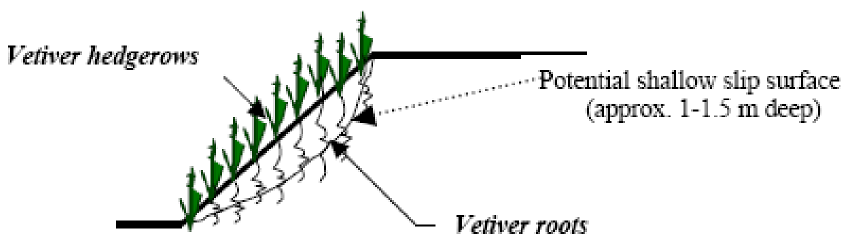


Fig.2 : The root matrix

Fig. 3 Slope stabilization mechanism by vetiver



3.0 The hill slope on Noonmati- Kharghuli Road, Guwahati

This hill slope on the eastern part of Guwahati is badly affected by landslide. The slips were observed to be shallow, about 1m. The slope was very steep before intervention. At locations it was almost vertical.

It was not possible to trim the entire slope uniformly to a gradient of about 45 deg. The district administration of Guwahati does not allow hill cutting on a major scale. Hence the slope fascia was trimmed to the extent possible just to give a smoother profile. Thus the slope at certain locations remained as steep as 60 deg.

3.0.1 Soil characteristics:

Type of soil = Inorganic clay

Specific gravity – 2.67

C= 0.35, Φ=15 º

Grain Size analysis-	Sand	Clay	Silt
	10%	70%	20%

Chemical Test, PH value- 5.5

4.0 Doria bridge approach:

This vetiver demonstration site for bridge approach was selected in the river island Majuli. Majuli is notorious for erosion and the local soil is silty sand. There is no rock/boulder available in the entire island. Transportation of boulders from elsewhere is exorbitantly costly. Planting was carried out in April, 2010 and the first phase was completed in May, 2010. The condition of slope monitored before, during and after the monsoon season in 2010.

The embankment was not properly consolidated. However, Vetiver grass can establish and thrive on almost any type of soil. The length of the embankment is about 200m on either side. The gradient of the side slope was supposed to be 1V: 2H. But actually the slope was steeper. The vertical height of the embankment near the bridge abutments was 8 m.

3.0.1 Soil characteristics:

Type of soil = Silty sand

Specific gravity – 2.65

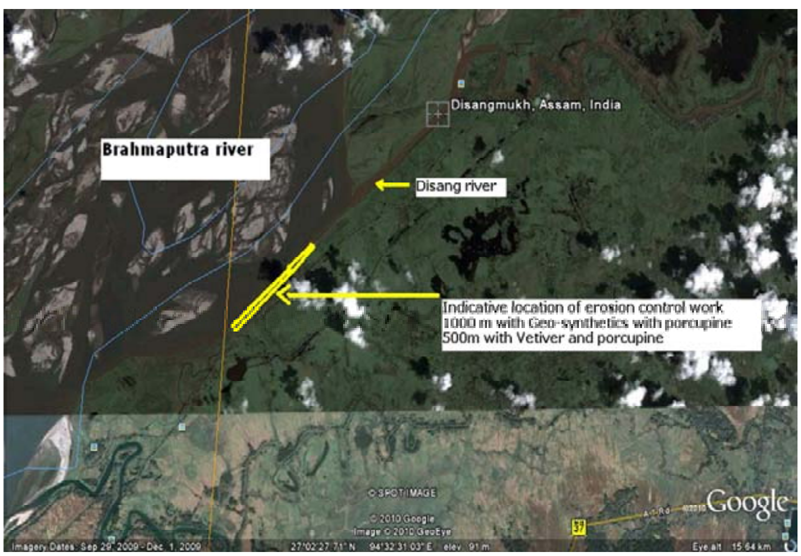
C = 0.1 , $\phi = 26^{o}$

Grain Size analysis-	Sand	Clay	Silt
	70%	8%	22%

PH value- 6

5.0 River bank protection work at Afala

This location was selected by the Water Resources department of Govt. of Assam. The bank retreated by a staggering amount of more than 1000 metre over the last 12 years. A large channel of the Brahmaputra has moved southward eroding the bank. Here the Water Resources Department decided to use the state of the art geosynthetic mattress on a 1000 m stretch, Vetiver system on 500m stretch just downstream of the geosynthetic mattress. Over the entire stretch, RCC porcupine (a permeable spur) was laid to reduce the energy of flow near the bank. These porcupines were placed at 250m apart.



5.0.1 Soil characteristics

Soil was not analyzed. Physically it was silty sand. Local variety of vetiver was seen thriving well in the location. This led to the belief that the vetiver system will work well.

6.0 Climate

Climate is an important factor for the vetiver plant to grow well and determines the optimum time for planting.

- In Assam the rainy season that starts April and lasts until the end of September. The average annual rainfall is about 3000 mm/ year.
- The rain along with the summer temperature of about 35 deg C helped the growth.

But with Govt. funded projects the planting time depends on the placement of order. In the Doria and Afala projects, the plantation got delayed due to official clearance and the plantation had to be done during heavy rains.

7.0 Propagation of Vetiver Plants

Nurseries were established at every site *not* to multiply, but to establish the vetiver plants in poly pouches required for the works. The stock of vetiver plants of Karnataka variety were brought from certified mother nurseries around Guwahati. The tillers, immediately after transportation, are de-stressed in a specially prepared pit of mud and cow dung slurry mix. After de-stressing for about a week, the plants are put in plastic pouches. Pouches are filled with 50% soil and 50% dry cowdung. The pouched plants, after about one month, are again transplanted first in first out basis.

8.0 Planting Specification

The planting pattern depends on the soil properties of the bank/slope, gradient, run-off and the hydraulics of the river flow.

8.0.1 Chunsali hill slope:

The Chunsali hill slope described in this paper was planted with vetiver along the contour to the extent possible in rows with 1m spacing measured along the slope. Although the slope was quite large, no water management was resorted to for the purpose of taking the run-off away from the slope initially. The aim was to see the efficacy of the vetiver in the worst case.

8.0.2 Doria bridge approach:

At Doria approach, the design was as given in fig. 4, 5, 6 below.

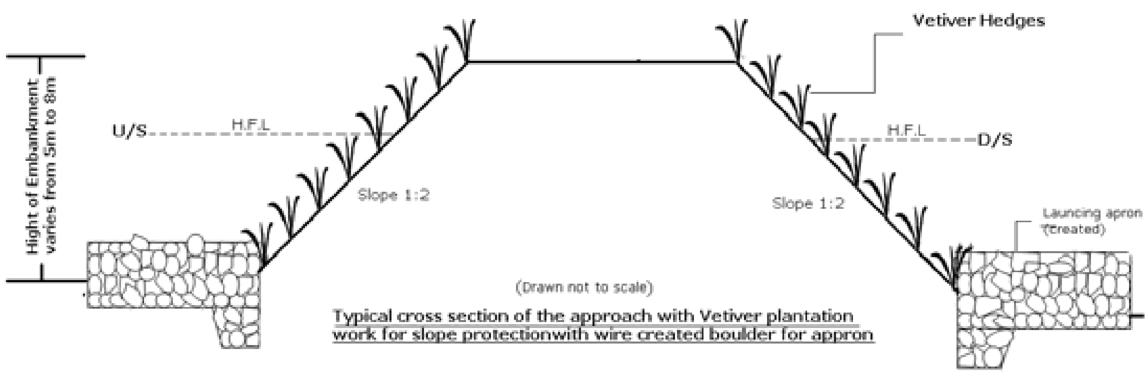


Fig. 4

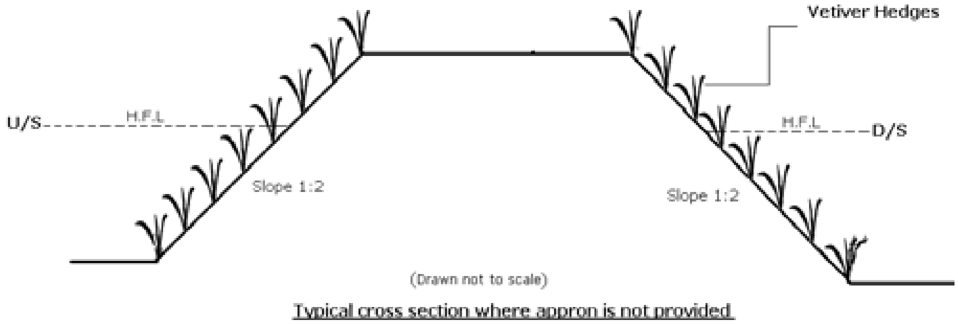


Fig. 5

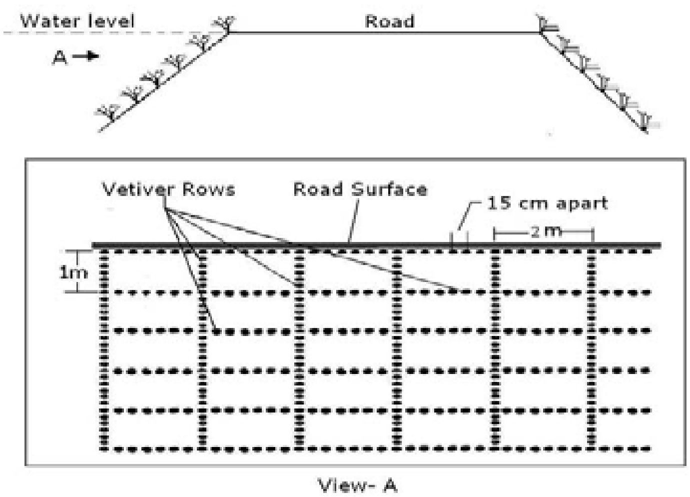


Fig. 6

8.0.3 Riverbank protection work at Afala:

The bank was trimmed to a gradient 1V : 2H. Plantation was started on 28/2/2010. Plantation was done in grid pattern with the distance between rows parallel to river flow being 1m and between the rows normal to the river flow 2m. plant to plant distance was 10cm. On the crest of the slope, a strip of 4m was planted in diamond pattern to prevent formation of tension cracks. Plantation was done from the LWL.

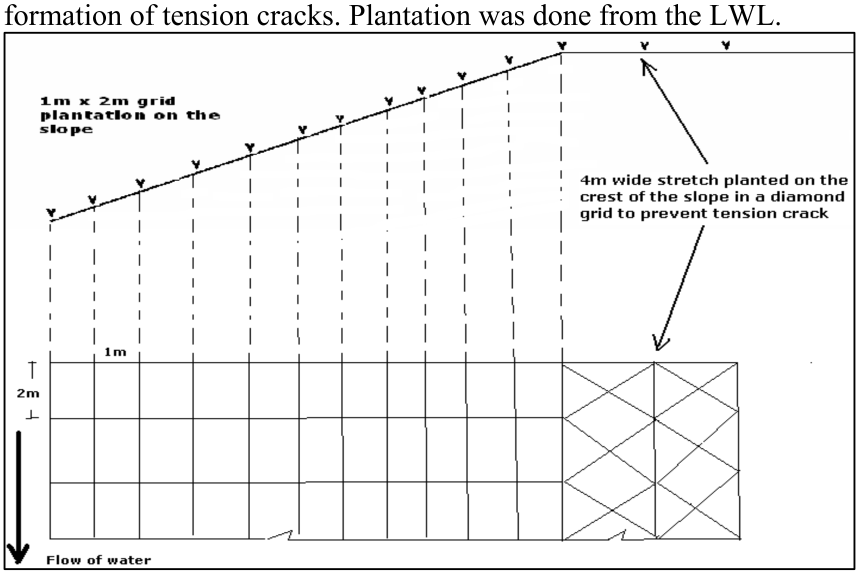


Fig.7

9.0 Description Prior to Planting, during growing period and after monsoon

9.0.1 Chunsali Hills: The hill slope was facing surface erosion and heavy rain cuts. There was mud flow during heavy rain which affected the road down below. The run-off from above the slope was too large for normal turfing to handle. There was no engineered drainage system. However, there was no large mass failure perhaps because of the toe wall.

It was not possible to trim the entire slope uniformly to a gradient of about 45 deg. The district administration of Guwahati does not allow hill cutting on a major scale. Hence the slope fascia was trimmed to the extent possible just to give a smoother profile. Thus the slope at certain locations remained as steep as 60 deg.

Several benches were cut to facilitate planting as well as maintenance. Poly pouched plants were used, planted at a spacing of 100 mm. Cow dung and DPA was added during plantation. Vesicular Arbuscular Micorrhiza (VAM) was also used for promoting quick growth. Irrigation was not necessary as the plantation was done during the rainy season

This work started on 16th February, 2010 and completed on 12th April,2010.

Photograph of the slope before Vetiver plantation is given at fig.7 below.

The growth was very good from the initial stage itself. We found that use of VAM accelerates the growth. There was some rain cuts in the initial stage which were plugged and plants which were washed away were replanted. Care was taken to ensure that there is no gap in the hedge. Photographs at Fig. 8, 9, 10,11& 12 show it all.

Severe land slide on Noonmati- Kharghuli Road

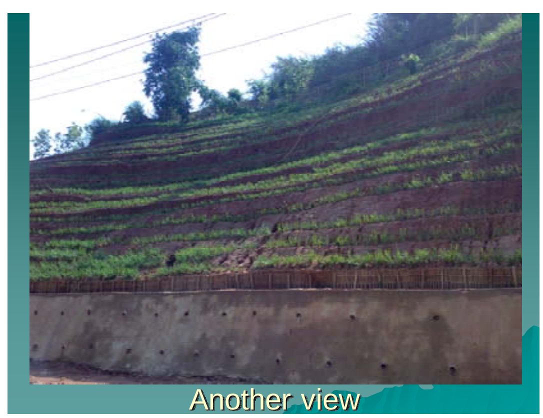
Fig.8

Plantation of Vetiver on the same slope

Fig. 9

Vetiver plantation in the 3rd month

Fig.10



Another view

Fig.11

Fig. 12

9.0.2 Doria bridge approach: The bridge approach was poorly compacted**.** The gradient was also more than 1V: 2H. Sand bags were used during planting so that the soil did not slide down. Also as the plantation was done during the rainy season, regular maintenance was required to plug rain cuts, replanting Vetiver. Here also Poly pouched plants were used, planted at a spacing of 150 mm. The pouching was started from December, 2009 and the pouched plants were well established by the time field plantation started. Cow dung and DPA was added during plantation. Vesicular Arbuscular Micorrhiza (VAM) was also used for promoting quick growth. Irrigation was not necessary as the plantation was done during the rainy season

Of course the warmth of the summer and the rain aided quicker establishment.

Refer fig. 13,14,15,16,17,18&19 The vetiver plantation performed wonderfully withstanding heavy rains.

Establishment of a nursery near the site

Fig.13

The plantation

Fig.14

Fig.15

fig.16

fig.17

fig.18

Fig.19

9.0.3 The river bank erosion control work at Afala :

The Brahmaputra is said to be the most difficult river to control in the entire world. National as well as international team of experts have studied this river for the last 50 years without being able to give any solution to control the erosion of the mighty Brahmaputra.

The site allotted to us by the Water resources department, Govt. of Assam was about 2 km downstream of the point where the river Disang meets the Brahmaputra. The length of the

stretch is 500m. just upstream of the vetiver intervention, a 1000 m strip was covered with the state of the art Geosynthetic mattress. The Water resources Department, Govt. of Assam, wanted to see the efficacy of both the system and do a comparison.
The cost of the geosynthetic mattress was Rs.1840.00 (about 40 US dollar) per square meter. Whereas the cost of Vetiver plantation and maintenance was Rs.137.00 (about 3 US dollar)
Erosion due to fluvial scouring as well as due to sloughing occurs. The former occurs naturally during the rainy season/flood season in the summer. Sloughing takes place in the winter when the water level goes down and the bank collapses.

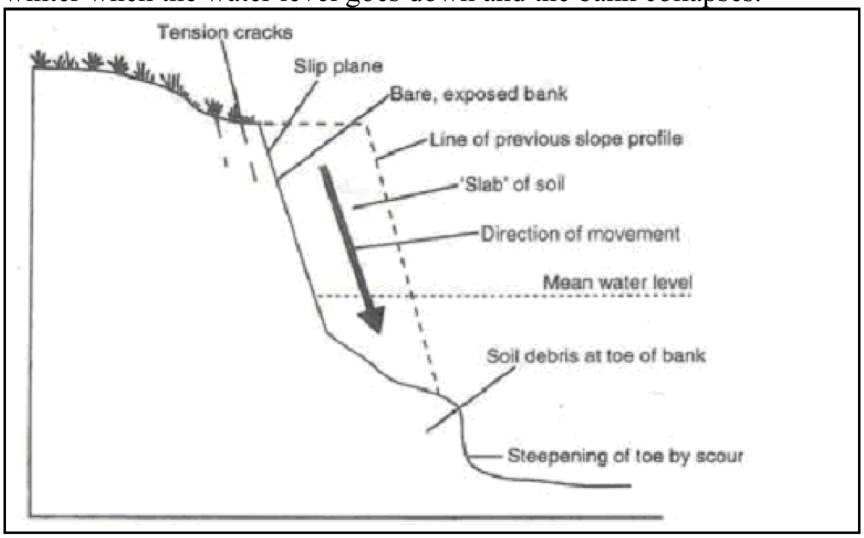


Fig.: 20

The bank height during the winter was a massive 5-6 m. There was severe erosion. Photograph 21 & 22.The bank profile was almost vertical. Soil was silty sand.

Fig.: 21

Fig.: 22

Plants were pouched before transplantation in the field. Cowdung and Vesicular Arbascular Micorrhiza were used. No irrigation as the rains started immediately – from the first week of March. There was unpredictable early rain this time and the rains started before the plantation could be finished. Problems like rain cuts had to be tackled with sand bags.

With the rise of water level immature plants got underwater and on 17/4/ 2010, the entire area was totally submersed. Since then there was total submergence on atleast 5 other occasions. Water receded in between exposing about 3-4 rows (out of 12 rows parallel to the river flow along the slope).
We tried our best to help the plants recover and indeed they recover. Except the rows which remained under water from the beginning.
The flood water started receding in October. It was seen that there was no erosion due to flood. However, this location suffers serious sloughing due to the drawdown after the flood. But the Vetiver could prevent the sloughing whereas the geosynthetic mattress failed miserably.

Fig.: 23 (Nov./2010)

Fig.:24 (Dec./2010)

Fig.: 25 (Jan./2011)

Fig.: 26 (April/2011)

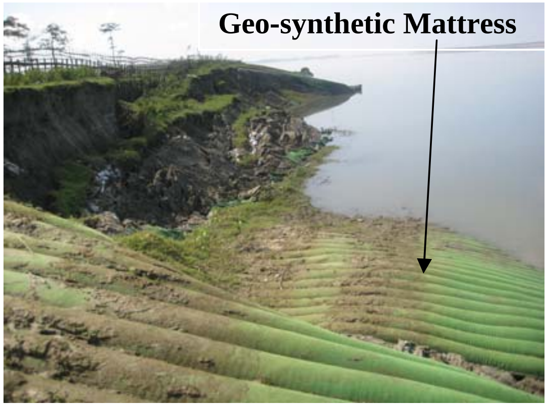


Fig.: 27

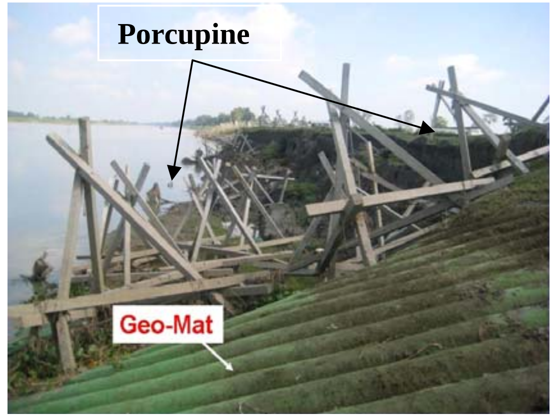


Fig.: 28

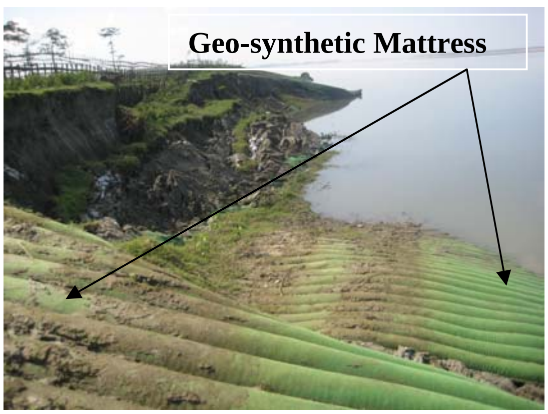


Fig.: 29

Fig.: 30

Erosion continued downstream of the vetiver intervened stretch as shown in fig. 31 & fig.32. Thus it could be concluded decisively that Vetiver could stop the erosion where the geomat intervened upstream and the untreated downstream failed.


Fig.: 31(Jan, 2011)


Fig.: 32 (Jan, 2011)

9.0 Maintenance regime:

DAP was applied as top dressing in the third and fifth month. Panchagavya (an Indian bacterial concoction) was also used as foliar spray twice, in the second and fourth months. Vetiver increases the Micorrhizal activity around the root zone and increases groundwater recharge making the soil fertile for other plants. Hence the weed growth was profuse between the rows of vetiver. This necessitated weeding at regular interval. Manual weeding was resorted to. The entire plantation in both the projects was rain-fed.

10.0 Suggestions:

1. Potted/pouched plants have shorter stress period and hence grow quicker and healthier than bare rooted slips. This was corroborated from results of other projects also.
2. Large slope should be provided with intermediate benches. Vetiver Network recommends benches every 5m vertical distance
3. The plants should be pruned to encourage lateral growth and to reduce the canopy. This exposes the slope surface to enhanced evaporation thus quicker release of trapped water.
4. The top rows on the slopes should be dense to dissipate the energy of the run-off. Hence the planting should not be more than 10 cm apart.
5. On unconsolidated fills, the Vetiver plants themselves should be protected against erosion during the initial period by bamboo palisades/ sand bags.

11.0 Conclusions :

- The vetiver plant grows well in the Assamese climate and the red sandy clay of the hills and sandy river bank
- The vetiver system proved to be one of the rare techniques which proved successful against the erosion of the Brahmaputa
- The hill slope planted with vetiver showed no erosion during the 2010 monsoon season.
- Vetiver grass provides an alternative tool for erosion control on slopes that can be used alone or in combination with traditional engineering structures.
- Assam which is a very high precipitation area can use this green technology to usher in a paradigm shift in the erosion control regime.
- Vetiver can play a major role in sustainable management of infrastructure by controlling the erosion of road batters, bridge approaches, high embankments, roads without cross drainage, mountain roads etc. in an economical and environment friendly way.
- Community involvement is essential for the success of the treatment, particularly for protecting the young plants from animals and pruning the plants 3 months before the monsoon and after the monsoon.
- The community involvement will strengthen the social aspect, one of the three pillars of sustainability.
- Vetiver is a C4 plant which absorbs about 30% more CO_2 from the atmosphere. Thus it is a great tool for reduction of global warming and for realizing the endeavour of the road engineering fraternity to go for green roads.

13.0 Recommendations for Future Works

- Wherever possible the slopes/ river banks should be trimmed to a slope of no more than 1v: 2h.
- The slopes should be contoured so as to produce as smooth a profile as possible so as to reduce the potential stress concentration.
- Proper drainage should be designed to take the precipitation away from the vulnerable slope.
- The top rows, as stated above, should be dense.
- Any gap noticed in the hedgerow due to death of any plant should be promptly closed with replanting.
- For river bank protection work, protecting the toe is paramount. Using Vetiver system with other techniques in tandem should be explored. Possibility of planting a strip of local reeds capable of withstanding inundation should be explored.

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