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Application of Vetiver (*Vetiveria Zizaniodes*) as a Bio-technical Slope Protection Measure –Some Success Stories in Bangladesh

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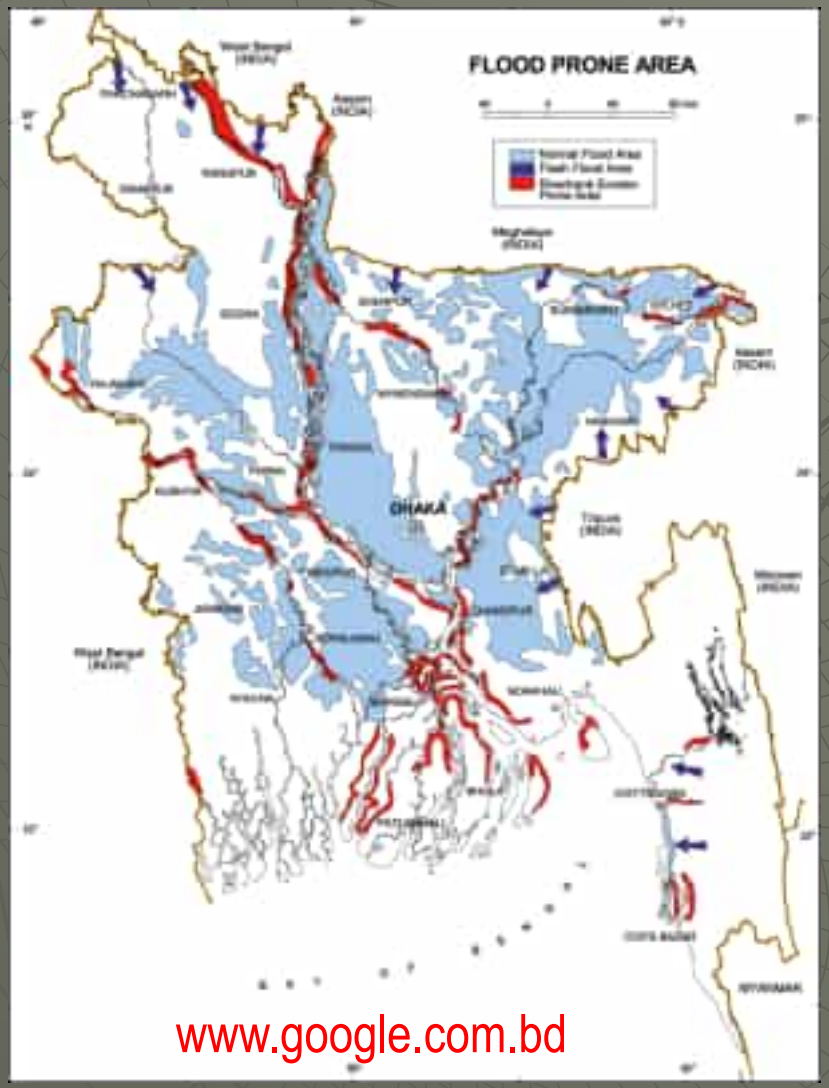
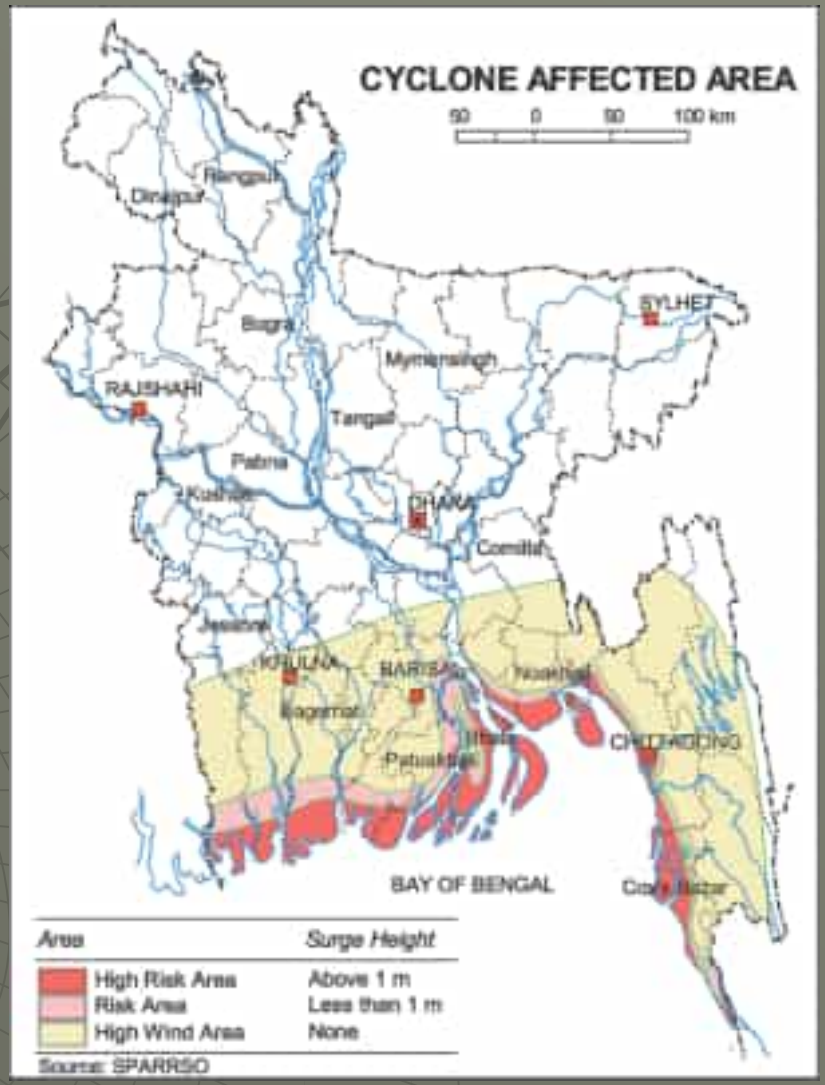
BUET

Bangladesh Map

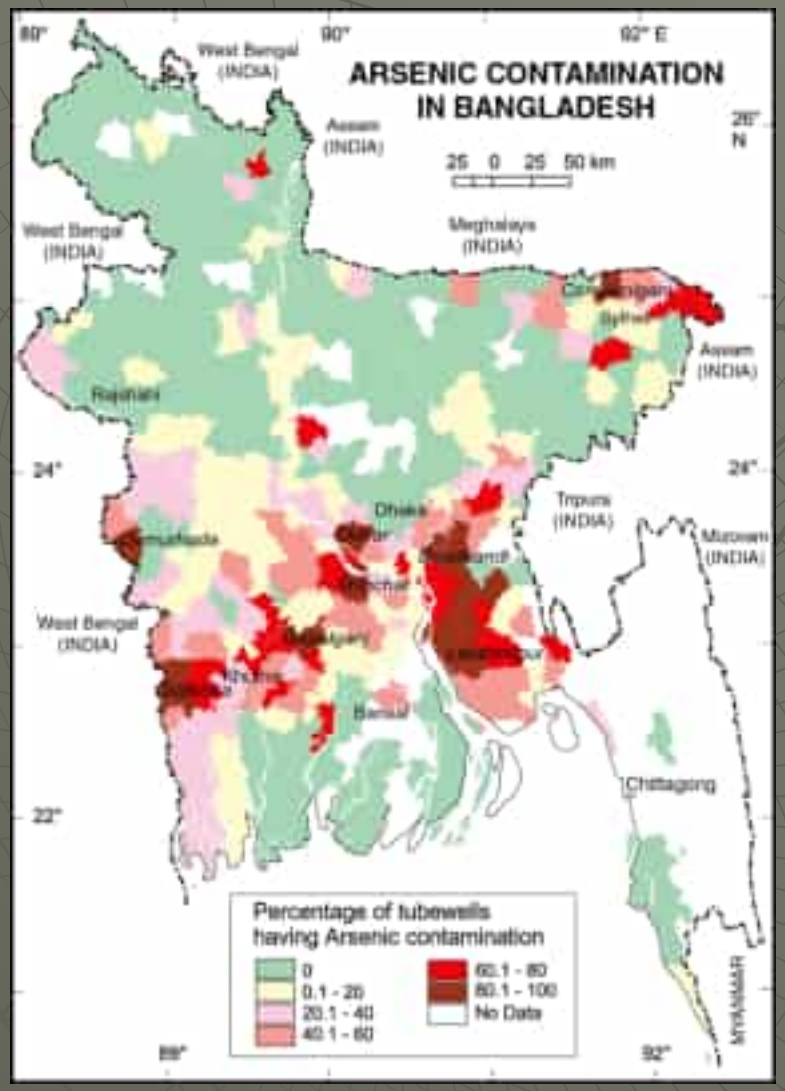
- Population Density: 1203 pop/square km
- Located between 20° to 26° North and 88° to 92° East
- About 50% of the land is within 6-7m of MSL
- Average temperature ranges from 17°C to 20.6°C during winter and 26.9°C to 31.1°C during summer; Annual Rainfall: Maxm. 5690 mm (northeast); Minm. 1110 mm (west)

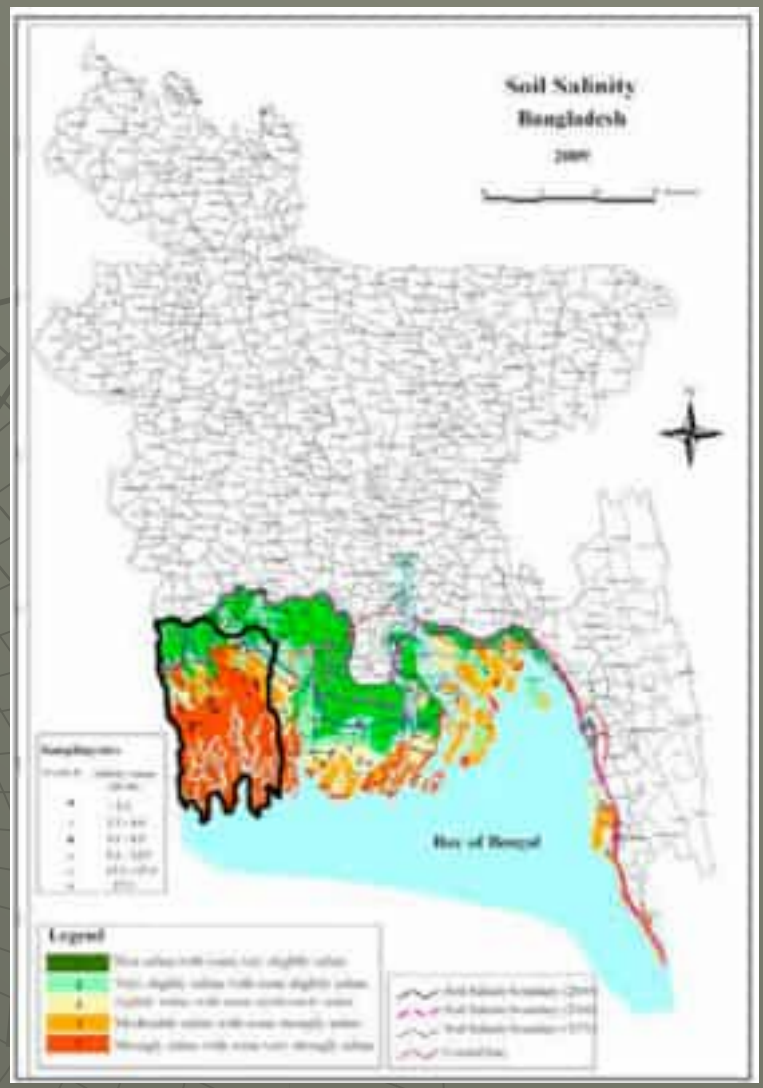
Common Disasters in Bangladesh: Flood and Cyclone



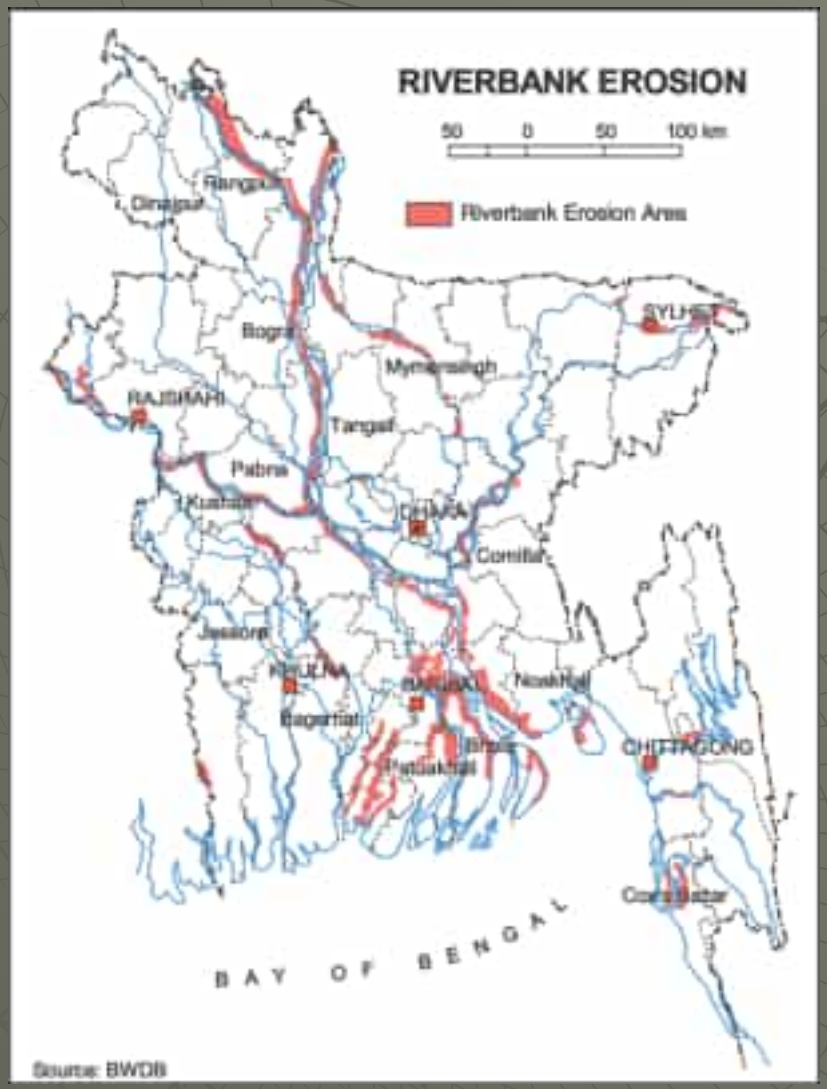


Common Disasters in Bangladesh: Arsenic Contamination and Salinity





Common Disasters in Bangladesh: River Bank Erosion & Seismicity



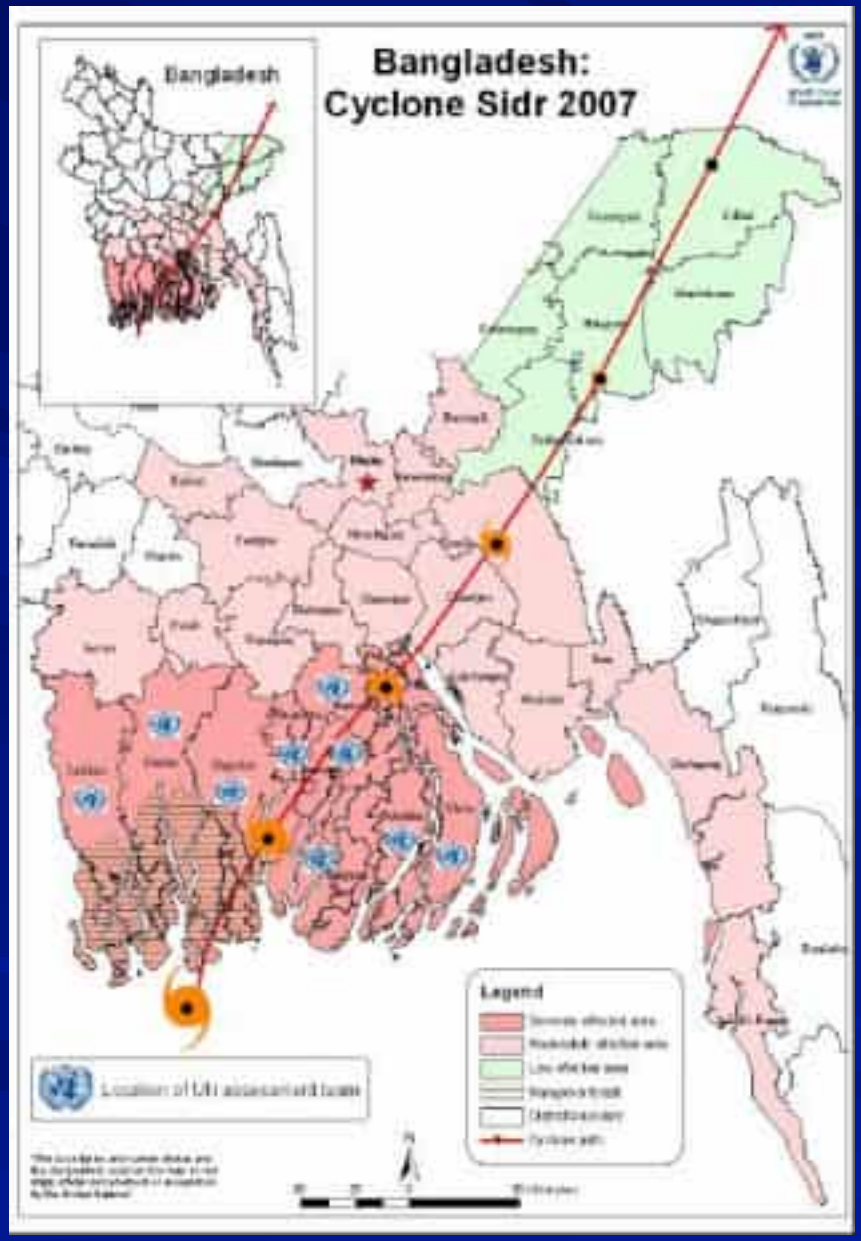
Common Disasters in Bangladesh

Bangladesh is frequented by natural disasters due to its unique geological formation. The most common disasters are:

- Cyclone
- Heavy Rainfall and Flood
- Earthquake
- Arsenic contamination, Salinity intrusion
- Contaminated Water (heavy metal, arsenic, industrial waste, etc.)

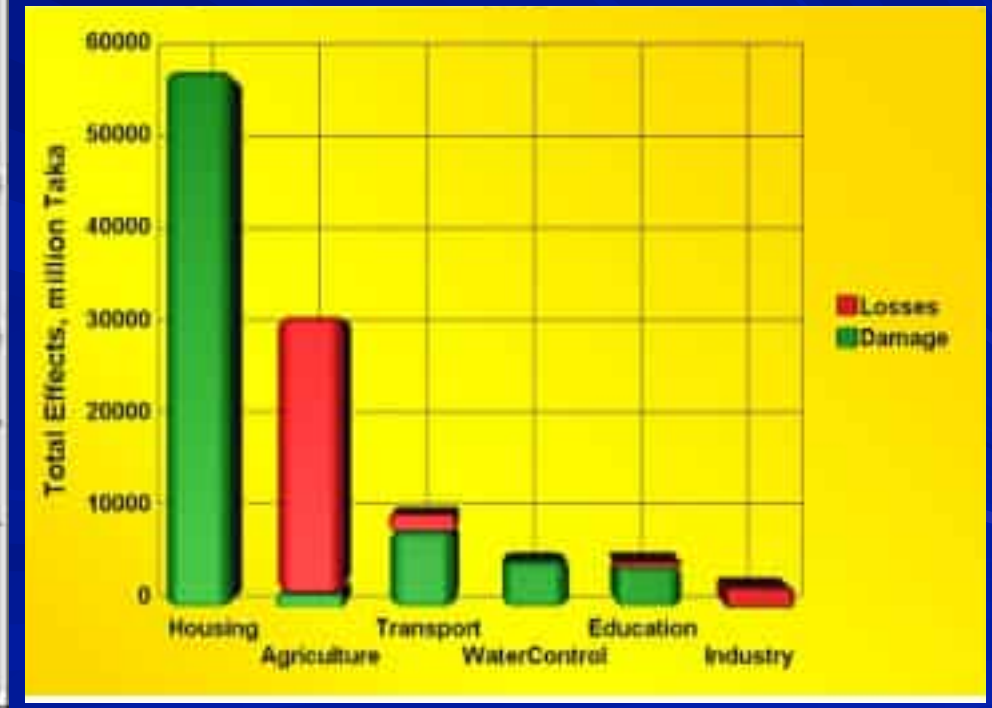
How can we help the Disaster Affected People?

Roads and Embankments



- 1/3 of the country was affected by the cyclone
- Wind speed: 250 km/hr
- Economic loss: 3.1 billion dollars
- Occurred in 2007

SOURCE: DMB (2008)



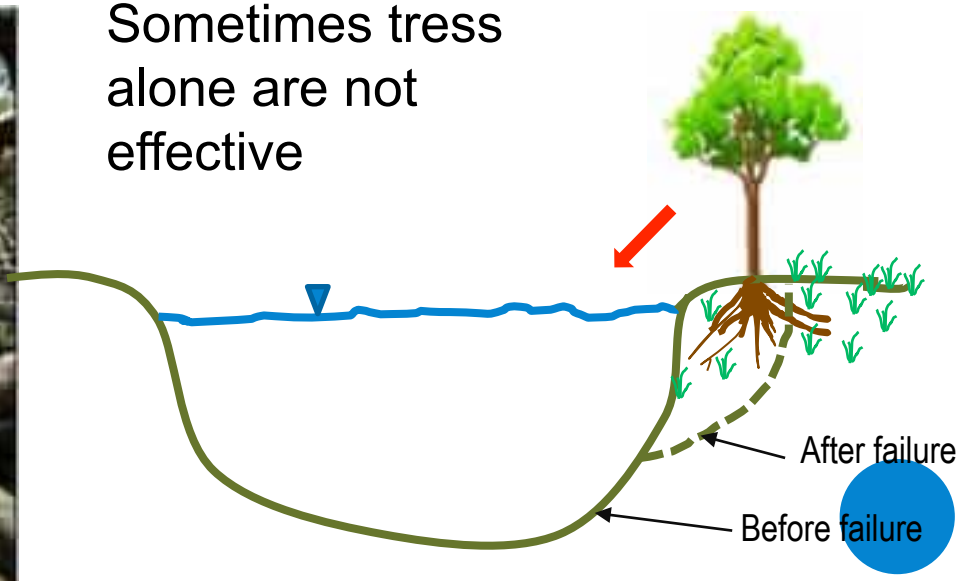
Survey after Cyclone SIDR 2007

Bangladesh has many rivers.

Although Bangladesh is a small country, it has very long coast (750 km).

More than 4000 km coastal embankment has been constructed.

Sometimes tress alone are not effective



REASONS FOR EMBANKMENT FAILURE

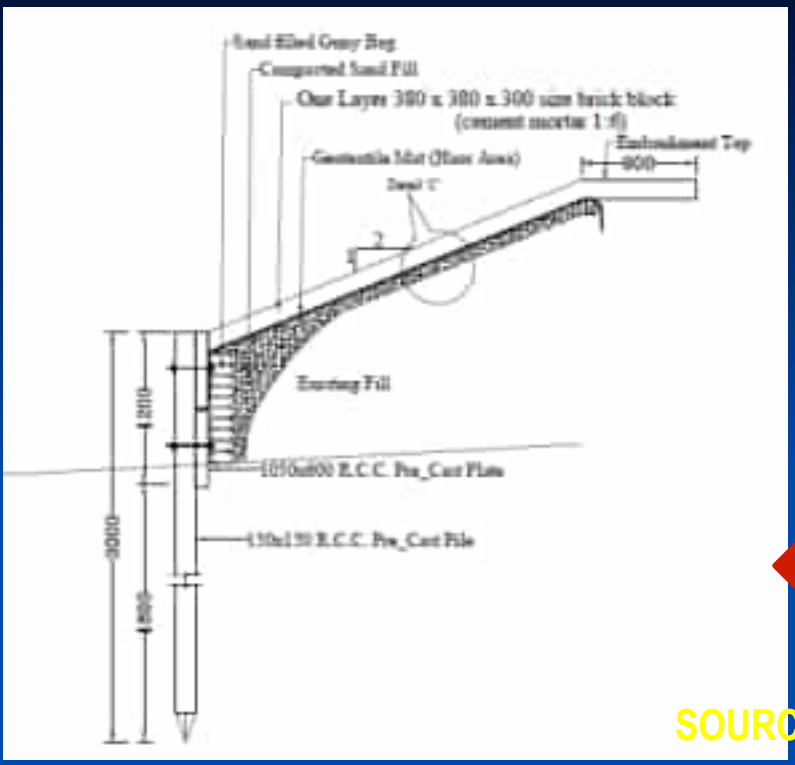
Poor construction practices and improper design of road and embankments without compaction make the embankments easily erodible to rain and wave action.

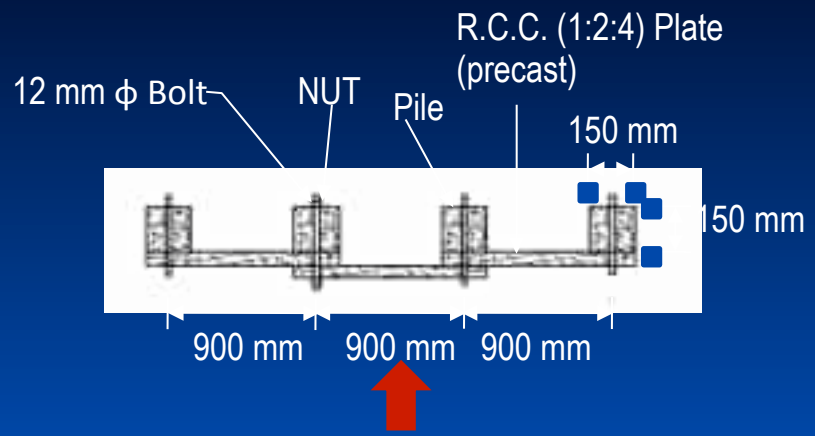
- Rain-cut erosion/Rainfall impact: Bangladesh is a low lying delta formed by recent deposits. Embankments are mostly constructed using dredged material from nearby river bed which are silty sand.
- Wave action/turbulent water currents cause erosion of embankments.
- In some locations soft-soil also cause failure of embankments.
- Human activities (travel paths for men and cattle, cattle grazing, unplanned forestation of embankment slopes).

Dredge material

Dredge material used for road embankment construction

Usual Practices of Topsoil Erosion Control of Roadside Slopes

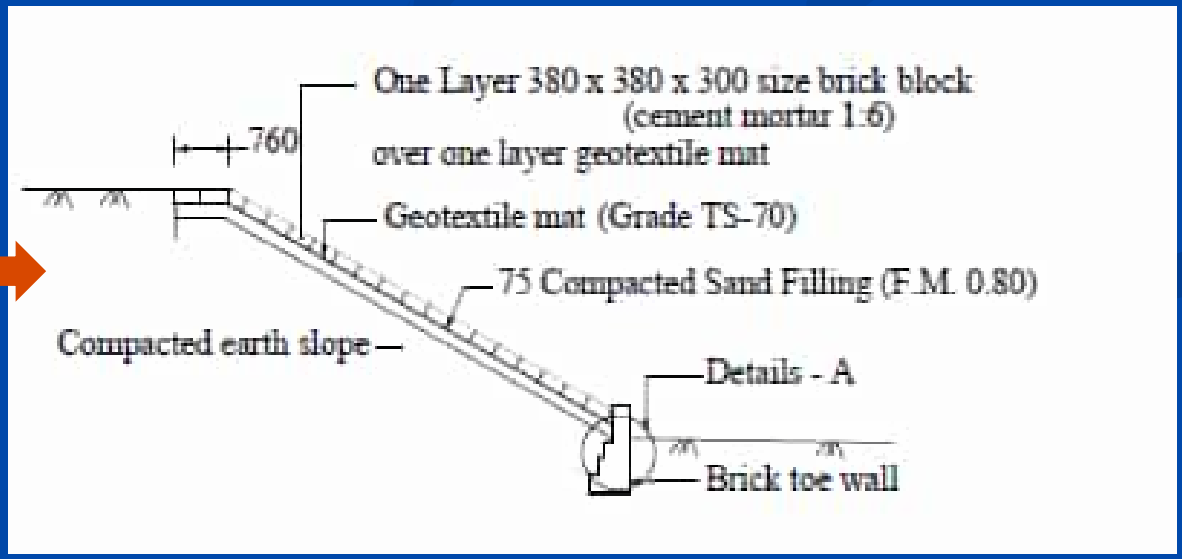




Slope protection work with CC slab on slope and palasiding work at toe

SOURCE: ROAD DESIGN STANDARDS- RURAL ROAD of LGED (2005)

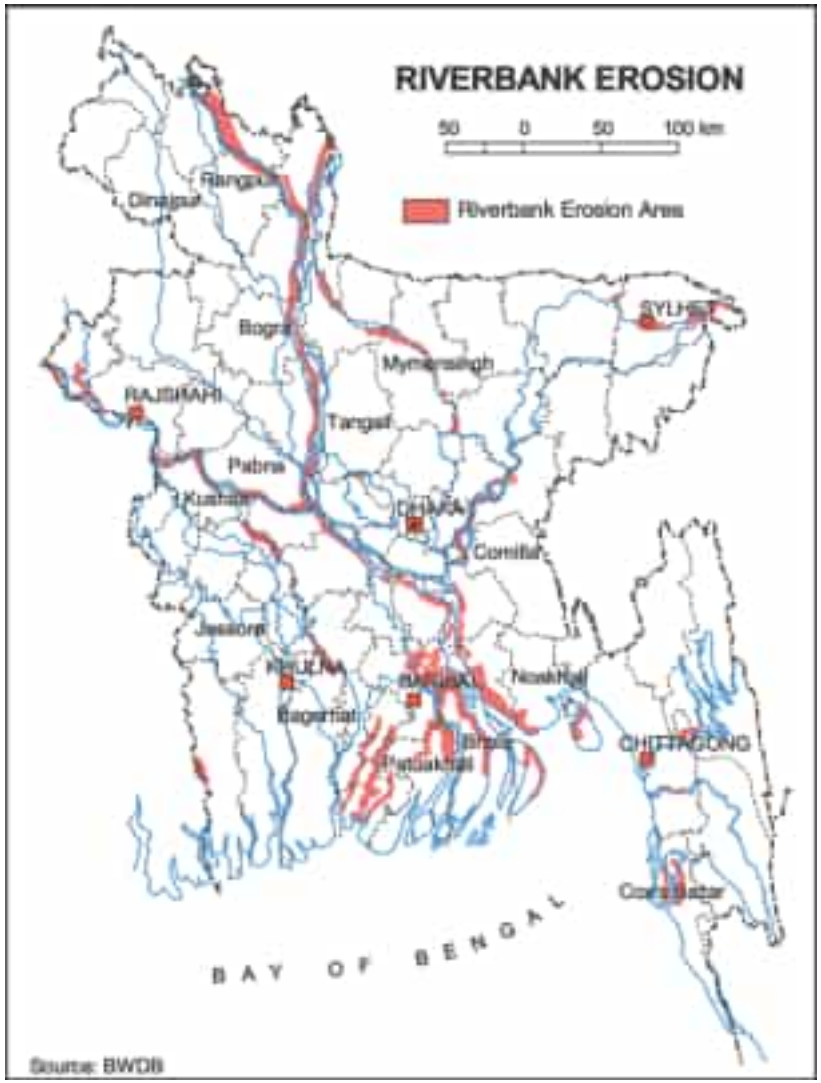
Slope protection work by brick block and geo-textile



River Bank Erosion

যমুনার পানি বাড়ার কারণে তীব্র স্রোতে গতকাল সিরাজগঞ্জ শহররক্ষা বাঁধের গয়লা মসজিদ ও শ্মশানঘাট এলাকায় বড় ধরনের ধস দেখা দেয়। এতে ঘুমন্তির মুখে পড়ে বাঁধটি ● ছবি : এনামুল হক

River Bank Erosion



Daily Prothom Alo, dt: 04.04.2011

The common practices are expensive and in many cases these are not effective during their design life.

Hill Slope

Top Soil Erosion due to Rain-cut at Hilly Regions of Bangladesh

All these slopes are either uncovered or denuded

Landslides a growing concern

In Bangladesh

Farzana Haq

WHEN the harmony of nature is disturbed, it takes revenge. People of Bangladesh have recently seen this devastating side of nature, when soil of Chittagong Hill Tract collapsed, causing death to so many people.

In Chittagong many plants and vegetations have developed on the hill slopes. These plants have been grown for millions of years. The hill tracts are naturally laid on a slope as 1:2 or 1:3, which indicates the proportion of vertical to horizontal distance. In this slope, soil remains safe and comparatively stable.

In Bangladesh the rainy season, the rainfall is heavy and frequently ranges between 1,500 — 2,500 mm per year. This rainfall has a normal tendency to slide down the hill slope. When the hill is covered with plants and huge vegetations, the risk of sliding is less. The heavy raindrops first hit the plants before the slope that reduces their energy. This slowed down raindrop cannot erode the top soil easily.

But when people cause deforestation in the hilly region, this situation alters completely. People living in hilly areas practice 'Jhum' cultivation. They burn plants on hills to create land. As a result, hill top becomes bare and exposed. The rain drops falling on this bare soil causes significant erosion resulting in continuous washing of topsoil.

People living at the foot of the hills in Chittagong maintain a vulnerable existence. They often cut down the soil of hills to construct their houses. In this way, the normal comfort level of this hilly zone is being disturbed hugely. The natural slope of the hill is also altered by making it 1:0, instead of 1:2 or 1:3.

Because of this imbalance in slope as well as deforestation, frequent landslide occurs in the Chittagong Hill Tract.

Is there any way to arrest such erosion of hill slopes?

Dr. Muhammad Shariful Islam, *Associate Professor, Bangladesh University of Engineering and Technology (Buet)* answers:

There are different solutions. To restore a slope to its former condition, filling of that particular section might be needed. But this may not be possible. An eco-friendly long-term solution to this problem is plantation of long rooted vegetation.

If we sow seeds on a slope, then a specific period will be needed to grow these plants. During this period, we can use 'geojute' on the slope surface. Geojute is an open mesh type geotextile. It is biodegradable, eco-friendly and cost effective. Moreover, geojute can absorb water of about 4-5 times its dry weight. The rough surface of jute makes the passing of rainwater difficult on the topsoil by reducing its velocity. This helps to reduce soil erosion. Tree plantation along with vegetation can hugely reduce landslide on hills.

From our experience in various projects, we have seen that some small bushy type plants possess a long and very strong root system. One example is 'Vetiver', which can go up to 5 feet, but its root system can go up to 14 feet below the ground. This strong root system protects the soil from erosion, and thus prevents landslide. At last, we all must remember that we should live in nature by respecting it.

The writer is a civil engineering graduate.

Daily Star: A daily Newspaper in Bangladesh

Haor Area

Haor islands are continuously eroded by wind induced wave action

North eastern part of Bangladesh

Photo: Prof. M. Shamsul Hoque, BUET

Protection System:

Soft Vegetative Protection Measure

-Using Dholkolmi
-Using Bamboo/Murta/'Binna grass
-Using Hizol/Koros Trees
-Bamboo with *Chailya* Grass

Semi-Hard Protection Measures

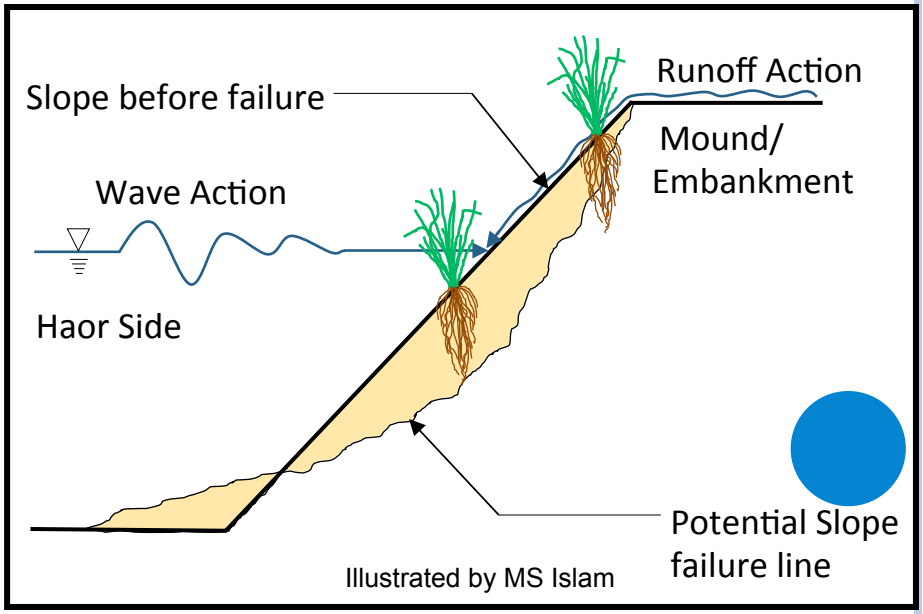
-Using Boulders
-Using Sand Cement Mixture
-Using Cement Concrete Blocks

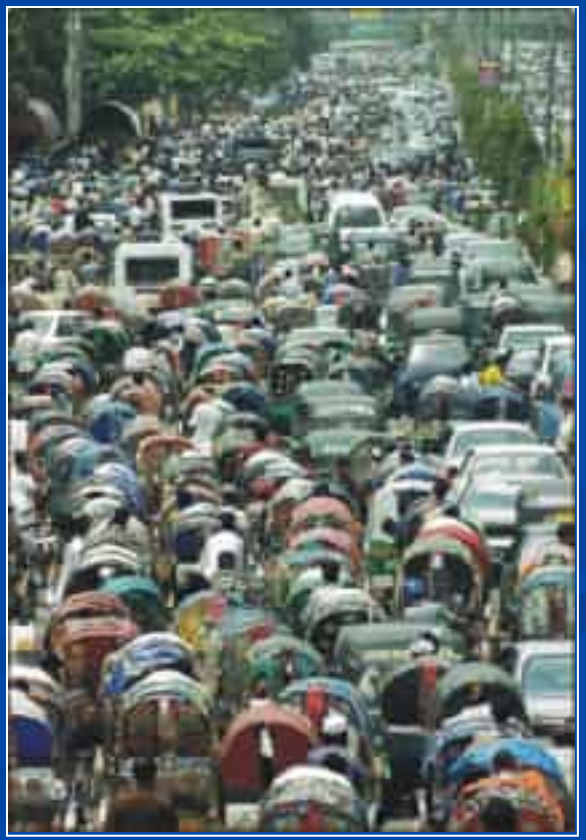
Retaining Wall Based Hard Measures

Ref. Hoque (2013)

Some of these methods are not effective, some take long time, and hard solutions are very expensive.

Slope Failure mechanism and protection using vetiver in Haor Area





Dhaka, the capital city of Bangladesh

Heavy Metals Contamination to Water

জনস্বাস্থ্যের ভয়ঙ্কর হুমকি

নদীতে ধাতব বিষ

প্রতিদিন ১৩ লাখ ঘনমিটার মৃগিত বর্জ্য নদীতে ফেলা হচ্ছে

Heavy metal in Rivers; everyday 13,00,000 ton waste are disposed to rivers

-Daily Janakantha, Bangladesh

Background

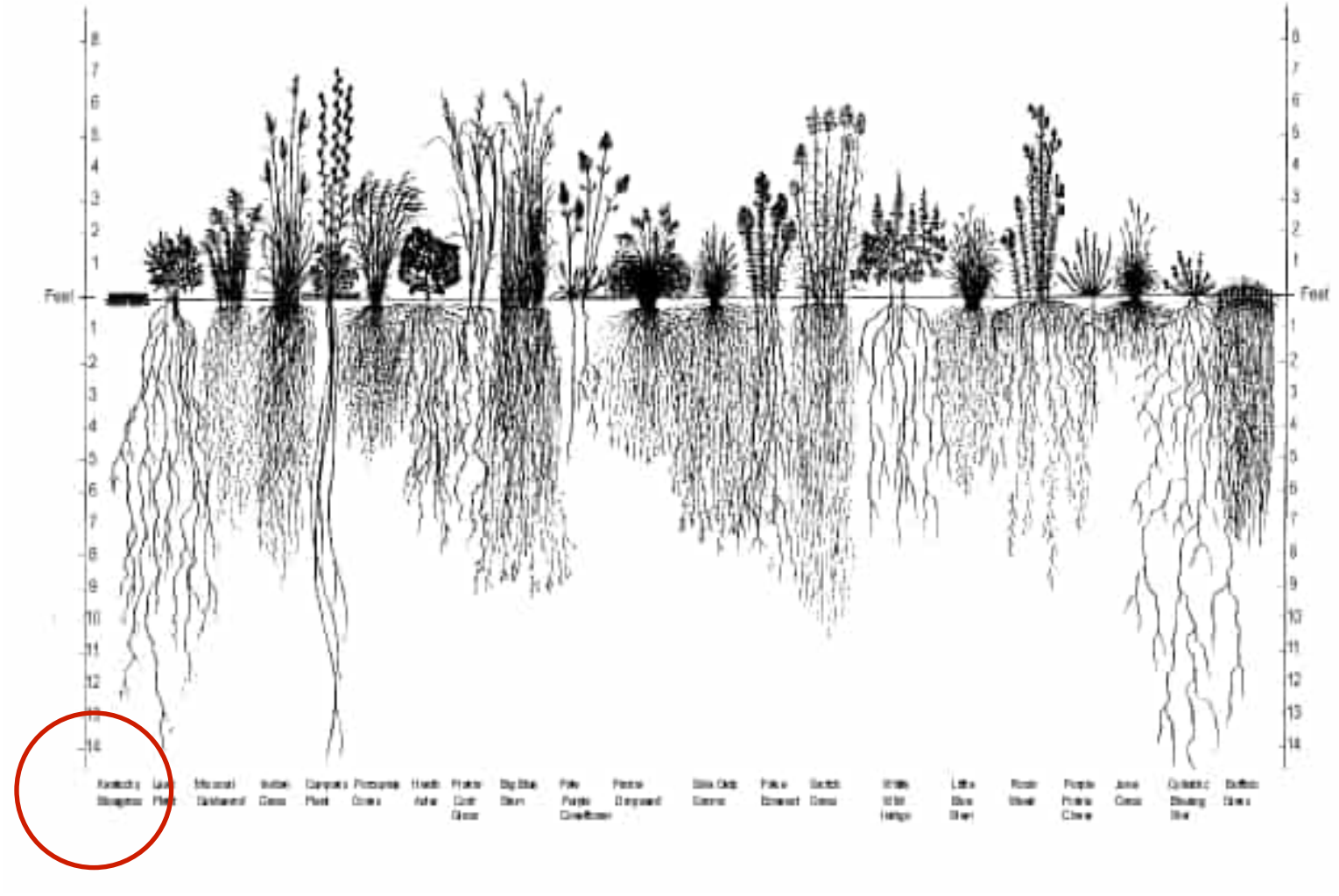
- Failure of embankment and riverbank erosion are common problems in Bangladesh. Devastating flood, excessive rainfall and tidal surge accelerates the failure process.

- Unfortunately our State budget is never sufficient which confines rigid structural protection measures to the most acute sections, never to the full length of the river bank or coastline and embankment.

- This hard engineering structures makes the scenic environment unpleasant and helps only to transfer the problem from one place to another place, to the opposite site, or downstream.

- Establishment of vegetation as a soft bioengineering technique to rigid or hard structures accepted all over the world due to its low cost, longevity and environment friendliness.

Root Length of Various Grasses



Slope Protection: Why Vetiver?

- Vetiver grass is an “ecological-climax” species. It outlasts its neighbors and seems to survive for decades showing no aggressiveness or colonization ability. It withstands drought and high levels of flooding.
- It is tolerant to high levels of pesticides and herbicides and also to a wide range of toxic and heavy metals. Temperature variation from -14º C to 55 º C, Soil pH from 3.0 to 10.5, High level of tolerance to soil salinity, sodicity and acid sulphate.
- 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. The roots of the grass have an average tensile strength of MPa 75 and improve the shear strength of soil by between 30% and 40%. Engineers liken them to a "Living Soil Nail".
- Vetiver grass is an economic attractive solution. In most countries in South-East Asia Vetiver grass can be planted for less than $ 3 per meter, which is 60-70% less relative to hard engineering practice.

All the attribute show that Vetiver grass will be very suitable for slope protection in Bangladesh context.

MAJOR CATEGORIES OF RAINCUT EROSION

Raincut Erosion

-Top soil erosion
-Block slide
-Manmade unstable slopes

Factors for Raincut Erosion

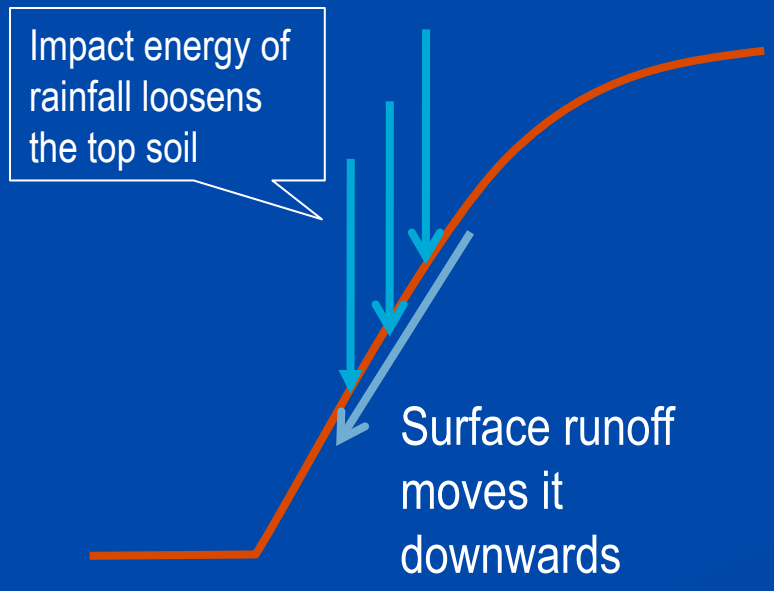
Soil
-Texture
-Particle Size
-Moisture Content
-Surface roughness

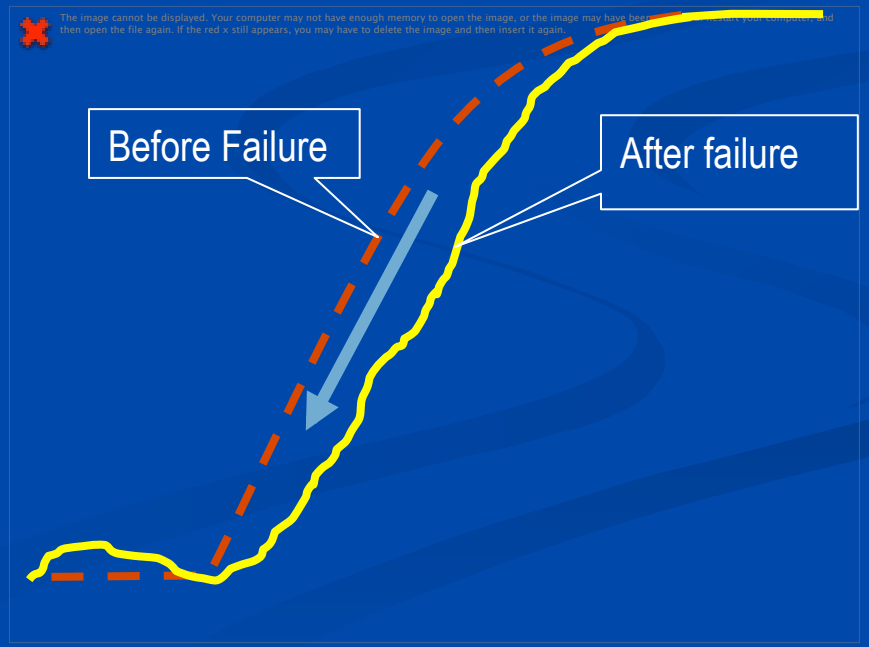
Vegetation
-Type
-Height
-Density of Cover
-Seasonal distribution

Climate
-Temperature
-Rainfall distribution
-Rainfall intensity

Mechanism of top soil erosion

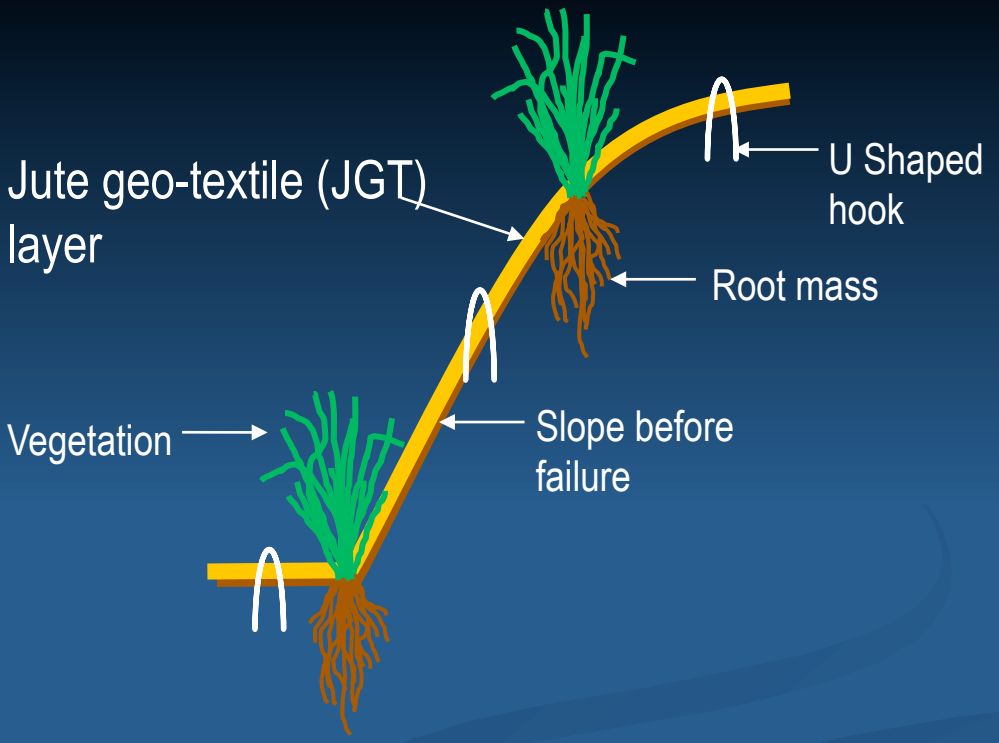
Two fold mechanisms may be involved with top soil erosion:





BIO-ENGINEERING SOLUTION AIDED BY GEOJUTE

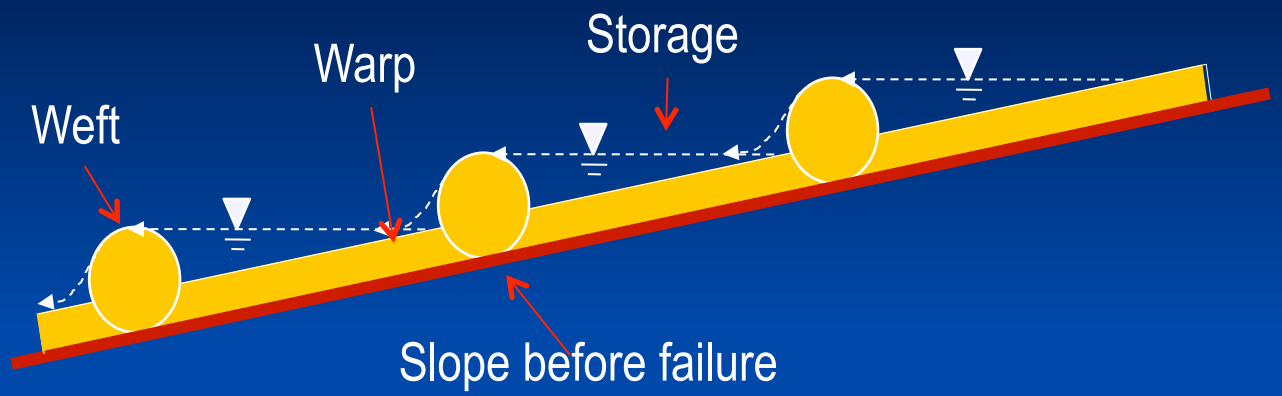
WOVEN TYPE JGT (OPEN MESH)



- **500 gsm-750 gsm**
- **Opening area about 50%**
- **Moisture absorption is about 500% its dry weight**
- **Cost: Tk. 1.60 per sft for 500 gsm**
- **Durability: 2 years**

SOURCE: Bangladesh Jute Mill Corporation (BJMC) and PRIVATE JUTE MILLS

How JGT and Vegetation Act together ?



SCIENCE BEHIND ACTION

•Geojute absorbs water required for vegetation growth and acts as mulch on its biodegradation. As the Geojute degrades with time, grasses and trees grow up and take over the job of Geojute.

•

OBJECTIVES

- Exploration of vetiver availability and their growth characteristics in Bangladesh. Identification of properties of local vetiver (leaf, shoot and root).
- Determination of slope stability of vetiver grass protected slope. Field trials for determining the efficacy under different soil (saline, non-saline, contaminated soil) and geographic condition (flood plain and coastal zone) in Bangladesh.
- Heavy metal extraction from industrial waste contaminated soil. Salinity tolerance of vetiver and salinity removal using vetiver.
- Dissemination of the technology to local people, academia, engineers, NGOs, government agencies and policymakers.

Vetiver (Vetiveria Zizanoides)

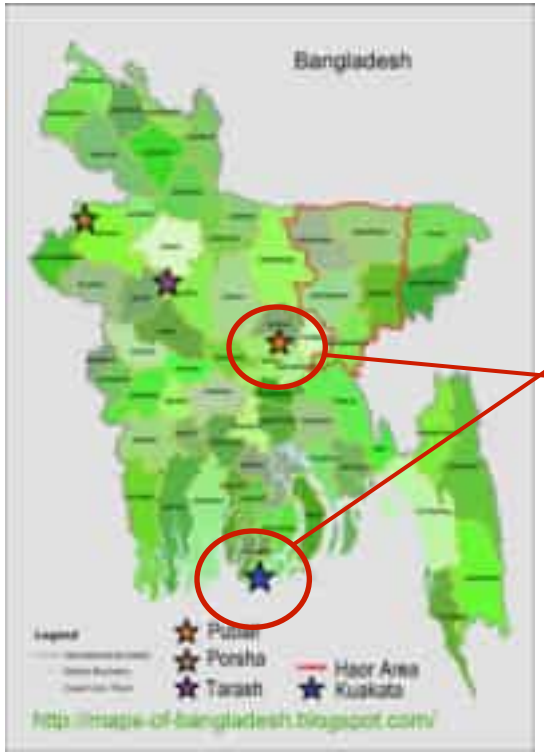
Inflorescence

Vitiver: The root system goes up to 14 ft deep in 6 to 8 months time

Past Researches on Vetiver in Bangladesh

Author(s)	Objectives
Rahman et al. (1996), Uddin (2000), Islam (2000), Thomas et al. (2002), Huq (2006), Islam et al. (2008), Bhuiyan et al. (2008)	Mainly studied the vetiver availability and potential uses of vetiver in Bangladesh.
Moula and Rahman (2008)	Investigated the optimum number of tillers per clump for the proper propagation of vetiver grass.
Moula and Rahman (2009)	Investigated seed germination potential of vetiver grass.
Thomas et al. (2002)	Presented the trials of vetiver grass in 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.

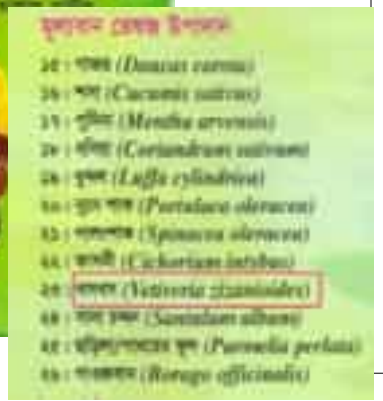
Availability of Vetiver in Bangladesh

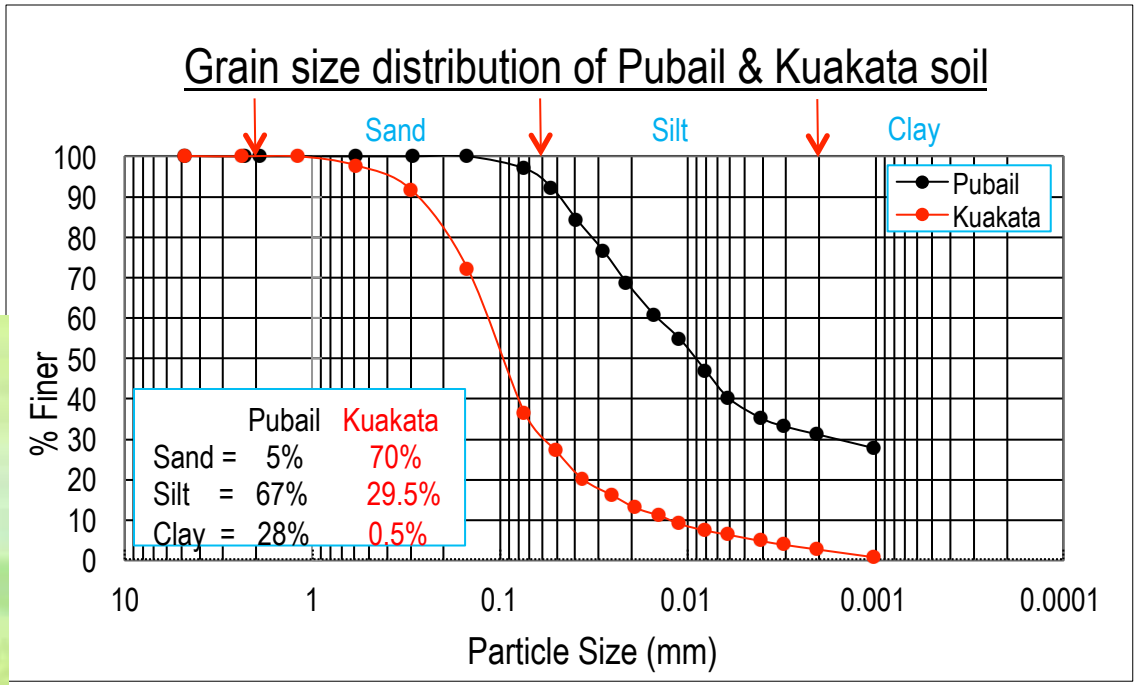


Coastal Zone

Flood plain

A local popular drink





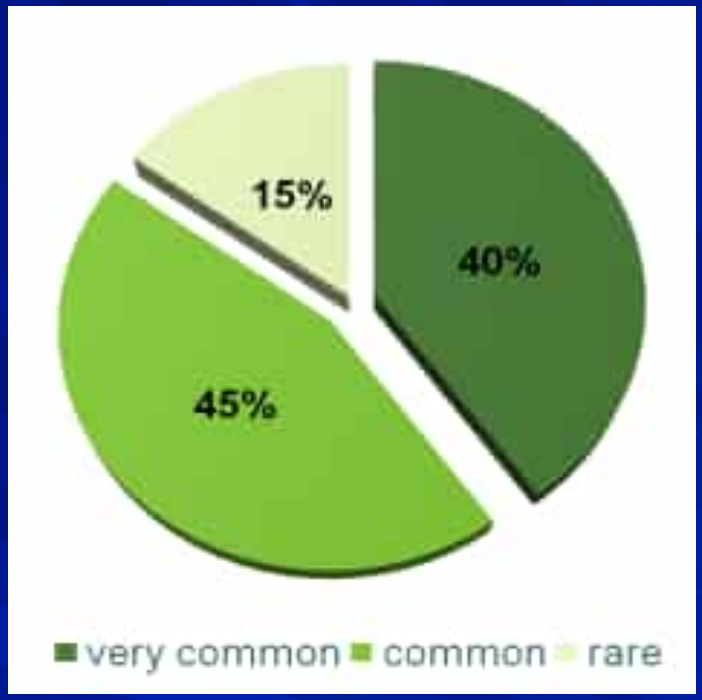
Availability of Vetiver in Bangladesh

Observations

- Vetiver grows both in the clay and sandy soil in the climatic condition of Bangladesh.
- The available type is ***Vetiveria Zizanioides***.
- People already use it for different purposes. As it is a **labour intensive** technique it will be a well accepted in Bangladesh.

VS is not the only solution, but it will be very good for Bangladesh, particularly with sea level rise and increased coastal and flooding damage. VS should also be used for waste water treatment in Bangladesh.

Vetiver Availability in Bangladesh



Reproduced from
Thomas et al. 2002

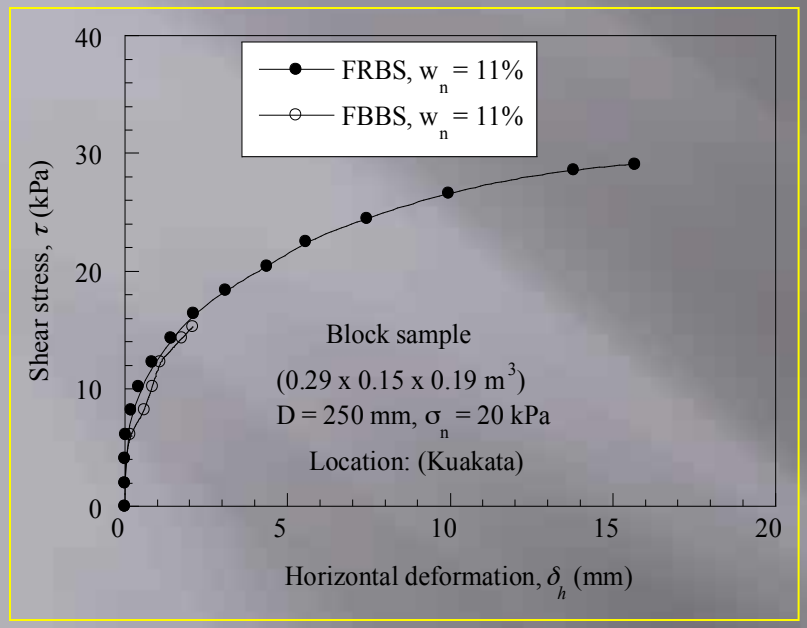
In-situ Test:
Determination of Shear Strength of Rooted Soil

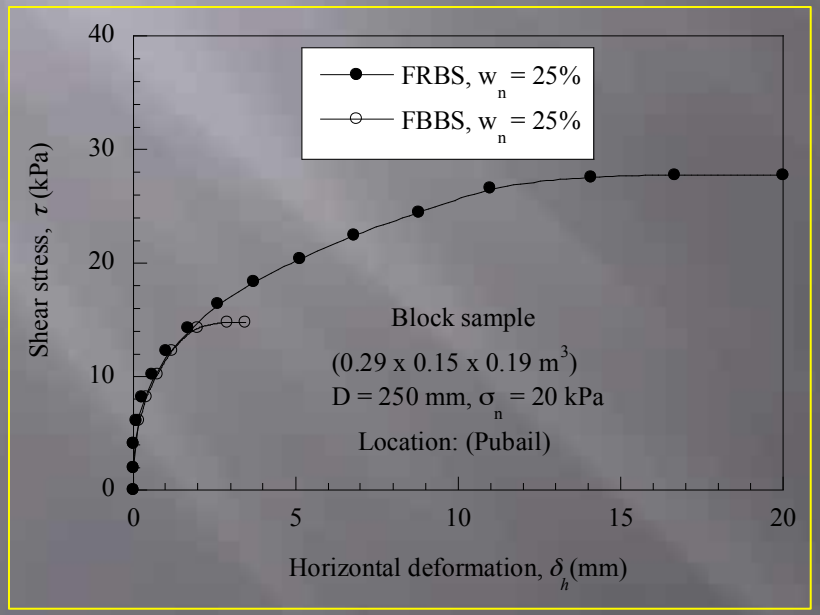
Test Set-up for
In-situ Shear Strength
Determination

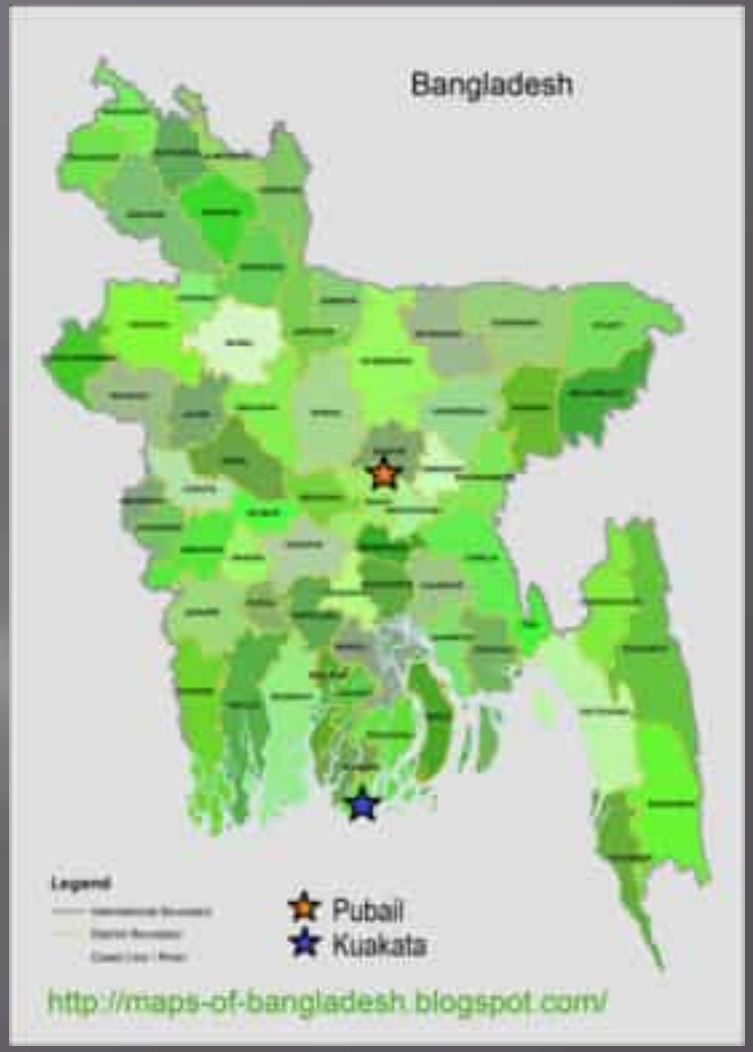
Reasons for Embankment Failure

Un-rooted block sample

Rooted block sample

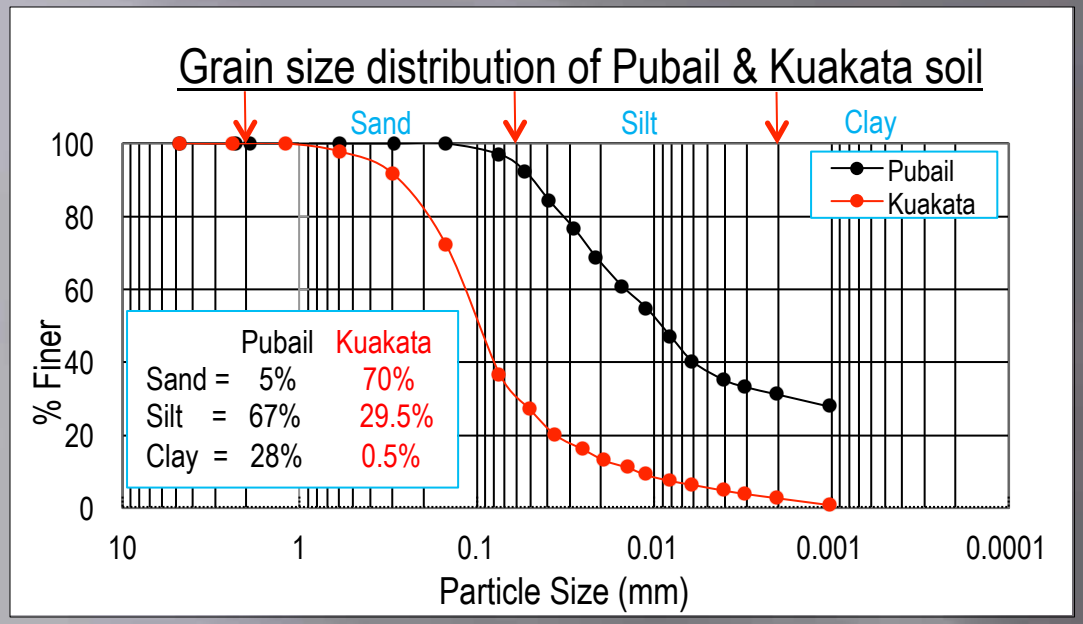


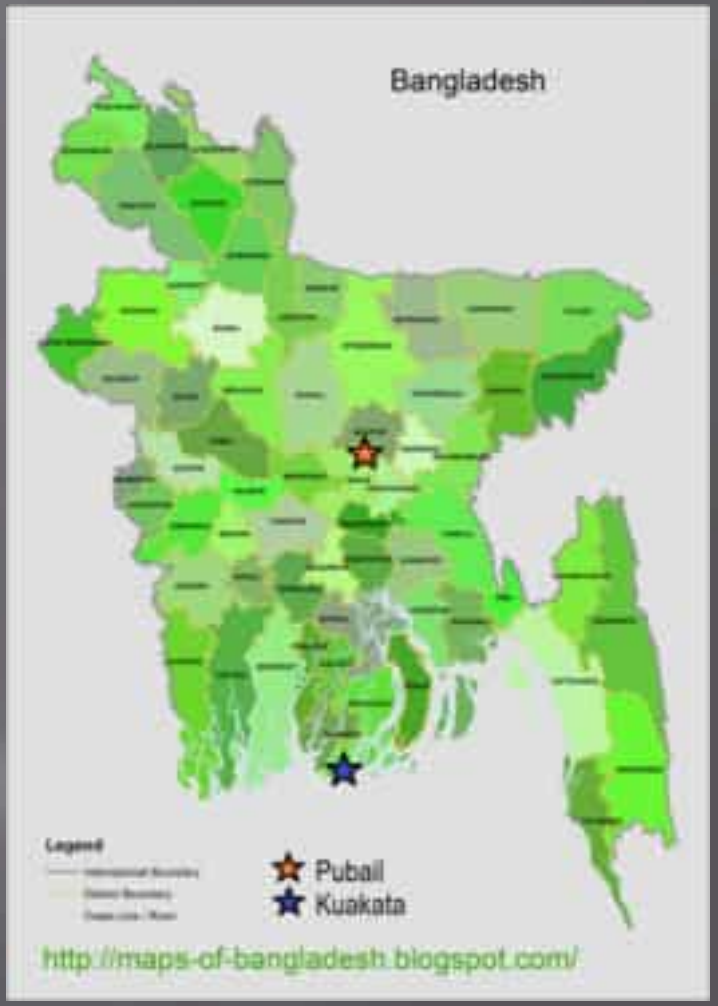


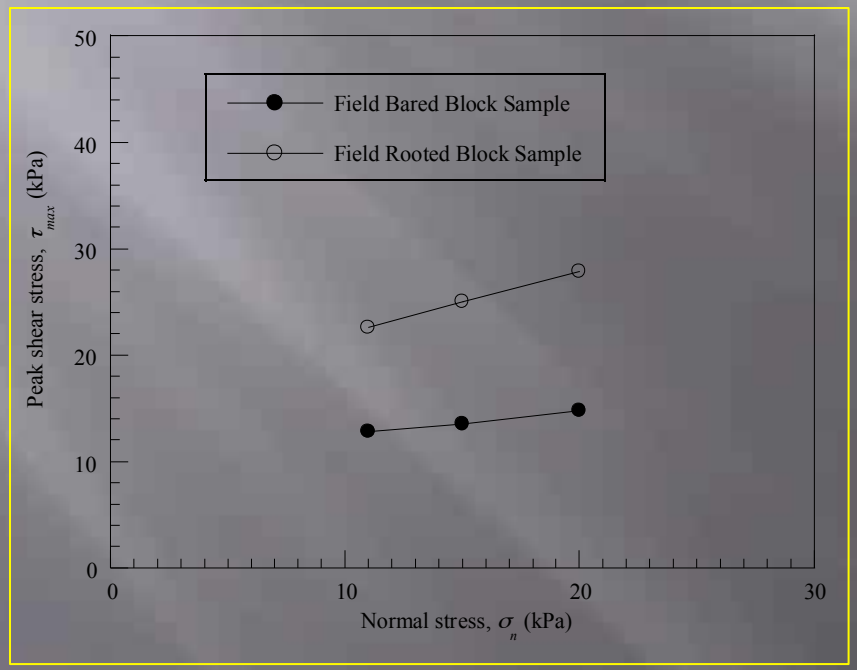


Pubail: Flood prone area
Kuakata: Coastal Zone

Both strength and deformation capacity of vetiver rooted soil matrix are higher than those of the bared soil





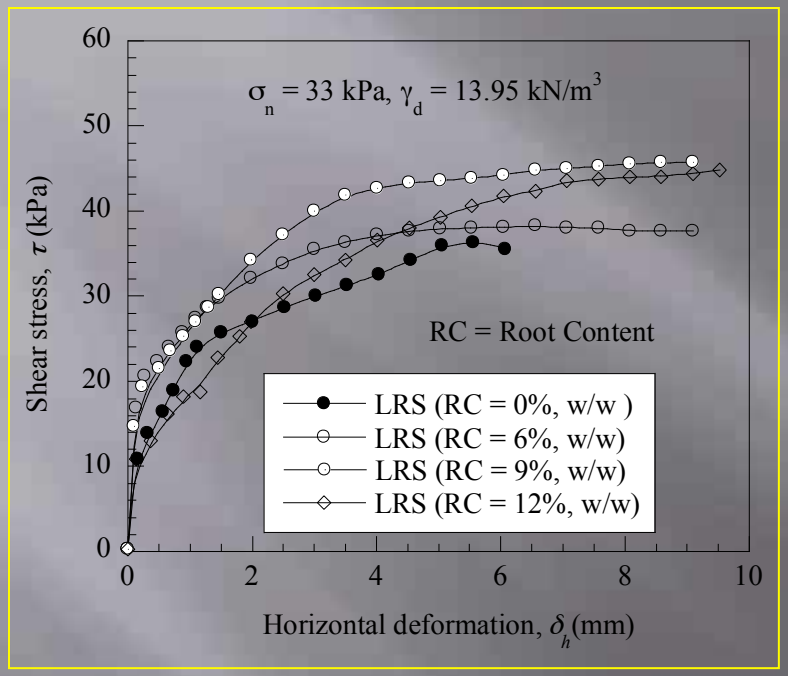


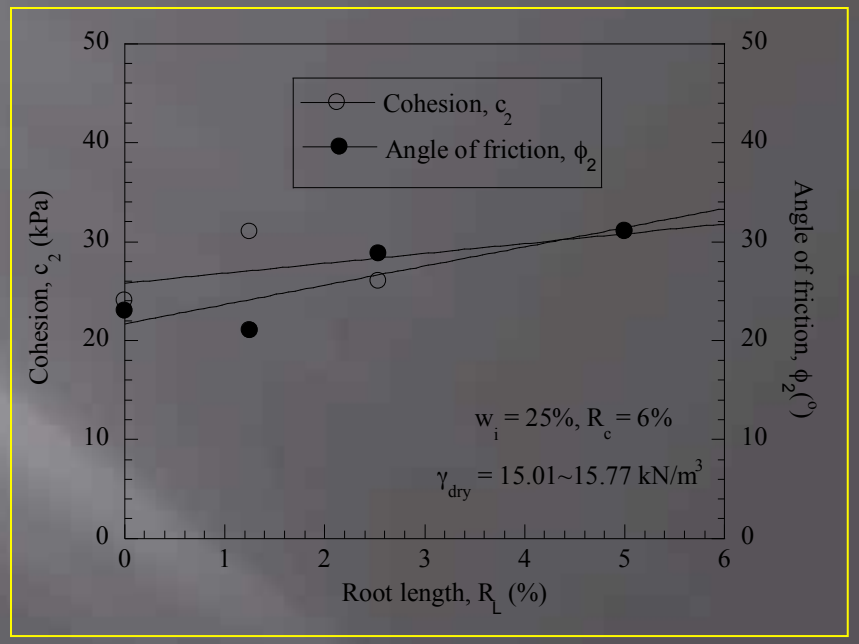
Strength of vetiver rooted soil matrix is 2.1 times higher than that of the bared soil

Laboratory Test

Reconstituted Sample Preparation

Strength of Reconstituted Samples





Strength and ductility of rooted soil samples are higher than those of the unrooted soil samples.

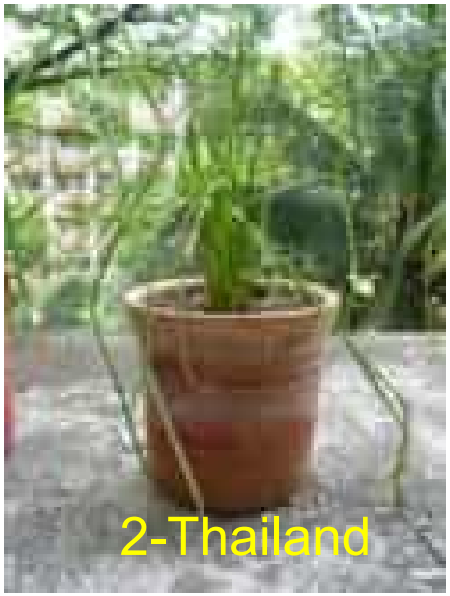
Islam, M.S., Arifuzzaman, Hossain, M.S. and Nasrin, S. (2013), "**Effectiveness of vetiver root in embankment slope protection: Bangladesh perspective**", *Intl. J. of Geotechnical Eng.*, **7**(2), 136-148.

Growth Study

Local vetiver grow better than other collected from other countries.

Vetiver grew even on concrete dump.

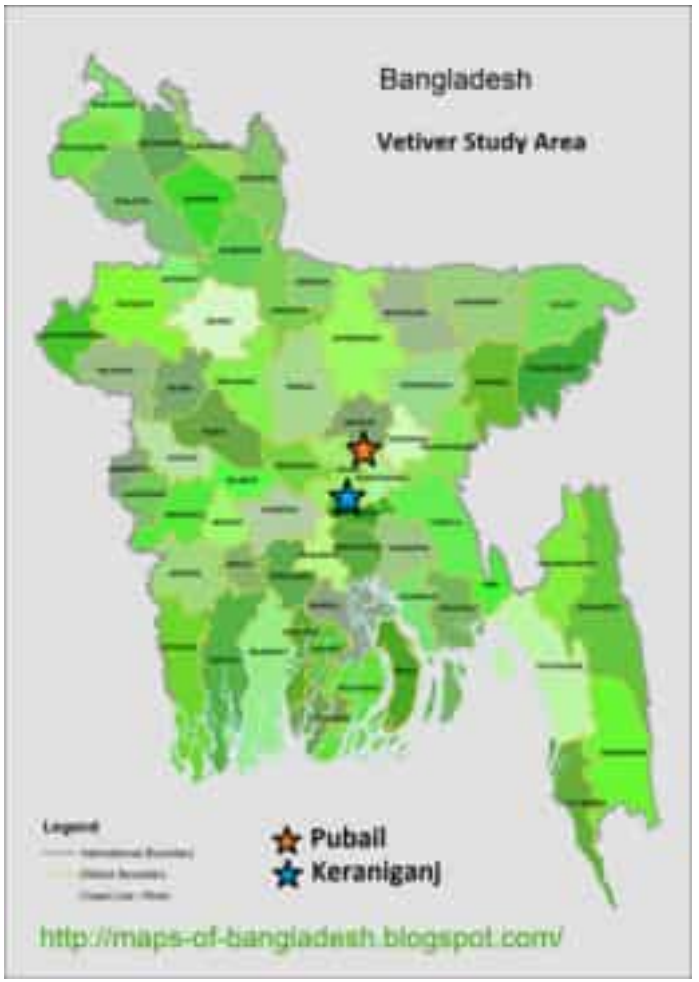
Study on Growth of Vetiver



Training Local People for Vetiver Nursery

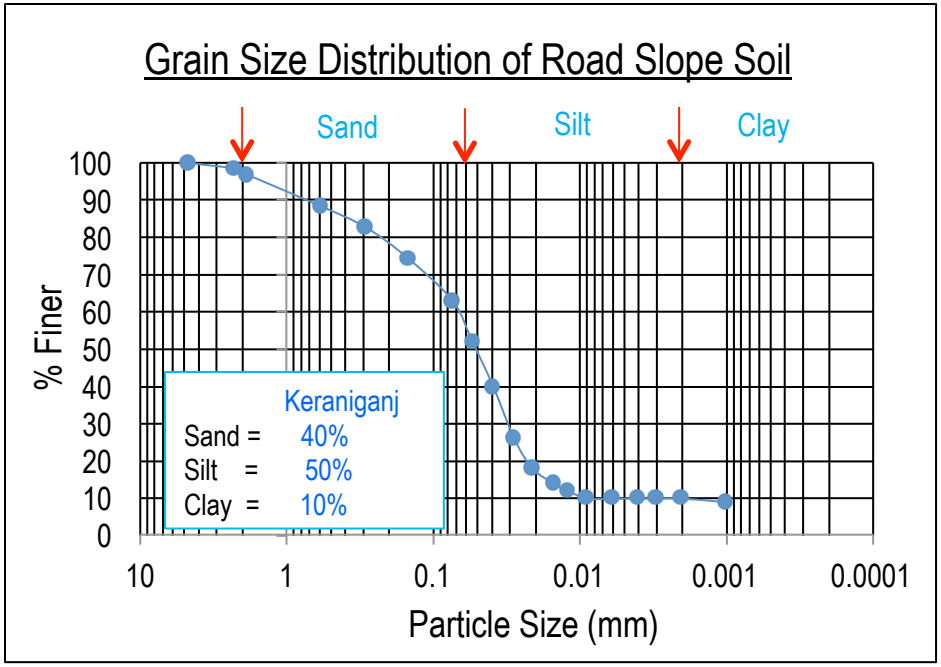
Field Trial- Road Slope Protection
Rain-cut Erosion

Keraniganj-Kholamura-Hazratpur-Itavara-Hemayetpur Road
Zilla Road (District Road)



AADT: 73.18; Temperature: 14-34°C
Humidity: 45-79%; Annual Rainfall: 1875 mm

Grain Size Distribution of the Top-soil of the Road Side

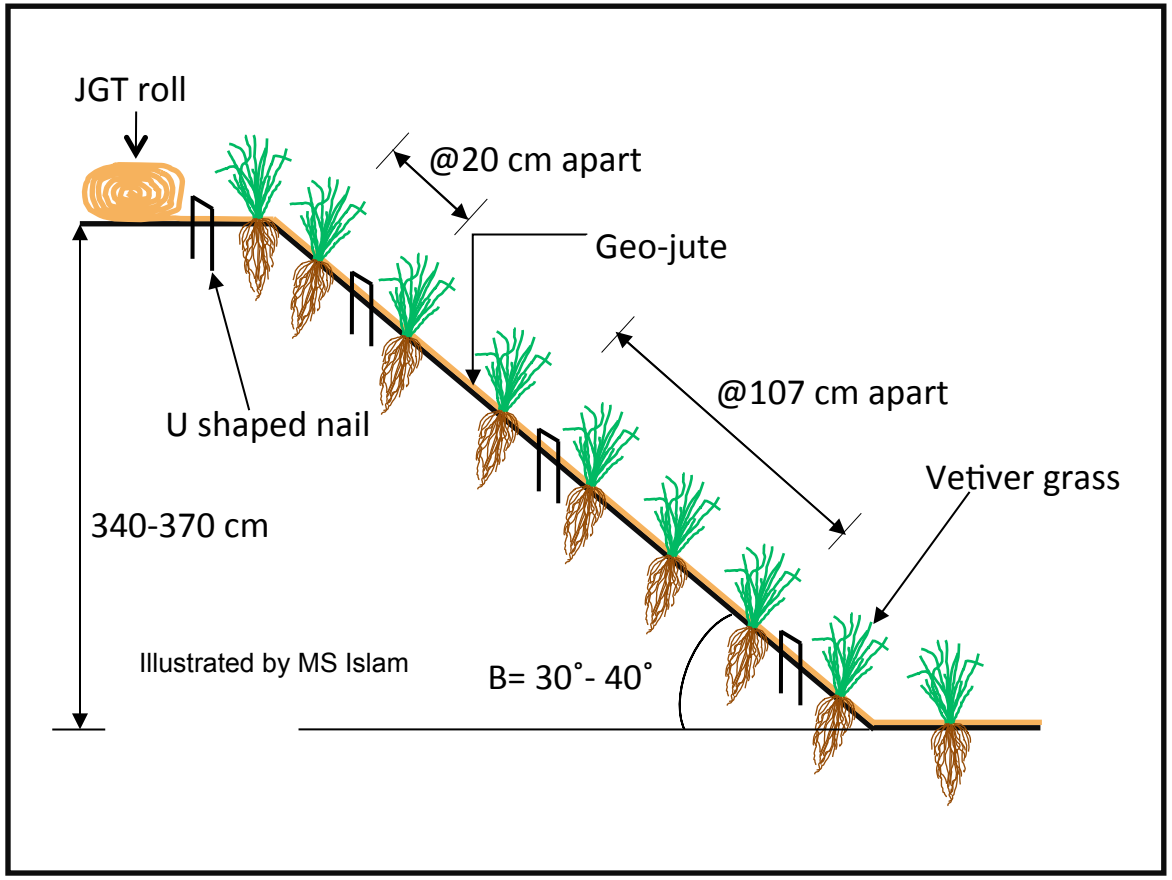


A stretch of mild sloped roadside was selected for protection with geo-jute and vegetation

Slope soil is susceptible to erosion

msharifulislam@ce.buet.ac.bd

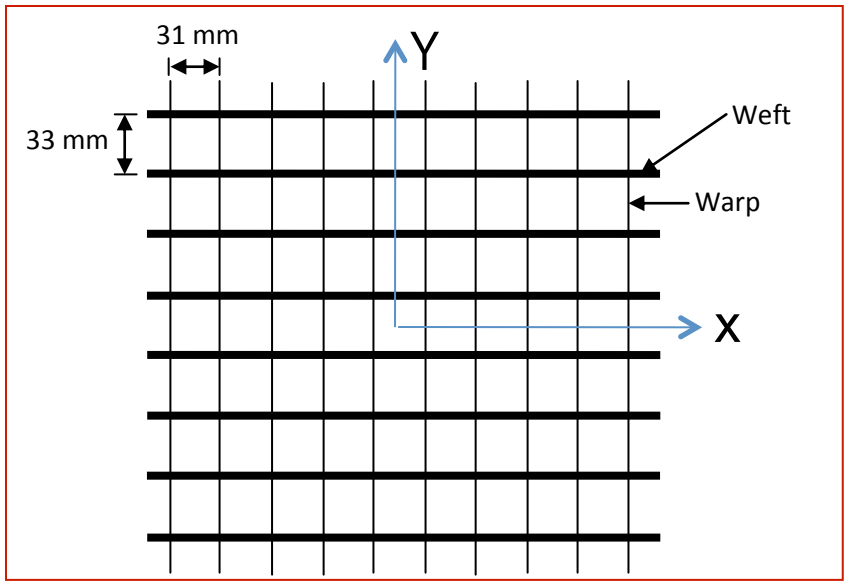
Design of Slope Protection Scheme



Vetiver plantation: 20 cm x 20 cm in square grid pattern

Implementation of the Proposed Erosion Control System

Work Started on 25/10/2011 (Winter)



Unit Mass: 700 gsm, Opening: 31 x 33 mm2
Tensile strength: 21092 N/m (x); 5886 N/m (y)
Absorption capacity: 2.75

Implementation of the proposed Erosion Control System

Work Started on 25/10/2011

Naturally grown vetiver grasses are collected from Pubail (40 km away from the site): 40,000 tillers were used

Implementation of the proposed bio-technology

Work Started on 25/10/2011

Organic fertilizer

A)Slope preparation

Implementation of the Proposed Bio-technology

Work Started on 28/10/2011

Fixation of geo-jute by steel clip
(10 x 24 cm)
107 cm apart along the slope
60 cm along the road length

B) Laying and fixing of geo-jute

Implementation of the Proposed Bio-technology

28-30/10/2011

C) Vetiver plantation

Work Finished on 30/10/2011

D) Watering
First 14 days: Eveready
Next 14 days: @ Alternate day

E) Monitoring

After 1 month:
Root length: 10 cm
Shoot length: 30 cm

E)Monitoring

13/07/2012 More than 8 Months

Root length: 18 inch, Shoot: 6 ft

Visit of RHD, LGED, JDPC Officials to the Site

21/09/2012

Field Trial- Pond Slope Protection
Wind Induced Erosion

Pond Slope Protection in Rajshahi

Grown Vetiver

Vetiver clumps were collected from Tarash

Field Trial- Saline Zone
Dyke Protection

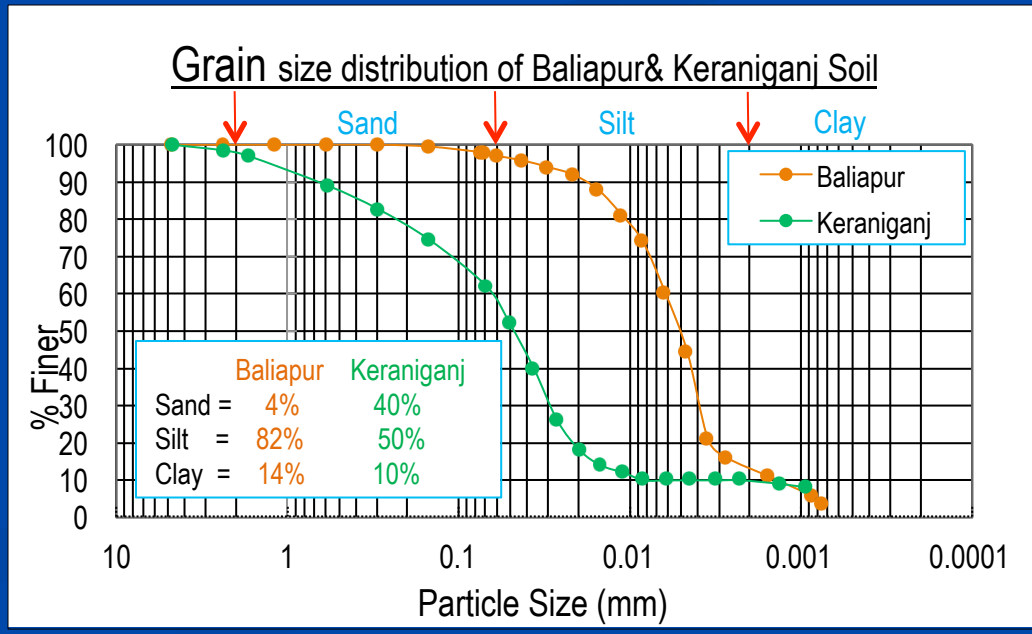
No vegetation is seen on the dykes

Saline Zone	Salinity (ds/m)
Kaliganj	1.57
Baliapur	3.93
Nildumur	4.19
Bashkhali	12.37

Kaliganj: EC= 1.5 ds/m

This initiative was taken to demonstrate to the local people & to plant to other places

Shrimp cultivation in dykes, but generally vegetation do not grow

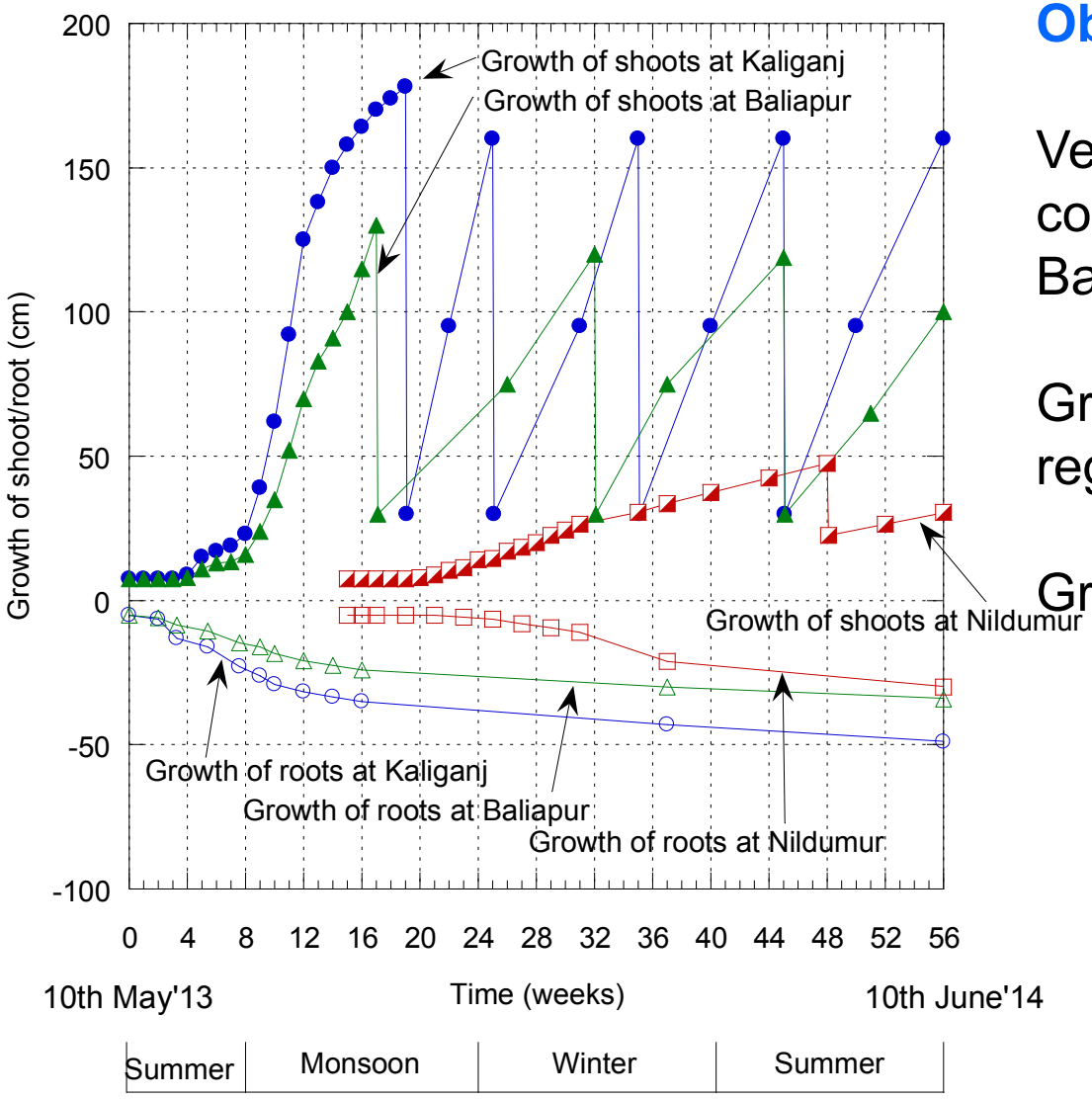



Baliapur: EC= 3.93 ds/m


Nildumur: EC=4.19 ds/m


Baliapur: EC= 3.93 ds/m


Bashkhali: EC= 12.37 ds/m



Observations:

Vetiver grows in flood plain, coastal zone and saline soil of Bangladesh.

Growth is different in different regions.

Growth is less in saline zone.

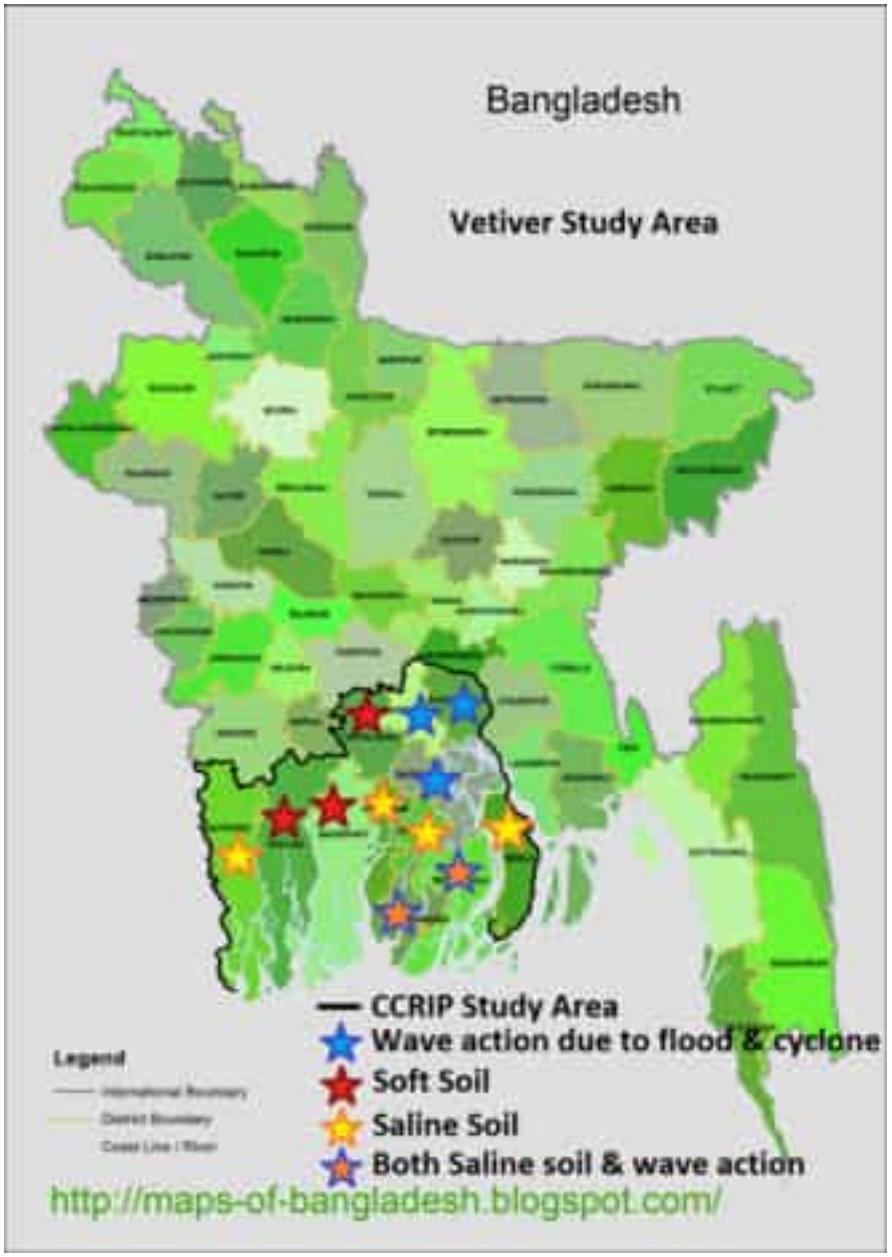
Root and Shoot Growth with Time

Model Test for Erosion

Bared slope

Slope with VS

Coastal Climate Resilient Infrastructure (CCRIP)



A project of Local Government Engineering Department (LGED). Funded by IFAD, UN

12 districts in the coastal zone of Bangladesh:
-Raincut erosion
-Wave action
-Soft soil problem
-Salinity

Heavy Metal Removal from Contaminated Soil

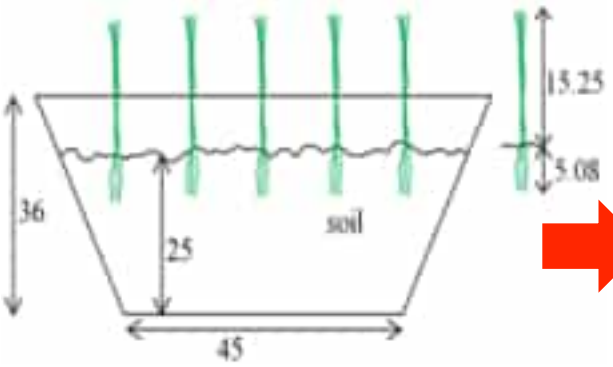
Cleaning Contaminated land and water


Collecting soil from *Buriganga* river bed


Vetiver clump


Tray for vetiver plantation

Soil Properties:
Silt= 91.5%
Clay= 8.5%




Planted vetiver in contaminated soil

Salinity Tolerance and Salinity Removal

Salinity Tolerance/Salinity Removal

Vetiver clump

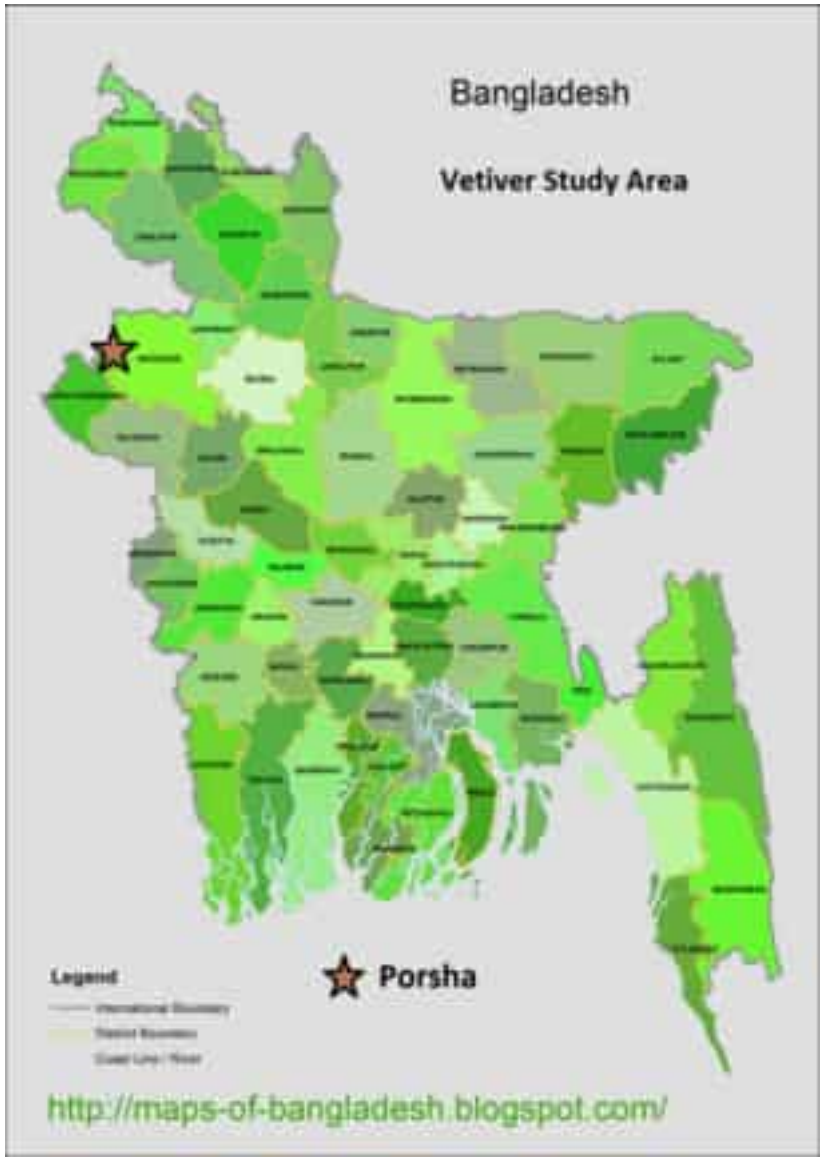
Alluvia Soil
Sand= 84%
Silt= 4%
Clay= 12%

EC= 4.8 to 12.5 ds/m

Vetiver planted in saline soil

Vetiver grass survived in saline soil and also found effective in salinity removal.

Earthen Block Stabilization



Drought prone area

People started to make CGI sheet houses as they found difficult to make earthen house due to shortage of water.

Earthen House

Discussion with community people

Soil Vetiver straw

Training local people

Completed earthen house

Analyses

Method Name	Bishop's Method	Coppin and Richards Method	Remarks
Equation	$Fs = \frac{\sum \frac{1}{m_\alpha}[c'b + (W - ub)\tan\phi']}{W\sin\alpha}$	$Fs = \frac{c' + (\gamma z - \gamma_w h_w)\cos^2\beta \tan\phi'}{\gamma z \sin\beta\cos\beta}$	FS safety estimated for bared slope by these two methods are same
Description	c'= cohesion of soil b =width of slice W= weight of slice u= pore water pressure ϕ'= angle of internal friction of soil. m_α= (1+tanø tanα/F_s)cosα	c' = Effective soil cohesion γ = Unit weight of soil, Vertical height of soil z = Above slip plane β = Slope angle γ_w = Unit weight of water h_w = Vertical height of GWT above slip plane φ' = Effective angle of internal friction of the soil	
Values used	c'= 20 kN/m2; b= 2m; ϕ'= 230	c' = 10 kN/m2; γ = 18 kN/m3; z = 1.0 m; β = 350; γ_w = 9.8 kN/m3; h_w = 0.5 m; φ' = 350	

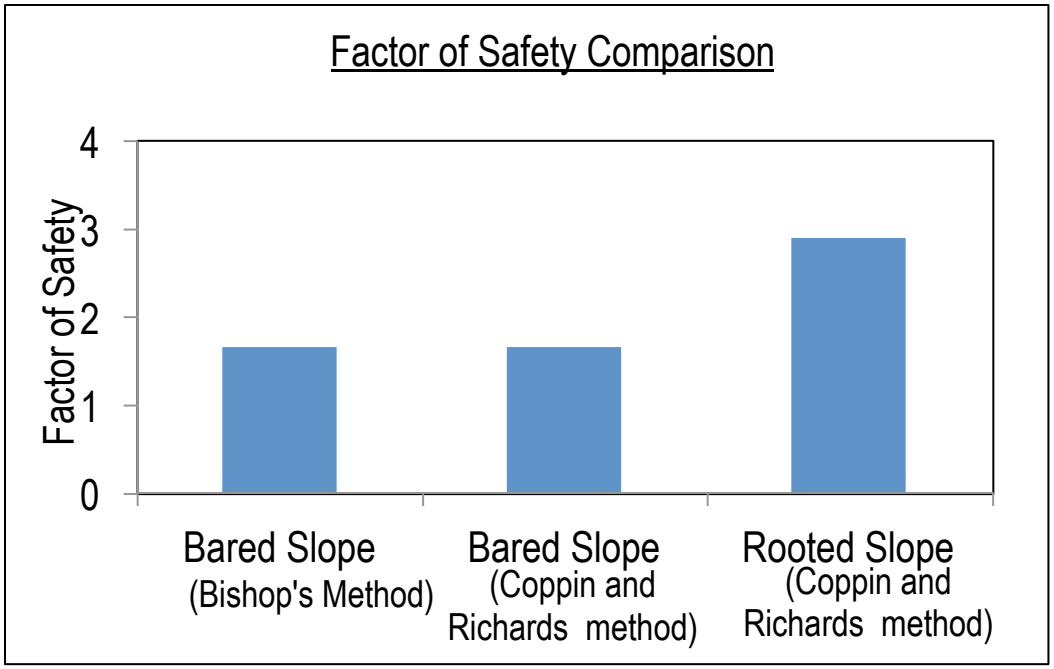
$$Fs = \frac{(c' + c'_R) + [\{(\gamma z - \gamma_w h_v) + W\}\cos^2\beta + T\sin\theta]\tan\phi' + T\cos\theta}{\{(\gamma z + W)\sin\beta + D\}\cos\beta}$$

For Rooted soil (Coppin and Richards Method):

c'_R = Enhanced effective soil cohesion due to soil reinforcement by roots
W = Surcharge due to weight of vegetation
h_v = Vertical height of GWT above the slip plane with the vegetation
T = Tensile root force acting at the base of the slip plane
θ = Angle between roots and slip plane
D = Wind loading force parallel to the slope

Value used:
c'_R = 9.1 kN/m^3; W = 2.5 kN/m^2; h_v = 0.4 m; T = 5 kN/m; θ = 45^0; D = 0.1 kN/m

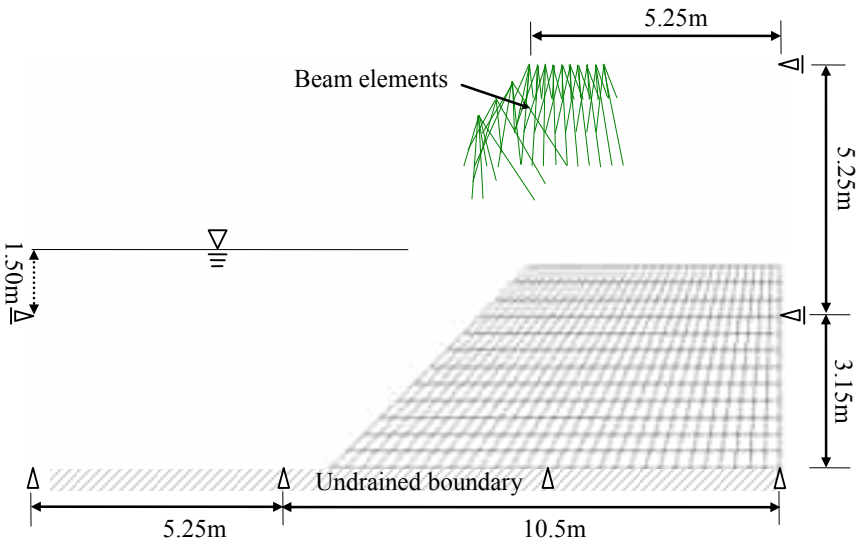
Comparison of Factor of Safety



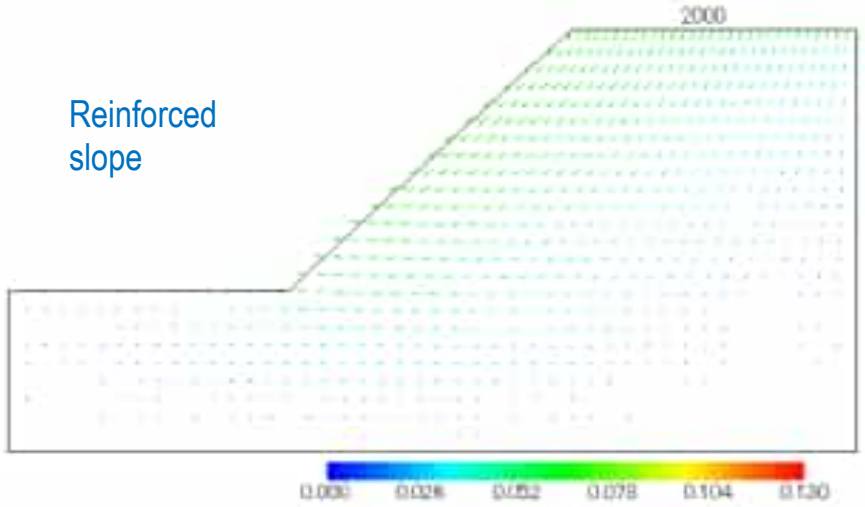
FS increased by 75%.

The Program of Prati Amati, Srl (2006) also showed that the installation of vetiver will increase slope stability by about 40%.

Slope Stability Analysis: FE (subloading t_{ij} model)



Displacement Vectors



Avg. dia of root= 0.75 mm
Avg. root length= 2.5 m
E= 2.65 GPa

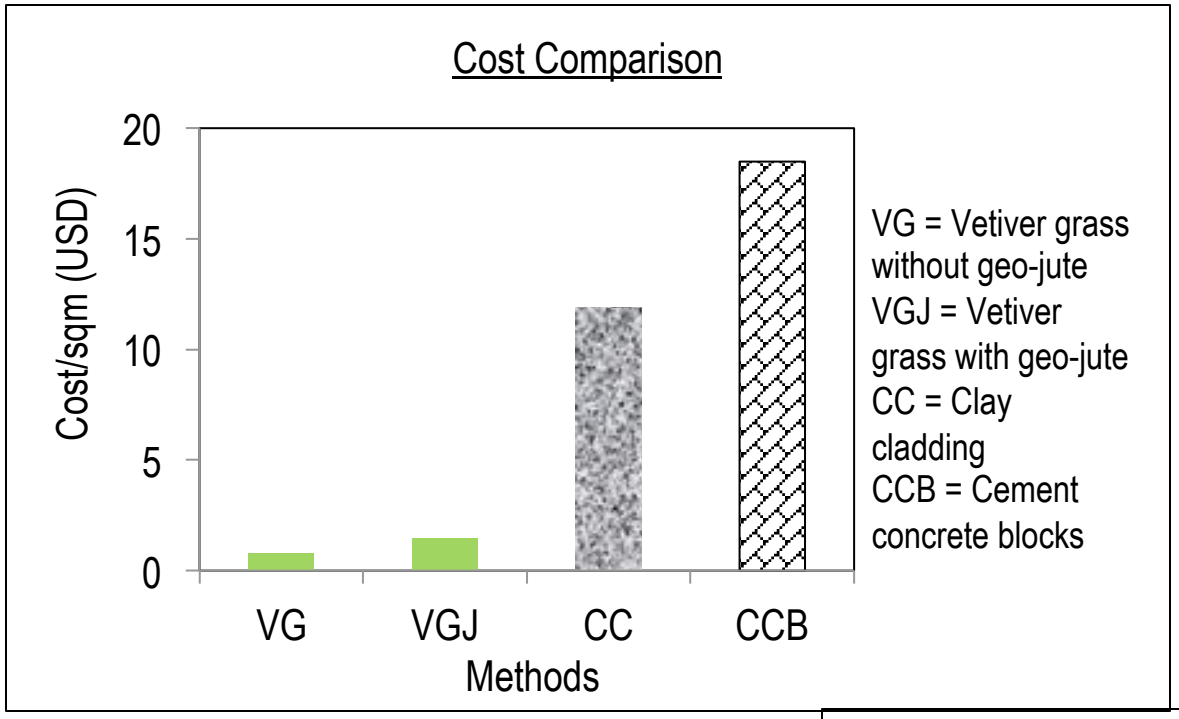
Islam, M.S. and Hossain, M.S. (2013), "**Reinforcing effect of vetiver (*vetiveria zizanioides*) root in geotechnical structures- experiments and analyses**", *Journal of Geomechanics and Engineering: An International Journal*, 5(4), 313-329.

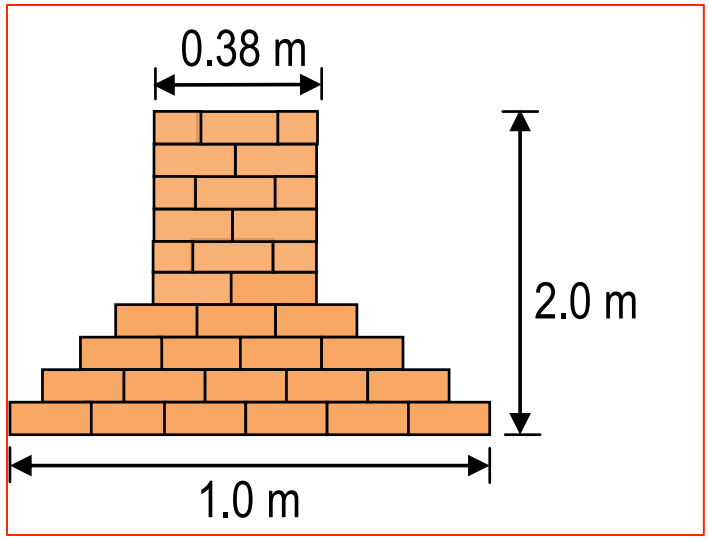
Slope Stability Analysis: FE (subloading t_{ij} model)

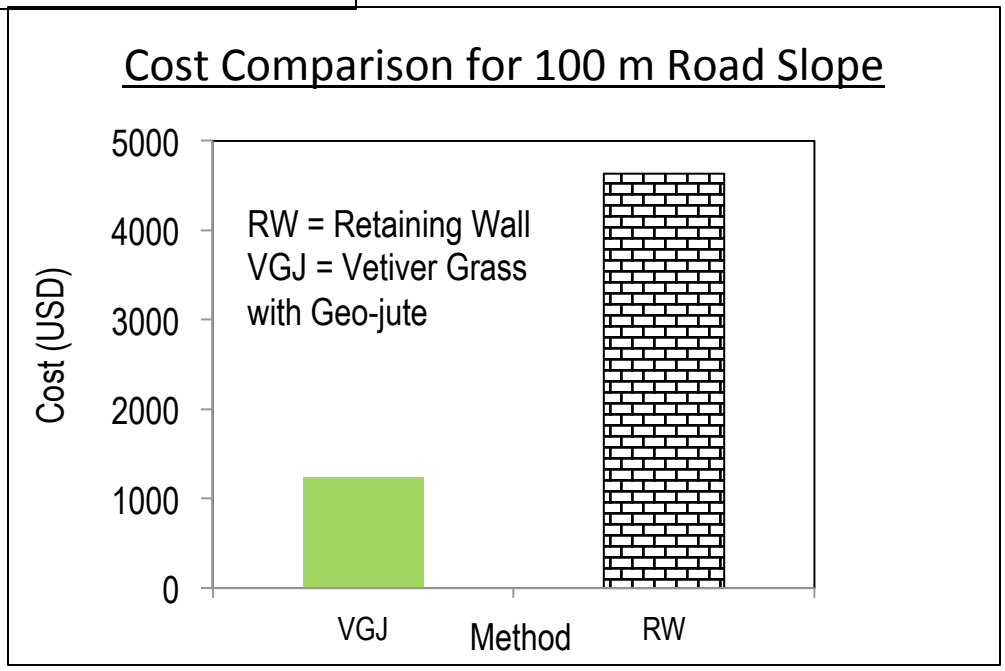
Observations

From the analyses, it was revealed that reinforcement with vetiver roots causes a significant reinforcing effect in the Pubail and Kuakata ground.

The vetiver root enhances the bearing capacities of the grounds and stabilizes the embankment slope.


Cost Comparison
20
15
10
5
0
Cost/sqm (USD)
VG
VGJ
CC
CCB
Methods
VG = Vetiver grass without geo-jute
VGJ = Vetiver grass with geo-jute
CC = Clay cladding
CCB = Cement concrete blocks


0.38 m
2.0 m
1.0 m


Cost Comparison for 100 m Road Slope
5000
4000
3000
2000
1000
0
Cost (USD)
RW = Retaining Wall
VGJ = Vetiver Grass with Geo-jute
VGJ
Method
RW

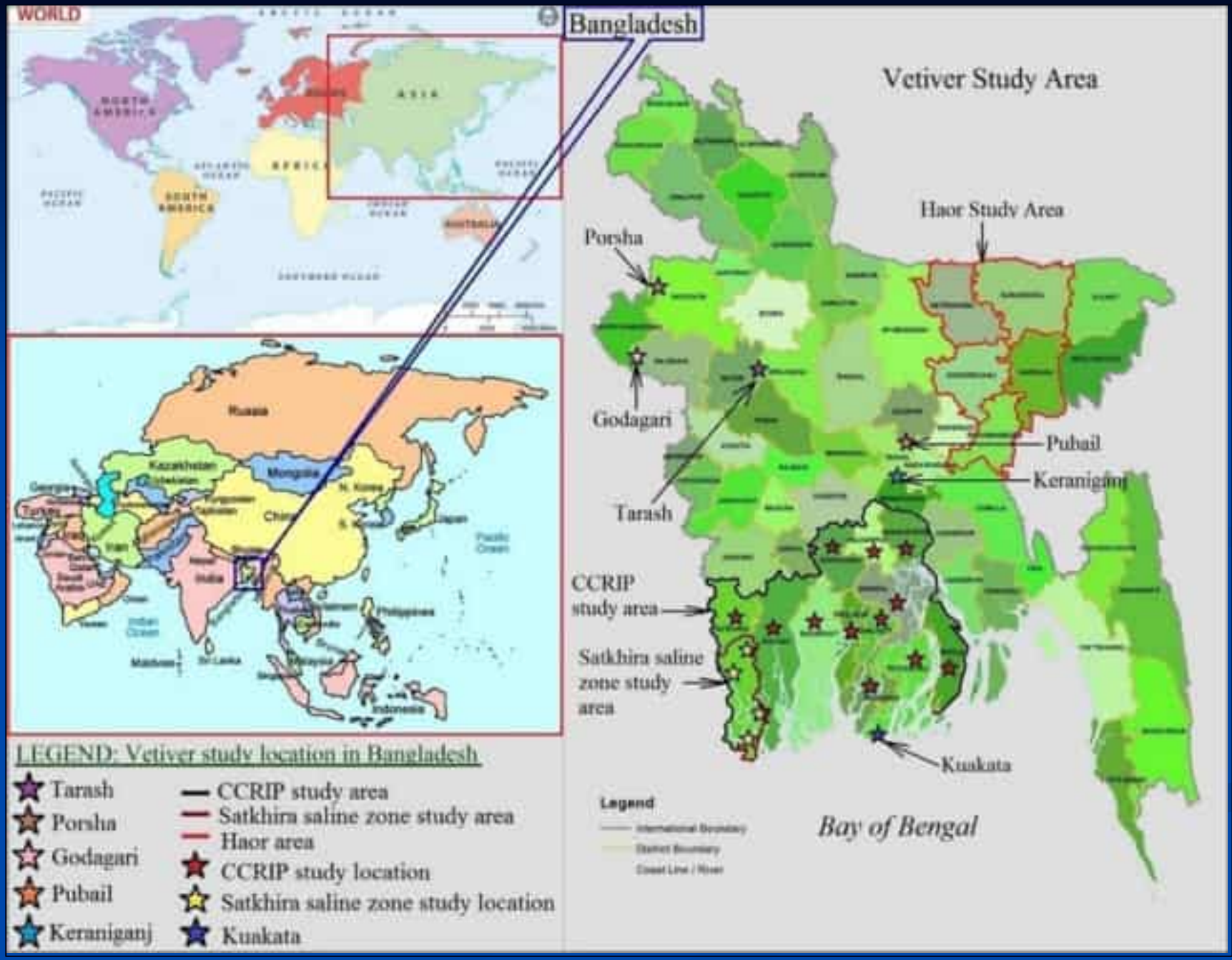
Transferring Technology to the People

জাদুর ঘাস

সমুদ্রপৃষ্ঠ থেকে বাংলাদেশের গড় উচ্চতা ১০০ মিটারও কম। বন্যা তাই নিত্যসঙ্গী। আর তা ঠেকাতে নদীর পাড় ও বেড়িবাঁধই ভরসা। দাঁইগাই কিন্তু একটি সমুদ্র ঘাস রোপণ করে তাদের শক্তিশালী করা যায় ওই ভয়। মিয়া মাসের ওই ঘাস নিয়ে গবেষণা চলছে সুন্দরে। আলোচনায় আলোকচিত্রে জুবায়েরের মোহসিন ও আহমিদা হক

ড. মুহাম্মদ শহীদুল ইসলাম,
সহযোগী অধ্যাপক,
মৃত্তিকাবিজ্ঞান বিভাগ, সুন্দরী

ফটো : শহীদুল ইসলাম রাজু


WORLD
Bangladesh
Vetiver Study Area
Haor Study Area
Porsha
Godagari
Pubail
Keraniganj
Tarash
CCRIP
study area
Satkhira saline
zone study
area
Kuakata
Bay of Bengal
Legend
LEGEND: Vetiver study location in Bangladesh
Tarash
Porsha
Godagari
Pubail
Keraniganj
CCRIP study area
Satkhira saline zone study area
Haor area
CCRIP study location
Satkhira saline zone study location
Kuakata

Summary & Recommendations

Embankment failure due to erosion is a common problem in Bangladesh. Plantation of vetiver system along the slope of embankments, river banks and hill slope is an alternative green solution to the problem. Field and laboratory tests were conducted to determine the strength of vetiver rooted soil. Field trail has been conducted to investigate the suitability of vetiver with geo-jute for slope protection. The main findings of the study are as follows:

- In-situ shear tests conducted on vetiver rooted soil system showed that shear strength of vetiver rooted soil matrix is 2.0 times higher than that of the bared soil. Again, the effective cohesion of vetiver rooted soil matrix is 2.1 times higher than that of the bared soil. The vetiver rooted sample showed ductile behavior. Direct shear tests conducted on laboratory reconstituted unreinforced and reinforced samples showed similar trend as observed in in-situ tests.

- Field trials have been conducted in road embankment and slope protection with vetiver at different sites. It is found that the sub-tropical climate of Bangladesh is suitable for vetiver plantation. Plantation of vetiver along with the use of geo-jute(JGT) can be a cost-effective, sustainable, eco-friendly method for the erosion control of slopes in Bangladesh.

Summary & Recommendations

- Slope stability analyses conducted for both bared and vegetated slopes. The factor of safety is about 1.66 for bared slope and 2.90 for rooted slope. Finite Element (FE) analyses revealed that reinforcement with vetiver roots causes a significant reinforcing effect in the Pubail and Kuakata ground.
- Vetiver plantation costs least compared to other common practices such as cement concrete block and clay claddings.
- Vetiver is also found to be effective in uptaking heavy metal and salinity removal.
- Vetiver is effective in stabilizing earthen block.
- Extensive field trails are being conducted with the cooperation of Government and NGOs.
- International collaboration is needed to establish vetiver network and accelerate the use of vetiver in Bangladesh.

Acknowledgements

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- Dr. Matiur Rahman, Ex-Director, National Herbarium, Bangladesh for classifying vetiver.
- WAB Trading International (Asia) Ltd. and GIZ, Germany for their cooperation in field trails in saline zone.
- LGED for their collaboration in CCRIP project.
- JDPC for their cooperation in getting the JGT for Keraniganj Trial.
- Caritas, Bangladesh and CRATterre, France for LCH project.
- Finally, the cooperation of all the students of BUET who have participated in the research.

Thank You

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