The First Indian National Workshop
"Vetiver System for Environmental Protection and Natural Disaster Management"

# VETIVER SYSTEM FOR NATURAL DISASTER MITIGATION IN VIETNAM

Tran Tan Van, Paul Truong and Elise Pinners

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## 1. Introduction

- ✓The use of Vetiver grass for natural disaster mitigation in Vietnam has become very popular.
- ✓Despite the fact it has been introduced into Vietnam for such purpose only 5-6 years ago and met with some pessimism at the beginning.
- ✓Thanks to the faith and efforts of the Vietnam Vetiver Network, the grass is now known throughout the country and is in use in about 40 provinces (out of the total 64).

# 2. Natural disasters in Vietnam: types and causes

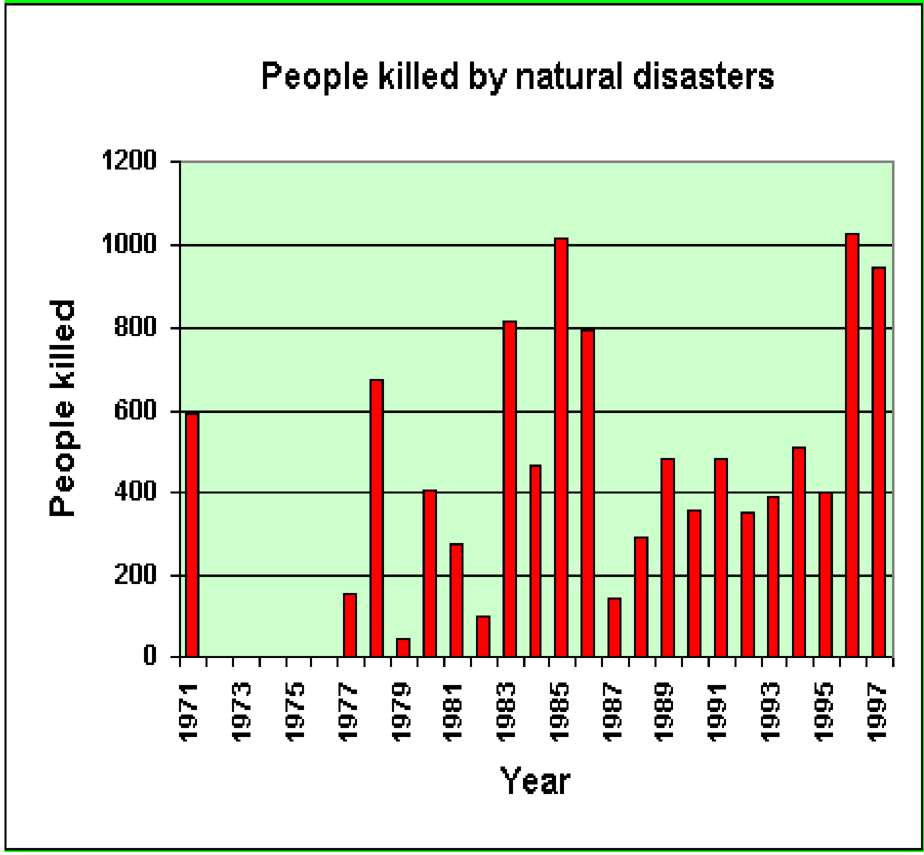
1. **Geohazards of endogenous origin**, incl. earthquake, volcanic eruption, faulting, regional subsidence, tsunami etc. and geophysic-geochemic anomalies (radioactive emission, lack or surplus of micro-elements etc.);
2. **Water-related geohazards**, by combined action of endogenous, exogenous processes and human activities, incl. the following:
   a) *Geohazards where water plays the main destructive role*, incl. flash flood, flood, drought, desertification etc.
   b) *Geohazards where water is one of important causes*, incl. landslide, debris flow, erosion, coastal and river bank erosion, subsidence etc.;
   c) *Geohazards where water is the hosting and transmitting medium*, incl. water pollution, sea water intrusion etc.; and
3. **Other geohazards** (sand storm/flow, gas accumulation etc.).

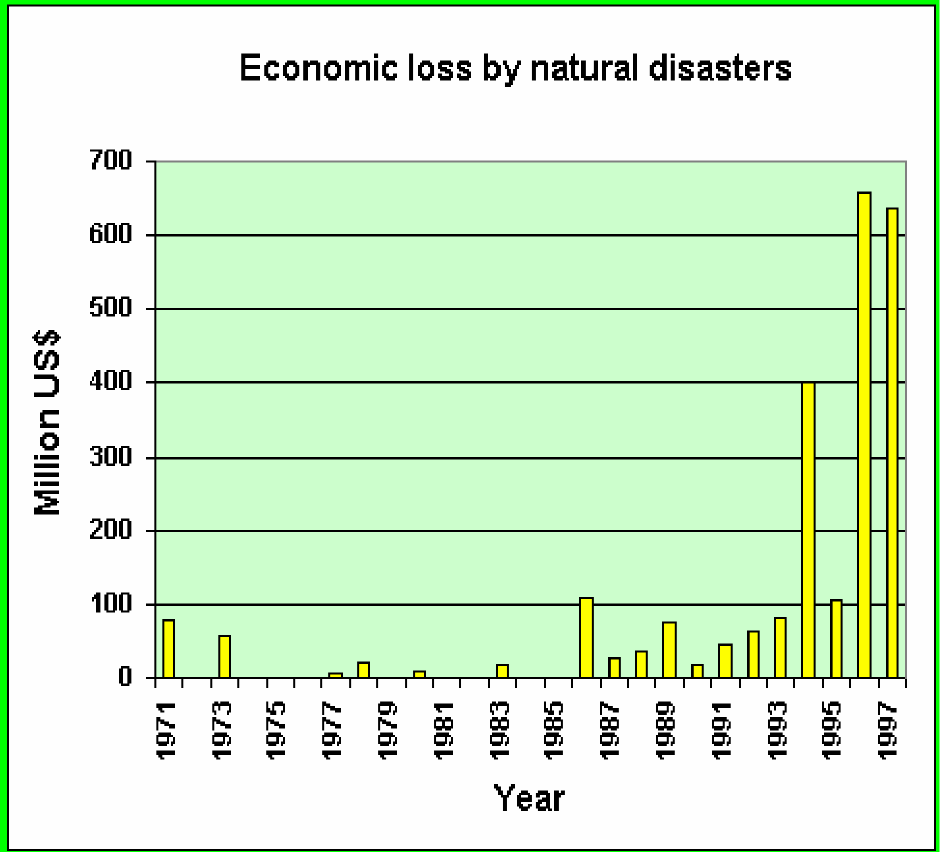
## 2. Natural disasters in Vietnam: types and causes

- A natural disaster-prone country:
  - Tropical monsoon climate: rainfall app. 2,000 mm/year, 200 rainy days/year, 75-80% during summer, major portion in just about 10 days with > 100 mm/day records;
  - ¾ territory mountainous, very diverse geological conditions, incl. many rock/soil types, active tectonic regime;
  - Densely populated, fast economic and demographic growth with uncontrolled negative environmental degradation during the last two decades;
- Most frequent and destructive disasters: floods, flash floods, landslides and debris flows, river bank and coastal erosion, sand storm/flow etc.

# 2. Natural disasters in Vietnam: losses

- Natural disasters-induced loss of life and properties rapidly increased.
- From 1991-2000: app. 8,000 people killed, 2.8 billion US$ economic loss, i.e. 1.8-2.3% GDP or 300 million US$ yearly.



## 2. Natural disasters in Vietnam: research and survey

VIGMR:

- 2000-2002 – a research project on geohazards for 8 coastal provinces of Central Vietnam;
- 2003-2005 – similar project for HCM-HW from Ha Tinh to Kon Tum province;
- 2004-2006 – similar project for Northeast Vietnam;
- 2008-now – another project for the rest of Northeast Vietnam.

Geological Survey of Vietnam:

- 2000-2002 – similar project for Central Highland provinces;
- 2003-2005 – similar project for Northwest Vietnam.

# 2. Natural disasters in Vietnam: some examples


Fig. 1. Flooding and inundation in the Red River Delta due to the recent storm No. 7.

Fig. 2. Flash flood and inundation in the mountainous karst area of NW Vietnam.

# 2. Natural disasters in Vietnam: some examples

Fig. 3. Coastal erosion in Hai Hau (Nam Dinh) due to recent storm No. 7 - a used to be nice and crowded walkway along the coast.

Fig. 4. A collapsing guest house near the Hoa Duan coast (Thua Thien-Hue province) due to coastal erosion.

# 2. Natural disasters in Vietnam: some examples

Fig. 5. Right bank erosion along Tra Khuc River in Quang Ngai province.

Fig. 6. River bank erosion along Ganh Hao River (Bac Lieu province), causing complete collapse of the fishery jetty.

# 2. Natural disasters in Vietnam: some examples

Fig. 7. A big landslide in the completely weathered granite at A Roang Pass, Ho Chi Minh Highway (Thua Thien-Hue province).

Fig. 8. Even a rigid concrete retaining wall did not help - a rock slide near Phong Nha (Quang Binh province).

# 2. Natural disasters in Vietnam: some examples

Fig. 9. A garbage site in A Luoi (Thua Thien-Hue province), leachate from which would move down to the A Sap River.

Fig. 10. An AO-contaminated landfill at A So Airport, A Luoi district (Thua Thien-Hue province). The board says the AO content here is 29 times higher than allowable.

## 2. Natural disasters in Vietnam: some examples

Fig. 11. Untreated waste water from a paper mill in Bac Ninh province - to be pumped directly into the Ngu Huyen Khe River.

Fig. 12. An environmental ponds at the fertilizer plant in Bac Giang province. This measure can’t help reducing suspended and soluble toxic elements.

# 2. Natural disasters in Vietnam: some examples

Fig. 13. Sand flow in Le Thuy district (Quang Binh province) in 1999, exposing the pumping station's foundation...

Fig. 14. … And destroyed a 3-room brick house of this woman.

# 3. Traditional remedial measures and their drawbacks

- Structural, localized rigid protection measures e.g. concrete or rock riprap bank revetment, groins, retaining walls etc.
- **Cost**: Very expensive and State budget is never sufficient
  - ✓ River bank revetment costs 2-300,000 US$/km, sometimes 0.7-1.0 million US$/km, extreme cases 7 million US$/km.
  - ✓ Sea dyke costs 0.7-1.0 million US$/km, not rare 2-2.5 million US$/km. Still not rigid and strong enough (storms up to 9$^{th}$ level). Stronger dyke system needs 7-10 million US$/km.
  - ✓ River bank protection in one province alone needs >20 million US$, while annual State budget allocation is only 300,000 US$.

# 3. Traditional remedial measures and their drawbacks

- **Technical and/or environmental constrains:**
  - ✓ Rock/concrete is mined/produced elsewhere, where it can cause environmental problems;
  - ✓ Traditional measures do not absorb flow/wave energy and tend to displace erosion to another place, opposite or downstream. In so doing, they even aggravate the disaster, rather than really reduce it for the river as a whole.
  - ✓ They bring in considerable amount of stone, sand, cement into the river system, disposing considerable volume of bank soil into the river, all eventually causing the river to become full, changing, raising the river floor, thus worsening flood and bank erosion problems.

# 3. Traditional remedial measures and their drawbacks

- ✓ Not compatible with the soft ground particularly on erodible soils. As the later is consolidated and/or eroded and washed away and undercut the upper rigid layer.
- ✓ Replacing concrete plates with rock rip-rap with or without concrete frame leaves the problem of subsurface erosion unsolved.
- ✓ Can only temporarily reduce erosion but they can not help stabilize the bank in case of big landslides with deep failure surface.
- ✓ Concrete or rock retaining wall for road slope stabilization is passive, waiting for the slopes to fail. When they do fail, they also cause the walls to fail.

# 3. Traditional remedial measures and their drawbacks

- For river bank erosion, the most popular bio-engineering method is planting of bamboo, while for coastal erosion, mangrove, casuarina, wild pineapple, nipa palm etc. are used.
- Bamboo, wild pineapple for river bank protection:
  - ✓ Growing in clumps, bamboo can not provide closed hedgerows. The flood water tends to concentrate at gaps in-between clumps, where the water destructive power increases, thus causing more erosion to occur;
  - ✓ Shallow (1-1.5 m deep) bunch root system, not in balance with the high, heavy canopy, therefore clumps of bamboo put an additional heavy surcharge on a river bank, without contributing to the bank stability;
  - ✓ In many cases erosion undermines the soil below, creating conditions for larger landslides to take place;

# 3. Traditional remedial measures and their drawbacks

- Mangrove for coastal protection:
  - ✓ Where they can grow, form a very good protection buffer zone for reducing wave power, thus reducing coastal erosion.
  - ✓ However, establishment of mangrove is difficult and slow as its seedling is eaten by mice, and thus, of the hundreds of hectares planted, only a small part can develop to become forest.

# 3. Traditional remedial measures and their drawbacks

- Casuarinas, wild pineapple for sand dune protection:
  - ✓ Good mainly for reducing wind power and respectively, sand storm but not sand flow as they do not form closed hedgerows and do not have deep root systems. Thus can't prevent sand fingers to invade arable land;
  - ✓ Casuarinas seedlings can hardly survive sporadic but extreme cold winter (less than 15$^{o}$C) while wild pineapple dies from extremely hot summer in North Vietnam;

## 4. Vetiver grass as a bio-engineering tool: Some Vietnamese experiences

- Vietnamese experiences show:
  - Vetiver - A fast growing grass with unique features, offers a simple, cost-effective, environmental and community friendly bio-engineering method for natural disaster mitigation which effectively replaces the traditional measures mentioned above.
  - Can be used alone or, in a more conservative case, in combination with traditional measures.

# 4. Vetiver grass as a bio-engineering tool: Some Vietnamese experiences

Introduced into Vietnam in 1999 by:

- Ken Crismier of The Vetiver Network International (TVNI).
- Paul Truong and Diti Hengchaovanich.
- Several workshops in Hanoi, Ho Chi Minh City and Nghe An.
- Several trial sites were set up. However, due to lack of good design, experience and care, the trials did not give good results in central and North Vietnam.
- Pham Hong Duc Phuoc from The Ho Chi Minh City University of Agro-Forestry carried out some trials in Central Highland for land slips control and steep slope stabilization.
- THIEN SINH Co., Paul Truong and Phuoc developed specifications for land slip control on the HCM highway.

# 4. Vetiver grass as a bio-engineering tool: Some Vietnamese experiences

- Tran Tan Van tried to stabilize sand dunes and river banks in Central Vietnam since early 2002.
- Organized a successful seminar in early 2003, thanks to which Vetiver grass was tried by an AUSAID funded natural disaster reduction project at 4 sites in Quang Ngai Province for riverbank, dyke erosion and flood control.
- Successful results allowed for mass planting in other sites of the province.
- World Vision tried in Quang Tri province.
- Also in 2003, Ministry of Transport allowed the wide use of Vetiver grass for slope stabilization along National Highways, most notably along hundred of km of the Ho Chi Minh Highway.

## 4. Vetiver grass as a bio-engineering tool: Some Vietnamese experiences

- In 2004, Dannish Red Cross tried VS in Hai Hau district for sea dyke system.
- But before that, Dyke Dept. and local PC have successfully tried for the field side of the sea dyke system.
- Meanwhile, new applications also emerge from elsewhere in the world. Very good results were achieved by Paul Truong on the use of Vetiver grass for waste and pollution control.
- Since 2005 similar attempts were made in Vietnam i.e. several waste water treatment and polluted land reclamation are carried out in Dong Nai, Hau Giang, Thua Thien-Hue, Bac Giang and Bac Ninh provinces with initial encouraging results.
- Vetiver grass applications are now well known in nearly 40 out of 64 provinces of Vietnam.

## VS for road batter stabilization and landslip control

- A particular bold move was made by the Ministry of Transport, allowing for mass application of VS for slope stabilization along the newly constructed Ho Chi Minh Highway and other national, provincial roads.
- This is probably one of the largest applications of VS for infrastructure protection in the world.
- Along the Highway, Vetiver is planted on a variety of soils and climate: from skeletal mountainous soils and cold winter in the North to extremely acidic Acid Sulfate Soil and hot and humid climate in the South.

**Construction of HCM HW causes numerous problems**



**Traditional rigid structures**

**Traditional rigid structures**


**Vetiver protects the cut slope of HCM HW in Quang Binh**

**Vetiver protects the cut slope of HCM HW in Quang Binh**

# VS for river bank erosion control

- Dutch Embassy-funded pilot project in Central Vietnam in 2002, followed by mass planting by local Dyke Dept. and World Vision-supported communities;
- Ausaid-funded natural disaster mitigation project in 2003-2004, first pilot in 4 sites, followed by mass planting by local Dyke Dept. and communities;
- In the Mekong Delta by local Dyke Dept. with technical advises and seedlings from Can Tho university. River bank protection and Flood-Escaping-Cluster protection. An Giang and Tien Giang provinces.

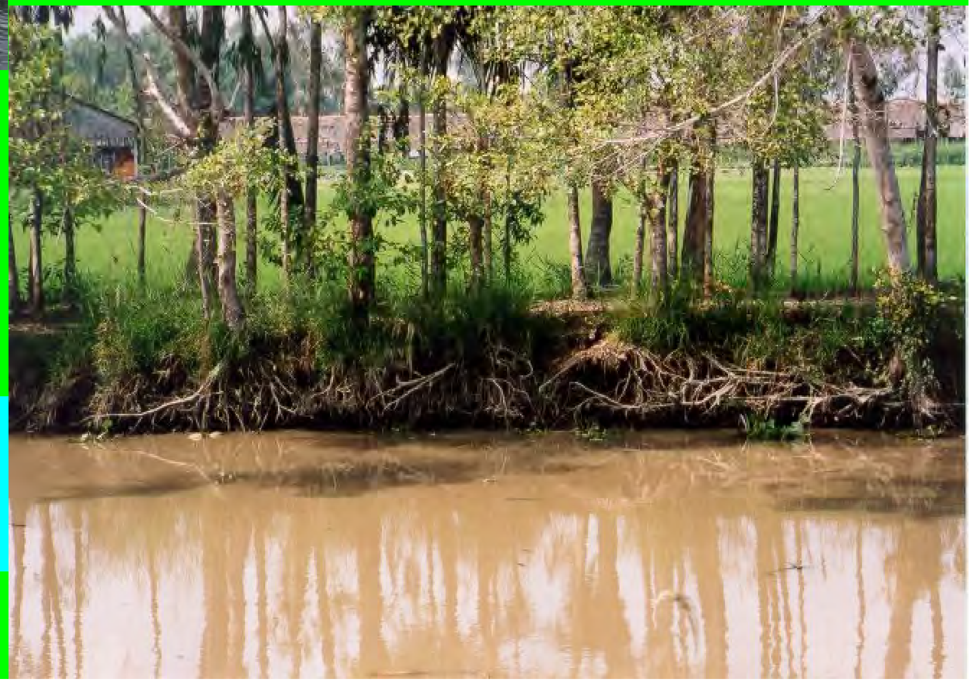
Concrete plate cover on river dyke in Central Vietnam

Concrete plate cover on river dyke in Central Vietnam


The bank of the Red River in Hanoi is repaired after recent flood using gabions and rock baskets

# Some examples of river bank and coastal erosion in Central Vietnam, with bamboo, casuarinas and coconut tree protection

Some examples of river bank protection in the Mekong Delta. Using the water hyacinth barrier. But Erosion continues behind it.



Trees are of not much help either.

Native grass is equally ineffective.

The picture up right looks impressive. But erosion continues as waves from unprotected section upstream got behind it.

# Đà Nẵng

Mass planting for river bank protection, Đà Nẵng - 02/2003.

After 2 flood seasons, farmers plant themselves to protect shrimp ponds - 12/2004.

# Đà Nẵng

Vetiver helps local species to growth for protecting river bank Đà Nẵng - 12/2004.

After 2 flood seasons, farmers plant themselves to protect shrimp ponds - 12/2004.

# Đà Nẵng

Farmers' houses behind are well protected for already 2 flood seasons - 12/2004.

# Quảng Ngãi

A section of the river dyke in Quang Ngai.

A section of anti-salinity dyke in Quang Ngai.

The same site after one month (above right) and several months (right).

A section of anti-salinity dyke in Quang Ngai.

# Quảng Ngãi

The same site after several months.

# Quảng Ngãi

An anti-salinity dyke in Quang Ngai at VS planting.

The same site after several months.

An irrigation canal in bad shape in Quang Ngai.

The same site at planting (up right) and after several months (right).



Dry season

Vetiver survives well the flood in Tri Tôn, An Giang


Protecting flood escaping clusters in An Giang

And being taken care of by local farmers

Vetiver protecting flood divering canals in Tân Châu-An Giang

A precious piece of land 5m wide is kept intact due to Vetiver

**Eucalyptus can’t help protecting the land.**


Without Vetiver


**A precious piece of land 5m wide is kept intact due to Vetiver**

# In combination with Vetiver (Vị Thanh-Hậu Giang)


People are happy
(Cai Lậy-Tiền Giang)

# VS for coastal erosion control

- In 2001 with financial and technical supports from the Donner Foundation and Paul Truong respectively, Le Van Du from Ho Chi Minh City Agro-Forestry University initiated works on Acid Sulfate Soil to stabilize canal and irrigation channels and sea dike system in Go Cong province;
- In 2004, at the recommendation of Tran Tan Van, the Danish Red Cross funded a pilot project using Vetiver grass for sea dike protection in Hai Hau district, Nam Dinh province. The project implementers came in and to their biggest surprise, they found out that Vetiver grass had already been planted 1-2 years earlier to protect several km of the inner side of the local sea dike system.

# Some examples of coastal erosion in Central Vietnam, with bamboo, casuarinas and coconut tree protection

# Nam Định

A section of sea dyke in Hải Hậu and what is left.

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# Nam Định

Planting Vetiver on the sea side of the dyke in Hải Hậu.

Vetiver protecting a pond just next to the sea in Hải Hậu.

# Nam Định

## Địa phương tự làm

Dyke Dept. plants Vetiver on field side of sea dyke in Hai Hau

# Gò Công

Vetiver protecting sea dyke in Gò Công, behind the mangrove.

# VS for sand dune stabilization

- In February 2002, with financial support from the Dutch Embassy a project was initiated to stabilize sand dunes along the coastline in Quang Binh province;
- Followed by mass planting in Oct. the same year, local initiative;
- Workshop in early 2003, followed by similar attempts by local communities supported by World Vision;
- And Ho Chi Minh Highway project and Ausaid-funded natural disaster mitigation project in Quang Ngai province.

Examples: Trial of Vetiver grass for protecting sand dunes in Quang Binh. Establishment of the demo site.

Examples: Trial of Vetiver grass for protecting sand dunes in Quang Binh. Four months after planting.

Four months after planting. The grass is more than 1.7 m high.

The sand dune is fully stabilized after one year, favouring the growth of other trees.

After two years, other trees fully establish.

# Quảng Bình

Workshop and mass planting - 03/2003.

# Advantages and disadvantages of Vetiver System

- Low installation cost;
- Low maintenance cost;
- Environmental friendly;
- Simple and community friendly;
- Particularly effective in poor and highly erodible and dispersible soils;
- Particularly suitable for regions or countries with low cost labor forces.

# Advantages and disadvantages of Vetiver System

- Intolerance to shading particularly in the establishment phase;
- An initial establishment period of about 2-3 months in warm weather and 4-6 months in cooler time is required;
- Gaps in between clumps should be timely re-planted;
- Difficult to plant and water on very high slopes;
- Protection from livestock during establishment phase;

# 5. R&D results on unique characteristics of vetiver grass suitable for slope stabilization

- Extremely deep and massive finely structured root system, capable of reaching down to 2 to 3m in the first year. Many experiments show Vetiver grass can reach 3.6m in the first 12 months on fill slope.
- Vetiver roots can penetrate compacted soil profile such as hardpan and blocky clay pan common in tropical soils.
- Although classified as a grass, for land stabilization purposes, Vetiver plants behave more like fast growing trees or shrubs i.e. like living soil nails or dowels that are commonly used in 'hard approach' slope stabilization works.
- This extensive and thick root system binds the soil and at the same time makes it very difficult to be dislodged and extremely tolerant to drought.

## 5. R&D results on unique characteristics of vetiver grass suitable for slope stabilization

The following unique attributes of Vetiver grass have been researched, tested and developed:

- Tolerance to extreme climatic variation such as prolonged drought, flood, submergence and extreme temperature from -14°C to 55°C (Truong *et al*, 1996).
- Ability to re-grow very quickly after being affected by drought, frost, salt and other adverse soil conditions when the adverse effects are removed.
- High level of tolerance to soil acidity, salinity, sodicity and acid sulfate conditions (Le Van Du and Truong, 2003).


***V. zizaniodes*, 2.5m tall, erect and stiff stems. It flowers but no seed**


***V. nemoralis*, 1m tall and soft stems, its seeds**

## This thick barrier acts as a very effective filter trapping both fine and coarse sediment

# Deep, extensive and penetrating root system

One year old: 3.3m deep

Extremely drought tolerant in western Queensland.

Growing vigorously in water on a dam wall in north Queensland. Vetiver can survive more than 50 days when completely submerged.

# Tolerant to high salinity

Saline threshold level is at $EC_e$=8 $dsm^{-1}$, and vetiver can survive at 47.5 $dsm^{-1}$ under dryland salinity conditions

**Tolerant to high acidity:** Highly erodible acid sulfate soil in coastal Queensland

**One year after planting**

# Adaptable to various soils

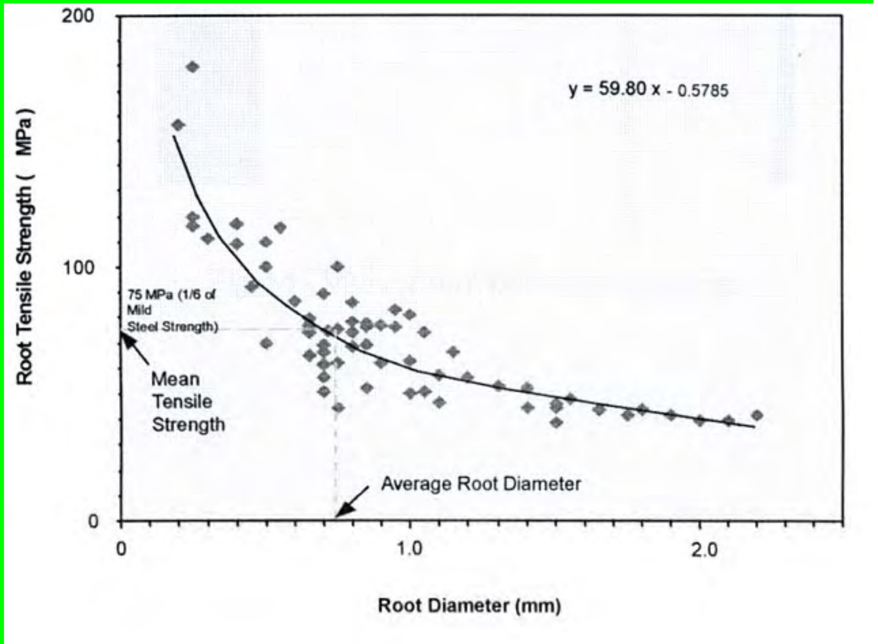
Heavy cracking clay on the Darling Downs, Qld, Australia.

Two months after planting on a sand dune in Quang Binh, Vietnam

# 5. R&D results on unique characteristics of vetiver grass suitable for slope stabilization

Tensile strength of vetiver roots:

- Tensile strength increases with reduction in root diameter, i.e. stronger fine roots provide higher resistance than larger roots.
- Tensile strength of vetiver roots varies between 40-180 MPa for the range of root diameter between 0.2-2.2 mm.
- Mean design tensile strength is 75 MPa (app. 1/6 of mild steel) at 0.7-0.8 mm root diameter - the most common size of roots.
- This indicates vetiver roots are as strong as, even stronger than many hardwood species (Hengchaovanich and Nilaweera, 1996).



# 5. R&D results on unique characteristics of vetiver grass suitable for slope stabilization

**Table 1.** Tensile strength of roots of some plants.

| Botanical name | Common name | Tensile strength (MPa) |
|---|---|---|
| *Salix* spp | Willow | Sep-36 |
| *Populus* spp | Poplars | May-38 |
| *Alnus* spp | Alders | Apr-74 |
| *Pseudotsuga* spp | Douglas fir | 19-61 |
| *Acer sacharinum* | Silver maple | 15-30 |
| *Tsuga heterophylia* | Western hemlock | 27 |
| *Vaccinum* spp | Huckleberry | 16 |
| *Hordeum vulgare* | Barley Grass, | 15-31 |
| | Forbs Moss | 2-20 (2-7kPa) |
| ***Vetiveria zizanioides*** | **Vetiver grass** | **40-120 (average 75)** |

# 5. R&D results on unique characteristics of vetiver grass suitable for slope stabilization

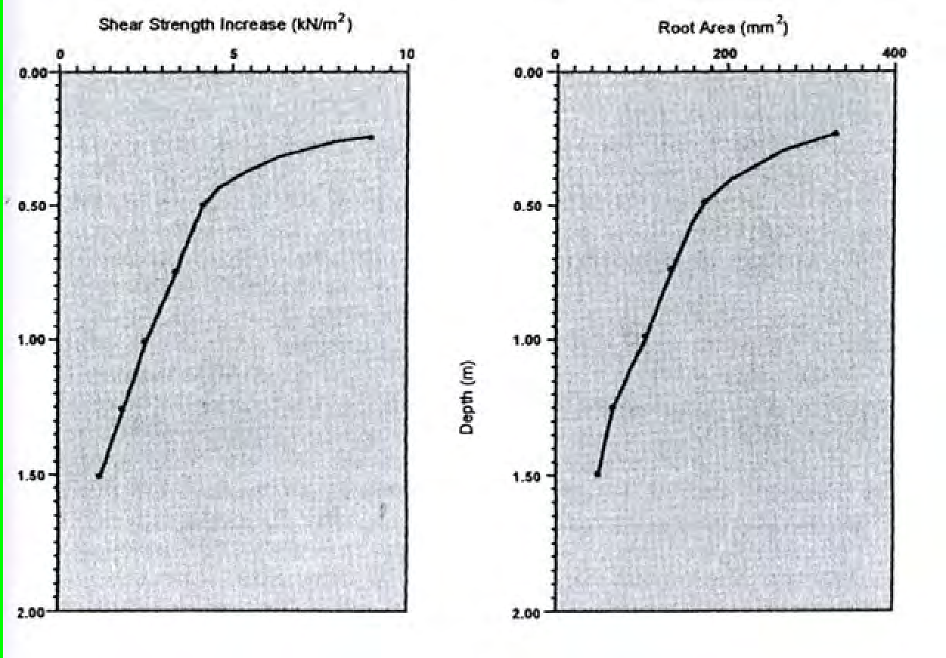
**Table 2.** Diameter and tensile strength of root of various herbs.

| Grass | Mean diameter of roots (mm) | Mean tensile strength (MPa) |
|---|---|---|
| Late Juncellus | 0.38±0.43 | 24.50±4.2 |
| Dallis grass | 0.92±0.28 | 19.74±3.00 |
| White Clover | 0.91±0.11 | 24.64±3.36 |
| ***Vetiver*** | ***0.66±0.32*** | ***85.10±31.2*** |
| Common Centipede grass | 0.66±0.05 | 27.30±1.74 |
| Bahia grass | 0.73±0.07 | 19.23±3.59 |
| Manila grass | 0.77±0.67 | 17.55±2.85 |
| Bermuda grass | 0.99±0.17 | 13.45±2.18 |

# 5. R&D results on unique characteristics of vetiver grass suitable for slope stabilization

Shear strength of vetiver roots:

- Soil block shear test also showed that root penetration of a two year old Vetiver hedge with 15 cm plant spacing can increase the shear strength of soil in adjacent 50 cm wide strip by 90% at 0.25 m depth. The increase was 39% at 0.50 m depth and gradually reduced to 12.5% at 1.0 m depth.
- Moreover, because of dense and massive root system it offers better shear strength increase per unit fiber concentration (6-10 kPa/kg of root per cubic meter of soil) compared to 3.2-3.7 kPa/kg for tree roots (Hengchaovanich and Nilaweera, 1996).



## 5. R&D results on unique characteristics of vetiver grass suitable for slope stabilization

- Stiff and erect stems, up to 2-2.5m high, which can stand up to relatively deep water flow (0.6-0.8m).
- It forms dense hedges when planted close together, reducing flow velocity, spreading and diverting runoff water and forming a very effective filter for erosion control. The hedges slow down the surface run-off, reducing its turbidity, allowing more time for water to infiltrate into the ground.
- New roots are developed from nodes when buried by trapped sediment. Vetiver will continue to grow with the new ground level eventually forming terraces, if trapped sediment is not removed.
- In addition, this sediment can also contain seeds of local plants hence facilitating the latter’s growth.

## 5. R&D results on unique characteristics of vetiver grass suitable for slope stabilization

- Together with its fast growing ability in difficult soil conditions, these characteristics make the grass a much better candidate for slope stabilization than other plants.
- By planting Vetiver grass in contour lines, many natural slopes, cut slopes and filled embankments can be stabilized. The deep, rigorous root system helps stabilize the slopes structurally while its shoot helps spread out the surface run-off, reduce erosion and trap sediments to facilitate the growth of native species.

## 5. R&D results on unique characteristics of vetiver grass suitable for slope stabilization

To reduce water disasters such as flood, river bank and coastal erosion, dam and dike instability etc., Vetiver grass is planted in rows either parallel or across the water flow or wave direction. The following additional unique characteristics of the grass are also very useful:

- Vetiver survives under prolonged submerged conditions as it is a wetland plant. Recent trial on the Mekong River bank in Cambodia showed vetiver can survive up to 15m deep and for at least 5 months under muddy water during flooding.
- Due to its extraordinary root depth and strength, once fully established it is extremely resistant to high velocity flow. Experiences in Queensland (Australia) show Vetiver has withstood flow velocity higher than 3.5m/sec in river under flood conditions and up to 5m/sec in a drainage channel.

## 5. R&D results on unique characteristics of vetiver grass suitable for slope stabilization

- Under shallow or low velocity flow, the erect and stiff stems of Vetiver act as a barrier to reduce flow velocity (i.e. increase hydraulic resistance) and trap eroded sediment. In fact, it can stand erect in the flow as deep as 0.6-0.8m.
- Under deep and high velocity flow Vetiver tops will bend down, providing extra protection to surface soil and at the same time reducing flow velocity.
- Thus planted dams or dikes, Vetiver hedgerows help reduce the flow velocity, decrease wave run-up, over-topping and consequently the volume of water that may flow in the area protected by these structures.
- They also help reduce the so-called retrogressive erosion that takes place when the water flow or wave retreats back after over-topping dams/dykes.

# 5. R&D results on unique characteristics of vetiver grass suitable for slope stabilization

Pore Water Pressure

- Increase in water infiltration is one of the major effects of vegetation cover on sloping lands and there is concern that extra water will increase the pore water pressure in the soil which could lead to slope instability.
- However, field observations show much better counter-effects. First, planted on contour lines which would trap and spread runoff water on the slope, the extensive root system of vetiver grass helps prevent localized accumulation of surplus water and distribute it more evenly and gradually.
- Second, increased infiltration is also balanced by a higher, and again, gradually rate of soil water depletion by the grass.

# 5. R&D results on unique characteristics of vetiver grass suitable for slope stabilization

Pore Water Pressure

- Research in soil moisture competition in crops in Australia (Dalton et al, 1996) indicated that under low rainfall condition this depletion would reduce soil moisture up to 1.5 m from the hedges, thus increasing water infiltration in that zone, leading to the reduction of runoff water and erosion rate.
- Geotechnically, these conditions have beneficial effects on slope stability. On steep (30-60$^o$) slopes the space between rows at 1m VI (Vertical Interval) is very close, this moisture depletion would be greater therefore further improve the slope stability.
- In high rainfall areas, to reduce this potentially negative effect of vetiver grass on slopes, vetiver hedges could be planted on a gradient of about 0.5% to divert extra water to stable drainage outlets (Hengchaovanich, 1998).

# 5. R&D results on unique characteristics of vetiver grass suitable for slope stabilization

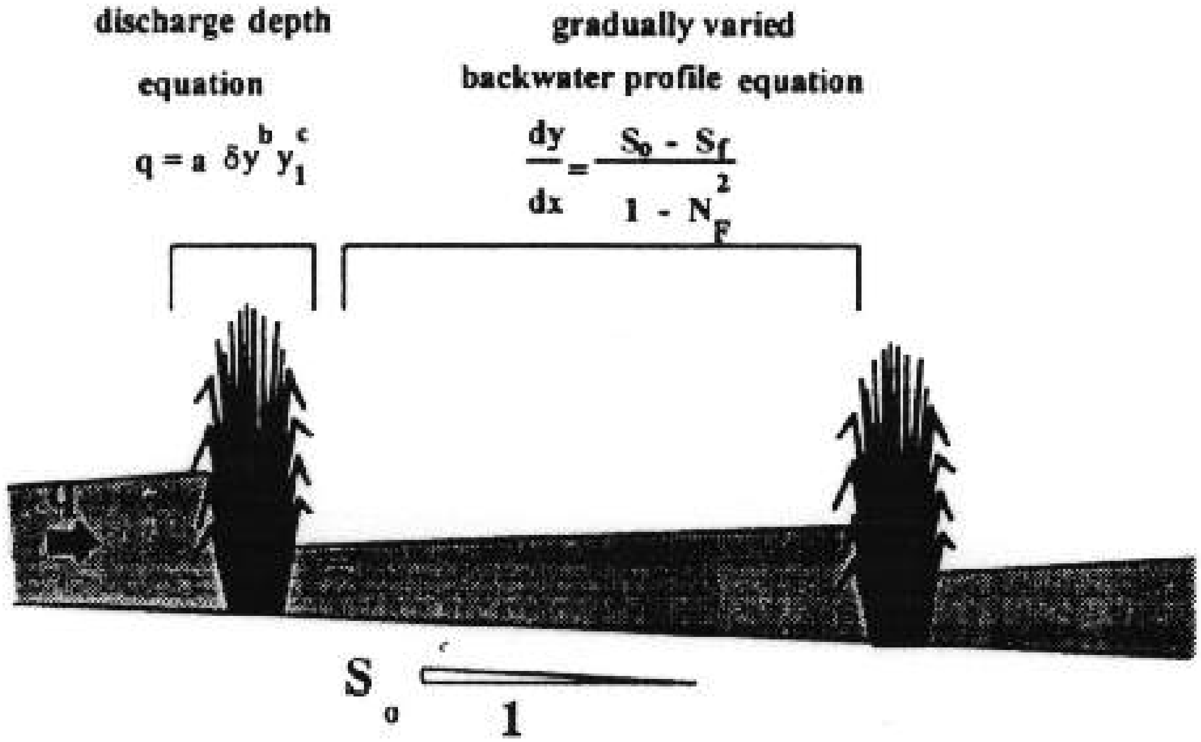



Figure 1: Hydraulic model of flooding through vetiver.

**Hydraulic Model of Flooding through Vetiver Hedges**
(P. Dalton, 1998)

Where: q = discharge per unit width; y = depth of flow; y1 = depth upstream; So = land slope; Sf = energy slope; NF = the Froude number of flow.

## 5. R&D results on unique characteristics of vetiver grass suitable for slope stabilization

- Because of the above characteristics, Vetiver grass is very effective in erosion control of both cut and fill slopes associated with road construction.
- It is also very effective in controlling water disasters such as flood, coastal and river bank erosion, dam and dike erosion and instability, and for protection of bridge, culvert abutments and the interface between concrete/rock structures and soil.
- It is particularly effective in highly erodible and dispersible soils such as sodic, alkaline, acidic and acid sulfate soils.

Each of these types represents some sort of slope failure, and its basic principles should be learnt so that VS could be applied properly to fully mobilize its unique characteristics.

## 5. R&D results on unique characteristics of vetiver grass suitable for slope stabilization

- For upland natural slope, cut slope, road batter etc., their stability is based on the interplay between two types of forces, driving forces and resisting forces. Driving forces promote down slope movement of material, whereas resisting forces deter movement. When driving forces overcome resisting forces, these slopes become unstable.
- Erosion of bank and instability of water retaining structures is slightly more complicated, being the result of interactions between hydraulic forces acting at the bed and toe, and gravitational forces acting on the in-situ bank material.

# 5. R&D results on unique characteristics of vetiver grass suitable for slope stabilization

- Failure occurs when erosion of the bank toe and the channel bed adjacent to the bank have increased the height and angle of the bank to the point that gravitational forces exceed the shear strength of the bank material.
- After failure, failed bank material may be delivered directly to the flow and deposited as bed material, or dispersed as wash load, or deposited along the toe of the bank as intact block, or as smaller, dispersed aggregates.

## 5. R&D results on unique characteristics of vetiver grass suitable for slope stabilization

- Fluvial controlled processes of bank retreat are essentially twofold. Fluvial shear erosion of bank materials results in progressive incremental bank retreat. Additionally, increases in bank height due to near-bank bed degradation or increases in bank steepness due to fluvial erosion of the lower bank may act alone or together to decrease the stability of the bank with respect to mass failure.

# 5. R&D results on unique characteristics of vetiver grass suitable for slope stabilization

- Depending on the constraints of the bank material properties and the geometry of the bank profile, they may fail by any one of several possible mechanisms, including planar, rotational, and cantilever type failures.
- Non-fluvial controlled mechanisms of bank retreat include the effects of wave wash, trampling, as well as piping- and sapping-type failures, associated with stratified banks and adverse groundwater conditions.

## 5. R&D results on unique characteristics of vetiver grass suitable for slope stabilization

The main driving force is gravity which, however, does not act alone. Slope angle, climate, slope material, and especially water contribute to its effect:

- In the form of rivers and wave action, water erodes the base of slopes, removing support, which increases driving forces;
- Water can also increase the driving force by loading, i.e. filling previously empty pore spaces and fractures, adding to the total mass subjected to the force of gravity;

# 5. R&D results on unique characteristics of vetiver grass suitable for slope stabilization

- The presence of water results in the so-called pore water pressure which reduces the shear strength of the slope material. More importantly, abrupt changes (both increase and decrease) in pore water pressure are believed to play the decisive role in causing slope failure;
- Interaction of water with surface rock and soil (Chemical weathering) slowly weakens slope material, reducing its shear strength, therefore reducing resisting forces.

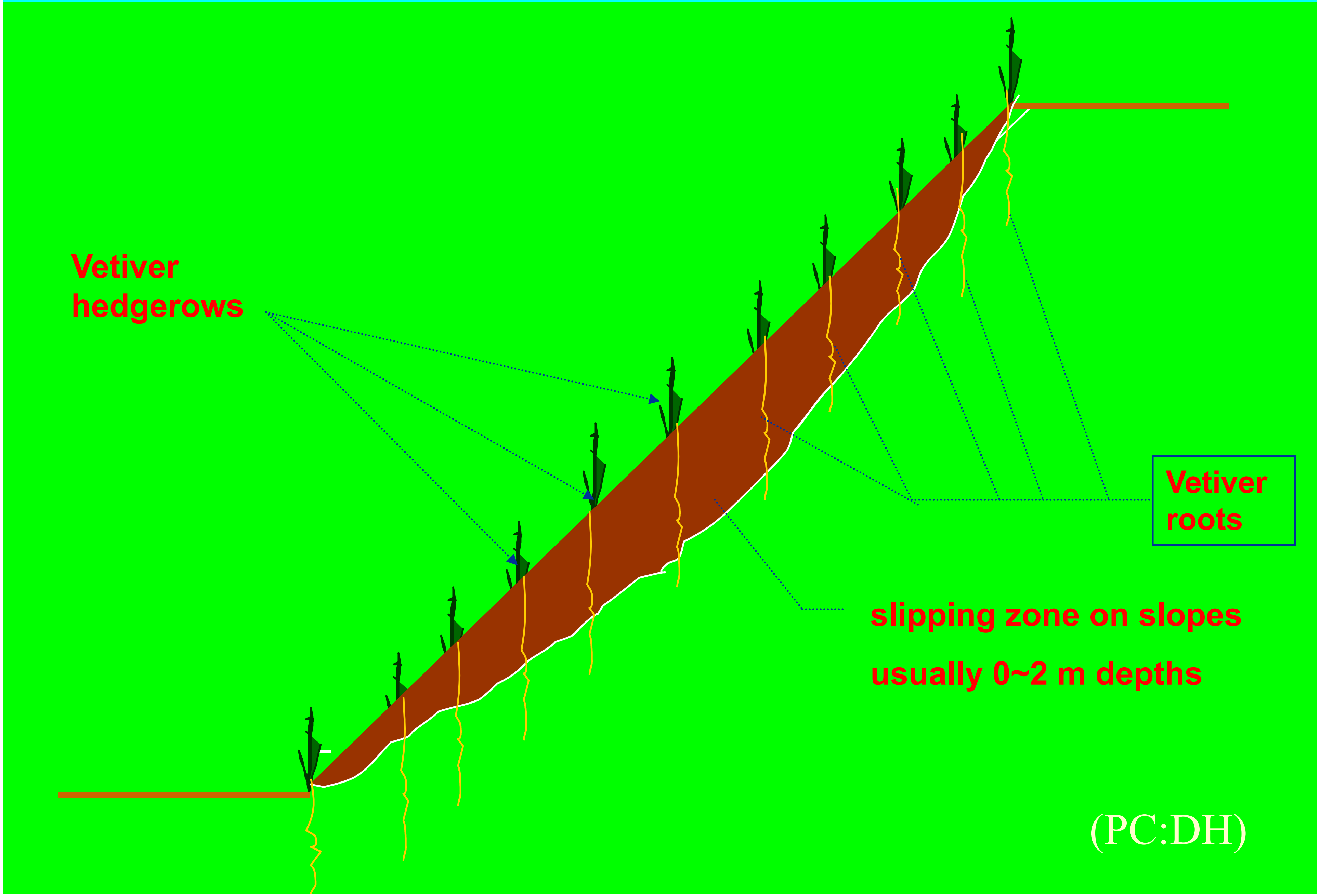
## 5. R&D results on unique characteristics of vetiver grass suitable for slope stabilization

- The main resisting force is the material's shear strength, a function of cohesion (ability of particles to attract and hold each other together) and internal friction (friction between grains within a material), which acts oppositely of driving forces.
- The ratio of resisting to driving forces is called the factor of safety (FS). If FS >1 the slope is stable, usually a FS of 1.2-1.3 is marginally acceptable.

## 5. R&D results on unique characteristics of vetiver grass suitable for slope stabilization

- Under factors mentioned above, a slope may become unstable due to: 1). surface erosion; and 2). internal structural weaknesses.
- Surface erosion leads to rill and gully erosion, which with time deteriorates slope stability, while structural weakness causes mass movement or landslip.
- With time, surface erosion can also cause slope failure and, therefore, slope surface protection should be considered as important as other structural reinforcements.
- In a way, slope surface protection is a preventive measure while the latter are corrective ones. In many cases, it is sufficient just to apply preventive measures to ensure slope stability, which always cost much less than corrective ones.

# LANDSLIP CONTROL MECHANISM BY VETIVER



# 5. R&D results on unique characteristics of vetiver grass suitable for slope stabilization

**Table 3.** Different types of slope failure.

| Type of movement | | Material involved: Rock | Material involved: Soil |
|---|---|---|---|
| *Falls* | | - rock fall | - soil fall |
| *Slides* | Rotational | - rock slump block | - soil slump blocks |
| | Translational | - rock slide | - debris slide |
| *Flows* | Slow | - rock creep | - soil creep |
| | | | - saturated & unconsolidated material |
| | | | - earth flow |
| | | | - mudflow (up to 30% water) |
| | | | - debris flow |
| | Fast | | - debris avalanche |
| *Complex* | Combination of two or more types of movement | | |

**Table 4.** General physical effects of vegetation on slope stability.

| Effect | Physical Characteristics |
|---|---|
| ***Beneficial*** | |
| Root reinforcement, soil arching, buttressing, anchorage, arresting the roll of loose boulders by trees | Root area ration, distribution and morphology; Tensile strength of roots; Spacing, diameter and embedment of trees, thickness and inclination of yielding strata; Shear strength properties of soils |
| Depletion of soil moisture and increase of soil suction by root uptake and transpiration | Moisture content of soil; Level of ground water; Pore pressure/soil suction |
| Interception of rainfall by foliage, including evaporative losses | Net rainfall on slope |
| Increase in the hydraulic resistance in irrigation and drainage canals | Manning's coefficient |
| ***Adverse*** | |
| Root wedging of near-surface rocks and boulders and uprooting in typhoon | Root area ration, distribution and morphology |
| Surcharging the slope by heavy trees (sometimes beneficial) | Mean weight of vegetation |
| Wind loading | Design wind speed; mean mature tree height for groups of trees |
| Maintaining infiltration capacity | Variation of moisture content with depth |

# Vetiver grass as a bio-engineering tool: Some Vietnamese experiences

**Table 5**. Slope angle limitations on establishment of vegetation.

| **Slope angle** (degrees) | **Vegetation type** | |
|---|---|---|
| | **Grass** | **Shrubs/trees** |
| 0-30 | Low in difficulty; routine planting techniques may be used | Low in difficulty; routine planting techniques may be used |
| 30-45 | Increasingly difficult for sprigging or turfing; routine application for hydro seeding | Increasingly difficult to plant |
| > 45 | Special consideration required | Planting must generally on benches |

## 6. Some lessons, recommendations and conclusions

- Application of VS requires the understanding of biology, soil science, hydraulic and hydrological as well as geotechnical principles.
- It is best for the technology be designed and implemented by experts in Vetiver application, a combination of an agronomist and a geotechnical engineer, with assistance from local farmers.
- It has to be understood that Vetiver is a grass by botanical classification but it acts more like a tree with its extensive and deep root system.

## 6. Some lessons, recommendations and conclusions

- In addition, VS exploits its different characteristics for different applications, for example deep roots for land stabilization, thick growth for water spreading and sediment trapping and extraordinary tolerance to various chemicals for land rehabilitation etc.
- Failures of VS in most cases can be attributed to bad applications rather than the grass itself or the technology recommended. Experience in Vietnam shows that the use of Vetiver is very successful when it is applied correctly, but improper applications may fail.

# 6. Some lessons, recommendations and conclusions

- VS application results in very good results:
  - ✓ Applied primarily for slope surface protection it greatly reduces surface erosion, which otherwise would cause hazards downstream;
  - ✓ By preventing shallow failures, it greatly stabilizes cut slopes and consequently greatly reducing the number of deep slope failures;
  - ✓ In some cases where deep slope failures do occur, it still does a very good job in slowing down the failures and reducing the failed mass; and
  - ✓ It helps increase the environmental friendliness of the road etc.

# 6. Some lessons, recommendations and conclusions

- Success and failure along the Ho Chi Minh Highway show further lessons:
  - The slopes should first be internally stable, as the Vetiver grass is not immediately effective (slopes can fail before roots have established). Stabilization may take place earliest 3-4 months after planting; hence timing is also very important to avoid slope failure in the first rainy season;
  - Appropriate slope angle should not exceed 45-50$^{o}$; and
  - Regular trimming is also important to ensure further growth of the grass to achieve good, dense hedgerows etc.

Immediate sliding down the slope without Vetiver

Sliding down but very slow

Vetiver protects the cut slope of HCM HW in Quang Binh

**Can’t help prevent deep failure (HCM HW).**


With wooden structure
Can act alone
Or with concrete/rock rip-rap structures.

Planted in rows on dykes to get a closed turf.


5 1 2005
Even better than concrete

Planted on the field-side of the sea dyke, and can be partly on the sea-side.

Planted behind the mangrove on the sea-side of the dyke to help recover local species.

## 6. Some lessons, recommendations and conclusions

- From the results of research and the successes of numerous applications presented above, it is clear that we now have enough evidence that VS is a very effective and low cost bio-engineering tool for the stabilization and rehabilitation of disturbed lands caused by civil construction.
- However it must be emphasized that to provide an effective support for engineering structures, the two most important points are:
  - good quality of the planting material; and
  - the all-important appropriate design and correct planting techniques.

**Thanks for your attention!**