

SLOPE STABILITY IMPROVEMENT WITH VETIVER SYSTEM TECHNOLOGY



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WHAT IS VETIVER?

Vetiver (*Chrysopogon zizanioides*) is a fast growing perennial grass with a vast interlinked root system and strong stems, which create a versatile plant that has been used worldwide to address a myriad of environmental and engineering rehabilitation issues. Vetiver is the most researched non-agricultural and non-industrial crop ever reported.

Vetiver is being used in more than 100 countries as a bioengineering tool for erosion and sediment control particularly on steep slope



VETIVER



Vetiver Characteristics - Roots

STRONG, DENSE, DEEP & PENETRATING ROOTS

- Tensile strength 1/6th of mild steel = 75Mpa
- Improve soil shear strength by 45%
- Grow vertically, reaching depths of 5+ metres
- Interlocking root matrix create vast, dense and strong underground walls, reinforcing soil conditions
- Uptake nutrients and moisture from deeper soil depths = drought resistant
- Can develop new roots from nodes when buried
- Increases soil microbial activity, breaking down and absorbing metal toxicities, herbicides, pesticides and excess nutrients – allowing for rehabilitation and revegetation of soil
- Fine root structure – does not interfere with the integrity of infrastructure

Vetiver Characteristics - Roots



Very fine and massive root system



One year old with 3.3m deep root system

Strong root reinforcement holding up this earthen wall against water erosion



Deep and penetrating root systems



Root reinforcement more than 2m deep

Vetiver Characteristics - Stems

STRONG, STIFF & THICK SHOOTS:

- Perennial tufted grass
- Create dense hedges when planted close together
- Dissipate wind and water energy
- Slow down water flow
- Withstand high velocity flows of 5m/sec
- Control water run off
- Trap sediments
- Increase water infiltration and retention
- Recharge groundwater
- Flowers but does not produce seeds, which means it is sterile
= NO WEED POTENTIAL
- Can grow up to 3 metres tall
- Hydrophyte - snorkels air from above the water

Vetiver Characteristics - Stems



Erect stems up to 2m tall



Forming a thick hedge

Vetiver Characteristics - Resilience

- Thrives in a variety of soils: sandy, saline, water logged, toxic, acidic and alkaline (pH 3.3 – 12.5)
- Withstands prolonged periods of flooding and drought
- Crown adjusts itself to ensure it will not be buried alive
- Survives in air temperatures of -15C to 55C
- Disease and pest resistant
- Crown lives below the surface, to protect itself from fire, grazing and trampling



THE VETIVER SYSTEM

The Vetiver System is designed using Vetiver's unique stem and root system, which when planted in rows develop into dense hedges that work both above and below ground.

The methodology and planting dimensions are dependent on the particular project requirements, with each system individually designed according to project specifications and needs.



SOIL BIOENGINEERING

EFFECTS OF VEGETATION ON SLOPE STABILITY

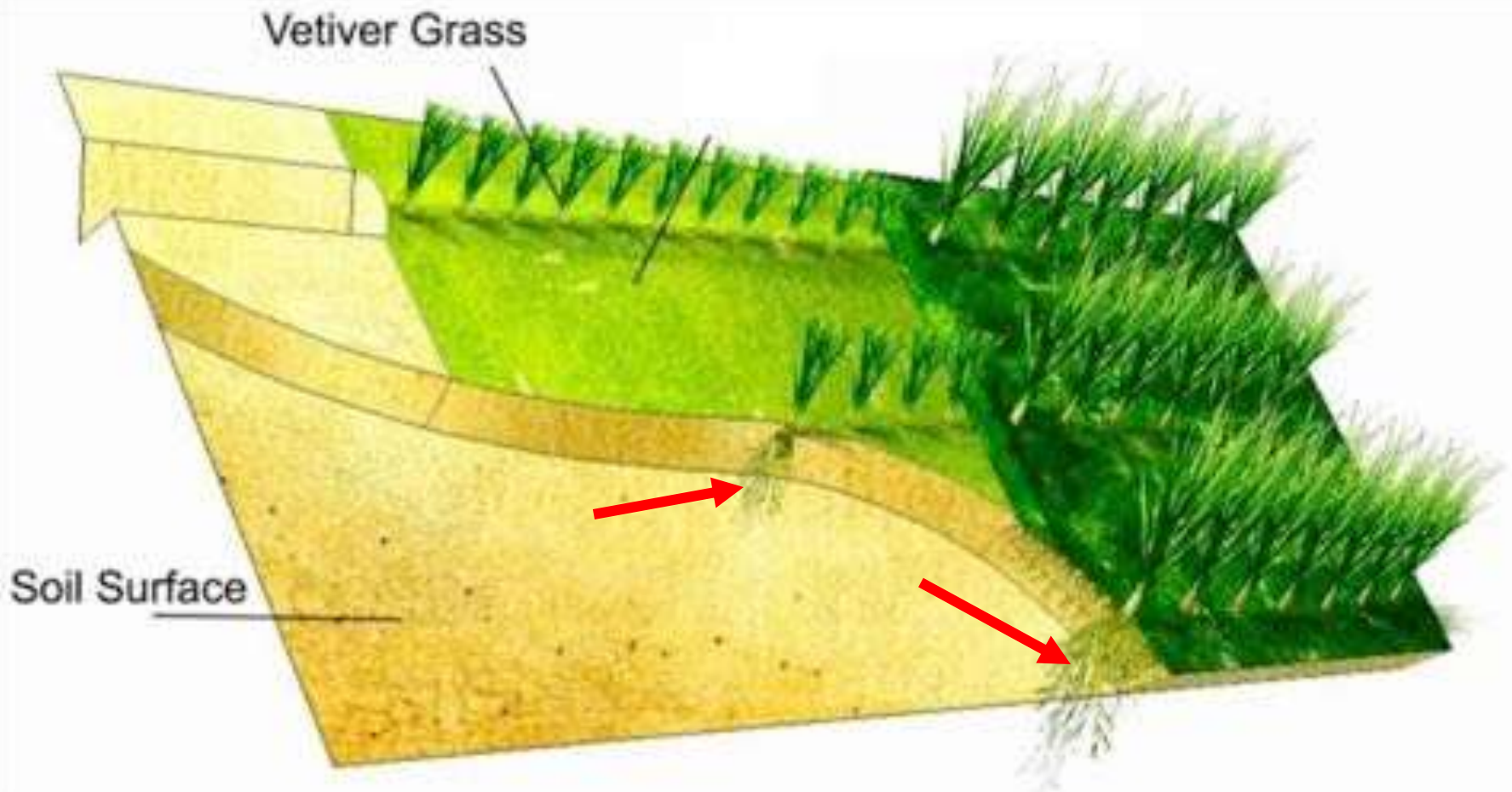
Vetiver's unique attributes, the root and stem system, combine to work both above and below ground to provide the structural strength and protection mechanisms to address the main causes of slope instability: surface or sheet erosion and internal structural weakness.

Vegetation works in three ways to address slope stability:

1. Root reinforcement improves shallow mass stability by increasing the shear strength of the soil.
2. Serves to modify the hydrologic activity of the slope, serving as an energy dissipater for water and wind. The grass slows the water flow, allowing the natural INFILTRATION process to occur, absorbing the excess water and soil moisture, stabilising internal structural weaknesses.
3. The root system penetrates across the soil mantle, into fractures and fissures in the underlying bedrock, residual soil, or transition zones, increasing the soil shear strength.

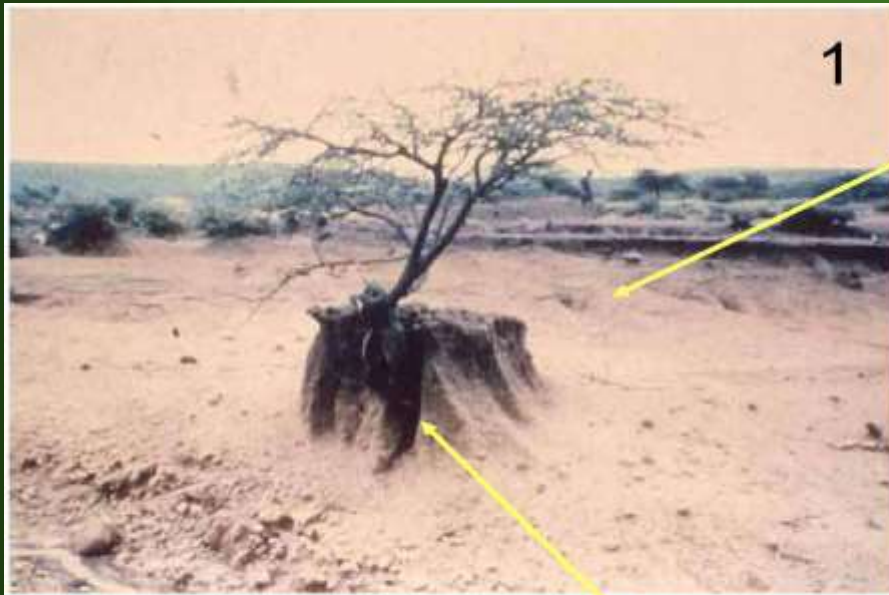
PRINCIPLES OF SOIL BIOENGINEERING

EFFECTS OF VEGETATION ON SLOPE STABILITY



Common Types of Slope Instability¹.

1-Surficial erosion 2. Shallow mass movement 3. Slides, slips, deep-seated mass movement, failure

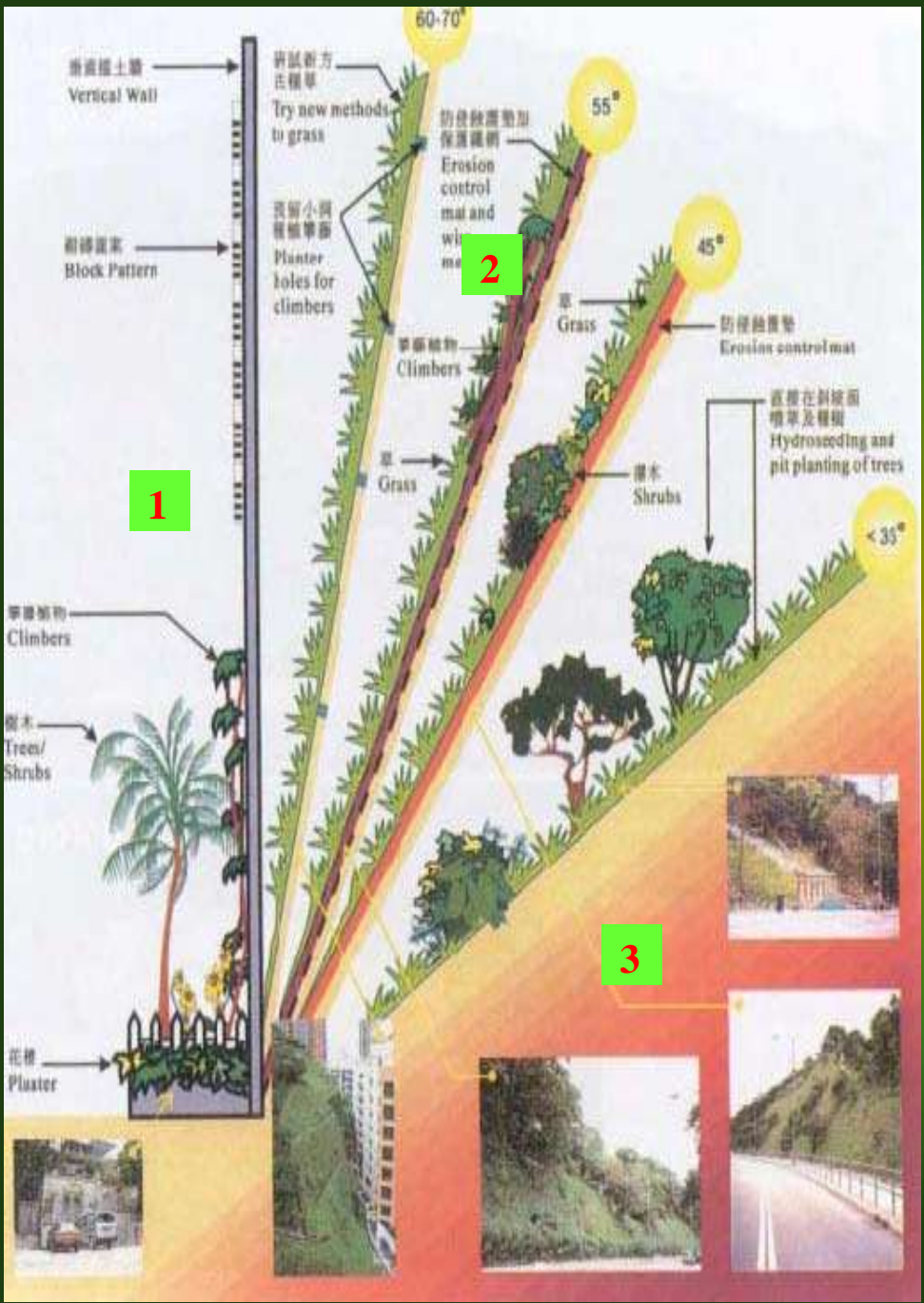


DYNAMIC roots function
in topsoil = erosion
control

Deep Roots penetrate
subsoil = **PASSIVE**
anchorage / soil
reinforcement



Options for slope stabilisation with hard and soft measures



- Options for slope protection:**
- 1. Hard structure**
 - 2. Combination of hard and soft structure**
 - 3. Bioengineering alone**

EFFECT OF VETIVER PLANTING ON SLOPE STABILITY

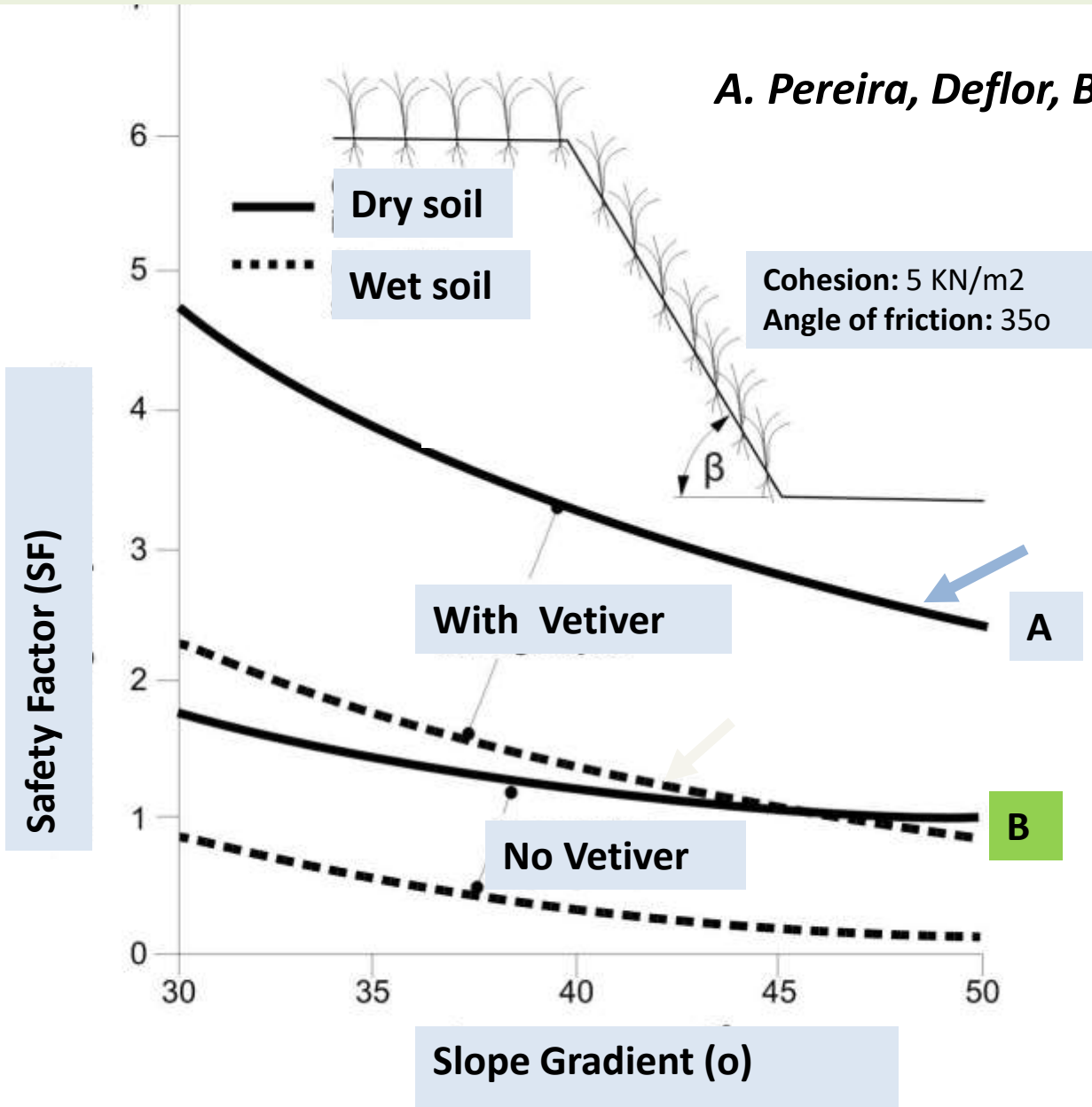
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Factors of Safety (FoS) or Safety Factor (SF), is an index used to measure slope stability under different conditions

VARIANTS		Safety Factor (SF)			
		With Vetiver			Without Vetiver
Ages (years)		2	4	6	
Gradient	< 30°	7,80	8,93	10,00	3,30
	30 - 45°	6,76	7,95	9,01	2,91
	>45°	5,95	7,31	8,70	2,60
Angle of Repo (o)		24,60	33,90	36,20	19,30

EFFECT OF VETIVER ON SLOPE STABILITY ON DRY AND WET SOIL

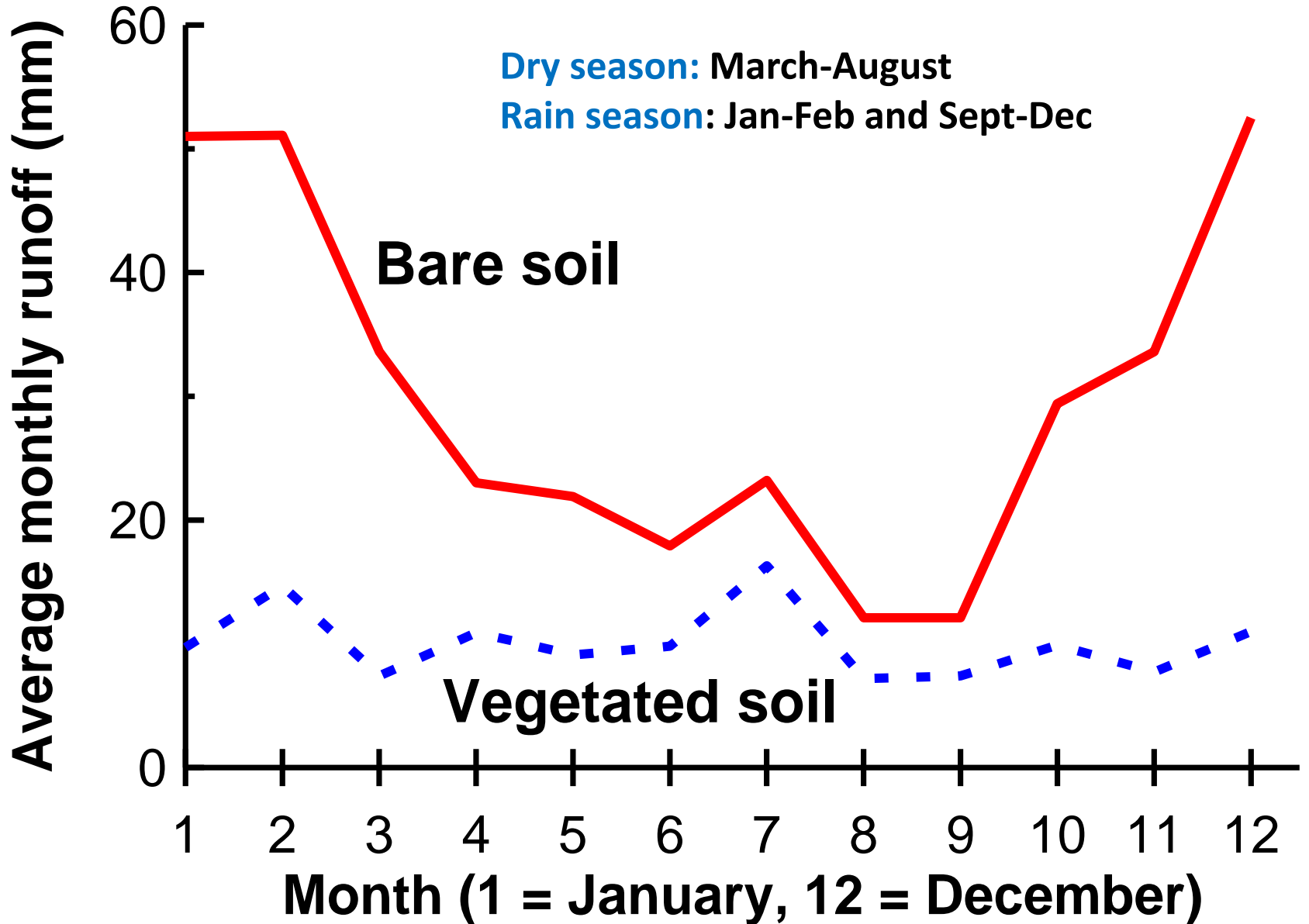
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On dry soil with Vetiver (A), when slope gradient increases from 30o to 50o, FS reduces from 4.8 to 2.5

When dry soil with Vetiver (B) became wet, FS reduces from 4.8 to 2.2 at 30o slope

Effects of Vegetation on Surface Runoff



Small Scale Laboratory Experiment at Indonesian Institute of Road Engineering



ROOT GROWTH TRIAL

SLOPE 45°,
GRASS, PLACEMENT VARIATION
,
SILTY LAY LOAM



FIELD LABORATORY AT NAGREG – WEST JAVA



**SLOPE 80°,
AGE: 4 MONTHS
BEFORE TRIMMING**



**SLOPE 80°,
AGE: 4 MONTHS
AFTER TRIMMING**

**SOIL TYPE: CLAY,
SLOPE HEIGHT
VARIATION (7M)
SLOPE LENGTH
(5M/TREATMENT)**

Penurunan Tingkat Erosi untuk Masing-masing Perlakuan Lokasi Nagreg KM 43 – Kabupaten Bandung

Pola Penanaman	Reduksi Laju Erosi (%)
Rumput Vetiver (V)	77,4
Rumput Bahia (B)	91,8
Kombinasi Rumput Vetiver : Bhaia (V1B2)	99,2
Kombinasi Rumput Vetiver : Bahia (V2B1)	99,3

FIELD LABORATORY AT CIPULARANG TOLL ROAD, WEST JAVA



SLOPE 60°,
AGE: 3 MONTHS



SLOPE 45°,
AGE: 3 MONTHS



SLOPE 30°,
AGE: 3 MONTHS

SOIL TYPE: SILTY CLAY,
SLOPE HEIGHT VARIATION (3, 6, 9 M)
SLOPE LENGTH(5M/TREATMENT)

FIELD LABORATORY AT CIPULARANG TOLL ROAD, WEST JAVA



SLOPE 60°,
AGE: 3 MONTHS



SLOPE 45°,
AGE: 3 MONTHS

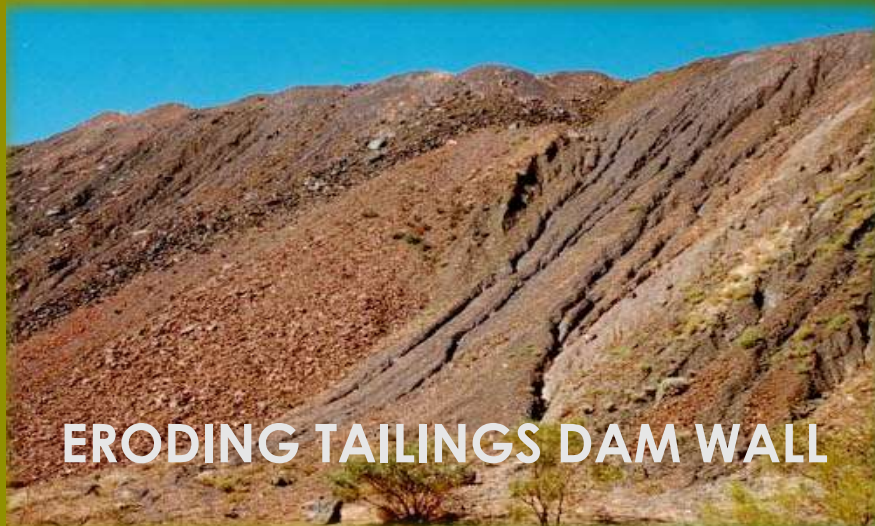
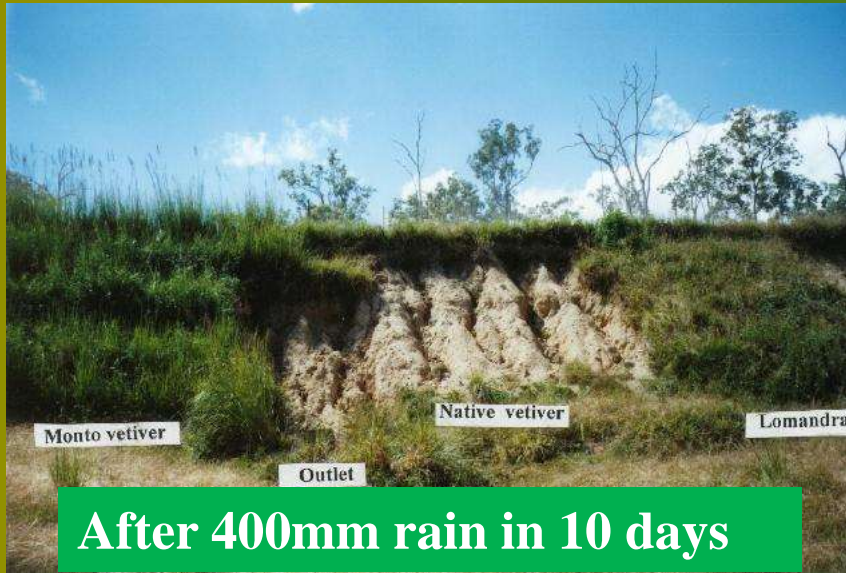


SLOPE 30°,
AGE: 3 MONTHS

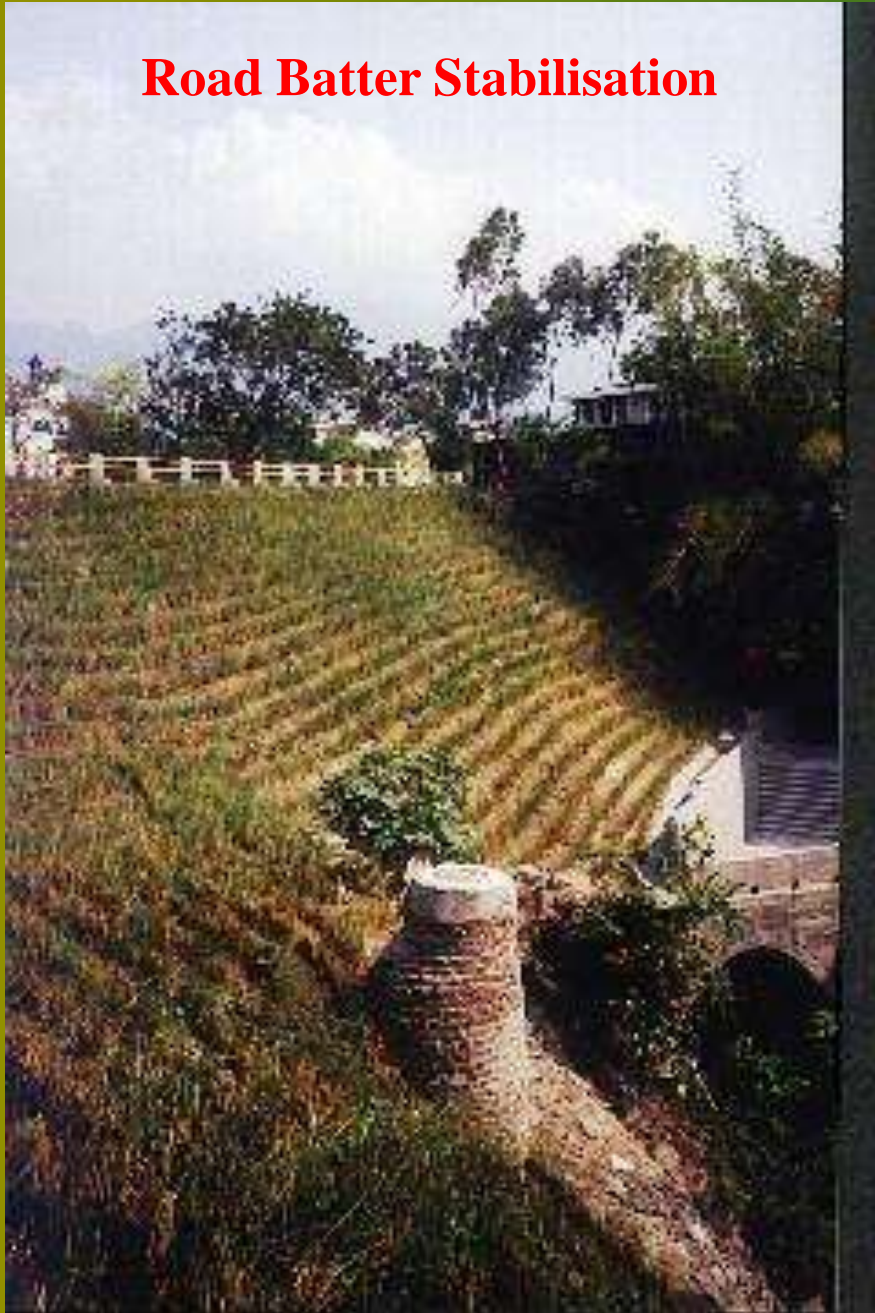
SOIL TYPE: DUSTY CLAY
SLOPE HEIGHT VARIATION (3, 6, 9 M)
SLOPE LENGTH(5M/TREATMENT),
STABILITY INDEX: UNSTABLE

GLOBAL CASE STUDIES OF VETIVER SYSTEM

AUSTRALIA



Road Batter Stabilisation



Land slip rehabilitation



CHINA

PC: L Xu



HIGHWAY BATTER STABILISATION



COLOMBIA

PC:

URIEL SALAZAR G.
BIOTECNIA DE SUELOS



HIGHWAY BATTER STABILISATION



PC: D Londono



COLOMBIA

PC: D Londono



IN COMBINATION WITH SOIL NAILING



CONGO

PC: A NDONA



RAVINE REHABILITATION WITH SANDBAGS

HIGHWAY BATTER

STABILISATION



MADAGASCAR

PC: R Noffke

PC: Y Coppin



SAND DUNE REHABILITATION

RAILWAY BATTER STABILISATION



SOUTH AFRICA

PC: R Noffke



HIGHWAY BATTER STABILISATION



SOLOMON ISLANDS

PC: R Vanoh



LANDSLIP STABILISATION



THAILAND



HIGHWAY BATTER STABILISATION



Arachis pintoii



HIGHWAY BATTER STABILISATION



VIETNAM



Broken concrete



The best trial, where the first
PC: V Tran
stable, though still having

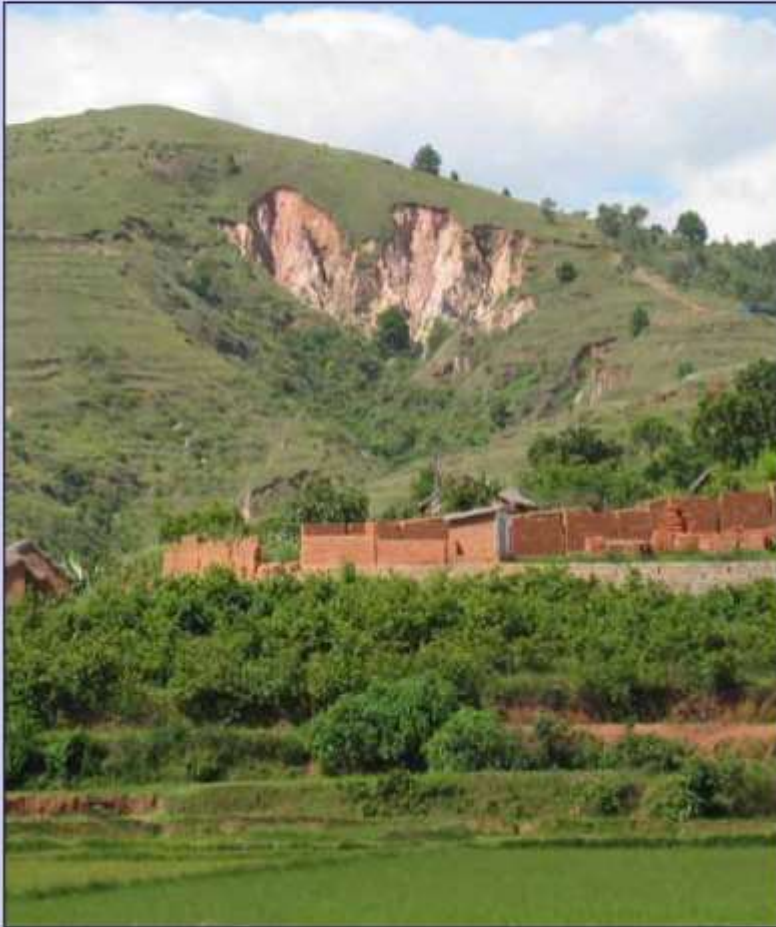
HO CHI MINH HIGHWAY BATTER STABILISATION



Thank You

PC: Y Coppin

"Vegetation is like the skin of the Earth..."



...when you remove the skin, the Earth bleeds."