Chapter 1

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The Role of Vegetation on Slope Stability

1.1 Introduction

The cutting of slopes for development purposes, although not a new phenomenon in Malaysia, has in recent years been hastened to such an extent that it has caused geographical as well as environmental problems, including erosion and landslides. Reports have also revealed the impact of slope development on water supply, biodiversity (flora and fauna survival) and socio-economic activities (New Straits Times, 13 May, 1997). Studies have found that the occurrence of landslide has a close relationship with the geological characteristics, hydrological condition and rainfall distribution (e.g. Woo, 1996). Relating to Malaysia's climate with an annual average rainfall of nearly 2,500 mm, the hydrological influence on slope stability becomes a crucial element (Business Times, 31 January, 1997) and has been a major cause of previous disasters. For example, in June 1995, intense rainfall triggered a mud slide along a hill road leading to Genting Highlands leaving 28 holiday makers dead and scores of vehicles buried in mud. It was reported that landclearing in nearby area could be the cause of the disaster (Juhaid and Hamidah, 1995). A massive landslide along the North-South Expressway near Gua Tempurung in Perak claimed the life of a lorry driver who was swept into a ravine. Meanwhile, a landslide in Sandakan, Sabah, claimed three lives and injured three others (Pang, 1996). In another tragedy, an Orang Asli settlement was swept away by a torrent of water and debris from a nearby hill at Pos Dipang, near Kampar, Perak. Heavy rain had caused Dipang river to swell and water level of the river rose rapidly. Fifteen people were killed and about forty others were missing on the first day after the event (New Straits Times, 31 August, 1996). Subsequent fatality figure swelled after that.

Given the pace of hill development in the past decade and ensuing landslide tragedies, a suitable and effective solution has to be taken to enhance the stability and sustainability of slopes to avoid further damage to the environment.

1.2 Literature Review

1.2.1 Slope Instability

Slope failure was reported to be associated, *inter alia*, with the destruction of vegetation covers following severe cutting of slopes (Nortcliff *et al.*, 1990). After trees are cut and root begin to decay, the frequency of slope failure tend to increase (Abe, 1997). Earlier, Bishop and Stevens (1964) also concluded that the destruction of vegetation and gradual decay of interconnected root systems were the principle cause of increased slope failure.

It was reported recently that 150 tonnes per hectare of soil is lost per year in the Main Range, Peninsular Malaysia (Pang, 1996). How can we make up for the loss? Based on the Universal Soil Loss Equation (USLE), soil erosion is governed by the following factors : the intensity, duration and total amount of rainfall (erosivity); soil composition; steepness and length of slope; and the extent of vegetation cover and conservation measures taken (Gray, 1995). Amongst the factors, rainfall and soil type are inherent, largely beyond our control while the other two factors are man-controlled. Soil losses due to rainfall can be decreased a hundred fold by maintaining a dense cover of sod, grasses or herbaceous vegetation (USDA Soil Conservation Service, 1978). In view of that, based on ecophysiological importance, it is recommended that slopes be revegetated upon land developing (e.g. Barker *et al.*, 1994).

1.2.2 Vegetation and Slope Stability : Water Relations and Root Reinforcement

The role of vegetation in stabilising slopes has gained increased recognition. One of the major contributions of plant is related to "soil-plant-atmosphere continuum". In this system, water flow takes place from higher to lower potential energy, with the concept of "water potential" equally valid and applicable in the soil as in the plant and the atmosphere. Plants can then contribute to drying the slopes by absorbing part of the ground water (Zaruba and Mencl, 1969) and subsequently, this soil water will be removed through enhanced transpirative area of the leaves to the atmosphere (Coppin *et al.*, 1990). This water cycle system would result in drier and more stable slope.

In addition, vegetation also contributes to mass stability also by increasing soil shear strength *via* root reinforcement (Gray, 1995). Various studies have documented the important effects of root density in preventing landslides (e.g. Gray, 1995; Abe, 1997). Moreover, the different plant compositions can also cause differences in root reinforcement properties and hence in shear strength value (Tobias, 1995). Grimshaw (1995) for example envisaged that the success of the common species for slope stabilisation, vetiver grass, is due to its deep rooting system. Apart from the soil binding through its deep root, its other biological characteristics would also provide for a dense and effective barrier thus filtering out run-off sediment, dissipating hydraulic forces and spreading out excess water evenly across the length of the hedge barrier. There are other beneficial effects of vegetation as has been summarised on herbaceous plant (Table 1.1) and on woody plant (Table 1.2) by Gray (1995) and Greenway (1987), respectively.

In contrast, the loss of vegetation cover caused top soil degradation. This removes carbon, nitrogen and other nutrients present previously in an ecosystem. Subsequently, with more erosion, more nutrients get depleted until the fertility of soil is lost and making it impossible for plants to grow. Example of reports on nutrient status of slope soil at different experimental sites is given (Table 1.3).

Table 1.1: Beneficial effects of vegetation and grasses on slopes stability (Gray, 1995).

EFFECTS	MECHANISMS
Interception	Foliage and plant residues absorb rainfall energy and prevent soil detachment by raindrop splash
Restraint	Root systems physically bind or restrain soil particles while above-ground portions filter sediment out of runoff
Retardation	Stems and foliage increase surface roughness and slow velocity of runoff
Infiltration	Plants and their residues help to maintain soil porosity and permeability thereby delaying onset of runoff

Table 1.2 : Hydro-mechanical influences of woody vegetation on slopes stability (Greenway, 1987).

EFFECTS	MECHANISMS
Root Reinforcement	Roots mechanically reinforce a soil by transfer of shear stress in the soil to tensile resistance in the roots
Soil Moisture Depletion	Evapo-transpiration and interception in the foliage can limit build up of positive pore water pressure
Buttressing and Arching	Anchored and embedded stems can act as buttress piles or arch abutments to counteract downslope shear forces
Surcharge	Weight of vegetation can (in certain instances) increase stability *via* increased confining (normal) stress on the failure surface.

Table 1.3 : The values of nutrients measured at different soil samplings (Rosli *et al.*, 1994).

Sites	Nutrients (%)				
	Na	K	Mg	Ca	N
Tanjung Malim – K.L highway (land slip slope)	0	0	0	0.02	0
K.L. – Seremban highway, km 38 (land slip slope)	0.06	0.54	0.06	0.03	0
K.L. – Seremban highway, km 46 (land slip slope)	0.23	0.40	0.06	0.02	0
Bare soil (along East-West highway)	0.12	0	0	0.01	0
Slope with cover crops	0.14	0.48	0	0.38	0.90
Fertilised garden soil (control), 3:2:1: of soil:sand:cow dung	1.34	1.81	0.12	0.94	3.00

1.2.3 Influence of Vegetation Type

Certain types of plants are better than others depending on the desired functions including, soil reinforcement, water uptake and removal and surface protection (Coppin *et al.*, 1990). Herbaceous vegetation, *viz.*, grasses and shrubs are most effective for improving the resistance to surface erosion, whereas woody vegetation, *viz.*, trees are more effective for the prevention of shallow mass wasting. The relative advantages and disadvantages of different plant types are listed (Table 1.4).

1.3 Philosophy and Objectives: Monoculture *vs.* Mix-culture

Traditionally, grasses or legumes are used to stabilise slope along highway in Malaysia and the rest of the world. This vegetation faded away within 2 -3 years, arguably due to heavy rain and other climatic factors. In view of this, it has been suggested that mixed cropping, in the form of "bush ecosystem" is a useful and more sustainable method of stabilising slopes compared to monoculture (Barakbah, 1994). In addition, through observations and some semiempirical assessments, monoculture covers have failed to stabilise and protect slopes (Bayfield, 1995). Schiechtl and Stern (1996) viewed that the establishment of "bush-ecosystem" needs the right species of fast growing cover and self-sustaining plants.

The objective of this project is to investigate the effects of mixed-cultured plants, in line with the concept of so-called "bush-ecosystem", on slope stability. Various physiological and water relations aspect including root reinforcement, effect of pre-treatment, vegetation type, vegetation growth and soil water profile will be examined.

In order to create data base on the relationship between vegetation and attributes of slope, which is woefully lacking in Malaysia, a survey is necessary. This extensive survey, carried out on various types of slope, ranging from stable to badly failed ones

Table 1.4 : Plant types for different functions and applications (Coppin *et al.*, 1990).

TYPE	ADVANTAGES	DISADVANTAGES
Grasses	Versatile and cheap. Wide range of tolerances. Quick to establish. Good dense surface cover.	Shallow rooting. Regular maintenance required.
(e.g. reeds & sedges)	Establish well on riverbanks, etc. Quick growing.	Hand planting expensive. Difficult to obtain.
Herbs	Deeper rooting. Attractive in grass sward.	Seed expensive. Sometimes difficult to establish. Many species died back in severe condition.
(e.g. legumes)	Cheap to establish. Fix nitrogen. Mix well with grass.	Not tolerant to difficult sites.
Shrubs	Robust and fairly cheap. Many species can be seeded. Substantial ground cover. Deeper rooting. Low maintenance. Many evergreen species.	More expensive to plant. Sometimes difficult to establish.
Trees	Substantial rooting. Some can be seeded. No maintenance once established.	Long time to establish. Slow growing. Expensive.
(e.g. willows & poplars)	Root easily from cuttings. Versatile many planting techniques. Quick to establish.	Care required in selecting corrective type. Difficult to grow from seed.

along the NSE, is aimed to study the root, the soil and root/water profiles. The influence of root density and soil water profile on various measure of soil strength including penetrability and shear will also be analysed.

1.4 Screening of the Species of Shrubs

Five species of shrubs have been chosen (Table 1.5) based on several visual observations as follows:

(i) larger leaf area
(ii) woody
(iii) medium size upon maturity (1 - 3 m height)
(iv) aesthetic value (flowers, coloured leaf, etc.)
(v) attractive to bees and insects (to create flora and fauna interaction)

Based on these criteria and on the availability of stock plants at PPC, five species were chosen: *Justicia betonica*, *Lantana camara*, *Exoecaria bicolor*, *Hibiscus mutabilis* and *Thunbergia erecta* (Table 1.5). These plants will be subjected to a first screening procedure (Chapter 2) based primarily on root length density. After this first screening, the species chosen will be subjected to water stress conditions (Chapter 3). Beyond this second screening, the species chosen will be deemed fit for trials on slopes with all the inherent environmental stresses (Chapter 4). It is imperative at this point to examine attributes of stable slopes as compared to unstable ones. As such a survey on a range of slopes will be carried out primarily to relate the vegetation to slope stability.

Table 1.5 : Introduction to the species of the shrubs studied (Graf, 1992) .

SPECIES	FAMILY	ORIGIN	OTHER NAME	TAXONOMY
Justicia betonica	Acanthaceae	Tropical Asia, South Pacific	"White Shrimp Plant"	Handsome bush ; opposite, corrugated ovate leaves; the stems terminated by slender bracted spikes, the bracts – white with green veining; flowers white to bluish.
Lantana camara	Verbenaceae	West India	"Shrub Verbena"	Small hairy shrub with thin-woody, angled branches sometimes prickly, with ovate, toothed, rough-bristly leaves; very floriferous with stiff-erect, small but showy heads of verbena-like flowers, changeable, usually opening pink or yellow, becoming red or orange, and several colour combination may be found on the same plant; summer-blooming.
Exoecaria bicolor	Euphorbiaceae	Vietnam	"Picara"	Smooth shrub with milky sap used as fish poison; shiny green, leathery leaves 12cm long, and red beneath; small flowers in narrow spikes.
Hibiscus mutabilis	Malvaceae	South China	"Cotton-rose"	Fast-growing shrubby bush becoming tree-like where planted in the tropics and subtropics; green stems becoming woody, the large 3 to 5-lobed leaves 10-20cm wide, dull green and rough pubescent; toward branch ends the showy axillary flowers 10-12cm across, opening white or rose in the morning with crimson centre and a divided maroon column; by evening the flower becomes deep red. In colder areas the plant is deciduous.
Thunbergia erecta	Acanthaceae	Tropical West Africa	"King's Mantle"	Erect evergreen shrub to 2m; thin branches with almost glossy ovate leaves 3-6cm long; axillary trumpet-shaped flowers 6cm in length, with large violet lobes, and yellow inside tube.