STUDY ON THE NATIVE VEGETATION ON CUT SLOPES IN THE SOUTHERN HIGHWAY, SRI LANKA

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***ABSTRACT*:** Landslides which occur due to soil erosion and mass movement have become one of the disasters faced by Sri Lanka today. The improper human activities and the carelessness have also caused occur the landslides which affect widely on the loss of human lives, the destruction of property and the environment. Although the hilly area is usually categorized as the landslide prone area, the Southern part of the country has faced the slope failures and the erosion problems in the recent past. As stabilization of slopes using mechanical structures is costly to establish and maintain, biotechnical slope protection is an alternative which is more aesthetically pleasing and cost effective. Hence, in this research, an overall study about the positive impacts of the presence of native vegetation for the slope stability is studied in the manmade slopes of the Southern Highway. Recently, it could be noticed that the importance of the slope stability because of few slope failure in the cut slopes from Kottawa to Dodangoda. This paper explores the effect of the native vegetation in the cut slopes with different slope angles of the Southern Highway by identification, categorization and studying of the salient features of them according to the soil classification for relevant slope by using both Unified Soil Classification System and US Department of Agriculture. This research recommends suitable native vegetation against soil erosion and subsequent slope failures in cut slopes.

KEYWORDS: Slope stability, Erosion control, Vegetation

1. INTRODUCTION

One of the major natural hazards faced by Sri Lanka is landslides which occur due to soil erosion and mass movement which are usually accelerated by human activities. Their improper activities and carelessness while the constructions are being carried out in the slope areas have also caused occurring landslides. Although, the upcountry is usually categorized as the landslide prone area, the low country has been also affected by the landslides today.

Manmade and natural slopes can be affected by landslides. Advantages due to the presence of plants for the slope stability have been studied in other countries. So this paper explores the study of manmade or cut slopes with different native plants in the Southern Highway.

Loss of human lives, destruction of property and environment are caused by landslides. Hence, it is costly to rehabilitate the areas affected by this natural disaster. It is therefore necessary to mitigate the impact of slope failures on lives. Further, the cost effective and sustainable solutions are needed for a developing country like Sri Lanka. Biotechnical slope protection is one of the most suitable methods as a solution for the above problem.

Highways play an important role in accelerating economic growth, creation of productive employment and reduction of poverty (Performance report, 2010). To achieve this, when highways are constructed new lands have to be cut causing steep slopes. Then steep slopes are needed to be stabilized using a suitable engineering stabilization method. Hence, the biotechnical slope protection referred with stabilization of slopes using the vegetation is more cost effective and aesthetically pleasing than the stabilization of slopes using the mechanical structures.

The slopes of the either side of the Southern Highway have been chosen for this study because this area has faced the slope failures and the erosion problems during this highway construction.

1.1 Objectives

This study has been mainly targeted at the selection of the best suitable plant species for different slope angles at cut slopes in the Southern Highway by identification, categorization and studying of the salient features of the native vegetation used for biotechnical slope protection.

1.1.1 Identification of soil and slope types

Soil type is classified using the Particle Size Distribution and Atterberg Limit Test results and the slopes with classified soils are observed to find out the slope angle. Further, the surface drainage is also observed.

1.1.2 Identification of vegetation

The dominant plant species and native plants available in the soil slope surfaces are identified using the help of an expert in Botany. Plant species which are hard to identify can be collected and the samples can be checked later. The easiness to grow them in the area, their cost-effectiveness and needed effort to grow should be considered.

1.1.3 Study on the plant properties

Salient properties of the selected plants such as its density, height, propagation rate, life time, shape of the leaf, soil surface covering ability and relative climatic conditions etc are studied to select the most suitable native vegetation types to grow in the available soil slopes.

2. METHODOLOGY

The below procedure was carried out for this study.

2.1 Literature Survey

2.1.1 Erosion and Infiltration

Rainfall is one of the major factors creating the erosion and the infiltration. The erosion of the soil surface and the infiltration which makes soil heavier occur in the slopes due to the direct exposure of the soil surface to the rainfall. Due to the rainfall, runoff of the surface proportionally increases and then, infiltration increases the pore water pressure. As this flow is downward, this washes down the soil and causes the soil erosion. Finally, this type of erosion could cause major landslides.

The surface soil of the slopes can be eroded due to the wind as well. To protect the soil slope surface, exposing the surface of the slope to the direct rain and wind should be prevented.

2.1.2 Slope surface protection

Surface slope protection is a method used to prevent the infiltration occurred in the soil slopes by rainfall. So this method can be used for manmade or cut slopes by applying shotcrete plaster, masonry blocks or rip rap. However, their aesthetic value and the cost effectiveness are very low when compared with the vegetation.

Vegetation and slope stability are interrelated by the ability of the plant life growing on slopes to both promote and hinder the stability of the slope. The relationship is a complex combination of the type of soil, the rainfall regime, the plant species present, the slope aspect, and the steepness of the slope.

2.1.3 Vegetation

According to the data from past few years, vegetation has exhibited its importance in soil erosion control and slope failure control. As well as it plays a main role to protect the soil surface from rain, wind and sunlight etc through its vegetation cover, it has a special ability to control the soil slope failure through its root system which runs in to the surface soil up to some depth.

There are four major ways in which vegetation influences the slope stability such as the wind throwing, removal of water, mass of vegetation and mechanical reinforcement of roots (www.Wikepedia.com).

Vegetation controls the sediment generation and maintains the bio-diversity. Rain drops have the kinematic energy which is the reason for the disturbance of soil particles. However, the kinematic energy will be dissipated by plants. So, it is an advantage against the soil erosion. Further, the importance of natural vegetation is that it grows rapidly and easily without much maintenance.

2.2 Vegetative survey

The vegetation types, their root systems and other salient properties are identified relative to their locations through number of site visits to the Southern Highway. This section is 34.4 km long and a number of cut slopes exist along the highway which is sometimes 20 m high. Vegetation types differ according to the height of the slopes either side of the highway.

Photos of the native vegetation are taken in relevant slopes and the data about the plants such as their common names, root systems, climatic conditions and the ability to cover the soil surface etc are also collected through interviewing the residents of the area. Knowledge of the underlying slope stability as a function of the soil type, its age, compaction, and other impacts is a major aspect of understanding how vegetation can alter the stability of the slope (www.Wikepedia.com).

Those collected information on native vegetation were discussed with some botanical specialists. According to the plant density of each plant available at slopes, the plants with high densities are selected here to carry out this study. A plant can be identified by the plant leaf, flower or whole plant. There are several species in one family found during the study. Heen bovitiya and Katakalu bovitiya are good examples for that.

2.3 Soil classification

Soils in relevant slopes are classified where the vegetation identification carried out in common view through the site visits. Through the wash sieve analysis, the particle size distribution for the collected soil has been done. Hence, the particle size distribution curves are drawn for the soil samples at each location using the data provided by China Harbour Engineering Company, Bandaragama.

Quantities of the gravel, sand and silt & clay contents of the soil in relevant slopes were estimated according to the Unified Soil Classification System. Liquid limit and the plastic limit tests of each soil sample have been determined for those collected samples. Using the above results, the soils at selected soil slope surfaces were classified according to both Unified Soil Classification System and US Department of Agriculture (Das, 2004)

2.3.1 Study on selected plant properties

The salient properties of the selected plants after the survey on vegetation is carried out are further studied to select the most suitable plant species relevant to the soil surface of the cut slopes. In similar manner, the vegetation with common and scientific names, its density, height, propagation rate, life time, shape of the leaf, soil surface covering ability and relative climatic conditions etc have been included in this report for the people who prefer to know those information.

3. RESULTS AND DISCUSSION

3.1 Soil classification

Soil is generally called gravel, sand, silt or clay according to the predominant size of particles within the soil (Das, 2004).

Table 1: Soil – separate - size - limits

Grain type	Gravel (mm)	Sand (mm)	Silt (mm)	Clay (mm)
US Dept. of Agriculture USDA	>2	2 – 0.05	0.05 – 0.002	<0.002
Unified Soil Classification System (USCS)	76.2 – 4.75	4.75 – 0.075	Fines Silts & Clays < 0.075	

Table 2: Particle size distribution results at CH 08+810 RHS (STDP Records)

Sieve size (mm)	37.5	20	10	5	0.6	0.063
Passing %	100	100	96.5	82.6	63.7	42

Here, it has been assumed that 0.063µm sized particles are equal to 0.05µm sized grains for the particle size distribution under USDA due to lack of data.

Table 3: Content of different soil types using USCS and USDA (STDP Records)

	USCS	USDA
Coarse gravel	18%	26%
Sand	39%	32%
Silt & Clay	43%	42%

Table 4: Soil type classification at CH 8+810 under USCS (Das, 2004)

Observation	Result
The % finer than 200 (F_{200}) = 43% < 50%	Coarse grained soil
Sand% = 39% > gravel% = 18%	Group symbol starts with a prefix S
Fines% = 43% (It is in the range between 12% & 49%) PI = 29% LL = 72%	Using plasticity chart, it is SM
Soil type – SM SM – Non plastic fines (Silty sands, poorly graded sand-silt mixture)	

3.2 Plant identification & selection of most suitable plant types

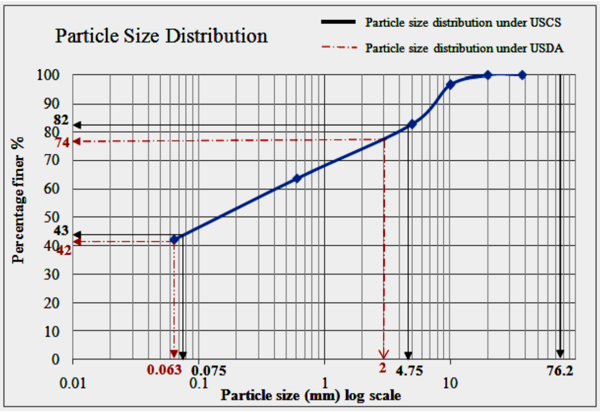


Figure 1. Particle size distribution according to USCS and USDA

After examining the cut slopes of the Southern Highway, some plant types which are common to most of the slopes are found. The plant densities have been recorded as the percentages per $100m^2$ area (for creepers) or number of plants per $100m^2$ area(for trees or bushes). While the plant densities vary from 5 percent to 50 percent for some plants, some plant densities vary from 2 plants to 25 plants. Hence, the plants which have less density are omitted and the plants having considerable density are further studied. So the number of plants observed reduces to a limit which can be analyzed easily.

Figure 2: Plant identification by using the flower, root, leaf or whole plant

According to the plant density data, 6 creepers and 7 trees have been selected and plant density data corresponding to the each chainage, the plant densities of those locations for each selected plant were summarized. For this analysis, the maximum

Table 5: Suitable plant selection according to plant density (www.Vegetation Management, www.Botany Plant-names Sinhala Plant, and Gunasekara, 2009)

Plant Type	Common Name	Scientific Name	English Name
Creepers	Nidi Kumba	*Mimosa invisa*	Creeping mimosa
	Heen Undupiyaliya	*Desmodium triflorum*	Three-flower beggar weed
	Ma Undupiyaliya	*Desmodium heterophyllum*	Spanish clover
	Heen Madu	*Ipomoea angustifolia*	African morning vine
	Demala Wel (Wathu Palu)	*Mikania micrantha*	Mile in a minute
	Pora Wel	*Pueraria phaseoloides*	Puero
Trees	Podi Singhngho Maran	*Chromolaena odorata*	Siam weed
	Yak Wanassa	*Anisomeles indica*	Malabar catmint
	Heen Bovitiya	*Osbeckia spp*	
	Andana Hiriya	*Crotalria micans*	Caracas rattlebox
	Heen Apala	*Urena sinuata*	Bur mallow
	Raja Pohottu	*Celosia asiatica*	
	Monara Kudumbiya	*Vernonia ceneria*	

and minimum percentage of each particle size has been considered as the important parameter. So, the plant can grow between the range of minimum and maximum. Then, the most suitable soil for the plant can be found. However, the most important parameter taken is the best suitable plant for a soil with a unique particle size distribution.

Therefore, using the maximum and minimum passing finer percentage obtained from the particle size distribution charts of each selected plant, the ranges of soil needed for both creepers and trees or bushes were defined.

As an example, the grading curve envelope of Heen Bovitiya is shown in Figure 3.

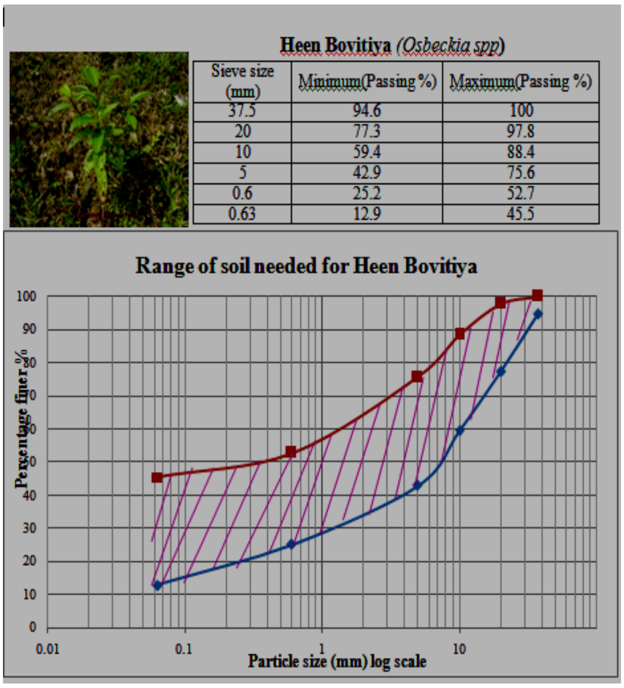


Figure 3: Range of soil needed for Heen Bovitiya

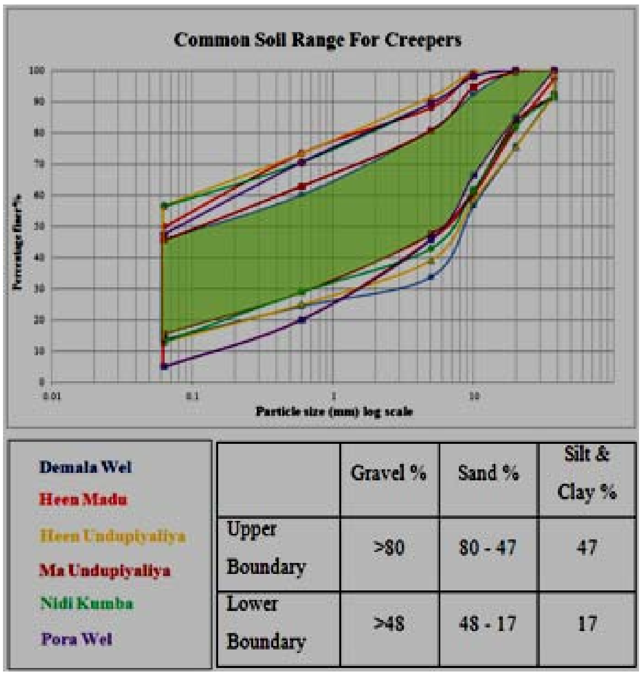
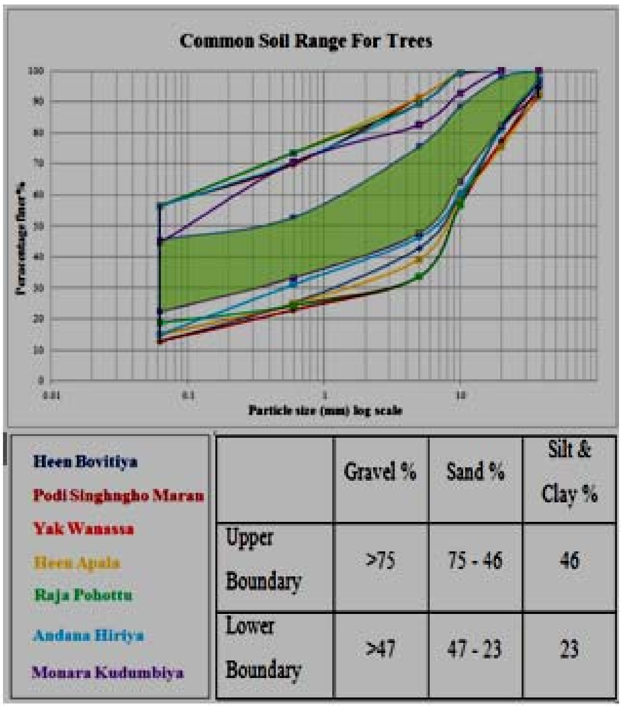


Figure 4: Common soil range for creepers

By using the drawn graphs, two common soil ranges for both creepers and trees or bushes were defined respectively as given in Figures 4 and 5.

Table 6: Plant identification summary

Native Vegetation	Climatic Condition	Root System	Soil Surface Covering Ability
Wathupalu	Wet	Surface root system	✓
Pora Wel	Wet	Surface root system	✓
Heen Undupiyaliya	Wet & Dry	Surface root system	✓
Ma Undupiyaliya	Wet & Dry	Surface root system	✓
Heen Bovitiya	Wet	Tap root system	x
Yak Wanassa	Wet & Dry	Fiber root system	x
Nidi Kumba	Wet	Surface and fiber rooting system	✓



	Gravel %	Sand %	Silt & Clay %
Upper Boundary	>75	75 - 46	46
Lower Boundary	>47	47 - 23	23

Figure 5: Common soil range for trees

Hence, above defined soil ranges for creepers and bushes or trees are not very much different from each other. According to the Unified Soil Classification System, this common soil type can be classified as SM or ML.

At most of the locations, the range of the slope angles varies from 26˚ to 30˚. However, at some other locations the slope angle has even increased up to 90˚.

. According to the above analysis, Heen Undupiyaliya, Ma Undupiyaliya, Wathupalu, Nidi Kumba can be recommended for the soil slope surface erosion control and slope stability. However, the positive and negative effects occurred by growing those plants in cut and natural slopes are needed to be further analyzed.

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REFERENCES

[1] Braja M. Das, (2004), Principles of Geotechnical Engineering, Fifth Edition, Thomson Brooks

[2] Records from the site office, China Harbour Engineering Company, Bandaragama

[3] www.Vegetation Management, A Guide for Puget Sound Bluff Property Owners.mht

[4] www.Botany Plant-names.Sinhala Plant names.mht

[5] Gunasekara,L, (2009), INVASIVE PLANTS - A guide to the identification of the most invasive plants in Sri Lanka , Sarasavi Publishers

[6] Performance Report – 2010, Ministry of Highways

[7] Wikipedia.com