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Methodology Article

Study the Native Vegetation around the *Al Hosh* Highway Slope in Sudan (Gezira State) as Bioengineering Method of Slope Erosion Protection

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Abstract: Soil erosion occurs due to rainfall intensity and soil movement had become one of the disasters faced by Al Hosh highway today. And the carelessness (Where there is no any type of protection) it has also caused occur the soil erosion due unprotected embankment side slope of the *Al Hosh* highway, which affect widely of the loss of human lives according to traffic accidents, the destruction of cars and large vehicles. Although the area is usually categorized as eroded area because of high rainfall intensity during the autumn season time, the Middle East states of the Sudan as Gezira state is known by the heavy rainfall. 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 on the positive impacts of the presence of native vegetation for the slope stability were studied in the *Al Hosh* embankment side slope. Trying to use native vegetation as the local grasses to restore the *Al Hosh* highway slope as a new bio-engineering method in Sudan. This paper explores the review the native vegetation and its ability to use it in protecting Al Hosh slope erosion with different slope angles 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, Native Vegetation Slope, Erosion Control, Ecological Protection, Bio-technical Techniques, Rainfall Intensity, Geotechnical Properties, Soil Fertility

1. Introduction

The simplest and the most cost-effective means of stabilizing bare soil surfaces is through the use of vegetation or mulches. The objective of all surface stabilization techniques is to establish, as rapidly as possible, a dense vegetative cover to minimize available sources of sediment. Native plants generally require less expense and maintenance as well as being visually harmonious with the natural landscape [1]. Use species that are native to the area whenever possible. A native plant landscape is naturally water conserving. They are adapted to local rainfall averages and, once established, do not need supplemental watering. Native grasses and wildflowers provide seasonal color and species diversity and are low maintenance. Natural landscaping is an excellent example of how to create less intensively managed landscapes, which help reduce maintenance costs, conserve natural resources, increase biodiversity, and benefit wildlife [2]. The important to find new methods to protect soil erosion along *Al Hosh* and reduce the number of traffic accidents, these reasons were strong, encouraging and motivated to carry out this study.

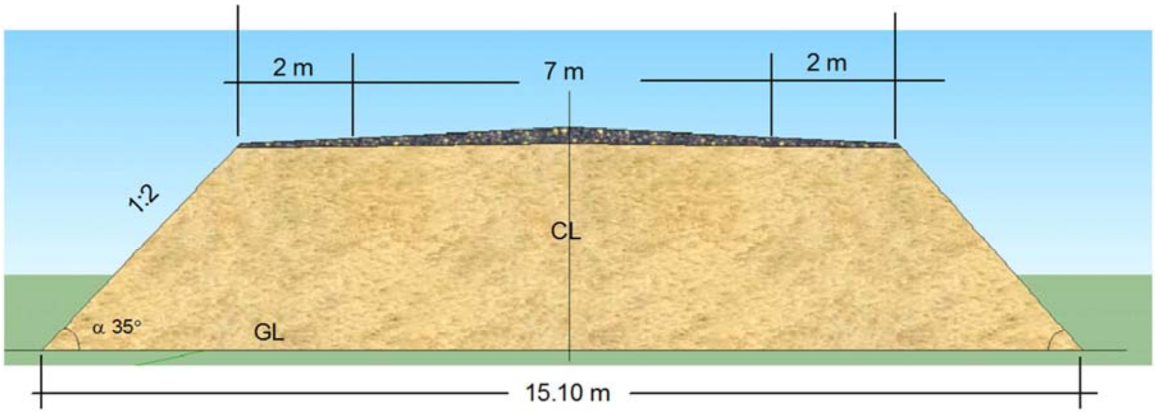
2. Materials and Methods

2.1. Study Area

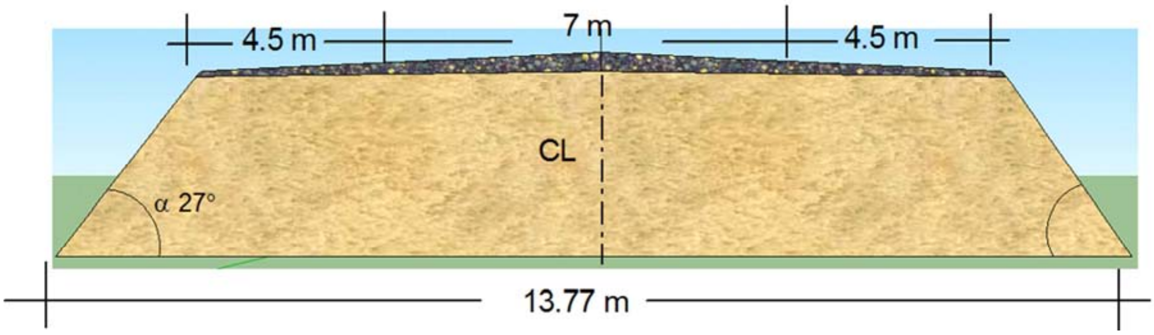
The study is located in the Gezira state, in the center of Sudan. This road linked between the capital city of the Wad Medani City and the city of Sennar, the capital of the Sennar state near the Sennar dam. Then *Al-Hosh* highway is part of the National Road. In the Gezira state, there is a larger agricultural scheme named (Gezira scheme). The road is also used to transport passengers, crops, and products between two cities, and continues to the north of Khartoum reach the capital of Sudan.

2.2. Site Description

Type of slope of the *Al Hosh* highway is filled slope, constructed as a road passing agricultural area in Gezira scheme. With no derange system as side ditches or main channel. The height of slope between 2.5 to 4.5 m, the angles starts from (27 – 45) degrees. Slope cross-sections as shown in Figure 1:



(a)



(b)

Figure 1. *Cross-sections of the Al Hosh road.*

2.3. The Problems of Al Hosh Highway

According to the police traffic administration and highway authority, there were many dangers in using parking on its side shoulders during the autumn season. Rainfall intensity during autumn affect it embankment side slope materials and making soil erosion. Still, according to the police traffic records the victims on this road due to traffic accidents bout 15 – 25 person per year. And this is showing the importance of the project. The side slope height is 1.05 - 2.5 meters. The research chooses the longitudinal section 650 m as the most dangerous part of the street. For solving and reduce the number of traffic accidents this research study hopes to find a method to protect the high embankment slopes about it as shown in (Figure 2 and 3).

Figure 2. *Eroded Al Hosh Slope shows slope situation.*

Figure 3. *Erosion in Al Hosh Road Slope- left side.*

2.4. Climate of Gezira State

The Gezira state climate is tropical, and hence some climate characteristics [3]:

1. Rainfall monitoring stations in Gezira state: The study used four monitoring stations to measure the rainfall readings (*Al Shaabargha*, *Algeria*, *AL Hos*h and Um Al Quran). Rainy season during the months of (July-September), to an equatorial rainy zone in the south having a short dry season in the months of (December-January) and the rainfall intensity increased in the south of the Gezira state. (Average of rainfall intensity is 350 - 373 mm). (Average annual high temperature is 36.5°).
2. Average annual minimum temperature is 24.6°.
3. The brightness of the sun 7.5 – 10 hours/day.
4. The humidity percentage is 180- 70% and decreases during the dry season reach 32-18%. Sudan is one of high humidity African countries, this due to the presence of rivers, Blue Nile and White Nile, where the White Nile is in the Centre of Sudan besides the Red Sea. Sudan. (The average of humidity percentage is 22%).
5. Wind: in the summer blowing from the south to southwest, and in winter blowing from the north to northeast. And these causes the dust that reduces the visibility during the day configuration.

One of the major natural hazards faced the Gezira State highways is the soil slope erosion, which occurred due to rainfall intensity which is usually these highway fill slope did not have any kind of the slope protection. The highway construction contractor companies they are careless, and they did not make any slope protection against rainfall intensity. Although, Al Gezira state is usually categorized as a rainy zone area, and non-protected fill highway slopes affected by the rain erosion [3].

Man-made Slopes (Fill Slopes) can be affected by the erosion due to rainfall intensity. Some advantages due to the presence of native plants for the slope stability have been studied in other countries. So this paper explores the study of fill slopes with different native plants to stabilize the slopes in the Sudan Highway. Loss of human lives caused by traffic accidents at eroded highway slope and the impact of the environmental problems was caused by soil erosion. Hence, it is costly to rehabilitate and restore eroded slopes which 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 Sudan. Biotechnical slope protection is one of the most suitable methods for a solution to the above problem. Highway̓s play an important role in accelerating economic growth, the creation of productive employment and reduction of poverty To achieve this when highways are constructed new lands have to be filled the highway embankment as to be a base of road surface till design formation level 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 on the other side of *Al Hosh* Highway have been chosen for this study because this area has always faced the slope failures and the erosion problems during the autumn season and causing high mechanical maintenance costs annually in Sudan.

2.5. Objectives of the Study

This study has been mainly targeted at the selection of the best suitable plant species to cultivate on the fill slopes of *Al Hosh* Highway by identification, categorization, and studying of the salient features of the native vegetation beside the project area to use as biotechnical slope protection.

2.6. 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.

3. Methodology

The below is the procedure which was carried out for this study following some literature and field surveying and soil experiments.

Literature Survey

The methodology depended on the reviewed works of literature in this field, stating the new and the modern theory of using vegetation in reducing slope erosion caused by rainfall intensity.

i. Erosion and Infiltration

How does vegetation control erosion? Vegetation works in many ways; it stabilizes soil by the root system, it provides a ground cover that improves microclimate and soil conditions as well as acting as a protective layer for bare soil against rain splash, it may enrich the soil by fixing nitrogen in its roots [4].

ii. 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 easiest to grow them in the area, their cost-effectiveness and needed the effort to grow should be considered.

iii. Study on the Plants Properties

The Salient properties of the selected plants such as its density, height, propagation rate, lifetime, the 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 on the available soil slopes.

iv. The Role of Vegetation how It Works

How does controlling erosion? Mechanical methods have an immediate effect and operate more or less at maximum design efficiency, but are costly to construct and maintain. Biological methods such as the use of live vegetation established from seeds and cuttings are generally cheaper but their immediate effect is smaller. However, once established, vegetation provides a self-perpetuating and increasingly effective permanent control [5]. 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 on 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 slope failure. 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.

v. 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 fill 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.

vi. Vegetation

According to the data from the 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 into 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 Figure 4 root system in the soil.

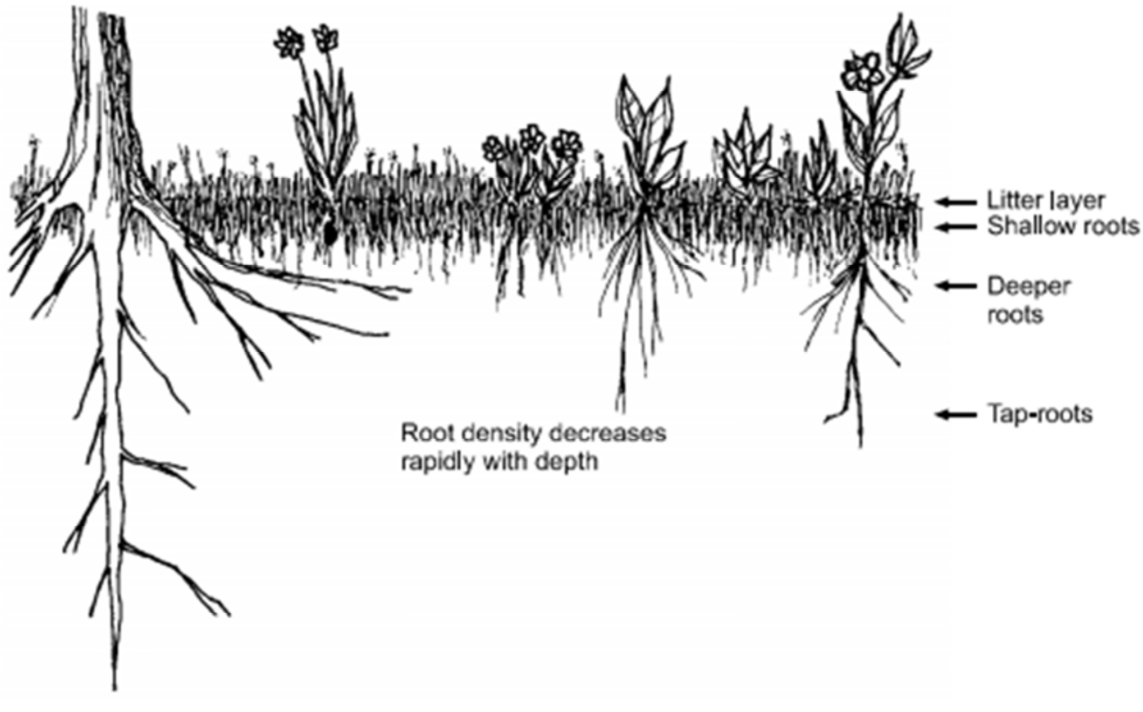


Figure 4. *Roots system in the soil.*

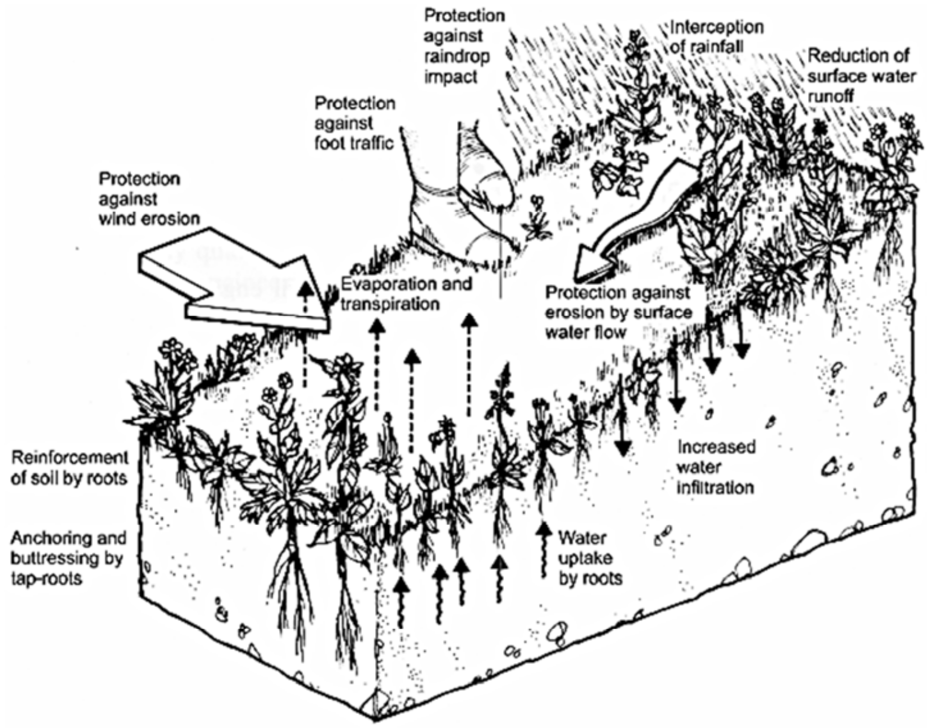


Figure 5. *Some influences of vegetation on the soil.*

Vegetation controls the sediment generation and maintains the biodiversity. Rain drops have the kinematic energy which is the reason for the disturbance of soil particles as in Figure 5 is a faithful copy of Figure 1 of Coppin et al. (2007) - "Use of vegetation in civil engineering". Inform the reference [5].

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.

vii. Vegetative Survey

The vegetation types, their root systems, and other salient properties are identified relative to their locations through a number of site visits to the *Al Hosh* Highway. This section is 650 m long and a number of fill slopes exist along the highway which is sometimes 4.5 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. That collected information on native vegetation was discussed with some botanical specialists. According to the plant growth of each plant available around the slope, 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. Cynodon Dactylon and Vetiver are good examples for that.

4. Soil Classification

Soils of the slope were classified then local vegetation identification carried out through the many site visits. Through the wash sieve analysis, the particle size distribution of the collected soil has been done, Figure 6 shows the field density test on the site and Figure 7 illustrates a sieve analysis experiment. Hence, the particle size distribution curves are drawn from the soil samples at each location using the lab result data of the civil engineering department at Wad Medani Technological College (WMTC) in the Gezira state as in the Figure 9 about Particle size distribution according to USCS.

Figure 6. *Field density test.*

Figure 7. *Soil Classification Tests at (WMTC).*

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 [6].

For selected vegetation, the salient properties of the selected plants after the survey of vegetation is carried out are further studied to select the most suitable plant and species relevant to the soil surface of the fill slope. In a similar manner, the vegetation with common and scientific names, its density, height, propagation rate, lifetime, the 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 that information.

5. Results and Discussions

5.1. Results of Soil Classification

The soil is generally called gravel, sand, silt or clay according to the predominant size of particles within the soil. From the soil experiments, the soil percentage of different particle size distribution as Gravel 4.1%, Sand 8.6%, Silt 75.3% and Clay 12%Soil information, Moisture Content: WC = 22.1%. PI = 18%, PL = 32% and Ll = 50%, Field density (Sand Cone) Bulk density γd = 1.510 and Dry density γd = 0.939. Using USCS to classify the soil and it > 50% is finer than 75 μm, it's below A line, and then the

Soil will be MH (Soil is: Silt high Plasticity). Chemical test and soil nutrients Experiments as: 0.4 – 0.5 less than 1%, (N) 0.03 - 0.4 %, (P) 2 – 4 ppm, (K) 0.5 – 0.6% me/100g, (pH) 7.5 – 8.5%.

5.2. Geotechnical Experiments

The fundamental features of these analyses are presented in this part, as a detailed description of the soil by conducting many soil experiments as water content, field density, sieve analysis, hydrometer test, liquid-plastic limits, and last is soil separated grain-size limits as shown in Table 1.

Table 1. *Soil separated grain- size, and limits.*

Grain type	Gravel (mm)	Sand (mm)	Silt (mm)	Clay (mm)
Unified Soil Classification System (USCS)	76.2 – 4.75	4.75 – 0.075	Fines Silt & Clay <0,075	
US Dept. of Agriculture, USDA	>2	2- 0.05	0.05- 0.002	<0.002

The grain size or particle size distribution of coarse-grained soil is generally determined by means of sieve analysis. Table 2 shows the grain-size and the percentage of each particle as gravel, sand and (silt and clay) according to two international classifications Unified Soil Classification System (USCS) and United States Department of Agriculture (USDA).

Table 2. *Grain- size distribution results.*

Type of Soil	USCS	USDA
Coarse Gravel	18%	26%
Sand	39%	32%
Sit and Clay	43%	42.3%

Several organizations have attempted to develop the size limits for gravel, sand, silt, and clay on the basis of the grain sizes present in soils. Table 3 presents the size limits recommended by the American Association of State Highway and Transportation Officials (AASHTO) and the Unified Soil Classification Systems (Corps of Engineers, Department of the Army, and Bureau of Reclamation).

Table 3. *Soil-Separate Size Limits.*

Classification system	Grain size (mm)
Unified	Gravel: 75 mm to 4.75 mm Sand: 4.75 mm to 0.075 mm Silt and clay (fines): mm
AASHTO	Gravel: 75 mm to 2 mm Sand: 2 mm to 0.05 mm Silt: 0.05 mm to 0.002

The geotechnical properties of soil such as its grain-size distribution, plasticity, compressibility, and shear strength can be assessed by proper laboratory testing, DAS [6] as in Table. 4 show the sieve analysis result of the Al Hosh highway slope soil.

Table 4. *Sieve Analysis Test Result.*

Sieve No	Sieve Opening	Mass of Sieve	Mass of sieve + Retained soil	Mass of Retained soil	Retained %	Cum. Retained %	Passing %
	(mm)	(g)	(g)	(g)	(%)	(%)	(%)
3"	75.0	1057.0	1057.0	0.0	0.0	0.0	100.0
2"	50.0	1199.0	1199.0	0.0	0.0	0.0	100.0
1.5"	37.5	1084.0	1084.0	0.0	0.0	0.0	100.0
1"	25.0	1187.0	1187.0	0.0	0.0	0.0	100.0
3/4"	19.0	716.0	716.0	0.0	0.0	0.0	100.0
1/2"	12.5	584.0	584.0	0.0	0.0	0.0	100.0
3.8"	9.5	586.0	590.0	4.0	0.5	0.5	99.5
No 4	4.75	567.0	577.0	10.0	1.3	1.8	98.3
No 8	2.36	390.0	399.0	9.0	1.1	2.9	97.1
No 10	2	355.0	365.0	10.0	1.3	4.1	95.9
No 16	1.18	313.0	325.0	12.0	1.5	5.6	94.4
No 30	0.6	287.0	303.0	16.0	2.0	7.6	92.4
No 50	0.3	462.0	482.0	20.0	2.5	10.1	89.9
No 100	0.15	261.0	281.0	20.0	2.5	12.6	87.4
No 200	0.075	424.0	425.0	1.0	0.1	12.8	87.3
Pan	------		435.0	698.0	87.3	100.0	-------

Following moisture conditions - liquid limit, plastic limit, along with shrinkage limit are referred to as the "Atterberg Limits", after the originator of the test procedures. The test to describe the laboratory procedure for determining the liquid limit of soils. The method described herein is based upon AASHTO Designation T89 which has been modified for New York State Department of Transportation use. Report the water content corresponding to 25 blows, read from the 'flow curve' as the liquid limit. A sample 'flow curve' is given as in Figure 8.

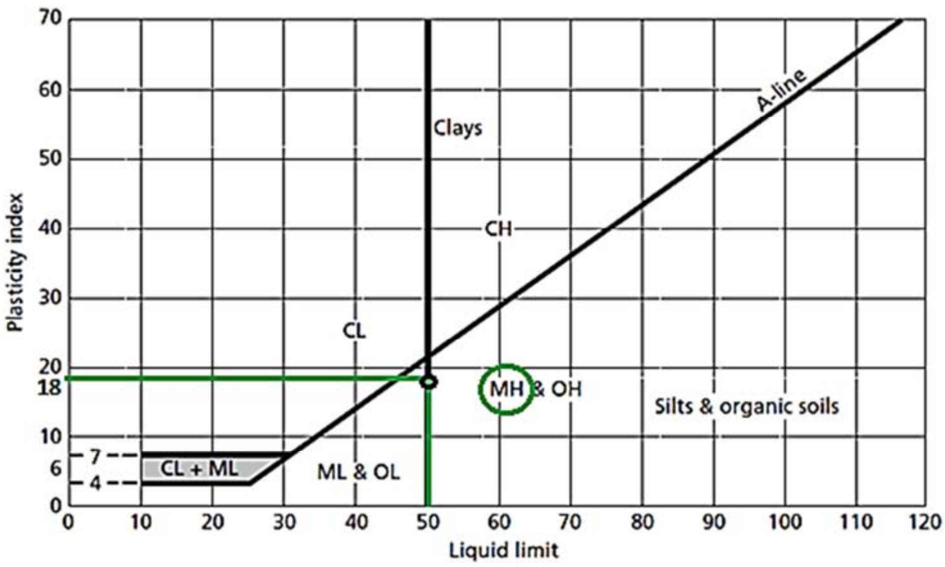


Figure 8. *Liquid – Plastic Limit Chart.*

Table 5. *Water content test.*

Number	Item Cont. No	Cont. No (W)	Test Weight (kg)
1	Mass of empty Cont.	W_1	0.070
2	Mass of Cont.+ Wet Soil	W_2	0.134
3	Mass of Cont. + Dry Soil	W_3	0.122
4	Mass of Moisture	$W_2 - W_3$	0.012
5	Mass of Dry Soil	$W_3 - W_1$	0.052
Moisture Content	$\frac{w_2 - w_3}{w_3 - w_1} \times 100$	W%	22.1

In soil classification one of the important measures determines the water content, which is usually expressed in percentage. Das 2002 I soil mechanics laboratory gave a clear method of determining the water content, in the Table. 5 state the results and the percentage of water content of the soil from *Al Hosh* highway site.

Table 6. *Soil type classification under Unified Soil Classification System (USCS) (Das, 2004).*

Observation	Results
The % finer than 200 (F_{200}) = 75.3% > 50%	Finer grained soil
Sand % = 8.6% > Gravel % = 4.1%	Group symbol start with prefix S
Fines % = 75.3% PI = 18% PL = 32% Ll = 50% Soil type – MHMH- Silt high Plasticity	Using plasticity chart, it is MH

The Unified Soil Classification System (USCS) was originally proposed by Casagrande in 1942 and was later revised and adopted by the United State Bureau of Reclamation and U.S. Army Corps of Engineers. The system is currently used in practically all Geotechnical work [11]. In the Unified System, the symbols are used for identification shown in Table 7.

Table 7. *Symbols are used for identifying the soil types. Symbol.*

	G	S	M	C	Pt	H	L	W	P
Description	Gravel	Sand	Silt	Clay	Organic Silt and Clay	Peat and High Organic Soils	Low Plasticity	Well-Graded	Poorly Graded

For a fine-grained soil (small particles), the grain-size distribution can be obtained by means of hydrometer analysis [6]. Table. 8 illustrates the results of the hydrometer experiment for the finer-grain size soil from the Al Hosh site.

Table 8. *Hydrometer analysis test results for Silt and Clay.*

Specific Gravity of the Soil 2.67. Test Temperature C24 degree.								
Elapsed Time (min)	**Actual Hydrometer Reading**	**Composite Correction**	**Corrected Hydrometer Reading**	**Effective Depth (cm)**	**Coefficient K**	**Grain Size (mm)**	**Finer (%)**	**Finer Combined (%)**
0.25	1.0325	-0.0019	1.0306	7.70	0.129	0.0506	97.85	85.37
0.5	1.0320	-0.0019	1.0301	7.84	0.0129	0.0506	96.25	83.98
1	1.0310	-0.0019	1.0291	8.10	0.0129	0.0260	93.05	81.19
2	1.0310	-0.0019	1.0291	8.10	0.0129	0.0164	93.05	81.19
5	1.0310	-0.0019	1.0291	8.10	0.0129	0.0116	93.05	81.19
10	1.0305	-0.0019	1.0286	8.23	0.0129	0.0083	91.45	79.79
20	1.0300	-0.0019	1.0281	8.36	0.0129	0.0068	89.85	78.40
30	1.0290	-0.0019	1.0271	8.63	0.0129	0.0069	86.66	75.61
60	1.0275	-0.0021	1.0254	9.03	0.0129	0.0050	81.22	70.86
1440	1.0270	-0.0019	1.0251	9.16	0.0129	0.0010	80.26	70.03
480	1.0070	-0.0027	1.0043	14.45	0.0129	0.0022	13.75	12.00
1440	1.0060	-0.0027	1.0033	14.71	0.0129	0.0013	10.55	9.21

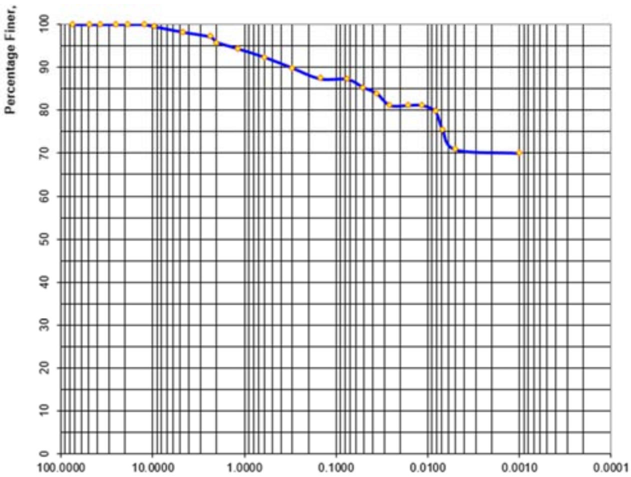


Figure 9. *Particle size distribution according to USCS.*

Collected data the chemical components (Nutrients tests) for determining soil fertility of the site, also it's a helpful to know the types of grass family and plants to use in future to slope ecological protection in the high embankment side slope of the *Al Hosh* road as Eco-Protection method. This chemical soil test did in the Gezira University – college of agricultural sciences and water resources. From collaborating with teachers from Gezira University we discussed the possibilities of using vegetation (plants and grass family) according to soil fertility, knowing the existing natural plant grasses in site, determining the suitable native vegetation to use it as Bio-Engineering method to protect the soil erosion along the *Al Hosh* highway, Figure 9 shows the chemical test and soil nutrients.

Table 9. *Chemical test and soil Nutrients.*

Fertility	**Amount %**
OM	0.4 – 0.5 less than 1%
N	0.03 - 0.4 %
P	2 – 4 ppm
K	0.5 – 0.6 me/100g
pH	7.5 – 8.5

5.3. Plant Identification & Selection Suitable Plant Types

After examining the fill slopes of the *Al Hosh* Highway, some plant types which are common to most of the slope area found. The plant densities have been noticed around the area Al Hosh highway slope as the *Cynodon Dactylon,* its roots have a significant increase soil erosion, shear strength [12], enhancing the stability of shallow soil [7].

Other plants as (trees or bushes) also found near the project area. Hence, the plants which have less density are omitted and the plants have a considerable density as Cynodon Dactylon and *Vetiver* [8], [14]. It is a fast growing grass, possesses some unique features of both grasses and trees by having profusely grown, a deep penetrating root system that can offer both erosion prevention and control of the shallow movement of surface earth mass. Literature studied experiments revealed that Vetiver grass roots are very strong with an average tensile strength of *75 Mpa* or one-sixth of the ultimate strength of mild steel. The massive root system also increases the shear strength of soil, thereby appreciably enhances slope stability. In addition to its unique morphological characteristics, Vetiver is also highly tolerant to adverse growing conditions such as extreme soil pH, temperatures, and heavy metal toxicities [8].

So the number of plants observed to a limit which can be analyzed easily. The trees and bushes which are found is *Mesquite*, which it have many benefits as it can contribute to environmental stability through stabilization of sand dunes, hedging, windbreaks, shelterbelts around villages and agricultural schemes, in addition to its contribution to soil conservation, *Cassia Angustifolia* which can grow in the low rainfall intensity areas [9] Singh, Rathod 2001, *Striga harmonica* or (*Striga Lutea*) as it known in Sudan and many others African countries, it is very harm plant, Corn, sorghum, and sugarcane crops affected by the *Striga Hermonthica* [10].

Figure 10. *Different Types of Native Vegetation in the area of Al Hosh Highway: Cassia Angustifolia, Cynodon Dactylon, Striga Hermonthica and Vetiver grass.*

According to the plant density data, two kinds of grass and two shrubs have been selected and plant density data corresponding to the each change, the plant densities of the native plants (grass or shrubs around the *Al Hosh* location were the studies in this research selected the vegetation which summarized in below Table. 10 and 11.

Table 10. *Suitable plant selection according to native plant around Al Hosh Highway.*

Plant Type	Common Name	Scientific Name	English Name
Grasses	Bermuda Gras Bunchgrass	Cynodon Dactylon	Vilfa stellate Vetiveria zizanioides
Plants	Alexandrian Senna Asiatic Witchweed	Cassia Angustifolia Striga Hermonthica	Cassia Officinalis Witchweed
Trees	Alexandrian Senna Prosopis	Mesquite	Prosopis Juliflora

The 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.

Table 11. *Native Plant Identification summary.*

Native Vegetation	Climate Condition	Root System	Soil Surface Coverage
Cynodon Dactylon	Warm Climate& Dry	Deep creeping	✓
Vetiver	Warm Climate & Dry	Massive, Deep, Fibrous Root	✓
Cassia Angustifolia	Warm Climate & Dry	fibrous Root	x
Striga Hermonthica	warm Climate & Dry	Host Root	✓
Mesquite	warm Climate & Dry	Deep	✓

Hence, above to natives plants identification and according to the Unified Soil Classification System, this common soil type can be classified as MH or OH. At most of the locations, the range of the slope angles varies from 27° to 45°. However, at some other locations, the slope angle has even increased up to 60°. According to the above analysis, Cynodon Dactylon, *Vetiver* and Cassia Angustifolia can be recommended for the soil slope surface erosion control and slope stability. And however, the positive and negative effects occurred by growing those plants infill and natural slopes are needed to be further analyzed. And exclude both of *Striga Hermonthica* and *Mesquite*, *Striga Hermonthica* is the very harm of growing crops and it can affect rapidly and creep to farms, and the mesquite growth quickly and it is height, reach many meters so can effect on distance sights for drivers of Al Hosh highway and increase the traffic accident. Persistent Restriction Technology about Slope Ecological Protection (2016CFA085). The authors would like to acknowledge Prof. Adam Ibrahim, Prof. Muawia El-Badawi, Dr. Ali Babikr, Dr. Mahmoud Mohammed, Dr. Zhao, Eng. Osman Altayeb, Eng. Altayeb Albthany and Tech. Haram Adam for their indispensable cooperation.

6. Conclusion and Recommendation

Based on the discussed results of the study, it was found that:

(1) Although there are no multi-species plants (Vegetation), the study has been proven through the vegetation surveying, Geotechnical studies (Soil Properties and Classification), and chemical soil data (Soil Nutrients), that they were some plants and grasses they are available around research area.

(2) Study noticed throw all above mentioned work, the

suitable vegetation for eco-engineering protection using three native plants and that based on the nature and climate conditions, and recommended (*Cynodon Dactylon, Vetiver and Cassia Angustifolia*) can be used in ecological slope protection as a new method in Sudan for slope surface erosion and increase slope stability.

(3) Use of vegetation technology achieves the protection of the sedimentation soil of the Al Hosh Highway. Vegetation also has many benefits, including the improvement the area landscape surrounding the highway, and helps to improve the intensity of rainfall, if it can use in large open areas to protect soil erosion due to rainfall intensity and improve the meteorological situation in Gezira state.

(4) The study recommends to apply the Eco- Protection techniques to protect the highways slope failure due to the erosion occurs from the intensity of rainfall in the fall season and reduce the traffic accident victims because of the highways fail in autumn.

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