REVIEW OF GRASS COVER AS A PROTECTIVE LAYER AGAINST SURFICIAL EROSION

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Abstract— **The undesirable effects on the soil (loss of fertile top soil) have been observed mainly due to erosion by water. The soil surface with an appropriate cover helps improving the soil structure for which many agronomic soil conservation practices have been used. This paper integrates that why a simple grass cover has been recommended to cope with this inevitable issue. The grass structure, influence of the root zone, grass efficiency against runoff and soil loss, and grass application at different slope angles have been studied. This paper further review the different parameters which must be considered while protecting the soil against erosion including hill slope shapes, characteristics of different plant types, proper compaction, soil modification, and cost comparison of different soil protection techniques.**

Keywords: Surficial erosion, Soil Protection, Grass cover

I. INTRODUCTION

Engineering practice requires knowledge on rainfall and runoff response for developing the humid tropical regions [1]. Soil erosion is an inevitable process which cannot be neglected [2]. It is such an issue for which it is appropriate to say "think globally, act locally" as it leads to sedimentation which is responsible for both on-site and off-site problems [3]. Erosion is one of the vital environmental issues which spoils the nutrient-rich top soil and increase the concentration of pollutants in the water bodies for which the treatment of the diffused pollutants at its source is considered effective [4]. Figure 1 shows surficial erosion which is responsible for the detachment and transport of the individual particles for which grasses are suggested to be one of the most effective measures that can help mitigating this process [5].

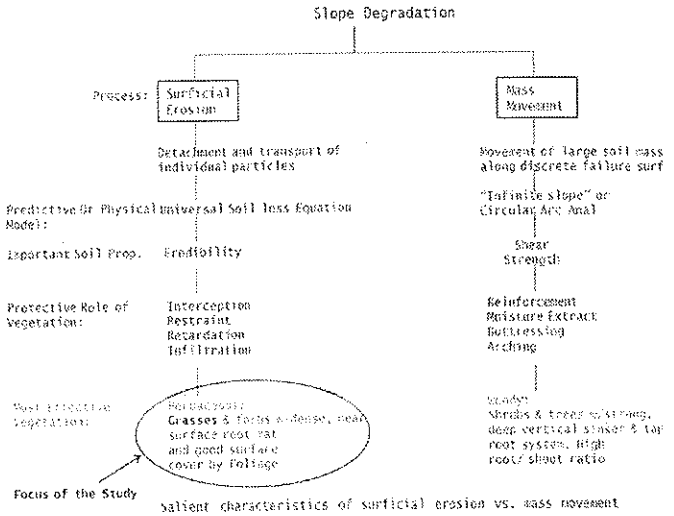

Figure 1. Salient Characteristics of Surficial Erosion vs. Mass Movement [5]

There is a contradiction that soil cannot be protected from erosion by planting grass on the slopes [6]. Land cover influences the runoff intensity which is responsible for the erosion occurrence [7]. A diminution in sediment production was observed by 31% in the catchment area caused by gully erosion in Chinese loess plateau, when a farmland was decreased by 46% and the forestland and grassland were increased by 42% [8]. More the percentage of grass cover, greater would be its resistance against raindrop impact and runoff flow [9]. Herbaceous vegetation is considered more effective than woody vegetation in controlling surficial erosion [5]. The high roughness of grass decelerates the runoff velocity and allows water to infiltrate [4]. Grass germinates quickly and provides complete cover with a dense root network which strengthens the soil by binding the particles [10]. The presence of plant cover softens the raindrop impact on the soil surface which conserve soil and reduces surface runoff [11].

II. PROBLEM STATEMENT AND RESEARCH OBJECTIVES

Soil Erosion relates to the impact of rain drop which is the most significant factor as it loosens, erodes and removes the

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soil particles from their place of origin. This affects the soil geometry and undermines the soil arrangement, resulting in its failure. It allows the detached particles to flow with the surface runoff which then reaches the rivers and the process of deposition occurs which deteriorate the water quality and affects the marine life.

The objective of the study is to recommend the approach that can protect the soil particles from the direct impact of the raindrop and can immediately stabilize the bare surface.

III. Literature Review

A. The Grass Structure

Figure 2 shows the description of a simple grass structure which clarifies that why its use has been recommended by the previous studies. The *Gramineae* family of plants for which the common name is "Grass" is one of the largest families on earth having more than 9000 known species. The grass structure is very simple having fibrous roots at the base which grasp into the soil, collect nutrients and protect the plant. The Culms which are also called grass stems originate from the crown. The culms are stiff in many of the grass species expect at the joints (nodes).The leaves raise from the culms with the alternate directions. The first leave originate from right, the second one from the left and so on. The upper part of the leaf is called blade and the lower part is called sheath. The connection between the blade and sheath is surrounded by a ligule which is in the form of thin membrane. Through photosynthesis grass collects the energy from the sun and the green color of grass is due to the presence of photosynthesizing chlorophyll in the leaf. The rhizomes are the stems that grow below the grass and the stolons are the stems that crop along the ground [12].

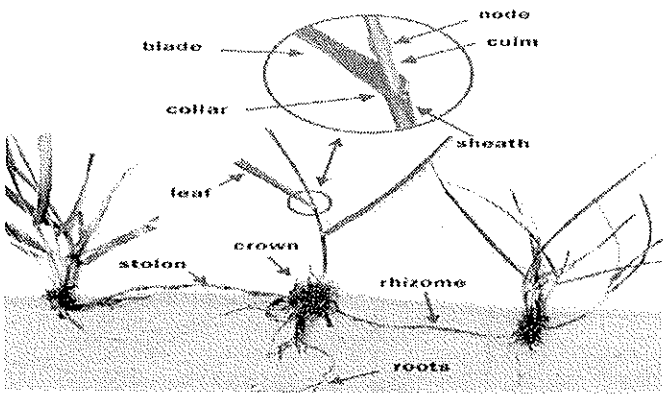

Figure 2. A Simple Grass Structure [12]

B. The Influence of Roots

The integral part of the plant which is also called the root zone is mostly disregarded. The major function of the root includes absorption, anchorage, and hormone synthesis. Absorption of nutrients and water from soil is the primary purpose of the roots which helps growing shoot zone. Roots firmly fix the plant and make it stable which restricts it from being blown away and washed away. Roots are considered to be the principal source of gibberellins and cytokinins which are considered as a necessary medium for the development of shoot zone [13].

C. The Planting Opportunities at Different Slope Angles

Figure 3 shows the planting opportunity at different slope angles i.e. 35°, 45°, 55°, and 60-70° for erosion control; however, the use of grass has been suggested for all the inclined planes [14].

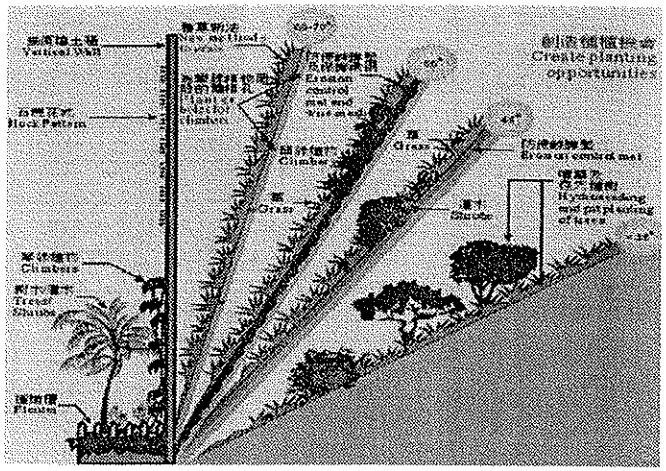

Figure 3. Planting Opportunities for Different Slope Angles [14]

D. Grass Efficiency Against Runoff and Soil Loss

Figure 4 shows that the cumulative runoff is inversely proportional to grass cover percentage. Increasing the grass cover decreases the surface runoff [9].

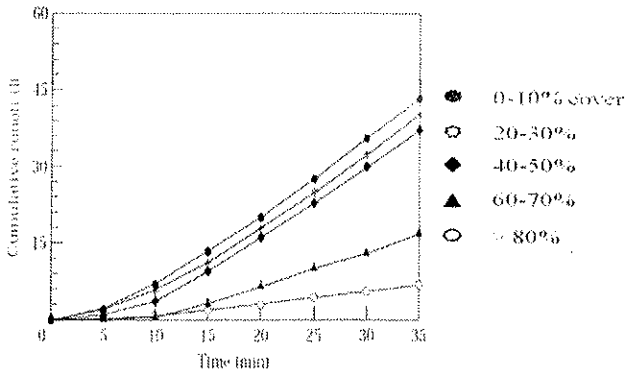

Figure 4. The Influence of Grass Cover on Runoff [9]

Figure 5 shows that the rate of erosion is inversely proportional to the grass cover percentage. Increasing the grass cover decreases the erosion rates [9].

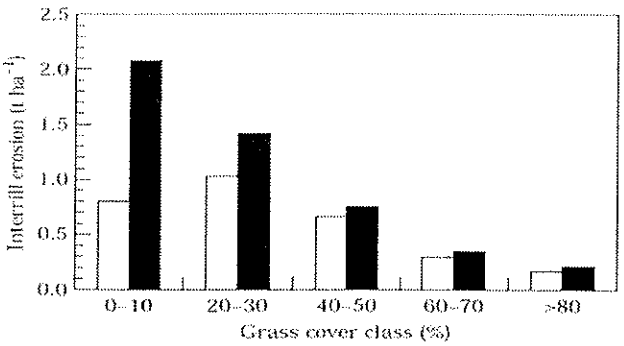

Figure 5. The Influence of Grass Cover on Interrill Erosion [9]

Table I shows the soil erosion rates were observed at different rainfall intensities for three plots, Plot A (grass covered plot), Plot B (mulch covered plot), and Plot C (bare surface). It was observed that the rate of erosion were comparatively lower for the grass covered plot, whereas the bare plot was found more erosive [15].

TABLE I. Erosion Observed at Different Rainfall Intervals for Three Different Plots

Rainfall Pattern	Date	Rainfall Intensity ($mm\ h^{-1}$)	Sediment Yield		
			A ($Kg\ mm^{-1}\ ha^{-1}$)	B ($Kg\ mm^{-1}\ ha^{-1}$)	C ($Kg\ mm^{-1}\ ha^{-1}$)
Middle Rain	10th Dec, 2003	0.8830	0.0137	0.0120	0.3299
Heavy rain	17th April, 2004	1.3826	0.0025	0.0038	0.0440
Rainstorm	21st Feb, 2004	2.5592	0.0038	0.0051	1.0998
Heavy Storm	17th July, 2002	5.1455	0.0042	0.0057	6.2789

(Source: LI Xin-Hu, 2010)

When compared with bare surfaces, 90% erosion reduction was observed by establishing 60% of the grass cover [16]. Grass germinates quickly and provides good dense surface coverage whereas shrubs are more expansive to plant and their germination period is long and considered difficult to establish [5]. Table II shows the average runoff and soil loss rate for the grass and shrub cover. Grass cover being inexpensive showed adequate results when compared with the shrub cover at different rainfall intensities [17].

TABLE II. Average Runoff and Soil loss Rates from Grass and Shrub Cover

Rainfall Intensity (mm/hr)	Average runoff rate (mm/hr)		Average soil loss rate ($g/min.m^2$)	
	Grass	Shrub	Grass	Shrub
45	4.2	9.3	5.7	5.6
87	31.9	25.9	18.1	12
127	73.1	58.2	120.3	84.4

(Source: Xiao, P, 2011)

E. *Characteristics of Different Plant Types and Suitability of Various Applications*

Table III shows merits and de-merits of various plant types. It mentions that which plant type is expensive to seed, difficult to germinate, and suitable for which condition [5].

TABLE III. Merits and De-merits of Different Plant Types

Type	Advantage	Disadvantage
Grasses	Good dense surface coverage. Wide range of tolerances. Quick to establish. Relatively inexpensive.	Shallow rooting. Regular maintenance required. Competes with woody vegetation
Reeds and Sedges	Establish well on riverbanks, etc. Quick growing.	Hand planting is expensive. Difficult to obtain.
Dune grasses	Trap drifting sand and build protective dunes. Thrive in droughty and harsh conditions.	Shade intolerant and out competed by other plants on relatively stable sites.
Herbs	Deeper rooting. Attractive in grass sward.	Seed expensive. Sometimes difficult to establish. Many species die back in winter.
Legumes	Cheap to establish. Fix nitrogen. Mix well with grass.	Not tolerant of difficult sites
Shrubs	Hardy and fairly cheap. Many species can be seeded. Substantial ground cover. Deeper rooting. Low maintenance. Many ever green species.	More expansive to plant. Sometimes difficult to establish.
Trees	Substantial rooting. Some can be seeded. No maintenance once established.	Long time to establish. Slow growing. Relatively expensive. Ineffective for-surface erosion.
Willows and dogwoods	Root easily from cuttings. Applicable to soil bioengineering treatments. Relatively easy to establish.	Care required in selecting correct type. Cuttings must be placed during dormant season.

(Source: Bert, R., 2007)

F. *Hillslope Shapes*

Land topography is one of the major factors which must be considered while dealing with the surface runoff and soil erosion. Figure 6 shows hill slope shapes for different topographic scenarios. The hydrological response varies with the difference in topography [18]. The sediment loss from the concave slope profile is comparatively less than that of uniform planar slope and even the slope stability of the concave slope is high. The sediment deposition is high as compared to convex, uniform and complex convex-concave shapes [3]. Figure 7 shows the results of a study conducted by Young and Mutchler in the year 1969 who observed the soil loss for a concave, uniform, and convex slope. For the concave slope, pronounced soil loss was observed at the top which lightly ended towards the bottom and the deposition was observed at the foot of the slope. The erosion rates were comparatively high for both convex and uniform slopes shapes from the top to bottom [19].

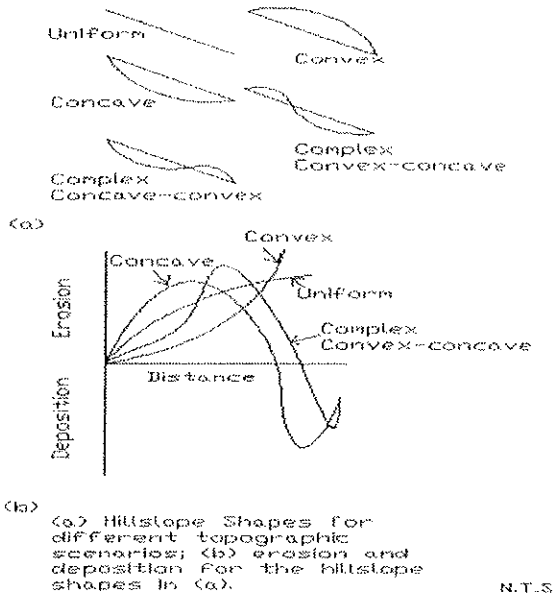

Figure 6. Hill Slope Shapes, their Deposition and Erosion Rates (Adapted and modified from [3])

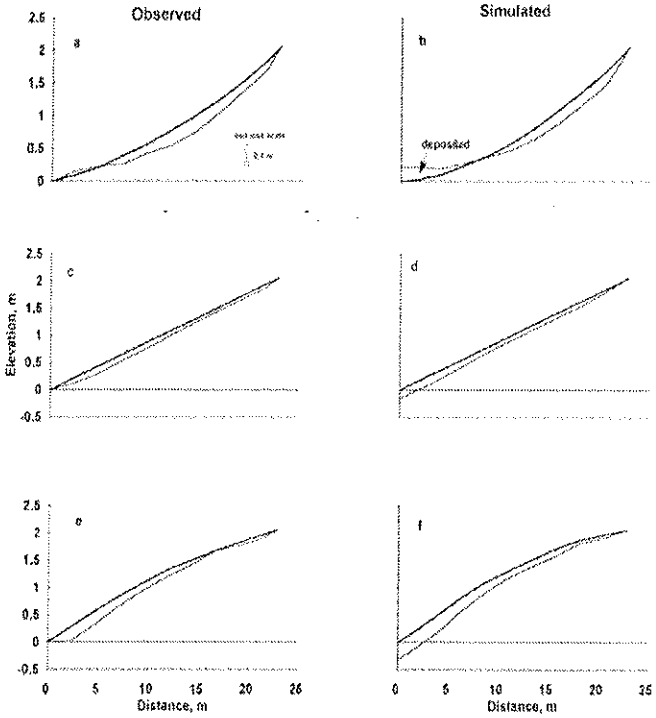

Figure7. Observed Soil Loss for Concave Slope (a,b), Uniform Slope (c,d), and Convex Slope (e,f) [19]

G. *Soil Compaction and Modification*

When the external stress is applied to the soil, process of densification occurs which removes the air voids and is termed as compaction. The influence of soil compaction on plant growth is affected in a variety of ways. Minimal soil compaction is therefore recommended so that the interconnected voids provide passage for air and water in the soil [5].

The soil properties below 0.5 meters of the top soil lack nutritional conditions to support vegetation growth. The high salinity (shown by the degree of chloride and electrical conductivity), the sodicity (reflected by the convertible percentage of sodium level) and the pH level needs to be improved for a sustainable grass growth. To counteract the negative impact of the sodium content, calcium is used which decreases the value of the exchangeable sodium percentage. Application of lime before seeding is done for the sodic soil having the pH value below 7. It helps raising the pH level and supply calcium. However, when a change in pH is not required for the sodic soil, application of Gypsum (being neutral) is considered. Increase in the soil porosity, structural ability, soil infiltration, hydraulic conductivity and decrease in soil swelling, shrinkage and surface crusting was observed when calcium was applied to the sodic soil. The calcium application further improves root penetration. Fertilizer, if required can be used for providing the nutrients which are necessary for the grass growth [16].

H. Cost Comparison of Various Seeding Techniques (in work hour)

To reduce rate of erosion and runoff, a variety of practices have been implemented. However, to ensure erosion control quick establishment of permanent vegetation is needed [3]. Figure 8 shows the cost comparison of different seeding techniques for growing grass which includes standard seeding, hayseed seeding, hydro seeding, dry seeding, mulch seeding, mulch seeding with long straws, rolled turfing, and natural turfing [20].

Standard seeding is a simple, rapid and cheap method. It is not immediately effective and the presence of topsoil is mandatory. Hayseed effects are same as other mulch seeding and even for the immediate protection it provides cover to the soil. Its availability is only in the areas where meadows cutting are still practiced. Hydro seeding consists of a mix of fertilizer, seed, soil improvers, water, and binding agent that creates a good seed bed and enable seeding of the inaccessible slopes that are very steep. To access the site the hydro seeding machine must be in range. Dry seeds can be manually applied by hands or seed blowers can be used for it application. For mulch seeding, once seeding is done mechanical blower is used for spreading the chopped straws on the seeded surface. Its application is very limited to the gradients that are steeper than 1:1. Mulch seeding with long straws includes few steps. Firstly, even layers of straws are placed. Secondly, seeds are then mixed and fertilizer or manure is applied at the same time. Soil improvers are then added, if required. Thirdly, the mulch is mixed with the bitumen emulsion and sprayed for preventing the shifting of mulch. The entire work can be done with the hands except of the application of bitumen. For rolled turfing, depending upon the dimension vertical placement of the longish section is preferred on the slope. Similarly, like natural turfing rolled turf is placed by piercing a wooden pin into it. For natural turfing continuous lying of individual turfs without leaving any gap is used to protect the slope surface [20].

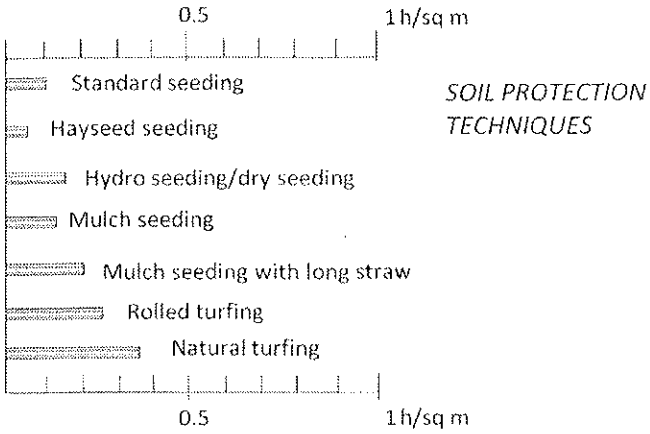

Figure 8. Cost Comparison of Various Construction Techniques [20]

The cost of various construction techniques is given in work hour to avoid the fluctuations of the value of money which recommends that the application of hayseed seeding would be cheap and effective, if considered.

IV. Conclusions

To cope with the surficial erosion, grass cover provides immediate stabilization. The shoot zone of grass is efficient enough to mitigate soil erosion and runoff, whereas the root zone is well capable of absorbing water, nutrients and binding the soil particles. However, its recommendation at different slope angles validates its authenticity. The compaction and modification of soil is among the vital aspects that must be considered before planting grass. The slope shapes are one of the major factors which are studied and based on the previous results concave hill slope shape is recommended. Cost comparisons of different seeding techniques have been reviewed and the application of hayseed seeding is recommended.

V. Acknowledgement

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