**Overview of soil erosion**

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# Abstract

Soil, a complex and dynamic natural resource, plays a pivotal role in supporting terrestrial ecosystems and providing essential services to humanity. This abstract delves into the multifaceted nature of soil by exploring its composition, properties, and functions, highlighting its critical importance in sustainable land management. The composition of soil involves a heterogeneous mixture of mineral particles, organic matter, water, air, and various microorganisms. The interactions between these components give rise to distinct soil horizons, each with its unique characteristics that influence soil's physical, chemical, and biological properties.

Top of Form

# Soils

**Figure 1 Classification of soils**

In some locations, the rocks forming the original slope have been altered, disturbed and mixed so much that they have lost most of their original characteristics. In figure 1 represent the classification of soils. The result is a material, which in engineering terms can cover anything not defined as a pure rock. Some materials have been altered sufficiently to be classed as a soil [1]. Whatever their state, all soils and altered materials have their own characteristics when subjected to geomorphological process. For this reason, they must be examined separately in any consideration of slope stability [2].

This research focus on reducing soil erosion and degradation combined with shallow landslips prevention, to have better understanding it is necessary to analyse the soil types in the study area. Soils in the study area is broadly classified into five types such as Red loam, black soil, alluvial soil, colluvial soil and in certain areas lateritic soils were also found. Among them red sandy soil and red loams occur in small patches in the district, it is noticed that black soil is also developed among the valleys susceptible to logging of water during rainy seasons. Valleys and major river beds and surrounding areas contains alluvial and colluvial soils [3].

## Red Sandy Soil

Red soils form a group of soil which is developed in moist and warm, temperate climate near the deciduous forests. They possess smaller organic or inorganic mineral layers over an alluvial red layer. Red soil is a group of soils that are developed in a warm temperate, moist climate under deciduous or mixed forests and that have thin organic and organic-mineral layers overlying a yellowish-brown leached layer resting on an alluvial red layer. They are taken from crystalline rocks, termed as poor growing and contain low nutrients, humus, possess low capacity in terms of water holding. They belong to omnibus group and are developed over Gneiss, Archaean granite and few crystalline rocks. Color of soil is owing to the presence of ferric oxides that occurs in thin coatings surrounding the soil particles their color indicates the presence of ferric oxide in the soil which surrounds the soil particles as a coating[4].

## Red Loam Soil

Loam is a type of soil that is not mostly sand, silt or clay as per Textural classification, they contain more moisture and nutrients coupled with humus when compared with any sandy type of soils, and also they possess more drainage capabilities. Every different type of loam soils have varying characteristics concerned with drainage characters, they naturally contain about sand: silt: clay as 40:40:20 by weight.

## Black Soil

Black soil is a major type of soil which is created due to disintegration of lava rocks and hence they are found mostly in mountaneous regions, also its abuntandly found in coastal regions and its found to be more suitable for growing cotton which created a name “Black Cotton Soil”. They are called as black cotton soil or tropical black earth which has been developed due to the weathering of lava, their color is due to the presence of titaniferous magnetite, iron and Al2SiO3, soil humus and hydrated double iron and Al2SiO3. This type of soils have more clayey texture with clay content of more than 50% generally, but the clay content will be more uniform than other varieties of soil [6].

## Colluvial Soil

Colluvial soil or in general colluvium is the name given for loosely packed, sediments that are unconsolidated and deposited in the hill base owing to various agents such as rain, sheet wash, downslope creep or combination of multiple factors mentioned. It is made up of heterogeneous rocks and sediments covering from silt to rock fragments of various sizes, this term colluvium may also refers to the sediment deposits that may occur due to the surface runoff or sheet erosion.

## Soil Erosion

Hilly regions face many problems such as soil degradation combined with soil compaction, deterioration of organic content, soil structure loss, reduced internal drainage, soil saline issues and acidity related problems, the study area is affected by all of those issues coupled with soil erosion. Soil loss from slopes and farmlands results in reduced crops production potential, surface water quality reduction and discontinuous drainage networks. Major factors causing soil erosion along a slope can be classified into energy factors (erosion due to rain, runoff volume, angle and length of slope), protection factors (coverage of soil with plants, land management and population density) and resistance factors (erodibility of soil, infiltration capacity of soil and management of soil). Soil erosion in an area may be resulting due to any of this parameter or mostly due to the combination of the above parameters, identifying a single factor causing the soil erosion is tedious. During rainfall, when the exposed soil surface is touched by the rain water droplets, it ends up in any of the following: Production of smaller aggregates, particle dispersion and keeping them in suspension, deposition and translocation of particles. Break down of aggregates depends on soil strength, a certain amount of kinetic energy is required for the water to induce soil detachment, and this can be prevented by the prevailing plants. It is found that soils with high particle content suffers with more detachment such as silty loam, find sand, sandy loam etc. (particle size between 0.063 mm to 0.250 mm). In the study area most of the area is covered with this variety of soil and it’s susceptible to soil erosion with higher intensity of rainfall [8].

## Rainfall Intensity and Runoff

Soil erosion is a major cause of concern that should be addressed in hilly regions, both precipitation and overflow components must be considered in analysing water Erosion issue. Raindrops falling on the soil surface can separate soil mass and may scatter the total

material, if the material is lighter (fine sand, sediments etc.), they can be moved away effectively when it falls over them. For moving larger particles such as rock particles and bigger sand more velocity is required. Spillover may occur at the points where there is more water particles in a slope which cannot be drained or stopped naturally. Water runoff may occur when there is excess water prevailing in a slope that cannot be absorbed or trapped on the surface [9].

# Soil Bio-Engineering

Many methods are available for slope stability such as soil nailing, retaining structure, geosynthetic reinforcement, geotextile reinforcement, shotcrete, Vibro compaction. Here we adopt a moderate method to reduce the small-scale landslides by using soil bioengineering. Bioengineering is the use of living plants for engineering purposes. Vegetation is carefully selected for the functions it can serve in stabilizing roadside slopes and for its suitability to the site. It is usually used in combination with civil engineering structures. Bioengineering offers the engineer a new set of tools, but does not normally replace the use of civil engineering structures. Incorporating bioengineering techniques usually offers a more effective solution to the problem. The materials and skills are all available in rural areas, however remote. Soil bioengineering is a new technique which may focus on the slope stability by root traits. It is the science which reduces the small-scale landslides by using the plant/tree roots and understanding on how the root contributes to the slope stability. The root behaved in two different manners, first is to act as mechanical reinforcement and second is giving efficient hydrological properties. The soil has high strength on compression, but less resistance at tension. Similarly, root has a high resistance at tension and low strength at compression. In practically it is applicable for slope stability, so we conduct experiments for quantifying the root behavior on slope stability i.e, an increase in soil shear strength properties.

The presence of vegetation increases the slope stability and shear strength of soil, thus, stability is based on the type of plant and its root system. In soil bioengineering selection of suitable plants play key role while applying this technique locally. Certain bioengineering practices such as cutting, live fascines and brush mattress in tandem with geogrids that are vegetated, geo-gabions were employed in many river bank constructions . Root anchorage capacity can be studied either in-situ or in the laboratory, it is found through pull-out tests that soil root interaction creates more shear strength [10].

The soil-root system should perform the duty of a reinforcing agent and absorb the tensile stresses acting on the soil through an increase in shear strength; the reinforcement capacity depends on the roots length, its penetration depth, and roots lateral spread, thickness and root hairs development. Several researchers suggested that if the penetration of root is more, slopes strength against failure will be more [11].Also the roots growth is defined by the type of soil, roots will get confined to cracks in clay or clayey loam texture but they will grow through large pores if the soil has granular structure, mechanical properties of root depends on type of plan, characteristics of soil and installation method of plants [12].

Tree roots in the oldest stand were the most resistant in tension compared to roots growing in the middle and young stands for the same diameter range. The root tensile strength difference observed between plantations could be explained by differences in the root structure, as older trees may possess higher quantities of cellulose[13]. Therefore, it would be of interest to analyze cellulose content in roots from the three plantations. Soil bioengineering is a method of using the plants to provide supporting engineering functions such as catch, armor, reinforce, drain and support, it is found to be an effective tool to convert potential failure surface to a stable and non-eroding surface. This practice is widely adopted across the globe as a potential solution for soil erosion and preventing unstable slopes from failure [14].

## The Role of Bioengineering

* + - * Bioengineering reduces the instances of shallow planar sliding.
      * Bioengineering can be used to protect almost all slopes against erosion.
      * Bioengineering can be used to improve surface drainage and reduces slumping.

Bioengineering systems work in the same way as civil engineering systems and have the same functions. They are effective at a depth of up to 500 mm below the surface. They are not effective for deep-seated slope failures. Bioengineering involves the usage of grasses, shrubs and some varieties of trees to protect the slopes using the hydrological and mechanical effects of plants used. Factor of safety of the slope is proved to be increased due to the presence of vegetation; this parameter is well recognised among the researchers. Vegetation cannot be used alone but in tandem with engineering structures, many regions have factors that supports usage of this technique such as abundant amount of labour, most of the population working on agriculture based works, huge diversity of indigenous plants which are well suited to grow in that particular region. Bioengineering has limitations in that it cannot affect the stability of the slope beyond the rooting depth. Frequently this is effectively limited to 1 m. Claims are often made for deep rooting depths of trees, bamboos and grasses. These should be treated with care as quoted figures tend to be exceptions rather than the rule. The effects of vegetation on a slope are also citing specific and it is inappropriate to make generalizations which may generate false optimism on what can be achieved. Obviously, the use of bioengineering techniques costs more in the short term than the do nothing approach. But in the long term, there should be additional benefits from reduced maintenance costs [14].

## Bioengineering systems and their effects

Using vegetation for engineering purpose in practice differs somewhat from the theory. On gentle slopes, a simple planting pattern is often enough. On steep and often intrinsically unstable roadside slopes, however, experience has shown that only a relatively small number of robust techniques serve the range of engineering functions required.

The slopes addressed by the techniques in this manual are extreme in their length and steepness, the disturbance and weakness of the materials of which they are composed, and the intensity of periodic monsoon rainfall. At this stage, it is necessary to consider only the engineering functions required to stabilise them. So far, the principles of vegetation in engineering have been considered, and the contribution made by individual plants. Plants used in combination can provide much greater effects than can single plants. For example, a single grass plant can catch a small amount of debris and reinforce a small volume of soil with its roots. But grasses can be planted across a slope, to form a continuous line to catch debris, and so provide a line rather than a point of reinforcement. In the process of serving these functions, however, the contour line of grass will also increase the infiltration capacity of the soil. Despite the versatility of the bioengineering techniques, the complexity of most sites means that a range of techniques are usually required, just as civil engineering works usually require a range of different structures serving separate but complementary functions[15].

# Root Morphology

It is the architecture, structure and shape of root system that is being used in soil bioengineering purpose, it plays key role in soil strength enhancement and nutrient acquisition (Bibalani et al., 2007, Noorasyikin and Zainab Mohamed, 2015). Presence of plant roots enhances the apparent cohesion of soil through root reinforcement, which in turn increases slope stability (Schmidt et al., 2001, van Beek et al., 2005). The root soil reinforcement model developed by Wu (1976), and enhanced by Waldron (1977), is widely used to express additional cohesion due to the presence of roots in the soil matrix (Bischetti et al., 2005). Some of the main features of root morphology that are viewed while considering the plant for bioengineering includes root biomass, spread of root, depth of root, distribution of root [16].

## Root Area Ratio (RAR)

It is the ratio of the cross-sectional area of root covered on the soil to the cross- sectional area of root covered on soil at rooting depth. It is calculated by counting the total roots of various diameter classes in a particular cross sectional area of the soil, exposed on a vertical face (De Baets and Poesen, 2008). It is an important parameter that defines and controls the shear strength increase due to the presence of roots. The Root Area Ratio can be found by dividing root biomass by the unit weight of the root ﬁber (Leuschner et al., 2004). A model for determining the unit weight of roots per stand was established by measuring length, diameter and weight of a selection of roots.

## Root Biomass

It is calculated by weighing the total amount of roots per unit volume of soil, roots were taken from core samples and separated as per their diameter classes before weighing (Drexhage and Gruber, 1998). Each diameter class of root is weighed with a precision balance of accuracy greater than 0.001 mg and the root biomass was obtained according to the volume of auger, it’s usually expressed in g /m3.

## Root Distribution

Distribution of root inside the soil depends on type of plant and the type of roots it develop, also the resource uptake and efficiency is influenced by the distribution, this can change the stress distribution , plastic type of strains that develop in the soil and also it modifies the pull-out resistance. Studies convey that most preferred systems are dichotomous than herringbone when it comes to anchorage of roots. In any plant, if the root forks grow vertically downwards, they may cross the potential shear zone and they can anchor the soil properly [19].

# Root Traits

**Figure 2 Classification of Root Traits**

Root reinforcement is the main parameter that should be looked upon while deciding the stability of slopes. On the figure 2 represent the classification of root traits. One of the researcher studied and obtained the root characteristics that may have possible impact of reducing soil erosion. After the intersection point they found the parameters namely root length density, Root Area Ratio, root taper, basal diameter, root density, root inclination, percentage of bare soil with fine roots, maximum root depth, branching pattern, angle between lateral roots, and total length. Also, it is evident that in a soil permeated root, when concerned with the mechanical behavior of soils, the root architecture plays key role. Other than those parameters we calculate the further investigate on root traits such as root length density, root density, specific root length, root length, root diameter, root angle, leaf area index [20],

## Root Density

Root density is the main affecting the permeability of the soil caused by creates the voids. It is the weight of root per unit volume of the root. Normally it is expressed in g/cm3. The proliferation of shear strength due to vegetation is directly proportional to the root density [20].

## Root Length Density

It is a critical feature which determines the crops potential to uptake soil water and nutrients, mostly it’s a parameter that is very difficult to measure which has no standard methods to measure. It is measured that the resistance to pull-out will increase with the increase in root length density since it causes the roots to break in tension rather than slipping out of soil. Soil water content also affects the slopes stability and a plant having higher RLD is desirable since they absorb more water [20].

## Specific Root Length

It is defined as the length of the roots per unit dry soil mass, higher the value indicates more thinner roots and if it’s low the plant will have less but thick roots, for soil bioengineering practice it is advisable to have herbs and grasses with high SRL values as much as possible [21].

## Root Angle

Root angle is the angle between the daughter and mother roots measured in both vertical and horizontal planes, a plant that contains roots with multiple orientation ranges, will develop wide shearing zones, it can fully mobilize the root reinforcement by the tensile strength of the roots [22].

## Root Topology

Topology of roots in the organization of the roots branching, it influences various parameters such as uptake of resources (soil nutrients) and can also effect the stress distribution within soil and also modifies the pull-out resistance of the roots. Concerned with root topology preferred for soil bioengineering Dichotomous systems are preferred than herringbone systems owing to their better anchorage capability [23].

## Root Tensile Strength

Tensile strength of root is defined as the maximum resistance it can offer without disintegrating in tension, to mobilize fullest strength a high resistance is required and also to increase the shear strength of the soil. Thus it’s preferred to have more finer and smaller roots in soil, rather than having few long and thick roots [24].

## Leaf Area Index

It is defined the ratio of the area of one leaf to the whole leaf covered to the soil. It will give a state of plant growth proliferation. It can be helpful to the study on how the plant grew and their area of leaf spreading [24].

## Root Decay Rate

Roots decay when the plants die, the rate of decay depends on diameter of the root, roots chemical composition and the plant species. Concerned with soil bioengineering plant roots that possess slow decaying characteristics is preferred since they will be able to fix soil for quite longer period, also the decayed roots create a flow path for the water to drain [23].

# Root Reinforcement

In hilly terrain slope stability is directly proportional to the vegetation’s contribution in terms of root reinforcement (Sidle et al., 1992). A plant root plays a huge role in soil reinforcement function through anchoring the soil and formation of a binding network within the layers of soil which ties the soil masses. Quantification of roots reinforcement capability is bit more complex owing to the heterogeneity or root distribution and the turnover dynamics which ends up creating complexity in calculation of slope stability (Schwarz et al., 2013). The factors that influences the FOS includes density of soil, porosity, saturation level of soil, natural water content, permeability characteristics etc. In terms of hydrological concepts, the plant canopy present above the ground acts as a soil erosion protection agent owing to its intercepting capability of raindrops. Also, it enhances the soil filtration rather and removes the water present is soil through evapo-transpiration. The quantum of reinforcement a plant can offer is related to the capacity of its individual roots tensile strength and the architecture of the roots, it varies from plant to plant and depends on the diameter of root, its age, the properties of soil nutrients, moisture content of soil and the chemical composition[25].

**Conclusions**

In summary, the exploration of soil types serves as a reminder of the intricate relationships between Earth's geological processes, ecological systems, and human activities. As stewards of the land, it is incumbent upon us to recognize the value of soil diversity, implement responsible practices, and safeguard this precious resource for present and future generations. Through continued research, education, and conscientious actions, we can ensure that soil types remain a foundation for thriving ecosystems and sustainable development.

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