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TREES AS NATURAL SOLUTIONS FOR SLOPE STABILIZATION

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A slope or hillside can begin to fail (slump or wash out) over time because it lacks the internal strength to withstand water and gravity. The strength of a hillside can be compared to that of a bridge or any other structure. When the strength of a bridge is fully known, it is easy to predict when it will fail. In contrast, it is extremely difficult to determine the exact strength of a slope, even with today's technology. However, we do know that the strength of a slope, like that of a bridge, is determined by the basic materials involved (soil in the slope, steel, concrete or wood in the bridge), the binding power of these materials (what holds the soil particles together, the adhesion of concrete to reinforcing rods, or the fasteners on a wooden bridge), the amount of water in the materials, and the amount of the forces acting on the slope (the weight of the soil, the water pressure on the soil, the vegetation on the slope, etc.). Vegetative slope stabilization is the process through which plants, including but not limited to grasses, shrubs, and trees, prevent soil erosion and enhance the strength of soils. The mechanism in this practice stems from the vegetative rooting systems holding the soil together, therefore reducing runoff and enhancing slope stability.

Factors Affecting Tree Selection for Slope Stabilization

In general, a system for slope stabilization requires that vegetation establish as soon as possible after the earthmoving and grading actions have been completed. This means that the advantages for erosion prevention during the construction phase as well as long-term plant survivability must be factored into the selection of the plant materials. The selection of the proper plant materials that are best suited for the site begins during the project design phase and continues on through the construction phase. The success of the project often depends on the design and the development of plant materials that are capable of providing both the

short-term erosion control as well as the long-term stability and attractiveness of the site (Gobinath et al., 2022; Mairaing et al., 2024).

In the selection of the tree species that are used when revegetating disturbed lands, there are a number of considerations that must be taken into account in order to establish a root system that will provide the necessary support to prevent erosion. These considerations include the root depth, root distribution, spread of canopy, the speed of establishment, the potential for overstory tree development, the length and frequency of seed drop, the rapidity of the decline of the herb and subshrub layers, the vegetative habit, vegetative patterns, the nutritive value of foliage and any other attributes of the species. Individual sites may require the use of single species, or mixtures of species, plant materials depending upon a variety of factors.

Soil Erosion and Water Runoff

Soil erosion is a process that removes soil from the earth's surface due to transport by wind, water, and ice after soil pores clog, which helps water to remove soil after rain. Soil (up to a 10 cm layer) is the fertile medium for the growth of plants, as well as storing organic matter and some nutrient elements. During cultivation, soil tillage, or natural disasters such as floods and droughts, the fertility of the soil volume will reduce and become harder, which leads to low utility for crops. A large amount of sediment will be discharged into rivers. It is observed that having vegetation on the slope can increase water absorption and slow water flow on the soil surface. This will increase soil permeability when planting vegetation, for example, tree species which have a deep root system. Soil erosion is an ongoing process that leads to the destruction of soil. This not only affects the productivity of the soil but also causes a loss of its function in physical, chemical, and biological properties. Soil erosion in mountainous regions is higher than in plain regions because of topographical and hydrometeorological factors. Hydrometeorological factors are the factors that need water to occur, such as rainstorms, cloud bursts, floods, and fine days with bright sunshine. Topographical factors are caused by high steep slopes or long gentle slopes with channel characteristics. It is interesting to note the methods of tree plantation along the mountainous region. The purpose is to achieve economic benefits, and the important thing is that it can reduce soil erosion and regulate the water supply for the country and community. Based on vegetation, it can protect the soil and control landslides in the mountains before water flow occurs (Bordoloi and Ng, 2020). As the choice of species depends very much on the district

conditions and the objectives of afforestation, it is very difficult to give advice on the selection of tree species without more information. The following points are common in deciding the best species, however: soil, climate, and water are the chief factors to be considered for most tree species. Even within the same tree species, there are differences in these characteristics, but it is impossible to deal with all those differences here. However, do keep in mind that selection of the right species for the right place is a very important issue in afforestation.

Terracing and Contour Planting

Terracing is generally recognized as a particularly effective way to modify the slope of a hilly area in order to grow trees or crops. The construction of terraces involves cutting the slope along steep sloping lands. It reduces the steepness of the slope and allows for flat areas for planting. This method helps cut down on erosion and runoff. We recommend terracing when the slope is greater than 30 degrees. But since terraces are made manually and are expensive, only a few terraces are recommended for a particular plantation. On the other hand, planting of trees in contour lines is effective when the slope is less than 30 to 35 degrees, just as contour plowing is effective for crops when the slope is less than 30 to 35 degrees. Ground preparation and planting of trees are easier and cheaper than in terracing. Also, contour planting is effective and attractive for environments, especially along the slope.

The basic purpose of terracing and contour planting is similar, that is, minimizing soil erosion by decreasing the gradient of the hill. Contours are lines drawn on the ground with elevation. Each line is mostly determined on the basis of a 2-meter horizontal and 1-meter vertical distances. Therefore, the distance between two contour lines represents the gradient of the hill initiation. In contour terracing (also called terracing), both contour lines are drawn on the hillside and the distance between the lines is about 5 meters. In contour plowing, both lines are made with plowing tractors during park and each line acts as a miniature dike for runoff.

Using Trees for Slope Erosion Control

Trees play a critical role in mitigating slope erosion through several mechanisms:

Root Systems: The intensive rooting system of trees adds to soil binding and compaction. It improves the cohesion and stability of soil against wind and running water, thereby reducing soil displacement during heavy rains or wind.

Canopy Cover: Tree canopies intercept rain and consequently decrease the energy with which raindrops hit the soil surface. This decreases surface runoff and, in turn, reduces erosion.

Water Absorption: Trees absorb water in large quantities through their roots, reducing the content of soil moisture and reducing the possibility of landslides and erosion.

Soil Structure Improvement: Trees add to better soil structure by increasing the content of organic matter and soil aggregations. This helps to enhance water penetration into the soil and to reduce surface runoff.

Windbreak: Trees serve as windbreaks and reduce the velocity of the wind at the soil surface. This way, strong erosive forces of the wind are kept at bay, especially in open areas.

Long-term Sustainability: The establishment of trees on slopes provides a long-lasting solution for erosion control. Through this, diverse plant and animal life can inhabit in a secure environment, thus giving a hand in the overall ecosystem health.

Conclusion

In conclusion, the use of trees within slope management practices proves to be a powerful and sustainable tool in erosion control. The benefits go beyond soil stabilization and include improved biodiversity, better water quality, and the strengthening of the ecosystem. A wide variety of tree species has to be selected for maximum results using site-matching criteria: soil type, climate, and slope characteristic.

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