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Desirable plant root traits for protecting unstable slopes against landslides

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A trait is defined as a distinct, quantitative property of organisms, usually measured at the individual level and used comparatively across species. Plant quantitative traits are extremely important for understanding the local ecology of any site. Plant height, architecture, root depth, wood density, leaf size and leaf nitrogen concentration control ecosystem processes and define habitat for other taxa. An engineer conjecturing as to how plant traits may directly influence physical processes occurring on sloping land just needs to consider how e.g. canopy architecture and litter properties influence the partitioning of rainfall among interception loss, infiltration and runoff. Plant traits not only influence abiotic processes occurring at a site, but also the habitat for animals and invertebrates. Depending on the goal of the landslide engineer, the immediate and long-term effects of plant traits in an environment must be considered if a site is to remain viable and ecologically successful.

When vegetation is considered in models of slope stability, usually the only root parameters taken into consideration are tensile strength and root area ratio. Root system spatial structure is not considered, although the length, orientation and diameter of roots are recognized as being of importance. Thick roots act like soil nails on slopes, reinforcing soil in the same way that concrete is reinforced with steel rods. The spatial position of these thick roots also has an indirect effect on soil fixation in that the location of thin and fine roots will depend on the arrangement of thick roots. Thin and fine roots act in tension during failure on slopes and if they cross the slip surface, are largely responsible for reinforcing soil on slopes. Therefore, the most important trait to consider initially is rooting depth. To stabilize a slope against a shallow landslide, roots must cross the shear surface. The number and thickness of roots in this zone will therefore largely determine slope stability. Rooting depth is species dependent when soil conditions are not limiting and the number of horizontal lateral roots borne on the vertical roots usually changes with depth. Therefore, the number and orientation of roots that the shear surface intersects will change significantly with rooting depth for the same plant, even for magnitudes of only several cm. Similarly, depending on the geometry of the root system, the angle at which a root crosses the shear surface can also have an influence on its resistance to pullout and breakage. The angle at which a root emerges from the parent root is dependent on root type, depth and species (when soil conditions are not limiting). Due to the physiology of roots, a root branch can be initiated at any point along a parent root, but not necessarily emerge fully from the parent root. These traits, along with others including size, relative growth rate, regeneration strategies, wood structure and strength will be discussed with regard to their influence on slope stability.

How each of these traits is influenced by soil conditions and plantation techniques is also of extreme importance to the landslide engineer. The presence of obstacles in the soil, as well as compaction, affects root length and branching pattern. Roots of many species of woody plants on shallow soils also tend to grow along fractures deep into the underlying bedrock which allows roots to locate supplies of nutrient and water rich pockets. Rooting depths of herbaceous species in water-limited environments are highly correlated with infiltration depth, but waterlogged soils can asphyxiate tree roots, resulting in shallow root systems.

The need to understand and integrate each of these traits for a species is not easy. Therefore, we suggest a hierarchy whereby traits are considered in order of importance, along with how external factors influence their expression over time.