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Quantifying the Ecophysiological Mechanics Driving Root Reinforcement of Soils

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Climate and vegetation are strongly coupled such that relatively small changes in precipitation and/or temperature can create major disturbances to ecosystems. A climate-induced shift in the species composition of an ecosystem in turn affects landscape morphology by changing the frequency and magnitude of erosion. The feedback between vegetation and erosion, particularly landslides, is controlled by the nature of plant root systems and their spatial and temporal response to differing environmental conditions. A poor theoretical understanding of the relationship between ecology and landslide initiation has meant that landslide models typically treat vegetation as a uniform parameter. In most landslide models, root resistance to the downslope movement of soil is estimated by summing the root tensile strength or failing roots progressively within a root bundle. The magnitude of reinforcement in these models depends on the diameter distribution of roots and strength in tension. The strength of roots in tension is controlled primarily by their cellulose content, suggesting that the physiology that controls the growth and formation of cellulose also affects the tensile strength. Field data has shown that soil moisture is a key environmental control on root cellulose content, likely because areas of relatively high soil moisture contain roots with larger (or more) vessels to aid transpiration. At a catchment-scale, soil moisture is controlled by the degree of topographic convergence, suggesting a possible link between topography and the ecological controls on landslide initiation. We present the results of a field experiment conducted at Coweeta Hydrologic Laboratory, North Carolina in which we measured the effect of topographically-controlled changes in soil moisture on physiology of tree roots and their potential for soil reinforcement. We excavated 12 soil pits from two common southern Appalachian species (Liriodendron tulipifera and Betula lenta). For each species, we sampled three sites on noses (divergent topography) and three in hollows (convergent topography), collecting all biomass from five depth intervals and soil moisture measurements at 30, 60, and 90cm depth. For each depth interval we measured the tensile strength of roots, their cellulose content, and the total biomass. Where we collected soil moisture data we also measured the hydraulic conductivity and tensile strength of roots. Increased soil moisture content results in an increase in the hydraulic conductivity of the roots and resulting decrease in tensile strength. This means that roots that are deeper within the soil profile are weaker, consistent with the presence of shallow sub-surface flow. At the whole pit scale, roots in hollows tend to be weaker on average than those on noses. Our results suggest that plants adjust their hydraulic architecture in response to topography which, in turn, affects their ability to resist the forces driving mass movement. Understanding the physiological controls on root strength therefore allows us to model the distribution of root reinforcement across a whole catchment, greatly improving the precision of current estimates of shallow landslide initiation.