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Characteristics of soil mechanical reinforcement using the root bundle model

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Recent quantitative studies of plant root reinforcement on steep hillslopes and river banks highlight the usefulness of considering progressive failure associated with bundles of roots (or fibers) rather than the traditional upscaling of individual root behaviors. The characteristics of progressive failure depend on the geometry and mechanical properties of the bundle. In this study we present the Root Bundle Model (RBM) for quantitative description of mechanical behavior of a bundle of roots under stress or strain-controlled mechanical forcing. The RBM explicitly considers typical values of root-size distribution, geometrical factors, and mechanical characteristics and interactions under different soil conditions. We provide systematic analyses of the roles of these factors on the mechanical response of the root bundle and explore the relative importance of various parameters to the macroscopic response of root systems. We distinguish between the increased strength imparted from small roots at small deformation and the resilience imparted by bigger roots with lower Young's modulus. Additionally, the model reproduces the gradual straining and ultimate failure of root systems often observed in hillslopes with progressive growth of tension cracks. These results are important for enhanced understanding of root reinforcement mechanisms and for implementation of root reinforcement modeling in stability calculations of vegetated slopes.