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Life's Impact on the Soil Production Function

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Soil melds life and lithology, but the top-down production of soil by the incorporation of organic matter has typically been viewed through a lens of soil biogeochemistry and the bottom-up weathering of bedrock viewed from a geomorphologic perspective. We merge these perspectives by developing a variation on the classic geomorphological soil production function [1] that accounts for the influence of top-down soil production by additions of organic material. In the classic view [1], production rate of soil from bedrock weathering is a function of the thickness of the soil horizon. Under steady state conditions, this thickness is controlled by a constant coefficient of diffusion and by the hillslope curvature. Across the globe, equilibrium landscapes can be hard to find. We explore the many ways that biota influence the upper soil horizons and move the soil-hillslope system out of steady state using measurements of in situ 10Be at depth in soil profiles. Our empirical case study is in the Luquillo Critical Zone Observatory of northeastern Puerto Rico, where long term ecological monitoring suggests an average of 375 m My-1 of litter fall [2] and as much as 17.5 m My-1 of dust [3] is contributed to the forest floor. This substantial volume of material forms an active surficial layer, functionally increasing the residence time of grains deeper in the soil profile. Litter recycling influences the cosmogenic dose rate to be higher by increasing the residence time of grains and to be lower by increasing environmental shielding. In unconstrained systems, probabilistic modeling can determine a range of solutions for the ages of grains determined with 10Be depth profiles[4]. We compare the probabilistic outcomes to actual measurements of the in situ 10Be at depth in soil profiles from the Luquillo Mountains. Life living in the soil, rather than on it, is of equal importance in the Luquillo Mountains. On average, the soil is occupied by 200 individual earthworms per m2 [5]. The depth of soil mixing in the soil profiles we collect is shown by the homogenization of 10Be concentrations in grains. Mixing changes the residence time of grains in soil. The length of this residence time is a critical component in the rate of weathering reactions, the mechanism by which material is lost to chemical dissolution and leaching. Additionally, mixing may drive the value of the diffusion coefficient, which determines the flux of sediment out of the soil mantle in the geomorphic soil production function. Life actively impacts the soil-hillslope system, and quantifying these effects is an essential modification of a fundamental paradigm in the geomorphology of soil-mantled landscapes.

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