Hydraulic Redistribution of Water through Plant Roots and Implications for Carbon Cycling and Energy Flux at Multiple Scales

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Hydraulic redistribution (HR) of soil water by plants occurs in seasonally dry ecosystems worldwide. During drought, water flows from deep moist soil, through plant roots, into dry (often litter-rich) upper soil layers. Using measurements and modeling, we are exploring small- and large-scale effects of HR on soil water content, microbial activity, and net ecosystem carbon and energy exchange, in seasonally dry ecosystems of the Western U.S.

At the single root scale, we have modeled a 10-cm radial soil domain, with root at center, and simulated solute transport, soil cation exchange, and root exudation and nutrient uptake under two water flow patterns: daytime transpiration without nighttime HR, and daytime transpiration with nighttime HR. During HR, water efflux flushed solutes away from the root, widening depletion zones for key nutrients like nitrate. Outward transport of cations (previously accumulated near the root by transpiration) led to competitive desorption of ammonium from soil further from the root and generation of hotspots of ammonium availability at night. A microbial community and small food web will next be embedded into this dynamic resource landscape to explore how organisms responsible for nutrient and soil carbon cycling respond to these fluctuating resource regimes.

At the ecosystem scale, we have folded Ryel et al.'s (2002) HR formulation into CLM4.5 and examined how well the combined model can simultaneously simulate measured evapotranspiration, the vertical profile of soil moisture, and the amplitude of HR-associated diel changes in water content, at multiple seasonally-dry Ameriflux sites: Wind River Crane (US-Wrc), Southern California Climate Gradient (US-SCs,g,f,w,d,&c), and Santa Rita Mesquite Savanna (US-SRM). In many cases, the combined model reproduced seasonal and diel observations with reasonable accuracy. However, two shrub and one desert sites proved challenging, for as-yet unknown reasons, though at all sites, soil moisture sensors sample from a small fraction of the eddy flux tower footprint, and in at least one site, groundwater in fractured bedrock (not considered in our model) is the source of water for HR. Our next step is to explore how biogeochemistry in soil layers is affected by the inclusion of HR in CLM4.5.

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