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ABSTRACT TITLE: Hydraulic redistribution of water through plant roots – implications for carbon cycling and energy flux at multiple scales

ABSTRACT: The rhizosphere (the volume of soil around plant roots, influenced physically and/or chemically by those roots) is a fundamental commodities exchange in terrestrial ecosystems. Carbon moves from roots to the microbial community, and the microbial community uses readily-available carbon for energy and to build biomass, influencing soil CO₂ flux and availability of nutrients to plants in the process. In the rhizosphere, interacting carbon and nutrient cycles are strongly affected by fluctuating soil water content driven by plant transpiration and hydraulic redistribution (HR) of soil water through root systems. During HR, soil water flows from wet soil zones into roots, through the root system, and out of roots into dry rhizosphere soil, exactly where the carbon and nutrient commodities exchange is active. Though warming-induced increases in atmospheric demand for evaporation, and resulting soil drought, are expected in the future, the current generation of dynamic vegetation and earth system models do not include HR. We are examining how HR affects soil carbon and nutrient cycling, as well as transpiration, plant carbon gain, and energy fluxes, in seasonally dry ecosystems. We are combining greenhouse work with Ameriflux site data, small-scale mechanistic and large-scale ecosystems and earth system modeling to explore the interactions shown in Fig. 1, particularly focusing on upward HR (“hydraulic lift”, HL) that occurs in seasonally dry systems during drought. HL provides a mechanism for simultaneously ameliorating limitations in shallow soil water content and plant nutrient availability, potentially enhancing plant carbon gain through “direct” and “indirect” pathways shown of Fig. 1, while also stimulating heterotrophic respiration. Whether net ecosystem exchange will shift positive or negative as a function of HR will depend on the relative strengths of direct and indirect effects mediated by plants and microbes, the signs and strengths of their component processes, the intensity of future drought, and the time scale over which HR’s effects are considered.

RESULTS TO DATE: We have established a greenhouse experiment that will hold availability of water to plants constant, while simultaneously preventing or allowing HL by controlling the timing of deep watering. Microbial, soil, and plant response will be assessed. We have also developed a new strategy for genetically engineering bacteria to use as microbiosensors to get the “microbial point of view” of dynamic water availability around plant roots. Root-scale reactive transport and microbial modeling using MIN3P will be informed by greenhouse and microbiosensor data, and will inform selection of key processes to be included during modification of larger scale models. We have gathered Ameriflux eddy flux and soil moisture data from most of our target sites, begun exploring the data for potential signatures of HL during dry seasons, and begun site-specific modeling capturing major drivers of water, energy, and carbon exchange (CLM4.0). Finally we
have tested configurations (and domain boundaries) for the regional climate model RegCM4-CLM4 and identified the configuration with best performance in the North American domain.