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Soil-plant interactions in silico: the role of plant water storage, hydraulic redistribution and competition among plants

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Because of its significance in forestry, agriculture and meteorology, the subject of representing soil-plant interactions in hydrological and ecosystem models continues to draw significant research attention. Here, a novel modeling framework that combines a 1D description of stem water flow, leaf-level photosynthesis, and transpiration with a 3D representation of soil-root water exchanges is featured. Model simulations are employed to explore the impact of plant water storage (PWS), nocturnal transpiration and hydraulic redistribution (HR) on short-term carbon/water fluxes as well as the role of competition among overstory and understory plants for water and light. Model results suggest that daytime PWS usage and nocturnal transpiration can significantly suppress the magnitude of HR, thus reducing potential bias in modeled water fluxes throughout the different soil-plant compartments. With progressive soil drying, PWS delays the onset of water stress and overstory-understory interactions enhance ecosystem resilience to drought through shading and localized HR fluxes that sustain understory transpiration over prolonged periods of water stress. Such plant scale interactions can only be captured by the detailed 3D soil-plant simulations but, with proper averaging, equivalent resistor-capacitor models can reasonably describe stand-level dynamics on longer time scales.