Modeling the impact of hydraulic redistribution on carbon fluxes and storage using CLM4.5 at four AmeriFlux Sites

TES program (PI Cardon)

Zoe G. Cardon, The Ecosystems Center, Marine Biological Laboratory, Woods Hole, MA 02543, zcardon@mbl.edu
Congsheng Fu, Dept. of Civil and Environmental Engineering, University of Connecticut, Storrs, CT 06269, cof13001@engr.uconn.edu
Guiling Wang, Dept. of Civil and Environmental Engineering, University of Connecticut, Storrs, CT 06269, gwang@engr.uconn.edu

In seasonally-dry ecosystems, when gradients in soil water content develop, plant root systems can serve as conduits for water flow from wet to dry soil (along the water potential gradient). This “hydraulic redistribution” (HR) of water affects landscape hydrology and plant physiology, but is not included in the current generation of standard dynamic global vegetation and earth system models. It has long been hypothesized that HR’s impact on soil moisture profiles also inevitably affects rhizosphere soil microbial activity, and thus heterotrophic soil respiration, carbon cycling, nutrient cycling, and nutrient availability to plants in seasonally-dry systems. Recent field evidence assaying microbial nitrogen cycling activity in dry Utah soils supports this idea. HR thus potentially can affect carbon cycling and land-atmosphere carbon exchange through two pathways: (1) by directly stimulating plant physiology (e.g. enhancing stomatal conductance and thus increasing photosynthesis), and (2) by affecting rhizosphere microbial activity in the soil profile, and therefore the magnitude of heterotrophic soil respiration and/or nutrient cycling rates and nutrient availability to plants. We modified the Community Land Model 4.5 with Century-based soil carbon and nitrogen pool kinetics to include the Ryel et al. 2002’s model of hydraulic redistribution (HR), and we investigated changes in modeled carbon fluxes and storage at four Ameriflux sites where HR is known to occur: US-Wrc (Douglas fir in Washington State), US-SRM (savanna in Arizona), US-SCf (oak-pine forest in Southern California), and BR-Sa1 (evergreen broadleaf tropical forest in Brazil). Model simulations with HR can better capture the net carbon exchange between ecosystem and the atmosphere (NEE) measured at the US-Wrc, US-SRM, and BR-Sa1 sites. The model results indicate that HR tends to increase GPP and enhance plant growth at all four sites, and reduce the temporal fluctuation of soil carbon storage at the three forest sites. The HR-induced increase of GPP is limited by nitrogen, and that limitation is the smallest at the Amazon BR-Sa1 site. HR influences the modeled ecosystem carbon dynamics through: (1) improving plant water availability thus supporting stomatal opening therefore photosynthesis, and (2) through enhanced nutrient availability caused by enhanced soil microbial activity due to HR-induced increase of moisture in shallow soils. CLM4.5 also includes a fire module, and we found that HR also modified fire susceptibility during the dry season. Of these three pathways, water availability affecting plant physiology played the dominant role in modeled effects of HR on carbon cycling.