Federal Agency-Led Research

Quantifying the interactions between plant water uptake and hydraulic redistribution on the components of evapotranspiration in a mature, unmanaged forest stand

A. Christopher Oishi (acoishi@fs.fed.us) - USDA Forest Service, Coweeta Hydrologic Laboratory, Jean-Christophe Domec (PI)- North Carolina State University & Duke University; John King- North Carolina State University; Asko Noormets- North Carolina State University; Ram Oren- Duke University.; Sari Palmroth- Duke University; Jennifer Swenson- Duke University (Co-PIs).

Evapotranspiration (ET) in unmanaged mature, deciduous, temperate forests has been shown to remain fairly consistent within and among years with varying water availability. Relatively high rates of ET during periods of low soil water availability are largely driven by transpiration from dominant trees. These mature trees have a well-established rooting system with the ability to access deeper reserves of water. When transpiration is halted, typically at night, due to stomatal regulation or low atmospheric demand for water, tree water status can increase to the point where the gradient drawing water from roots to shallow layers of dry soil becomes greater than drawing water into stem and branch tissue. This process of hydraulic redistribution can provide a subsidy of soil water for the dominant trees. However, unmanaged ecosystems are generally composed of several species with, as our results show, considerable overlap between roots of overstory and understory trees, especially in the top 0.5 m of soil. These conditions can result in competition for the 'lifted' water among overstory and understory trees as well as from soil evaporation. Further, some trees maintain water uptake throughout much of the night, either through transpiration or recharge of stem and branch water capacitance. In cases where nighttime water uptake occurs, the canopy becomes a competing sink for lifted water and redistribution to the shallow soil layers may not occur.

To quantify the effect of hydraulic redistribution on tree water use, we deployed above- and below-canopy eddy covariance systems, allowing us to partition the contribution of soil evaporation and shrub and sapling transpiration to the ET budget. We utilized eddy covariance together with sap flux measurements to compare individual species' contribution to total canopy ET. We present data from the first year of this ongoing study, showing that even in years with high growing season precipitation, high evaporative demand in the southeastern U.S. can lead to depletion of both shallow and deeper soil water. Nighttime sap flux (representing movement through tree stems at breast height) often exceeds ET, indicating that this water is resupplying stored stem water used earlier in the day. Furthermore, while the daily amount of transpiration is fairly consistent throughout the growing season, the proportion of water movement at night increases during dry conditions and is greater in diffuse porous than ring porous species.