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ABSTRACT TITLE: Quantifying the impact of nighttime transpiration on the magnitude of hydraulic redistribution in an unmanaged forest ecosystem (Duke Hardwood site, NC)

ABSTRACT: Plants lose water from leaves to the atmosphere as an unavoidable cost of allowing CO₂ diffusion to the carboxylation site. A portion of the water taken up during daytime from surface soil layers is made of water redistributed by roots during nighttime from deeper to shallower layers of the rooting profile. However, nighttime water loss may interfere with the hydraulic distribution (HR), potentially decreasing transpiration and photosynthesis. Both tree water uptake and HR in the soil are driven by variations in water potentials and resistances along the soil-plant-atmosphere continuum. The first decade of the 21st century was the warmest on record, and by 2050 the global average surface temperature is predicted to increase 2-4°C, with larger increases projected for the summers in most latitudes. In northern latitudes, nighttime temperatures are expected to increase more than daytime temperatures. Because relative humidity is not projected to change markedly, this may lead to higher nighttime evaporative demand (vapor pressure deficit, VPD). Although plants are expected to close their stomata at night to conserve water when carbon uptake is not occurring, there is growing evidence for relatively high nocturnal leaf stomatal conductance (gₛₙ) driving nighttime sap flux (Jₛₙ) in many C₃ species. Nighttime sap flux (water uptake), can limit HR because the two processes compete for the same water. We studied the magnitude and among-species differences in Jₛₙ, and its potential impact on HR in a oak-hickory forest using sap flux measurements and a process-based model MuSICA. We hypothesized that environmental conditions can cause significant nighttime transpiration, the magnitude of which might be sufficient to delay the onset of HR.

At this forest, mean nightly VPD was >0.4 kPa 23% of the time. In some species Jₛₙ increased with nighttime VPD in a saturating fashion, and represented 10–20% of daytime estimates. For diffuse porous species, the proportion of Jₛₙ from the total daily Jₛ was constant over a range of tree sizes, but the proportion increased with tree size for ring porous species, indicating different hydraulic adjustments to increasing tree size between the two species groups. Furthermore, Jₛₙ varied with soil moisture, showing higher sensitivity when soil moisture was low. In some cases, gₛₙ was more sensitive to VPD than daytime gₛ, but large differences were observed among species. Simulations with MuSICA demonstrated that when Jₛₙ is high, comparable to our estimates of Jₛₙ, trees (filling storage for daytime use) and the atmosphere are the strongest sink for soil water, owing to a greater water potential gradient between deep soil and the plant than between different soil layers; as a result HR to upper soil layers decrease by more than 30%. Current VPD is therefore sufficient to drive significant Jₛₙ and reduce the magnitude of HR. Stands composed of species with high Jₛₙ are expected to have lower soil moisture in the upper soil, transpiration, and photosynthesis than stands with low Jₛₙ.

Keywords: hydraulic redistribution, MuSICA model, night transpiration, sap flux, soil water content.