

Using Sap Flow Sensors to Measure Water Uptake in Trees: Challenges and Opportunities

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Abstract

Water is a resource crucial for the survival and growth of trees. Understanding water relations and how changes in water availability may affect the growth and survival of trees across spatial and temporal scales is critical to gain insights in the future of forests. Sap flow sensors allow estimating tree water flow in vivo using heat as a tracer. The relative simplicity of the various sap flow methods and the affordability of the associated sensors and their easy deployment has made them the most widely used approach to estimate tree-level water fluxes. Together with other measurements of tree biomass, leaf area, and growth, sap flow sensors can provide data with a high spatial and temporal real time resolution, vital to assessing the impacts of edaphic and climatic conditions on the establishment, survival and productivity of trees and associated forest ecosystems. In a first study, I evaluated and quantified the impact of changes in soil water availability, modulated by rooting depth and topography on leaf area and sap flow of 15-year-old trembling aspen and white spruce trees planted on a reclaimed site. Results indicate that scaling water fluxes from an individual tree to the stand-level is complex and require a deeper understanding of trees' physiological responses to variation in edaphic conditions. Another variable often ignored is the role of ontogeny in tree sap flow and its extrapolation to larger scales. Obtaining an accurate quantification of water flow in large trees is critical, but we currently lack direct calibrations of sap flow methods for large trees. In a second study, I

quantified the uncertainty associated with the use of sap flow sensors in a large tree by directly comparing sap flow rates to gravimetric measurements using the cut-tree method on a large mature trembling aspen tree. Also, estimating canopy transpiration using sap flow sensors inserted at the base of the stem is operationally efficient, but can fail to incorporate spatial variability of sap flow, especially for large and tall trees. The oversight of within-tree variability in wood hydraulic properties along with neglecting to incorporate the role of stem water storage and radial exchanges of water between tissues might produce biased estimates of short-term tree-level water fluxes. In a third study, I assessed the spatial partitioning of sap flux density and rate across azimuths and within the crown of a large tree and estimated the contribution of stem water storage to daily transpiration fluxes.

Overall, this PhD work highlights that sap flow sensors are a crucial tool that can help to improve our understanding of the spatial and temporal dynamics of trees' water relations in connection with edaphic and climatic conditions, however they should be used with caution particularly for large trees where significant circumferential and height-related spatial partitioning of sap flow might produce erroneous data that when extrapolated to larger scales could lead to is more likely than in young trees. Furthermore, sap flow sensors alone may not be sufficient to map and quantify the temporal and spatial relationships between sap flow, stem water storage and water exchanges with neighboring tissues in large trees, but best employed in combination with other methods.