A novel and robust procedure for upscaling sap velocity data based on the species-specific role of DBH and slope for explaining tree-to-tree variability

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Abstract

Multi-species forests display a substantial tree-to-tree variability in transpiration induced by various vegetation and landscape characteristics. However, how to model transpiration accounting for tree-to-tree variability still needs to be developed. Diameter at breast height (DBH) is a representative variable of tree characteristics related to age, size and social position in the canopy. Landscape characteristics affecting transpiration are usually defined by topographical factors including slope, aspect, curvature, flow accumulation and topographic position index. Among all transpiration drivers, DBH and topographical factors represent the most stable controls over a growing season. Both play a key-role in defining the accessibility and the availability of the water sustaining transpiration flux and consequently in determining tree-to-tree variability in transpiration. However, previous studies showed that DBH and topographical factors can exhibit contrasting effects on sap velocity (a proxy of transpiration) depending on species and the hydro-meteorological conditions. So far, we are still lacking a detailed understanding of the species-specific influence of DBH and topographical factors on sap velocity, which hampers our ability to predict future forest water-use by impeding our capability to build robust procedures for upscaling sap-flow that accounts for tree-to-tree variability. In this study, we used a relative importance analysis to investigate the specie-specific and dynamic role of DBH and topographical factors on sap velocity. We monitored sap velocity in 28 beech (Fagus sylvatica) and oak (Quercus robur/petraea) trees in a 0.45 km2 forested catchment. We found that the relative importance of DBH and topographical factors depended on species-specific water-use strategies. Based on these results, we developed a novel and robust procedure for upscaling sap velocity using a species-specific non-linear model of sap velocity response to temperature. This new procedure accounts for tree DBH and terrain"s slope for providing modelled time series of sap velocity. Finally, we compared our new procedure with other available upscaling procedure. In both cases, we used the measured sap velocity data to build models for each approach; then, we compared the modelled sap velocity to the real corresponding measured values of individual 28 trees in order to evaluate the differences between sap velocity estimations resulting from the two approaches. Over the whole year, the common procedure overestimated oak sap velocity by 39% ± 5.0 SE and 5% ± 2.3 SE for beech, while our new procedure led to an underestimation of only 4.8% ± 2.0 SE for oak and 12% ± 1.4 SE for beech. Our novel procedure also reduced the standard error of the estimation in both species and therefore the uncertainty on sap velocity of each tree. Moreover, our new procedure appeared to particularly outperform the common procedure during dry summer months when the estimation of forest transpiration is critical. During this period, our procedure slightly underestimated sap velocity by 5.8 ± 1.7% and 1.1 ± 1.9% while the common one overestimated sap velocity by 32.3 ± 4.8% and 8.5 ± 2.6% for oak and beech trees, respectively.