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Assessing reliability of HRM sap-flow sensors under large range of vapor pressure deficit

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Evapotranspiration (ET) is a major water flux of ecosystems and represents globally 60-80% of the incoming precipitation lost by terrestrial environments. In forested lands, tree transpiration (TR) is the dominant component of ET, yet remains challenging to measure. Over the years, sap-flow sensors have become the standard tool for quantifying tree TR and different methods based on thermal approaches have been developed. Heat ratio methods (HRM) are considered as the most reliable and accurate method to quantify absolute flows. Leading commercial brands ensure an accurate measurement of positive flows up to 100 cm hr^{-1} but different studies have highlighted a saturation effect at high flows with threshold for accuracy remaining elusive[RS1] . Due to climate change, the occurrence, the severity and the duration of extreme events like heat waves and dry periods are expected to increase in future, so the potential for high TR rate periods will also increase. Therefore, it is crucial to determine the species-specific environmental conditions allowing a reliable measurement of TR in order to improve or understanding of eco-hydrological and physiological processes during high potential TR periods that can be crucial for vegetation survival. In this study, we tested the accuracy of HRM sap-flow sensors for beech (Fagus sylvatica) and oak (Quercus robur) tree species under extreme vapor pressure deficit (VPD) conditions in order to determine threshold for reliable measurements. In greenhouse conditions, we collected a complete and dense series of TR response to VPD between 0.7 to 8.3 kPa for potted beech and oak trees using three different methods: infrared gas analyser, gravimetric method, and HRM sap-flow sensors. Responses shown a linear trend at the low-canopy leaf level (41.5 and 45.1 mg H_2O m^{-2} s^{-1} kPa^{-1} respectively for beech and oak) but a bi-linear conformation at the whole plant level (1^{st} slope = 12.04 ± 0.7 mg H_2O m^{-2} s^{-1} kPa^{-1} and break-point at 3.9 ± 0.07 kPa for beech trees). Sap-flow sensors using the HRM method displayed a clear inability to reliably measure flows under high VPD conditions. Thresholds of 2.25 ± 0.04 and 2.87 ± 0.14 kPa were identified as the maximum limit of method reliability for beech and oak respectively. In highly demanding environments, we suggest a bi-linear extrapolation beyond VPD threshold for better quantifying tree TR. Further experiments aiming at characterizing TR responses to VPD for a broad range of species and in different water deficit conditions are certainly needed for better understanding tree transpiration at the whole stand level.