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Quantification of transpirable soil water explains tree water use dynamics in a semi-arid pine forest

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The relationships between soil water dynamics and tree water use is essential for understanding the controls over forest productivity and sustainability. This, in turn, often relies on measurements of soil water content (SWC), and calculated 'fraction' of water availability (above a fixed minimum). This approach has some limitations because plant water use seems to correspond better with changes in water potential and absolute moisture quantity. Using data from a semi-arid Pinus halepensis forest site, a soil water potential threshold for tree transpiration (Tt, measured as sap flow) of -2.0 MPa is obtained. Using this threshold value and layer-specific water retention curves allows the calculation of the total soil column water content available for tree transpiration, the transpirable water content (tSWC), as well as its distribution with depth. Simultaneous examination of the seasonal changes in tSWC and Tt showed that initially Tt was 0.2-0.4 mm d-1 when tSWC > 0 only above 20 cm. Maximal Tt values reached 1.3 mm d-1 in spring, when tSWC > 0 was calculated only below 20 cm. The results indicated that onset of the productive season rely on shallow tSWC and peak activity on tSWC in deeper layers. Root density profiles showed maximum values (334 fine roots m-2) at the 20-40 cm soil layer, and [U+F064]18O measurements of tree sap water confirmed that this layer is the source of Tt in the dry season. Limited water infiltration to depth below 40 cm was associated with high water retention (51% clay, maintaining tSWC near zero at all time). The above analysis using the tSWC terms provided a basis to explain the observations of above 90% recovery of annual precipitation in the ecosystem evapotranspiration, and ∼60% in Tt. This approach also allows the estimation of the onset and termination of the productive season associated with gross primary productivity (GPP), which depends on tSWC > 0.