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Inferring plant physiologic parameters for root water uptake modelling from high frequency in-situ isotope measurements

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In the face of global climate change, a well-informed knowledge of plant physiologic key parameters is essential to predict the behavior of ecosystems in a changing environment. Many of these parameters may be determined with lab or pot experiments, but it could prove problematic to transfer results obtained in a such experiments with small trees to fully grown trees. Therefore, new approaches to determine relevant parameters for mature trees are still required. Regarding plant water uptake, parameters related to fine root distribution (maximum depth, depth distribution and rhizosphere radius) and parameters describing the physiological limits of root water uptake are important, but usually hard or costly to assess for fully grown trees. In-situ isotope probes (Volkmann et al. 2016a & 2016b) are a promising recent development that offer new possibilities for the investigation of plant water uptake and associated physiological parameters.

In this study we used in-situ stable water isotope probes in soil (six depths from 10 to 100 cm) and in tree xylem of mature (140 years) European beech trees (three heights between 0 and 8 m). With those probes, we monitored soil and xylem isotope signatures after an isotopically labeled (Deutrium-Excess = 100 ‰) irrigation pulse equivalent to 150 mm of precipitation and foursubsequent natural precipitation events over a period of twelve weeks with a high temporal resolution (six or more measurements per probe per day). Those measurements were complemented with measurements of soil moisture and sap flow dynamics. We interpolated our measured soil isotope and soil moisture data in order to obtain spatially and temporally continuous data for those soil parameters. Then we used this data as an input to the Feddes-Jarvis plant water uptake model, in order to predict the isotopic signature of plant water uptake at daily time steps. With the help of our observed isotopic signatures, we were able to directly constrain the critical water potential parameter of the Feddes model as well as the underlying fine root distribution. Furthermore, the observed dampening of the breakthrough curve of our Deuterium-labeling pulse allowed us to infer information on the rhizosphere radius and water transport velocities in the fine roots and stem between the points of root water uptake and the eight meter stem height.

With our field experiment we showed that in-situ isotope measurements in soil profiles and in tree xylem sap can help to constrain plant water uptake modelling parameters. Future experiments might use this approach to scrutinize lab-scale derived hypothesizes regarding tree water uptake and to investigate the temporal and spatial dynamics of root water uptake in the field.

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