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Delayed water uptake of European beech detected by in-situ measurements of stable water isotopes

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In most terrestrial ecosystems water uptake by vegetation is a key control on the water balance. Sap flow sensors can be used to quantify the amount of water taken up by trees, but their measurements do not contain any information on the origin of the water. Novel in-situ measurements of stable water isotopes in the tree xylem can elucidate this aspect of plant water uptake and provide valuable information for deeper process understanding.

We present the results of a low intensity sprinkling experiment of 160 mm, where an area of 200 m^2 covered by 140 year old European beech (Fagus sylvatica) trees has been irrigated with 60,000 l of isotopically labelled water. Over the course of five weeks we monitored the isotopic composition of the xylem water of two trees on the irrigated area and one tree on a neighbouring untreated reference area. In-situ vapour sampling probes were installed into the stem xylem of each tree at breast height and directly attached to an CRDS isotope analyser in the field. The data set was complemented with isotope data from soil cores, zero-tension lysimeters in 4 depths and bulk samples of subsequent precipitation events and measurements of soil moisture and sap-flow velocities. First traces of the labelled sprinkling water occurred three days after the sprinkling experiment, even though outflow from the lysimeters and soil cores taken 12 hours after the irrigation showed that the labelled sprinkling water already constituted a considerable proportion of soil water in the main rooting zone (up to a depth of 1.5 m). The fraction of sprinkling water in the xylem water peaked after 10 to 14 days at 30% to 50% of the total xylem water and slowly declined towards the end of the monitoring (and vegetation) period.

Sap flow velocity measurements imply water fluxes through tree stem, which are way too high to explain the observed delay of tracer arrival at the in-situ vapour sampling probes in the tree xylem. We hypothesize, that during the drought period preceding the sprinkling experiment fine roots in the dry main rooting zone were subject to increased mortality and water uptake shifted towards deeper soil layers. Due to a lack of functional fine roots in the upper soil, the trees could not immediately utilize the sprinkling water and had to regrow the fine roots first.