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Employing stable isotopes to determine the residence times of soil water and the temporal origin of water taken up by Fagus sylvatica and Picea abies in a temperate forest

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The availability of water is essential for the functioning of plants and ecosystems. We present a study, where we determined the temporal origin of precipitation that was taken by mature individuals of F. sylvatica and P. abies trees in a temperate forest over the course of four growing seasons. Specifically, we (i) assessed how the seasonal variability of δ2H and δ18O values in precipitation is integrated into the soil column and the xylem water of temperate trees, (ii) applied a hydrological model to estimate the residence time of precipitation in the soil at different depths, and (iii) identified when water that is taken up by temperate trees throughout the growing season has precipitated. Our data show that the seasonal variability in precipitation δ2H and δ18O values is transferred into the soil, but that the seasonal variation declined with soil depth. Calculated mean residence time of precipitation in the soil was on average 46 days in the upper soil layers and increased to 190 days in the lowest soil layer. Our study further shows that a substantial fraction of the tree's source water has precipitated several weeks or even months before it was taken up by the tree and that winter precipitation contributes substantial amounts of water to the water supply of temperate forests. Our study has implication for predicting the consequences of changes in seasonal precipitation patterns for the water availability of temperate forests in a changing climate. In addition, our study will help to approximate the δ2H and δ18O composition of temperate trees source water from precipitation isotope databases when these are needed, e.g. for the interpretation of tree ring isotope time series.