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Application of environmental and artificial stable isotope methods to investigate soil-plant-atmosphere interactions in a dry pine forest in southwest Germany

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The knowledge of water flow paths, residence times and source areas of water are crucial for the protection and management of groundwater resources. In this context, evapotranspiration and other processes involved in the soil-plant-atmosphere system are important components. In 2003 an interdisciplinary research project was initiated to investigate predicted impacts of climate change on water balance as well as water and nutrient availability of a Scots pine forest. For this purpose a forest with relative low precipitation and high evapotranspiration with typical water stress conditions during summer months was selected. The forest meteorological experimental site Hartheim is located in the flood plain of the upper Rhine valley in southwest Germany, where a lowering of the groundwater table up to 7 m below surface was induced by anthropogenic river regulations. Since July 2003 biweekly sampling was conducted including quantitative measurements of the water components and isotope concentrations (deuterium and oxygen-18) in precipitation, soil water, groundwater and xylem sap. Precipitation was collected in different heights above and below the Scots pine forest canopy. Soil water content and groundwater levels were measured continuously. Soil samples were collected in 2, 2-20, and 20-40 cm depth to extract soil water using the toluene distillation method. Xylem water was extracted from twigs using a vacuum technique and evapotranspiration was measured by the eddy covariance technique. Additionally, an artificial tracer experiment was carried out using deuterium enriched water in order to learn more about water uptake of trees and transpiration.

The results show that tracer methods are important tools to identify water flow pathways, residence times and groundwater recharge. The outcomes of this study lead to a better understanding of soil-plant-atmosphere interactions and mechanism of groundwater recharge.