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Root uptake and water redistribution in soils: neutron radiography and interpretation

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Water fluxes in soils with plants depend on the complex interactions between plants and soils. Water uptake by roots is a function of both, the root and the soil properties. In case of evenly distributed roots and wet soils, plants have easy access to water and soil conductivity is not a limiting factor. In case of isolated roots and well drained soils, root water uptake requires high gradients in water potential as soil resistance to water flow becomes a limiting factor for plant water uptake.
Objective of this study is to measure water fluxes in soil plant systems and to relate them to root and soil conductivities. We used the imaging technique of neutron radiography, which has high spatial and temporal resolution and high contrast to water. Eight rectangular containers of 15 x 15 x 1.5 cm with a porous plate at the bottom for controlling the water potent were filled with two types of sandy soil. The hydraulic properties of the samples were determined by making time-series radiographs of multi-step outflow experiments. Afterwards, we grew Lupin and Maize plants in these samples at controlled conditions and keeping the water potential at 0 hPa at the bottom of the sample. After 2 weeks, we imposed no flow conditions at the bottom and covered the top of the sample for reducing evaporation. Then we monitored the root uptake every three hours for 10 days. At the end of the experiment, we made a tomography of each sample to obtain the 3D root structures.
From the radiograms we quantified the water content and from the tomograms we segmented the roots structures. From the experimental water content and the measured soil hydraulic properties we calculated the fluxes of water. We observed that the water content decreases first in the upper layers and then the drying front moves uniformly

downwards as the plant uptakes water. The downward water flow results from the high water content in the samples. As water is taken up by the roots, the water potential in the soil rapidly re-equilibrates. Under these conditions, the soil resistance to flow is not limiting. Fluxes of water to the roots are more visible in plants with a single tap root and just a few lateral roots. In this case water uptake per root length is higher and requires higher gradients in water potential. As soil dries close to the roots, soil conductivity decreases and becomes a limiting factor for plant uptake. The described method provides a valuable data basis for understanding the relative importance of gravity, capillarity and root uptake in soil plant systems.