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Imaging of water infiltration in soil-plant-atmosphere systems by neutron radiography

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When precipitation or irrigation is reaching to the soil surface the water flux soon divides into a flux vertically downwards, a flux directly back to the atmosphere, a flux to roots and then indirectly back to the atmosphere, besides other water flow pathways and storage possibilities. We experimentally investigated this crucial area of water distribution by an imaging method with high sensitivity to water and sufficient spatial and temporal resolution to localize water redistribution processes. In a series of laboratory based neutron radiography experiments water infiltration events, subsequent water-uptake by roots and water drainage by gravity were studied. This method allows for two-dimensional transmission images and three-dimensional tomography, both obtained non-invasively and non-destructively. Therefore, experiments can be performed on a time scale of a single infiltration event but also could cover weeks of plant development and water uptake cycles.

The experiments overall included two types of sandy soil and two plant species, that is lupin with a tap root system, and maize with a fibrous root system. We mainly worked with rectangular containers of 15 cm x 15 cm and thickness between 1.3 and 1.5cm, the latter in direction of beam transmission. Some experiments were run with evaporation being possible, some were limited to transpiration. Infiltration was applied to the surface either as a homogeneous, ponding type of water application or via four drip irrigation pipes and a pump. The series cover experiments with relatively dry conditions before infiltration and larger irrigation fluxes, and experiments with moist conditions and smaller irrigation fluxes. Also, the root structure could be identified including first order lateral roots and sometimes even second order laterals. Furthermore, one sample was used to study water redistribution when no roots but artificial water storage material, a commercial soil enhancer, were built in to take up and store water internally.

The results show water content maps and its temporal development. Water balances and root structure could be extracted from the series of images. They show varying relations of water uptake and root structure, soil moisture and soil structures. The results of this method are a good basis for numerical modeling to better understand the distribution of water between atmosphere, soil, plant and groundwater.