In-situ imaging of dynamic processes at the complex root-soil-interface

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Dynamic processes occurring at the soil-root interface are technically challenging to be captured *in situ* but crucially influence soil water, hydrochemical, and biological properties in the rhizosphere, and thus the whole plant and surrounding soil. At the same time, plant roots are well known to modify the properties of the rhizosphere in many ways, thereby, altering themselves conditions for water and solute uptake. We have developed and applied non-invasive methods to map soil and rhizosphere in 2-D and 3-D. This focuses on neutron imaging of water and roots, fluorescence imaging of pH and redox conditions, and combinations of it in joint measurements of the same sample at almost the same time.

Young plants of crop plants such as maize, lupin or chickpea are grown in soil prepared in special containers for the particular imaging task. For dry conditions the root system in the soil can be retrieved well in 2-D or 3-D by neutron imaging. After aqcuiring this fundamental information experimental periods of a few days are started in which water distribution is changing and plant roots' response to environmental factors such as nutrition, chemicals, limited oxygen supply or other stresses can be investigated. In 2-D set-ups the development of oxygen concentration and pH can be mapped with high spatial and temporal resolution. In 3-D X-ray CT measurements can be added to reveal local mechanical impacts of roots on soil. Sometimes tracers are added to be able to also study fluxes from soil through the rhizosphere into the plant roots. A recent development aims for imaging water imbibition and root water uptake in 3-D with unprecedented temporal resolution of less than a minute.

The processes investigated include soil water flow, root water uptake, root growth, root respiration and the effects of root exsudation, e.g. on soil pH. The retrieved data sets constitute time-series of the undisturbed development of these processes resulting in quantitative information of the imaged concentrations. Thus, these imaging data create an excellent basis for high-level numerical modelling of soil hydraulic and biochemical process at the root-soil-interface, which in turn can contribute a more comprehensive interpretation of the processes acting and the development of quantitities that can not be accessed experimentally.