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Imaging biogeochemical gradients in the rhizosphere

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Dynamic processes occurring at the soil-root interface crucially influence soil physical, chemical, and biological properties at local scale around the roots that are technically challenging to capture in situ. Combining 2D optodes and 3D neutron laminography, we developed a new imaging approach capable of simultaneously quantifying H_2O-, O_2-, and pH-distribution around living plant roots while additionally capturing the root system architecture in 3D. The interrelated patterns of root growth and distribution in soil, root respiration, root exudation, and root water uptake can be studied non-destructively at high temporal and spatial resolution.

Neutron computed laminography (NCL), a tomographic approach specially adapted to samples with large lateral extension (here 15 x 15 x 1.5 cm) was applied to visualize the root architecture and soil water content three-dimensionally. Optodes, sensitive to pH and O_2 changes, were attached at the inner-sides of thin boron-less glass-containers where one maize plant was grown in each container. Knowledge about the distance of the roots from the container walls and thus from the optodes, support the interpretation of the optical images.

Neutron laminography made it possible to visualize and quantify the 3D root system architecture in association with the observed H_2O, pH and oxygen patterns. The older part of the root system with higher root length density was associated with fast decrease of water content and rapid change in oxygen concentration. Lateral roots acidified their rhizosphere by a quarter of a pH unit and crown root even induced acidification of up to one pH unit compared to bulk soil. The benefit of neutron laminography is that we can extract the root structure in 3D, identify root age and root types and relate this to spatiotemporal changes in water content distribution, oxygen concentration and pH values.