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Tracking soil structural changes during root growth with sequential X-Ray CT scanning

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Crop productivity is highly dependent on a good supply of water and nutrients. With increasing demand for food and variable water regimes due to climate change, it is important to get a better understanding on the processes involved in water and nutrient uptake by roots. Changes in soil structure affect water and nutrient availabilities for plants. It is known that roots change their environment during growth but little is known on how soil structural properties change as roots penetrate soils. More detailed information on root growth induced changes in the rhizosphere will help us to model water and nutrient uptake by plants.

The objective of this study was to measure directly how soil structure changes in close proximity to the root as a seedling root penetrates through the soil. 3D volumetric images of maize root growth during six hours were obtained using X-ray microtomography at a resolution of 21 μm. Roots were grown in soils of two different compaction levels (50 kPa and 200 kPa uniaxial load) and matric potentials (10 kPa and 100 kPa). Changes in porosity, pore connectivity and root-soil contact were determined from 2D cross sections for each time step. The 2D cross sections were chosen at 4 different positions in the sample, and each section was divided into sections of 64 voxels (1.3 mm^2) to determine changes in porosity and connectivity with distance from the root. Soil movement caused by root growth was quantified from 2D cross sections at different positions along the sample using Particle image velocimetry (PIV).

Changes in soil structure during root growth were observed. Porosity in close proximity to the root decreased whereas root-soil contact increased with time. The PIV showed a radial deformation of the soil. Greatest deformation was found close to the root. Some aggregates fractured during root growth whereas others were pushed into the pore space. These data on the changes in soil structure will help us to predict water and nutrient availability for plants. They are also a useful first step in a better understanding of root growth mechanisms and how they overcome physical constraints imposed by soils.