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A novel platform to quantify crack evolution in soil due to simulated plant water uptake

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Plant water uptake is a major driver of soil structure dynamics. Localized soil drying in the rhizosphere can induce soil shrinkage, leading to the development of cracks. However, the quantification of the spatiotemporal evolution of soil cracks remains challenging. Here we present a novel platform designed to capture the development of cracks around a local drying source representing a plant root based on automated time-lapse imaging. Soil is filled into custom made cells (height/width/depth: 55/50/5 mm) with a transparent front side to monitor crack evolution. To simulate root water uptake, polyethylene glycol (PEG) solution is pumped through semipermeable tubes, which are allocated on the backside of the soil-filled cells. Over the course of one week, crack development is recorded using commercial RGB cameras in two minute intervals at a spatial resolution of < 20 μm in twelve cells at the same time. Image acquisition is completely automated using Arduino® controlled camera dollies that autonomously switch position and take pictures. Furthermore, we developed fully automated image analysis tools to extract a number of parameters describing the evolution of cracks including crack length, crack width, and crack area, as well as measurements for crack branching and connectivity. A first experiment involving three soils with different shrinking behaviors and the simulation of three different root water potentials (i.e. by applying three different PEG concentrations) indicates the potential of the platform: The spatiotemporal evolution of soil cracks can be quantified and results are reproducible. Furthermore, we observed significant influences of the soil and the simulated root water potential on crack patterns.