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Efficient hydraulic properties of root systems

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Understanding the mechanisms of ecosystem root water uptake (RWU) is paramount for parameterizing hydrological models. With the increase in computational power it is possible to calculate RWU explicitly up to the single plant scale using physical models. However, application of these models for increasing our understanding of ecosystem root water uptake is hindered by the deficit in knowledge about the detailed hydraulic parameter distribution within root systems. However, those physical models may help us to identify efficient parameterizations and to describe the influence of these hydraulic parameters on RWU profiles. In this research, we investigated the combined influence of root hydraulic parameters and different root topologies on shaping efficient root water uptake.

First, we use a conceptual model of simple branching structures to understand the influence of branching location and transitions in root hydraulic properties on the RWU patterns in typical sub root structures. Second, we apply a physical model called “aRoot” to test our conclusions on complex root system architectures of single plants. aRoot calculates the distribution of xylem potential within arbitrary root geometries to satisfy a given water demand depending on the available water in the soil. Redistribution of water within the bulk soil is calculated using the Richards equation. We analyzed results using a measure of uptake efficiency, which describes the effort necessary for transpiration.

Simulations with the conceptual model showed that total transpiration in sub root structures is independent of root hydraulic properties over a wide range of hydraulic parameters. On the other hand efficiency of root water uptake depends crucially on distribution hydraulic parameters in line with root topology. At the same time, these parameters shape strongly the distribution of RWU along the roots, and its evolution in time, thus leading to variable individual root water uptake profiles.

Calculating RWU of three dimensional root architectures unveiled that the same effects can be observed at the single plant scale. Total transpiration is almost independent of root hydraulic properties. On the other hand, the arrangement of hydraulic properties significantly influences RWU efficiency. Furthermore the vertical root water uptake profiles are governed by the different root properties. They result from two combined re-distribution patterns over time: One within a rooting branch similar to the results mentioned above, and a second one between the different rooting branches within the root system. This leads to complex vertical uptake profiles, which cannot be predicted from a combination of root abundance and soil moisture, and depend strongly on the individual morphology.