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New theories of root growth modelling

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In dynamic root architecture models, root growth is represented by moving root tips whose line trajectory results in the creation of new root segments. Typically, the direction of root growth is calculated as the vector sum of various direction-affecting components. However, in our simulations this did not reproduce experimental observations of root growth in structured soil. We therefore developed a new approach to predict the root growth direction. In this approach we distinguish between, firstly, driving forces for root growth, i.e. the force exerted by the root which points in the direction of the previous root segment and gravitropism, and, secondly, the soil mechanical resistance to root growth or penetration resistance. The latter can be anisotropic, i.e. depending on the direction of growth, which leads to a difference between the direction of the driving force and the direction of the root tip movement. Anisotropy of penetration resistance can be caused either by microscale differences in soil structure or by macroscale features, including macropores. Anisotropy at the microscale is neglected in our model. To allow for this, we include a normally distributed random deflection angle α to the force which points in the direction of the previous root segment with zero mean and a standard deviation σ. The standard deviation σ is scaled, so that the deflection from the original root tip location does not depend on the spatial resolution of the root system model. Similarly to the water flow equation, the direction of the root tip movement corresponds to the water flux vector while the driving forces are related to the water potential gradient. The analogue of the hydraulic conductivity tensor is the root penetrability tensor. It is determined by the inverse of soil penetration resistance and describes the ease with which a root can penetrate the soil.

By adapting the three dimensional soil and root water uptake model R-SWMS (Javaux et al., 2008) in this way, we were able to simulate root growth and root water uptake in soil with macropores. The model was parametrized using experimental results of studies by Hirth et al. (2005) and Stirzaker et al. (1996). It proved to be capable of reproducing observed root growth responses to structured soil both at the single root and the plant root system scale.

This new approach enables us to investigate how plant roots use macropores to gain access to water and nutrient reservoirs in deeper, highly dense soil layers.

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