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Coupling root architecture and pore network modeling - an attempt towards better understanding root-soil interactions

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Understanding root-soil interactions is of high importance for environmental and agricultural management. Root uptake is an essential component in water and solute transport modeling. The amount of groundwater recharge and solute leaching significantly depends on the demand based plant extraction via its root system.
Plant uptake however not only responds to the potential demand, but in most situations is limited by supply form the soil. The ability of the plant to access water and solutes in the soil is governed mainly by root distribution. Particularly under conditions of heterogeneous distribution of water and solutes in the soil, it is essential to capture the interaction between soil and roots. Root architecture models allow studying plant uptake from soil by describing growth and branching of root axes in the soil.
Currently root architecture models are able to respond dynamically to water and nutrient distribution in the soil by directed growth (tropism), modified branching and enhanced exudation. The porous soil medium as rooting environment in these models is generally described by classical macroscopic water retention and sorption models, average over the pore scale.
In our opinion this simplified description of the root growth medium implies several shortcomings for better understanding root-soil interactions: (i) It is well known that roots grow preferentially in preexisting pores, particularly in more rigid/dry soil. Thus the pore network contributes to the architectural form of the root system; (ii) roots themselves can influence the pore network by creating preferential flow paths (biopores) which are an essential element of structural porosity with strong impact on transport processes; (iii) plant uptake depend on both the spatial location of water/solutes in the pore network as well as the spatial distribution of roots. We therefore consider that for advancing our understanding in root-soil interactions, we need not only to extend our root models, but also improve the description of the rooting environment.
Until now there have been no attempts to couple root architecture and pore network models. In our work we present a first attempt to join both types of models using the root architecture model of Leitner et al., (2010) and a pore network model presented by Raoof et al. (2010). The two main objectives of coupling both models are:
(i) Representing the effect of root induced biopores on flow and transport processes: For this purpose a fixed root architecture created by the root model is superimposed as a secondary root induced pore network to the primary soil network, thus influencing the final pore topology in the network generation.
(ii) Representing the influence of pre-existing pores on root branching: Using a given network of (rigid) pores, the root architecture model allocates its root axes into these preexisting pores as preferential growth paths with thereby shape the final root architecture.
The main objective of our study is to reveal the potential of using a pore scale description of the plant growth medium for an improved representation of interaction processes at the interface of root and soil.

References

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