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Efficient solution techniques for simulation nutrient uptake by plant roots

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Water and nutrient transfer to plant roots is determined by processes occurring from the single root to the entire root system. A mechanistic spatially distributed description of these processes would require a sub mm discretization which is computationally not feasible. In this contribution, we present efficient solution techniques to represent accurate nutrient uptake by plant roots.

The first solution technique describes nutrient transport towards a single root segment using a 1-D radially axisymmetric model (Barber and Cushman 1981). Transport to the entire root system is represented by a network of connected cylindrical models around the roots. This network of cylinders was coupled to a 3-D regular grid that was used to solve the flow and transport equations in the soil at the root system scale (Javaux et al. 2008).
The second technique was a modified time compression approximation (TCA), which can be a simple and reasonably accurate semi-analytical method for predicting cumulative nutrient uptake when the convection flux and diffusion coefficient change over time due to for instance soil drying. The analytical approach presented by Roose et al. (2001) to calculate solute cumulative uptake provides means to analyze cumulative nutrient uptake at a changing diffusive–convective flux over time but with constant convection and diffusion coefficient. This analytical solution was used in TCA framework to predict uptake when convection and diffusion coefficient change over time.

We compared cumulative nutrient uptake by the 1D / 3D coupled model with results obtained by spatially highly resolved 3-D model and the approximate analytical solution of Roose et al. (2001). The good agreement between both model approaches allows the use of the 1D/3D coupling approach to simulate water and nutrient transport at the a root system scale with minimal computational cost and good accuracy. This approach also accounts for the effect of transpiration and soil drying on nutrient uptake.
In our second solution approach we showed the accuracy of the results of the modified time compression approximation as compared to the analytical solution and the highly resolved numerical solution. The good agreement between modified time compression approximation and numerical solution shows that TCA approach yields a sufficient estimate of cumulative nutrient uptake.