Geophysical Research Abstracts
Vol. 16, EGU2014-1881-1, 2014
EGU General Assembly 2014

High resolution modeling of water and nutrient uptake by plant roots: at a scale from single root to root system

Betiglu Abesha, Jan Vanderborght, Mathieu Javaux, Andrea Schnepf, and Harry Vereecken
Agrosphere (IBG–3), Forschungszentrum Jülich GmbH, Jülich, Germany(b.abesha@fz-juelich.de)

Abstract
The uptake of nutrients by plant roots is a multiscale problem. At the small scale, nutrient fluxes towards single roots lead to strong gradients in nutrient concentrations around single roots. At the scale of the root system and soil profile, nutrient fluxes are generated by water fluxes and variations in nutrient uptake due to spatially varying root density, nutrient concentrations and water contents. In this contribution, we present a numerical simulation model that describes the processes at the scale of a single root and the scale of the entire root system simultaneously. Water flow and nutrient transport in the soil are described by the 3–D Richards and advection-dispersion equations, respectively. Water uptake by a root segment is simulated based on the difference between the soil water potential at the soil root interface and in the xylem tissue. The xylem water potential is derived from solving a set of flow equations that describe flow in the root network (Javaux et al., 2008). Nutrient uptake by a segment is simulated as a function of the nutrient concentration at the soil-root interface using a nonlinear Michaelis–Menten equation. An accurate description of the nutrient concentrations gradients around single roots requires a spatial resolution in the sub mm scale and is therefore not feasible for simulations of the entire root system or soil profile. In order to address this problem, a 1–D axisymmetric model (Barber and Cushman, 1981) was used to describe nutrient transport towards a single root segment. The network of connected cylindrical models was coupled to a 3–D regular grid that was used to solve the flow and transport equations at the root system scale. The coupling was done by matching the fluxes across the interfaces of the voxels of the 3–D grid that contain root segments with the fluxes at the outer boundaries of the cylindrical domains and by matching the sink terms in these voxels with uptake by the root segments. To demonstrate the feasibility of this method, we compared cumulative nutrient uptake by the coupled (3D–1D) with results obtained at the single root scale using a high resolution model and the approximate analytical solution of Roose et al., (2001). The good agreement between the fine mesh 3–D and a coupled (3D–1D) model makes this coupling approach capable to simulate a root system scale models without a high computational cost. Furthermore, the coupling allows to account for the effect of water uptake and soil drying on nutrient uptake and to account for spatial variations in root density and nutrient concentrations. These effects cannot be represented by a simple upscaling of single root scale models since they require the description of water and nutrient fluxes within the entire root zone.