1st TERRABITES Symposium
Hamburg, Germany, 9-11 February 2010
TERRABITES-70

Modelling effective root water uptake based on a detailed mechanistic model

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A 3-D water flow model R-SWMS that describes water flow in the soil and the root network was developed. Water flow in the soil, between the soil and the roots, and in the roots is calculated from the gradient in water potential and the hydraulic conductivity of the soil and the roots. Soil water flow is described by the 3-D Richards equation, which is solved numerically using a Galerkin finite element method. To describe flow in the roots, the root system is represented by a 3-D network or conductances, including radial and axial conductances, which leads to a set of linear equations. Since large potential gradients may exist close to the soil-root interface, an analytical solution of the radial flow equation in unsaturated soil was used to describe the water flow towards the linear root elements within the soil voxels. At the root collar, the potential transpiration flux is prescribed as a boundary condition until the water potential reaches a critical negative potential and the flux boundary condition is switched to a water potential boundary condition. The model input parameters are the spatial distribution of soil hydraulic properties, the root conductivities, the architecture or structure of the root network, and the potential transpiration rate. Given these parameters the model simulates how much and where water is taken up in the soil. In Figure 1, the root network, simulated water potentials in the root system, in the soil and local water uptake by the root are exemplarily shown. The model offers the possibility to evaluate the effect of spatially distributed water content, water potential, soil hydraulic properties, root architecture, and root parameters on root water uptake. Neither water stress functions, which describe the relation between water uptake, soil water potential, and potential transpiration rate, nor compensation functions, which account for increased root water uptake from wetter soil layers when part of the root zone is dry, need to be provided as model input but are calculated. Also phenomena such as 'hydraulic lift' are simulated by the model. The model therefore offers an interesting working tool in ecohydrological research. As an example, sensitivity analyses can be performed to evaluate the influence and importance of different model parameters (Javaux et al., 2008). Also the effect of dynamic hydraulic properties of the root system and of signalling of water stress at certain locations in the root system on root water uptake can be investigated with the model. These model simulations may then be used to quantify the effect of plant physiological mechanisms and to derive and parameterize 'macroscale' models of root water uptake that cannot describe water flow at the scale of the single root.