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Modelling of preferential flow in structured soils and along hillslopes

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In structured soils, water and solutes may under certain conditions bypass most of the soil matrix thereby creating local nonequilibrium conditions in pressure heads and solute concentrations between preferential flow paths and the soil matrix pore region. Preferential flow limits the applicability of standard models for flow and transport. A number of approaches have been proposed that mostly try to describe flow and transport separately for the different pore regions. Discrete fracture models are more frequently suggested in hydrogeology and for cracked clay soils. The two-domain approach assumes two interacting porous continua for either mobile-immobile or mobile-mobile pore systems. Such models were derived by rigorous 'upscaling' methods (microstructure models) or by assuming two macroscopic systems. Representation of the effective structural geometry remains a problem when applying these models to field soils. The dual-permeability models differ in the description of flow in the preferential flow domain (i.e. either Richards' equation assuming capillarity or kinematic wave approach for gravity flow) and with respect to the mass transfer formulation (i.e. from pressure head or saturation based first-order type formulations to more complex nonlinear formulations or numerical solutions of the local flow equation).
This contribution summarizes basic models for describing preferential flow in structured soils and arable fields and reviews hillslope models that include preferential flow components. Examples from 1D and 2D simulations of a tracer experiment at a subsurface drained field site demonstrate effects of soil structure parameters and surface boundary conditions on infiltration and larger scale drainage.