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A dual-permeability approach to preferential water flow and solute transport in shrinking soils

Antonio Coppola (1), giovanna dragonetti (2), Alessandro Comegna (1), Horst H. Gerke (3), and Angelo Basile (4)

(1) School of Agricultural, Forestry, Food and Environmental Sciences (SAFE), Hydraulics Division, University of Basilicata, Potenza, Italy. (antonio.coppola@unibas.it), (2) Mediterranean Agronomic Institute, Land and Water Division, IAMB, Bari, Italy. (dragonetti@iamb.it), (3) Institute of Soil Landscape Research, Leibniz-Centre for Agricultural Landscape Research (ZALF), Müncheberg, Germany. (gerke@zalf.de), (4) Institute for Mediterranean Agricultural and Forestry Systems (ISAFoM), National Research Council (CNR), Ercolano (Napoli), Italy.(angelo.basile@cnr.it)

The pore systems in most natural soils is dynamically changing due to alternating swelling and shrinkage processes, which induces changes in pore volume and pore size distribution including deformations in pore geometry. This is a serious difficulty for modeling flow and transport in dual permeability approaches, as it will also require that the geometrical deformation of both the soil matrix and the fracture porous systems be taken into account, as well as the dynamics of soil hydraulic properties in response to the domain deformations.

This study follows up a previous work by the same authors extending the classical rigid (RGD) approach formerly proposed by Gerke and van Genuchten, to account for shrinking effects (SHR) in modeling water flow and solute transport in dual-permeability porous media. In this study we considered three SHR scenarios, assuming that aggregate shrinkage may change either: (i) the hydraulic properties of the two pore domains, (ii) their relative fractions, and (iii) both, hydraulic properties and fractions of the two domains. The objective was to compare simulation results obtained under the RGD and the SHR assumptions to illustrate the impact of matrix volume changes on water storage, water fluxes and solute concentrations during: 1) An infiltration process bringing an initially dry soil to saturation, 2) A drainage process starting from an initially saturated soil. For an infiltration process, the simulated wetting front and the solute concentration propagation velocity, as well as the water fluxes, water and solute exchange rates, for the three SHR scenarios significantly deviated from the RGD. By contrast, relatively similar water content profiles evolved under all scenarios during drying. Overall, compared to the RGD approach, the effect of changing the hydraulic properties and the weight of the two domains according to the shrinkage behavior of the soil aggregates induced a much more rapid response in terms of water fluxes and solute travel times, as well as a larger and deeper water and solute transfer from the fractures to the matrix during wetting processes.