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Linking soil moisture balance and source-responsive preferential flow models for estimating groundwater recharge

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Results are presented of a detailed study into the vadose zone and shallow water table hydrodynamics of a fieldsite in Shropshire, UK. Tensiometry reveals that the loamy sand topsoil wets up via macropore flow and subsequent redistribution of moisture into the soil matrix. However, recharge does not occur until near-positive pressures are achieved at the top of the glaciofluvial outwash material that underlies the topsoil, about 1 m above the water table. Once this occurs, very rapid water table rises follow. This threshold behaviour is attributed to the vertical discontinuity in the macropore system due to seasonal ploughing of the topsoil, and a lower permeability plough/iron pan restricting matrix flow between the topsoil and the lower outwash deposits. Thus, although the wetting process in the topsoil is highly complex, a soil moisture balance model (SMBM) is shown to be skilful in predicting the initiation of preferential flow from the base of the topsoil into the lower outwash horizon.

The rapidity of the response at the water table suggests that Stokes type film flow rather than Richards type capillarity dominated flow is occurring and this conjecture is tested using a range of numerical models. A variation of the source-responsive model proposed by Nimmo (2010) is shown to reproduce the observed water table dynamics well, when linked to a SMBM as the source of recharge from the topsoil. The results reveal new insights into preferential flow processes in cultivated soils. If the conceptual and numerical models can be shown to be transferable to other ploughed soils, it promises to be a very useful and practical approach to accounting for preferential flow in studies of groundwater recharge estimation.

Nimmo, J. R. (2010). Theory for Source-Responsive and Free-Surface Film Modeling of Unsaturated Flow. Vadose Zone Journal, 9, 295-306.