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Modelling macropore flow on the basis of macropore geometry with SWAP

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Transport at the field scale of agricultural chemicals through structured soils to groundwater and surface waters is often strongly governed by flow through macropores. In the Netherlands, the ANIMO nutrient and PEARL pesticide leaching models are used for policy evaluations and policy support at field, regional and national scales. Both models apply the SWAP model to provide necessary data on water balance and flow. In order to improve simulation of water transport through, and nutrient and pesticide leaching from macroporous soils, SWAP was extended with a physically based description of macropore flow at the field scale.

The predominant feature of macropore flow is that precipitation and irrigation water with solutes are routed into macropores at the soil surface, bypassing the reactive unsaturated soil. This water is transported rapidly downwards and distributed over different depths in the soil, down to larger depths or groundwater. The concept adopted in SWAP for macropore flow, is based on a description of the geometry of macropore structure. In this concept, the macropore volume is described on the basis of continuity and persistency and lateral distribution.

Regarding continuity, the macropore volume is partitioned into two domains, i.e. a main bypass domain and an internal catchment domain. The bypass domain consists of a system of continuous, interconnected macropores that penetrate relatively deep into the soil. Rapid drainage to drains can occur from this domain. The internal catchment domain consists of discontinuous macropores ending at different depths. Inflow is captured at the bottom of these macropores and forced to infiltrate at that depth.

The distribution of macropore volume with depth and over both domains is obtained by analytical equations with five basic input parameters. Dynamic macropore volume is determined from moisture content and the shrinkage characteristics of the soil. Lateral distribution is described with an effective diameter of the soil matrix polygons.

Macropore inflow at the soil surface comprises direct precipitation into macropores and inflow of precipitation excess by overland flow. When matrix infiltration capacity is exceeded, the precipitation excess will flow into the macropores. Water flowing into the macropores is instantaneously added to the storage at the bottom of the macropores and infiltrates into the matrix over the depth of water storage. Exchange between the macropores and the soil matrix is described by Darcy-flow (wet and saturated soil) or Philip's sorptivity (unsaturated soil). Rapid drainage to drains can be generated from the main domain.

The extended SWAP model was calibrated and validated against experimental data on drain discharge and groundwater level from a tile-drained field-site on clay soil, using a Bayesian statistics based method. The calibrated model combined with the PEARL model was applied to predict measured peak concentrations of two pesticides. The model was well able to describe drain discharge, groundwater levels and peak concentrations of both pesticides. The calibrated SWAP-PEARL model was applied at the national scale to asses the importance of preferential flow as a pathway of pesticide losses in tile-drained clay soils in The Netherlands.