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Modelling rapid flow response of a tile drained hillslope with explicit representation of preferential flow paths and consideration of equifinal model structures

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Rapid water flow along spatially connected - often biologically mediated - flow paths of minimum flow resistance is widely acknowledged to play a key role in runoff generation at the hillslope and small catchment scales but also in the transport of solutes like agro chemicals and nutrients in cohesive soils. Especially at tile drained fields site connected vertical flow structures such as worm burrows, roots or shrinkage cracks act as short cuts allowing water flow to bypass the soil matrix.

In the present study we propose a spatially explicit approach to represent worm burrows as connected structures of high conductivity and low retention capacity in a 2D physically model. With this approach tile drain discharge and preferential flow patterns in soil observed during the irrigation of a tile drained hillslope in the Weiherbach catchment were modelled. The model parameters derived from measurements and are considered to be uncertain. Given this uncertainty of key factors that organise flow and transport at tile drained sites the main objectives of the present studies are to shed light on the following three questions:

1. Does a simplified approach that explicitly represents worm burrows as continuous flow paths of small flow resistance and low retention properties in a 2D physically model allow successful reproduction of event flow response at a tile drained field site in the Weiherbach catchment?

2. Does the above described uncertainty in key factors cause equifinality i.e. are there several model structural setups that reproduce event flow response in an acceptable manner without compromising our physical understanding of the system?

3. If so, what are the key factors that have to be known at high accuracy to reduce the equifinality of model structures?

The issue of equifinality is usually discussed in catchment modelling to indicate that often a large set of conceptual model parameter sets allows acceptable reproduction of the behaviour of the system of interest - in many cases catchment stream flow response. Beven and Binley (1992) suggest that these model structures should be considered to be equally likely to account for predictive uncertainty. In this study we show that the above outline approach allows successful prediction of the tile drain discharge and preferential flow patterns in soil observed during the irrigation of a tile drained hillslope in the Weiherbach catchment flow event. Strikingly we a found a considerable equifinality in the model structural setup, when key parameters such as the area density of worm burrows, their hydraulic conductivity and the conductivity of the tile drains were varied within the ranges of either our measurements or measurements reported in the literature. Thirteen different model setups yielded a normalised time-shifted Nash-Sutcliffe of more than 0.9, which means that more than 90% of the flow variability is explained by the model. Also the flow volumes were in good accordance and timing errors were less or equal than 20 min (which corresponds to two simulation output time steps). It is elaborated that this uncertainty/equifinality could be reduced when more precise data on initial states of the subsurface and on the drainage area of a single drainage tube could be made available. However, such data are currently most difficult to assess even at very well investigated site as the one that is dealt with here. We thus suggest non uniqueness of process based model

structures seems thus to be an important factor causing predictive uncertainty at many sites where preferential flow dominates systems response.

References

Beven, K.J. and Binley, A.M., 1992. The future of distributed models: model calibration and uncertainty prediction, Hydrological Processes, 6, p.279-298.