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Initial estimation of field-scale macropore parameters for use in dual-permeability models

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Macropore flow in near-surface soils can increase contamination risk of underlying water resources by agrochemicals. Macropore flow is commonly simulated using dual-permeability models (DPMs) involving separate equations for flow in the soil matrix and the macropores, which then are coupled using a lateral mass transfer equation. A large number of parameters and difficulty of measuring them independently under field conditions make routine application of DPMs a challenge. An additional difficulty is that soil profiles commonly show very heterogeneous distributions of macropores versus depth. A methodology is proposed to use disk infiltrometer data to obtain estimates of the two main macropore flow parameters: the relative macroporosity (w_f) and the matrix domain characteristic length, generally associated with soil aggregates (d_{ag}). Disk infiltrometry is used to obtain w_f estimates assuming the presence of cylindrical macropores. We expanded the approach for other macropore-matrix geometries (e.g., rectangular slabs) by invoking a transformation factor (ζ). Estimates of ζ were obtained using pore-scale modeling by comparing non-cylindrical macropores' values against those having cylindrical shapes. Values of ζ accounted for differences in macropore/matrix configurations and water flow rates. Remarkably, values of ζ were found to be constant (equal to 1.5) for different macropore/matrix configurations.

The proposed methodology can be applied to different cross-sections in a soil profile, which would account for natural variations in w_f versus depth. Because w_f and d_{ag} are geometrically related, both parameters could be obtained simultaneously. The approach was improved by automated calibration using HYDRUS 2D/3D simulations in conjunction with disk infiltrometer data at zero pressure head. Difficulties in the automated calibration were resolved using a meta-model for HYDRUS 2D/3D as generated in R script. The meta-model accounted for vertical heterogeneity in the macropore number using a general function with only four parameters: the value of w_f at the soil surface (w_{fs}), the effective macropore radius, the maximum depth of macropores, and the shape parameter of the w_f curve. The meta-model computed variations in w_f and d_{ag} versus depth, thereby reducing the number of HYDRUS 2D/3D parameters for calibration. We show how the meta-model parameters can be obtained directly from infiltrometer data by illustrating an example for field conditions. A complete parametrization of the HYDRUS 2D/3D matrix and macropore parameters resulted from the data, and previous studies, as updated by automated calibration. Only w_{fs} needed calibration, leading to a value about 3.5 times higher than its initial measurement (the Nash-Sutcliffe coefficient was 0.88). We could further relate several macropore parameters to w_{fs} during calibration using physical or mathematical relationships. A good match can be obtained by either increasing w_{fs} or the saturated hydraulic conductivity of the macropore domain. Future improvements may be possible by including additional information in the objective function, such as changes in storage water. Such changes could be estimated using non-destructive geophysical methodologies, such as ground-penetrating radar. Our study leading to initial point estimates of w_f and d_{ag} should improve regional risk assessment studies where data for calibration are scarce and/or detailed plot studies are necessary to estimate macropore flow parameters.

Time Block Preference

Time Block B (14:00-17:00 CET)

References

- (1) Urbina, C.F., van Dam, J., Hendriks, R., van den Berg, F., Gooren, H. and Ritsema, C. (2019), Water Flow in Soils with Heterogeneous Macropore Geometries. *Vadose Zone Journal*, 18: 1-17 190015. <https://doi.org/10.2136/vzj2019.02.0015>
- (2) Urbina, C.F., van Dam, J., van den Berg, F., Ritsema, C.J., Tang, D.W.S. Determination of the relative macroporosity and the effective aggregate width for different macropore geometries with disk infiltrometers. *Vadose Zone J.* 2020; 19:e20048. <https://doi.org/10.1002/vzj2.20048>
- (3) Urbina, C.F., van Dam, J., Gooren, H., Tang, D.W.S. and Ritsema, C. (2021), Estimating macropore parameters for HYDRUS using a meta-model. *European Journal of Soil Science*. Under Peer Review.

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