Inverse modelling of water flow and root water uptake in large lysimeters

Sascha C. Iden¹*, Henrike Schelle¹, Johann Fank² and Wolfgang Durner¹

¹ Institut für Geoökologie, Technische Universität Braunschweig, Germany
² RESOURCES - Water Resources Management, Joanneum Research, Graz, Austria
* Corresponding Author: s.iden@tu-braunschweig.de, Phone 0531 391 5602

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The unsaturated zone controls hydrological processes and water budget components like infiltration, the generation of surface runoff, groundwater recharge, and evapotranspiration. It is therefore crucial to assess the hydrological behaviour of soils to predict both the short-term reaction and long-term behaviour of watersheds. It is also widely accepted that the correct quantification of water and matter fluxes and heat transfer in soils relies on the accurate identification of soil hydraulic properties. Because of the intrinsic heterogeneities of soils, the hydraulic properties at scales larger than the representative elementary volume must be treated as effective properties. One way to derive such effective properties is their estimation from field observations under atmospheric boundary conditions at the system of interest by inverse modelling. Unfortunately, incomplete or erroneous information about boundary fluxes (precipitation, actual evapotranspiration, deep percolation) tends to make the resulting inverse problems ill-posed. Weighable precision lysimeters can overcome this limitation and, if equipped with additional sensors for water content and matric potential measurements, are powerful test systems to determine effective hydraulic properties. In addition, they are an indispensable tool to test our model concepts about hydraulic processes in the vadose zone and to explore possible needs to improve our process understanding, model formulations and measurement campaigns.

The aim of this work was to identify simultaneously effective soil hydraulic functions and root uptake parameters by inverse simulation of soil water flow in monolithic lysimeters under atmospheric boundary conditions using the Richards equation. The main topics treated are the existence of effective soil hydraulic functions, the magnitude of their uncertainties, and the propagation of these uncertainties into uncertainties of model predictions. To check whether it is possible to estimate simultaneously soil hydraulic properties and root water uptake parameters by inverse modelling, we first analysed synthetic data sets for different scenarios and instrumentation campaigns using atmospheric boundary conditions as measured at the lysimeter station in Wagna, Austria. We used classic models of the soil hydraulic functions like the van Genuchten Mualem model and highly flexible free-form functions to test the validity of the Richards equation as process description at the lysimeter scale. The information content of the synthetic data was varied by changing the number of data types included in the objective function and the magnitude of the measurement error. Then, we determined effective soil hydraulic properties of the lysimeter monoliths. This was based on long-term measurements of water flow and soil water state variables in Wagna. The results show that the simultaneous estimation of soil hydraulic properties and root-distribution parameters works very well for homogeneous profiles. The same holds for soil profiles consisting of two layers if soil hydraulic parameters are estimated for both layers. Finally, the identified properties were used for predicting the system behaviour under different boundary conditions and the results were compared to measurements which were not used for model calibration.