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Evaporation experiments for the determination of hydraulic properties of peat and other organic soils: An evaluation of methods based on a large dataset

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Soil hydraulic properties control water flow in the unsaturated zone and thus time-variable fluxes like evapotranspiration, groundwater recharge, surface runoff and interflow. Since peatland ecosystems have a very specific dependency on moisture conditions, several other processes like the carbon sequestration and release, greenhouse gas emissions, nutrient dynamics and vegetation development are tightly connected to the hydraulic properties of the peat layer. Hydraulic properties are frequently obtained in laboratory studies by evaporation experiments. The measurement principle is based on the simultaneous determination of sample mass and pressure heads at different depths. Different methods exist to infer soil hydraulic properties from evaporation experiments. Commonly proposed is the 'direct method' (or simplified evaporation method) by which soil hydraulic properties are calculated analytically with algebraic equations. A technically more complex and computationally more expensive alternative is given by inverse parameter optimization ('inverse method'). The advantage is that derived soil hydraulic parameters are not biased due to simplifying assumptions of the 'direct method'. Although soil hydraulic properties are frequently estimated by the 'direct method', only very few studies have focused on the question how accurate derived parameters can reproduce laboratory measurements. This can be achieved by modeling the dynamic and nonlinear water flow with a processed based numerical forward model. Here, we apply the 'direct method' and 'inverse method' to an unprecedentedly large dataset of evaporation experiments on 443 organic soil samples. The derived soil hydraulic parameters are used in HYDRUS-1D simulations of the evaporation experiments and their performance in reproducing measured states and fluxes is compared. As an additional analysis, we test how water contents at the permanent wilting point can aid stabilizing parameter estimation by adding information on water retention in the dry range. For all methods, soil hydraulic properties were determined with the frequently applied soil hydraulic functions of van Genuchten-Mualem and the recently proposed functions of Peters-Durner-Iden.

The results show that parameters derived with the 'direct method' provided accurate description of the water retention characteristic. However, when these parameters were used for HYDRUS-1D simulations, the measured pressure heads over the complete pressure head range of the evaporation experiments could frequently not be well reproduced. Parameters derived with the 'direct method' should thus always be evaluated with HYDRUS-1D simulations before further use. Parameters derived by the 'inverse method' provided a considerably better performance in the HYDRUS-1D simulations if the complete pressure head range of the evaporation experiments is considered but a weaker performance when focusing only on wet conditions (pressure heads > -100 cm). As expected, combining soil moisture measurements at permanent wilting point with the 'inverse method' improved the prediction of the soil moisture at the permanent wilting point. Thus, considering measurements at the permanent wilting point in the 'inverse method' is strongly recommended when the purpose of the application includes very dry conditions. The hydraulic functions of Peters-Durner-Iden performed better than the ones of van Genuchten-Mualem.