Geophysical Research Abstracts, Vol. 9, 07969, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-07969

Soil hydraulic characterization from evaporation and unit hydraulic gradient experiments

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Simulation of water and solute fluxes in unsaturated soil requires knowledge of the soil hydraulic properties, i.e., the relationships between water pressure head, h, volumetric water content, θ, and hydraulic conductivity, K. The reliability of the simulation model predictions in many agricultural and environmental fields, e.g. irrigation scheduling or leaching of pesticides and fertilizers, is strongly dependent on the accuracy of soil hydraulic characterization.

Unfortunately, none of the numerous laboratory methods proposed to determine the soil water retention curve, $\theta(h)$, and, particularly, the soil hydraulic conductivity function, $K(h)$, is free from disadvantages. Steady-state methods are often impractical given that long time is needed thus limiting measurements to few $\theta(h)$ or $K(h)$ pairs. On the other hand, transient methods are generally applicable to limited pressure head intervals and require more severe hypotheses in both initial and boundary conditions. Notwithstanding these warnings, soil hydraulic characterization is usually performed by a selection of various laboratory methods that often are applied to separate soil samples. The combination of different processes (infiltration or drainage), measurement methods (steady-state or transient) and sample sizes is likely to result in unreliable predictions.

A very effective and rapid transient laboratory method for simultaneous determination of both $\theta(h)$ and $K(h)$ relationships on the same sample is the evaporation method, firstly introduced about 40 years ago by Wind (1968). Besides being widely applied, the evaporation method may result in unreliable hydraulic conductivity estimates at h values near to zero. Near saturation, the very small hydraulic gradients may be actually very difficult to detect and the measurements affected by random experimental errors.

The unit hydraulic gradient (UHG) method allows measurement of near saturated hydraulic conductivity under highly controlled steady-state conditions (Bagarello et al., 2007). The UHG method is conceptually simple and requires very limited equipment and calculations. However, its application is limited to very limited pressure head range (0$<h<$-20 cm) thus making it impractical despite being coupled with other K measurements performed at lower pressure head values.

In order to obtain more reliable estimations of $K(h)$ at or near saturation, the evaporation method was coupled with the UGH method. Undisturbed soil cores (8.5 cm in diameter, 10 cm in height) were collected in the upper layer of three differently textured soils. Starting from saturation, hydraulic conductivity was measured by the UHG method for h values ranging from 0 to –20 cm. Then, the soil cores were allowed to dry in a temperature-controlled room while continuously monitoring total water content and pressure head at four depths. Coupled $h-\theta$ and $\theta-K$ values were determined by the Wind iterative procedure (Tamari et al, 1993; Wendroth et al., 1993).

Results from evaporation method confirmed that pressure head measurement errors may severely affect $K(h)$ determination for $h<$-100 cm. When data from the initial stage of the evaporation experiment were not considered, highly repeatable soil hydraulic functions were obtained for the sandy and loamy soils. In the silty loam soil, differences in $\theta(h)$ and $K(h)$ relationships determined by evaporation method were attributed to differences in bulk density. With only one exception, the result from evaporation were in close agreement with the UGH method. The Mualem-van Genuchten model fitted well the $h-\theta$ and $\theta-K$ values for all the investigated soil cores. Overall, the results showed that integration of two methods allows to sensibly improve the soil hydraulic characterization with a minimum increase in experimental setup.