Comparison of soil moisture retention characteristics obtained by the extended evaporation method and the pressure plate/sand box apparatus

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Introduction

The water retention curve (WRC) characterizes the capacity of soil to hold water at specified soil matric potentials. For many years, the sand-box-pressure plate apparatus are widely accepted as a reference laboratory procedure. To overcome shortcomings of the pressure plate, the evaporation method was introduced, besides others. The method is not dependent on hydrostatic equilibrium conditions, thus allowing much quicker measurements, and yields the WRC in very high resolution. The method furthermore enables to quantify the unsaturated hydraulic conductivity function. We investigated a set of 25 fine-textured soils with both methods. The samples were packed from aggregated, dried and sieved material. Eight (-5, -10, -33, -100, -400, -700, -1000 and -1500 kPa) water retention data points were obtained from sand-box-pressure plate apparatus. Evaporation measurements were performed with the commercial apparatus HYPROP® by UMS GmbH, Munich.

Material and Methods

Sand box/Pressure plate: A dataset, containing 135 samples, was gathered from different parts of Turkey. One hundred and thirty five disturbed and undisturbed (100 cm²) soil samples were collected from the surface soil (0-30 cm). Two undisturbed samples were taken from each location by using a dedicated soil sample ring kit (Eijkelkamp Agrisearch Equipment, Giesbeek, The Netherlands). Soil was sampled just after the first rains following the long dry period, at the beginning of the wet season. The water retention of the samples was measured at -5, -10, -33, -100, -400, -700, -1000, -1500 kPa using sand box apparatus (Eijkelkamp Agrisearch Equipment, Giesbeek, The Netherlands) and pressure plate apparatus (Soilmoisture Equipment, Santa Barbara CA, USA).

Evaporation Method: Disturbed soil samples were packed in stainless-steel cylinders (8 cm in diameter and 5 cm in height) to bulk densities corresponding to the field. Two tensiometers were installed in two depths (x1 and x2). The samples were saturated under vacuum, closed on the bottom and placed on a scale. The upper side of the samples was open to atmosphere so the soil moisture could evaporate. With the soil water tensions (kPa) the average matric potential and the hydraulic gradient was calculated. The mass difference, measured by the scale, was used to calculate the volumetric water content and the water’s flow rate. Tensions and sample mass were recorded at selected time intervals. A measuring campaign lasted until the tensiometers ran dry. Finally, the remaining moisture content was determined by oven drying the sample at 105°C for 24 hours. With these values the retention curve and the unsaturated conductivity was calculated according to Peters and Durner (2008a).

Results and Discussion

Evaporation method example results

The effective water retention of the packed soils in the wet range is dominated by the structural pores between the aggregates. With the pressure-head range extension, the HYPROP method yields data up to pF 3.7. At this point, the clay soil has still its textural pores filled. The figures below illustrates in two typical examples the hydraulic data of a clay soil (44#, left) and a loamy sand soil (#56, right). Figures show WRC points (ϕ,F), and HYPROP conductivity points (ϕ,F), together with curve fits, using the bimodal model of Durner/van Genuchten in combination with the Peters-Durner film-flow model for conductivity (Peters and Durner, 2008b). ϕ is defined as log10 of the suction in cm.

Method comparison: Individual examples

We found significant differences between the methods, which are illustrated here exemplarily for a clay (left, soil #44) and a loamy sand (right, soil #56) sample.

- At and near saturation, water content in the packed HYPROP samples was significantly higher. This is probably caused by the different saturation procedure (capillary for traditional methods, under vacuum for HYPROP samples).
- In the intermediate range (ϕ 2 to 3.5), water retention data from the traditional method and the HYPROP data lie in the same range. However, the retention data from traditional methods have a smaller slope and consequently the data from the two methods cross.
- In the moderately dry range, pressure plate data show higher water contents than the HYPROP measurements. This hints at a missing equilibration and confirms results, as e.g. obtained by Schelle et al. (2013).

Method comparison for 25 clayey soils

The findings found for individual soils are statistically confirmed by the larger dataset. This is illustrated by showing the results for the WRC measurements. The small symbols shows the set of measurements obtained with the HYPROP method for 25 clay or clay loam soil samples, and the large multicolored symbols show the corresponding sand box and pressure plate results for the same soils.

- At the air entry point, pressure plate samples had significantly higher water content than HYPROP samples. This is probably caused by the different saturation procedure (capillary for traditional methods, under vacuum for HYPROP samples).
- In the intermediate range (ϕ 2 to 3.5), water retention data from the traditional method and the HYPROP data lie in the same range. However, the retention data from traditional methods have a smaller slope and consequently the data from the two methods cross.
- In the moderately dry range, pressure plate data show higher water contents than the HYPROP measurements. This hints at a missing equilibration and confirms results, as e.g. obtained by Schelle et al. (2013).

Conclusion

We found differences in the sand box pressure plate method and the evaporation method. The former method lead to immediate drainage of water, whereas in HYPROP water started to drain only after reaching an air-entry point of ~ pF 1.3. Accordingly, HYPROP gave higher water contents until pF 2, compared to the sand box/pressure plate apparatus, but from this point on both curves begin to close and around the field capacity (pF 2.5) they overlap. Both methods show that the textural pore system starts to drain much later, around pF 3.5. We hypothesize that the reason for the different drainage behavior of the interaggregate pore system lies in the saturation procedure and in missing equilibrium for the pressure plate data.

References