Soil Hydraulic Properties Determined in Evaporation Experiments With Polymer Tensiometers

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Introduction and objective

The evaporation method applied to soil columns is a practical way to determine soil hydraulic properties (Wind, 1968; Schindler, 1980; Wendroth et al., 1993). One of the limitations of the method refers to the measuring range of tensiometers. Conventional tensiometers measure in the range of pressure heads limited between 0 to -9 m. A novel type of tensiometer (polymer tensiometer - Van der Ploeg et al., 2008) is now available and allows measuring soil water tension for pressure heads as low as -150 m or -15 atm. The use of polymer tensiometers in the experimental setup of an evaporation experiment allows the simultaneous measurement of soil hydraulic properties over the entire range of water contents of interest for ecological and agronomical studies. We apply this method for determining unsaturated hydraulic properties of several Brazilian soils; on this poster we show results for one of these soils.

Materials and Methods

Soil material from the surface layer of a Red-Yellow oxisol (30% clay content) was collected at an experimental site located in the municipality of Piracicaba, Brazil, 22° 42' S, 47° 38' W, air dried and sieved through a 2 mm mesh. A PVC ring (0.07 m high; 0.151 m inner diameter; surface area $A = 1.79 \cdot 10^{-2}$ m^2) was filled with the air dry and sieved soil material and slowly saturated with water from bottom to top by imbibition from a shallow layer of tap water. After that, the bottom was sealed with water resistant tape and some soil material close to openings in the ring at 2.3, 4.9 and 7.6 cm from the sample surface was removed to allow horizontal insertion of polymer tensiometer cups (Fig.1).

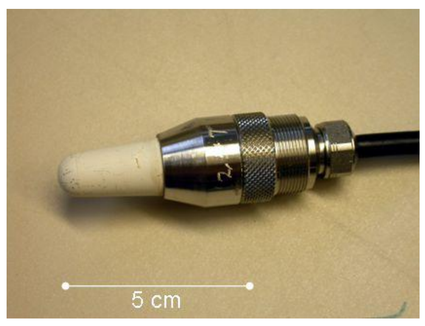


Fig. 1 - Polymer tensiometer cup and polymer chamber. The black cable connects to the datalogger.

The ring with soil material and polymer tensiometers was placed on a precision balance [capacity 8.2 kg, resolution 10^{-4} kg] and evaporation was allowed to start from the top surface (Fig. 2). Pressure heads at the three depths and total mass were automatically recorded every 10 minutes. The measurements continued for some weeks, until the upper tensiometer reached its suction limit of around -150 m. Six (2x3) replicates were performed.

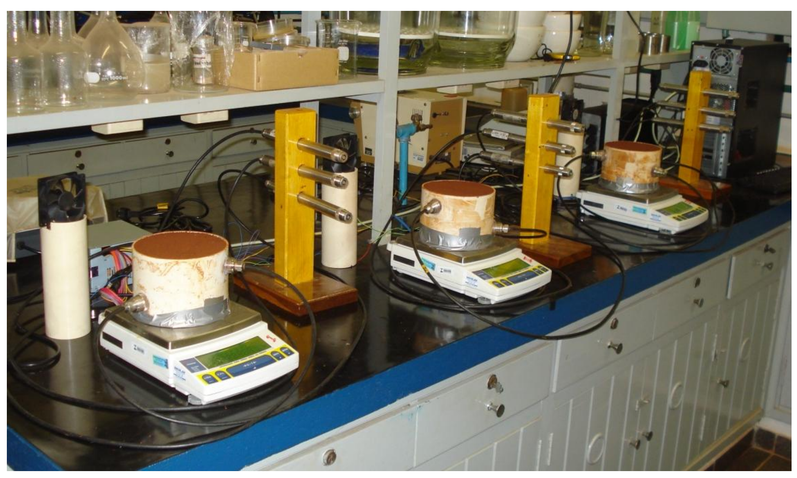


Fig. 2 - View of the evaporation experiment: 3 balances loaded with the rings containing soil and 3 polymer tensiometers each.

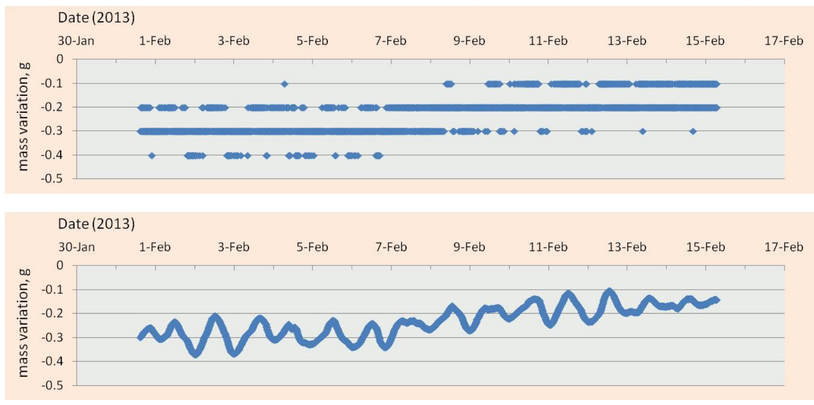
Results and discussion

Registered mass values were submitted to data smoothing using the Holt (1957) method: a new value y'_k is calculated as a function of the previous value y_{k-1} according to:

$$y'_k = a y_k + (1-a)(y'_{k-1} + t_{k-1}) \qquad \text{with} \quad t_k = b(y'_k - y'_{k-1}) + (1-b)t_{k-1}$$

a and b being the level and tendency smoothing constants, respectively. We used a = 0.03 and b = 0.1 based on a visual evaluation of resulting values. See Fig. 3 for an example of Holt smoothing.

Fig. 3 – Example of data smoothing using the Holt method: experimental mass variation before (top) and after (bottom) Holt smoothing.



Mass values together with pressure heads were used to determine the Van Genuchten (1980) retention parameters by minimizing the sum of squared errors of prediction (Fig. 4)

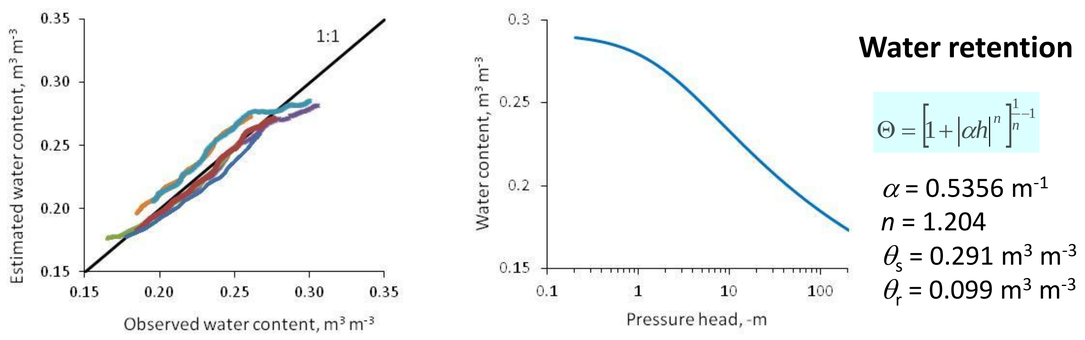


Fig. 4 - Observed and estimated water contents in the 6 replicates (left) and resulting water retention curve with Van Genuchten parameters (right).

Water flux densities between tensiometer depths in the samples were calculated from water content variations, and transformed in hydraulic conductivity using tensiometer readings. Fixing the n-parameter value obtained from the water retention fitting, the hydraulic conductivity curve was obtained fitting the Van Genuchten (1980) K parameters (K_s and λ) minimizing the sum of squared errors of prediction of K (Fig. 5).

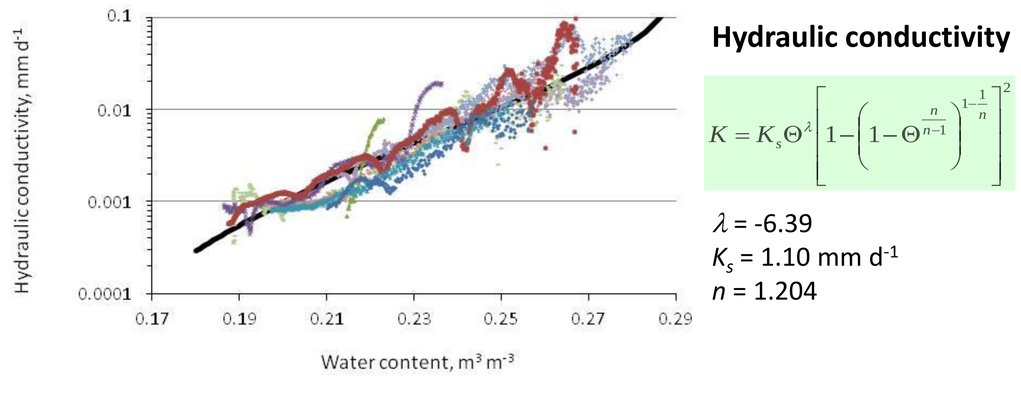


Fig. 5 - Observed (colored dots) and fitted (black line) hydraulic conductivity as a function of water content, together with Van Genuchten parameters (right), obtained in 6 rings and 2 depth intervals per ring.

Conclusions and Outlook

The evaporation method combined with polymer tensiometers allowed simultaneously determining water retention and unsaturated hydraulic conductivity over the pressure head range between -1 and -100 m. Experiments are ongoing. The data processing method is currently labor intensive and a software is being developed to automate the procedure.

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