Technische Universität Braunschweig

Institute of Geoecology
Soil Science and Soil Physics

Simplified evaporation method for determining soil hydraulic properties: a reinvestigation of linearization errors

Benedikt Scharnagl, Sascha C. Iden, and Wolfgang Durner

Technische Universität Braunschweig | Institute of Geoecology
38106 Braunschweig | Germany
benedikt.scharnagl@tu-braunschweig.de

Introduction

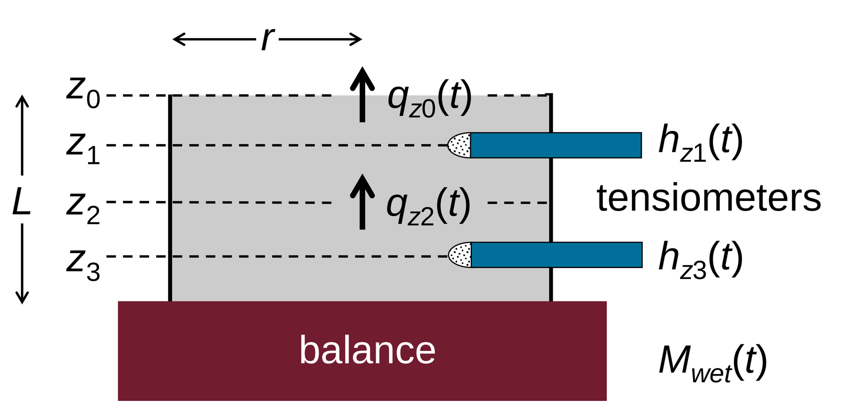
- In the simplified evaporation method of Schindler (1980, Arch. Acker- u. Pflanzenbau u. Bodenkd., 24:1-7), the soil hydraulic properties are derived as:

$$\theta(t) = \frac{M_{wet}(t) - M_{dry}}{\rho \pi r^2 L}$$

$$K(t) = \frac{q_{z2}(t)}{\nabla H_{z2}(t)}$$

$$q_{z2}(t) \approx \frac{q_{z0}(t)}{2} = -\frac{L}{2}\frac{\Delta\theta(t)}{\Delta t}$$

$$\nabla H_{z2}(t) \approx \frac{h_{z3}(t) - h_{z1}(t)}{z_3 - z_1} + 1$$



- Peters and Durner (2008, J. Hydrol., 356:147-162) evaluated this method using a process model that considers liquid water flow in capillaries only and found that it gives reliable results.
- In this study, we reinvestigate the simplified evaporation method using a more realistic process description that includes liquid water flow in films and water vapor flow. We treat the following questions:
  1. Are the conclusions of Peters and Durner (2008) still valid when film and vapor flow is taken into account?
  2. Does the kind of averaging of pressure heads affect the accuracy of the method?
  3. Is the accuracy of the method dependent on the flow rate and length scale of the sample?

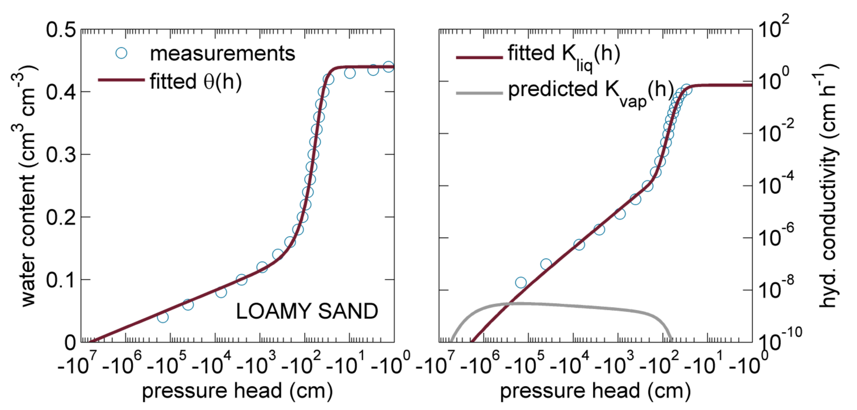
Methods

- We simulated evaporation experiments using an extended form of the Richards equation that includes isothermal vapor flow.
- Synthetic data from simulated evaporation experiments were evaluated with the simplified evaporation method. For calculating the mean pressure head, we used two different approaches:

arithmetic mean: $\bar{h}(t) = \frac{h_{z3}(t) - h_{z1}(t)}{2}$

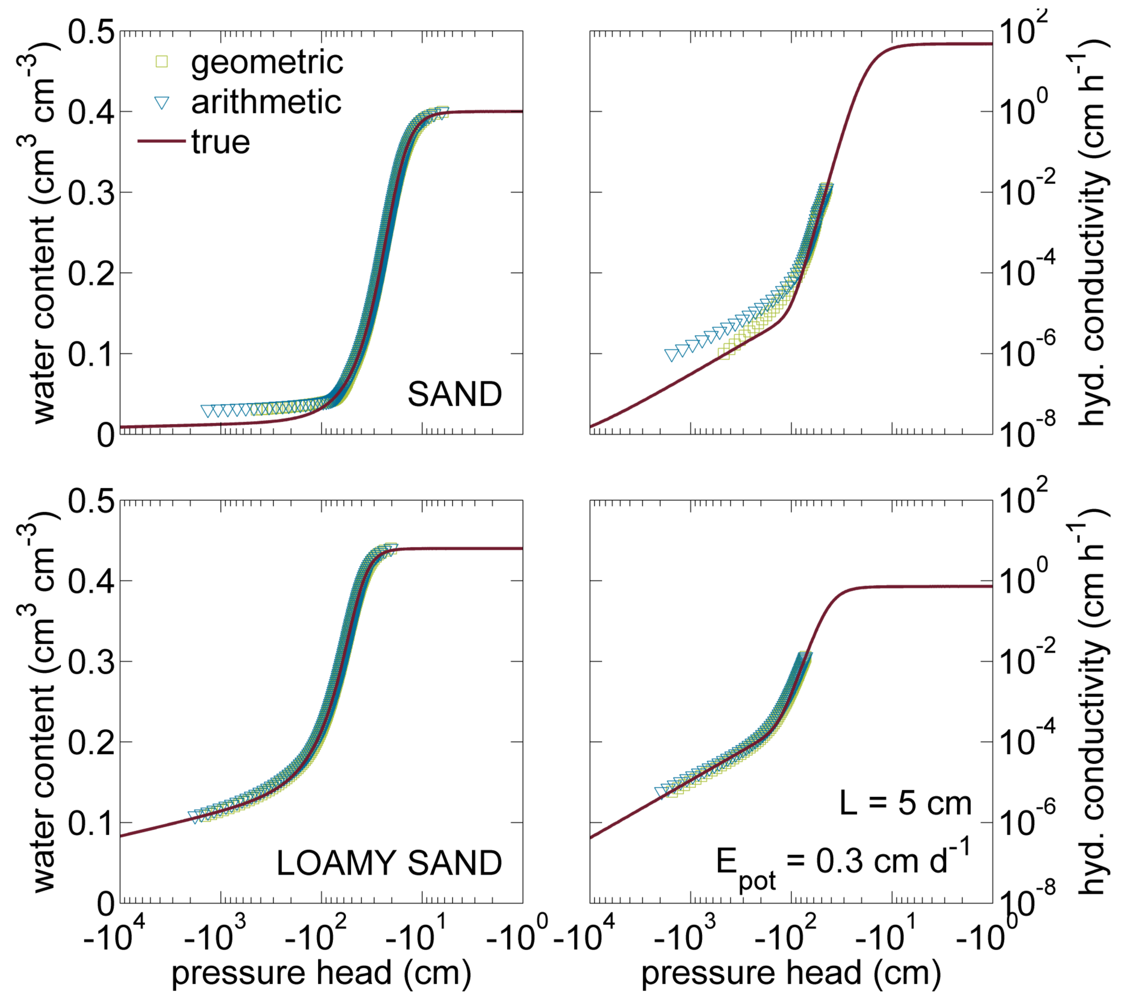
geometric mean: $\bar{h}(t) = \sqrt[2]{h_{z1}(t) h_{z3}(t)}$

- Soil hydraulic properties of a loamy sand (shown below) and a sand were derived from data reported in the literature and parameterized using the model of Lebeau and Konrad (2010, Water Resour. Res., 46:W12554), which includes a film flow component in the hydraulic conductivity function.



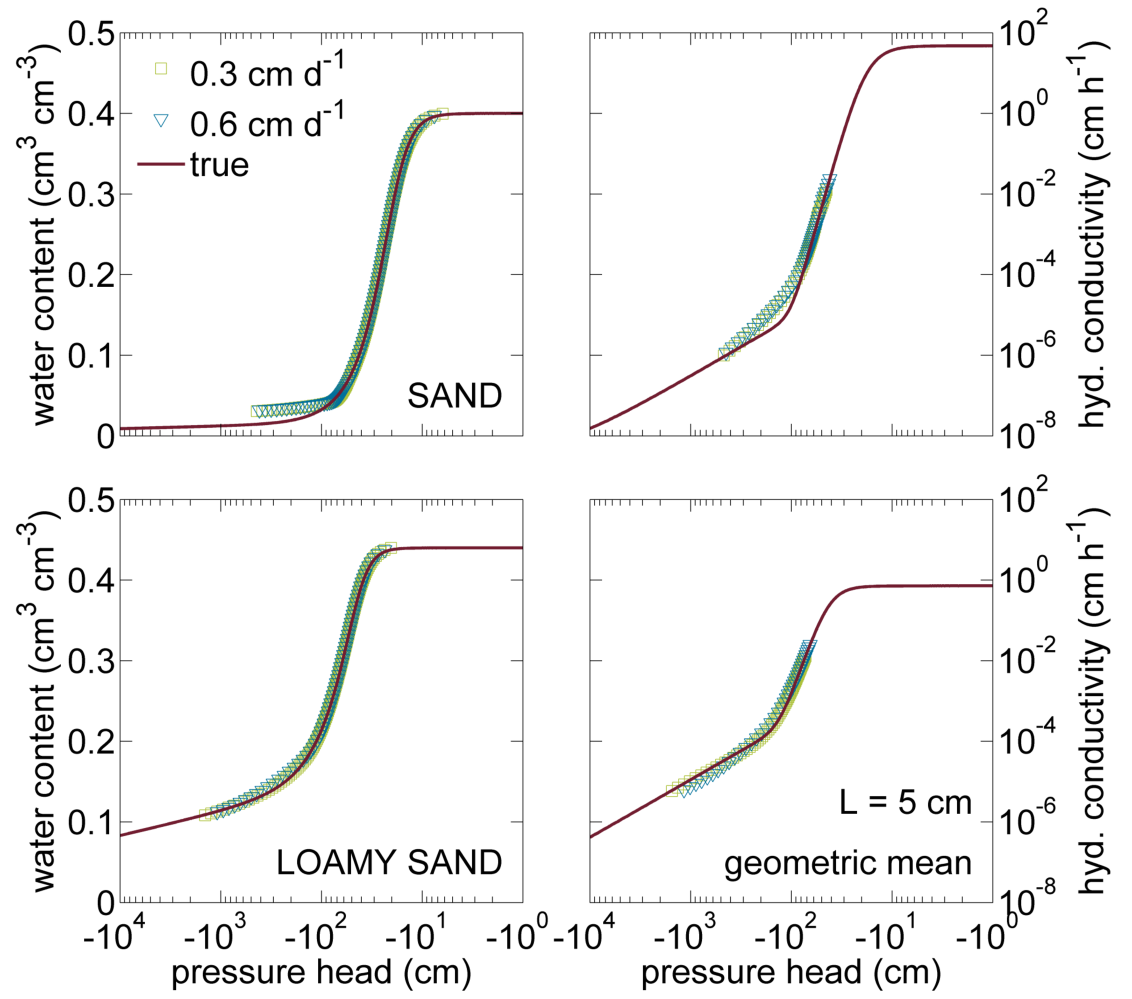
Results 1: Arithmetic vs. geometric mean

For medium-textured soils, both the arithmetic and the geometric mean give almost identical results. For coarse-textured soils, the geometric mean gives results that are closer to the true hydraulic properties.



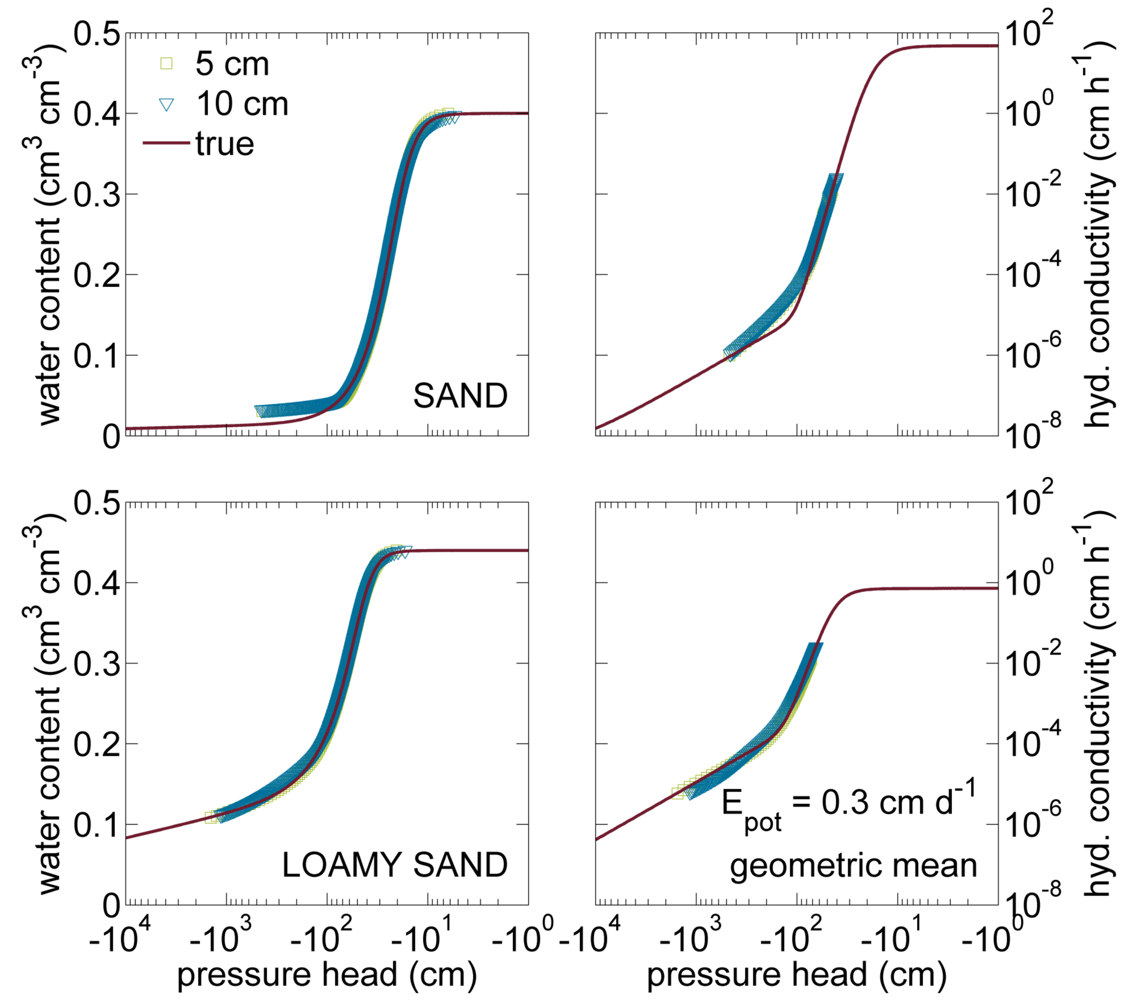
Results 2: Flow rate dependency

In general, deviations from the true hydraulic properties increase with increasing flow rate (potential evaporation rate). This effect is more pronounced for medium-textured soils.



Results 3: Length scale dependency

The accuracy of the simplified evaporation method decreases with increasing sample length. Again, this effect is more pronounced for medium-textured soils.



Conclusions

- The simplified evaporation method gives quite accurate results for medium-textured soils. Deviations from the true hydraulic properties are more pronounced for coarse-textured soils, especially in the medium to dry range.
- The use of the geometric mean for calculating the mean pressure head is preferable to the arithmetic mean.
- The accuracy of the derived soil hydraulic properties increases with decreasing flow rate. Our results indicate that a potential evaporation rate of 0.3 cm d^{-1} or less is generally acceptable.
- The accuracy of the derived soil hydraulic properties depends on the length of the sample. Our results indicate that samples should not be substantially longer than 5 cm.

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