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Evaluating a rapid approach for estimating soil hydraulic conductivity function from near-surface infiltration measurements

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ABSTRACT

Accurate estimation of the soil hydraulic conductivity function (SHCF), which describes the relationship between hydraulic conductivity and matric suction in soil, is essential for modeling flow and transport processes in the vadose zone. Traditional steady-state methods for directly determining SHCF are often laborious, time-consuming, and sometimes inadequate for capturing transient-state flow conditions. This study aims to propose a simple, quick, and accurate method for estimating SHCF that facilitates transient-state flow analysis during vadose zone modeling. The proposed method involves inverse numerical modeling using cumulative infiltration and final moisture content data from surface infiltration tests conducted with a handy mini disc infiltrometer (MDI). To validate this approach, the MDI-inverse modeling results were compared with SHCF results from another transient-state method, the instantaneous profile method (IPM), under similar initial soil conditions. The MDI infiltration tests were performed in homogeneously packed soil columns for two soils (identified as loam and silty clay loam textures) collected from nearby field sites. For each soil, separate IPM tests were conducted in soil columns equipped with soil moisture and matric suction sensors at various depths to facilitate calculation of reference SHCF. A comparison between the MDI and reference IPM results revealed a good agreement, with a low normalized RMSE (under 15%) for the estimated SHCFs and a low relative error (under 35%) for the optimized van Genuchten parameters α and n. The findings indicate that MDI-based cumulative infiltration measurements can reliably estimate SHCF via inverse simulation, providing a practical solution for field applications where traditional sensor deployment is challenging. Moreover, the results also establish MDI as a rapid, convenient, and non-invasive tool for determining SHCF for transient-state flow scenarios.

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INTRODUCTION

- **Soil hydraulic conductivity function (SHCF)** - relationship between hydraulic conductivity (K) and matric suction (ψ) or volumetric water content (θ) of the soil.
- Knowledge of SHCF is crucial for modeling solute and contaminant transport in the vadose zone, and for effective groundwater resource management.
- Direct methods like steady-state approaches are time-consuming, making transient methods such as the Instantaneous Profile Method (IPM) preferable.
- Indirect approaches, particularly parameter estimation techniques, are useful when prior knowledge of the SHCF model is available.
- This study presents an indirect method for estimating SHCF based on infiltration measurements obtained using a compact and portable Mini Disc Infiltrometer (MDI), validated against the IPM results.
- The proposed MDI technique offers a non-invasive, rapid, and reliable approach for characterizing SHCF from infiltration data.

METHODOLOGY

- MDI infiltration tests and IPM tests were performed in a laboratory cylindrical soil column, (Figure 1a & b) for 2 soils (loam (LM) and silty clay loam (SCL))- 6 repetitions each.
- Cumulative infiltration and initial soil moisture are recorded for each MDI experiment- used as input to determine SHCF and van Genuchten-*α* & *n* using the numerical inversion technique.
- For IPM- temporal variations of θ and ψ from the 1-dimensional wetting process were employed to determine SHCF using method from Leung et al. (2016).

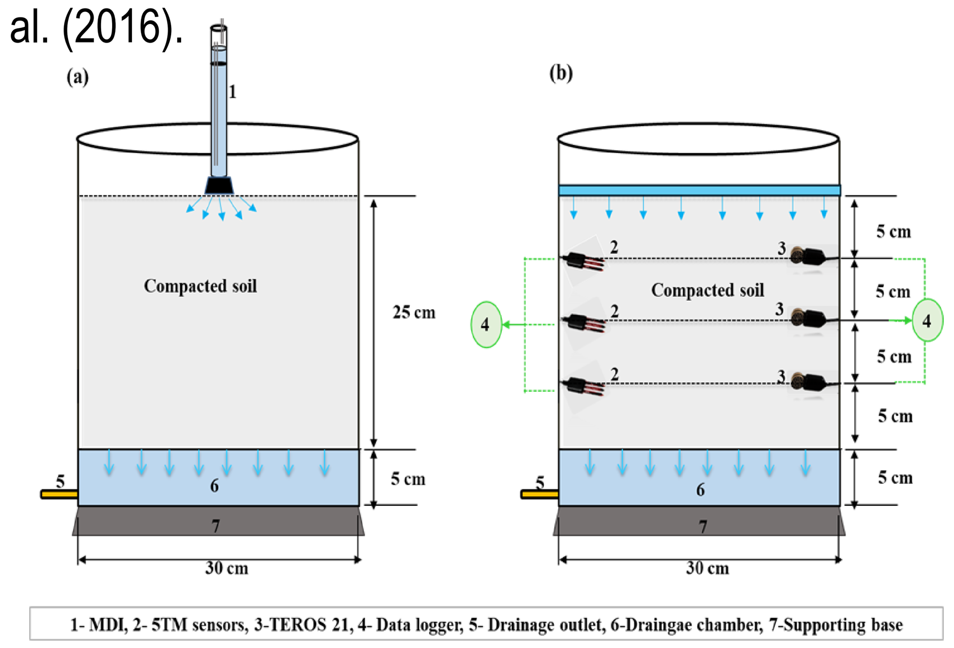

Fig 1. Schematic diagram of experimental setup for laboratory experiments for: (a) MDI infiltration tests and (b) IPM tests

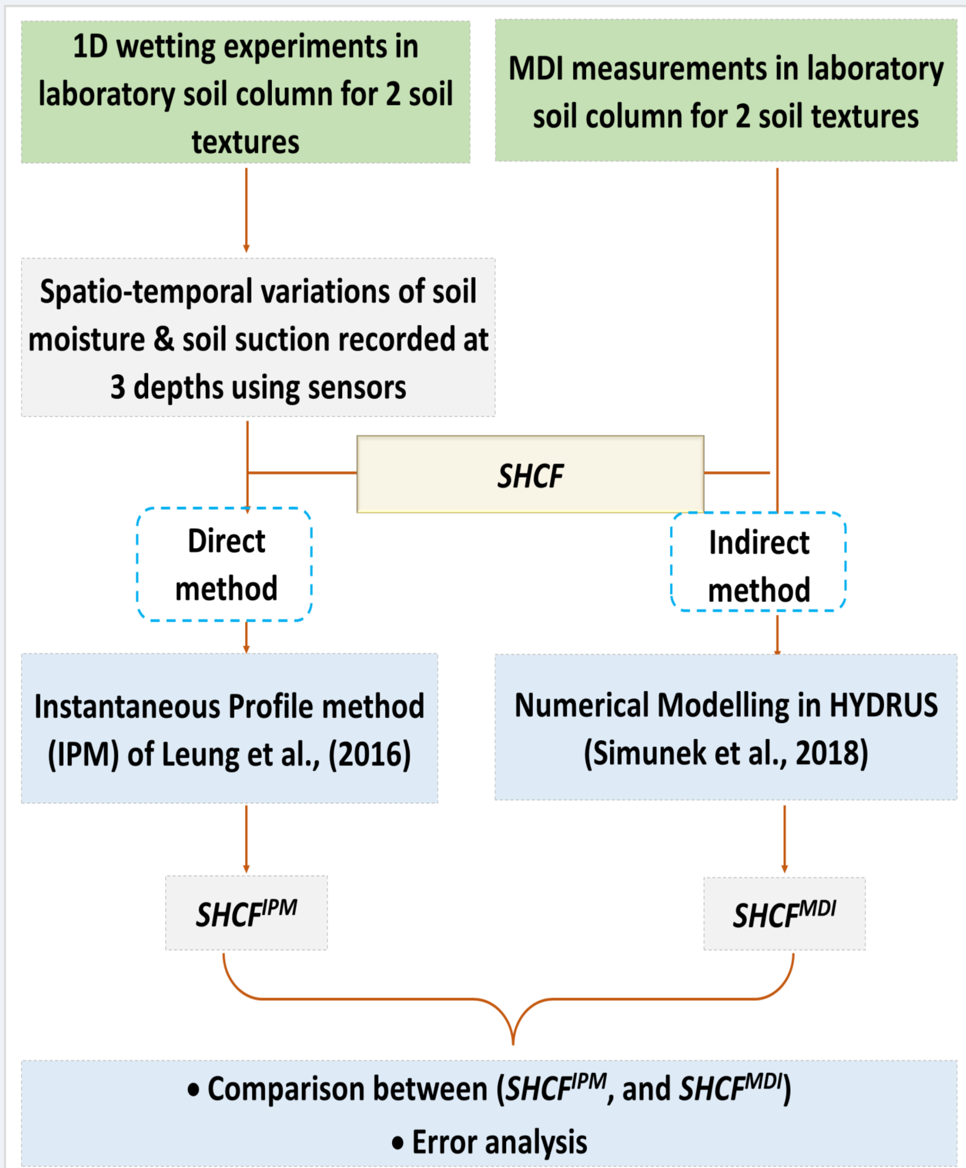

Fig 2. Flowchart of methodology

RESULTS

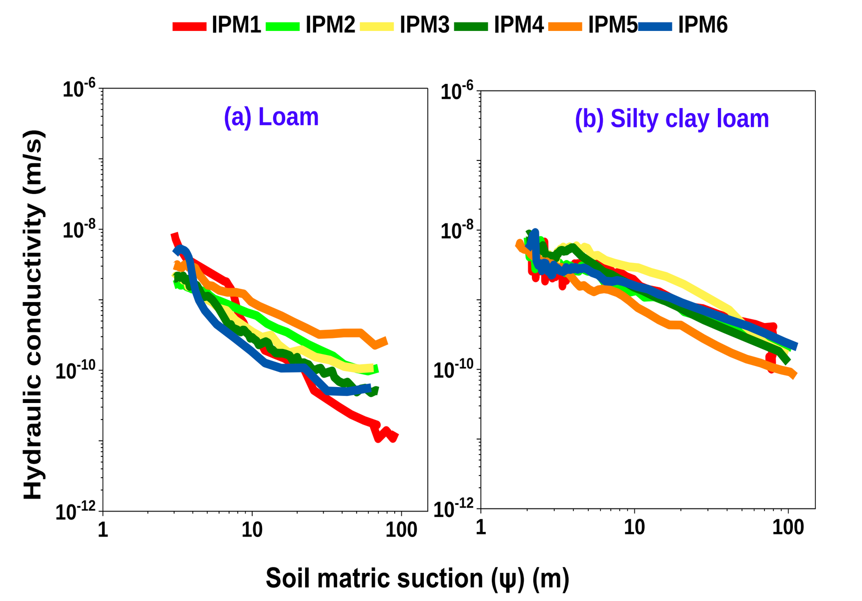

Fig 3. The SHCF curves determined from IPM for six repetitions of each (a) loam and (b) silty clay loam soils

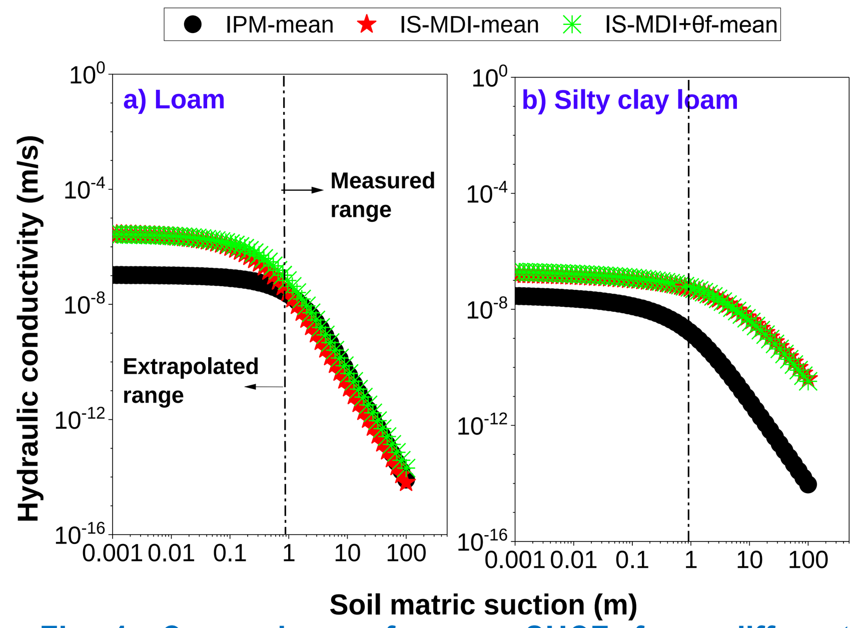

Fig 4. Comparison of mean SHCF from different methods for (a) loam and (b) silty clay loam

- Nearly consistent SHCF curves are obtained from all six repetitions for IPM (Fig. 3).
- For LM soil (for ψ in range of 3–100 m), $SHCF^{IPM}$ ranges from 10^{-8} to 10^{-11} m/s, and for SCL soil (for ψ in range of 2–100 m), it ranges from 10^{-8} to 10^{-10} m/s.
- For MDI tests- mean results from two separate inverse simulations ((IS-MDI) and (IS-MDI+θf)) are identical for each soil (Fig. 4)
- The mean SHCF from MDI and IPM are more comparable for LM soil than for SCL (Fig. 4 & Table 1); however, overall NRMSE for both soils is < 16%, indicating good agreement in SHCFs for each soil.
- Optimized α & n from the mean SHCFs of all methods exhibit only a marginal difference (Relative error < 35%)

Table 1. The normalised root mean square error calculated for various methods used for SHCF

Compared methods	NRMSE (%)	
	Loam	Silty clay loam
IPM & (IS-MDI)	9.7	14.6
IPM & (IS-MDI + θf)	10.6	14.9

Table 2. Optimized parameters (α and n) of the van Genuchten-Mualem model (1980) for SHCF and the error calculated for various methods

Soil texture	Method	Optimized parameters		Relative Error (%)	
		α	n	α	n
Loam	IPM	0.48	1.71	-	-
	IS-MDI	0.39	1.48	19.1	13.5
	IS-MDI+θ_f	0.35	1.35	27.4	21.1
Silty clay loam	IPM	0.74	1.37	-	-
	IS-MDI	0.96	1.38	-29.7	-0.7
	IS-MDI+θ_f	0.99	1.41	-33.1	-2.9

IPM: Instantaneous profile method,
MDI: Mini disc infiltrometer,
IS: Inverse simulation,
θf: final volumetric water content

CONCLUSIONS

- Investigated a realistic wetting process in unsaturated zone using laboratory infiltration tests beneath an MDI.
- Demonstrated compact MDI's efficiency in estimating SHCF and shape parameters (*α*, n) for two fine-textured soils.
- Validated inverse modeling results (SHCF, *α*, *n*) by cross-verifying with reference IPM measurements.
- NRMSE between SHCFs from MDI (IS-MDI and IS-MDI+θf) and IPM is <16% - acceptable for real soils.
- All three methods effectively generate SHCFs from infiltration-driven soil column studies.
- Cumulative infiltration from MDI, paired with initial moisture, enables robust inverse estimation of SHCF and parameters.
- Compact MDI offers a fast, non-destructive solution for SHCF measurement.

REFERENCES

1. Leung, A. K., Coo, J. L., Ng, C. W. W., & Chen, R. (2016). New transient method for determining soil hydraulic conductivity function. Canadian Geotechnical Journal, 53(8), 1332–1345. https://doi.org/10.1139/CGJ-2016-0113/ASSET/IMAGES/LARGE/CGJ-2016-0113FA5.JPEG
2. Naik, A. P., & Pekkat, S. (2025). Critical Evaluation of Viability of Mini Disc Infiltrometer for Determining the Unsaturated Hydraulic Conductivity Function. Journal of Irrigation and Drainage Engineering, 151(3), 04025008. https://doi.org/10.1061/JIDEDH.IRENG-10461
3. Simunek, J., Šejna, M., & Van Genuchten, M. T. (2018). New features of version 3 of the HYDRUS (2D/3D) computer software package. J Hydrol Hydromech, 66(2), 133–142. https://dspace.library.uu.nl/handle/1874/407892J. Simunek, M.T. van Genuchten, Water Resour. Res. 32(9), 2683-2696 (1996)
4. van Genuchten, M. T. (1980). A Closed-form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils1. Soil Science Society of America Journal, 44(5), 892. https://doi.org/10.2136/sssaj1980.03615995004400050002x