Sensitivity of soil water simulation using different soil hydraulic parameter characterization as initial input values

Meisam Rezaei[1,2,5*], Piet Seuntjens [1,2,3], Reihaneh Shahidi[4], Ingeborg Joris[2], Wesley Boënne[2], Wim Cornelis[1]

[1]Department of Soil Management, Faculty of Bioscience Engineering, Ghent University, 9000 Ghent, Belgium, [2]Unit Environmental Modeling, Flemish Institute for Technological Research (VITO NV), 2400 Mol, Belgium, [3]Faculty of Bioscience Engineering, University of Antwerp, 2020 Antwerp, Belgium, [4]Department of Plant production, Faculty of Bioscience Engineering, Ghent University, 9000 Ghent, Belgium, [5]Department of Soil Science, Gorgan University of Agricultural Sciences & Natural Resources, Gorgan, Iran

*Corresponding author and presenter:
Meisam.Rezaei@vito.be
Meisam.Rezaei@ugent.be

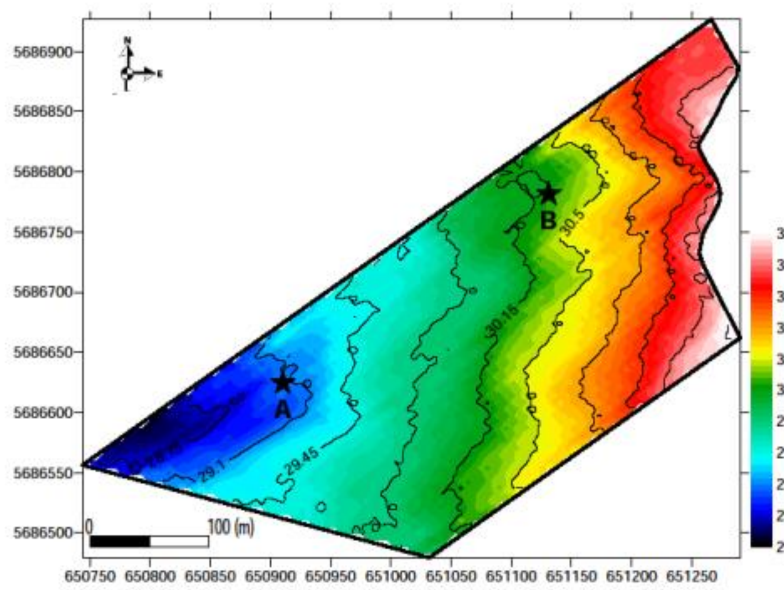
Background and objective

- Proper sets of soil hydraulic properties are indispensable as input for hydrological models which especially use a numerical solution of the Richards' equation to predict and describe water flow.
- The field **tension disc infiltrometer (TI)** and **laboratory undisturbed soil cores** are standard methods to measure soil hydraulic properties (**HP**).
- Objectives: i) comparing the results of in situ and laboratory measurements of soil HP; and ii) evaluating the relevance and the influence of differently calculated/estimated HP on hydrological model performance (to find a proper parameter set).

Methodology

A. The study site:

- Field: potato, typical sandy Podzol.
- Location: the border between Belgium and The Netherlands.
- Equipment at A and B: a weather station, a Diver water level logger, soil-water content sensor probe (at 10, 20, 30, 40, 50 and 60 cm) and tensiometer at 10 and 50 cm (hourly recorded).



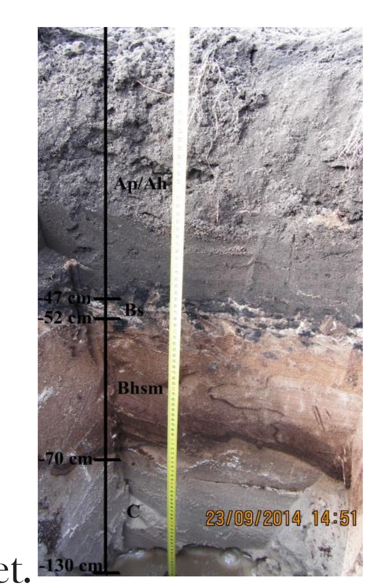
B. Measurements:

- In-situ TI experiments (2 replications) at five depths for two profiles (A and B) at consecutive negative pressure heads of 12, 6, 3 and 0.1 cm.
- Lab constant head and sandbox-pressure plate methods on undisturbed soil cores (3 replications) sampled at the same locations/depths of in-situ method.

C. Assessment of hydraulic parameters:

- Method 1- Analytical Wooding's solution using the nonlinear regression method of Logsdon and Jaynes (1993) to determine K_{fs} and α_G.
- Method 2- Inverse modeling, performing Hydrus-2D/3D[(4)] to determine K_{fs}, θ_s, α and n using initial values from method 1.
- Method 3- Mualem-van Genuchten (MVG) model using RETC software to determine θ_s, α and n. K_{fs} was determined directly by applying Darcy's law.

D. Simulation of water flow and root water uptake:



- Numerical model: Hydrus-1D
- Profile geometry: 150 cm with 3 layers
- Study period: growing season 2014 (12 Apr. - 22 Sep.)
- Hydraulic model: MVG without air entry value and hysteresis
- Root water uptake model: Feddes model without solute stress
- Upper boundary condition: atmospheric (precipitation, LAI and ETp,)
- Bottom boundary condition: variable pressure head (GWL)
- Input hydraulic parameters: field (Method 2) and lab (method 3) dataset.
- Evaluation: root-mean-square deviation (RMSE), coefficient of determination (r^2), and Nash–Sutcliffe coefficient of efficiency (C_e)

Results and discussion

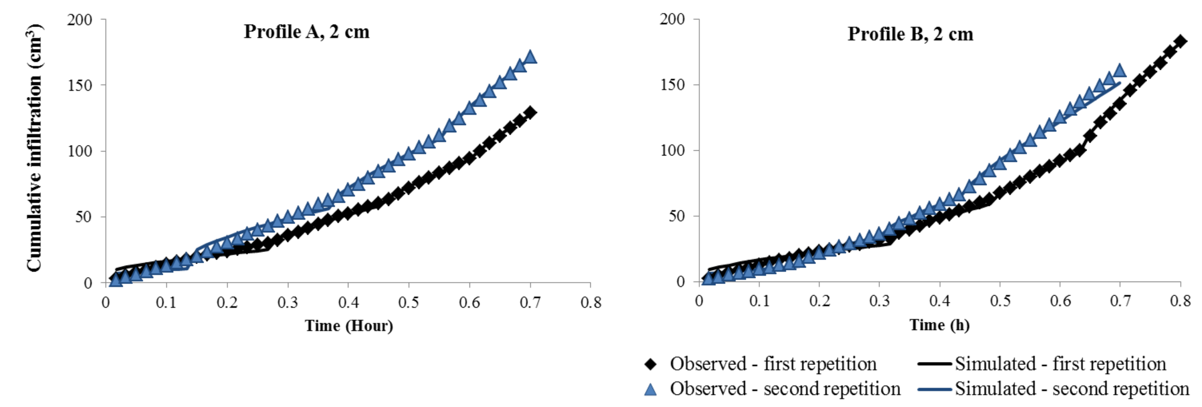
Lab hydraulic parameters

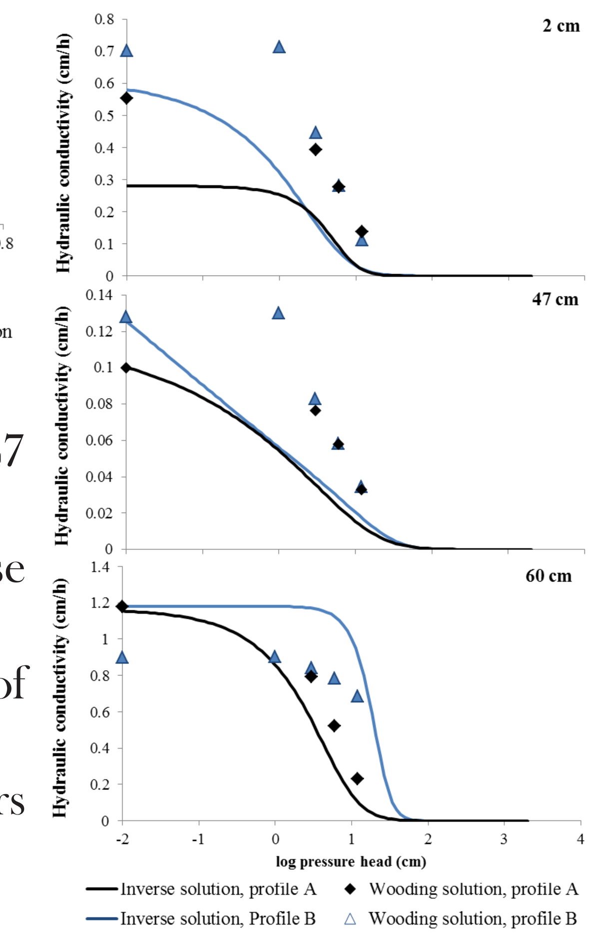
- ➢ K_{fs} and n increase and θ_s and α_{vG} decrease with increasing depth.
- ➢ Significant differences of K_{fs} values of profiles.
- ➢ Spatial variability in horizontal and vertical dimensions.

Profile	Depth cm	θ_r [A]	θ_s cm³ cm⁻³	α_{vG} cm⁻¹	n	K_{fs} cm h⁻¹
A	2	0.053[ab]	0.525[a]	0.05733[a]	1.567[c]	0.881[c]
	20	0.055[ab]	0.509[a]	0.05037[a]	1.584[c]	10.01[c]
	47	0.075[a]	0.403[b]	0.04029[ab]	1.449[c]	2.840[c]
	60	0.03[b]	0.35[b]	0.014[c]	2.213[b]	34.046[b]
	80	0.003[bc]	0.38.3[b]	0.02038[b]	2.885[a]	60.423[a]
B	2	0.069[a]	0.545[a]	0.07172[a]	1.456[ab]	1.483[b]
	20	0.072[a]	0.530[a]	0.05924[a]	1.508[ab]	3.365[ab]
	47	0.084[a]	0.367[b]	0.02448[b]	1.444[b]	0.761[b]
	60	0.013[b]	0.361[b]	0.02922[b]	1.879[a]	5.752[a]

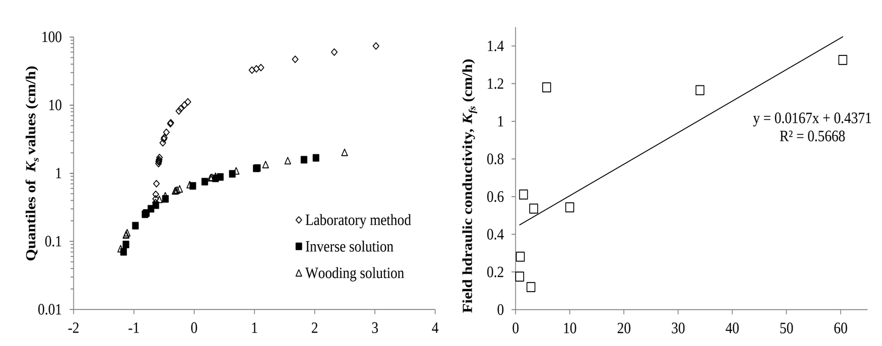
[A] Not estimated (measured at 15,000 cm). Means followed by the same letter do not differ across depths (in each profile) by the LSD test at the level of 5% probability.

Field infiltration, Wooding's solution and inverse optimization





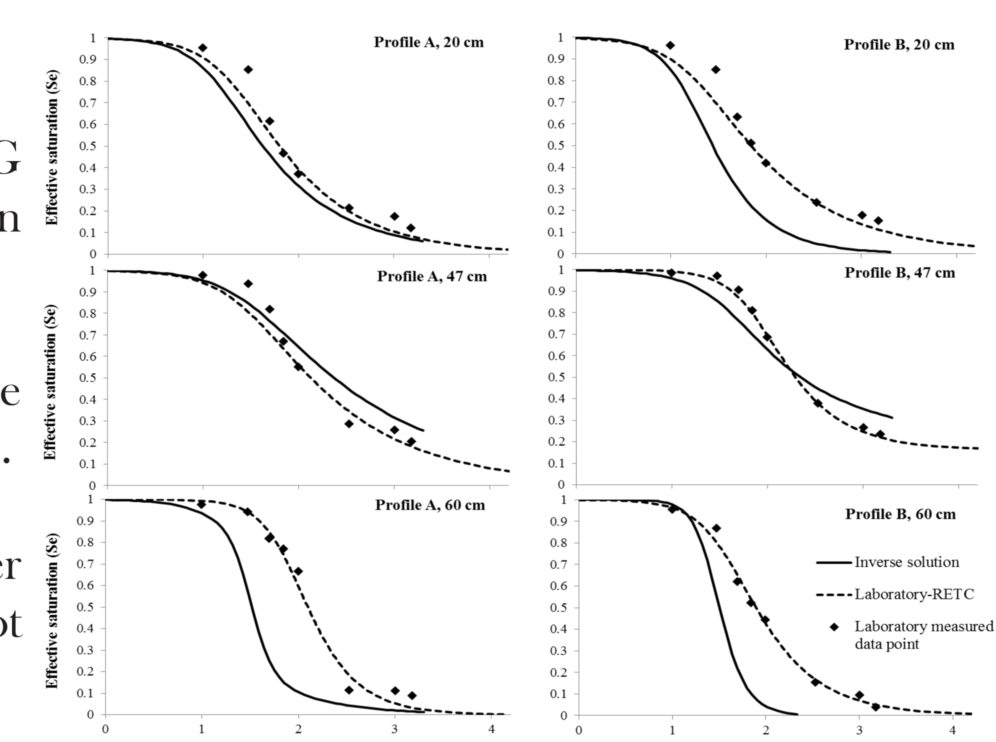
- ➢ The inverse modeling matched well the observed ones.
- ➢ The lowest infiltration rate was at the compacted layer (47 cm depth).
- ➢ The optimized parameter values for K_{fs} were mostly close to the initial values from Wooding's solution.
- ➢ No significant differences of θ_r, n, α and K_{fs} values of profiles A and B.
- ➢ Gardner's α_G is related to van Genuchten's parameters α_{vG} and n as $\alpha_G \approx \alpha_{vG}\, n$.



- ➢ Significant differences ($p \leq 0.05$) of K_s values for lab and field (optimization and Wooding approaches).
- ➢ A significant correlation between lab and field K_s (r = 0.75).

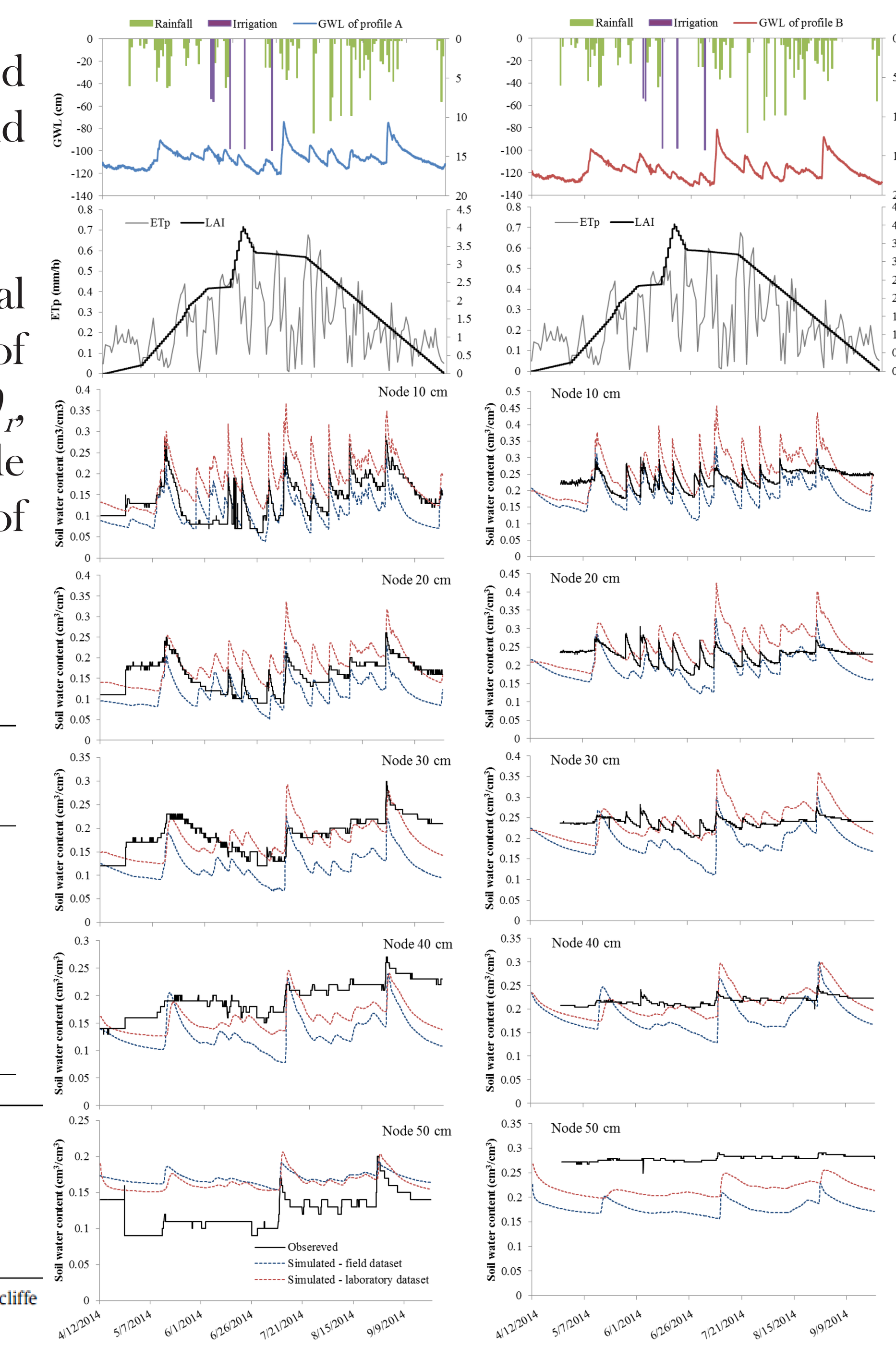
Water retention curves

- ➢ Significant differences of MVG parameters θ_s, n and α_{vG} values between lab and field measurements.
- ➢ Significant correlation between the slope of the WRC of both methods (r = 0.81).
- ➢ The underestimation of saturated water content results from the matrix not being fully saturated.



Relevance of hydraulic parameter set on model performance

- ➢ The model over and under predicted soil-water content using lab and field experiments data sets.
- ➢ Small sample volume, tempo-spatial variability and underestimation of hydraulic parameters, especially θ_r, using field methods could be possible reasons for the under prediction of soil-water content.



Node (cm)	Profile A					
	Field			Lab		
	RMSE[a]	C_e[a]	r^2[a]	RMSE[a]	C_e[a]	r^2[a]
Water content						
10	0.044	0.11	0.42	0.063	−0.85	0.44
20	0.053	−1.06	0.29	0.050	−0.78	0.20
30	0.072	−2.87	0.37	0.034	0.10	0.33
40	0.070	−4.58	0.27	0.043	−1.13	0.42
50	0.051	−3.64	0.39	0.045	−2.65	0.45
60						
Water potential						
10	217.7	−0.35	0.16	197.1	−0.10	0.01
50	99.0	0.05	0.30	156.4	−1.38	0.19
	Profile B					
Water content						
10	0.052	−3.0	0.38	0.056	−3.55	0.31
20	0.046	−3.6	0.26	0.054	−5.33	0.09
30	0.055	−19.3	0.40	0.037	−7.99	0.17
40	0.043	−25.4	0.37	0.024	−7.29	0.49
50	0.101	−391.2	0.29	0.062	−144.8	0.55
60	0.156	−121.6	0.38	0.122	−73.1	0.30

[a] RMSE, C_e and r^2 are the root-mean-square deviation (cm and cm³ cm⁻³), the Nash–Sutcliffe coefficient of efficiency and the coefficient of determination.

- ➢ According to the C_e and RMSE criteria the lab method yielded slightly better results (30 - 50 cm depths).

Conclusions and perspectives

- ➢ Inverse optimization resulted in excellent matched between observed and fitted infiltration rates using Hydrus-2D/3D.
- ➢ Field experiment parameter sets, which were achieved fast and simple, resulted in slightly better soil-water content simulation performance in the topsoil and soil-water potential in the subsoil.
- ➢ It is not possible to judge whether laboratory or field methods should be preferred and most appropriate data set to predict soil water fluctuations in a complete soil profile.
- ➢ The reasons behind the deviations should be further unraveled.
- ➢ Parameter optimization over long time such as a growing season in combination with independent soil-water content and soil-water potential data is necessary.

Further reading

Rezaei, M., Saey, T., Seuntjens, P., Joris, I., Boenne, W., Van Meirvenne, M., Cornelis, W., 2016. Predicting saturated hydraulic conductivity in a sandy grassland using proximally sensed apparent electrical conductivity. Journal of Applied Geophysics, 126: 35-41.

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