Technische Universität Braunschweig

Institut für Geoökologie
Bodenkunde und Bodenphysik

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Simple models of soil hydraulic properties in the complete moisture range: Testing the new PDI model system with a comprehensive experimental dataset

Wolfgang Durner, Tobias L. Hohenbrink, Sascha C. Iden, Andre Peters

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Pedotransferfunctions, PTF

Vereecken Harry

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Soil science and Hydrology

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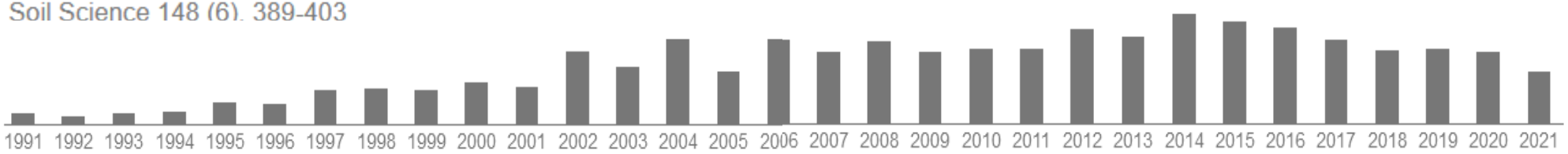


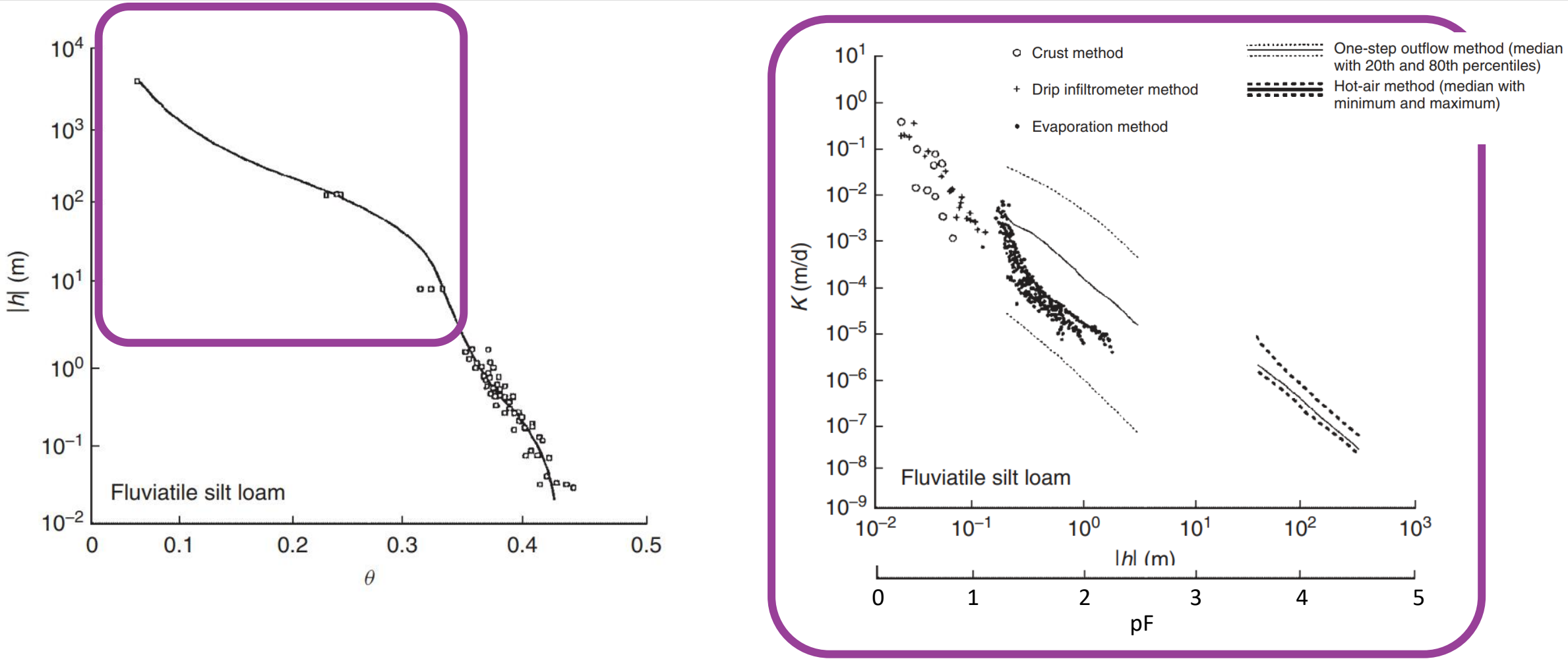
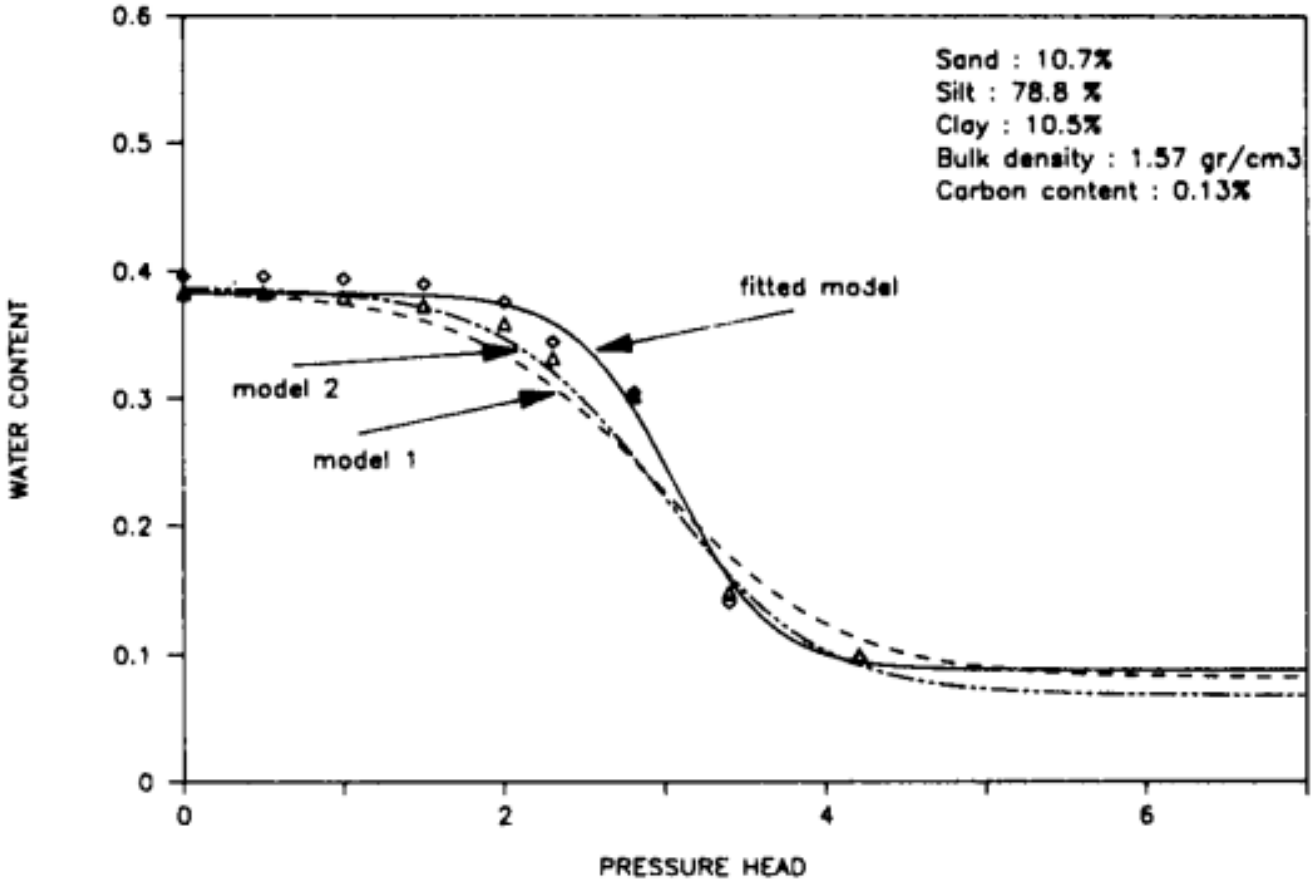


Figure 1 Hydraulic properties of a fluviatile silt loam. (a) Water retention curve measurements. (b) Unsaturated conductivity measurements, determined by five different methods (Reproduced from Stolte *et al.*, 1994 by permission of Soil Science Society of America)

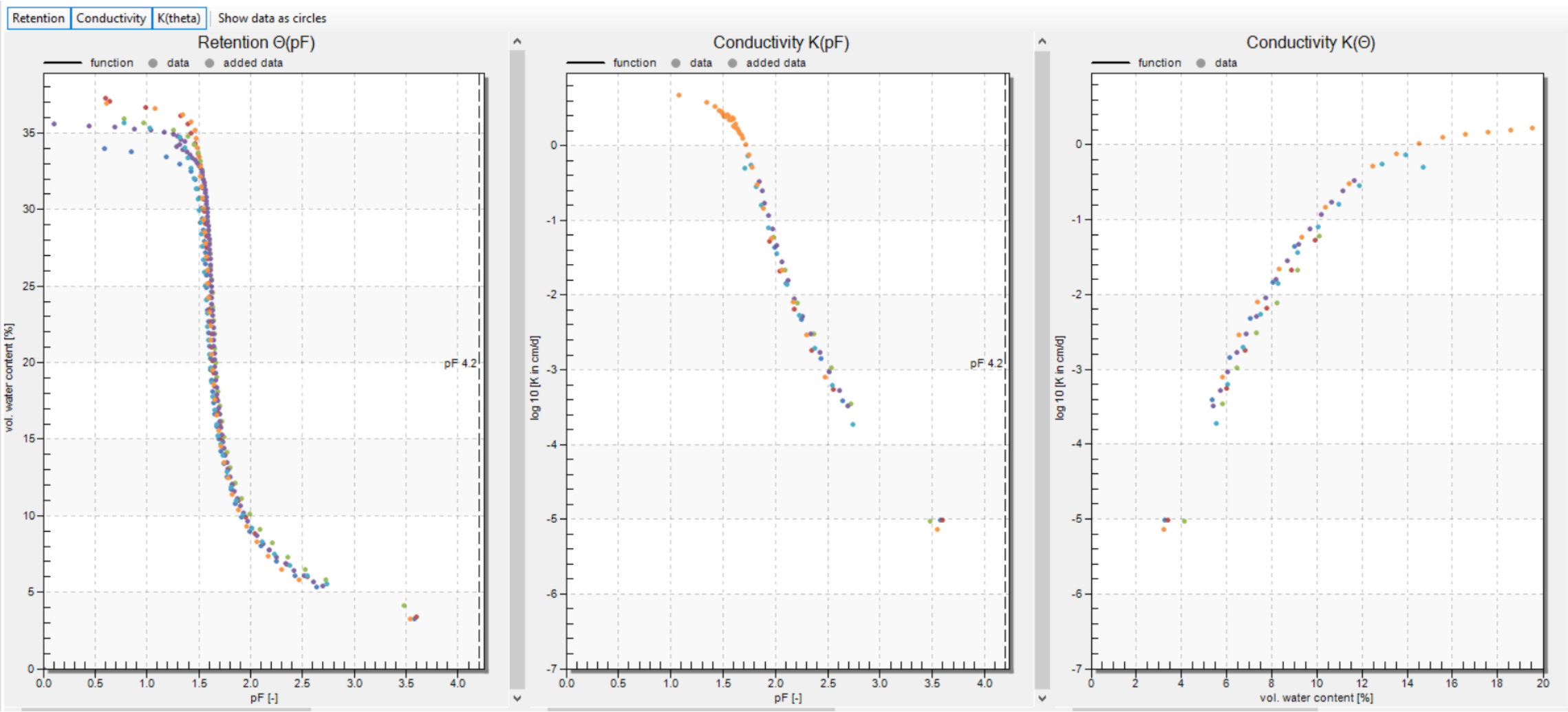
FIG. 4. Estimated moisture retention characteristics with two sets of regression equations (models 1 and 2) and fitted moisture retention characteristic for a sandy soil. The parameter vector of the fitted model equals: $\theta_r = 0.020$; $\theta_s = 0.325$; $\alpha = 0.0185$; $n = 2.993$. The data points are indicated by squares and triangles.

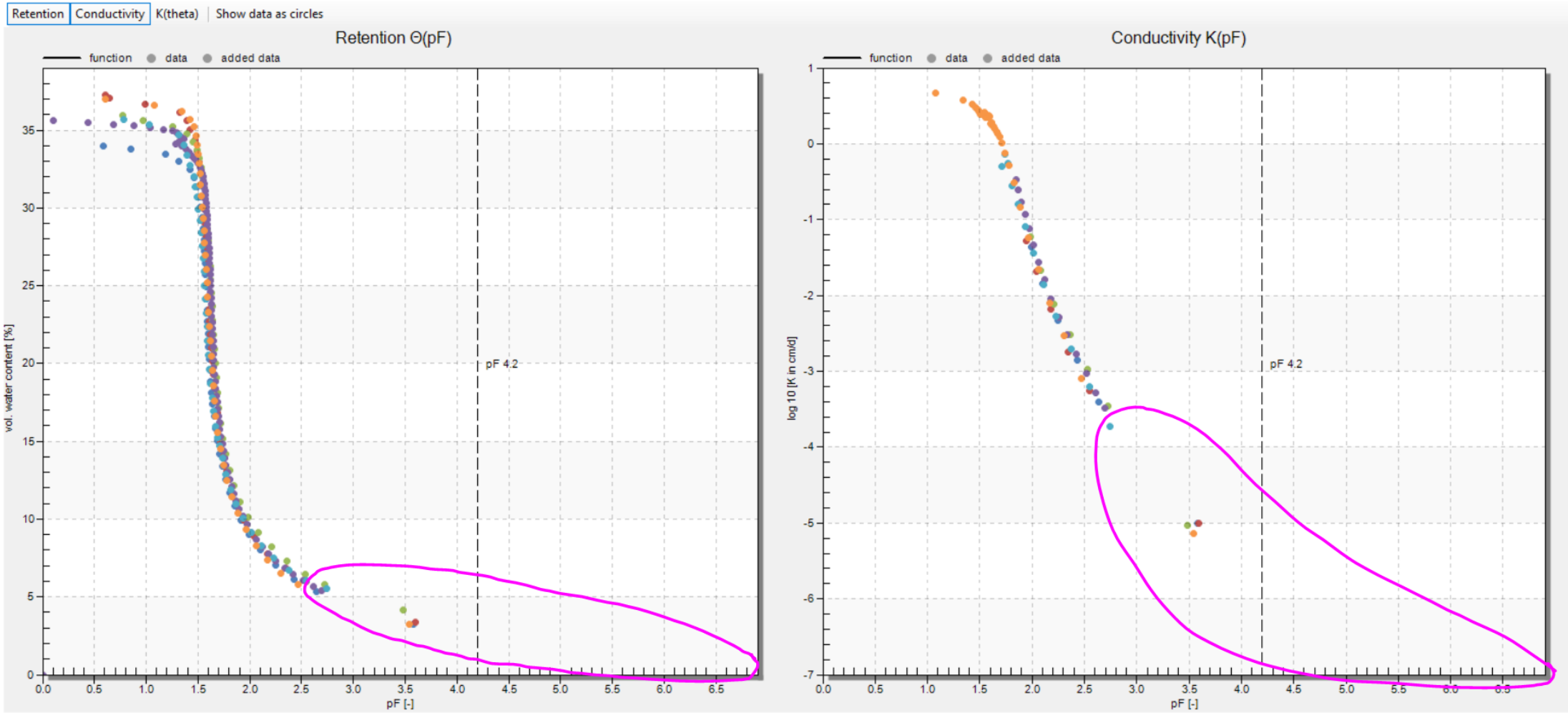


ESTIMATING THE SOIL MOISTURE RETENTION CHARACTERISTIC FROM TEXTURE, BULK-DENSITY, AND CARBON CONTENT
H VEREECKEN, J MAES, J FEYEN, P DARIUS
Soil Science 148 (6), 389-403

SHP from evaporation method

(HYRPOP, Soil Schunteraue, undisturbved cores, Boku Praktikum 2014, 6 independent replicates)




Retention
Conductivity
K(theta)
Show data as circles
Retention Θ(pF)
function
data
added data
vol. water content [%]
pF [-]
pF 4.2
Conductivity K(pF)
function
data
added data
log 10 [K in cm/d]
pF [-]
pF 4.2

Dewpoint Potentiameter

Messung der Retentionskurve

INSTITUT FÜR GEOÖKOLOGIE
Bodenkunde und Bodenphysik

Technische Universität Braunschweig

Bachelorarbeit

im Studiengang Umweltnaturwissenschaften

Einfluss der Salzkonzentration auf das osmotische Potential in trocknenden Böden

Vergleich von Messungen und Modellen

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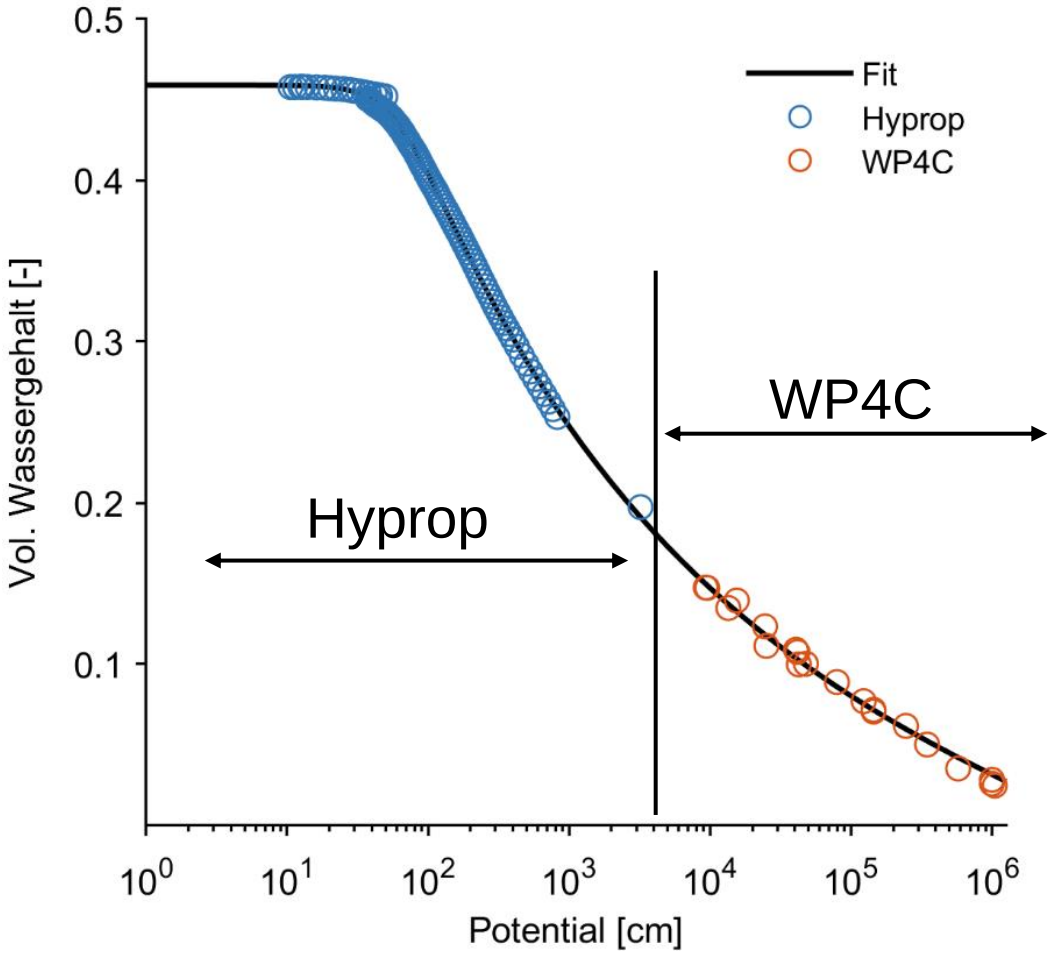
Abgabedatum:
19. Januar 2021

Erstprüfer:
Prof. Dr. Wolfgang Durner

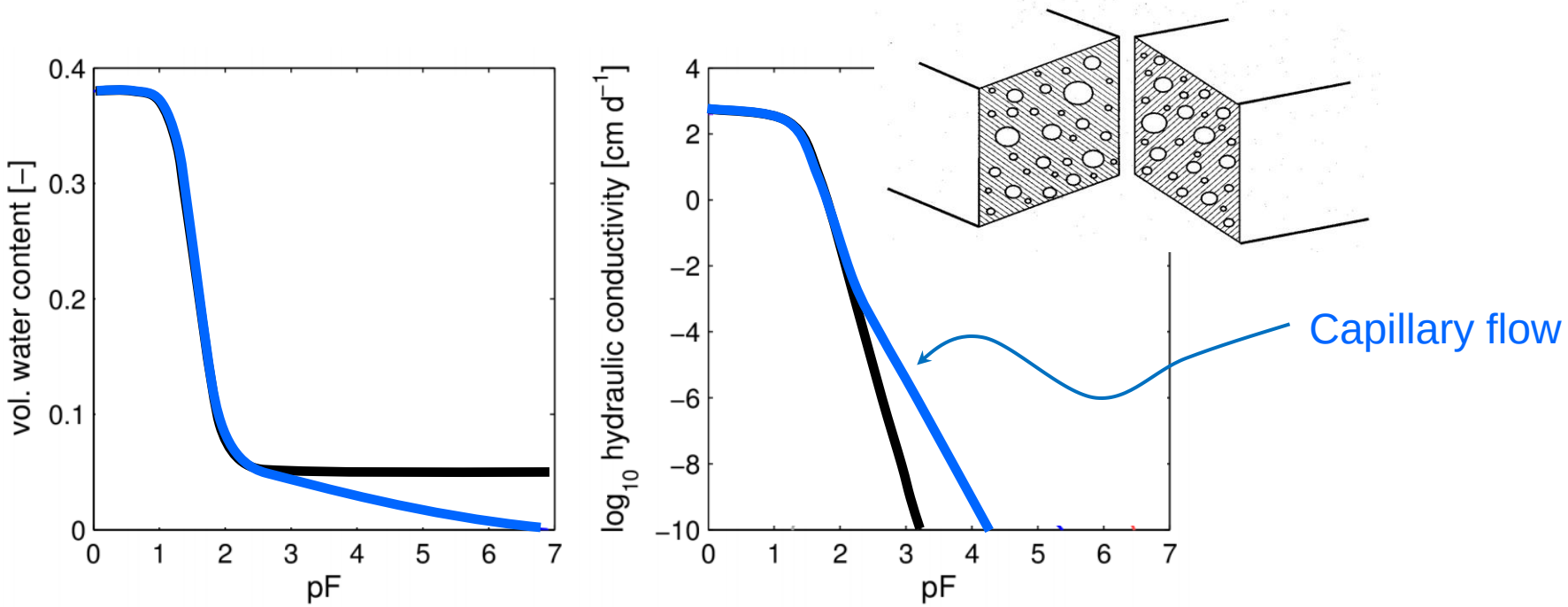
Zweitprüfer:
Dr. Andre Peters



Lessons learned

Lessons learned (1)

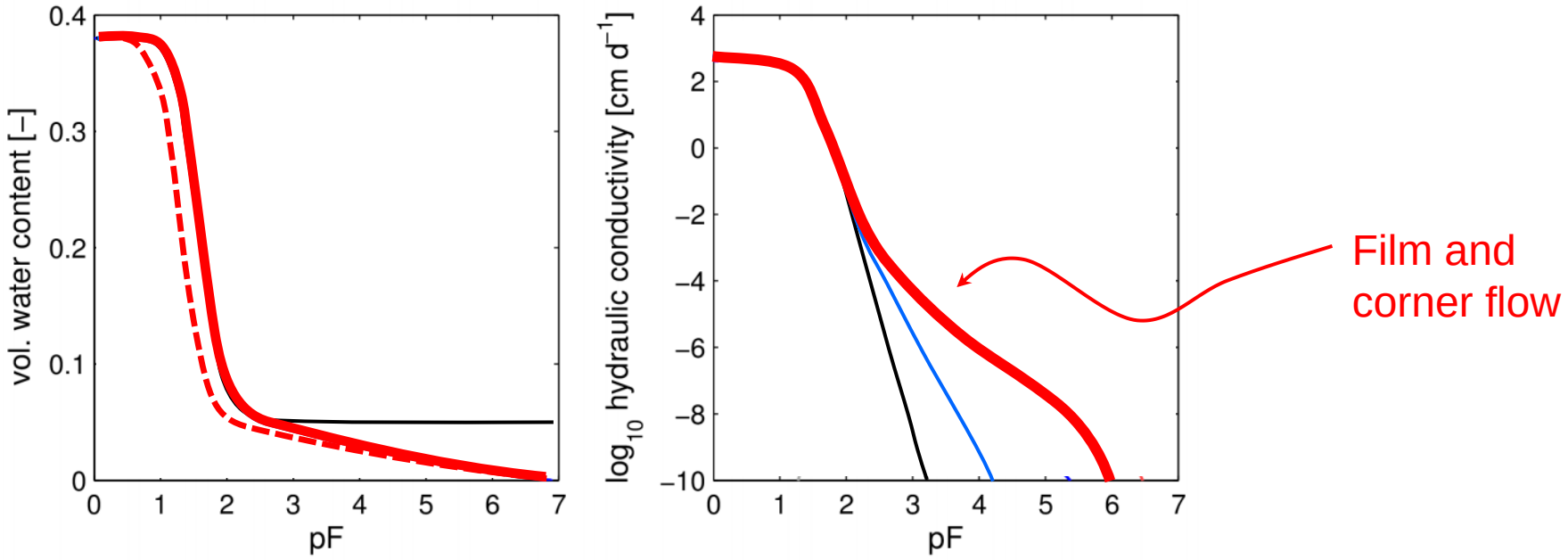
better …



Ross et al. 1991 | Campbell-Shiozawa 1992 | Rossi and Nimmo 1994 | Fredlund-Xing 1994 | Fayer-Simmons 1995| Morel-Seytoux and Nimmo 1999 | Webb 2002 |Groenevelt and Grant 2004| Khlosi et al 2006 | …

Lessons learned (2)

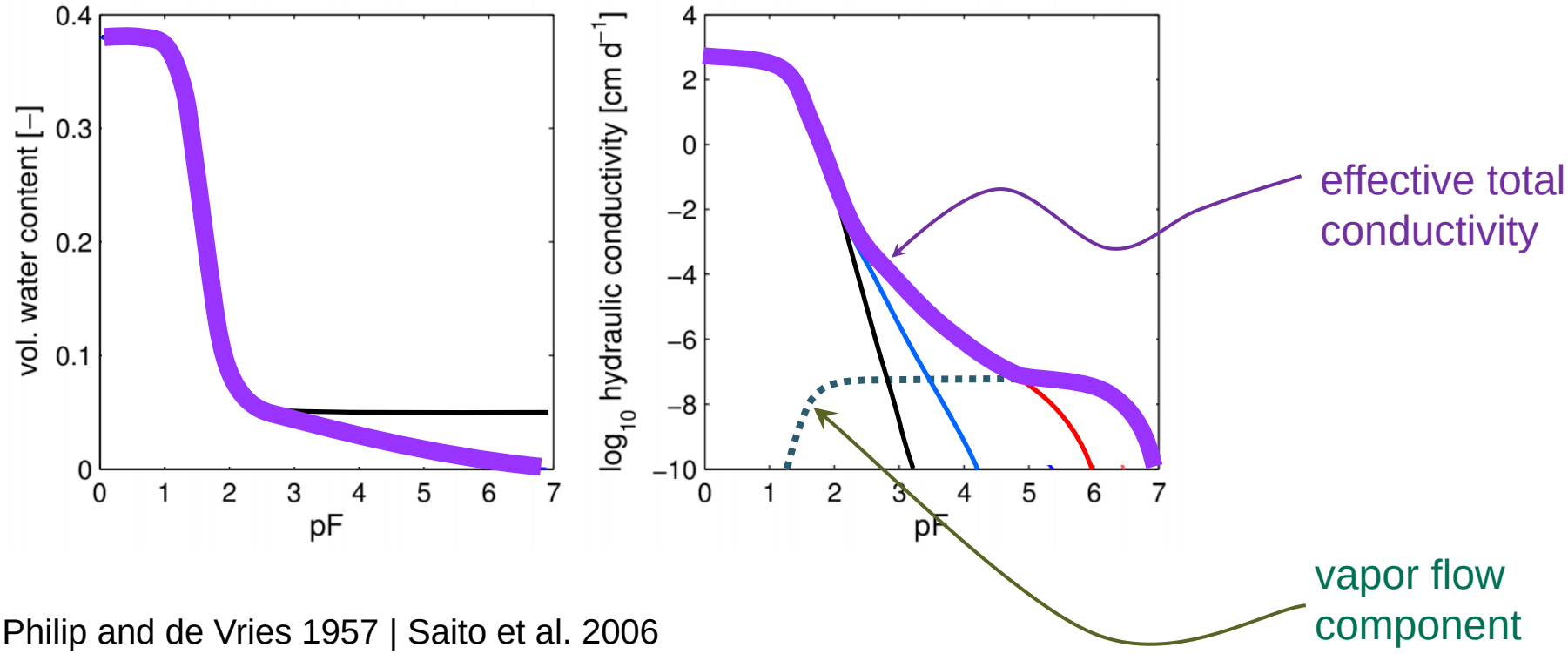
… even better …



Tuller-Or 2001 |Peters-Durner 2008 | Tokunaga 2009 |Lebeau-Konrad 2010| Zhang 2011 | Diamantopoulos-Durner, 2013 | …

Lessons learned (3)

… really good !

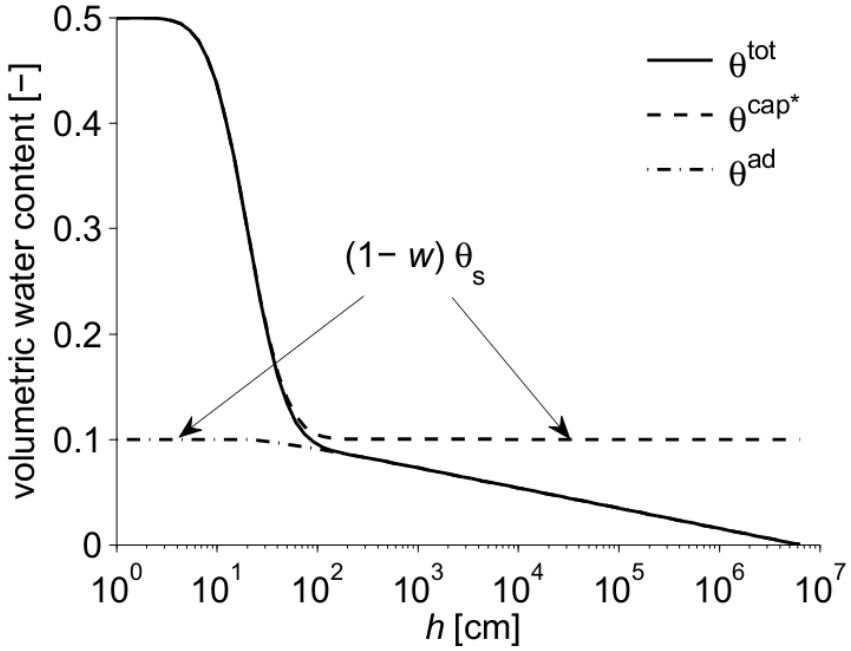


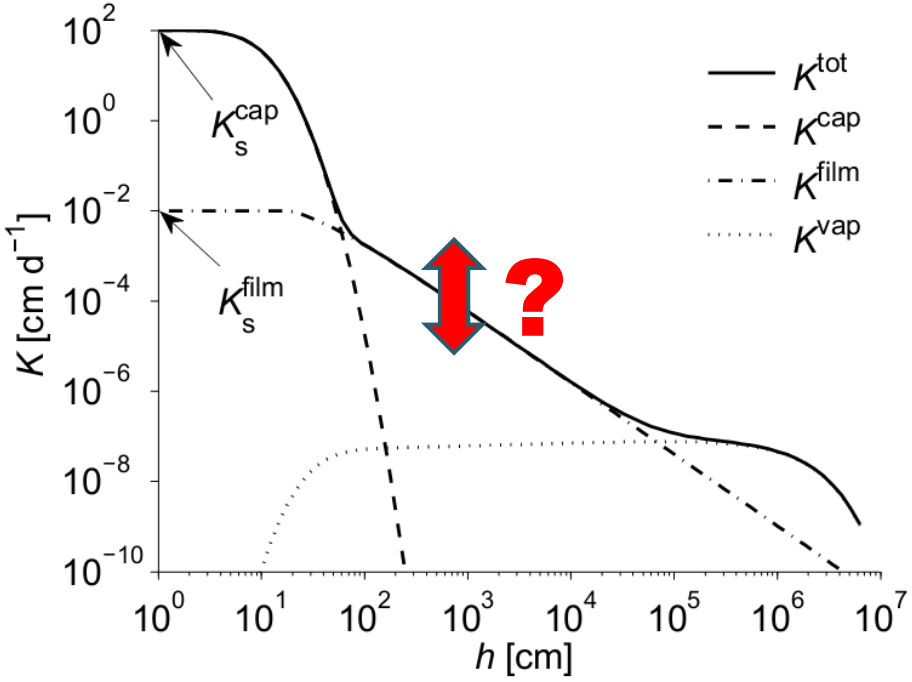
Philip and de Vries 1957 | Saito et al. 2006

A parsimonious SHP desription: The PDI model structure

$$\theta(h) = (\theta_s - \theta_r)\, S_{cap}(h) + \theta_r\, S_{ad}(h)$$

$$K^{lv} = K^{liq} + K^{vap} = K^{cap} + K^{film} + K^{vap}$$





The PDI model with K_{nc} prediction

Water Resources Research

Research Article | Open Access

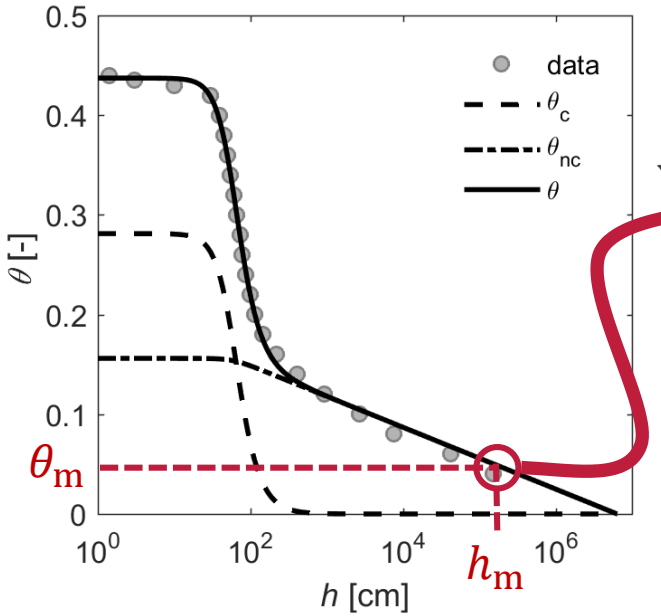
A Simple Model to Predict Hydraulic Conductivity in Medium to Dry Soil From the Water Retention Curve

Andre Peters, Tobias L. Hohenbrink, Sascha C. Iden, Wolfgang Durner

First published: 05 May 2021 | https://doi.org/10.1029/2020WR029211

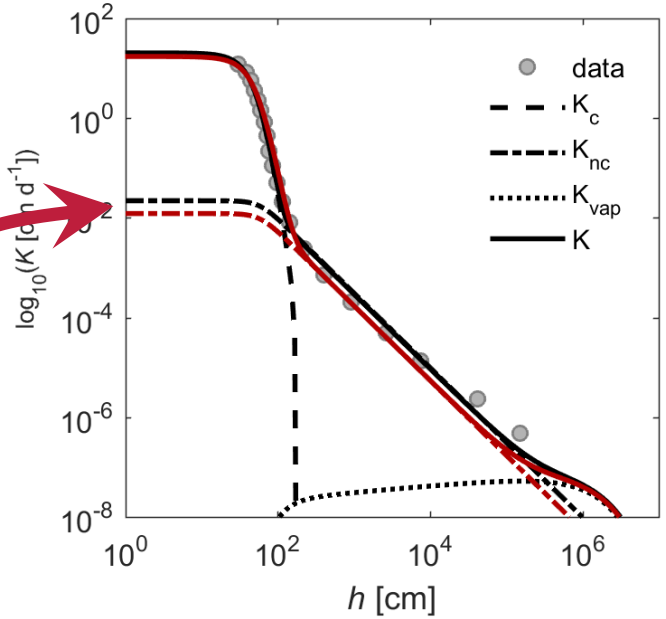
Retention Model

4 parameters



Conductivity Model

2 parameters



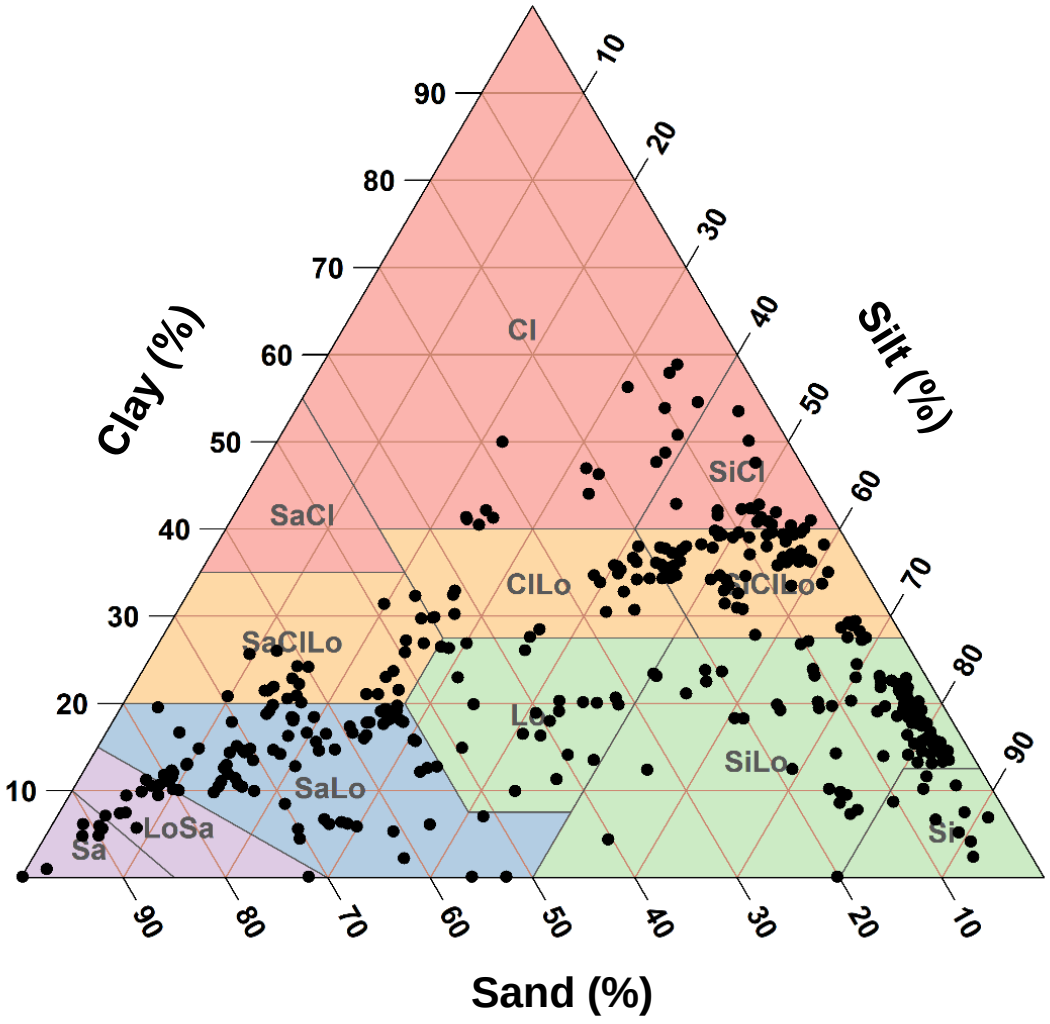
$$K_{s,nc} = \theta_m c h_a^{-1.5}$$

$$c = \frac{2}{3}\frac{\pi^{7/3}}{\eta(\rho g)^{1/6}}\left(\frac{6}{A_{svl}}\right)^{1/3}\left(\frac{\epsilon_r\epsilon_0}{2}\right)^{3/2}\left(\frac{k_b T}{eZ}\right)^3 h_m^{1/3} \approx 98\ \mathrm{cm}^{5/2}\ \mathrm{d}^{-1}$$

Test of the PDI k prediction

Model testing

- 484 **retention** and **conductivity** curves
- Determined on **undisturbed samples**
- Measured in the laboratory with:
  - **Evaporation method (HYPROP)**
  - **Dew point method (WP4C**



Model combinations

Shape function:

- van Genuchten/Mualem, $m = 1 - 1/n$ **(VGM)**

Consideration of non-capillary water:

- No consideration **(orig VGM)**
- PDI model system with K_{nc} fitted **(PDI)**
- PDI model system with K_{nc} predicted **(PDIc)**

Fitted (green) and fixed (orange) parameters of the investigated model combinations.

	α (cm^{-1})	n (-)	θ_r (-)	θ_s (-)	m (-)	k_s (cm d^{-1})	τ (-)	c (cm$^{5/2}$ d^{-1})	Number of parameters
VGM - orig	✓	✓	✓	✓	1-1/*n*	✓	✓	-	**6**
VGM – PDI	✓	✓	✓	✓	1-1/*n*	✓	✓	✓	**7**
VGM – PDIc	✓	✓	✓	✓	1-1/*n*	✓	✓	98	**6**

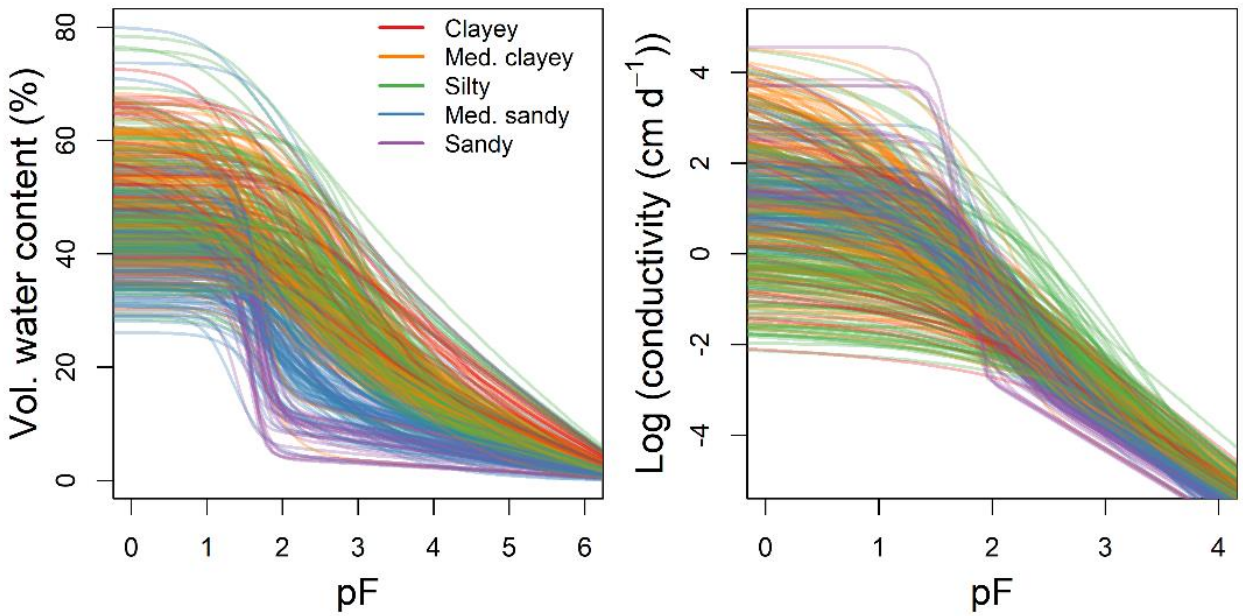
Estimation of model parameters

The **model combinations** were **fitted** to each **data set** from the data collection

Software: **SHYPFIT 2.0**

Algorithm: **Shuffled Complex Evolution**

Criterion: **Weighted Sums of Squares** (WSSQ)

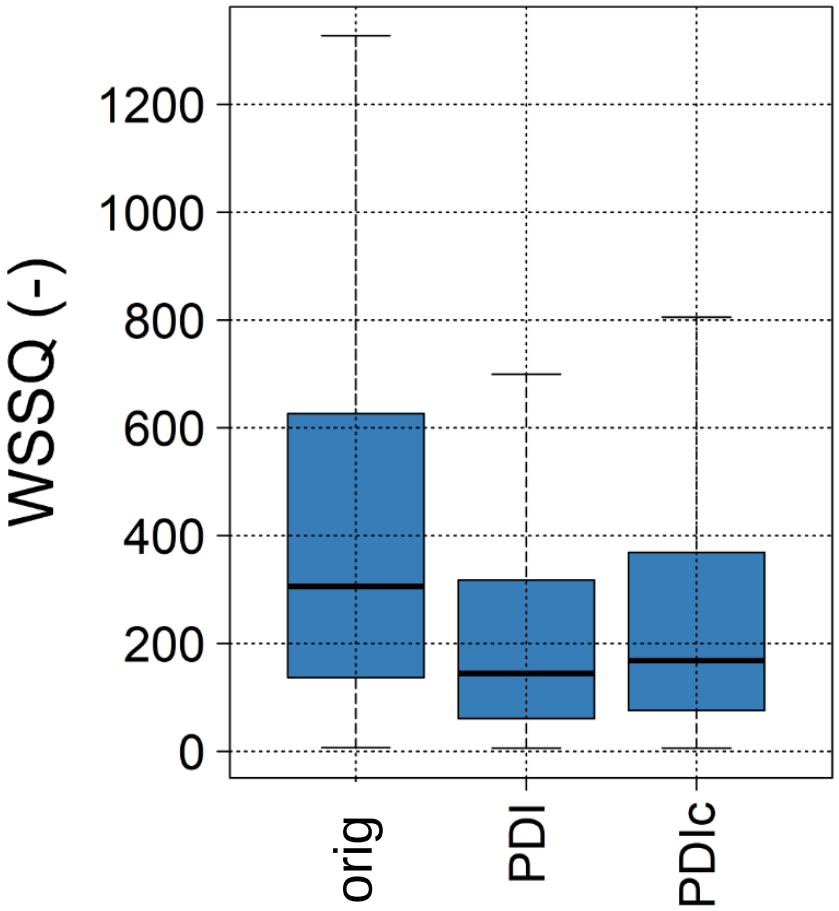


Soil water retention curves (left) and curves of hydraulic conductivity of the unsaturated soil (right) fitted for the VGM-PDIc model.

Overall model performance

WSSQ:

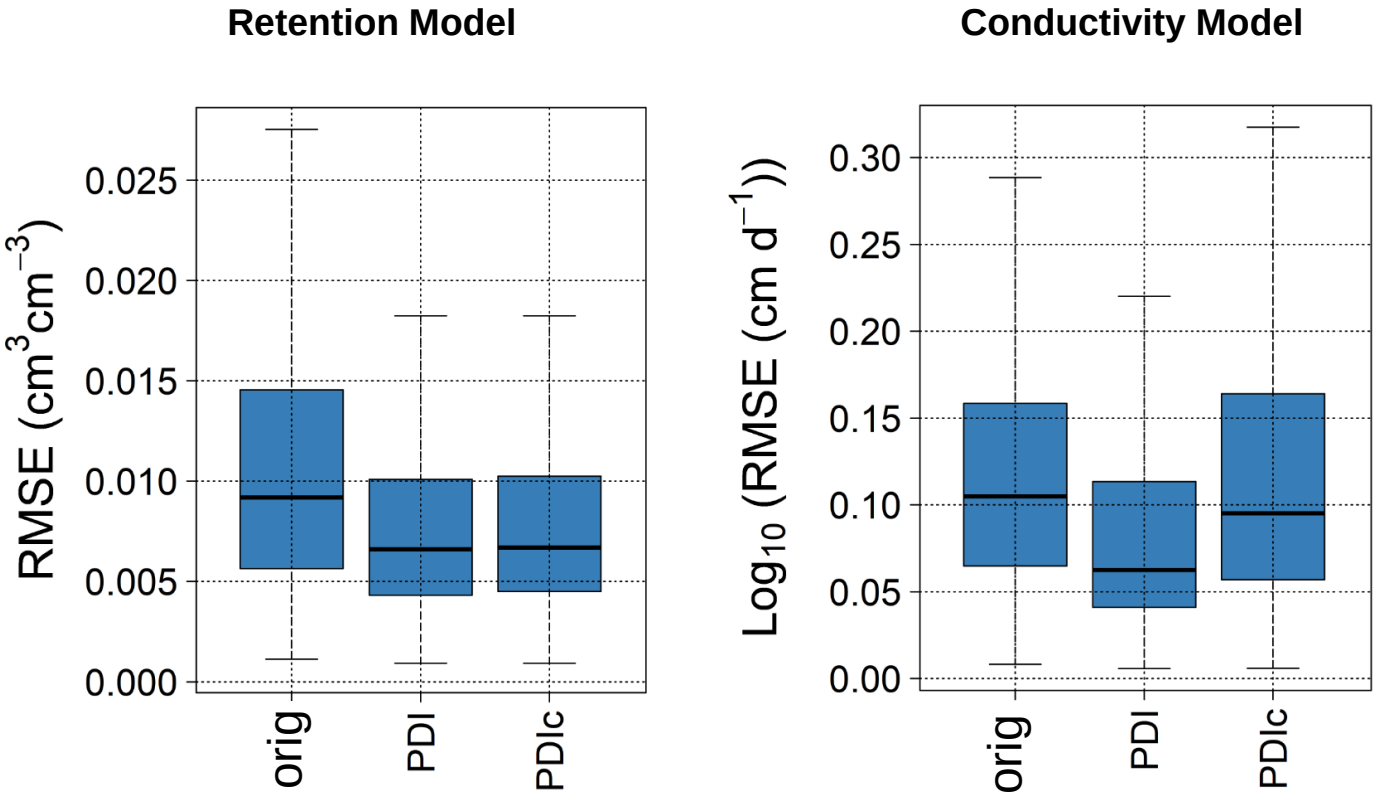
- PDI with and fitted and predicted K_{nc} perform smilarly
- WSSQ by about 50 % reduced as compared to original VGM



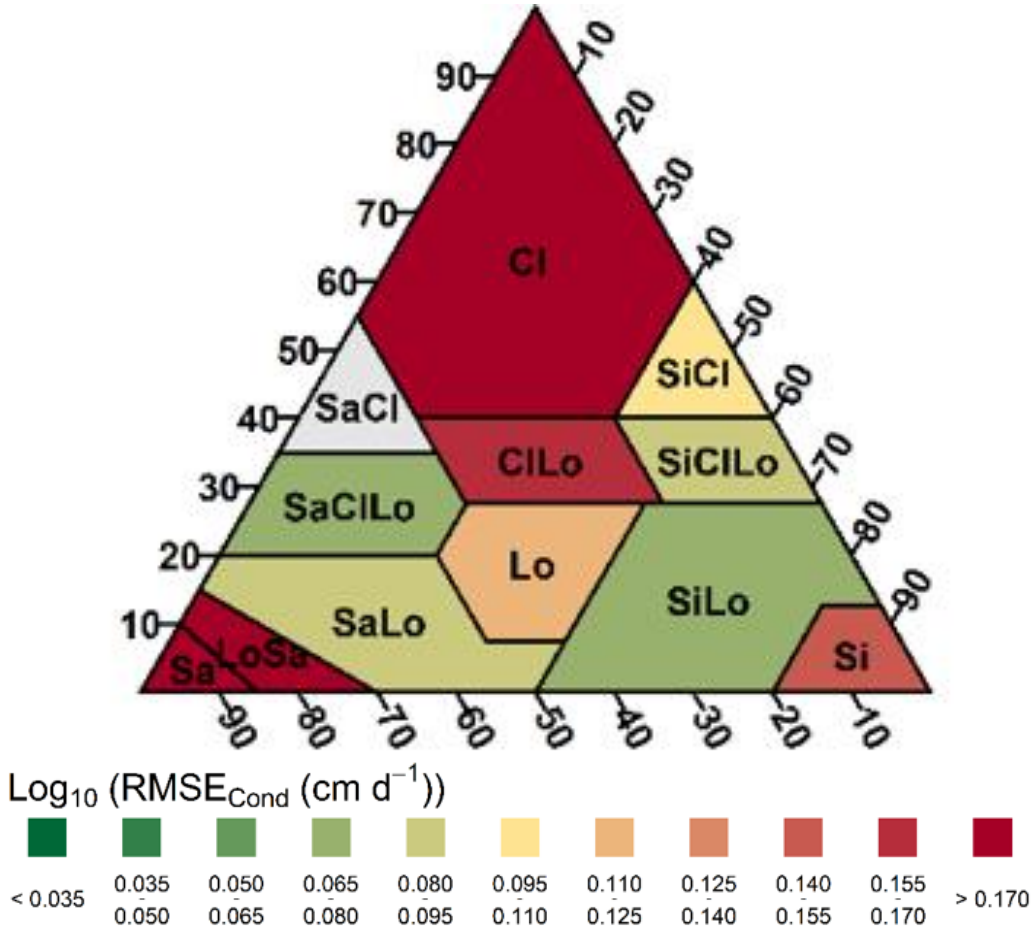
Model performance

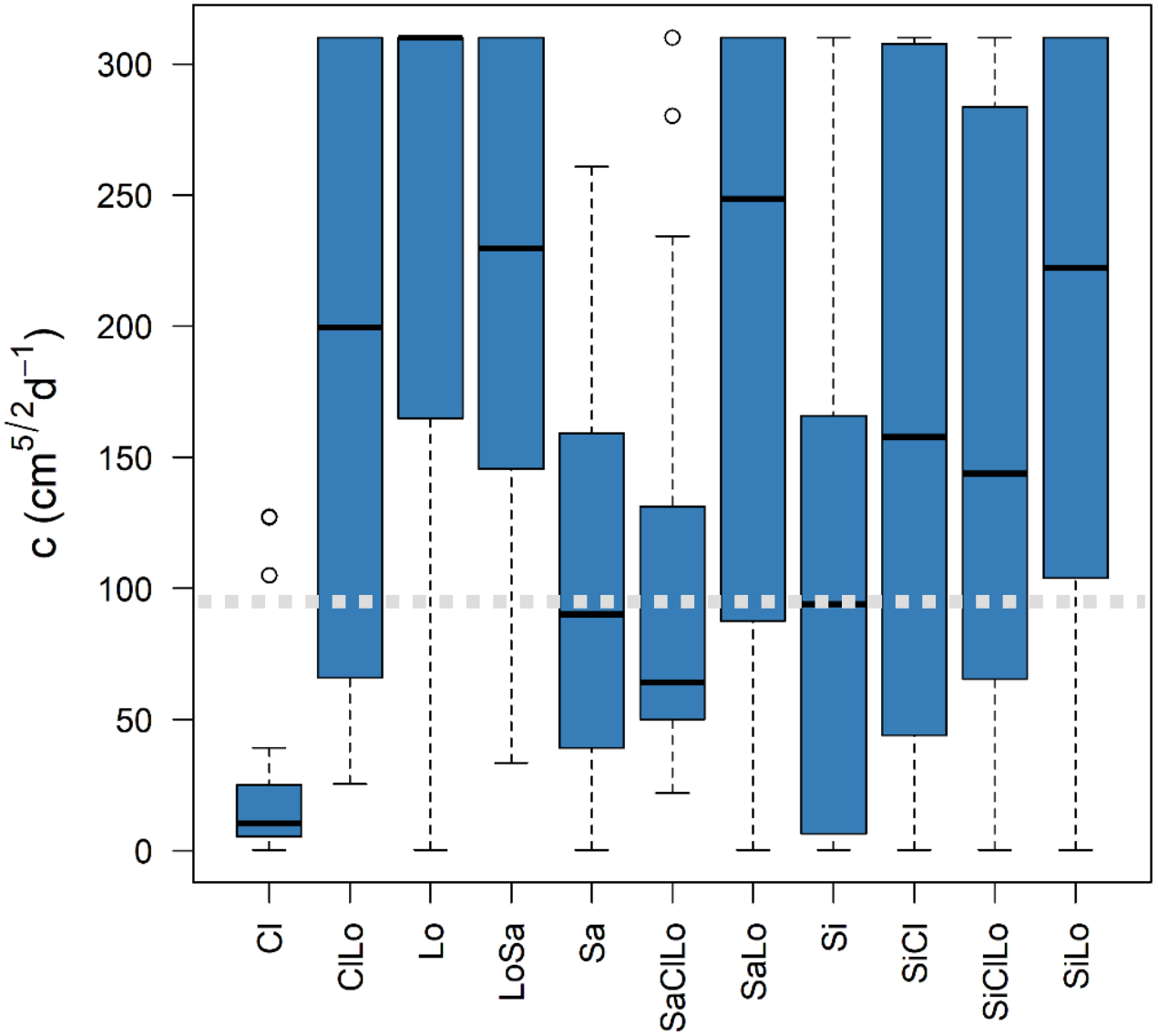
Root mean Squared errors (RMSE):

- Retention model: similar for **PDI** and **PDIc**
- Conductivity model: decrease in the order **orig** > **PDIc** > **PDI**

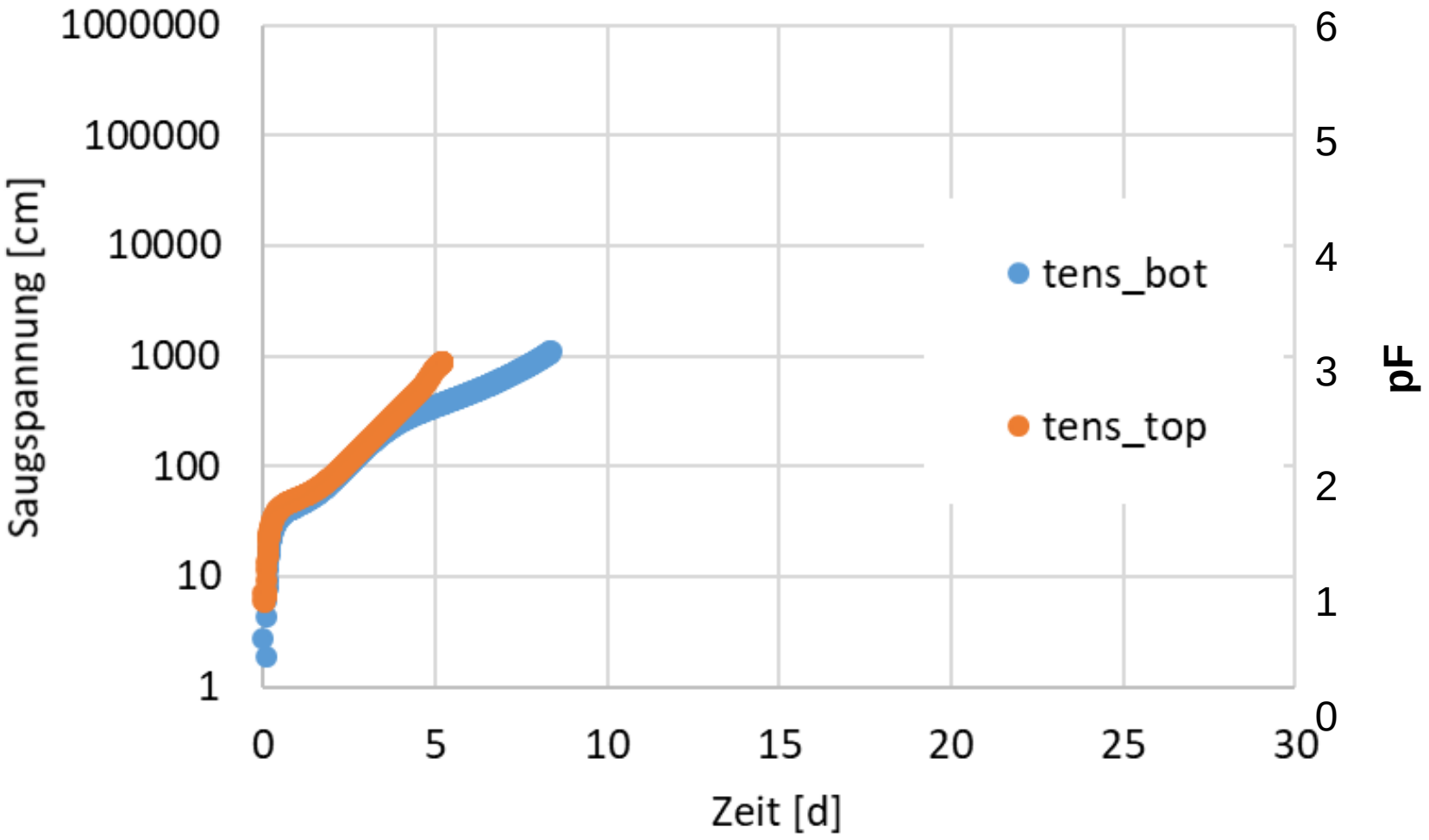


Is there a unique best „c“ for all soil texture classes?

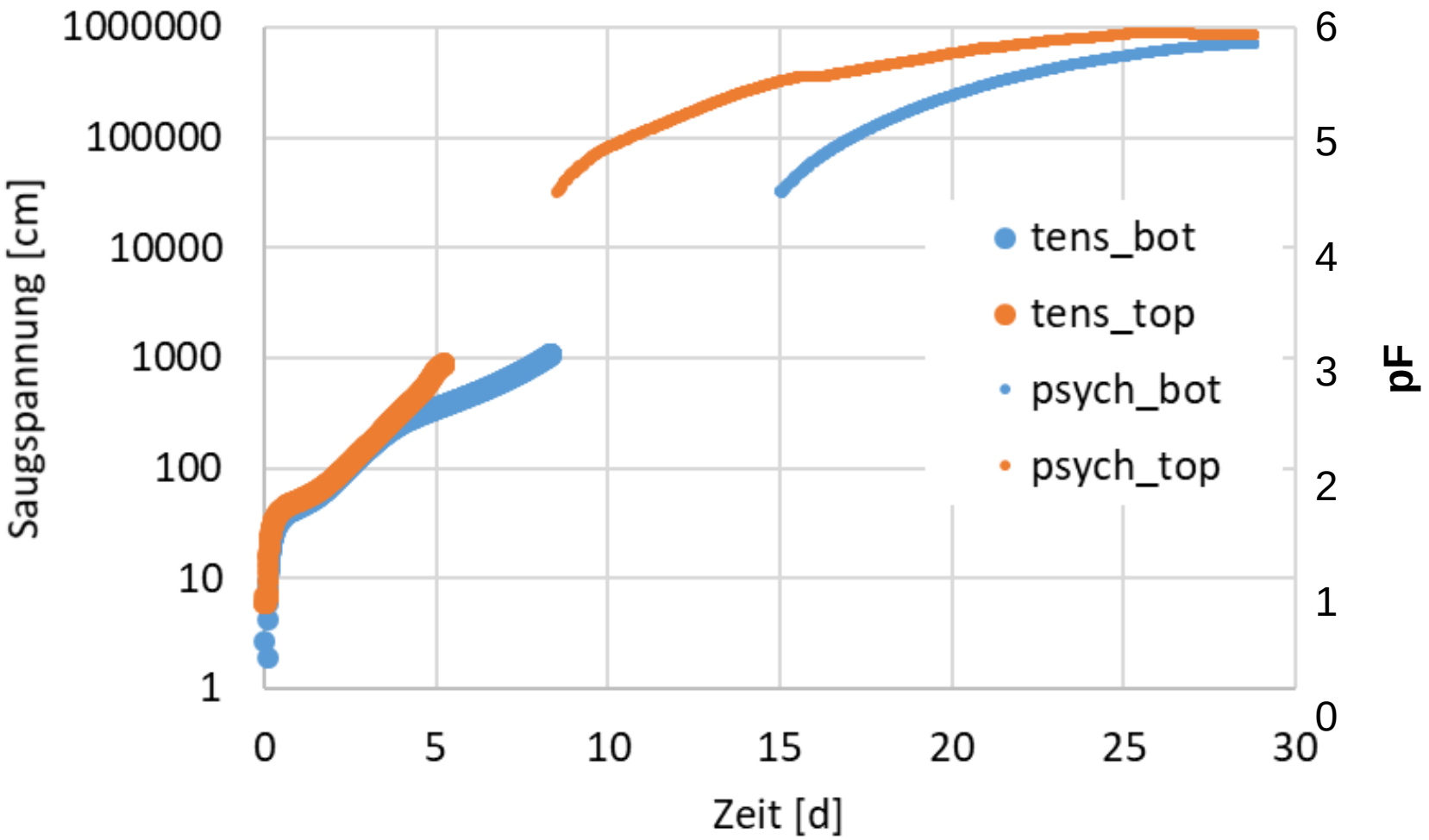




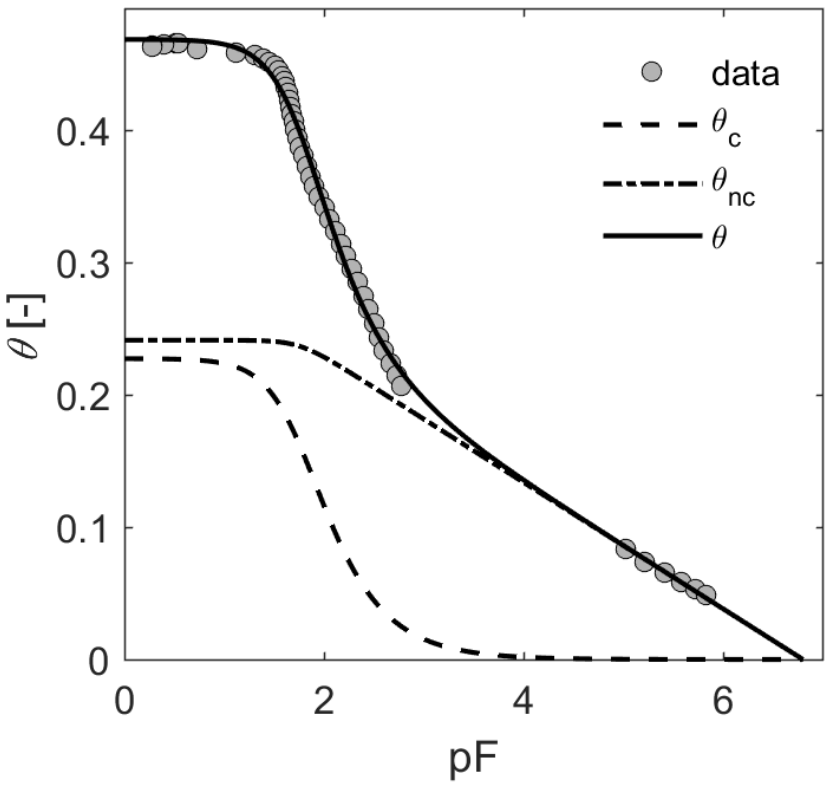
Outlook

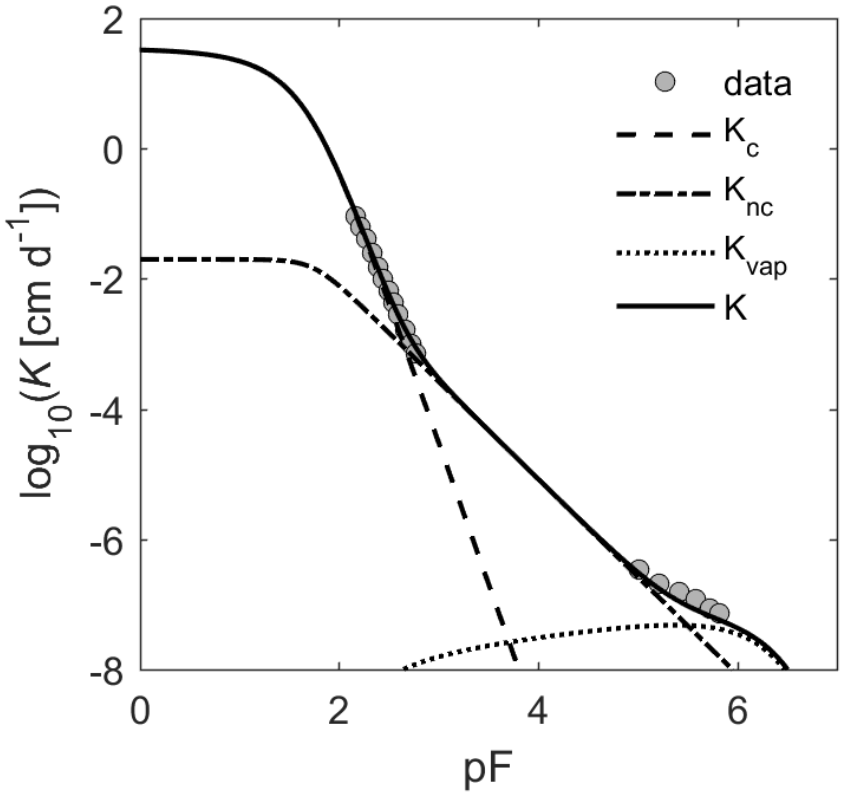


range of tensiometers:
pF 0 to pF 3



range of psychrometers: pF 4.5 to pF 6





Range for Psychrometers: pF 4.5 to pF 6

p: 0.5 for tensiometer data and 0.1 for psychrometer data

Acknowledgements

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- We thank **Conrad Jackisch**, **Johanna Metzger**, **Frederic Leuther** and **Janis Kreiselmeier** for providing data to our data collection.

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