143ESP - Soil Physics for Engineers

Soil hydraulic characteristics

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Models of porous media transport usually solve Richards equation

Richards equation

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial x}\left(K(h)\left(\frac{\partial h}{\partial x} + \cos(\alpha)\right)\right) - S$$

Soil water interaction is (in the model) controlled with **soil hydraulic characteristics**, such as:

- **retention curve**
- **hydraulic conductivity curve**

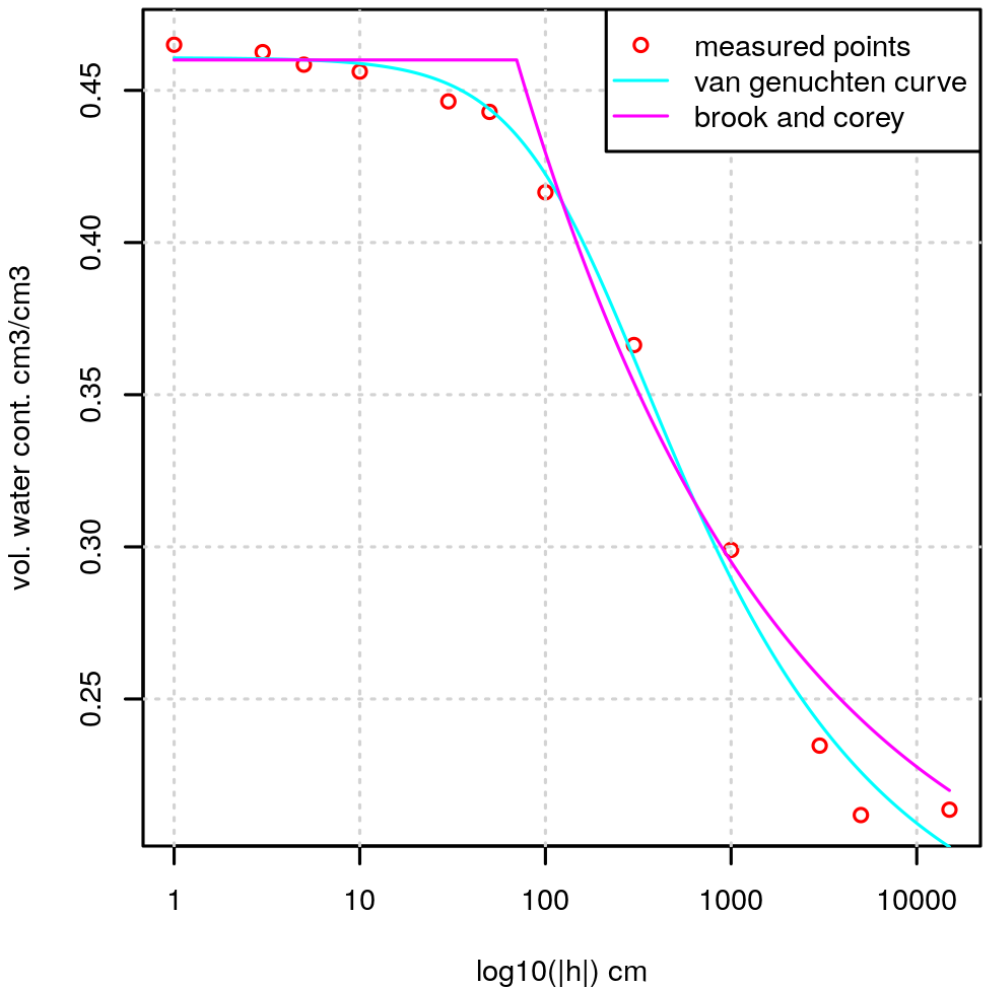
Soil hydraulic characteristics are **measured** or obtained with **pedotransfer functions**.

Retention curve

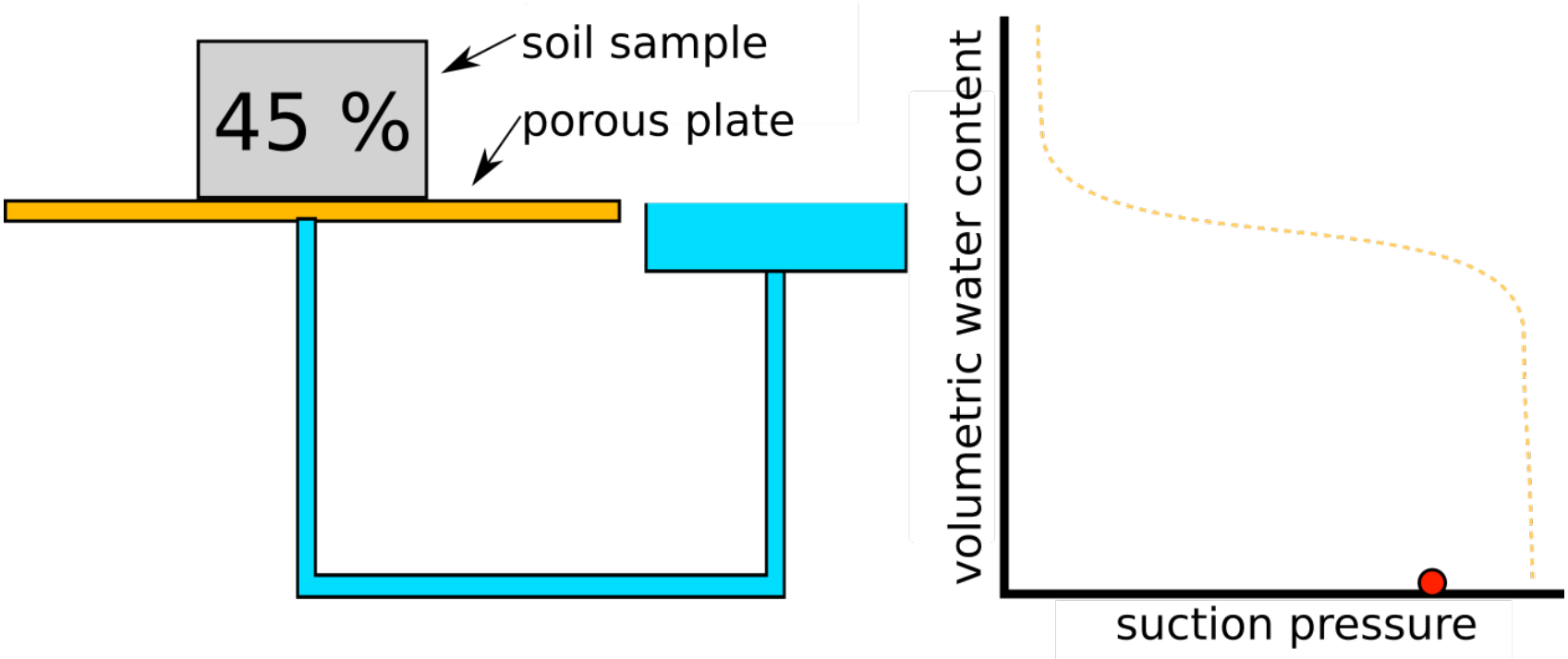
What is retention curve?

Retention curve

RC describes relationship between **suction pressure (sací tlak)** and **volumetric water content (objemová vlhkost)**.



Measurement procedure



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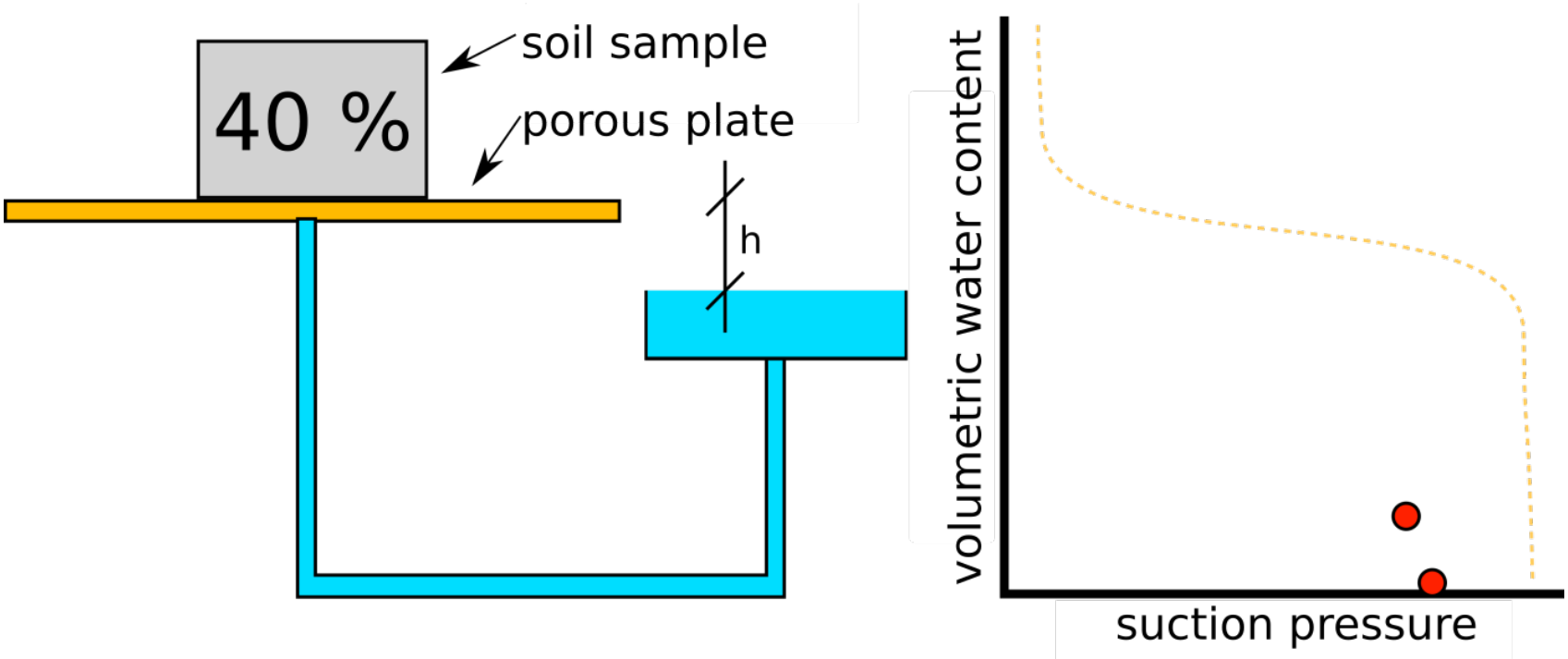

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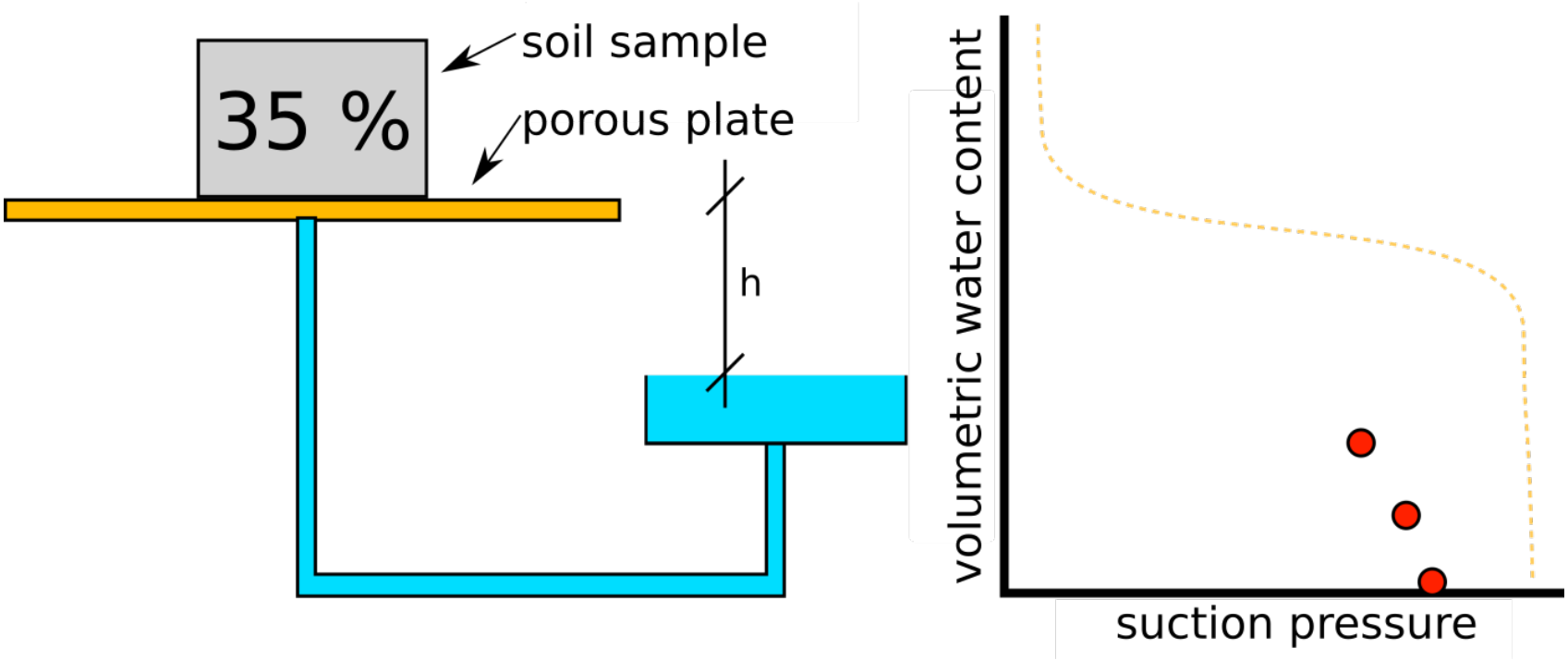

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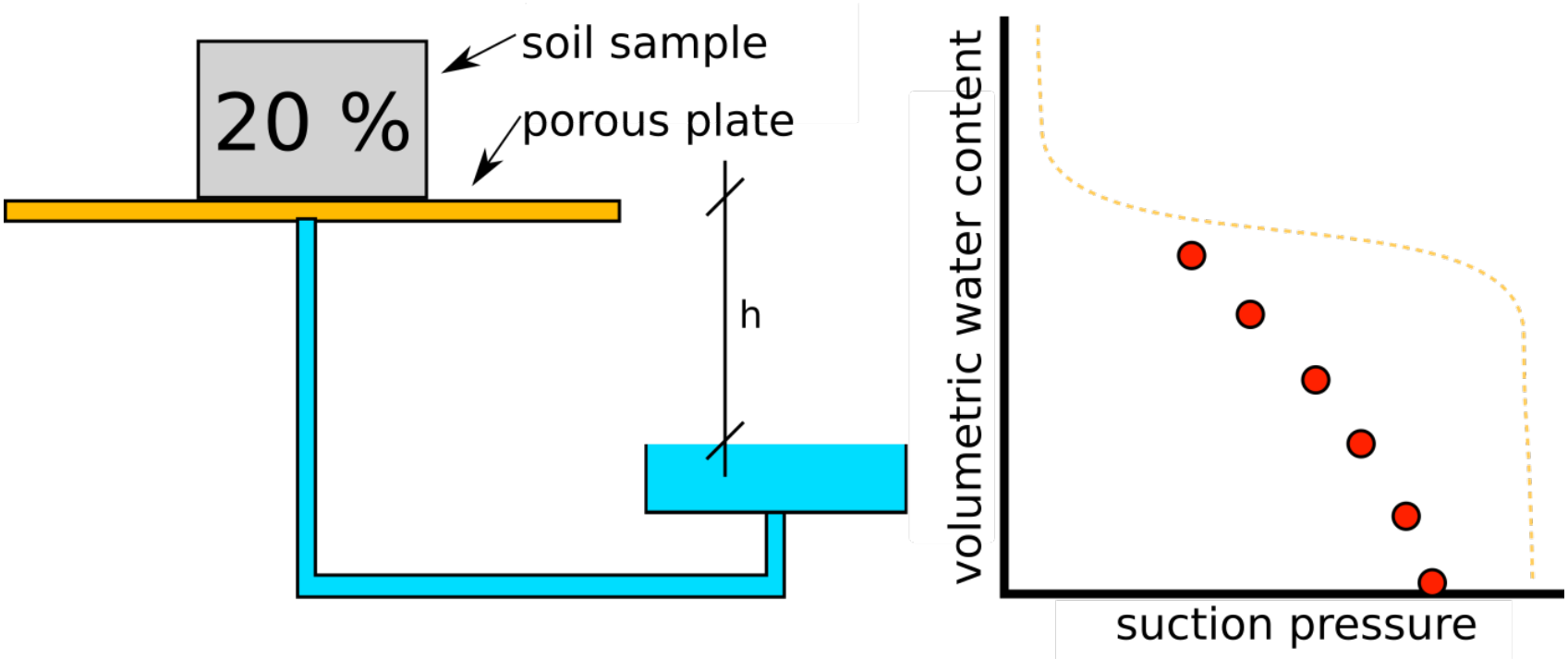

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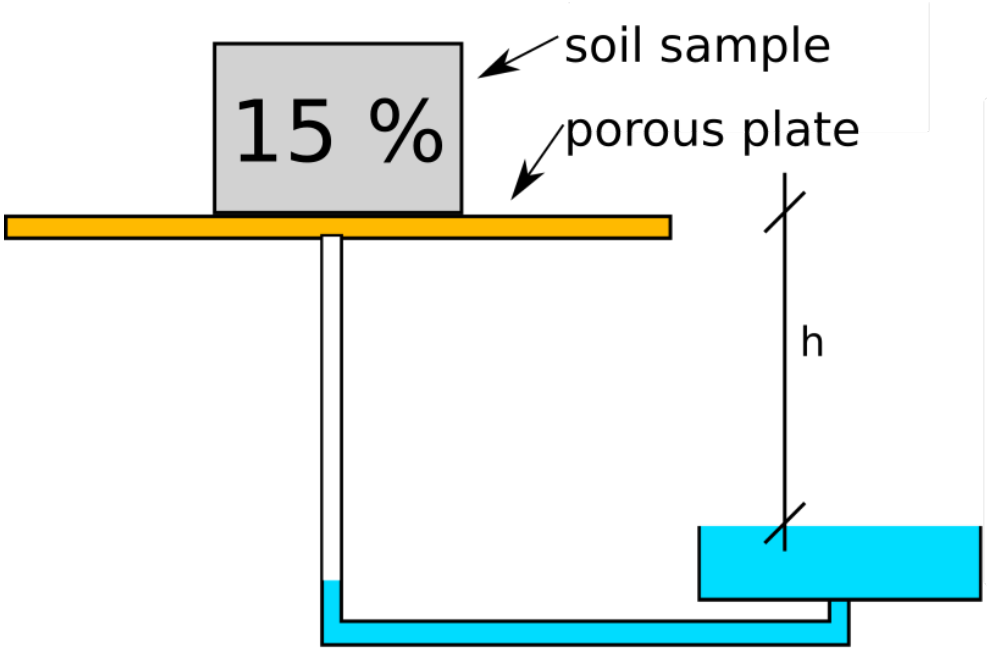
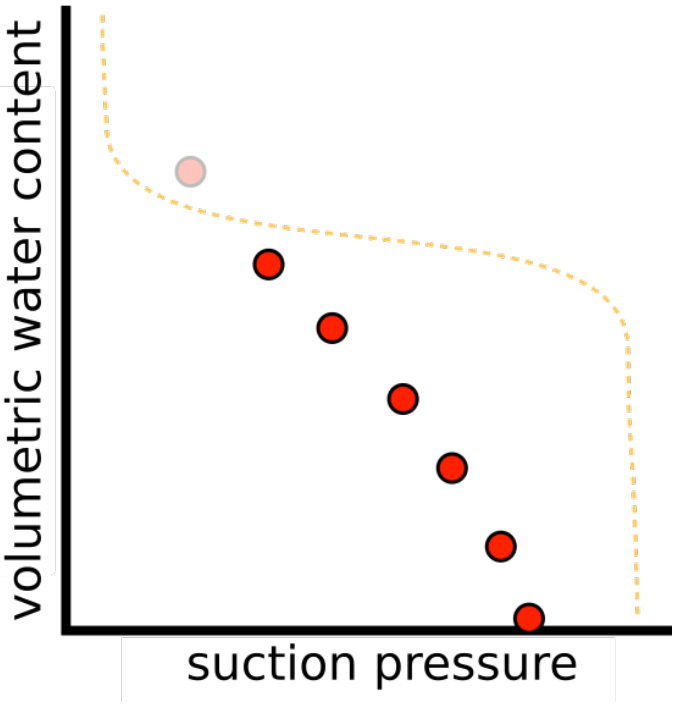




Retention curve

RC describes relationship between **suction pressure** and **volumetric water content**.

Measurement apparatuses

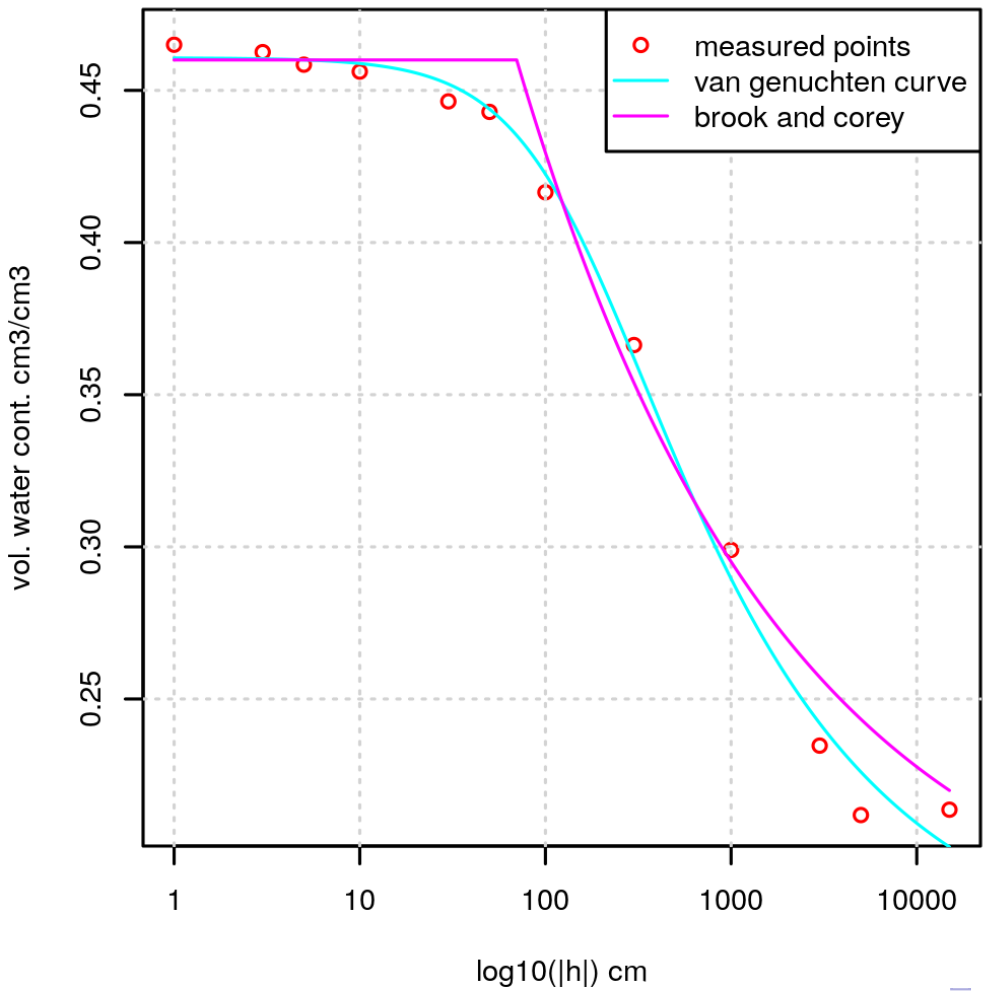
sand tank (pískový tank) - pressures 0 - 1 m
clay tank (jílový tank - pressures 0 - 5 m
pressure chamber (přetlakový aparát) - pressures up to 10 bars
evaporation method (výparoměrná metoda) - pressures up to 12000 hPa

100 cm (of water column) $\sim$ 100 hPa $\sim$ 0.1 bar

Measurement procedure

Retention curve

RC describes relationship between **suction pressure** and **volumetric water content**.



Retention curve - parametrization

RC is parameterized with a function. Most common ones is **Brooks & Corey (1964)**

$$\theta_e(h) = \begin{cases} \left(\frac{h_b}{h}\right)^{\lambda}, & \text{if } h < h_b \\ 1, & \text{otherwise} \end{cases}$$

where h_b is bubbling pressure (vstupní hodnota vzduchu) and λ is pore size distribution index.

Effective vol. water content θ_e is defined as

$$\theta_e = \frac{\theta - \theta_r}{\theta_s - \theta_r},$$

where θ_s is saturated water content and θ_r is residual water content.

Retention curve - parametrization

RC is parameterized with a function. Most common ones is

van Genuchten (1978)

$$\theta_e(h) = \begin{cases} \frac{1}{(1+(\alpha|h|)^n)^m} & \text{pro } h < 0 \\ 1 & \text{pro } h \geq 0 \end{cases}$$

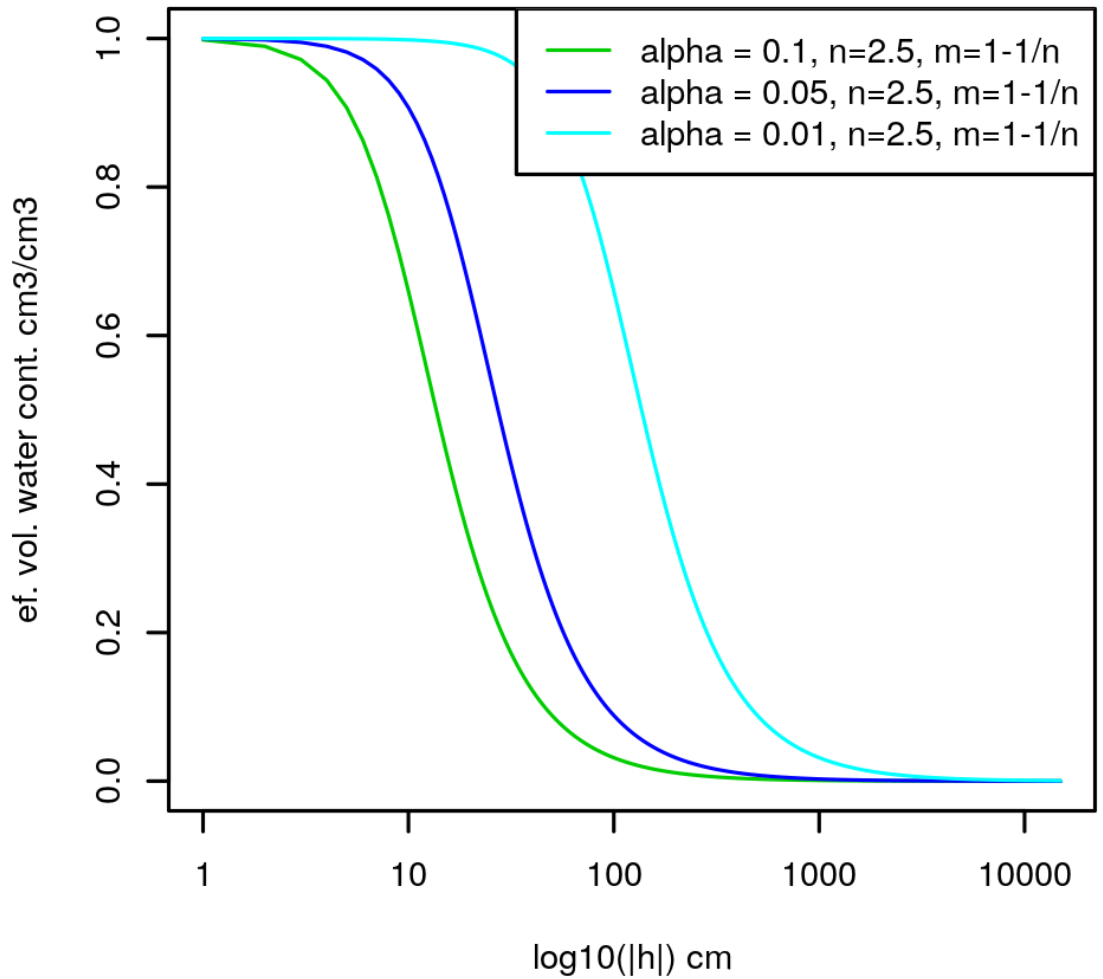
where α, n, and m are fitting parameters.

$\alpha = 1/h_b$
$\theta_e = (\theta - \theta_r)/(\theta_s - \theta_r)$, and

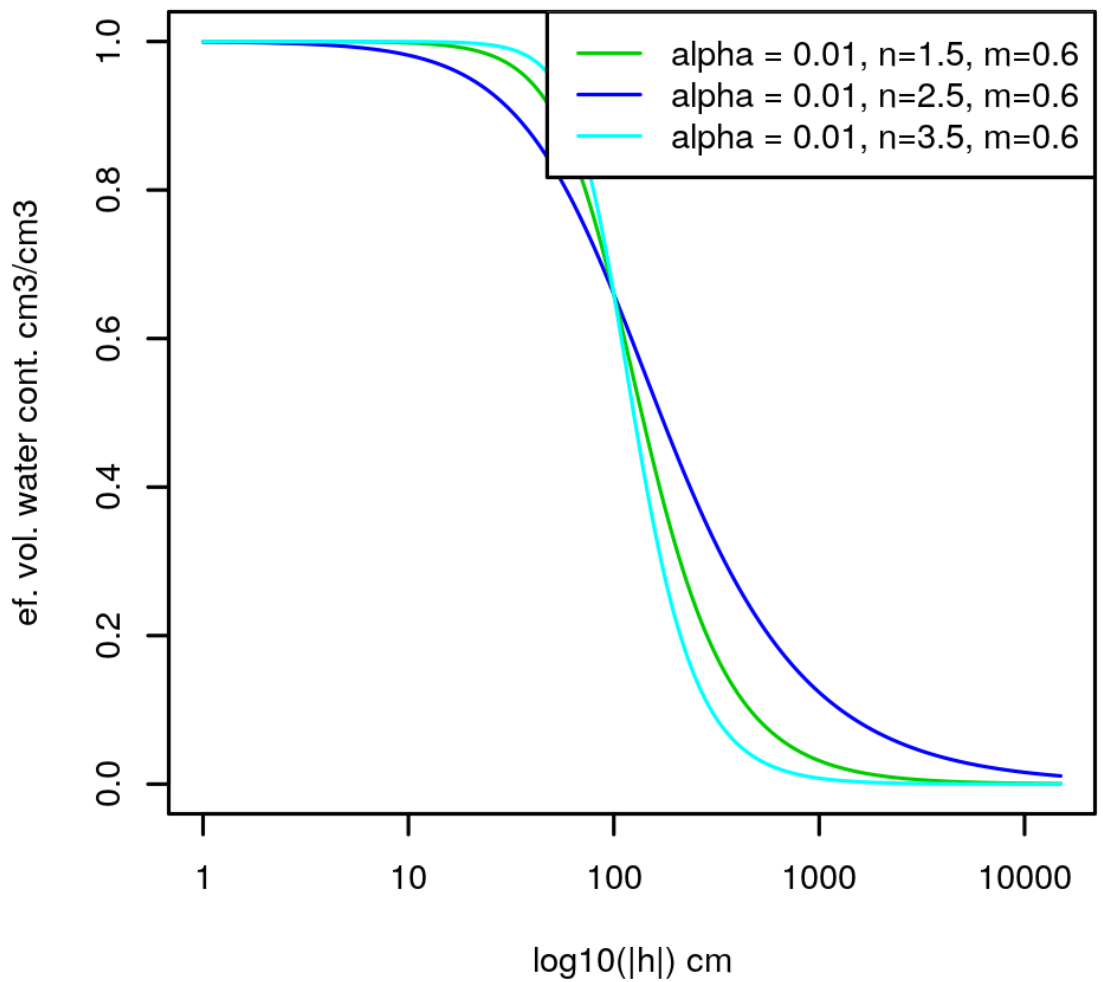
m is often
$m = 1 - 1/n$

van Genuchten RC is often used in models because it is continuously differentiable (in contrast to Brooks & Corey).

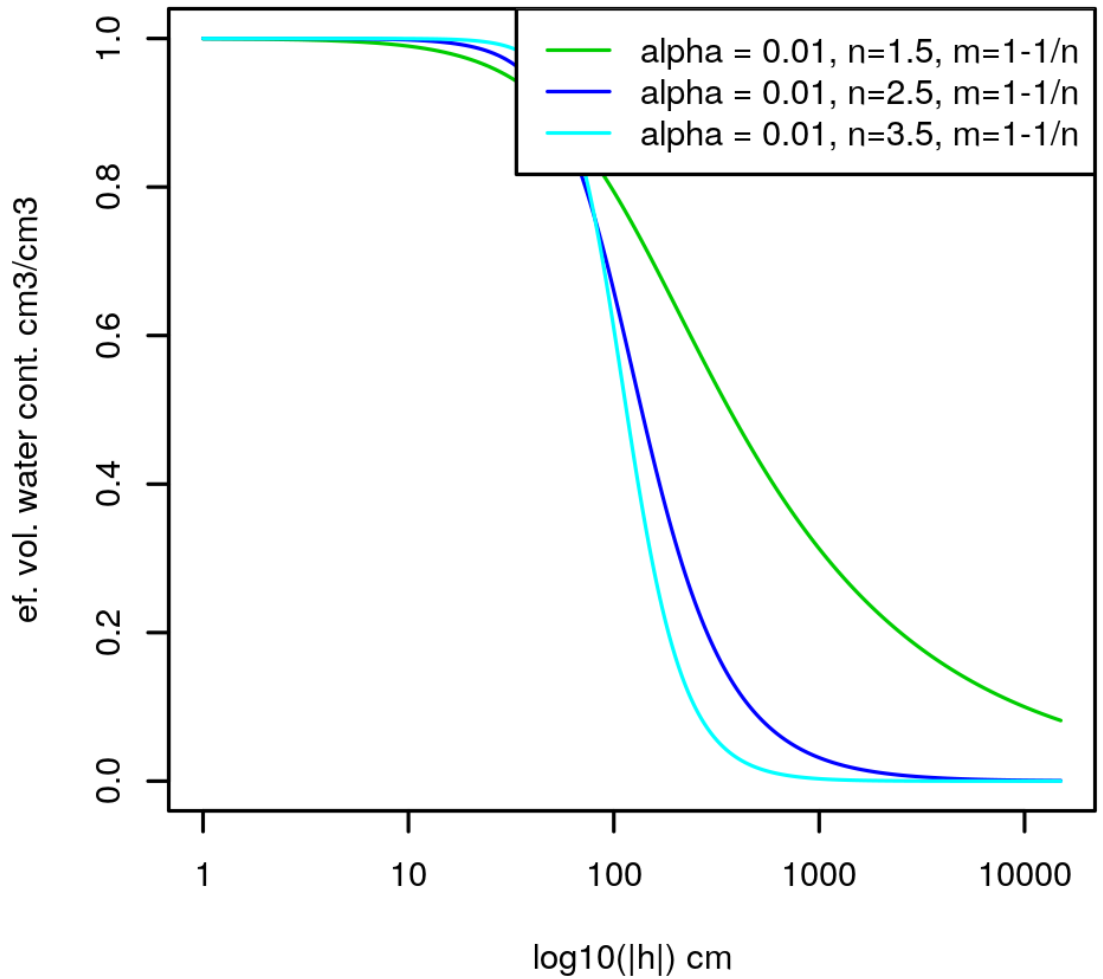
van Genuchten RC



van Genuchten RC



van Genuchten RC



Pedotransfer functions

What are pedotransfer functions?

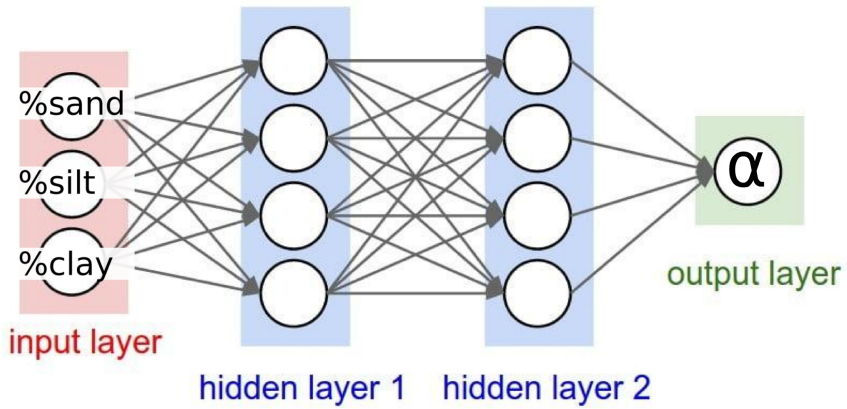
Pedotransfer functions

- Retention curve and unsaturated hydraulic conductivity is **hard to measure**
- PTFs estimate retention curve and unsaturated hydraulic conductivity from more readily available data
  - soil type, soil texture, bulk density
- Huge database of data is needed
- PTF is obtained by regression analyses of with artificial neural network (**ROSETTA in RETC**)

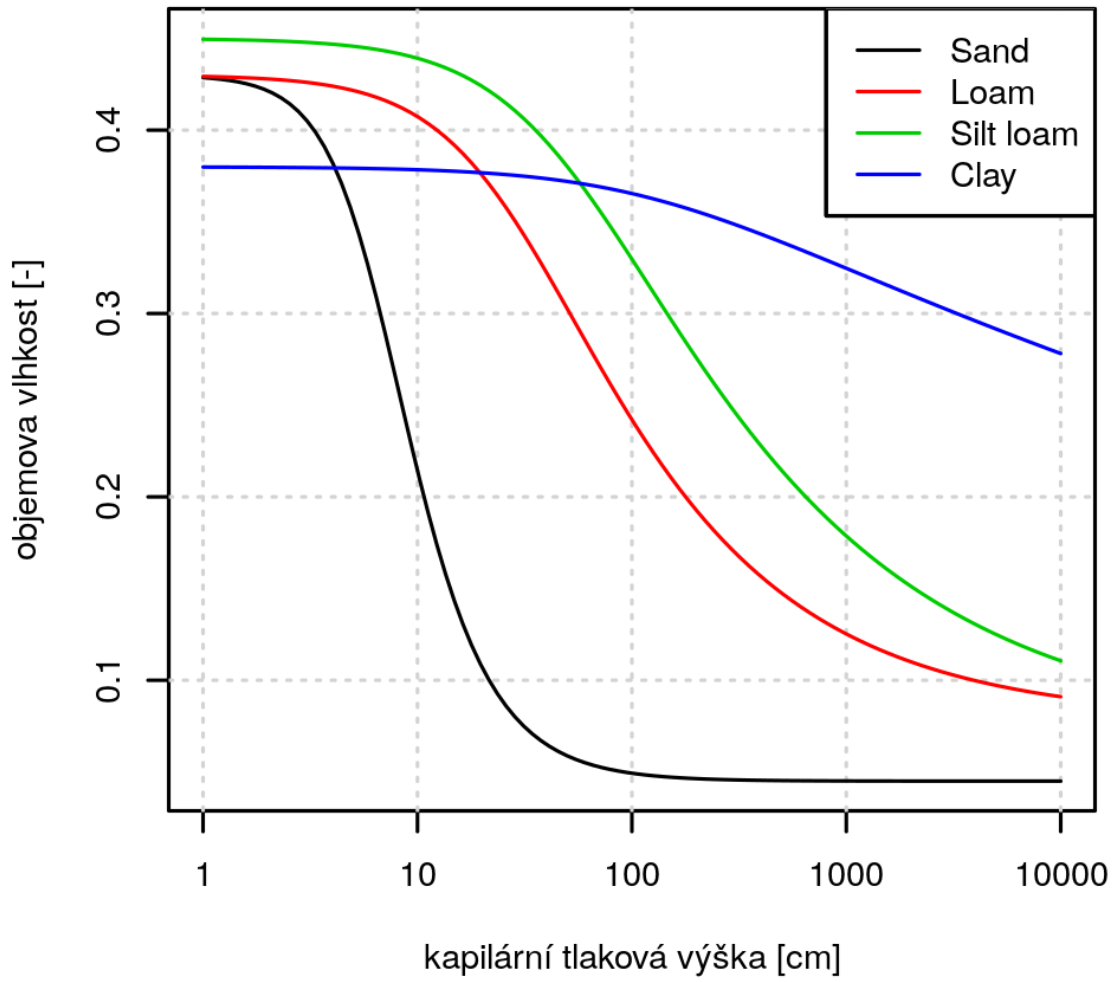
Regression analyses

$$\alpha = a\ \%sand + b\ \%silt + c\ \%clay$$

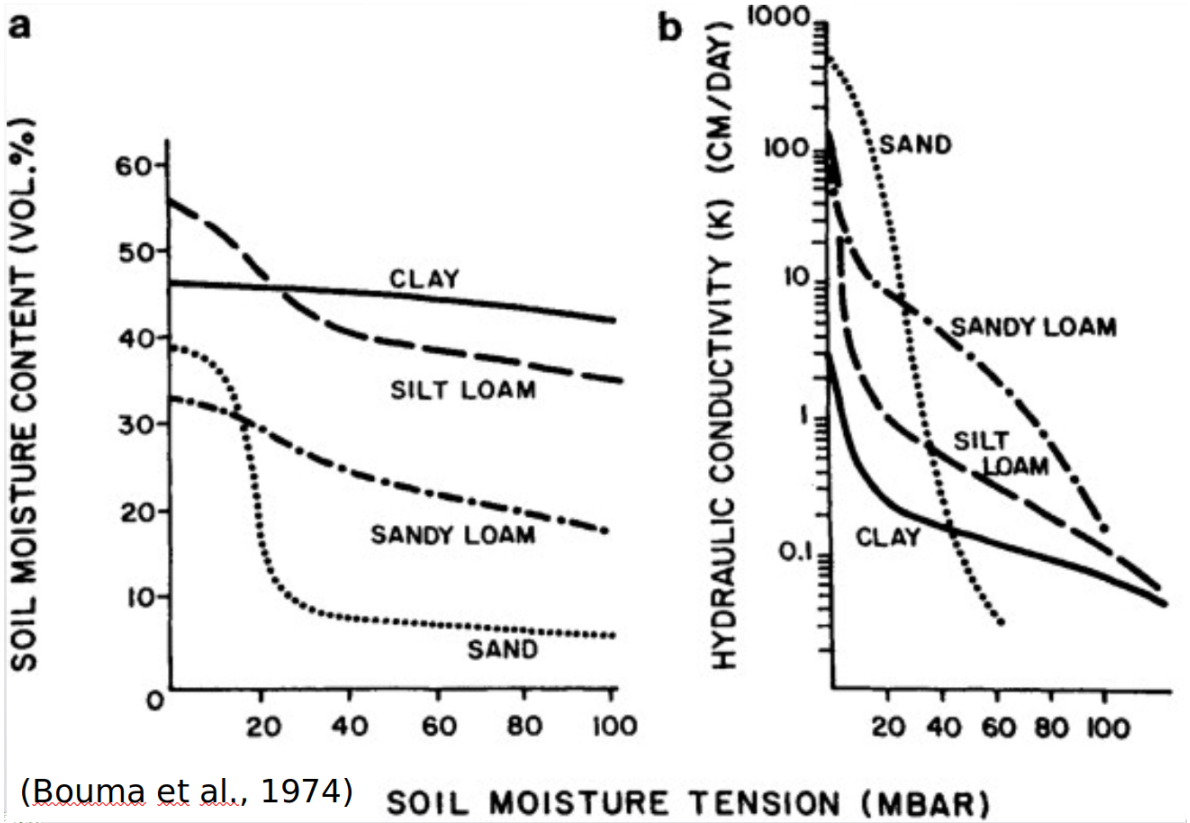
Artificial neural network



van Genuchten - Pedotransferové funkce



Retenční čára

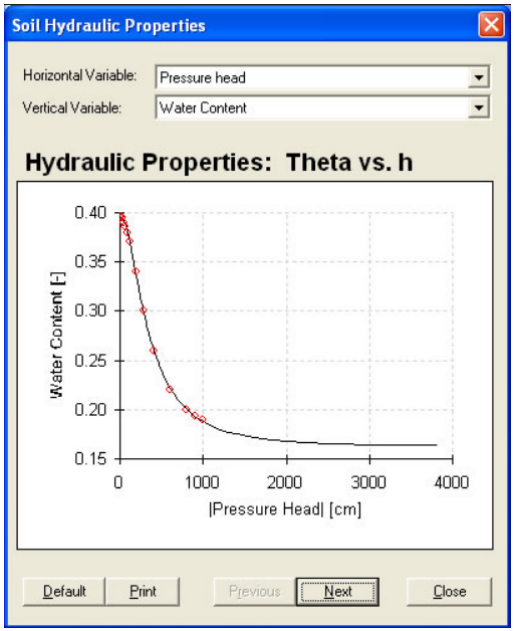


(Bouma et al., 1974)

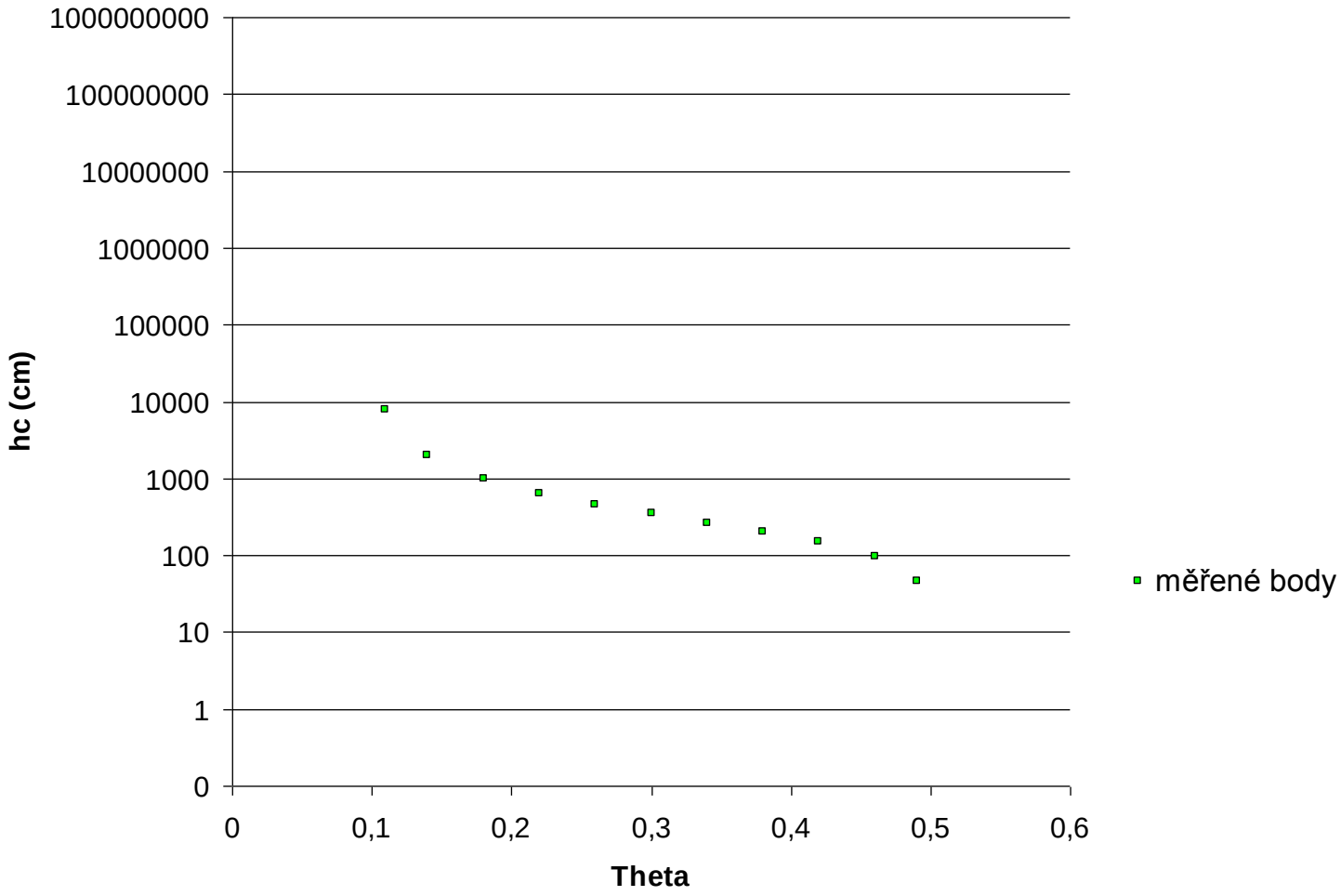
What is RETC?

RETC

- is a program for analysis of the **soil hydraulic parameters** in variable saturated porous media
- fits a measured RC data using **van Genuchten or Brooks & Corey**
- estimates unsaturated hydraulic conductivity based Mualem or Burnin model
- contains **ROSETTA**, a neural network predictor of the soil hydraulic parameters



Optimalizace parametrů pomocí RETC



Měřené body

theta	h [cm]
0.5	0
0.49	46
0.46	97
0.42	150
0.38	204
0.34	267
0.3	346
0.26	458
0.22	636
0.18	980
0.14	1990
0.11	7998

Iterační postup

NIT	SSQ	ThetaR	ThetaS	Alpha	n
0	0.76804	0.057	0.41	0.124	2.28
1	0.27738	0.078	0.4233	0.0368	1.6262
2	0.03992	0.107	0.4922	0.0082	1.3885
3	0.00237	0.0564	0.5155	0.0072	1.5746
4	0.00117	0.0666	0.5123	0.0062	1.6804
5	0.00047	0.0801	0.5081	0.0057	1.7832
6	0.00033	0.1023	0.5002	0.0049	1.9695
7	0	0.1001	0.5	0.005	1.9994
8	0	0.1	0.5	0.005	2
9	0	0.1	0.5	0.005	2

Průběh iterací

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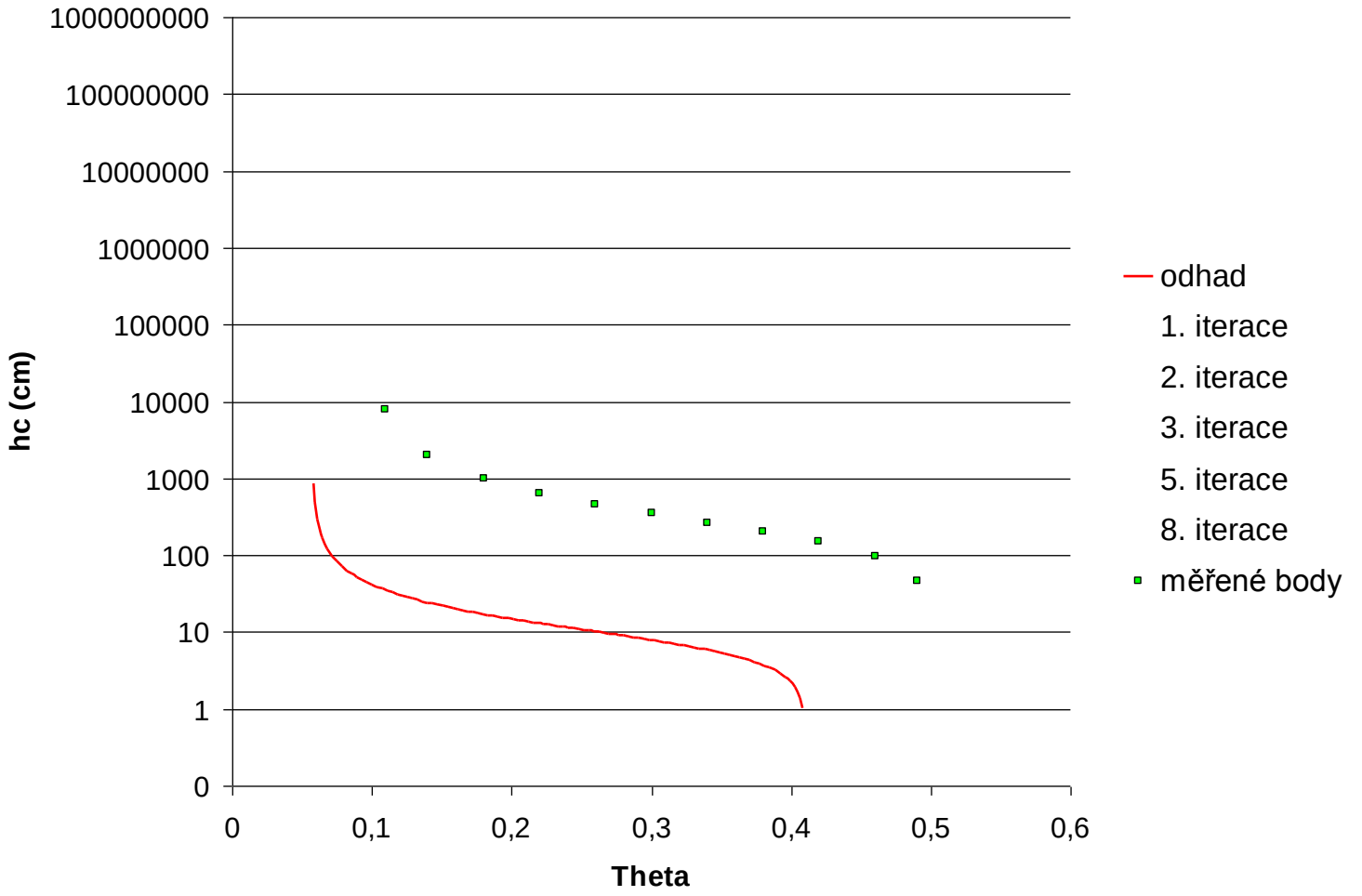

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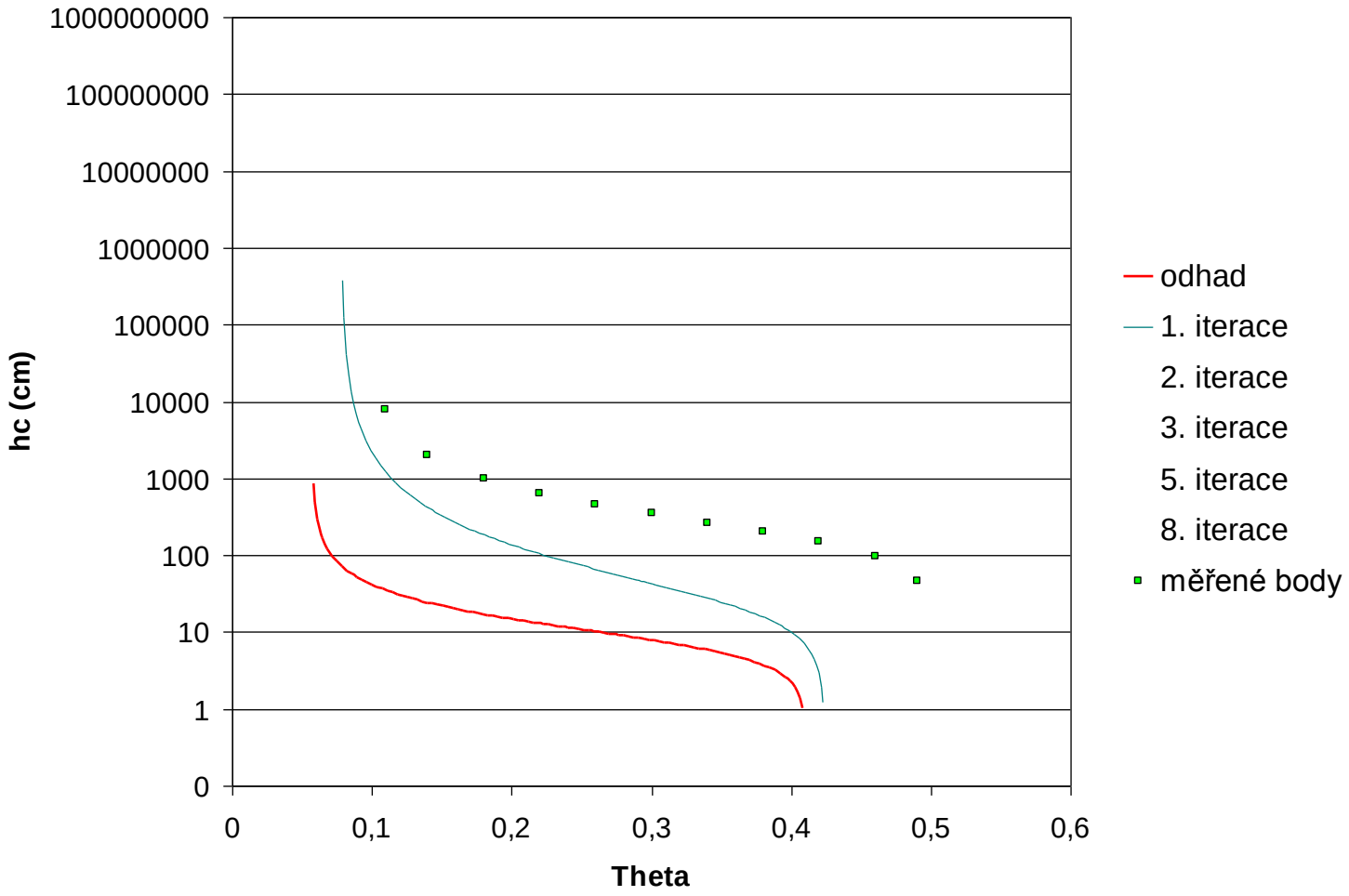

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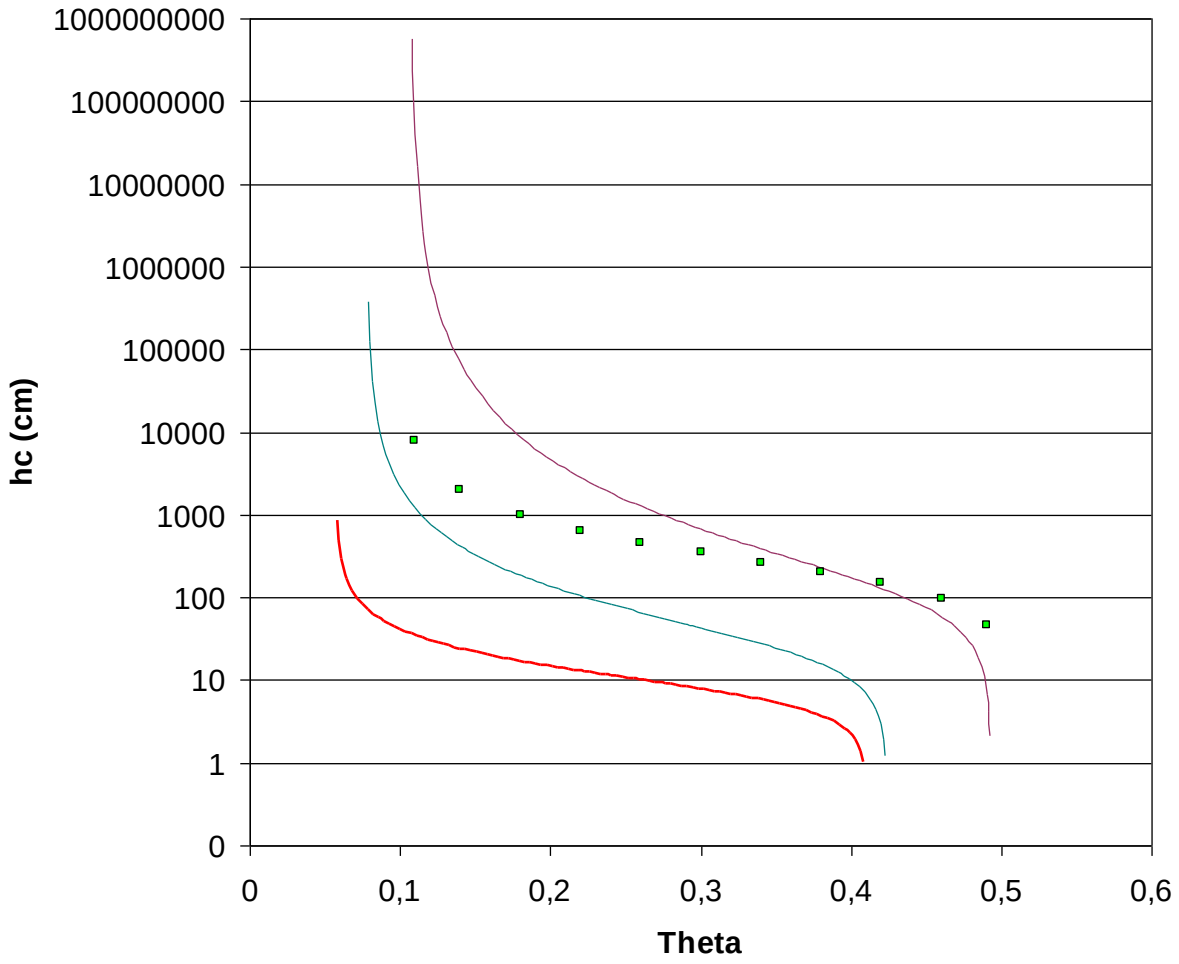

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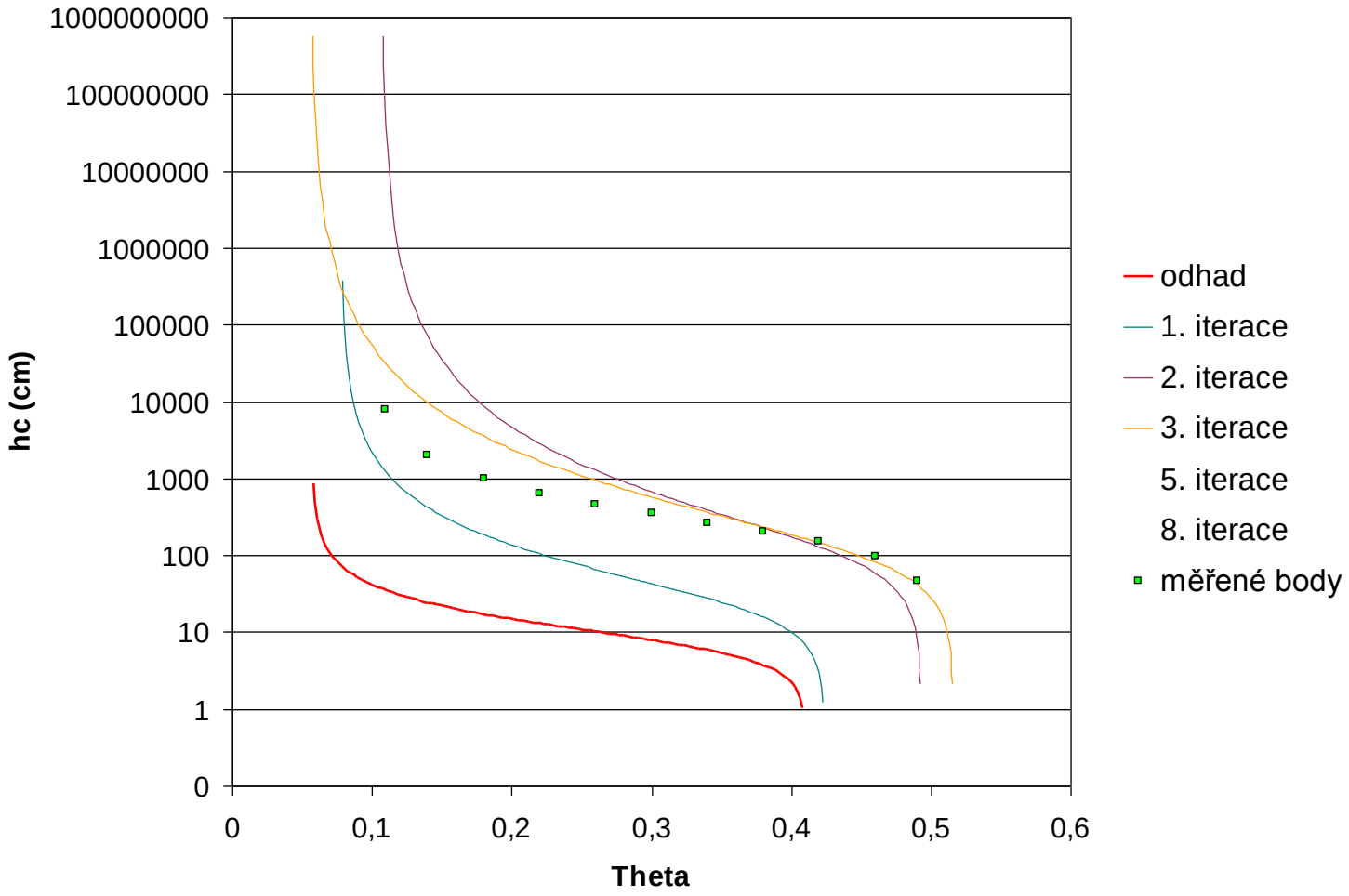

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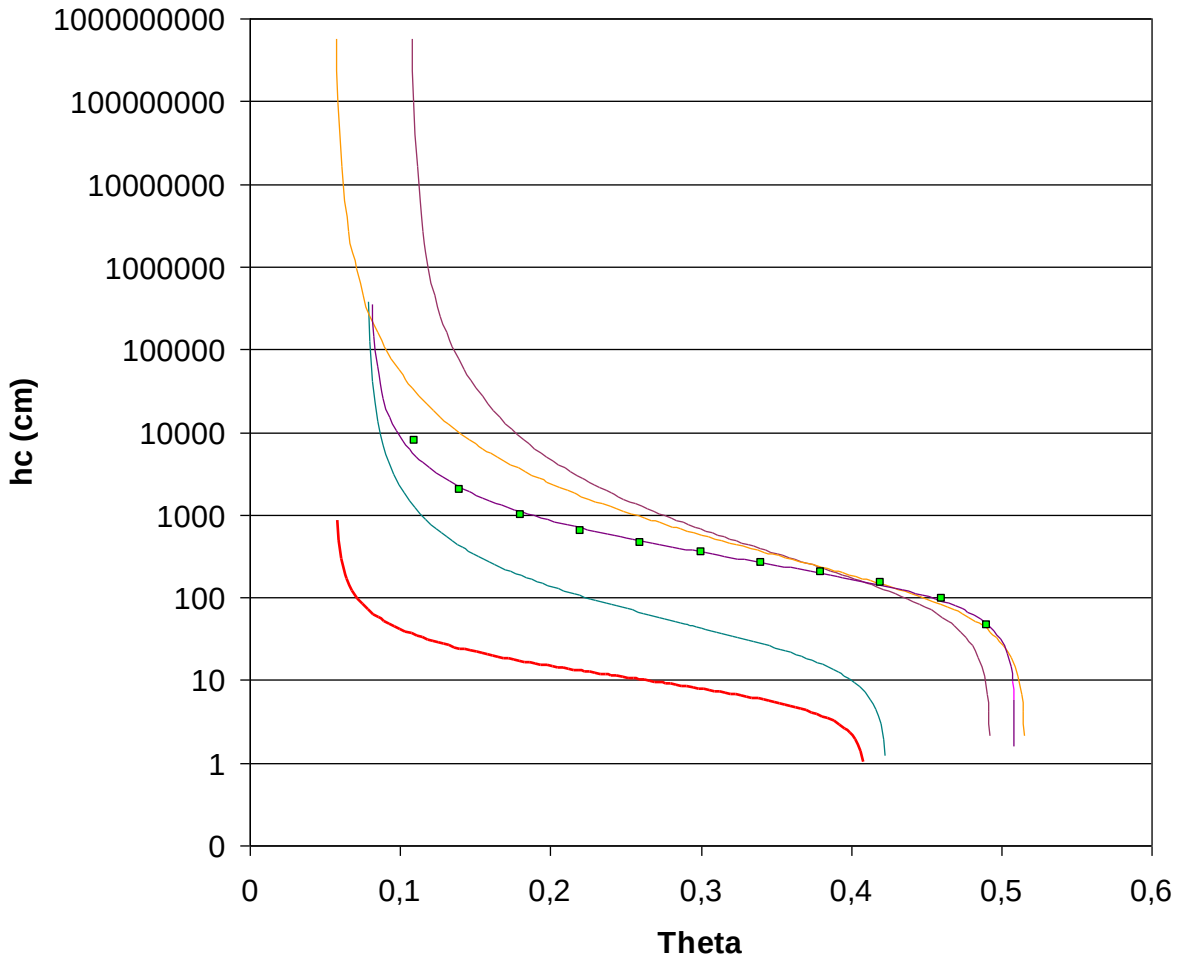

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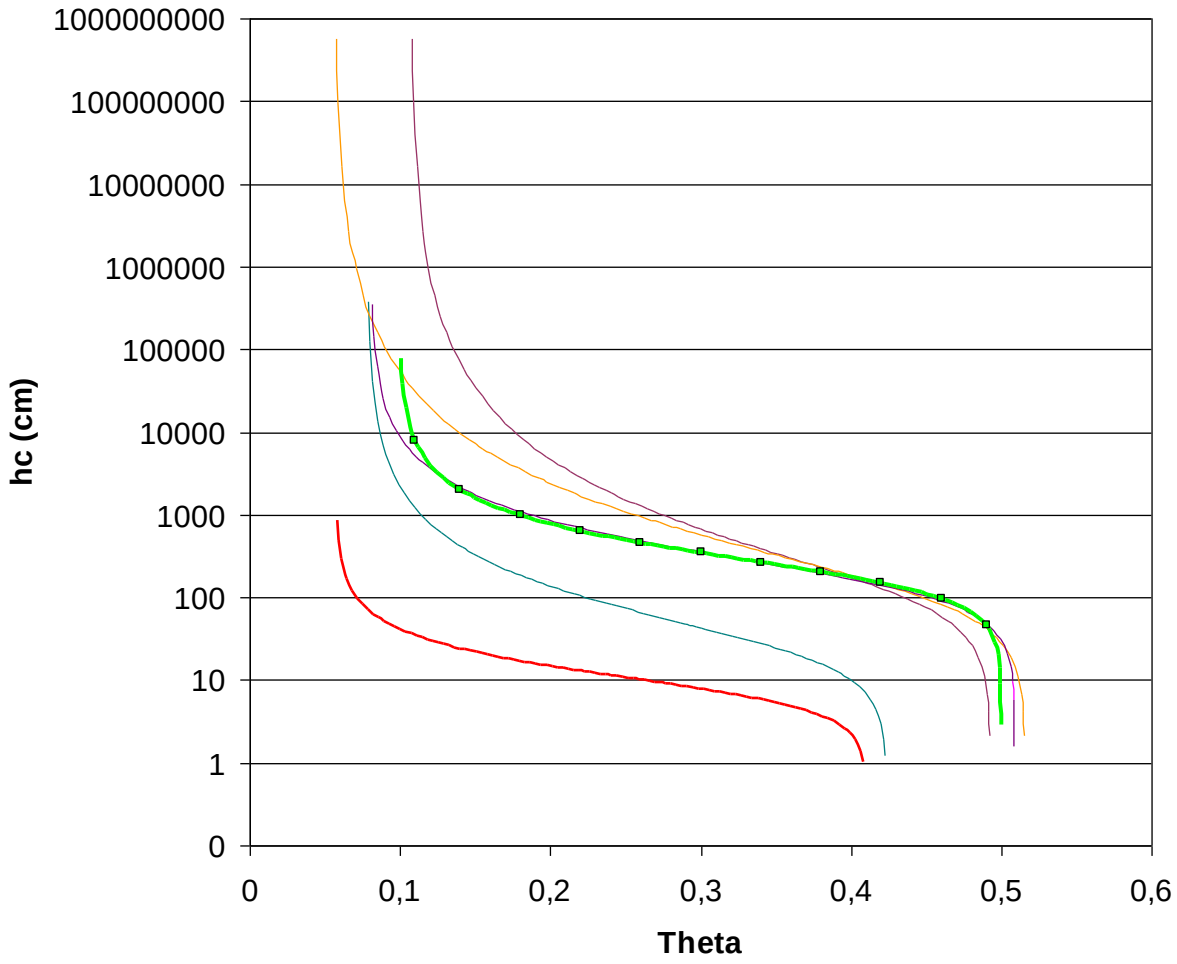

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Assignment - (1/3)

Data of retention curve were measured at 2 soil samples at sand tank and in pressure chamber.
Use program RECT to estimate van Genuchten's and Brooks & Corey RC parameters.

1. Get parameters: α, n, θ_r and θ_s for van Genuchten RC and h_b, λ, θ_r and θ_s for B&C RC.
2. Show measured points and parametrized RC in a graph

Measured data are bellow.

Assignment - (2/3)

Soil textural and bulk density data were obtained for one disturbed soil sample.
Use program RECT and neural network predictor ROSETTA to estimate parameters of van Genuchten's ~~and Brooks & Corey~~ RC.

1. Get parameters: α, n, θ_r and θ_s (van Genuchten) ~~and h_b (B&C)~~
2. Show parametrized RC in a graph

Measured data are bellow.

Assignment - (3)

Several tensiometers gauges were installed in the soil profile (tensiometer nest) at several depths. The soil profile is composed of three soils and the position of the water table is known.
Using the van Genuchten RCs from previous problems, analyze the water regime in the soil at a given time. Use transiometer measurements and knowledge of the position of the water table.

- Plot pressure head, total potential, and volumetric water content as a function of depth.
- Determine the amount of water in the soil profile above the water table.

The values of the tensiometers and and their installation depth can be read from the figure below.

Data for assignment (1/3)

SOIL 1

h (cm)	Water cont.
1	0.365
10	0.232
30	0.177
58	0.149
89	0.137
500	0.119
6000	0.107
Ks = 280 cm/day	

SOIL 2

h (cm)	Water cont.
1	0.310
10	0.268
30	0.241
58	0.199
89	0.177
500	0.152
6000	0.137
Ks = 65 cm/day	

Figure: Measure data of two soils.

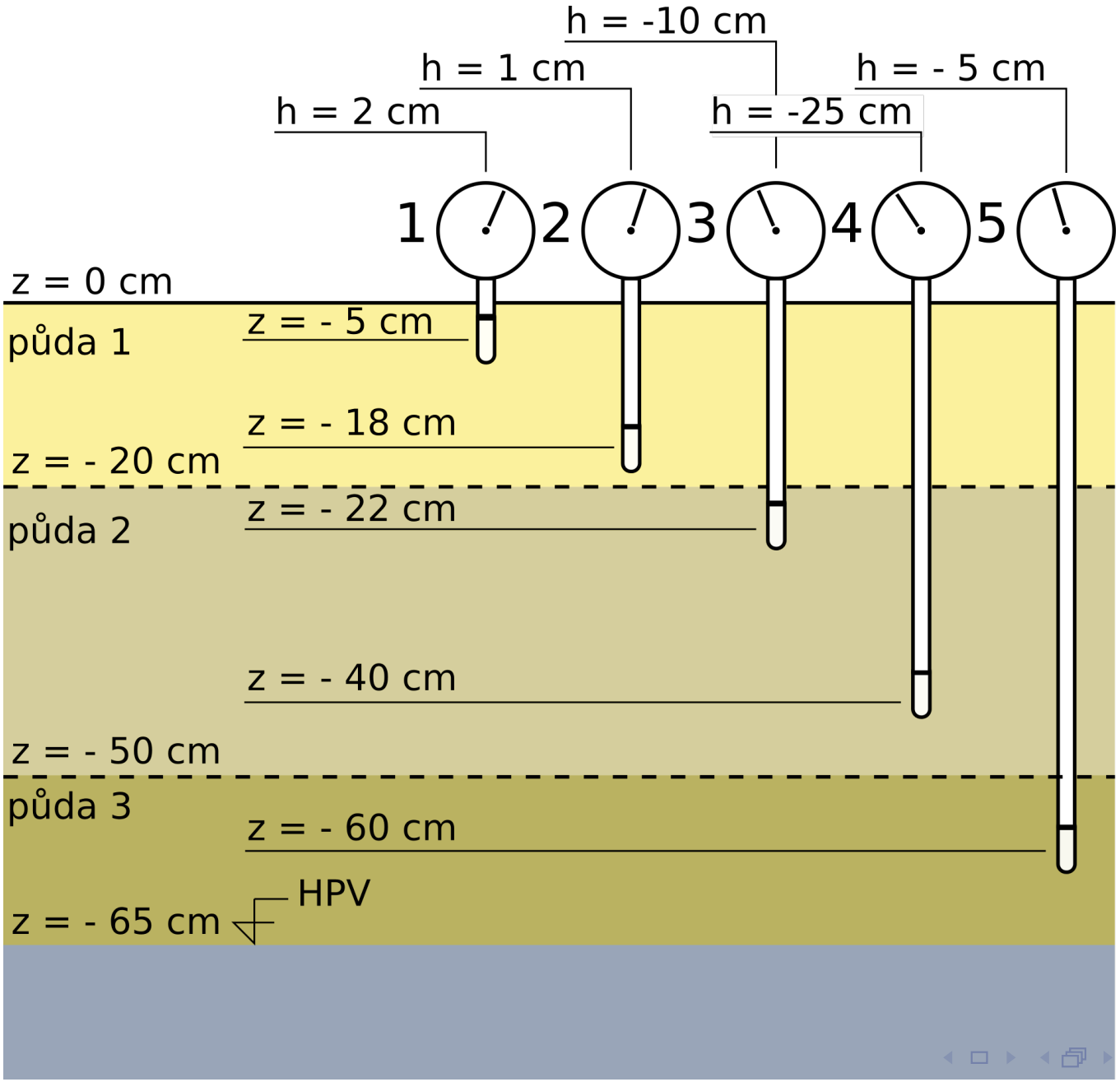
Data for assignment (2/3)

Coefficients :
A ... number of letters in first name
B ... number of letters in surname

bulk density $\rho_b = 1.5 + 0.1 * (A/3)\ g/cm3$

Soil texture data:
clay: $(A + B)$ %
silt: $(55 + B)$ %
sand: $100 - (clay + silt)$ %

Data for assignment (3/3)



Questions to answer

1. What data are needed to evaluate the retention curve using RETC?
2. What is the air entry value of all soils?
3. At what pressure head do soils 1 and 2 have the same volumetric water content?
4. Which soil is more sandy, which is more sandy loam, and which is clayey?
5. How much water is in the soil profile?
6. In which direction does the water in the soil profile flow?

Submit the Excel with problems 1 to 3 completed and answered. In person or by email to jakub.jerabek@fsv.cvut.cz. Please use subject: **143ESP**.

References

RETC: Manuál + program: www.pc-progress.com/

ROSETTA: Manuál + program: cals.arizona.edu/

Schaap et al., 2001. Rosetta: a computer program for estimating soil hydraulic parameters with hierarchical pedotransfer functions, Journal of Hydrology: link