On the role of structure in PTFs

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Outline

Soil structure and soil function

Incorporating structural information into PTFs

i) linking structure and function

ii) identifying structure forming agents

iii) finding proxies for inferring soil structure

PTFs, structure and scale

Rainer’s dilemma
What kind of structure are we talking about?

- Pore network
- Material distr.
- Chemical props.
  - Adsorption props.
- Mechanical props.
- Biology
- Scales are in the range of 1 to 3 cm
- Keck et al. 2017
- Keck et al. 2017
- Hapca et al. 2015
- Element distr.
Soil functions influenced by soil structure listed in Rabot et al. (2018):
“Soil structure as an indicator of soil functions: a review”

Are identical to the target properties of all the PTFs discussed in Van Looy et al. (2017):
“Pedotransfer functions in Earth system science: ...” !!!!!
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Structure and function

Mineralization
Nutrient accessibility
Surface area
Air diffusion/transport
Soil respiration
Redox potential
Soil fertility
Root development
Soil ecology
Filtering properties
Solute/colloid transport
Hydraulic properties
Heat capacity/transport
Mechanical stability
Erodibility
Trafficicability
It is known that soil structure plays a role for these functions...

But this knowledge is still mostly qualitative.

Future research needs to quantify importance of soil structure on the respective functions.
Incorporating structural information into PTFs

i) linking structure and function

ii) identifying structure forming agents

iii) finding proxies for inferring soil structure
Linking structure and function

An example

95 undisturbed soil columns
X-ray imaging
Ks measurement

SoilSpace project, NFR2013/668, PI: Attila Nemes
Predicting permeability from pore network properties

Linear, stepwise regression on log values of bootstrap samples

Out-Of-Bag validation

Most important predictors:

Critical pore diameter
Euler number
Fractal dimension
Ok, this was quite promising...

But a PTF that requires X-ray imaging is a step forward albeit Sample and image acquisition and analyses takes time and effort

Another step forward would it be to find proxy variables

That allow PTFs for soil structure

In the optimal case these would be derivable from remote sensing data or digital soil maps or similar
Suitable proxy variables for PTFs for soil structure require research on agents that are responsible for soil structural properties, e.g. the critical pore diameter.
What are candidates for such agents?

It is known that at least 10% of clay are needed for a stable structure (but that does not mean that other structural features are homogeneously distributed, e.g. soil water repellency)

Prime candidates for such agents are soil macrofauna like earthworms or vegetation (roots and their exudates)

In turn these will be subject to variables like local climate, geology, etc..
Why should proxy variables be derivable from remote sensing data or digital (3D) soil maps or similar?

Because scale matters and such maps deliver structural information that can be used for upscaling!
Different scale means different structures and associated processes and functions
Scale needs to be considered in PTFs or when applying them (see also Pachepsky and Hill, 2017)
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Small columns scale is the classical scale at which PTFs are derived

Why?
Because at this scale we can measure the soil properties relatively easily!!

Possible future developments

Development of PTFs at larger scales?

Upscaling of PTFs by including structural information?
Rainer´s dilemma

Soil macropore structure of an individual column

in June 2013  in September 2013
Time-series from a 3-D water retention experiments...

Large pores are growing on the expense of smaller ones during drying.
Worst case example of an imaged pore network before and after $K_{sat}$ measurement

SoilSpace project, NFR2013/668, PI: Attila Nemes
Soil matrix displacement caused by a growing dandelion root

Courtesy to Steffen Schlüter
Soil structure seems to be not overly time-stable!!

... which poses a large challenge for the Development of future PTFs!
Conclusion

By using non-invasive imaging techniques it becomes possible to investigate relationships between soil structure and soil function in unprecedented detail.

Development of PTFs including structural information that are applicable at a global scale is related with large challenges, i.e.

i) how to upscale and ground-truth cm-scale relationships
ii) how to deal with the temporal evolution of soil structure
Thank you for your attention!