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The need for and challenges in standardizing soil physical analysis

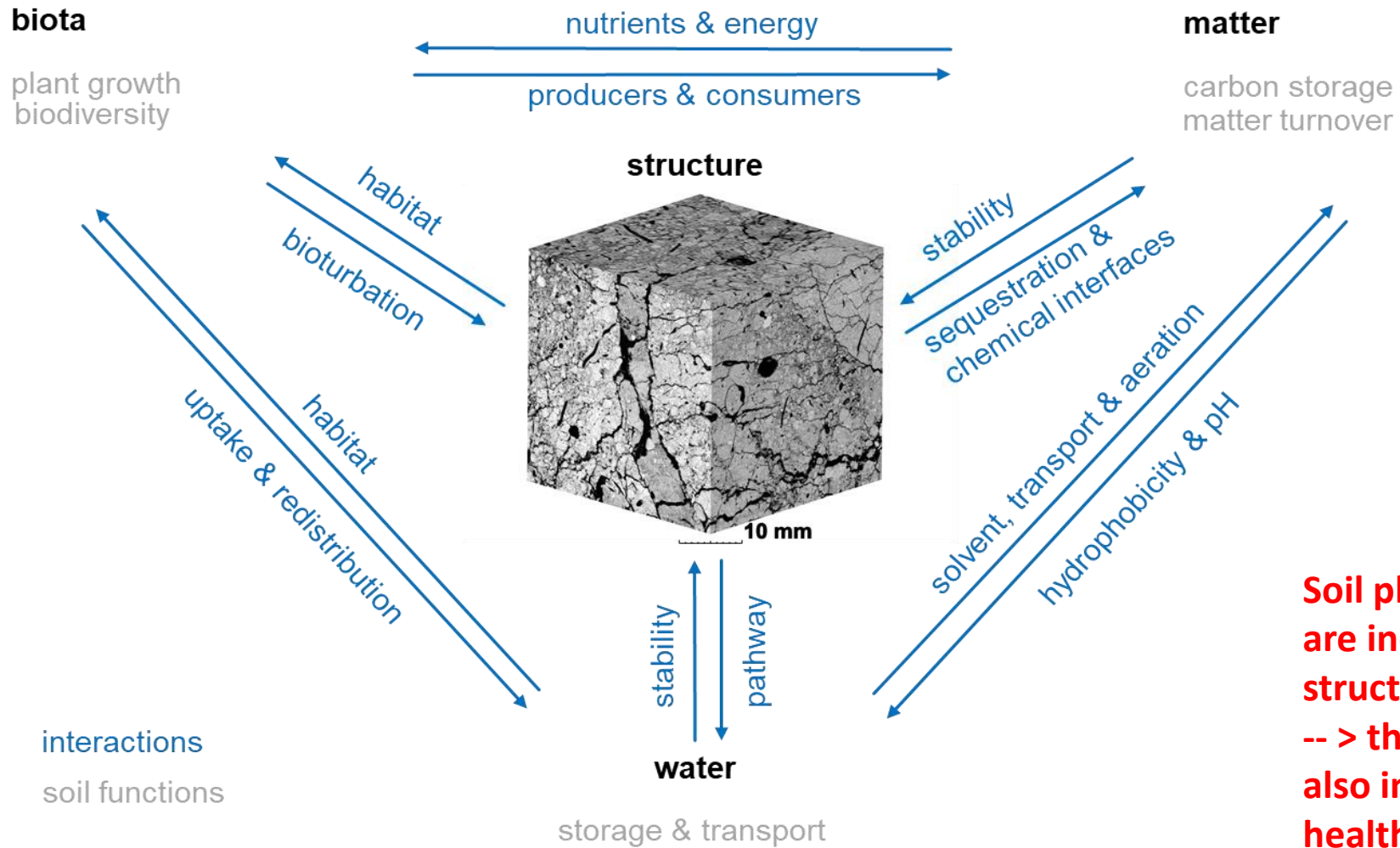
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Soil physical properties are indicators for soil structure



Soil physical properties are indicators for soil structure
-- > they are therefore also indicators for soil health

Schlüter & Koestel, Soil Structure, in: Encyclopedia of Soils in the Environment, Second Edition, 2023

Laboratory measurements of soil physical properties

Texture

Bulk density

Total porosity / solid phase density

Water retention curve

Saturated hydraulic conductivity

Hydraulic conductivity curve

Solute/colloid transport and diffusion properties

Gas conductivity

Gas diffusivity

Shrinkage curve

Uni-axial compressibility

Shear strength

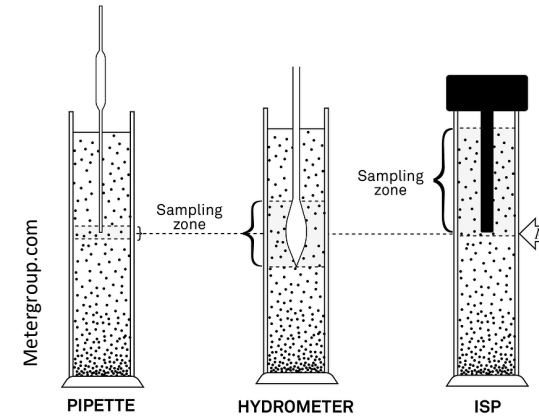
Penetration resistance

Aggregate size distribution

X-ray tomography

Thermal properties

...



Laboratory measurements of soil physical properties

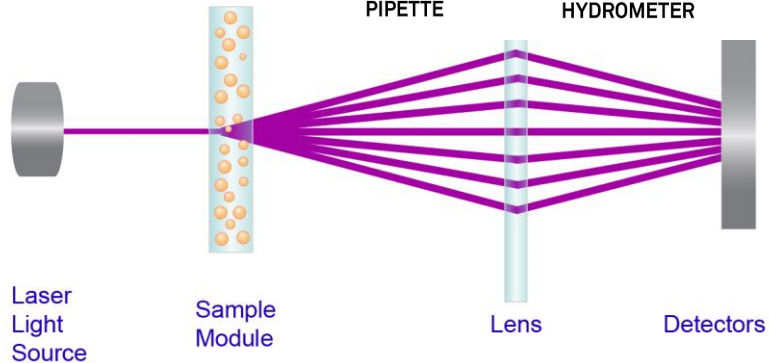
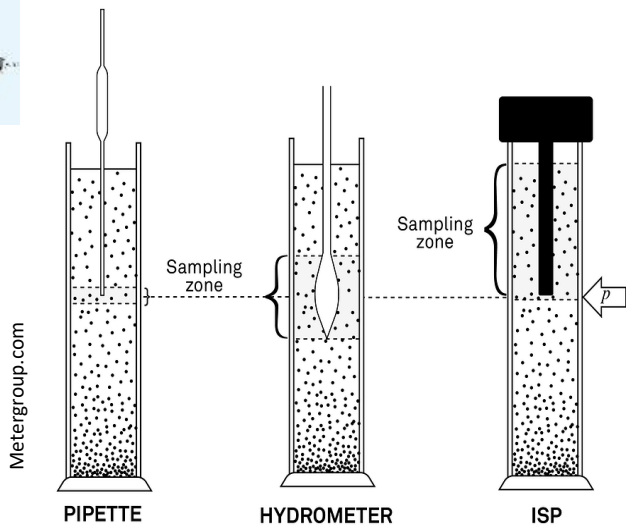
Texture
Bulk density
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X-ray tomography
Thermal properties
...

As appraised by the presenter

- «established» methods
- «established» methods, but new methods available
- new method becoming established
- method not fully established for diverse reasons
- status unclear to the presenter

Laboratory measurements of soil physical properties

Texture



Standard so far: sieving and pipette method

New methods: suspension pressure method (e.g. PARIO)
laser diffraction

Advantage of the new methods is that they yield a continuous particle size distribution

Results of new methods have been reported to differ from standard methods (e.g. Messing et al., 2024, Variability and compatibility in determining soil particle size distribution by sieving, sedimentation and laser diffraction methods, Soil and Tillage Research, Volume 238, 2024, 105987.)

Pitfalls:

- sample pre-treatment is fundamental (removing SOM, dispersing clay aggregates)
(e.g. Jensen et al., 2017. Soil texture analysis revisited: Removal of organic matter matters more than ever. PLoS ONE 12(5): e0178039)

Laboratory measurements of soil physical properties

Bulk density



Standard:

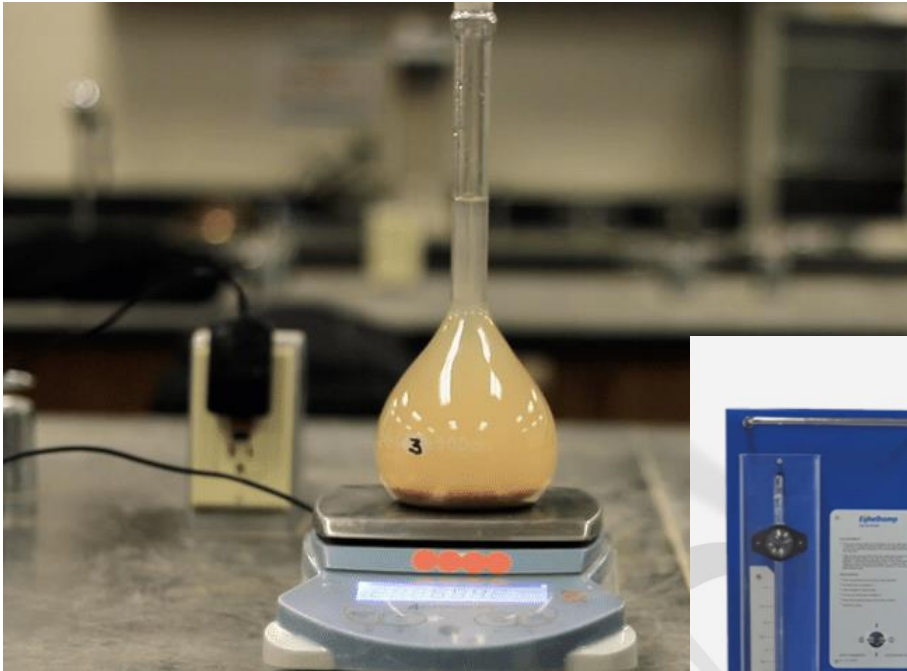
undisturbed samples are taken in sampling rings with defined volume;
soil is trimmed, then dried at 105 °C

Pitfalls:

- bulk density depends on the soil wetness at sampling time due to swelling and shrinking (the drier the soil at sampling, the larger bulk density)
- bulk density depends on consolidation level of soil: soil compaction when sampling due to friction at cylinder walls
- there is a scale effect: very small soil samples have larger bulk densities
- how to deal with gravel? Needs to be reported, but is not always
- ...

Laboratory measurements of soil physical properties

Total porosity



Standard: measure the solid phase density using pycnometry; together with bulk density derive porosity

Alternative: derive porosity directly on oven-dried undisturbed soil using gas pycnometry

Pitfalls:

- if bulk density is used, errors from its measurement will be propagated

- water pycnometry is cumbersome

- air pycnometry is reported to be biased; use of He instead of air may be a way out

(in research studies, solid phase density is often not measured but appraised by assuming specific mineral and organic phase densities)

Laboratory measurements of soil physical properties

Water retention curve



Standard: sandbed / suction plates combined with pressure plates

New method: evaporation method (e.g. HYPROP) and dewpoint method (e.g. WP4)

New method have advantage of also providing unsaturated hydraulic conductivity, more data points in the dry range and decisive shortening of measurement time

Pitfalls (sandbed/suction and pressure plates):

- sample saturation method important
- hydraulic contact needs to be established
- different approaches exist for preparing the sample for the wilting point measurement
- measurement takes months

...

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Metergroup.com



Let's stop at this point and move on to ...



Guidelines for standard measurements of soil physical properties

National reference methods – are still in use and exacerbate comparability

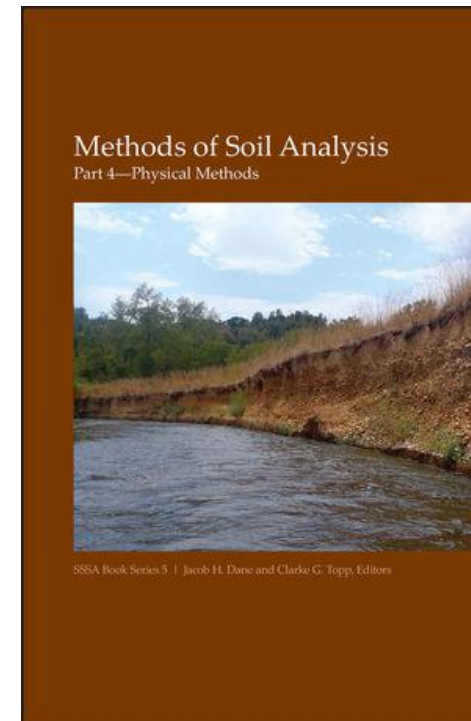
it appears that labs are reluctant to adapt new SOPs
fear of losing comparability of time series?
fear of a lot of extra work?
financial limitations?

National guidelines with international relevance

-

e.g. Methods of Soil Analysis

Standard procedures are described but allow different approaches and contain a lot of room for interpretations



What written SOPs are there at the moment?

Contacting a few European soil physics **research** labs revealed

that surprisingly often the exact SOPs for soil physical measurements only exists in the mind of the lab technician..

-- > defining global SOPs for soil physical measurements is definitely a good and timely endeavour.

However, there are some SOPs existing, e.g.

Stolte, J. (ed.), 1997. Manual for soil physical measurements; version 3. Wageningen, DLO-Staring Centre. Technisch Document/Technical Document 37. 77 pp.

Sommer, M. 2024. SOPs for Agroscope Soil Physics Lab. Unpublished.

What about commercial labs?

Global Soil Partnership

Overview Partners Regional partnerships ITPS Technical networks Areas of work Soil Doctors Programme Resources

back home

GLOSOLAN homepage

Soil Analysis

Standard Operating Procedures (SOPs)

GLOSOLAN globally harmonizes standard operating procedures (SOPs) and make them available online - to all users - for FREE. All our SOPs are compiled in the GLOSOLAN's Best practice manual, an online document structured as a flexible compendium of volumes to be published as soon as ready.

SOPs offer step-by-step instructions on how to perform laboratory analyses. SOPs are a critical component in ensuring the replicability of a measurement and the credibility and traceability of data. They are so important to be the first thing to look at in case of errors in the measurement or variable results in internal and external quality control exercises.

Before investing in new equipment, make sure that your staff is well trained and that SOPs are implemented! SOPs go hand-in-hand with the execution of internal and external quality control exercises.

- Why is GLOSOLAN harmonizing SOPs? And why is it making them available online for free?
- How does GLOSOLAN decide what SOPs to harmonize?
- How are GLOSOLAN SOPs harmonized?
- How did GLOSOLAN define the sustainability of methods?
- If I register my laboratory in GLOSOLAN, do I have to use GLOSOLAN SOPs?

Best Practice Manual

Partnership

Soil Program on Hydro-Physics via International Engagement (SOPHIE)

The objective of SOPHIE is that it supports the realisation of qualified soil hydro-physics (SHP) data, highly needed in EU policy making, coming from EU-wide agreed, preferred, and innovated cost-effective laboratory- and field methods, accomplished through international collaboration.

Downloads:

- 2019 - ULiege Gembloux Belgium
- 2019 - EGU Vienna Austria
- 2017 - INSPIRATION Brussels Belgium
- 2019 - WSC Wageningen Netherlands

Are there ring tests?

Ring tests for soil physical measurements have only been conducted occasionally.

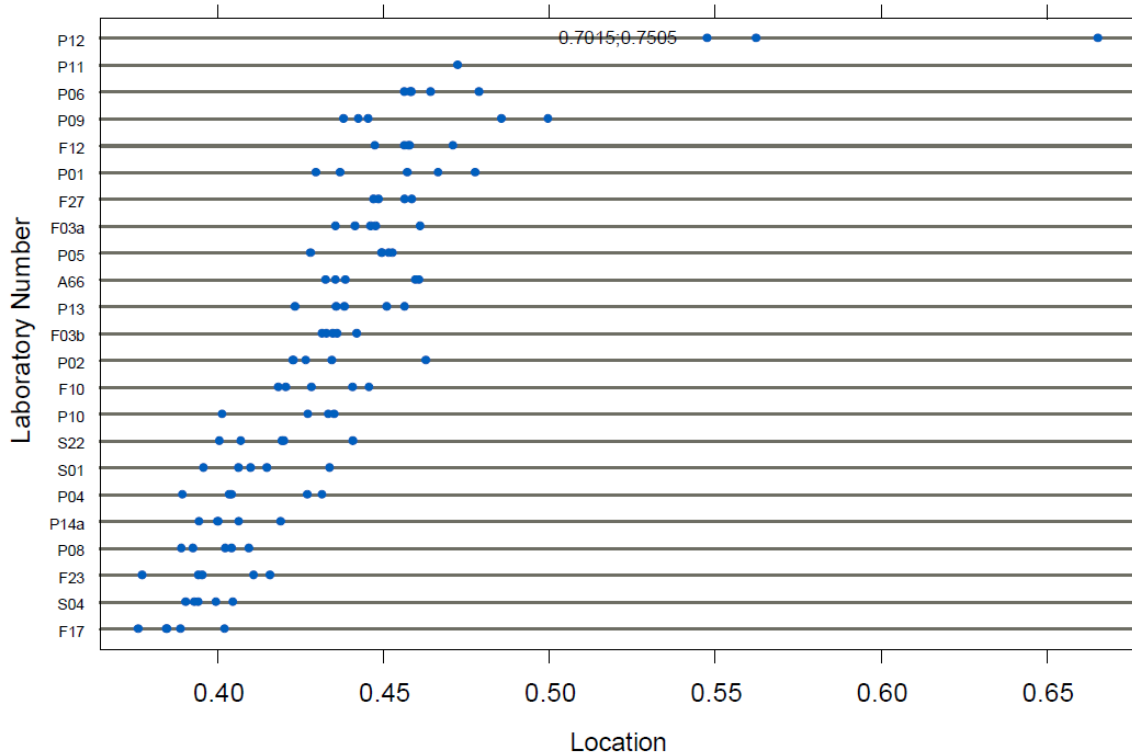
One difficulty is the lack of suitable standard samples for which the correct result is known.

Often, the best option is to sample a specific site at one point of time in a randomized pattern and distribute the samples to the participating labs.

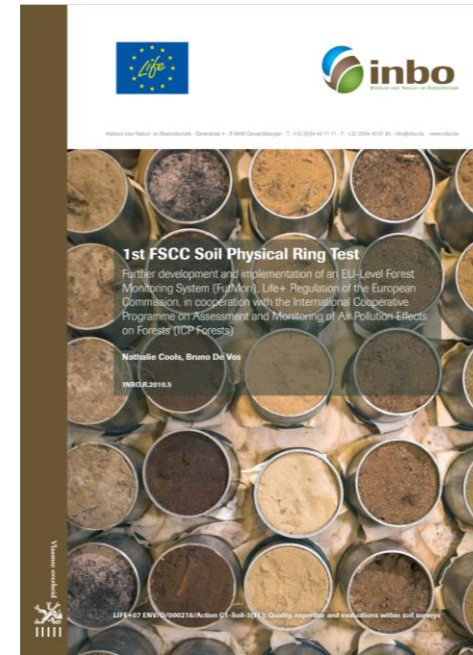


European ring test for forest soils on water retention

25 labs, 5 undisturbed soil samples per lab,
bulk density and water retention curve



saturated water content ($\text{cm}^3 \text{cm}^{-3}$)

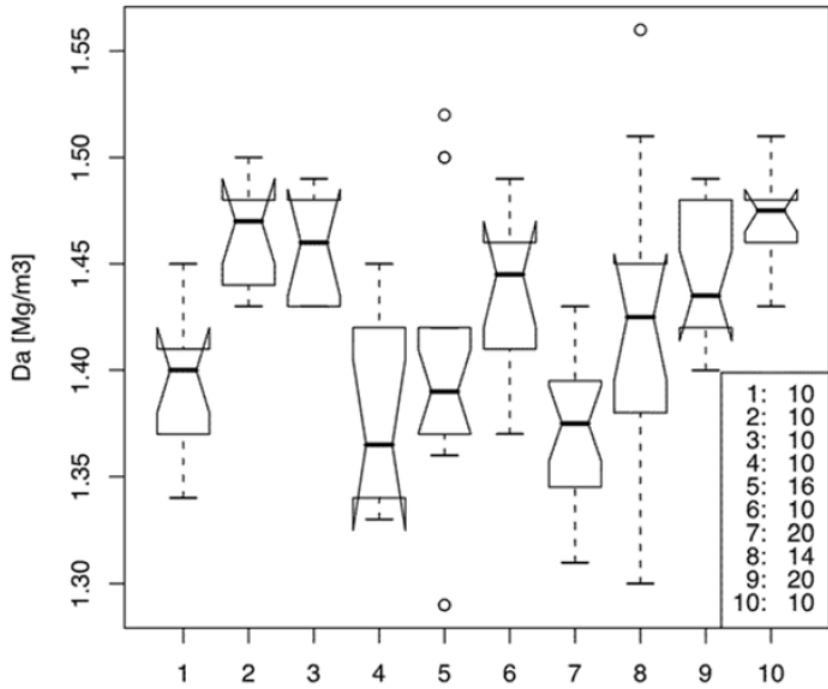


Cools et al., 2010

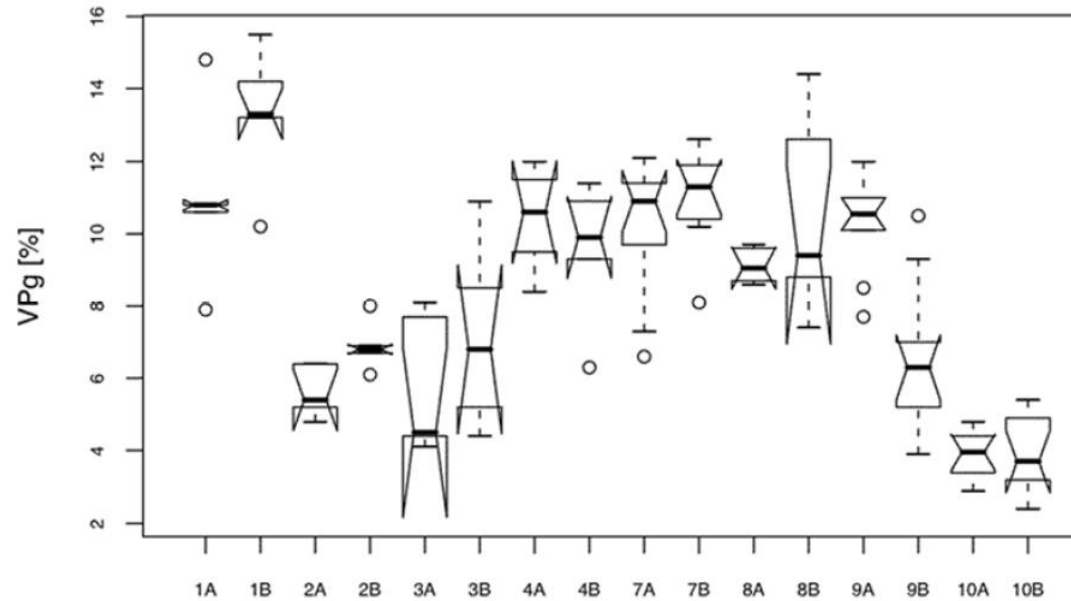
Parameter	CV(%)	% Between lab variance	% Within lab variance
VWC0	6.4	77	23
VWC-1	7.5	78	22
VWC-5	9.5	73	27
VWC-10	8.2	59	41
VWC-33	8.7	80	20
VWC-100	10.0	83	17
VWC-250	19.1	90	10
VWC-1500	42.3	98	2
dryBD	4.5	36	64

Swiss ring test on bulk density and soil water retention

10 labs, 10 undisturbed soil samples per lab,
impact of **sampling approach**, **sample preparation** and **impact of lab** investigated

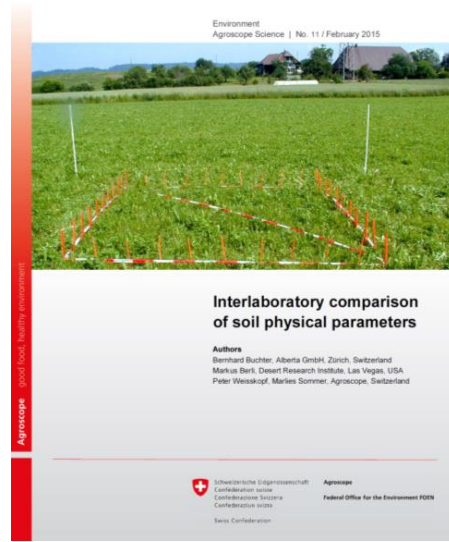


Bulk density (g cm⁻³)



Macroporosity at -60 hPa (cm³ cm⁻³)

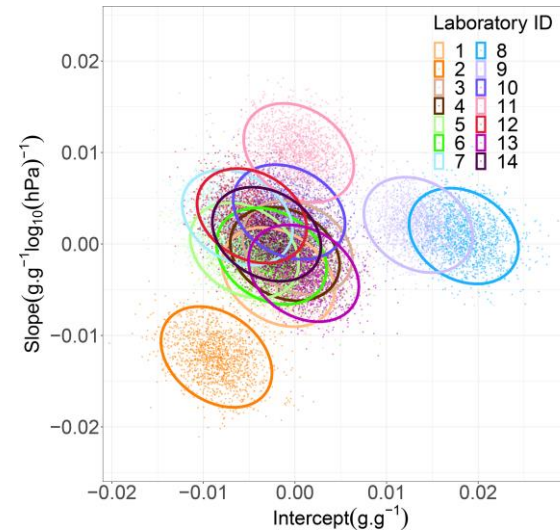
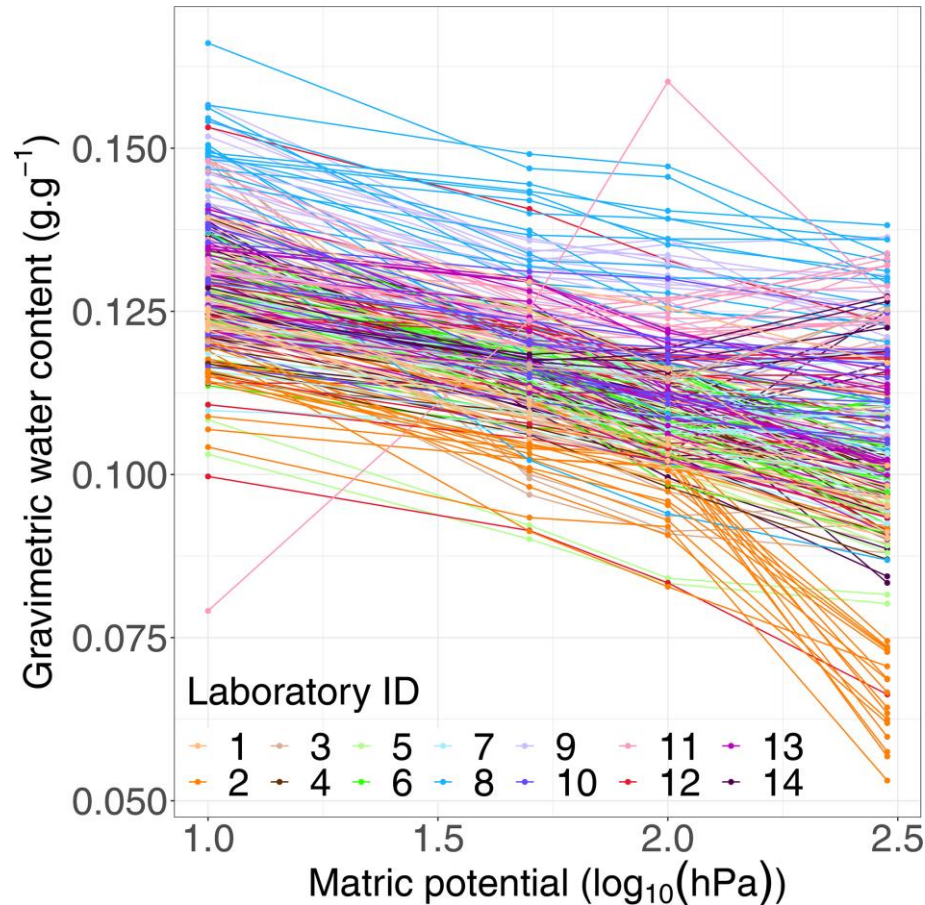
Authors conclude: Large inter-lab variation **is not** due to sampling technique, sample size or sample preparation **but it is due to different implementations of the measurement method!**



Buchter et al., 2015

European ring test on water retention

14 labs, 6 artificial, soil-like porous materials (porous glass beads and cement) per lab, water retention curve between -100 and -330 hPa, each sample was measured three times



Authors conclude that differences were **not** due to transportation or measurement repetition

but was due to different packing and measurement implementations at the individual labs

All samples should have identical water retention properties

Reproducibility of the wet part of the soil water retention curve: a European interlaboratory comparison

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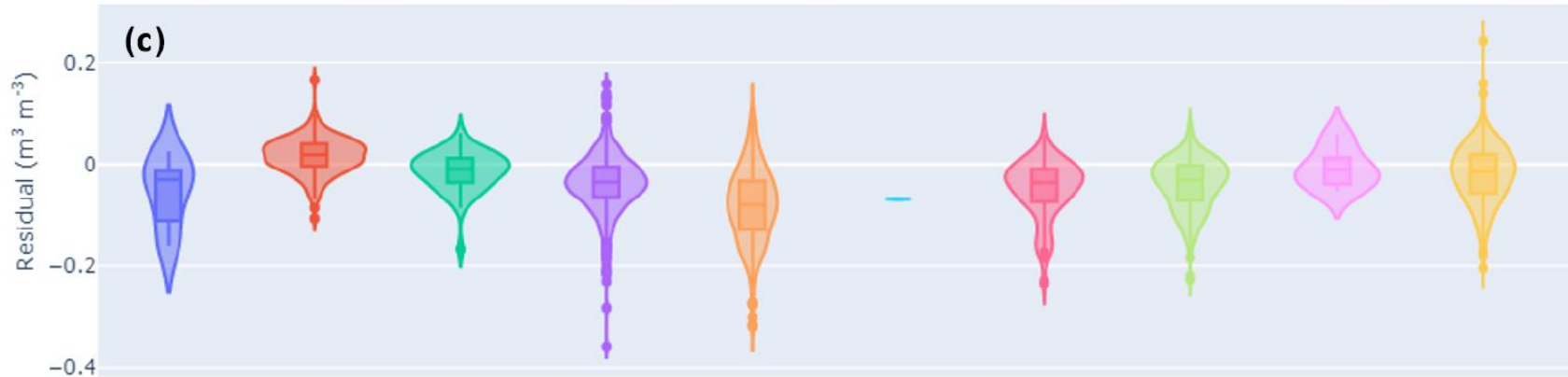
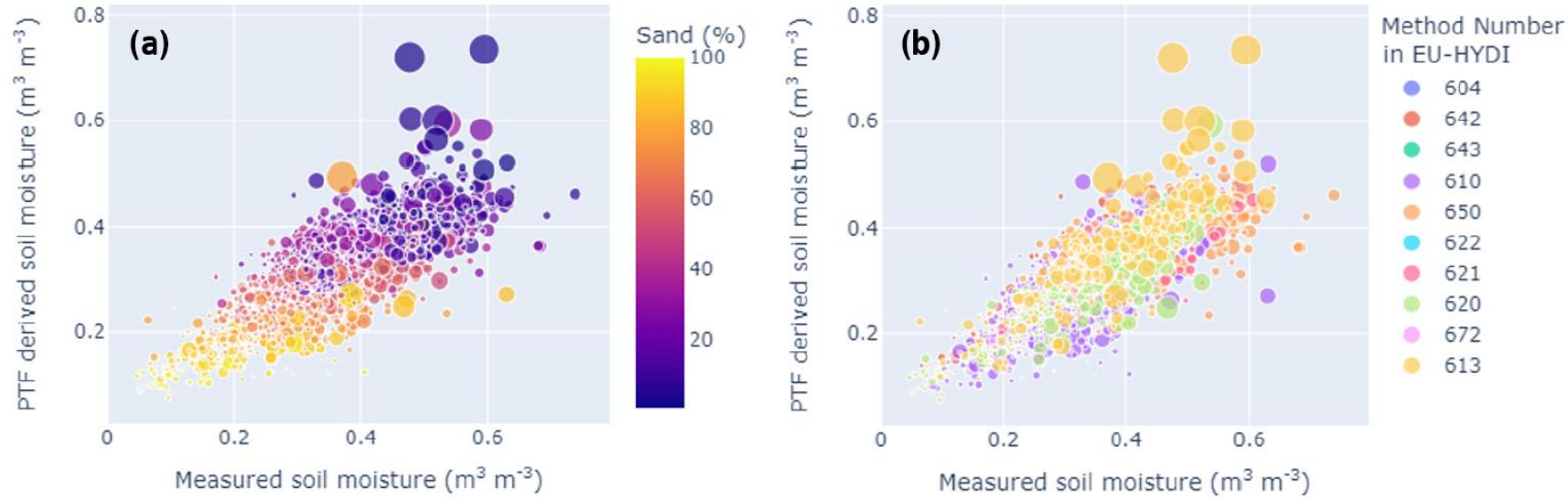
Received: 23 December 2022 – Discussion started: 6 January 2023
 Revised: 19 April 2023 – Accepted: 8 May 2023 – Published: 30 June 2023

Abstract. The soil water retention curve (SWRC) is a key soil property required for predicting basic hydrological processes. The SWRC is often obtained in the laboratory with non-harmonized methods. Moreover, procedures associated with each method are not standardized. This can induce a lack of reproducibility between laboratories using different methods and procedures or using the same methods with different procedures. The goal of this study was to estimate the inter- and intralaboratory variability of the measurement of the wet part (from 10 to 300 hPa) of the SWRC. An interlaboratory comparison was carried out between 14 laboratories, using artificially constructed, porous reference samples that were transferred between laboratories according to a statistical design. The retention measurements were modelled by a series of linear mixed models using a

Guillaume et al., 2023

Extra: Meta-analyses of EU-HYDI database

Data from 29 European soil physics research labs



Water content at $h = -100$ hPa

Each color represent a different sample size or measurement method

Hydro-pedotransfer functions: a roadmap for future development

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Weber et al., 2023

Extra: Meta-study on comparison of pressure plate and dewpoint methods

Data from 5 peer-reviewed publications and 2 labs



Università degli Studi "Mediterranea" di Reggio Calabria

Dipartimento di Agraria

Corso di Laurea Magistrale in "Scienze e Tecnologie Agrarie"

DETERMINATION OF WATER CONTENT
AT PERMANENT WILTING POINT
IN A LARGE SET OF SOILS:
ANALYTICAL COMPARISON AND STATISTICAL
ANALYSIS OF TWO LABORATORY METHODS

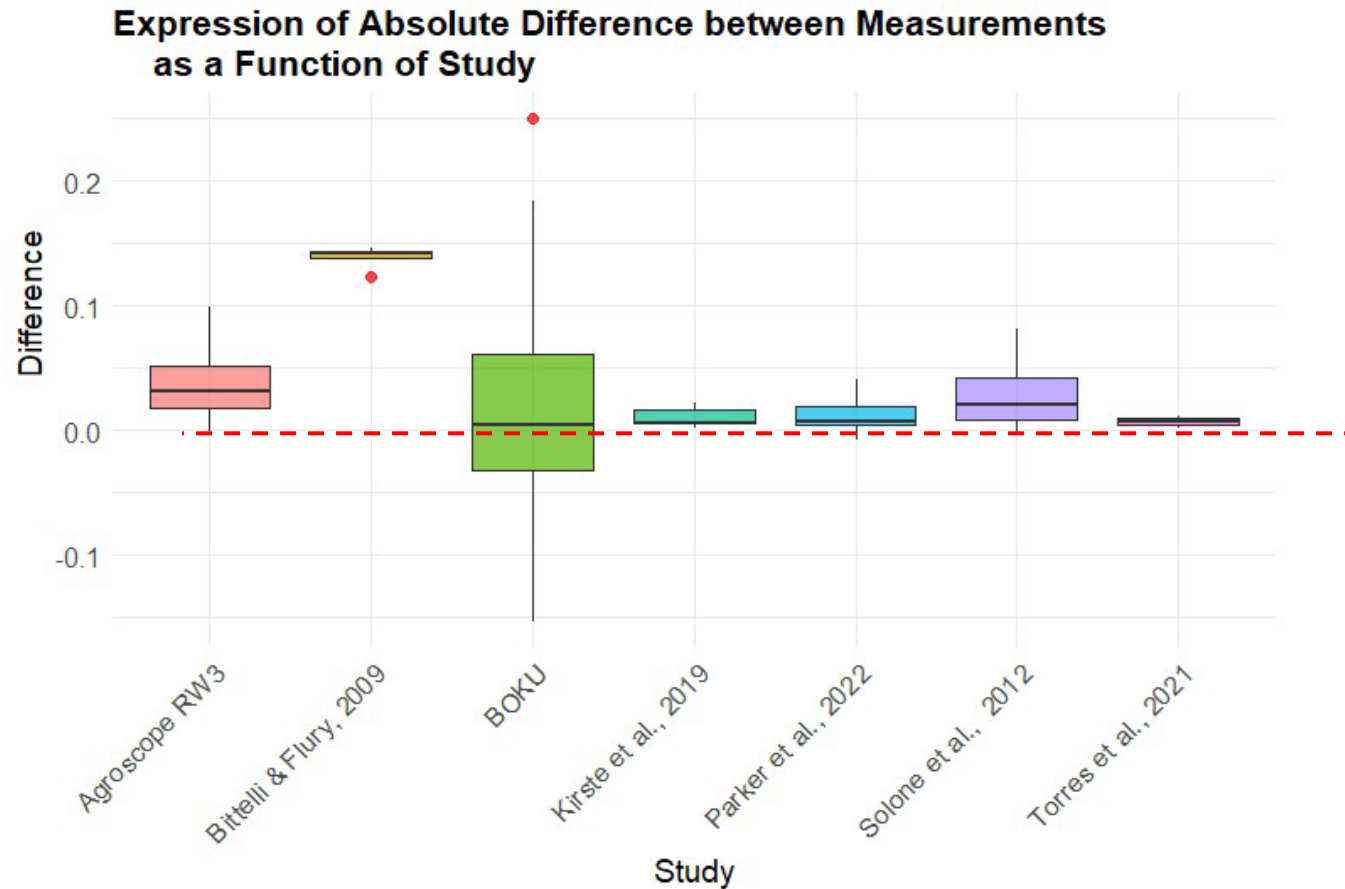
Relatore: Prof. Antonio GELSOMINO

Correlatore: Dott. Johannes KÖSTEL

Tesi di Laurea di
Lorenzo CERISCIOLI

ANNO ACCADEMICO 2023/2024

Ceriscioli 2024



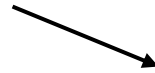
Difference in gravimetric water content (g g^{-1}) at permanent wilting point (pf 4.2) between pressure plate and dewpoint (WP4) measurements

Conclusion

If soil physical data is used as soil health indicator, bias in its measurements needs to be reduced or at least known.

Sources of bias and noise in soil physical lab measurements:

- size of the soil sample (scale effect)
- soil sampling technique
- point of time of sampling / soil wetness
- soil sample preparation
- transport
- storage
- measurement technique
- implementation of measurement
- measurement device
- errors when applying equations
- ...



A large portion of bias and noise could be reduced by establishing more detailed SOPs

Reasonable next steps

(broadly following what is already stated by GLOSOLAN or SOPHIE)

- Summon a critical mass of soil physics labs to support the development of more detailed SOPs
 - **organise a stocktake among these labs of used method and implementations**
 - make use of already existing initiatives like e.g. SOPHIE (Soil Program on Hydro-Physics via International Engagement)
 - **identify critical procedures during measurement implementation**
 - **quantify systematic bias between different measurement methods / devices**
 - **develop refined SOPs which are acceptable for a critical mass of laboratories**
 - make reference to SOPs mandatory for peer-reviewed publications
 - organize more ring tests
- Keep in mind that meta-data is required to correctly interpret the data
(land use, land management, day of measurement, soil moisture at day of measurement, sample size, ...)

How can this be funded?



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Thank you

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