Food and Agriculture Organization of the United Nations

GLOSOLAN
GLOBAL SOIL LABORATORY NETWORK

The need for and challenges in standardizing soil physical analysis

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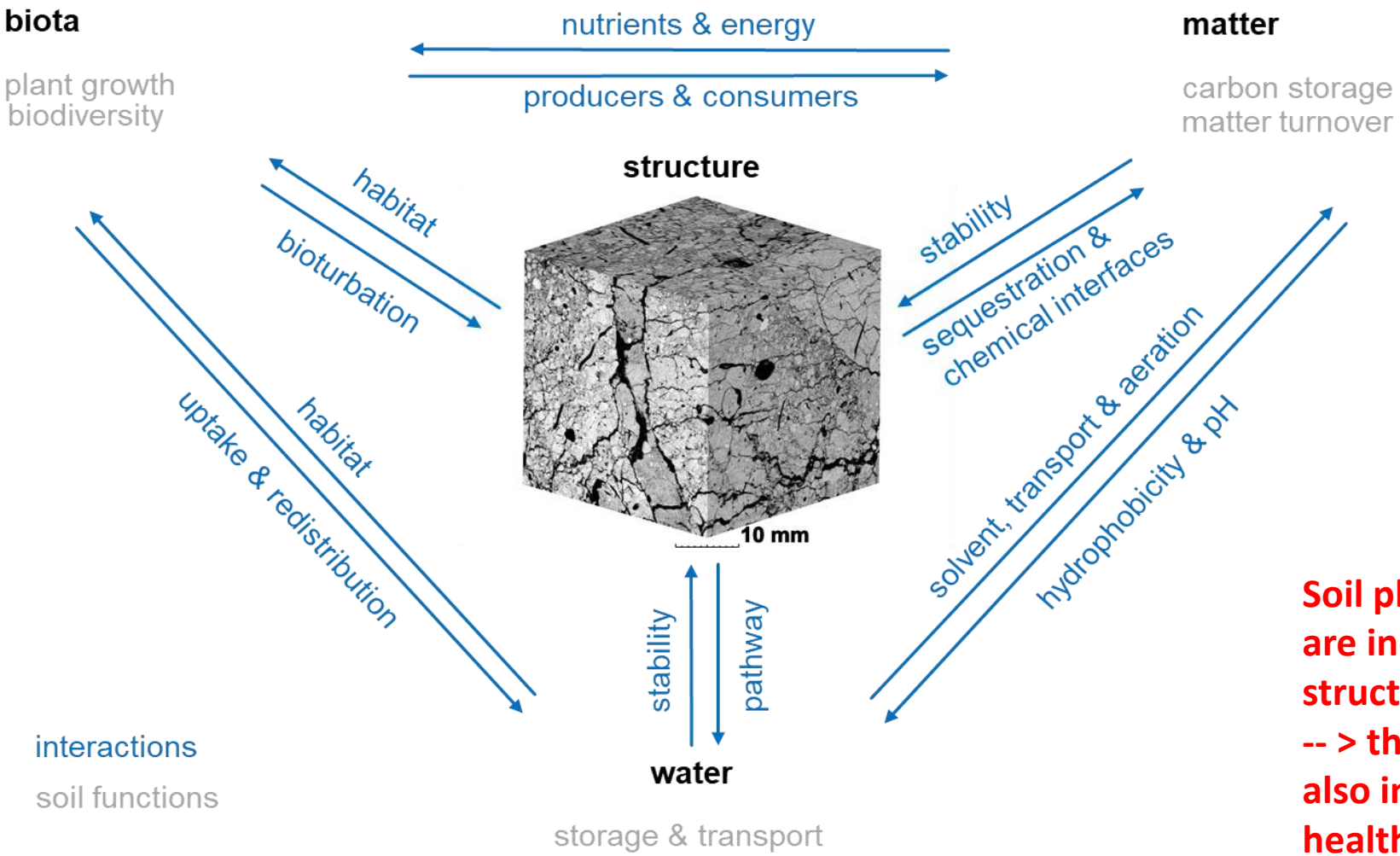
GLOBAL SOIL PARTNERSHIP

Soil physical properties are indicaotrs for soil structure



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

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

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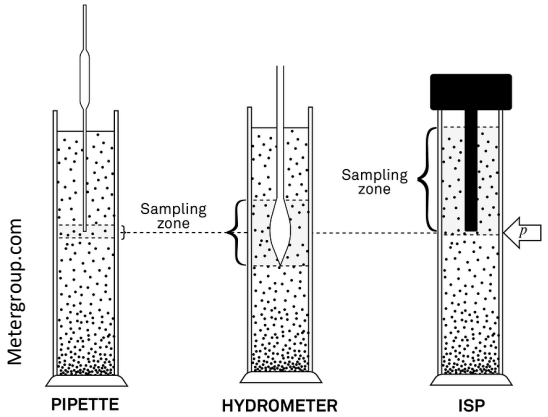
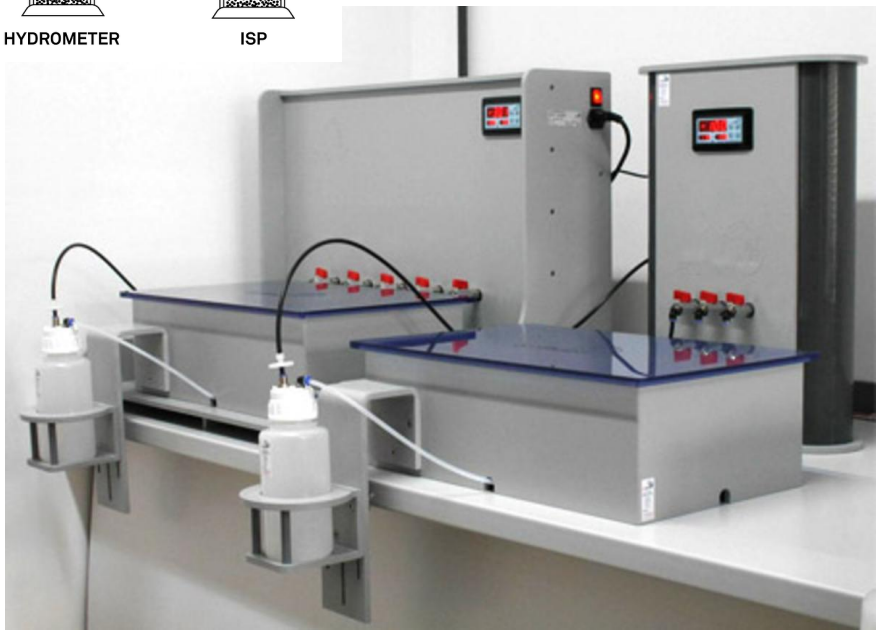
Laboratory measurements of soil physical properties

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
…





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Laboratory measurements of soil physical properties

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Water retention curve

Saturated hydraulic conductivity

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Shear strength

Penetration resistance

Aggregate size distribution

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

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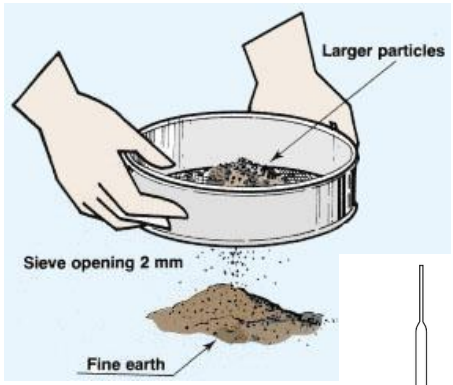
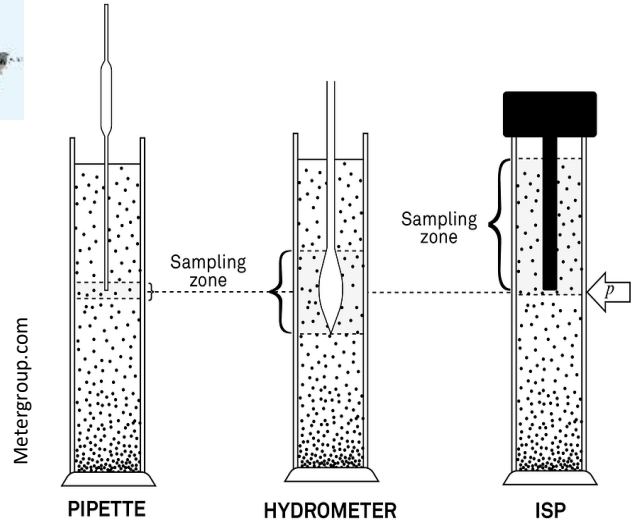
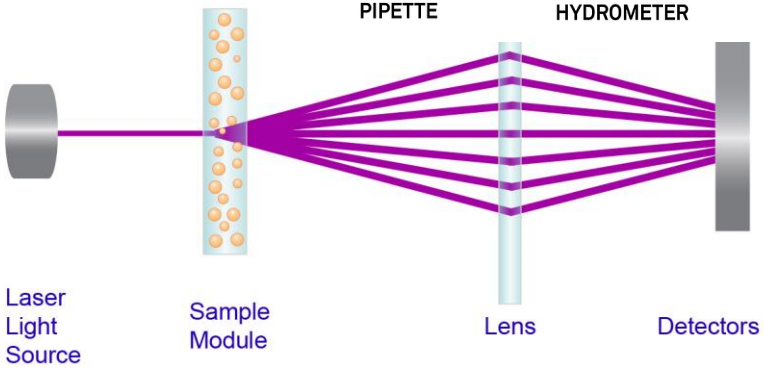
Laboratory measurements of soil physical properties

Texture







particletechlabs.com

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)

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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

…

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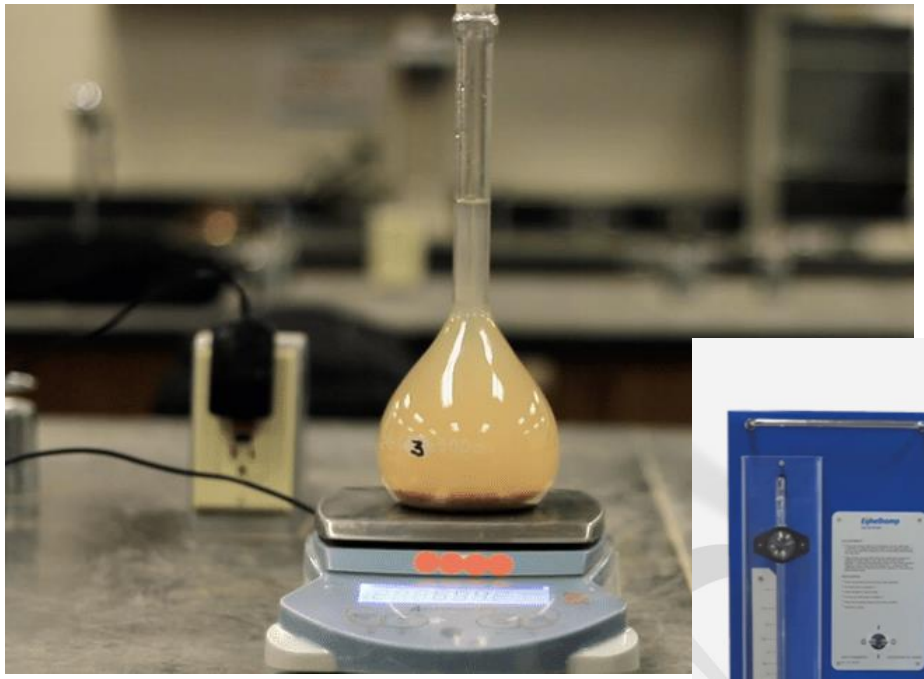
Laboratory measurements of soil physical properties

Total porosity



Eijkelkamp

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)

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Laboratory measurements of soil physical properties

Water retention curve

Soilmoisture Equipment Corp

Metergroup.com

ecoTech.de

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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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 excacerbate comparability

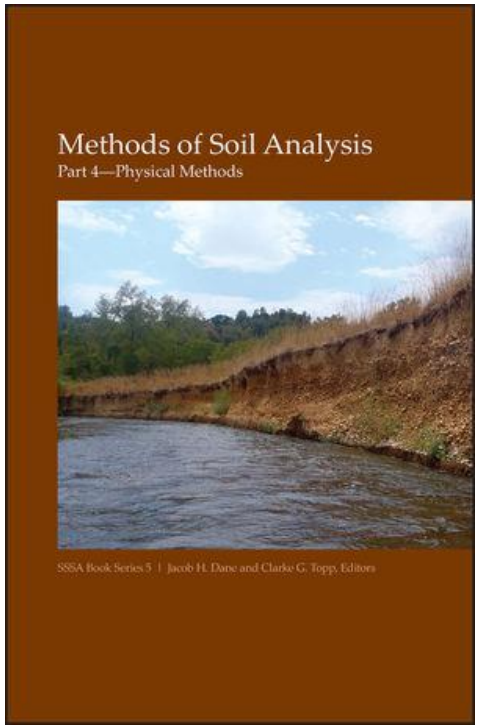
it appears that labs are reluctant to adapt new SOPs
- fear of loosing comparability of time series?
- fear of a lot of extra work?
- financial limitations?

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



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What written SOPs are there at the moment?

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

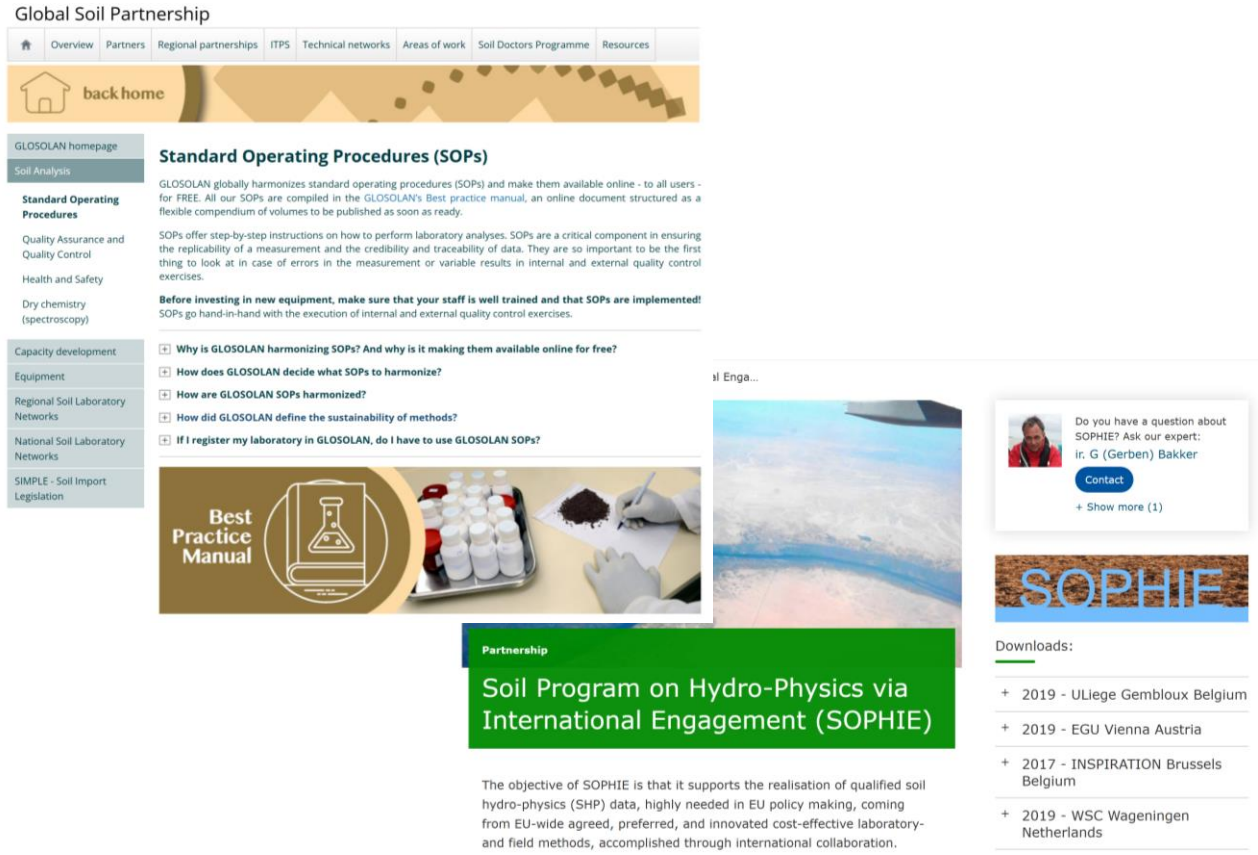
that surprisingly often the exact SOPs for soil physical measurements only exists in the mind of the lab technician..

-- > defining global SOPs for soil physical measurments 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?

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.

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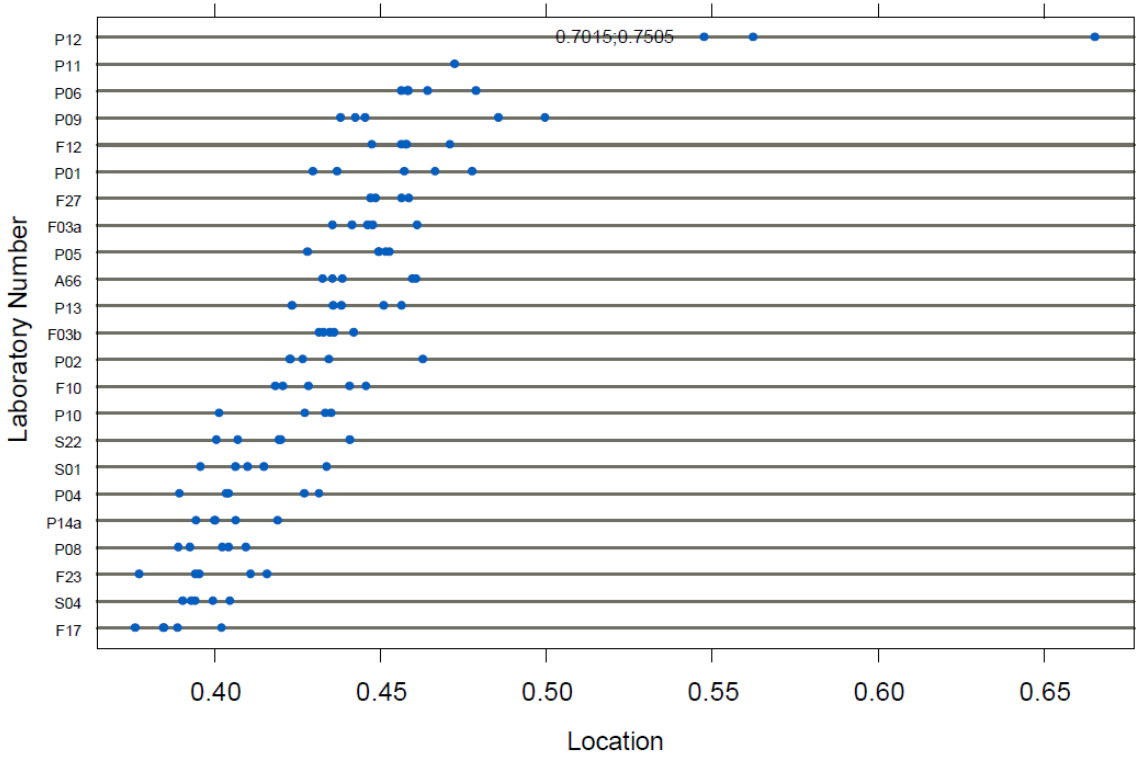
European ring test for forest soils on water retention

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



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

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

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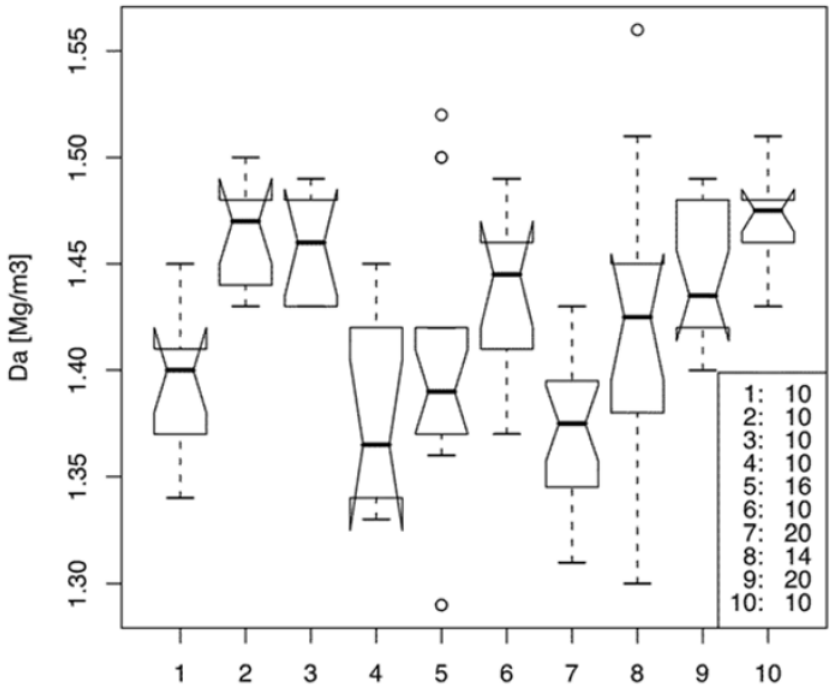
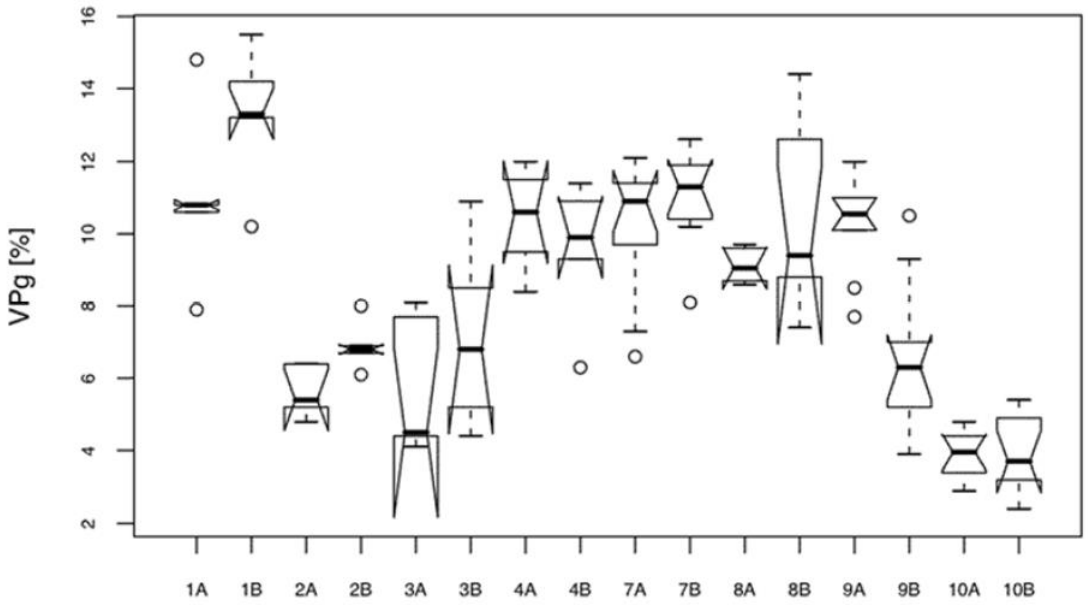
Swiss ring test on bulk density and soil water retention

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 (cm^3 cm^{-3})

Buchter et al., 2015

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!

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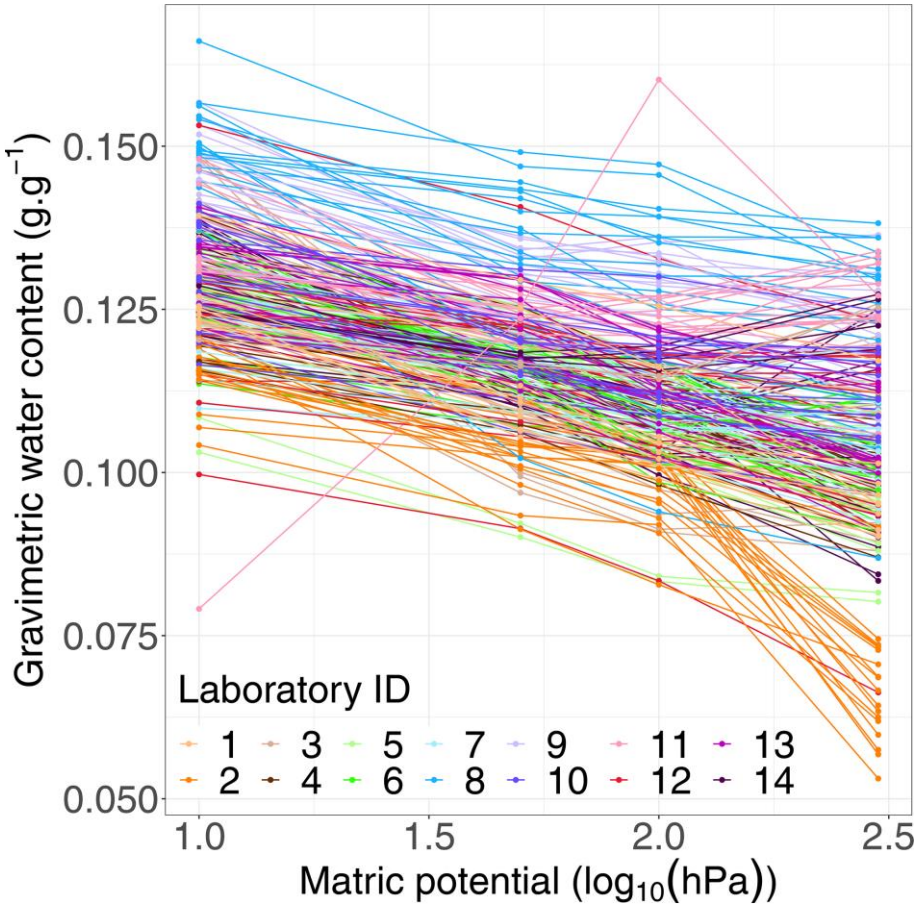
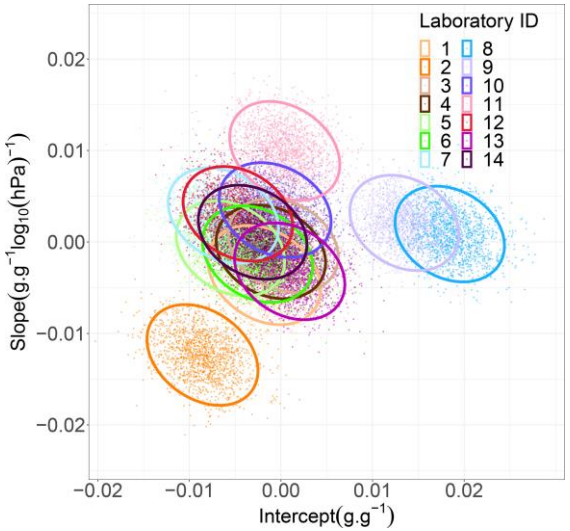
European ring test on water retention

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





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SOIL EGU

Original research article

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

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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

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

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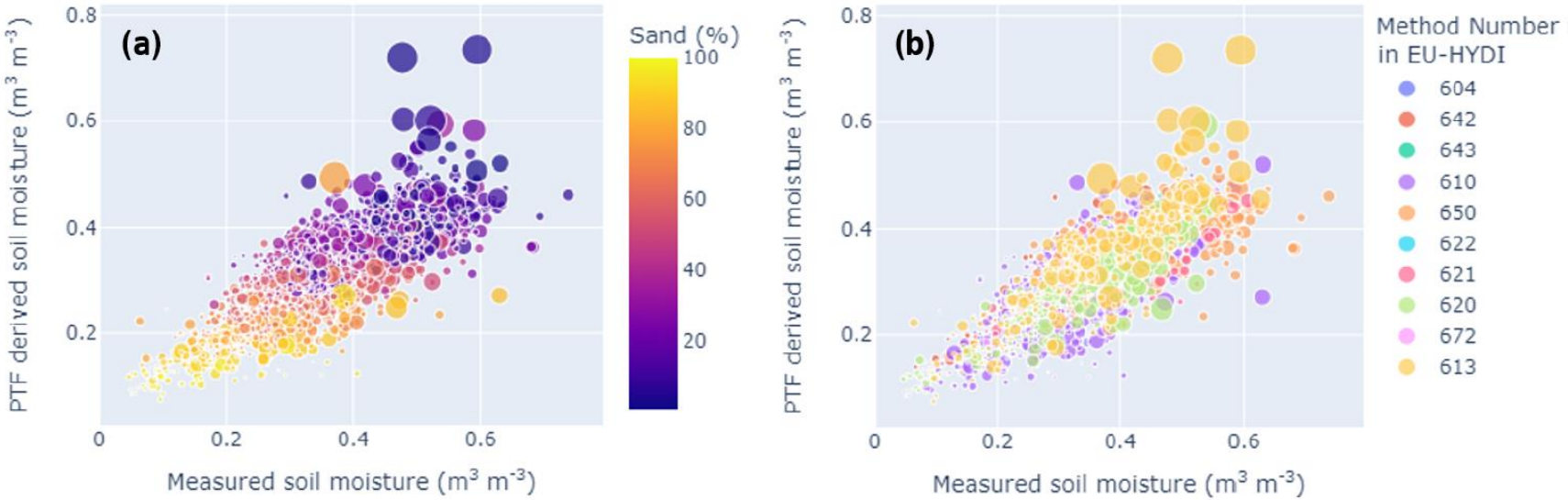
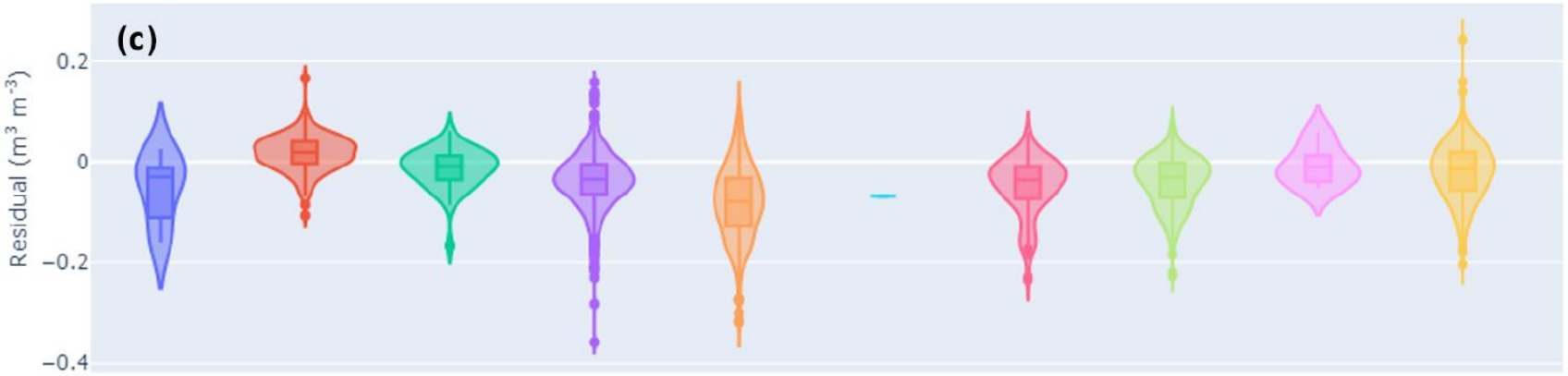
Extra: Meta-analyses of EU-HYDI database

Data from 29 European soil physics research labs



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Hydrology and Earth System Sciences

Hydro-pedotransfer functions: a roadmap for future development

Weber et al., 2023

Water content at h = -100 hPa

Each color represent a different sample size or measurement method

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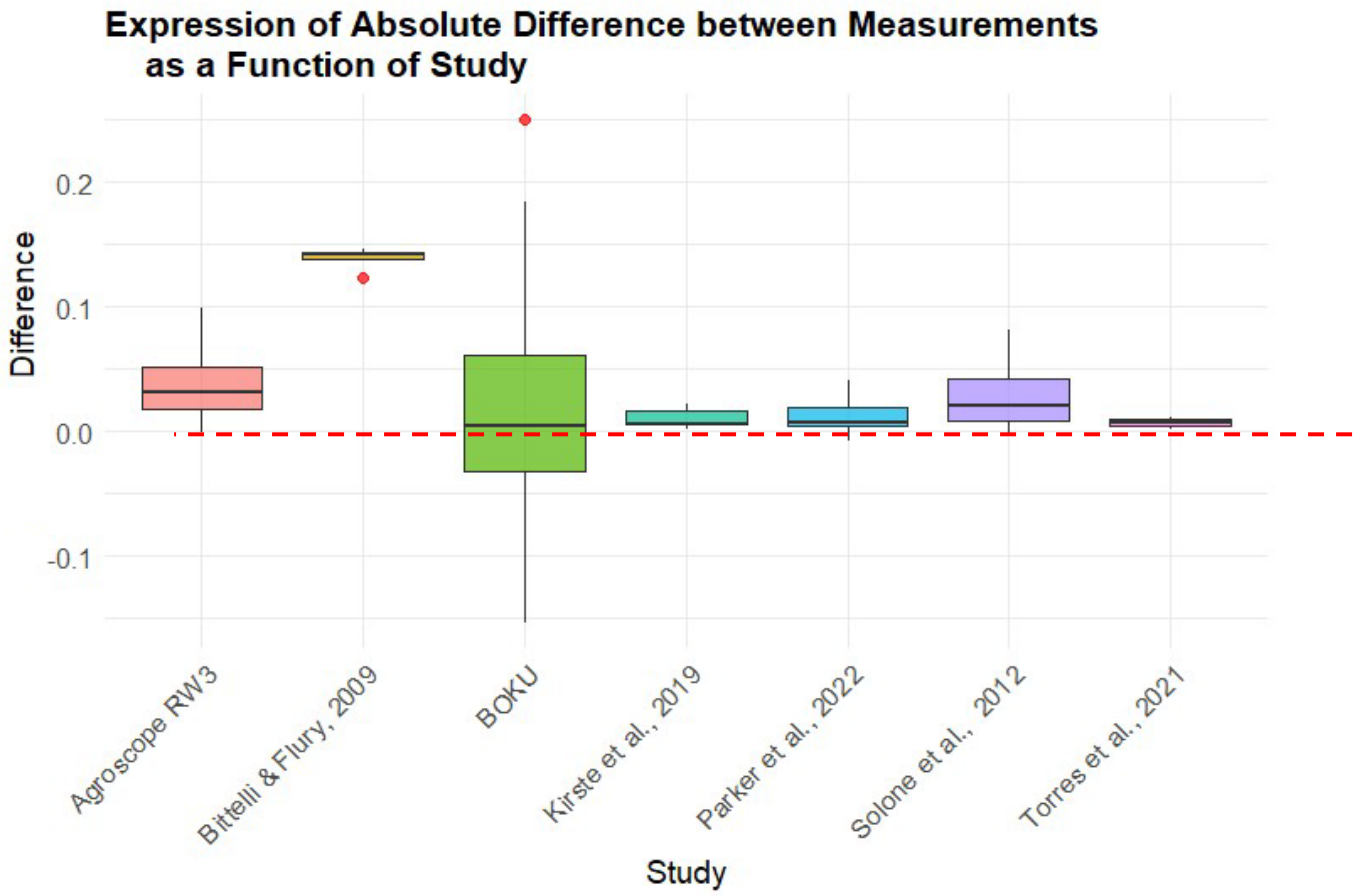
Extra: Meta-study on comparison of pressure plate and dewpoint methods

Data from 5 peer-reviewed publications and 2 labs



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

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

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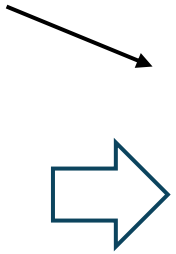
Conclusion

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

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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 stockstake 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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