Application of organic fertilizers alter the physical and biogeochemical properties of agricultural topsoil and subsoil

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Experimental
design
&
Sampling

OC Stocks

Nutrients

Hyper-
spectral
imaging

Soil
structure

Take home
message

Experimental design & Sampling

Experimental design

- Brandenburg, Germany
- Fertilizer application: **7 years**
- Randomized block design, 4 replicates
- Treatments :
 - Anaerobic biogas digestates (solid, liquid or total)
 - Solid farmyard manure (cattle)
 - Mineral fertilizer
 - No fertilizer (control)
- Fertilizers applied at equivalent N amount ($239 \text{ kg ha}^{-1} \text{ y}^{-1}$)
- Organic fertilizers applied at equivalent OC amount ($1,12 \text{ t ha}^{-1} \text{ y}^{-1}$)
- No phosphorus fertilizer (P is not balanced between the organic treatments)

Soil sampling

- Soil sampling to a **depth of 1 m** using a corer
- One core for **bulk biogeochemical laboratory analyses** (OC&N stocks, nutrients, soil aggregates)
- **Five depths:** 0-10 cm, 10-20 cm, 20-40 cm, 40-80 cm, 80-100 cm
- One un-disturbed core for **hyperspectral imaging**

General soil characteristics

- Cambisol
- Texture: sandy loam 0-80 cm, sandy clay loam 80-100 cm
- pH : 5.7

OC and N Stocks

Legend:

Highest total SOC stock after the application of **digestate cattle**

Finer investigation of the effect of Dm *versus* C and F on soil properties

Hyper-spectral imaging

Soil structure

Soil nutrients (0-20 cm & 20-40 cm, 0-10 cm for N_{mic})

Nitrate and nitrite

0-20 cm

20-40 cm

Plant-available phosphorus

0-20 cm

20-40 cm

Microbial biomass nitrogen

0-10 cm

Legend

Digestate

(*versus* mineral fertilizer)

- Higher plant-available phosphorus at 0-20 cm – no phosphorus fertilization in mineral fertilizer treatment
- Lower nitrate and nitrite content at 20-40 cm – more organic bound nitrogen
- Higher N_{mic} content at 0-10cm

Soil structure

Aggregate OC contribution to total OC (%)

Aggregate mass distribution

- Relatively higher amount of macroaggregates with no fertilizer in 0-40 cm
- Fine aggregate/particle size increase with depth

Aggregate OC contribution

- Fertilizers: relative decrease of OC contribution to macroaggregates in 0-40 cm

No fertilizer
Mineral fertilizer
Biodigestate cattle

Macroaggregate (> 250 μm)
Microaggregate (53-250 μm)
Silt and clay (< 53 μm)

Hyper-spectral imaging

Combination of hyperspectral imaging & machine learning ensembles
Artificial neural networks (ensemble ANN)

Sample
preparation

Data
processing

- Successful modelling results for SOC content
- SOC content differed for Dm *versus* C and/or F in ~ 0-25 cm and ~ 70-100 cm

Hyper-spectral imaging

Advantages of hyperspectral imaging

Consider soil **small scale heterogeneities** in estimation of C and N stocks and changes

High spatial resolution provides more insights for process understanding

Hyperspectral camera
and detector

Illumination

Data
processing

Core
sample

Hypspec VNIR-1800 camera
(Norsk elektro optikk, Norway)

Translation stage

Hyper-spectral imaging – Data processing

Take home message

- Overall, **low SOC stocks in 0-100 cm** (mean = 53 t ha⁻¹) → soil with sandy loam texture in the northeast of Germany
Mean in German croplands with permanent crops: 107 t ha⁻¹ (Poeplau et al., 2020)
- Application of **organic fertilizers / mineral fertilizer / no fertilizer** (7 years):
 - **SOC stocks**
 - Organic fertilizers (*versus* mineral fertilizer) : increase of the SOC stocks + 26 % in 0-10 cm and + 30 % in 20-40 cm
 - With equivalent OC amount applied for organic fertilizers, biogas digestate from cattle → highest SOC stocks
 - **Nutrients**
 - With equivalent N amount applied, lower soil nitrate/nitrite content with biogas digestates (*versus* mineral fertilizer)
 - Increase of plant-available phosphorus in 0-20 cm with biogas digestate fertilizers
 - **Soil structure**
 - Both mineral and organic fertilizer (*versus* no fertilizer) : relative decrease of the macroaggregate amount and of the OC contribution to macroaggregates in 0-40 cm