Soil organic carbon stocks in German agricultural soils

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Introduction

- agriculture: approx. 7% of German greenhouse gas (GHG) emissions
- changes in soil organic carbon (SOC) are climate-relevant
  - to be reported under UNFCCC
  - so far: only land use change effects on SOC mandatory
  - EU: in addition, management effects have to be reported
  - to detect and report changes, a homogenous and representative baseline is needed
German Agricultural Soil Inventory

- 8 x 8 km grid
- cropland, grassland and speciality crops
- 3104 sites sampled
- voluntary participation of farmers
- farming questionnaire: 10 years of management data

➢ first inventory down to a depth of 1 m and with 10 years of management data!
German Agricultural Soil Inventory – In the field

- 1 m³ profile pit and 8 'satellite' soil cores
- disturbed samples for chemical analysis
- undisturbed samples for physical analysis
- profile description and field parameters following German guideline to identify and describe soils (KA5)
German Agricultural Soil Inventory – In the lab

- \( N_t \)-content
- \( C_{\text{org}} \)-content
- rock fragments fraction
- fine soil mass
- root content
- soil texture (sedimentation)
- \( C_{\text{inorg}} \)-content
- soil pH, electric conductivity
- near infrared spectroscopy
- \( C_{\text{org}} \)-fractionation (selected sites)
- archive

\[ \text{SOC-stocks} \]
Average SOC-stocks in German agricultural soils

- **Organic soils**: ~5x more SOC than mineral soils in 0-100 cm

- **Mineral soils** (0-100 cm):
  - Croplands: 96 Mg ha\(^{-1}\)
  - Grasslands: 135 Mg ha\(^{-1}\)

- ~25% of the total SOC in agricultural soils is stored in 6% of the area (organic soils)
- Grasslands store ~40% more SOC than croplands
SOC-stocks in terrestrial ecosystems in Germany

- Forest and agriculture: **5 Billion Mg SOC**

![Pie chart showing the distribution of SOC stocks in Germany](chart)

- Forest vegetation: 26%
- Agricultural soils (0-90 cm): 48%
- Forest soils (0-90 cm): 23%
- Agricultural vegetation: 3%

Including litter layer.
Spatial variability of SOC-stocks in German agricultural soils

0-30 cm

SOC-stocks [Mg ha\(^{-1}\)]
- < 30
- 30-50
- 50-70
- 70-90
- > 90

cropland
grassland
speciality crop

30-100 cm
Explaining spatial variability of SOC-stocks in German mineral soils

- machine learning (here: Random Forest) used to explain variability
- > 200 variables (climate, land use and management, soil, geology, geomorphology)
- land use (grassland vs. cropland): important driver in topsoil only
- management and climate: not explaining much of variability
- site properties (e.g. clay content, bedrock material): most important drivers
- about 40% of variability explained only
- information on land use history so far incomplete
Measures to increase SOC-stocks or avoid losses

**Organic soils**
- avoid losses by controlling water level
- increase carbon inputs by
  - cover crops before summer crops
  - perennial crops
  - crop residue management
  - hedges
  - organic fertilizers
- improve yield stability (crop rotations)

**Mineral soils**
- avoid losses by avoiding grassland-to-cropland conversion
- increase carbon inputs by
  - cover crops before summer crops
  - perennial crops
  - crop residue management
  - hedges
  - organic fertilizers
Summary

• aricultural soils are the largest terrestrial carbon pool in Germany
• variability of SOC-stocks mainly driven by site properties
  ➢ organic soils (6% of the area) store 25% of total SOC
  ➢ but: ~60% unexplained variability in mineral soils
• changes in SOC-stocks depend on management (and climate)
• drained organic soils are a key source of greenhouse gas emission
  ➢ water level increase is key to slow down mineralization and to mitigate emissions
Summary

• for mineral soils, options to increase SOC are site and farm specific but should aim to increase carbon inputs

➢ potentials limited: feasibility of and limits to higher carbon input unsure, SOC-stability in medium and long term uncertain, increase of grassland/forage area needs to increase livestock numbers, additional nitrogen input through e. g. catch crop biomass increase N₂O-emissions....)

➢ management options to increase SOC are to be reflected intensely

• resampling of the Agricultural Soil Inventory will detect management-induced changes in SOC-stocks and validate predictions for SOC-stocks as determined by models

• so far, models (using management data, baseline-SOC) predict SOC-losses in mineral soils
Thanks for your attention!

You are welcome to download the report at:
https://www.thuenen.de/de/ak/projekte/bodenzustandserhebung-landwirtschaft-bze-lw/