Perspectives for soil carbon management

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Sufficient emissions reductions can only be achieved with carbon removal (carbon storage).

**Point sources (power plants):**
- CCS in geological formations

**Atmosphere:**
- Storage in vegetation (forest)
- Storage in soils
Sources and sinks of carbon

Current growth rate of CO$_2$ in atmosphere: 17.2 Gt CO$_2$/yr or 4.7 Gt C/yr
4 per mille concept

4 PER 1000
CARBON SEQUESTRATION IN SOILS
FOR FOOD SECURITY AND THE CLIMATE

The quantity of carbon contained in the atmosphere increases by 4.3 billion tons every year.

+4.3 bn tons carbon/year

CO2 emissions

Forest absorption

Oceans absorption

Human activities absorption

Deforestation emission

The world’s soils contain 1500 billion tons of carbon in the form of organic material.

absorption of CO2 by plants

storage of organic carbon in soils

If we increase by 4‰ (0.4%) a year the quantity of carbon contained in soils, we can halt the annual increase in CO2 in the atmosphere, which is a major contributor to the greenhouse effect and climate change.

increased absorption of CO2 by plants:

farmlands, meadows, forests...

+4‰ carbon storage in the world’s soils

= more fertile soils

= soils better able to cope with the effects of climate change
Challenges for 4 per 1000

Sufficient measures to enhance C sequestration
• Soil carbon is primarily (solely?) enhanced through higher organic matter inputs. This will compete with demands for biomass (food, feed, fibre, biofuels).

Permanence of soil carbon
• Existing high carbon pools in peatland soils should be preserved through high water table.
• Measures to maintain C stocks in mineral soils needs to be sustained.

Global warming increases soil carbon decomposition
• Higher temperatures enhance SOC decomposition. A 1 °C increase is estimated to reduce global SOC by 1.6 Gt C/yr.

Overall assessment
• The possibilities for enhancing SOC depends on the balance between enhanced C inputs and enhanced SOC decomposition.
• It will likely be challenging just to maintain current SOC levels.
Enhancing SOC by 4 per 1000

Current SOC stocks and required increase
• Current SOC on agricultural land: 161 ton C/ha
• Required sequestration rate: 0.6 ton C/ha

Need for enhanced inputs
• Assuming a 15% humification rate the requires additional input of:
  • Carbon in biomass: 4 t/ha
  • Dry matter in biomass: 9 t/ha

Typical effect of measures on SOC (topsoil)
• Cover crops: 0.4 t SOC/ha
• Straw incorporation: 0.3 t SOC/ha
• Manure: 0.2 t SOC/ha
• Grassland: 1.0 t SOC/ha
• Subsoil ???: (half of SOC is in subsoil)

Requirements to meet the challenge
• Enhance net primary productivity to have sufficient carbon return
• Enhance return of resilient carbon (manure, compost, biochar)
• Retain crop residues in the field
Storing carbon in soils

› **Prevent losses from existing stocks**
  › Stop draining of wetlands
  › Stop deforestation and grassland conversion

› **Enhancing carbon stocks**
  › Reforestation
  › Grasslands (and grassland management)
  › Carbon through enhanced inputs (reducing tillage have little effect)

› **Enhancing soil carbon also stores N, P and S**
  › C:N:P:S ratio is almost constant (11:1:0.21:0.16) in soil organic matter
Nitrogen surplus (input-output) and SOC

Contrasted relation between sites:
- SOC storage controlled by C inputs
- But also driven by N availability

N required for C sequestration
(Van Groenigen et al. 2017)
Issues

Changes in soil C contributes to the GHG balance (positive/negative)
Soil C affects soil functioning and thus productivity
Measures to enhance SOC may enhance other GHGs (N$_2$O, CH$_4$)
These issues are not (fully) incorporated in farm management practices, policies or incentives for agriculture

Total soil carbon in the topsoil of world soils (t/ha) (Minasny et al., 2017)
Critical issues (actors)

Scientific understanding of the role of soil organic matter for agroecosystem functioning
Quantification of effectiveness of measures to manage soil C (top/subsoil)
Farmer understanding of the role of soil organic matter (productivity)
Policymaker understanding of soil carbon (ecosystem services)
Barriers for improving SOC management (technical, financial)
Incentives to enhance adoption of practices (policies, institutions)
Understanding soil functions

**Improved understanding of soil carbon functions is needed**
What does soil carbon do for us?

China: Mean cereal productivity vs. SOM for blocks of Chinese provinces, 1949-1998

China: Mean cereal yield variability (%) of Chinese provinces, clustered according to climate

But what are causes and what are effects?

Pan et al. (2009) AEE 129:344-348
How soil carbon affects crop yield

Crop yield

Input intensity (N-fertilisation, pesticides, tillage)

Reduced need for inputs (C stock and flows)

Higher productivity (mainly caused by C stocks)
Effect of SOC on crop yield

Hijbeek et al. (2017)
Understanding and influencing farmer behaviour

Farm and farmer heterogeneity
Soil heterogeneity
Short-term farm business versus long-term benefits
7 principles of SOC management (1)

Soil organic carbon is sustained through sufficient inputs of organic matter in roots, crop residues, manure and compost to (out)balance losses from decomposition of soil organic matter.
Soil organic carbon contributes to sustaining soil productivity by enhancing soil water retention and nutrient supply.

Soil organic carbon enhances soil structure and soil workability on soils with high clay content.
7 principles of SOC management (3)

Soil organic carbon contributes to sustaining soil biodiversity, which also influences pests and diseases (positively and negatively) requiring management targeted to local conditions.
7 principles of SOC management (4)

Effective management of soil organic carbon requires a long-term effort and this commitment is more effective if it is a key element in strategic farm management.

“A society grows great when old men plant trees whose shade they know they shall never sit in.” Greek Proverb

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Effective SOC management depends on current soil carbon levels.

On soils with acceptable or good soil carbon, measures should target maintaining these levels of soil carbon and avoiding losses, e.g. through modified and adapted crop rotations and cover crops and residue retention.

On soils with low soil carbon, effective measures involve both securing carbon already in soil in combination with enhancing soil carbon inputs, e.g. through crop rotations, manure/compost application, residue retention and cover crops.

Such measures may be combined with no-tillage practices to further enhance soil carbon and improve soil structure in surface-near soil layers.
Soil organic carbon management also involves management of nitrogen and phosphorus.

Where soil carbon levels are targeted to be enhanced, this will only be effective if supported with sufficient input of nitrogen, phosphorus and sulphur to ensure this carbon storage.
The full benefit of enhanced soil organic carbon on crop yield is only fully captured, if the measures are timed well to provide the water and nutrients (in particular nitrogen) that the crop needs, and aligned with appropriate management to prevent weeds, pests and diseases.

This requires adaptation of the management measures to local soil and climatic conditions as well as to (region) specific farming systems.
Questions to be discussed

› How can the “4 per 1000” initiative facilitate general action at all levels?
  › Which actions to prioritize?
› As an actor or colleague, how can you invest in this move to action?
  › Which interventions to prioritize?
› What are the conditions that can boost or slow actions?
  › Classify conditions and environment elements by priority in two columns: boost versus slow down