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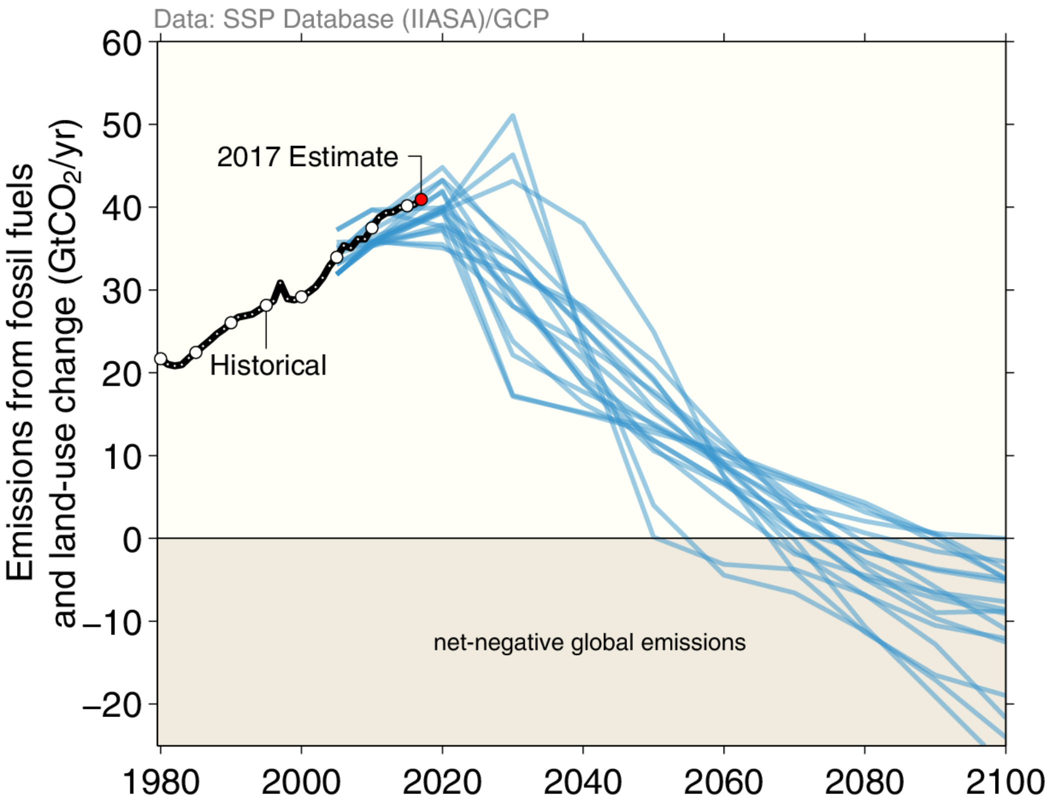
Perspectives for soil carbon management

Professor Jørgen E. Olesen

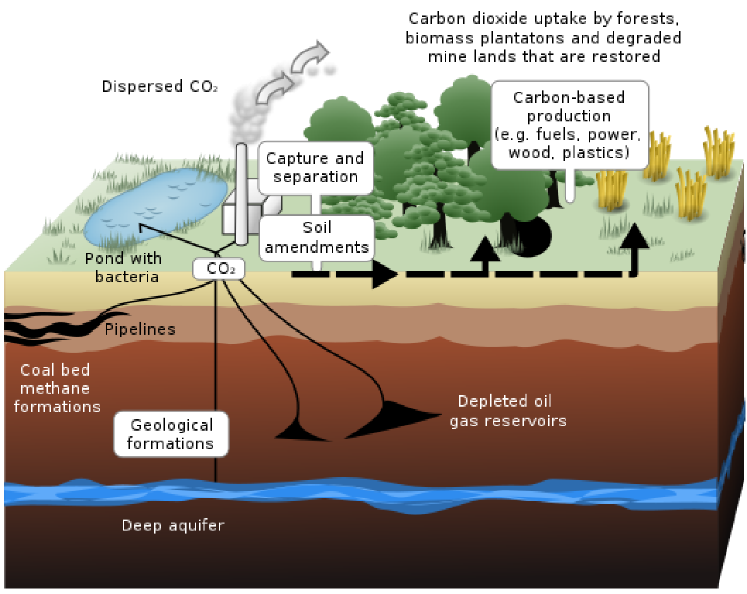
Pathways to 2 degree target



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

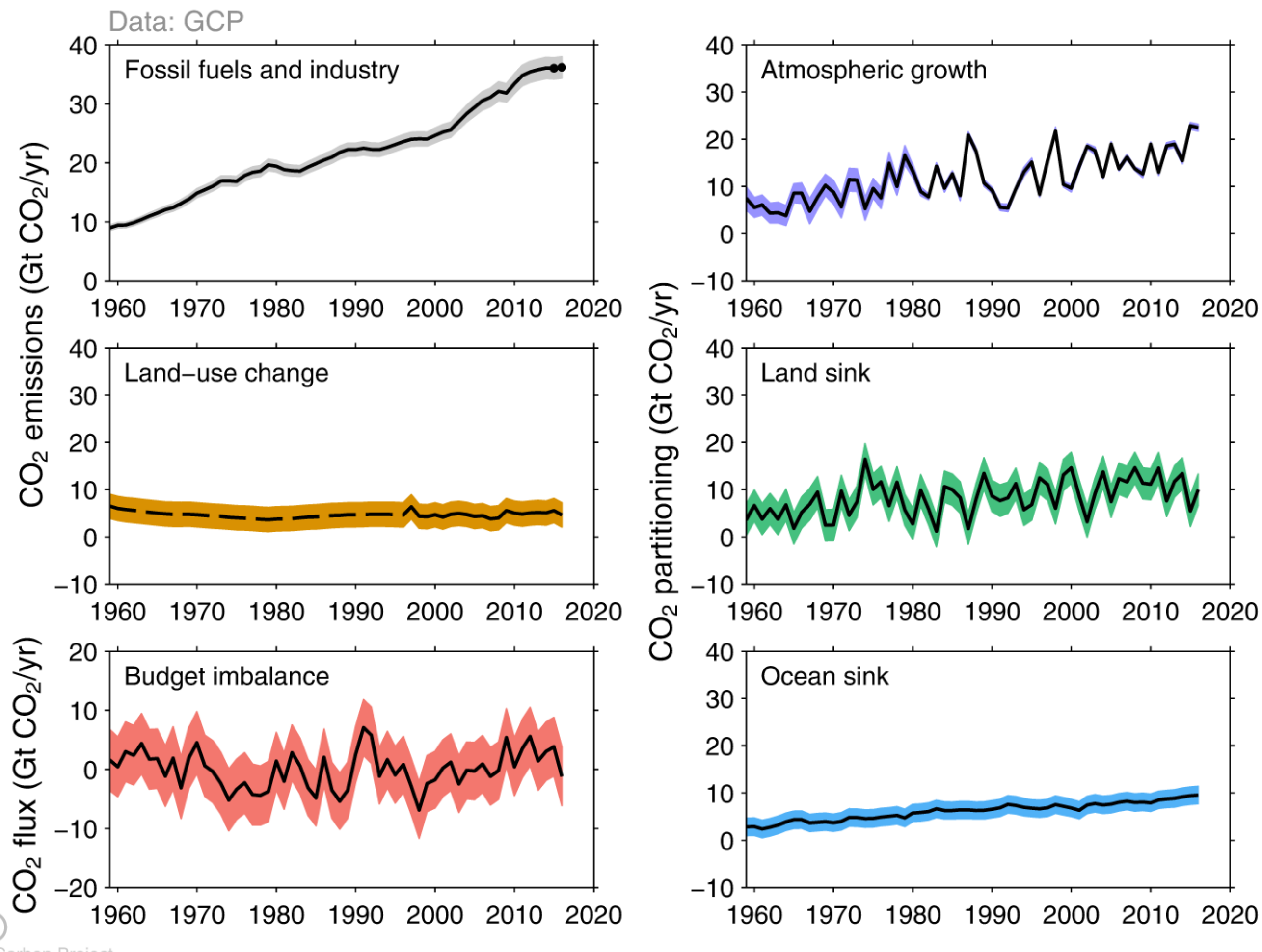
Point sources (power plants):
- CCS in geological formations

Atmosphere:
- Storage in vegetation (forest)
- Storage in soils



Global Carbon Project

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

Global Carbon Project

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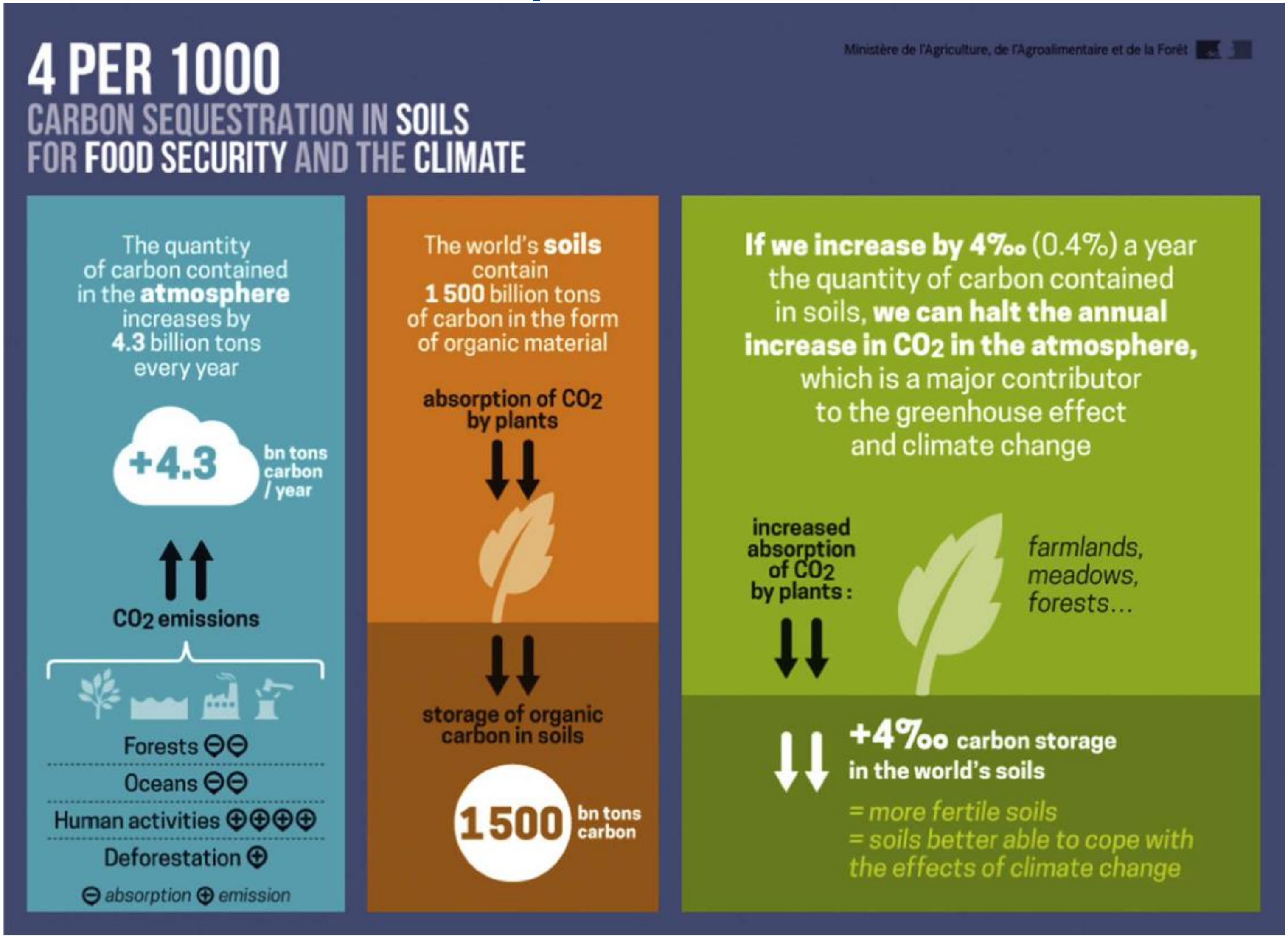
4 per mille concept



4 per 1000

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 ºC 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

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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



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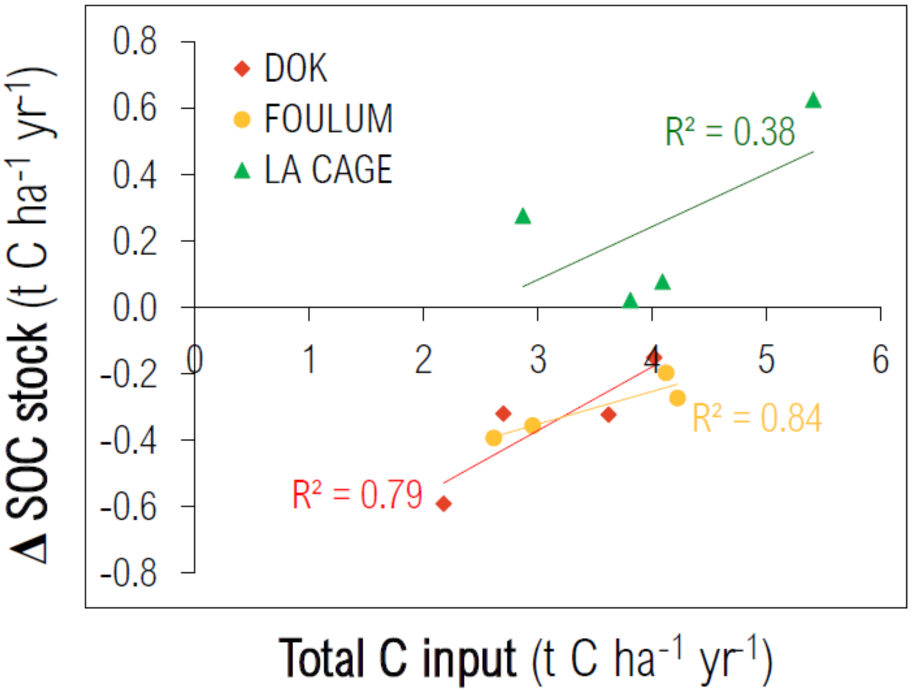
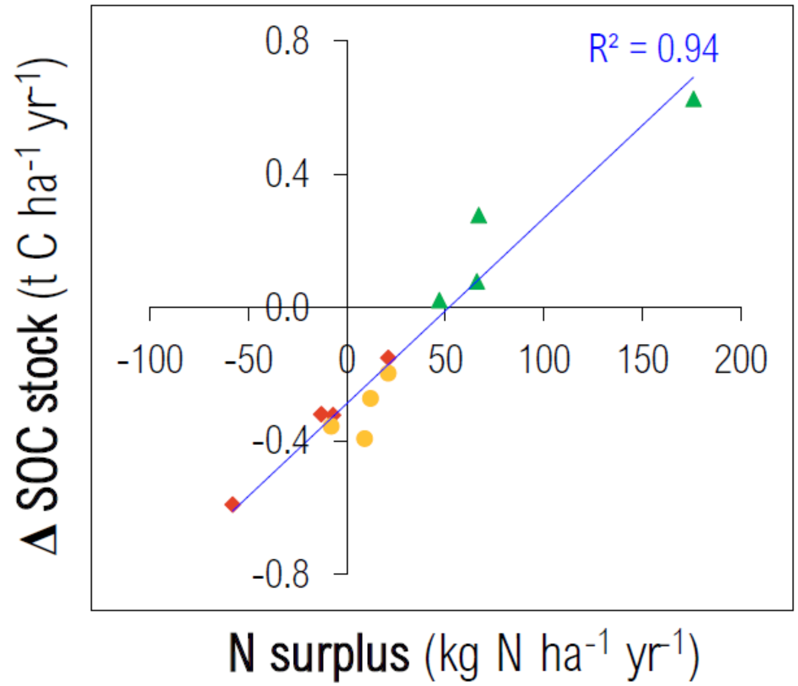
Nitrogen surplus (input-output) and SOC





- 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)

Bénédicte Autret, INRA

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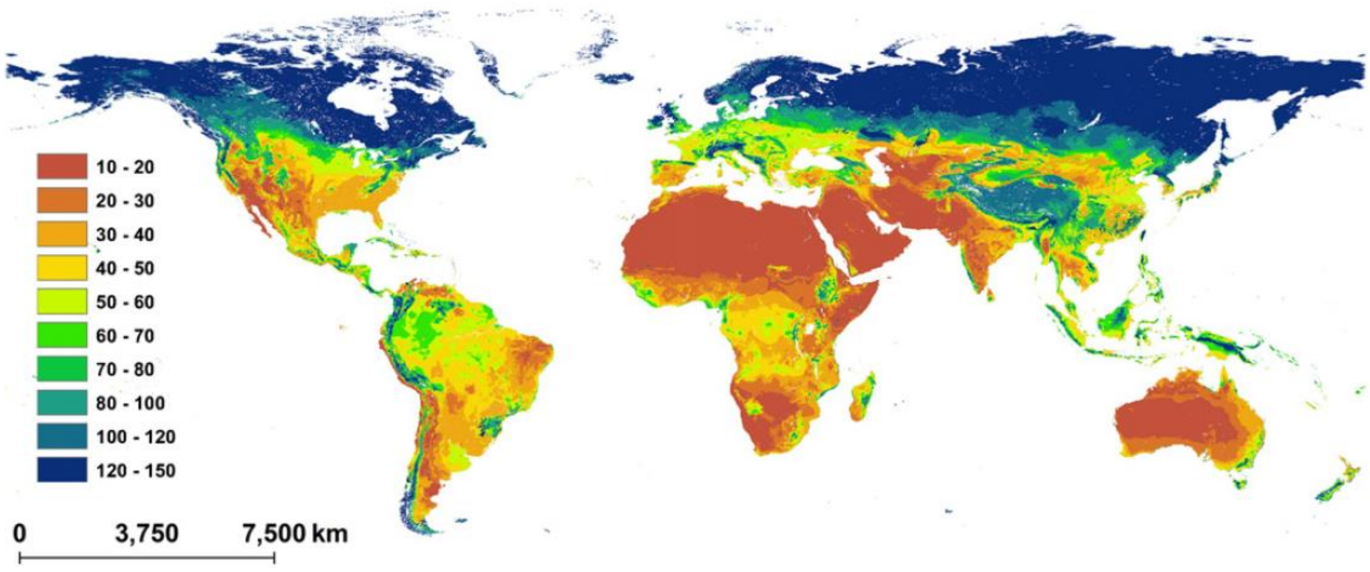
Issues

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_2O, CH_4)

These issues are not (fully) incorporated in farm management practices, policies or incentives for agriculture



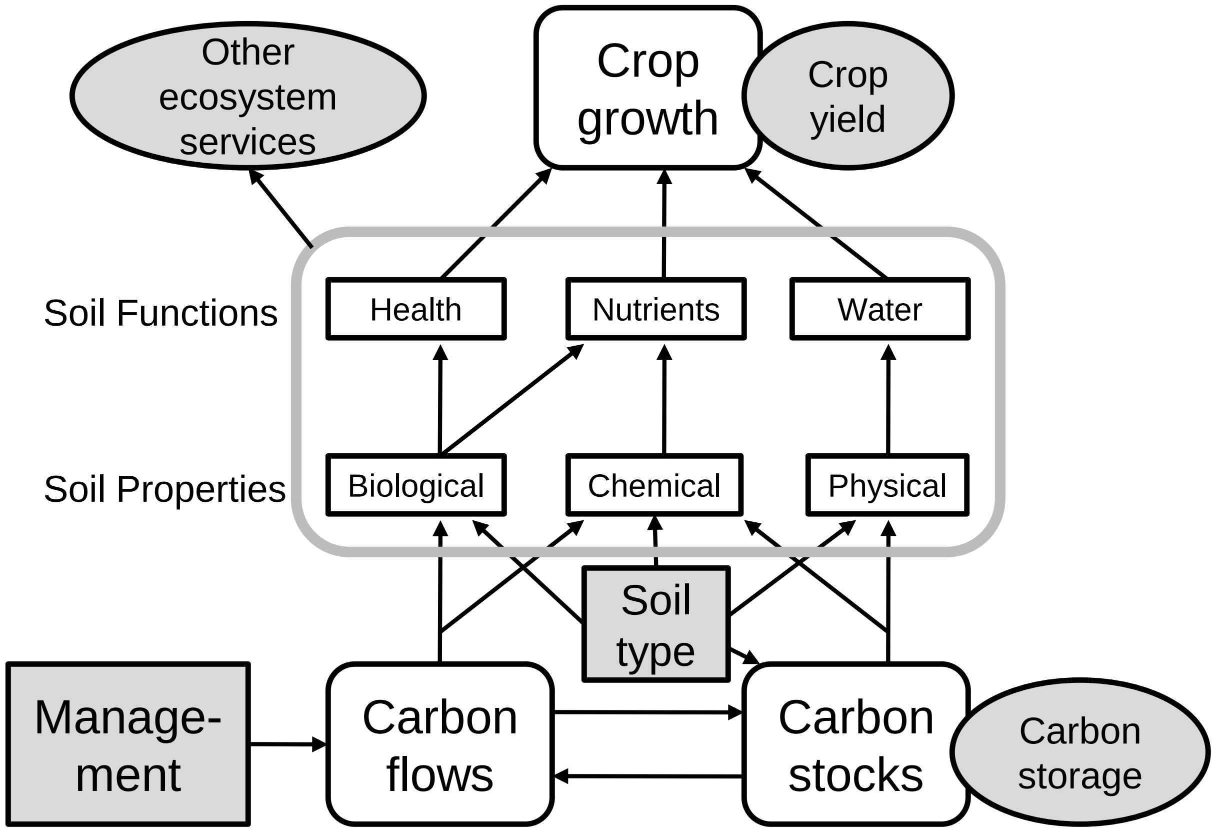
Total soil carbon in the topsoil of world soils (t/ha) (Minasny et al., 2017)

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)

- Countries, local governments, international and regional Organizations
- Banks, Devlopment Funds and Foundations
- Institutions of Research and Training
- Farmers and Foresters Organizations
- Civil Society Organizations and NGOs
- Commercial and for-profit Organizations - Businesses

Understanding soil functions



Improved understanding of soil carbon functions is needed

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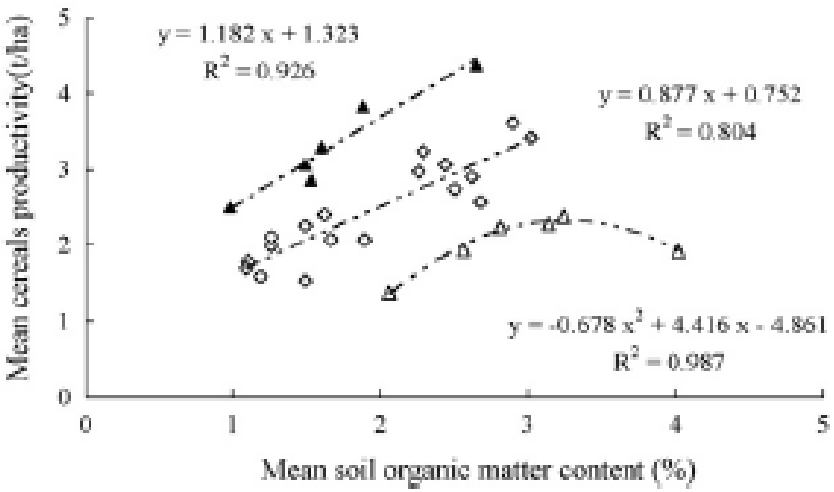
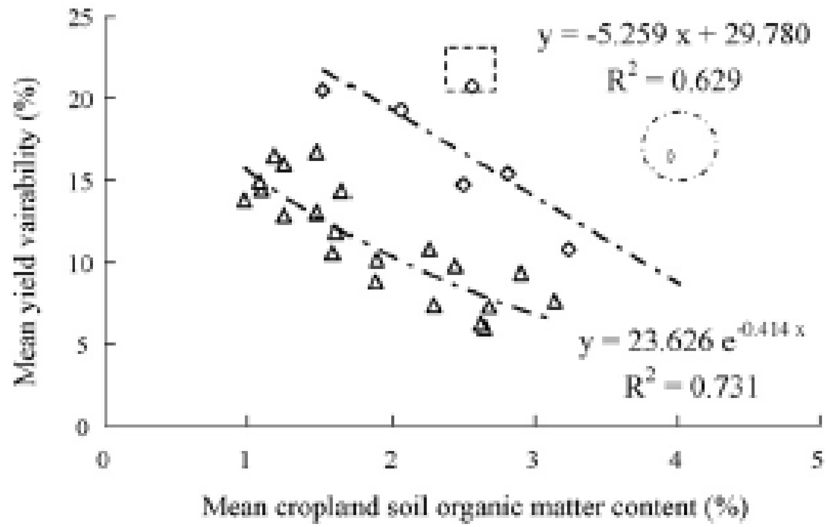
What does soil carbon do for us?



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

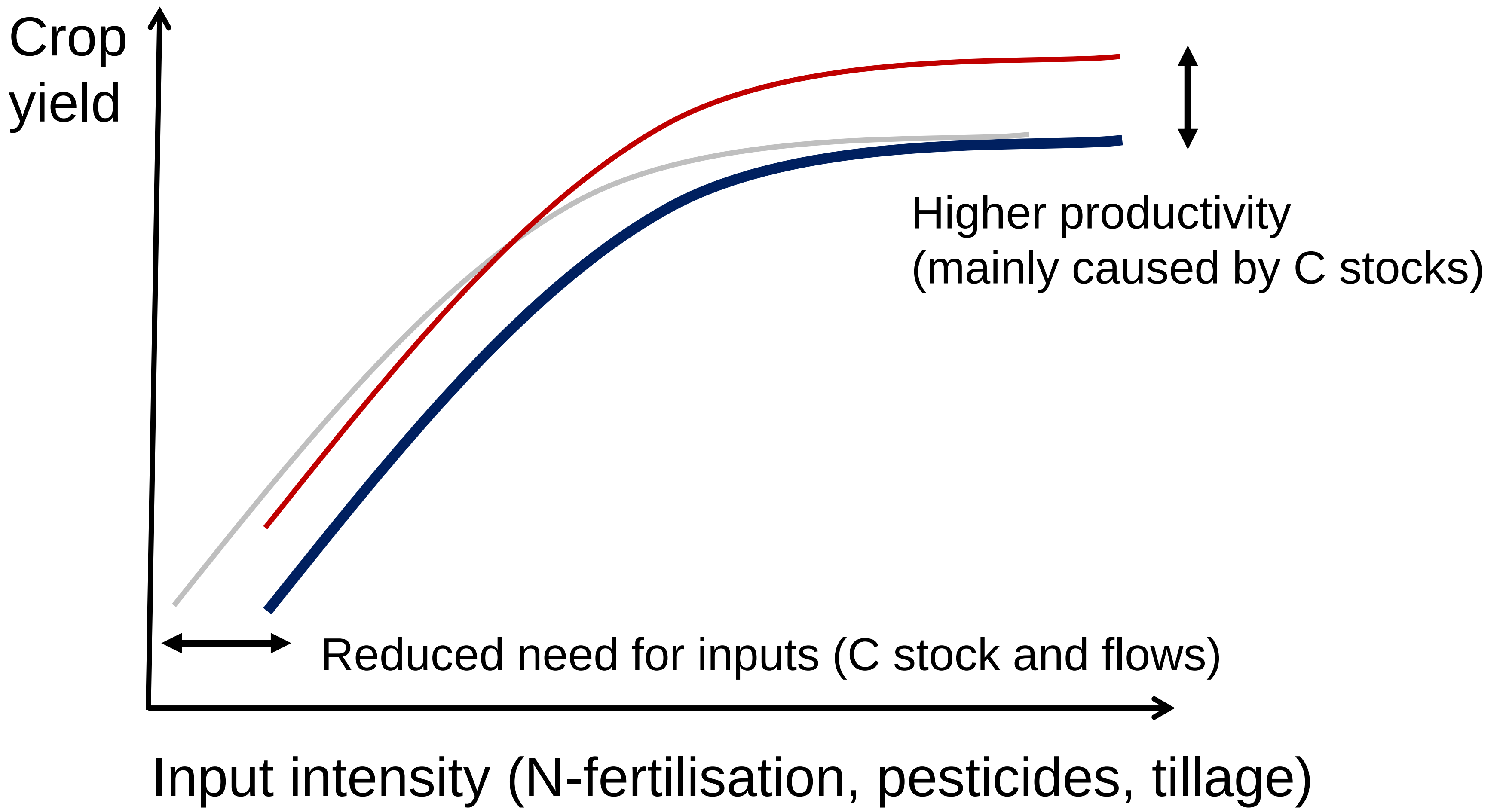


China: Mean cereal yield variability (%) of Chinese provinces, clustered according to climate

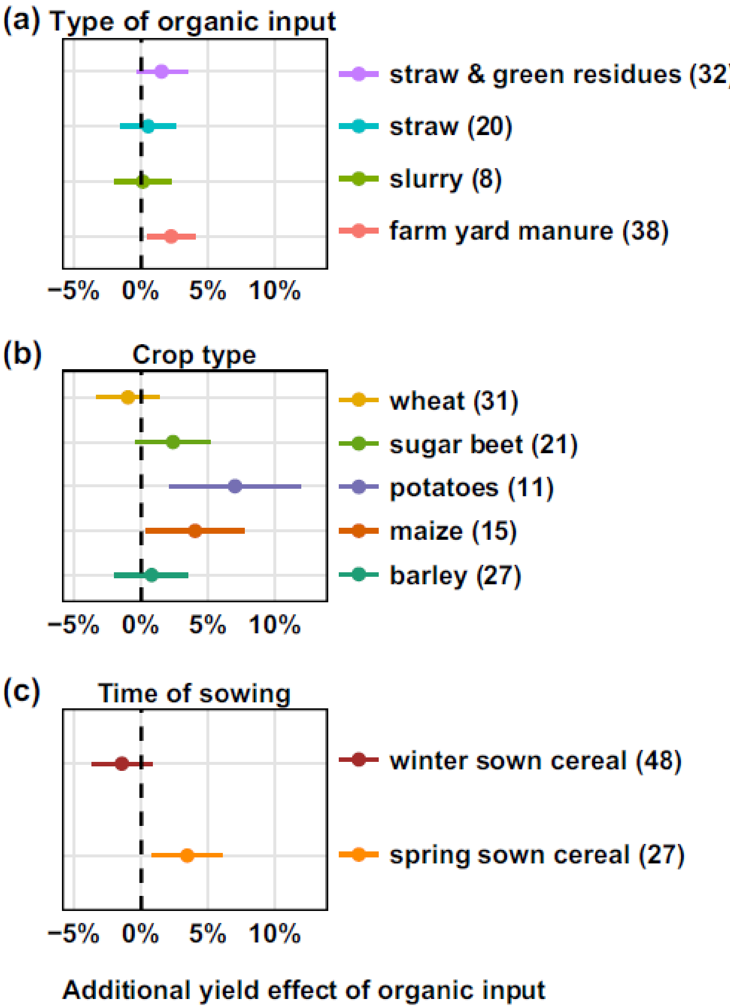
But what are causes and what are effects?

Pan et al. (2009) AEE 129:344-348

How soil carbon affects crop yield

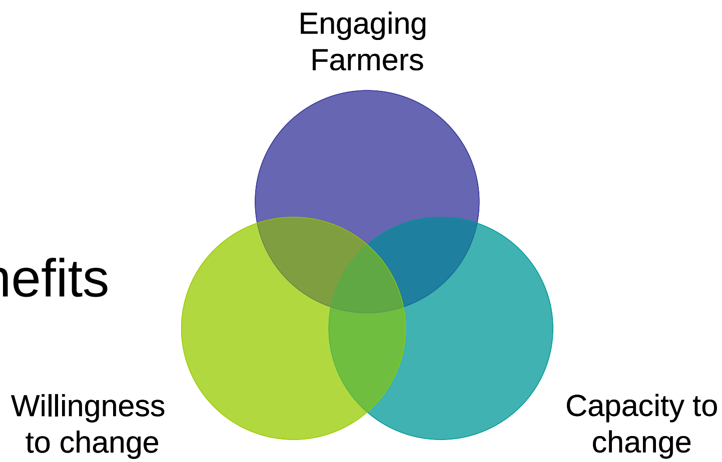


Effect of SOC on crop yield



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.

7 principles of SOC management (2)

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.

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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.

7 principles of SOC management (5)

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**.

7 principles of SOC management (6)

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.

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7 principles of SOC management (7)

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 by 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