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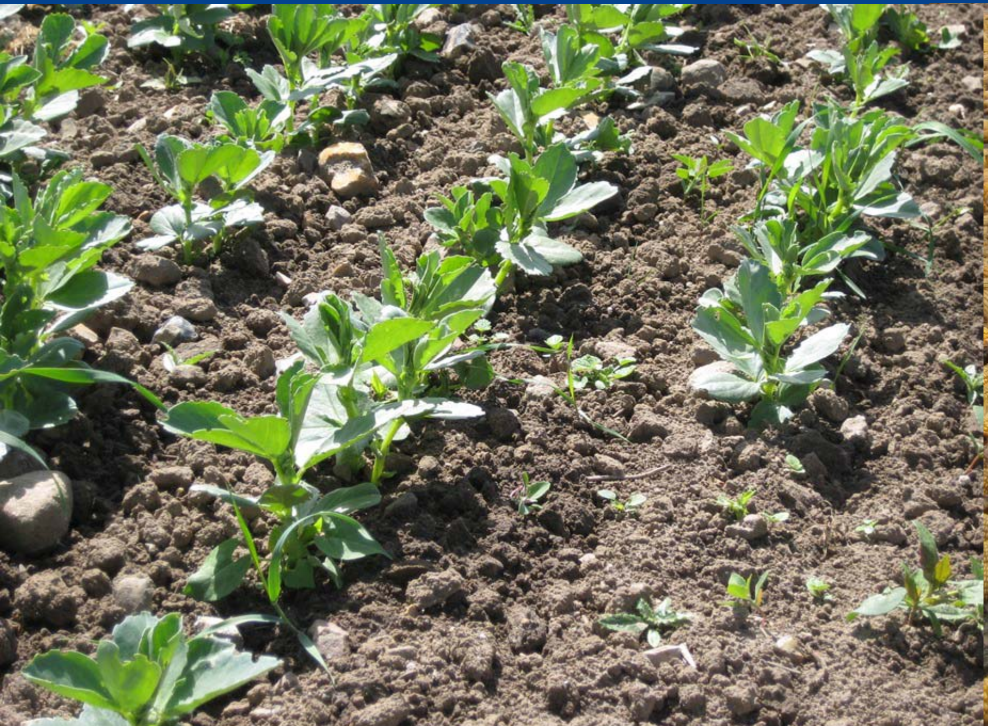
SmartSOIL
Sustainable farm Management Aimed at Reducing Threats to SOILs under climate change

Linking soil functions to carbon fluxes and stocks

Professor Jørgen E. Olesen

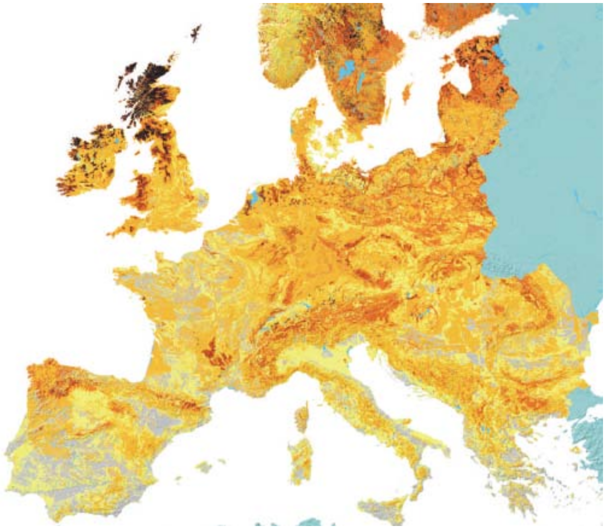


Issues

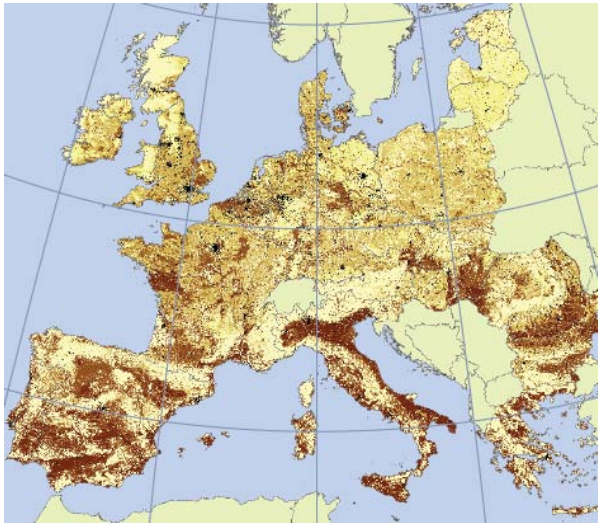
Changes in soil C contributes to the GHG balance (positively or negatively)

Soil C affects soil functioning and thus productivity

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



Soil C contents



Soil C loss potentials

Other issues

Scientific understanding of the role of soil organic matter for agroecosystem functioning

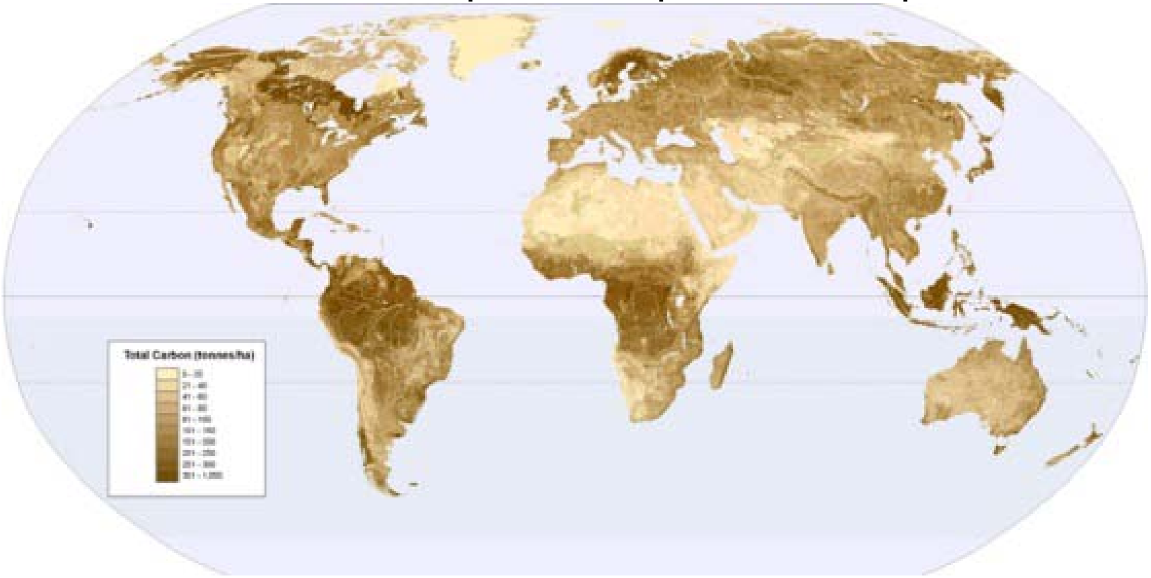
Quantification of effectiveness of measures to manage soil C

Farmer understanding of the role of soil organic matter

Policy maker understanding of soil carbon

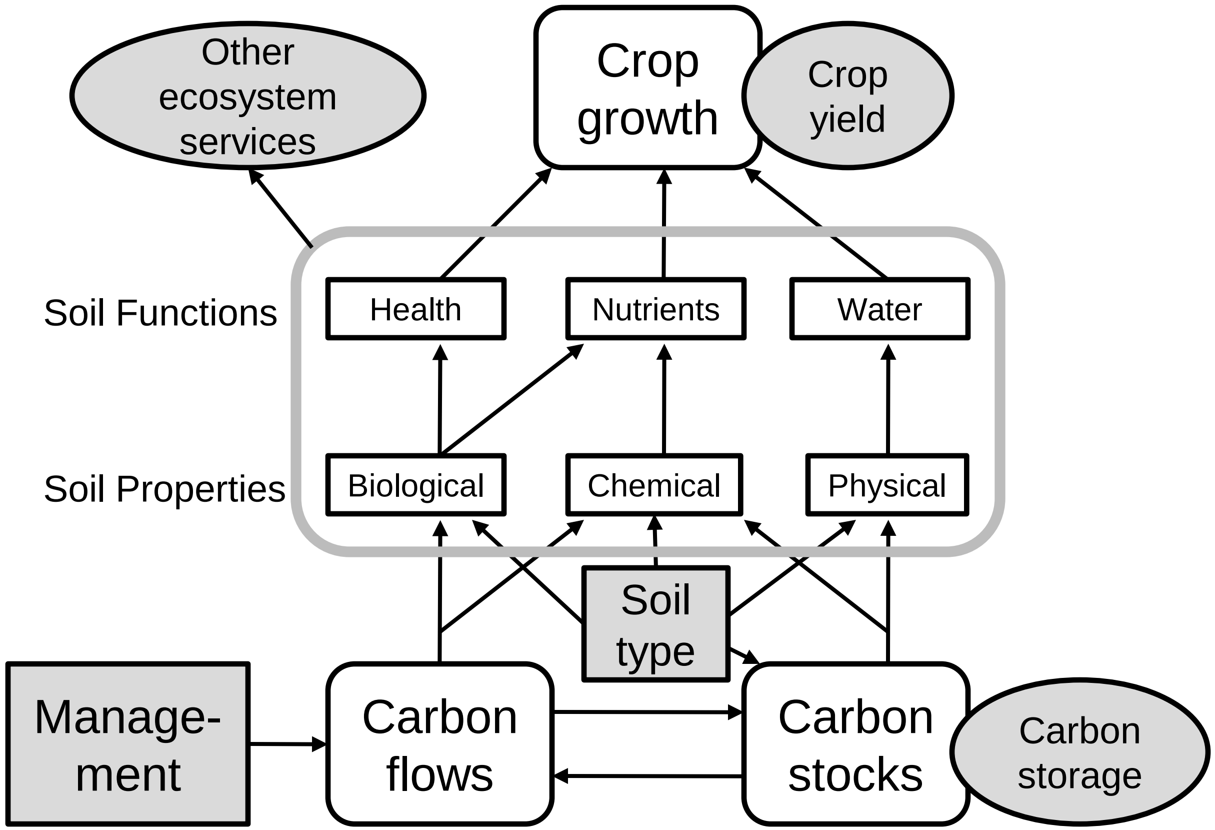
Barriers for improving soil organic matter management

Incentives to enhance adoption of practices (policies)



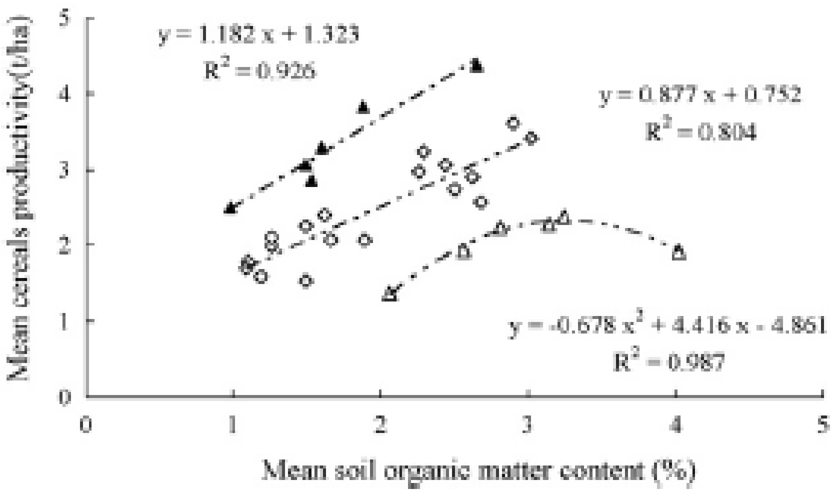
Total Carbon (t/ha) [UNEP-WCMC updated Global Carbon Map]

Understanding soil functions

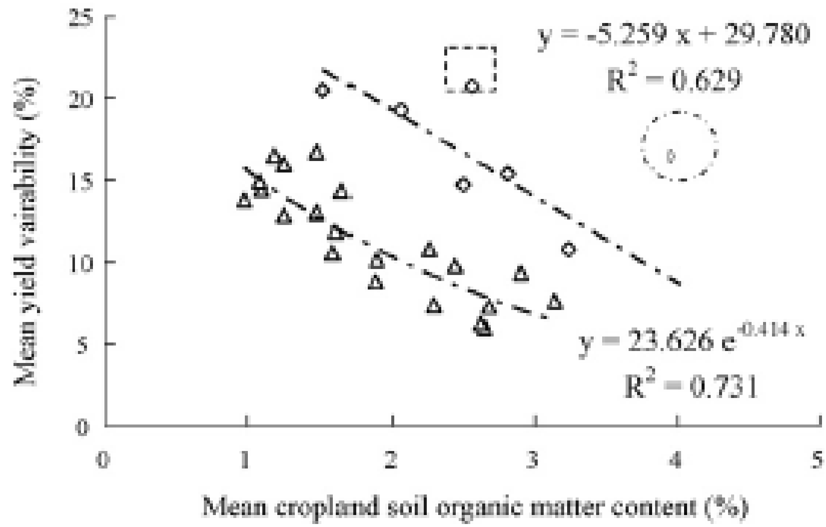


Improved understanding of soil carbon functions is needed

What does soil carbon do for us?



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



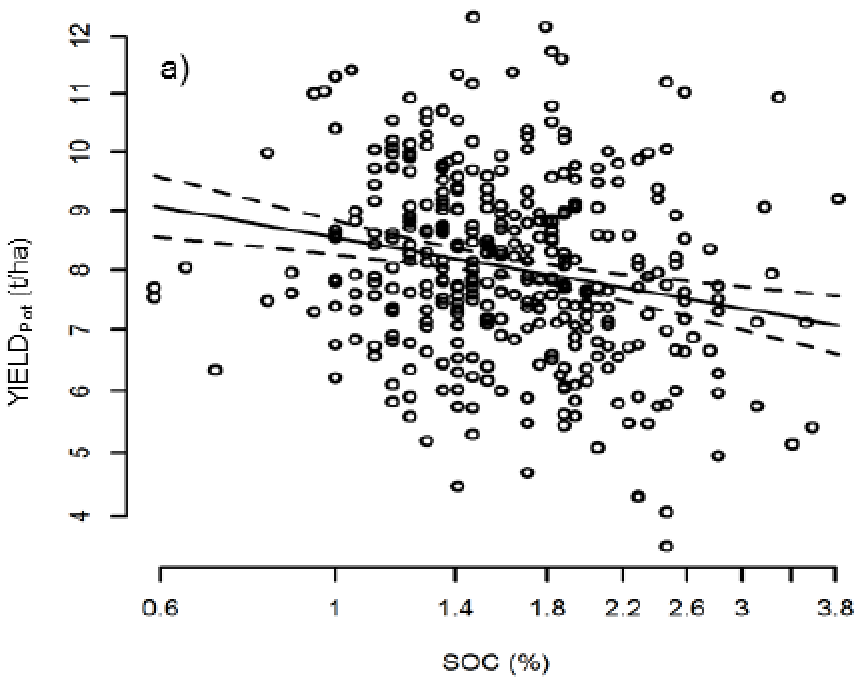
China: Mean cereal yield variability (%) of Chinese provinces, clustered according to climate

But what are causes and what are effects?

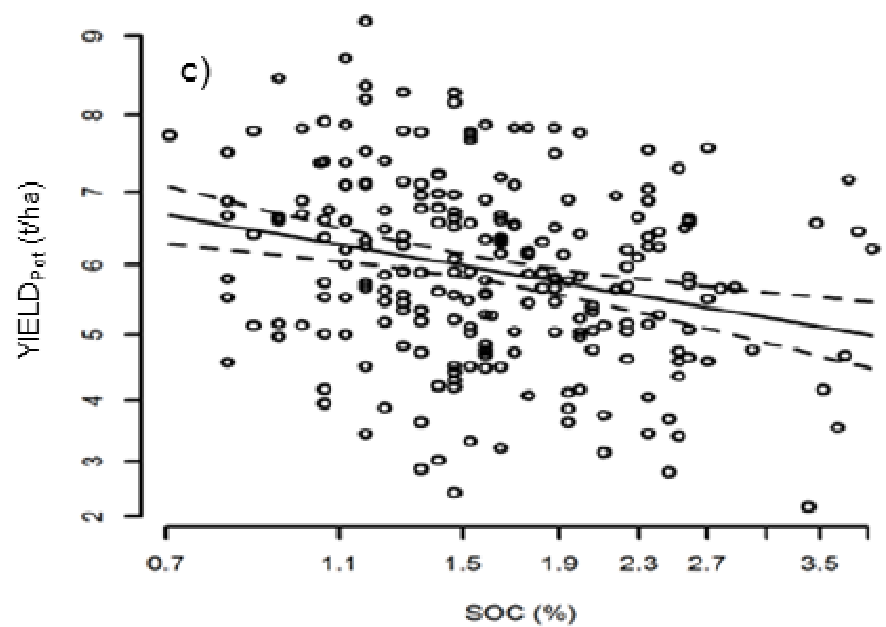
Pan et al. (2009) AEE 129:344-348

Yield at maximum N level in N fertiliser experiments across Denmark

Winter wheat



Spring barley



Oelofse al. (submitted)

Spring barley yield related to N-input

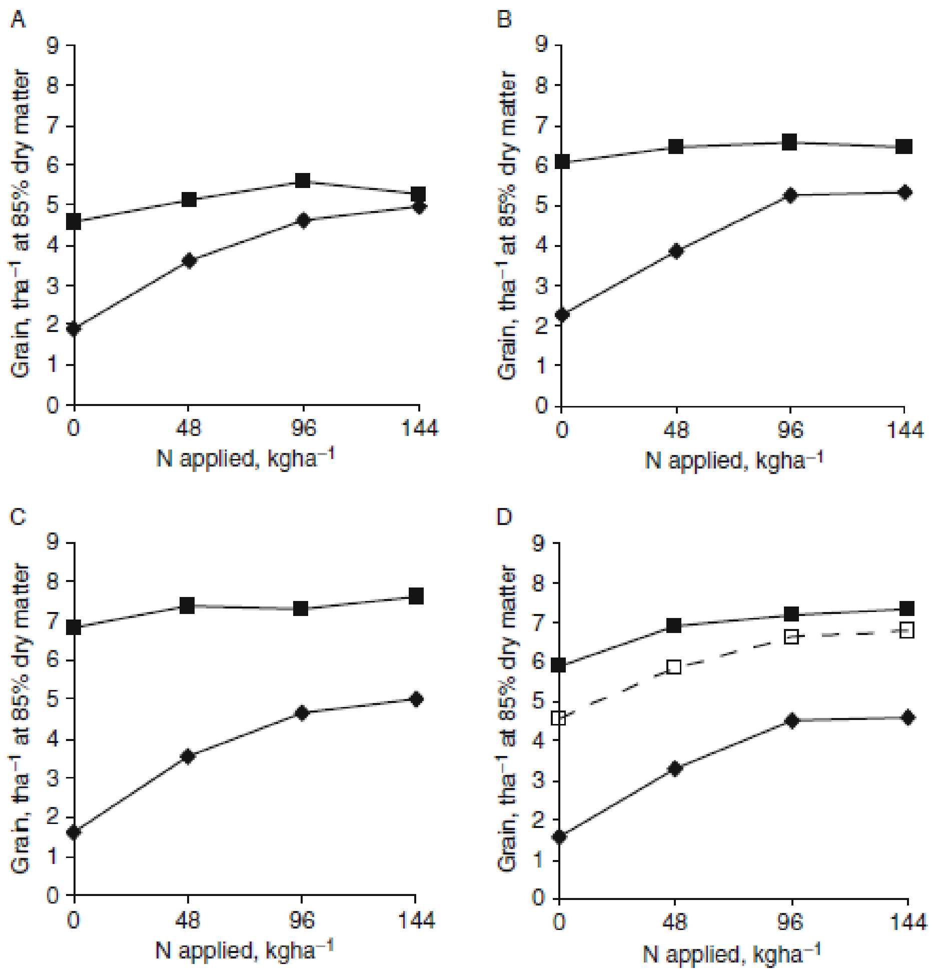
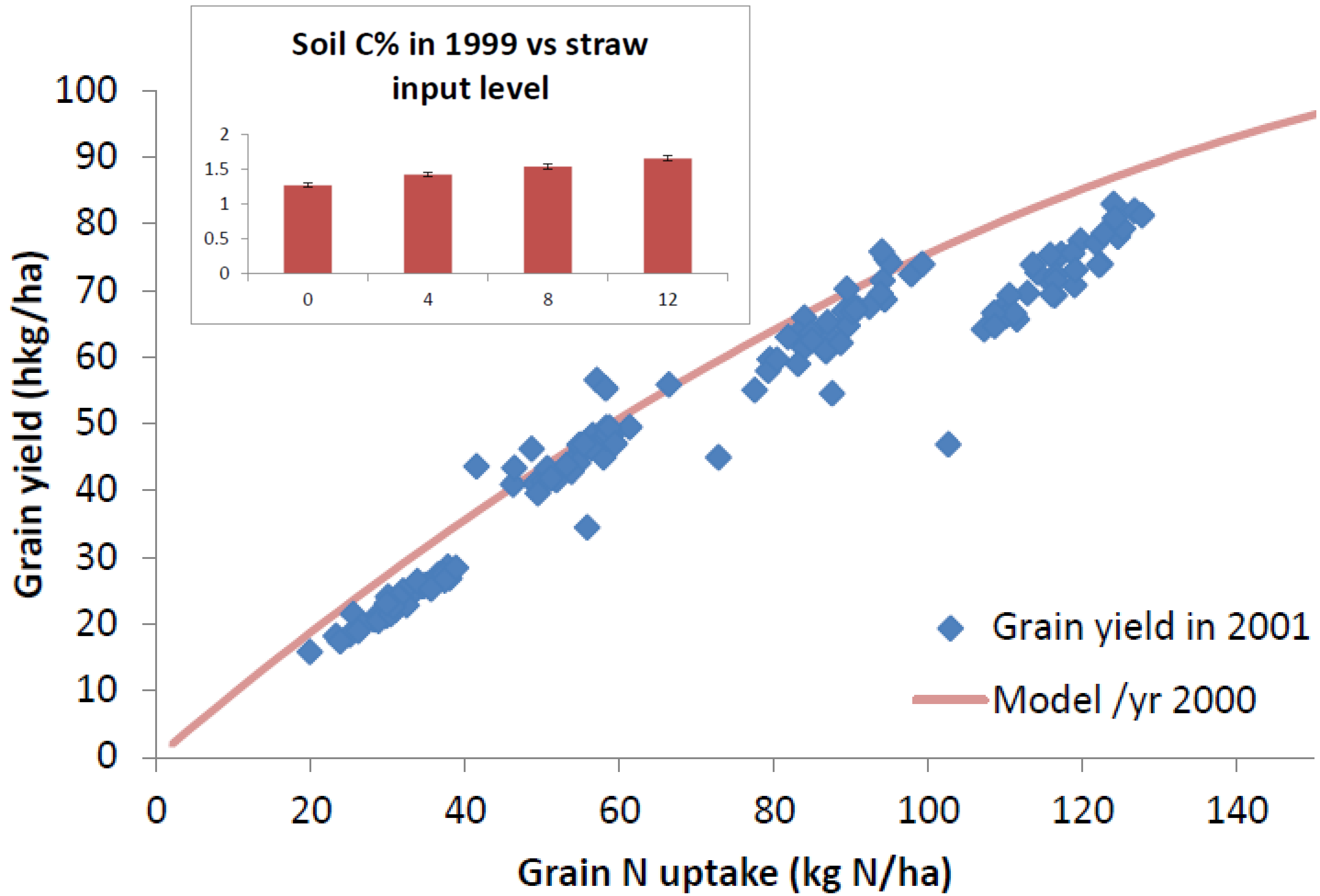


Figure 10 Yields of spring barley grain (t ha^{-1}) Hoosfield Continuous Barley, Rothamsted. Annual treatment 1852–2006: PK fertilizers, ◆; 35 t ha^{-1} FYM, ▪; annual treatment only from 2001 to 2006: 35 t ha^{-1} FYM, □. (A) *cv.* Julia, 1976–1979, (B) *cv.* Triumph, 1988–1991, (C) *cv.* Cooper, 1996–1999, and (D) *cv.* Optic 2004–2007.

Johnston et al. (2009)

Winter wheat at Askov with increasing N in a long-term experiment with straw



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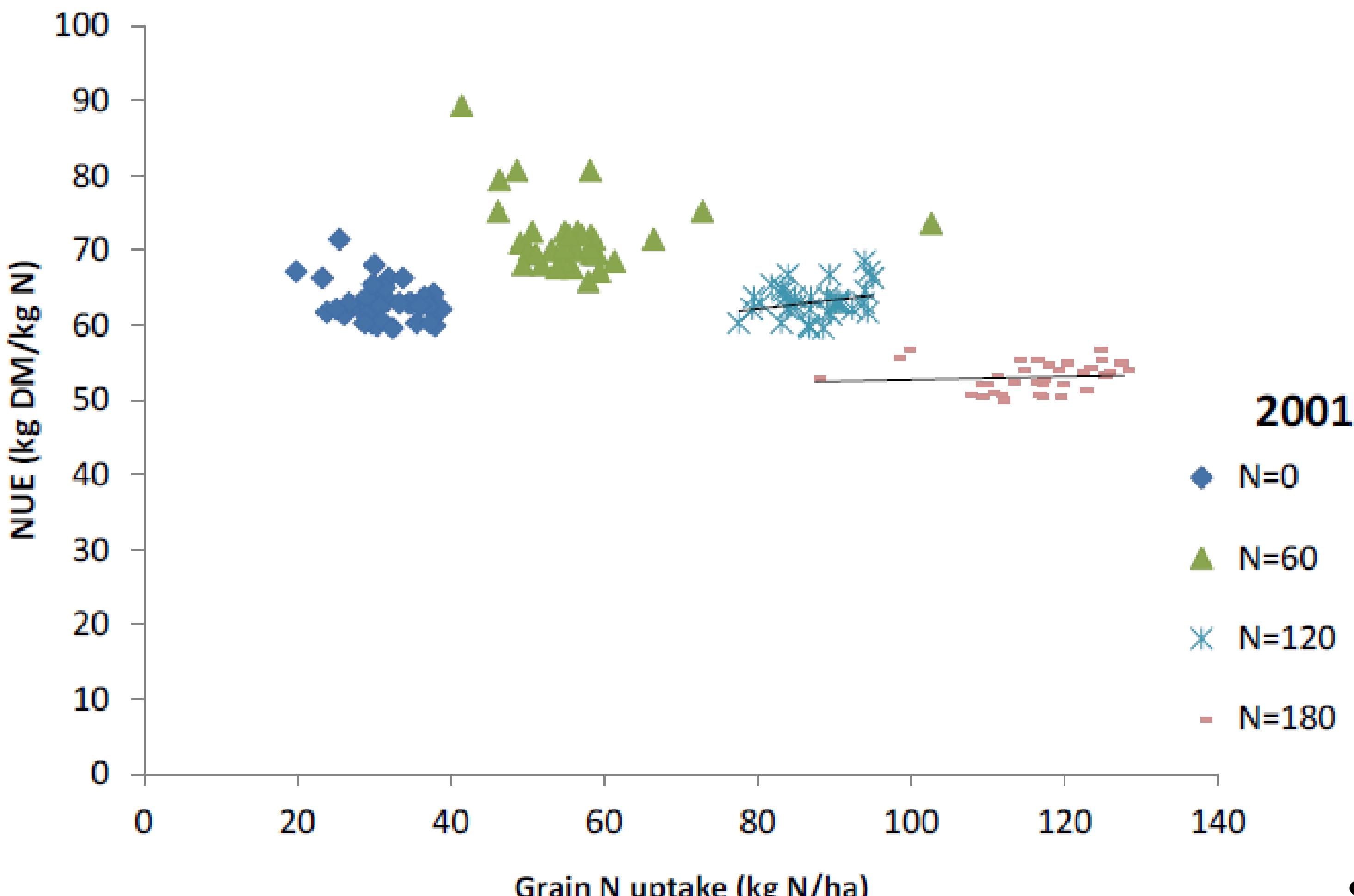

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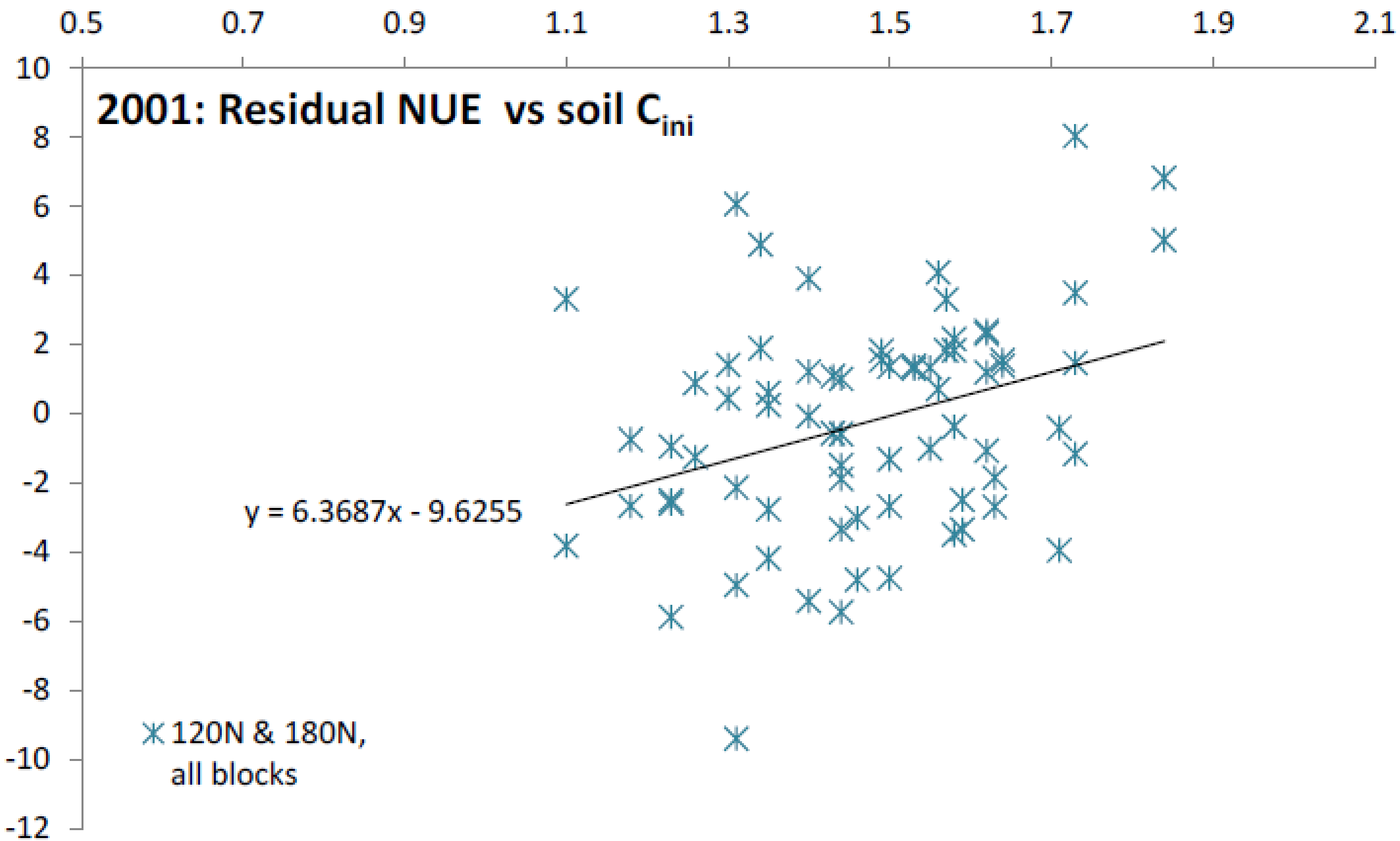
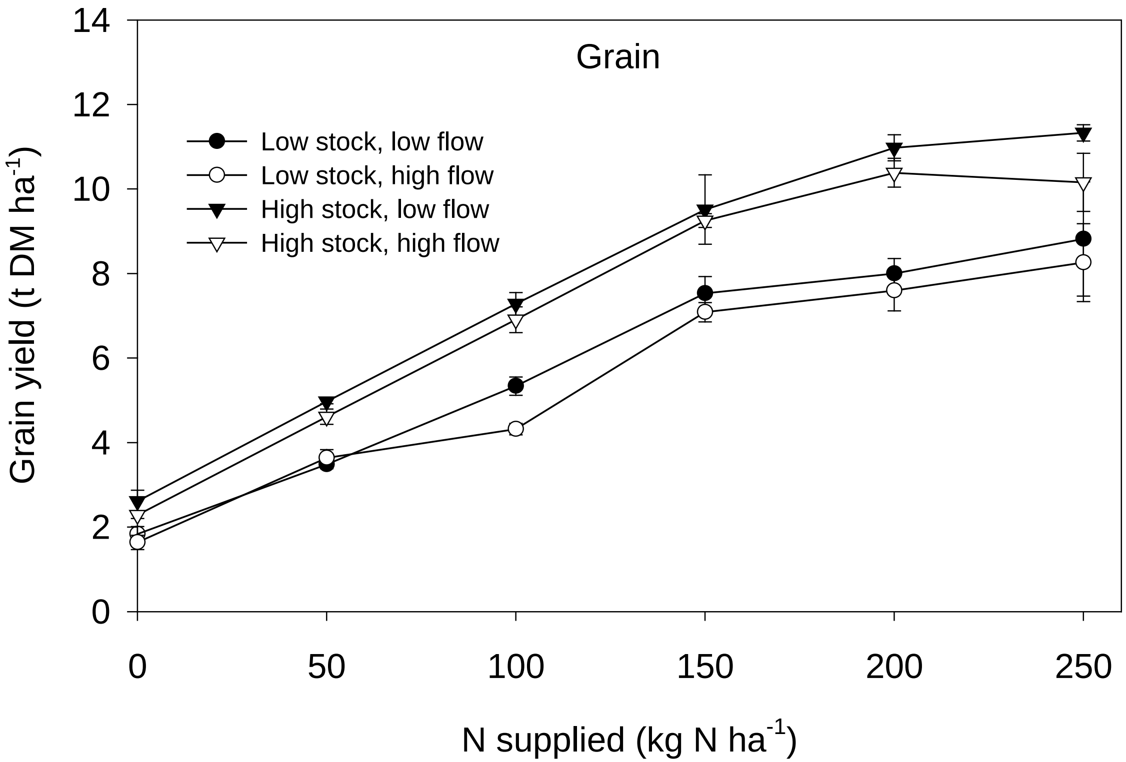
Winter wheat at Askov with increasing N in a long-term experiment with straw



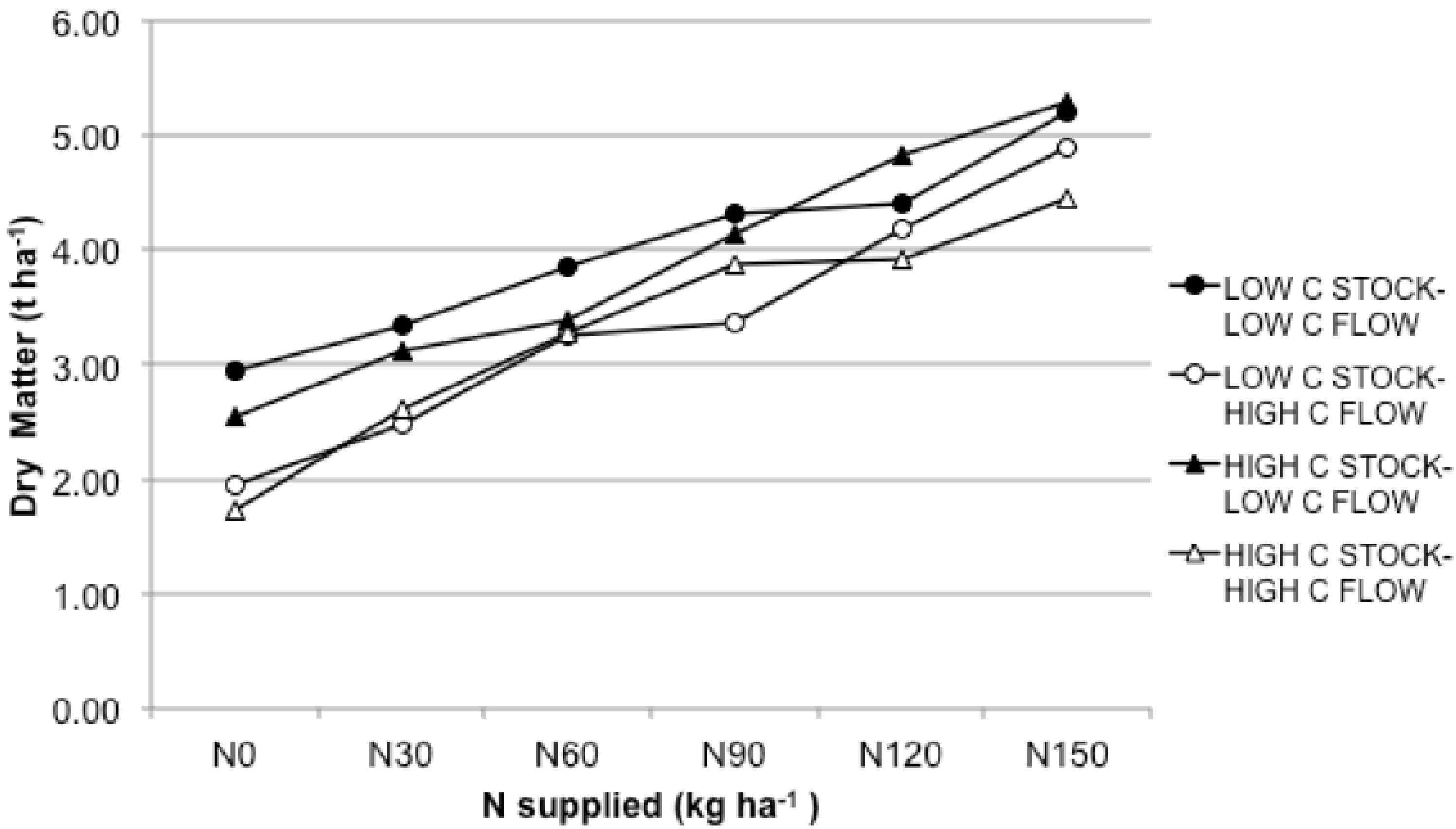
Soil carbon stocks seem to increase NUE (but what is the mechanism?)

SmartSOIL stock and flow experiment (Askov)



- Plots in long-term experiments with low and high stock were used
- Sub-treatments with low and high flow (straw) was imposed
- Increasing rates of mineral N was applied in miniplots.
- Data from N^{15} fertiliser labelling not yet available

SmartSOIL stock and flow experiment (Pisa)



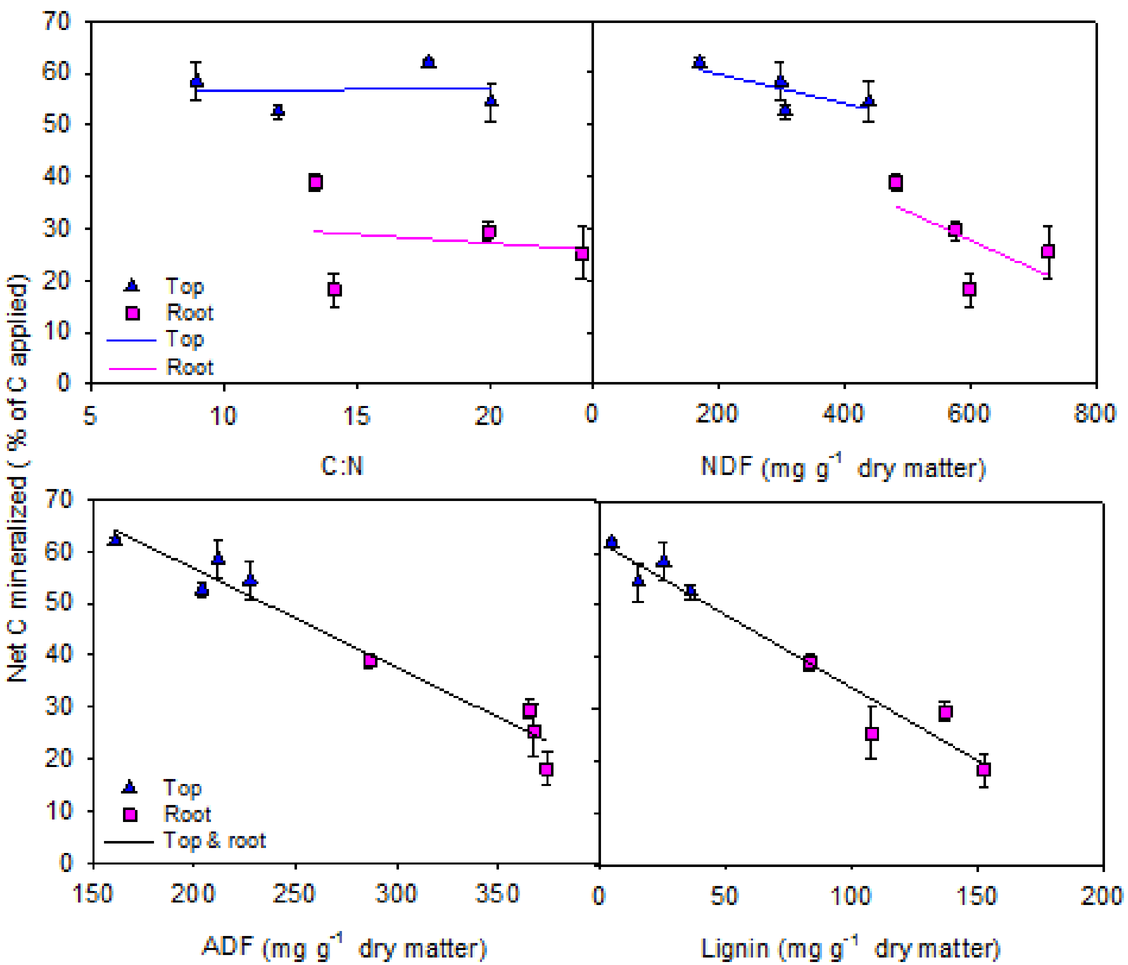
- Plots in not so long-term experiments with low and high stock were used
- Sub-treatments with low and high flow (straw) was imposed
- Increasing rates of mineral N was applied in miniplots.

Storing carbon

- **Prevent losses from existing stocks**
  - Stop draining of wetlands
  - Stop deforestation and grassland conversion
- **Enhancing carbon stocks**
  - Reforestation
  - Grasslands (and grassland management)
  - Soil carbon through enhanced inputs (and less tillage?)
- **Enhancing soil carbon also stores N, P and S**
  - C:N:P:S ratio is almost constant in soil organic matter

C decay rates for top and root

Carbon has short and long residence times in the soil



Incubation study. Four types of green manure for top and root. Net C mineralized in 100 incubation days at 15 C, as related to C:N ratio, fibres, and Lignin in the incubated plant material.
(*Li et al., in prep.).*

Root-derived C is more resistant to decay than than shoot-derived soil C
(Rasse et al. 2005)

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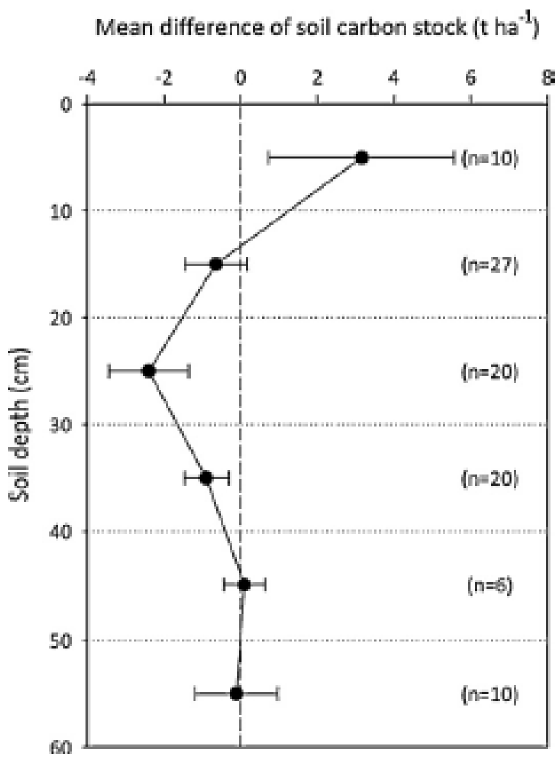
Management practices

- Organic manure
- Choice of crops:
  - Cover crops
  - Perennial crops (grasses, bioenergy crops)
  - Legumes (root biomass; N-rich)
- Incorporation of crop residues incl. straw
- No-tillage practices

Soil carbon management

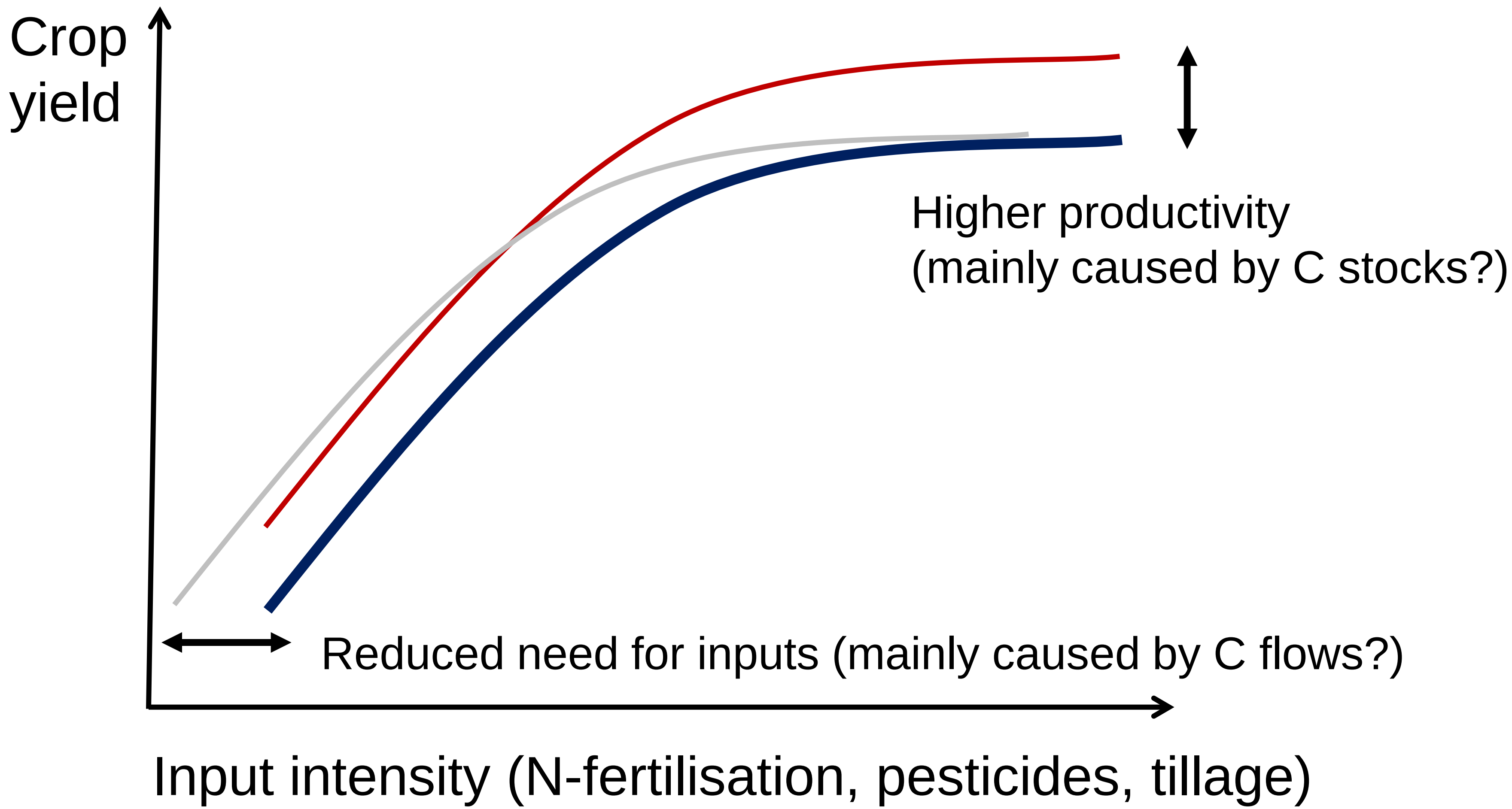
› Increase C input to the soil
› Minimize C losses from the soil



Review: 69 paired tillage experiments.
Mean difference of carbon contents
of soils under conventional tillage
and no-tillage.
(Luo et al. 2010)

Conversion from conventional tillage to no-tillage does not seem to increase the overall SOC stock – but promote surface near carbon (which may benefit some soil functions).

How does soil carbon affect crop yield?



Sources of nitrogen for crop N supply

- Long-term:
  - Soil organic matter (N in humus)
- Medium-term
  - Added organic N over the crop rotation(s) (previous 10 years)
- Short-term
  - Grass-clover or other green manure crops
  - Catch crops (with and without legumes)
  - Ammonium-N in manure

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Response of grain N yield to N input and weeds in a long-term organic arable farming experiment in Denmark

Variable	Winter wheat	Spring barley
Soil N	0.0036	0.0038
Annual organic N inputs	0.19	0.20
N in catch crops	-	0.37
Ammonium-N (Jyndevad)	0.18	0.56
Ammonium-N (Foulum)	0.56	0.46
Ammonium-N (Flakkebjerg)	0.40	0.45
Weeds	-0.53	-1.06

Response to N input is kg N in yield per kg N in input
Response to weeds is kg N in yield per % weed at flowering

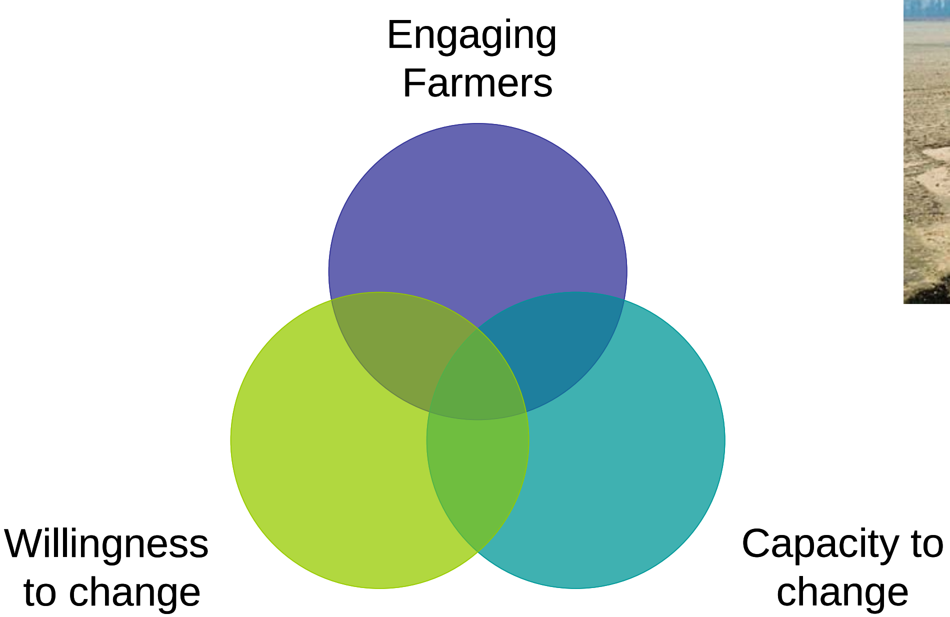
R^2 for winter wheat is 0.74 and for spring barley 0.69

Understanding and influencing farmer behaviour

Farm and farmer heterogeneity

Soil heterogeneity

Short-term farm business v. long term benefits



Promotion and awareness

- **Little evidence** of specific government policies
- Usually **advice integrated** as part of other programmes, e.g cross-compliance
- Soil carbon management relatively new issue so **awareness generally limited** - growing in Denmark and Scotland but remains low in Poland
- Variation in the extent of awareness within countries - reflects **farmer age and farming and educational background**

Barriers for management changes

- Perceived **scientific uncertainty** about benefits of managing soil for carbon
- Difficulty demonstrating the effects and economic benefits **over a long time** of managing soil carbon
- Farmers' **perceptions**, **priorities**, **knowledge and lack of familiarity** of managing the soil for carbon.
- Farmers unconvinced of benefits (soil and economic)

Incentives for management changes

- **Financial incentives**
- Messages - use **simple language and quantify impact**
- Evidence of benefits – impact on **productivity and profitability**
- **Integrating advice** into existing advice channels, policies and regulations
- Real life **case study** examples

SmartSOIL decision support

- Web-based (possible integration in advisory systems)
- Examples of good practices (descriptions, pictures, videos)
- Quantification of effects on soil C of management changes
- Estimates of effects of soil C on crop yield and needs for N fertiliser

Considerations for crop yield effects

- Nitrogen follows carbon
- Crop productivity is greatly affected by N flows
- C/N ratio of residue inputs affect N flows
- Crop water supply plays a major role in dry environments
- Water supply affected by soil water harvesting, retention and evaporation protection (C stocks and flows)
- Soil C stocks can affect soil structure affecting crop establishment
- Soil C flows can affect soil biota with resulting effects on crop health

Conclusions

- Effects of soil and crop management on soil carbon can be reasonably reliably predicted using relatively simple first order kinetic pool models
- Issues still remain on effects of tillage and below-ground inputs on soil carbon (in topsoil and subsoil)
- Soil organic matter plays a large role for crop nutrient (N) supply and this can be predicted
- Much less is know on other effects of soil C on crop growth and yield
- Farmers (and policy makers) need better information and incentives for soil organic matter management

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www.smartsoil.eu

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