Do organic fertilisers bring benefits to farmers beyond their nutrient value?

Can they contribute to climate change mitigation by sequestering C in soil as in the “4p1000” initiative?

David Powlson & Andy Whitmore

Rothamsted Research, UK

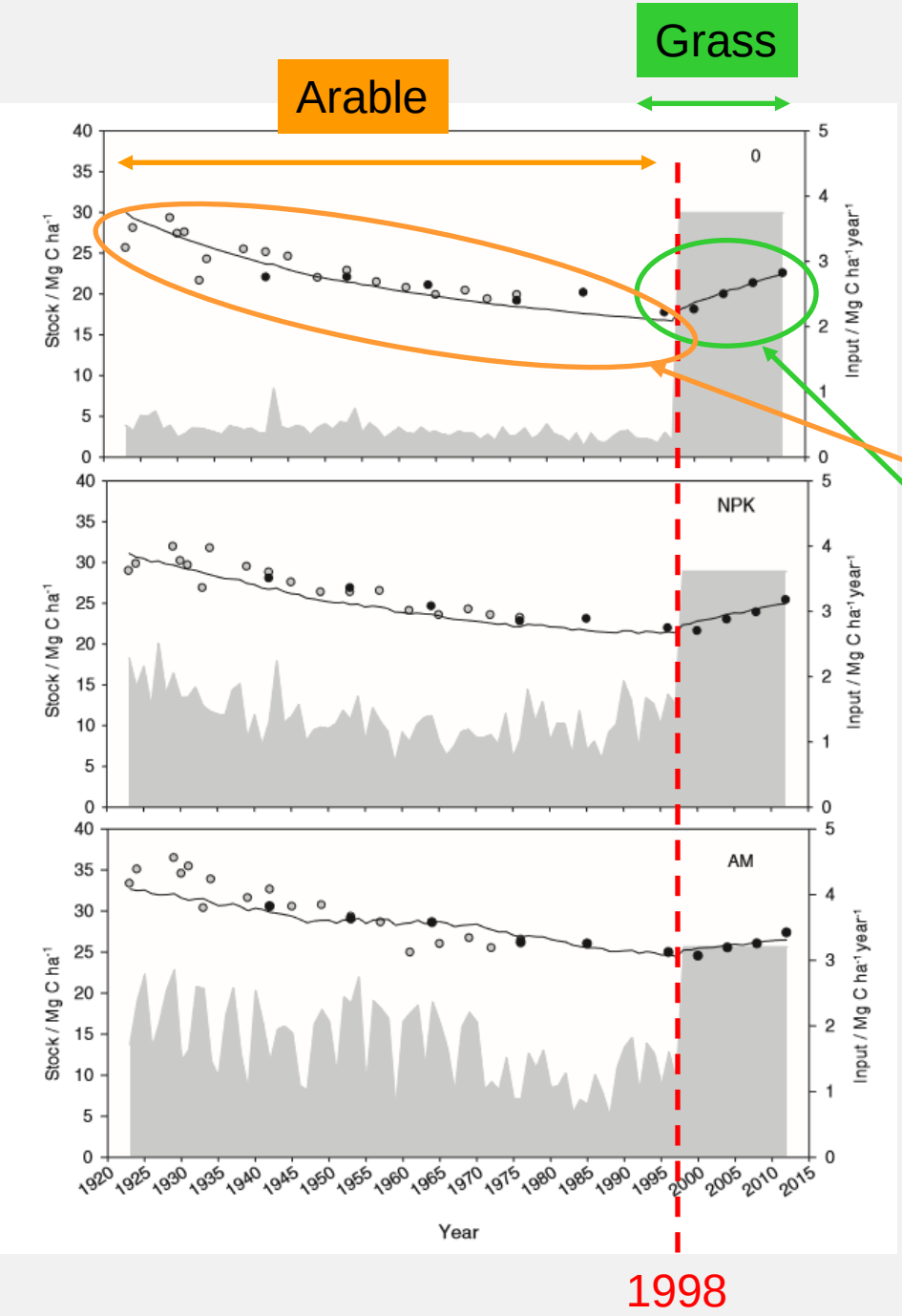
Organic matter influences soil properties in 3 ways:

- Provides nutrients
- Improves physical conditions
- Energy source for organisms which mediate the first two

- Arable soils – generally low in OM and difficult to increase substantially (*depends on clay content, climate, cropping system,* …)
- A little OM can have a surprisingly large effect
- OM can have an effect surprisingly quickly
- *No guarantee* of increased yields – but OM may increase *resilience* of yields

Sandmarken Experiment, Askov, Denmark

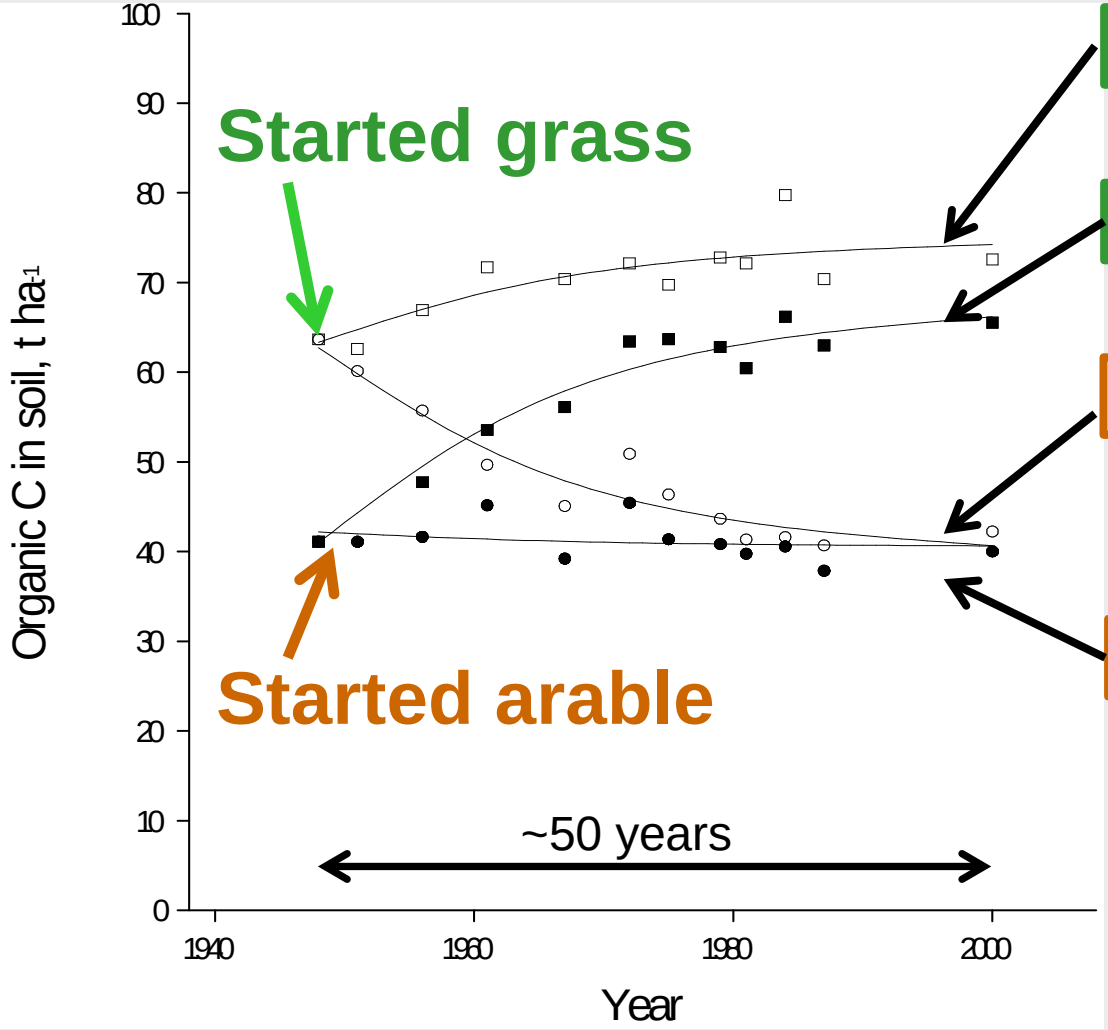
SOC increases following arable to grassland conversion



- Slow decline in soil C during 105 yrs in arable
- Increased at 0.39 Mg C ha^{-1} yr^{-1} during 14 yrs under grass (18 ‰ yr^{-1} *cf* initial stock)

Hu *et al* (2018) *European Journal of Soil Science* **70**, 350-360

SOC changes following land use change, Rothamsted

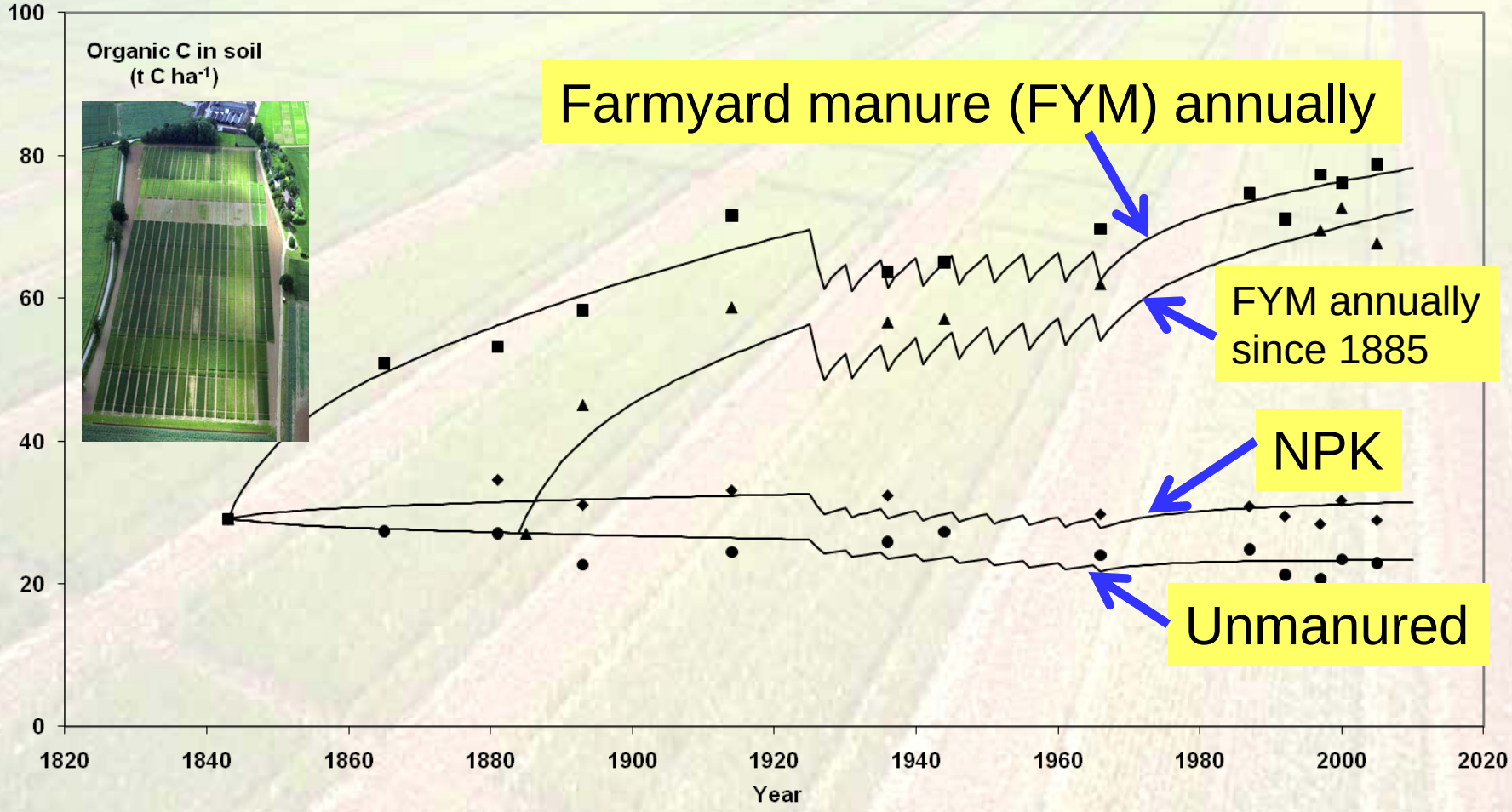


Movement towards new equilibrium SOC content

Johnston *et al* (2009) *Advances in Agronomy* **101**, 1-57

Broadbalk – started 1843

Soil organic C in selected treatments



Points: measured data. Lines: RothC simulation

Bad Lauchstädt Experiment, Germany (from 1902)

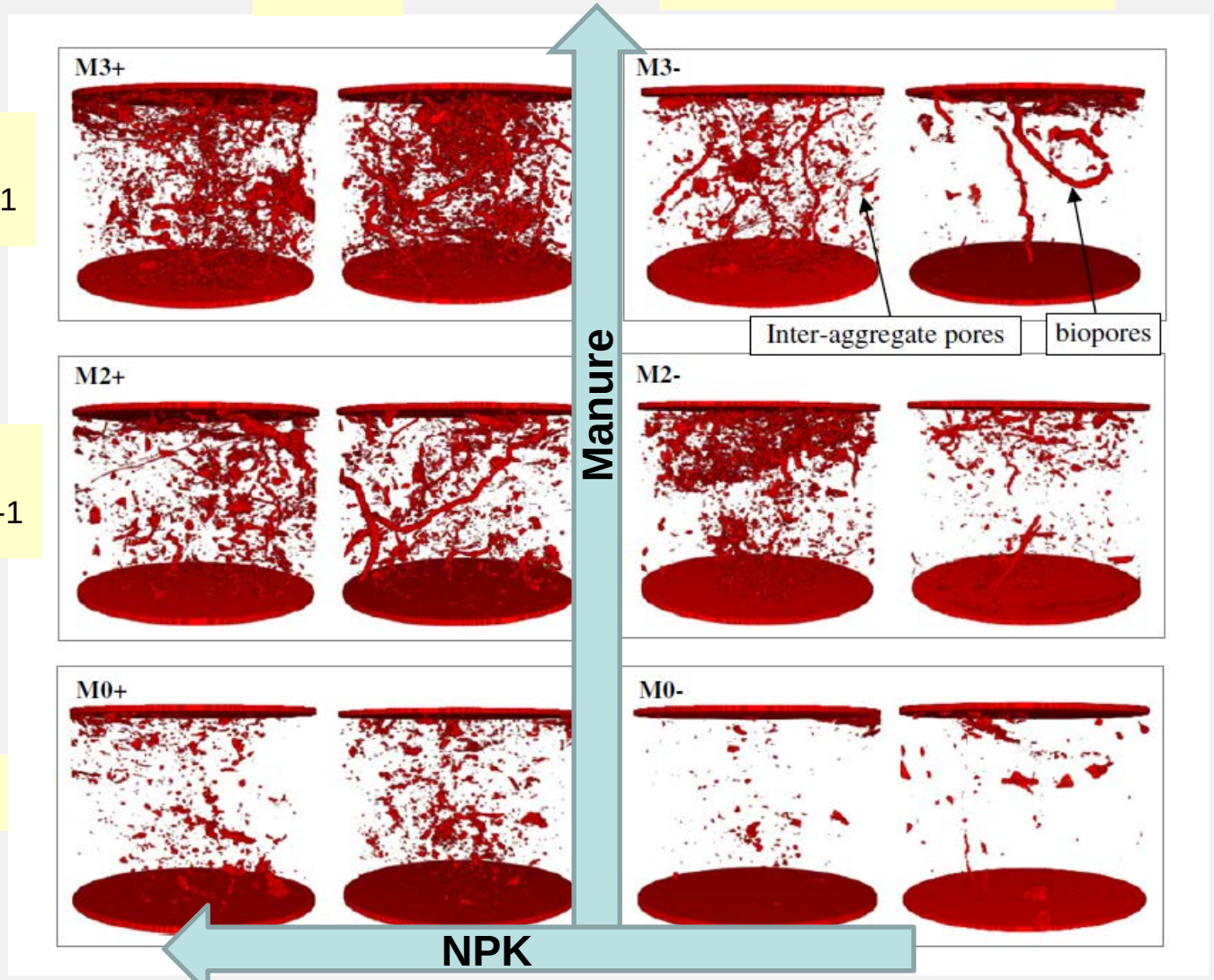
+NPK

No inorganic fertilizer

Manure
30 t ha^{-1} 2yr^{-1}

Manure
20 t ha^{-1} 2yr^{-1}

No manure



X-ray CT scanning used to visualise **soil pores**

Naveed *et al* (2014)
Geoderma **217-218**, 181-189

Results:

- Manure increases pores
- Adding inorganic fertilizers causes further improvement
- Pores beneficial for:
  - Water movement
  - Root growth

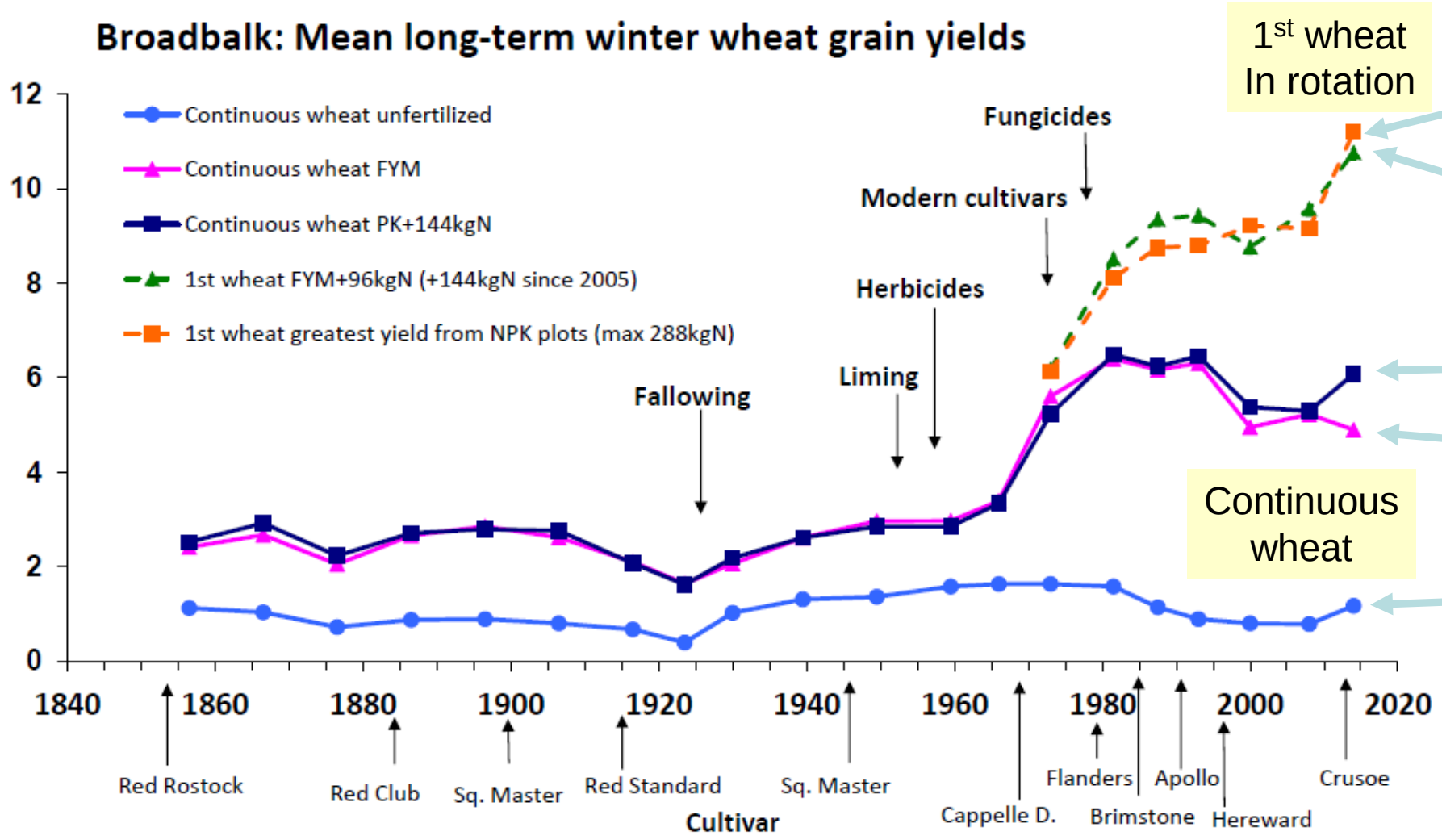
Hoosfield,
Spring Barley since 1852

Broadbalk,
Winter wheat since 1843

Crop yields

- Larger organic matter (OM) content in soil where manure applied for >100 years (x 2-3)
  - much better soil structure
- ***Winter wheat*** – yield *insensitive to OM content of soil*
  - can attain highest yield with inorganic fertilizers alone
- ***Spring barley*** – *only reaches highest yield where OM content is higher from manure applications*
  - but small OM increase (from fresh manure treatment) has large effect
- Likely reason for difference:
  - Spring barley – short growing season, 5-6 months
  - Winter wheat – 10 months – more time to overcome poor early growth

Winter wheat



1st wheat In rotation

Best NPK

Manure + N

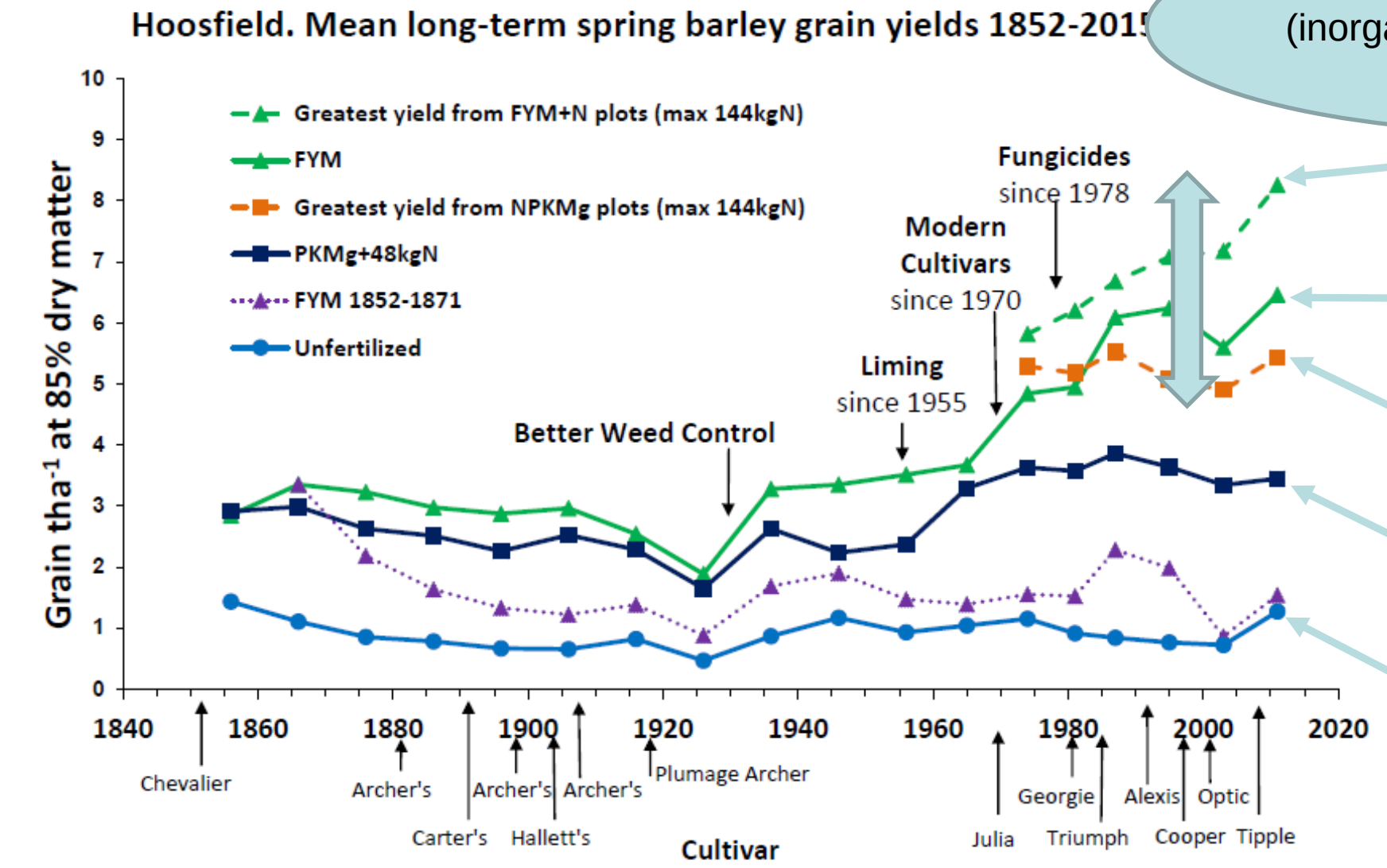
Best NPK

Manure + N

Continuous wheat

Control: no manure or NPK

Spring barley



Yield gap
(inorganic fertilizers cf. manure)
>2.5 t ha^{-1}

Manure + N

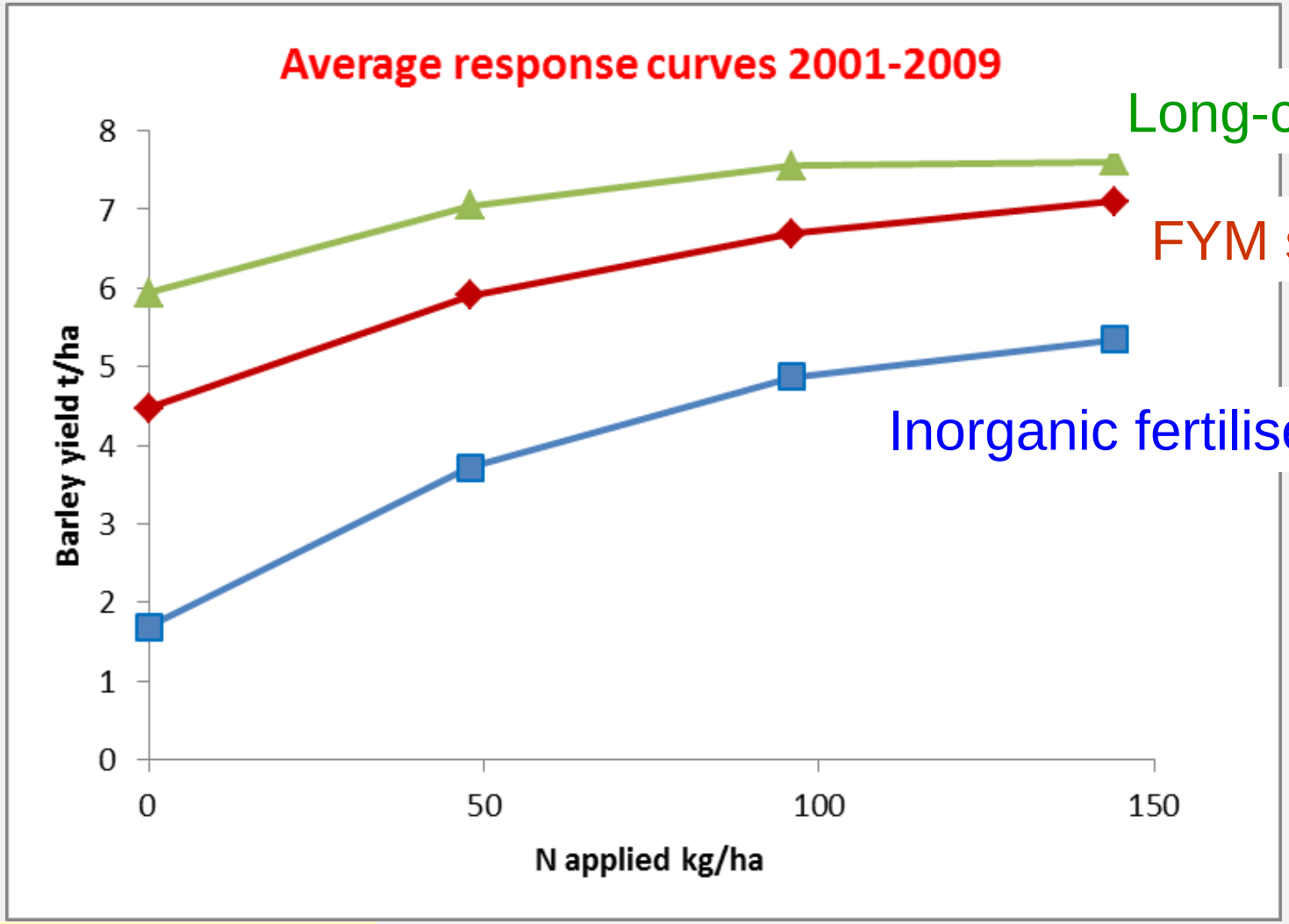
Manure

NPK: higher N
(best yield without manure)

NPK: low N

Control:
no manure or NPK

Spring barley, grain yields (Hoosfield Experiment)



Whitmore *et al* (unpublished)

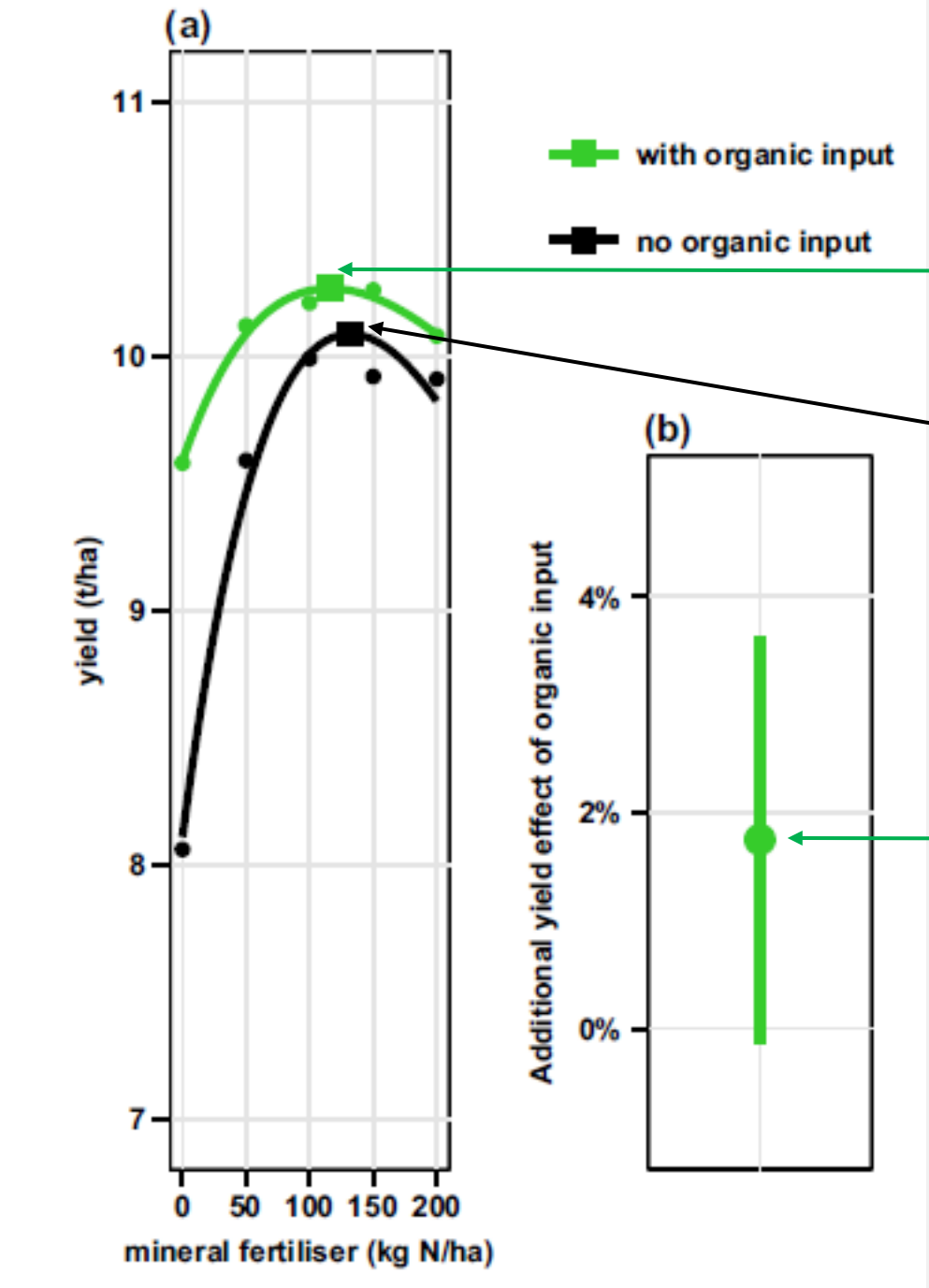
Do organic inputs matter – a meta-analysis of additional yield effects for arable crops in Europe

R. Hijbeek • M.K. van Ittersum • H.F.M. ten Berge • G. Gort • H. Spiegel • A.P. Whitmore

Plant & Soil **411**, 293-303 (2017)

- Only included sites with several N fertiliser rates applied to ***with*** and ***without manure*** treatments

Maize at Novi Sad, 1996-2003

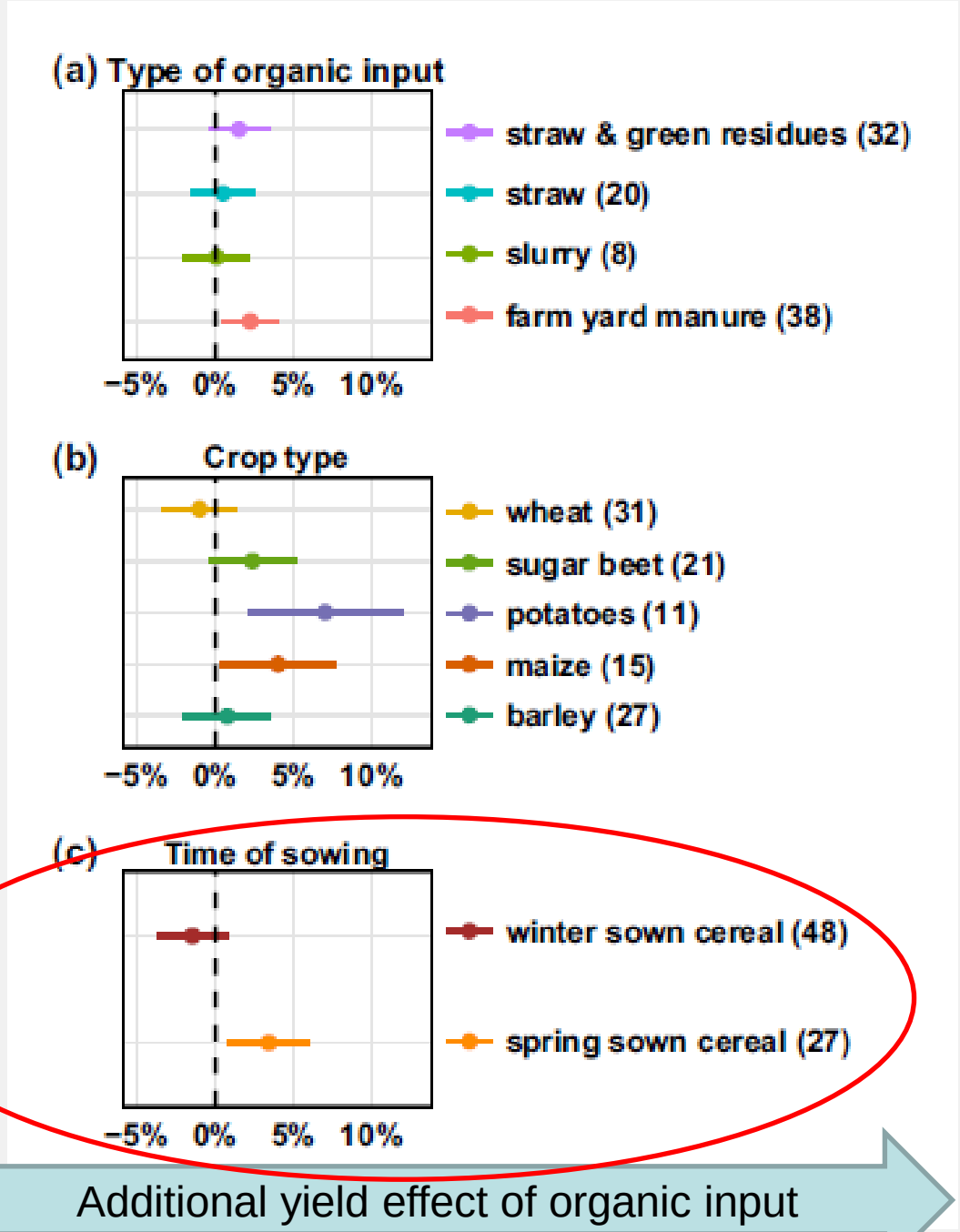


Max. yield ***with*** organic input

Max. yield ***without*** organic input

Difference in max. yields

Hijbeek *et al (2017) Plant & Soil* **411**, 293-303



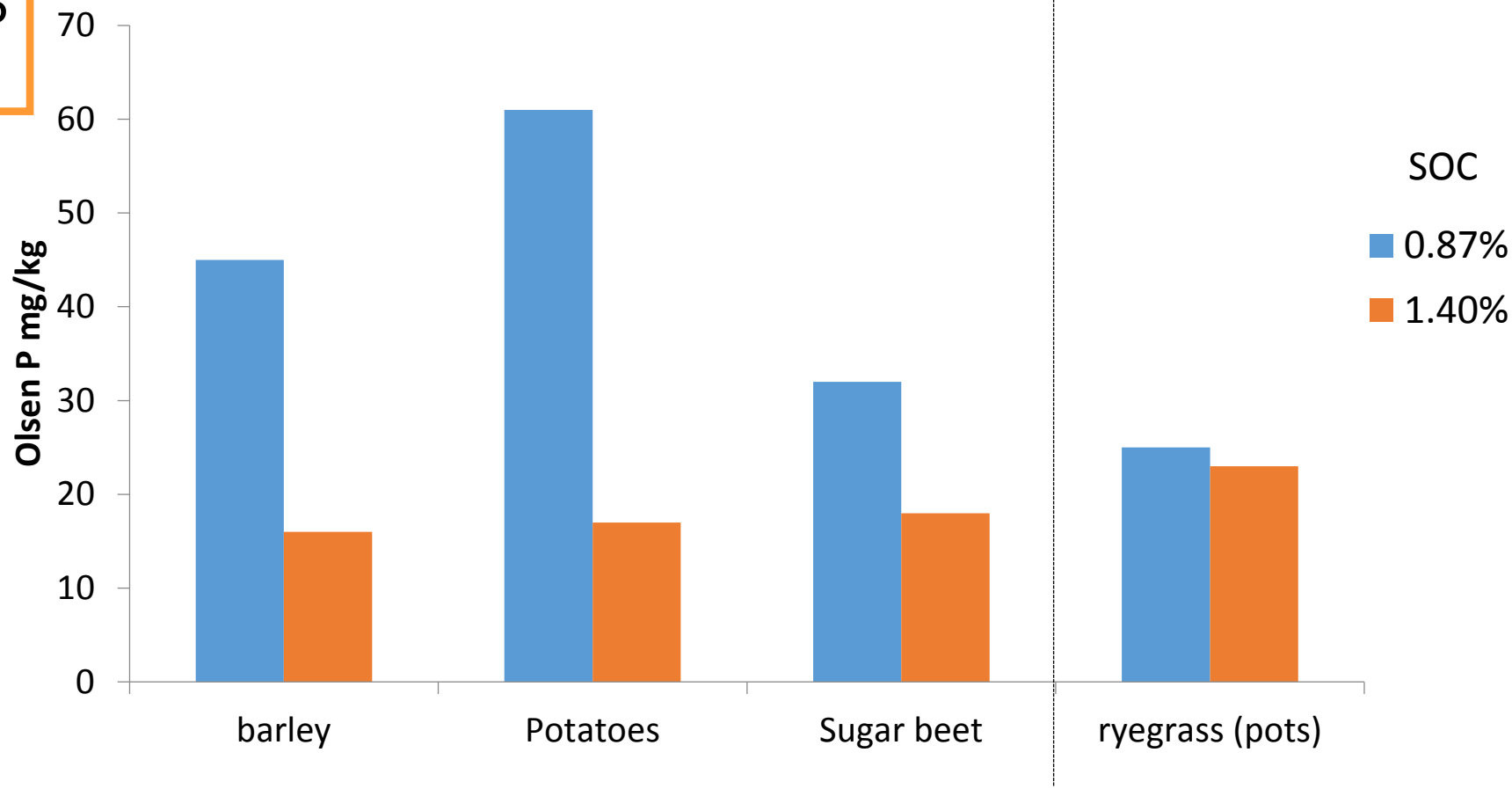
Hijbeek *et al (2017) Plant & Soil* **411**, 293-303

All crops, all sites

- Overall, effect on crop yields of extra organic matter in soil – *surprisingly small*
- But *greater with*:
  - Spring-sown crops
  - Crops very sensitive to soil physical conditions, e.g. potatoes

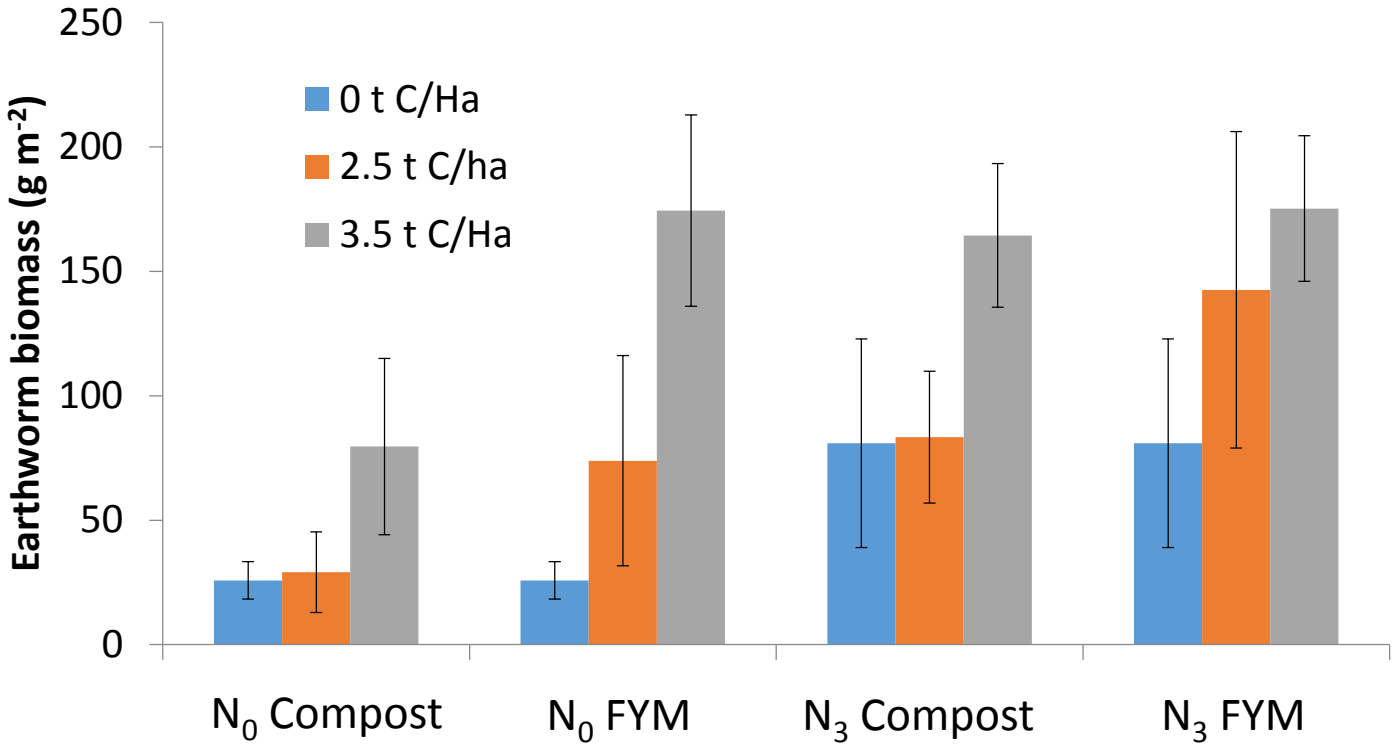
Larger root system – more effectively exploring soil for P

Moving the threshold: Olsen P required for 95% yield at two OC levels



Johnston, Poulton and Coleman, Advance in Agronomy 2008

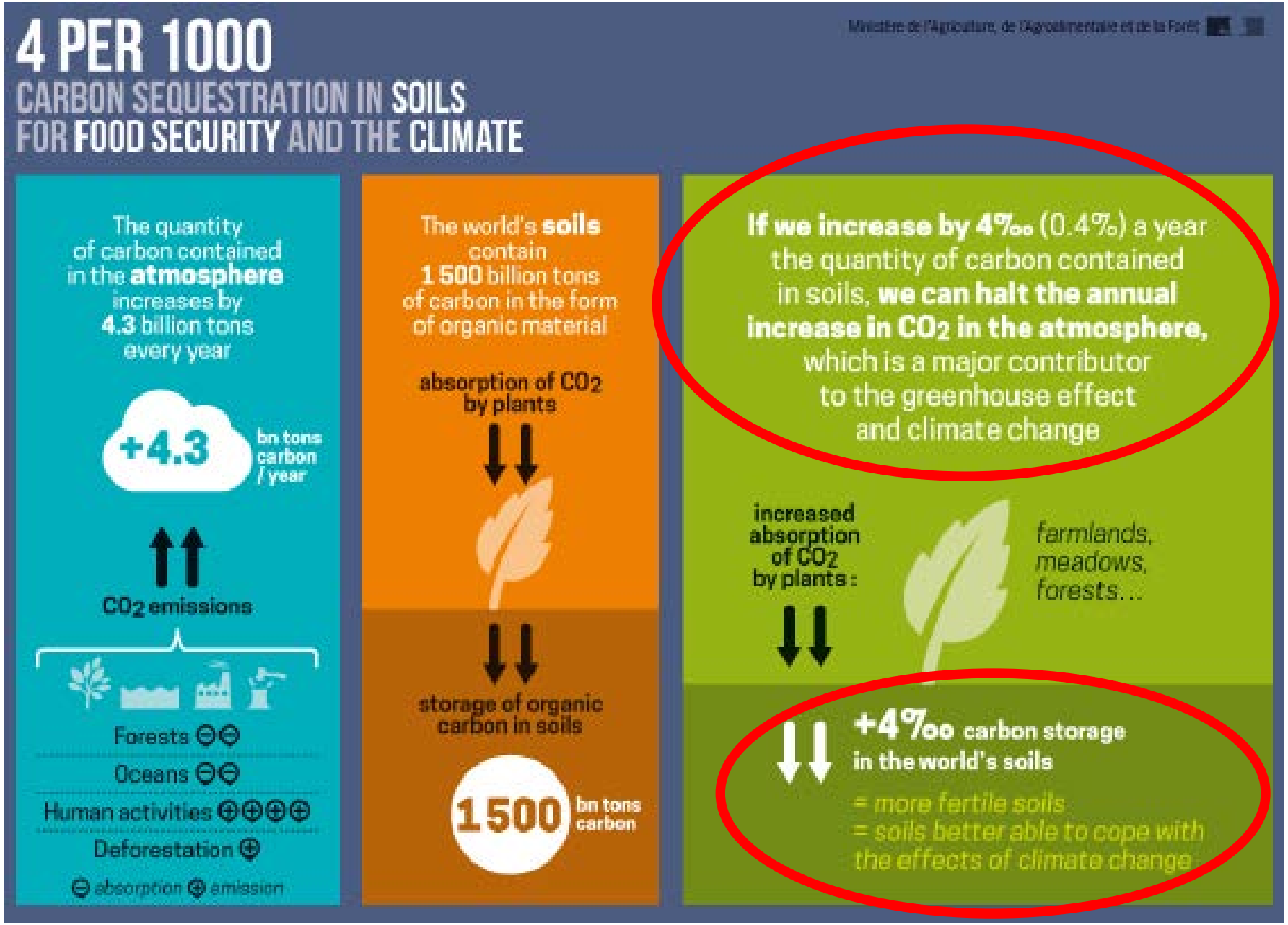
Earthworms



Earthworm biomass significantly increased by N rate ($p<0.05$) and organic addition rate ($p<0.05$)

Whitmore *et al* (unpublished)

https://www.4p1000.org/4-1000-initiative-few-words



Mitigation

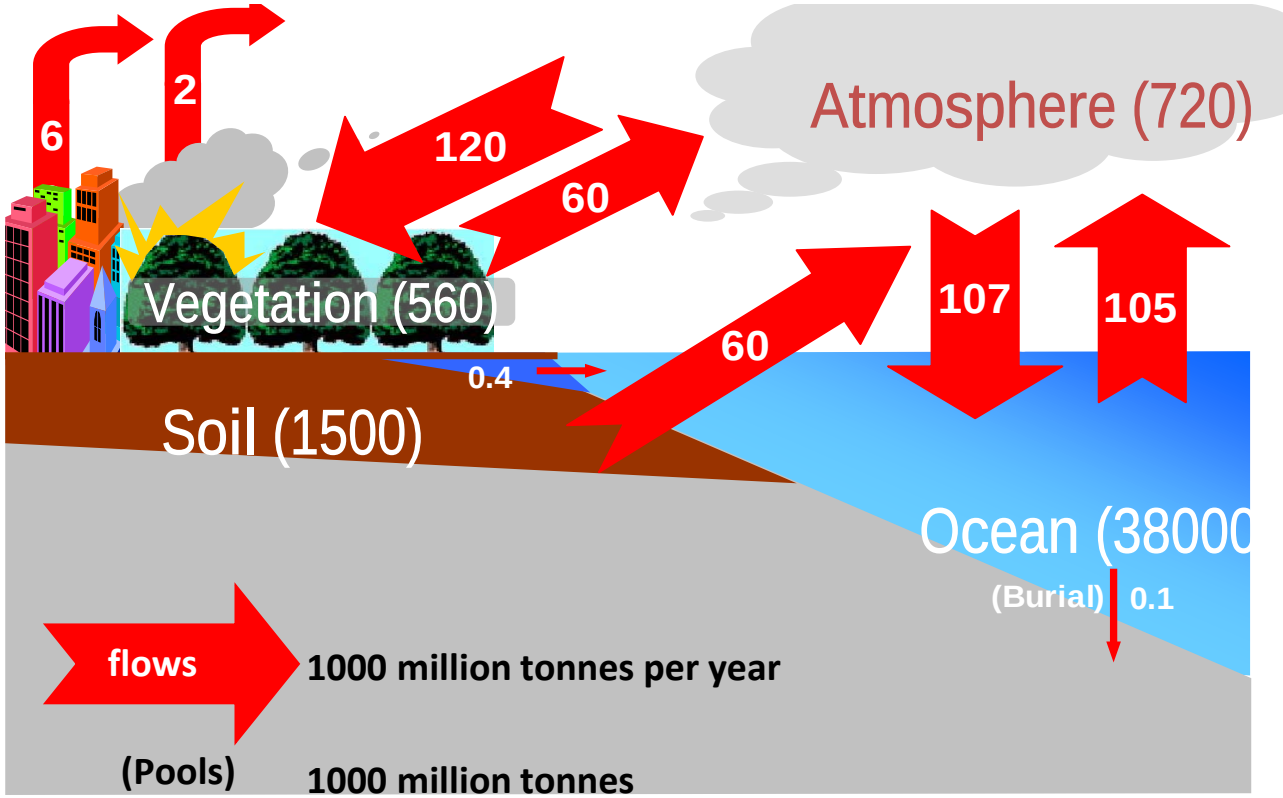
Adaptation

4 per 1000

- In principle, good
- Controversy over ***quantity of C sequestration practically achievable in arable soils*** (as opposed to removing soil from arable agriculture)
- Some confusion over details of soil C sequestration

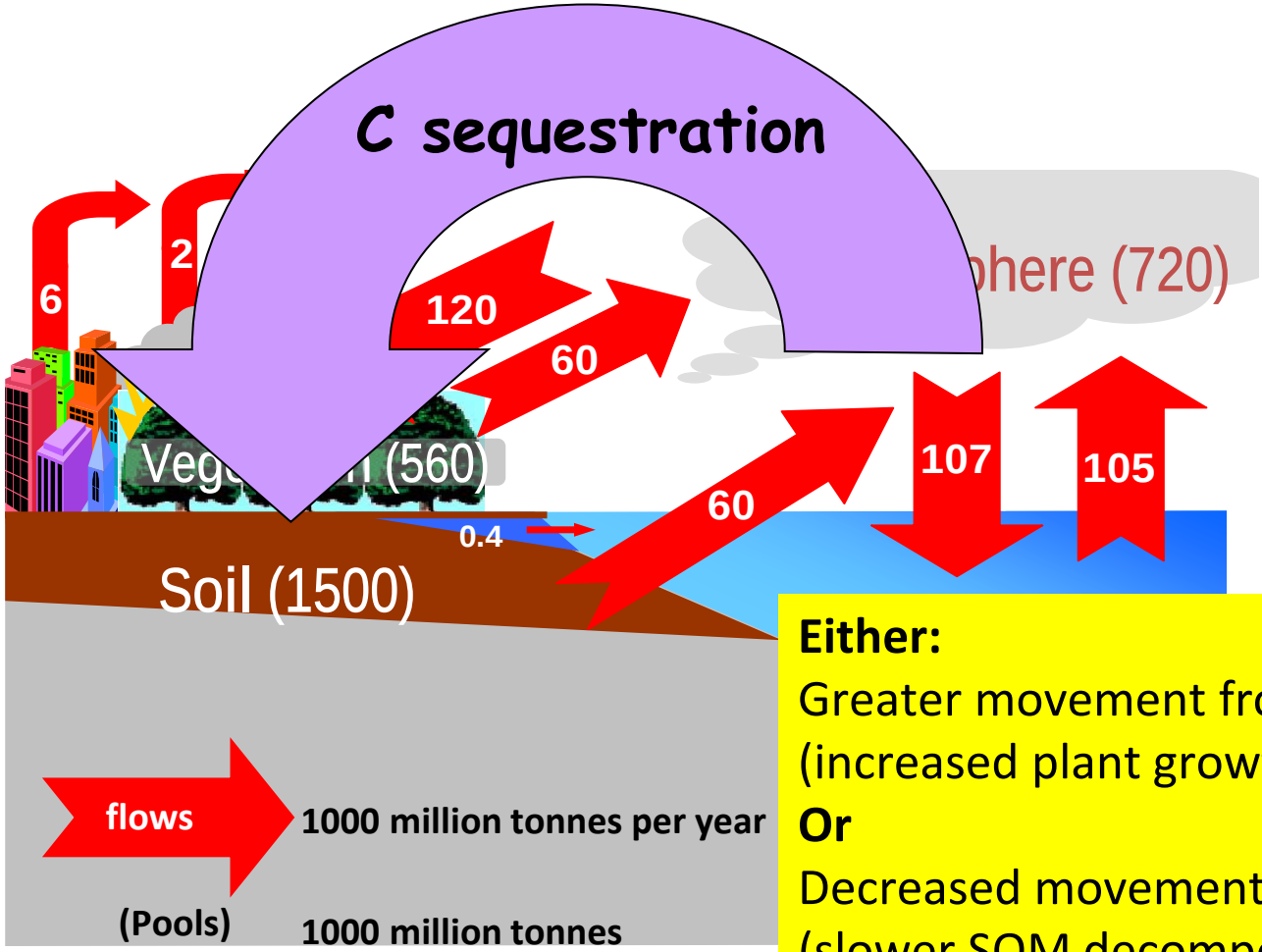
Global carbon: stocks and flows

ROTHAMSTED RESEARCH



BBSRC bioscience for the future

Global carbon: stocks and flows



Either:
Greater movement from atmosphere to land (increased plant growth)
Or
Decreased movement from land to atmosphere (slower SOM decomposition)

Confusion over organic additions

ROTHAMSTED RESEARCH

- **Manure addition**
  - Adding manure *increases soil C* – good for soil quality
  - And reduces N fertiliser requirement
  - But generally is a movement of organic C from one land location to another
  - ***NOT*** extra C transfer from atmosphere to land
  - So ***NOT*** genuine climate change mitigation
- **Organic fertilisers made from "wastes"**
  - If they would otherwise go to landfill or be incinerated, soil C increases ***ARE*** genuine mitigation
  - But beware of over-stating magnitude of increases

Concluding comments 1/2

Do organic fertilisers bring benefits to farmers beyond their nutrient value?

- ***Yes*** – improved soil physical structure and increased biological activity
- Improved root growth – increased pores
- May lead to lower required soil P concentration
- Increased water infiltration – decreases runoff and erosion risk
- Crop yields *may* be more resilient to annual variations in weather (moisture retention)
- Increased soil/rhizosphere microbial population *may* increase resistance to soil-borne pathogens
- ***BUT*** – increased yields not guaranteed – more likely with short growing-season crops (spring sown) and those very sensitive to soil physical conditions

Concluding comments 2/2

Can they contribute to climate change mitigation by sequestering C in soil as in the "4p1000" initiative?

- ***Yes*** – if source material would otherwise be incinerated or landfilled
- In contrast to animal manures *(though, of course, manures good for soil quality and nutrient supply)*
- ***BUT*** – be careful, don't claim too much: rates of soil C increase likely to be modest, but go in right direction

Thanks for your attention !

ROTHAMSTED RESEARCH

Soil sampling on Broadbalk, 1943

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