FCRN Soil Carbon Workshop

The potential for soil carbon sequestration, including the role of nitrogen

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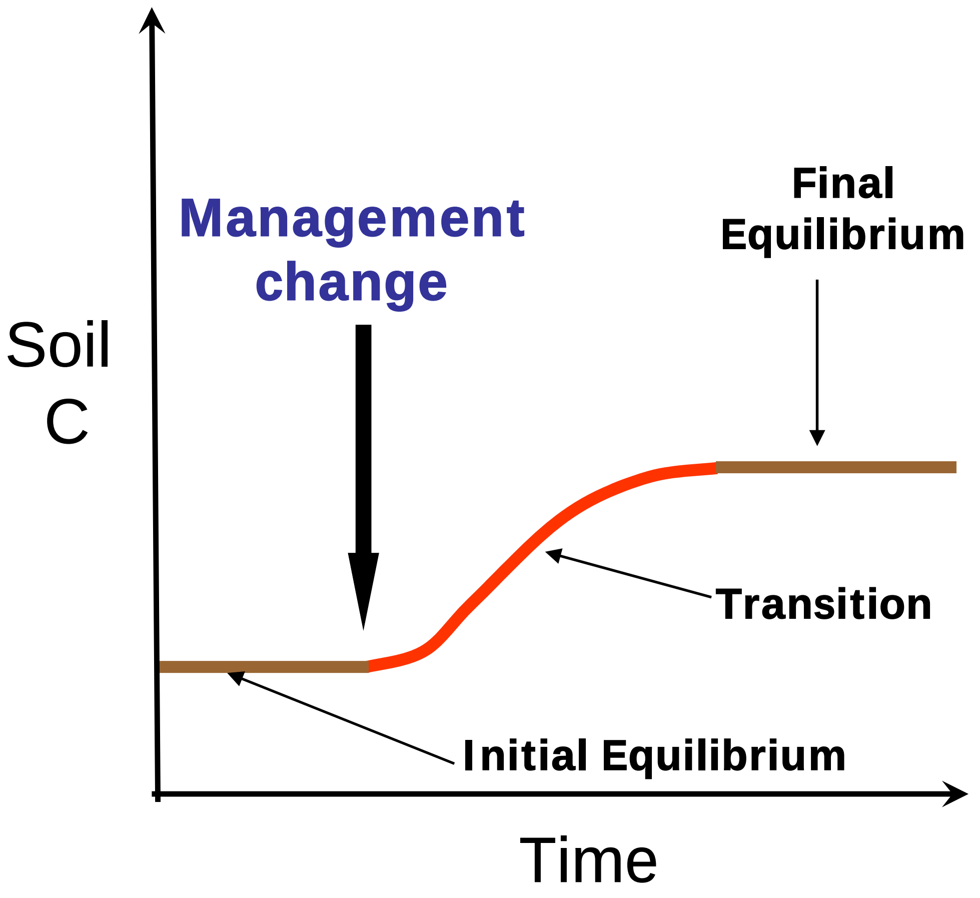
Carbon sequestration

- Dictionary definition of sequestration: ‘to hold on to’.
- Using this definition, ***any*** increase in Soil Organic Carbon (SOC) could be called ‘sequestration’.
- But in the context of Climate Change (CC), ‘sequestration’ usually implies some ***CC mitigation*****.**
- Must be a net transfer of C from atmosphere to land ….. ***not just a movement between land C compartments*****.**

Limitations to C sequestration in soil

- **Finite** – SOC moves towards new equilibrium value.
- **Reversible** – depends on continuing the new land management practice
- Potential **effects on N_2O and CH_4** – need full GHG budget



But extra C good for soil quality

Does nitrogen impact on C sequestration?

(Scientific American, 8 January 2009)

Discussion began after the controversial findings of Magnani (University of Bologna) and his team:

> for every 1 kilogram of nitrogen (N) deposited from the atmosphere, 400 kg of carbon would be absorbed by forests.

If this were true, it would imply a global CO_2 sequestration in forest ecosystems due to N deposition near 2.0 Pg yr^{-1}, being 30 % of the estimated 7.1 Pg C yr^{-1} release by human activities.

The disagreement among the scientists is about how large is this contribution of N with respect to C sequestration.

Research at forest monitoring plots found that, for 1 kilogram of N deposited from the atmosphere, approximately 30-70 kg of C was sequestered in both forests and forest soils. Multiplying this range by an estimated global N deposition, this corresponds to an annual global C sink of 0.15 - 0.35 Pg, being 2-4 % of the estimated release by human activities and c 10% Magnani's estimate.
(De Vries *et al*., 2008. *Forest Ecology and Management* **258,** 1814-1823.)

Quinn *et al*., 2010, *Nature Geoscience* (last Thursday): 0.31 Pg C yr^{-1}.

1 Pg $=10^{15}$ g = 1,000,000,000 tonnes

N fertiliser increases SOC in temperate regions, but only when crop residues were returned, and not in tropical regions.
(Alvarez, 2005, *Soil Use & Management* **21**, 38-52.)

A decrease in N in air pollution over the next 25 years will result in a 27% decrease in C sequestered by forests in The Netherlands but an increase in some biodiversity.
(Wamelink et al., 2009. *Forest Ecology and Management*, **258**, 1774-1779.)

So there is an important synergy between C and N, but the impact on C sequestration is not large.

Land management changes that could sequester C

- Crop residues
- Manures and Biosolids
- N fertilizers
- Plough to Min-Till (reduced tillage)
- Arable to forest
- Biochar
- Subsoil C?

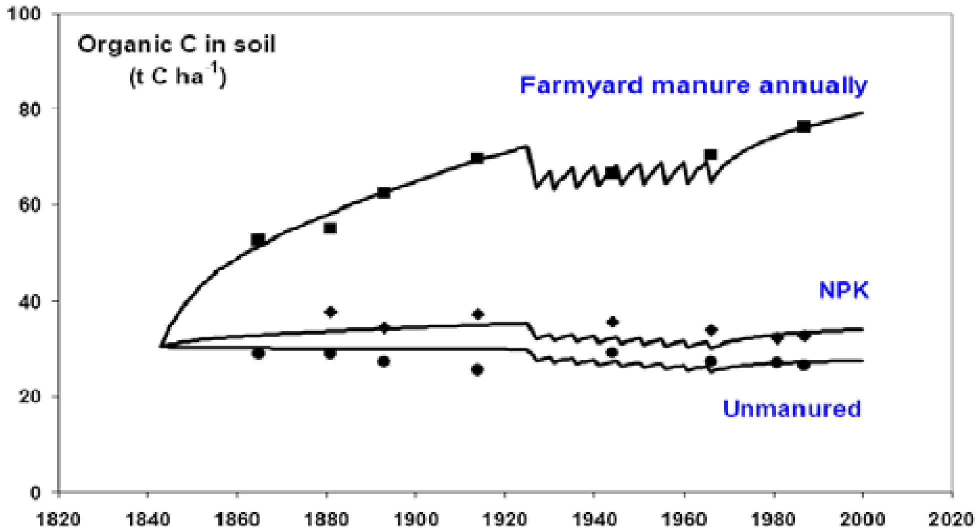
Crop residues

- 22% crop residue C is retained by soil

- But, if the residue would have been applied to land anyway and not burned, even on another farm, there is no C sequestration

Manures and Biosolids

- Manure increases SOC: c 23% of the FYM C and 56% digested sludge C is retained in the topsoil
- But most manure applied to land anyway
- So probably no C sequestration, merely a movement of C from one field to another



Manures and Biosolids

Risk of increased direct and indirect (from emitted and re-deposited NH_3 and leached NO_3^-) N_2O emissions if applied N is not effectively utilised.

But evidence suggests direct losses small:

Average loss, as N_2O, of N applied in slurry to:

- Arable land 0.8%
- Grassland 0.3%

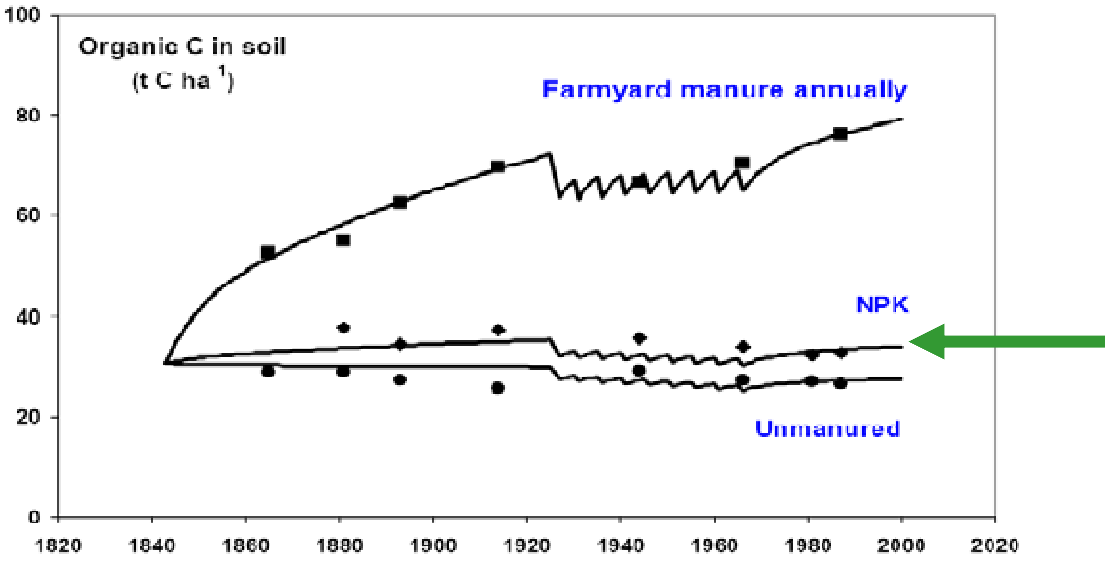
Smaller loss from grassland thought to be because of larger uptake of N over a longer period by grass.

Alternative uses of crop residues, manures or biosolids

- Incinerate straw for generation of electricity and heat.
- Anaerobic digestion of biosolids to produce biogas (methane); residue can add some nutrients to soil.

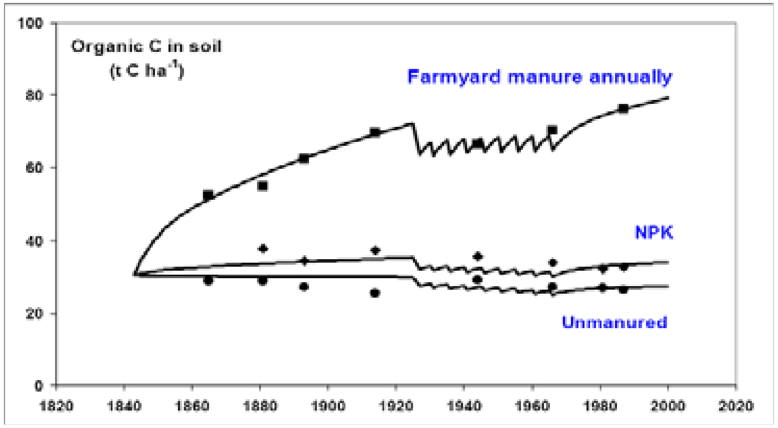
Both deliver greater CC mitigation than adding the materials to soil, through displacement of fossil fuel, but few benefits for soil quality.

Fertilizers



- Fertilizers (especially N) increase crop yields and returns of organic C in roots and residues to soil.
- A genuine transfer of C from atmosphere to land and an increase in food production.

Fertilizers



- SOC on Broadbalk increased by on average **0.2 t CO_2 ha^{-1} yr^{-1}** for only 50 years, then at equilibrium.
- But there are large GHG emissions (CO_2 + N_2O) from manufacturing N fertilizer, **at least 0.7 t CO_2 equiv. ha^{-1} yr^{-1},** as well as the losses of N_2O (and nitrate and ammonia) after application.

Plough → Min till

- Many claims of C sequestration after a change to min till from ploughing.
- Some evidence of overall SOC (surface) accumulation, but not large.
- Most experiments show increase in N_2O emissions.

Overall benefits of No- / Min-till

- Possibly small SOC accumulation:
  - Stern Report estimates 0.14 t C ha^{-1} yr^{-1} sequestered under No-till.
  - Recent estimate from UK experiments <u>0.31</u> (+/- 0.18) t C ha^{-1} yr^{-1} sequestered under No-till; perhaps half this for Min-till.
  - But in UK Min-tilled land often ploughed every few years.
- Other benefits of No- / Min-till:
  - Concentration of organic matter near surface: good for soil structure, seedling emergence water infiltration and retention.

Powlson & Jenkinson (1981). *J. Agric. Sci.* **97:** 713-721.
Baker *et al* (2007). *Agric. Ecosys. Env.* **118:** 1-5.

Net GWP effects of change to Min-Till

- Extra 3 kg N_2O ha^{-1} yr^{-1} could offset sequestration of 0.3 t C ha^{-1} yr^{-1} *. (Rothamsted experiments found an extra net emission of 4 kg N_2O ha^{-1} yr^{-1} from min-tilled land compared to ploughed land)
- No consistent pattern but reviews suggest N_2O emissions usually increase under Min-Till
- NB. <u>Most agricultural systems produce a net increase in GWP</u>

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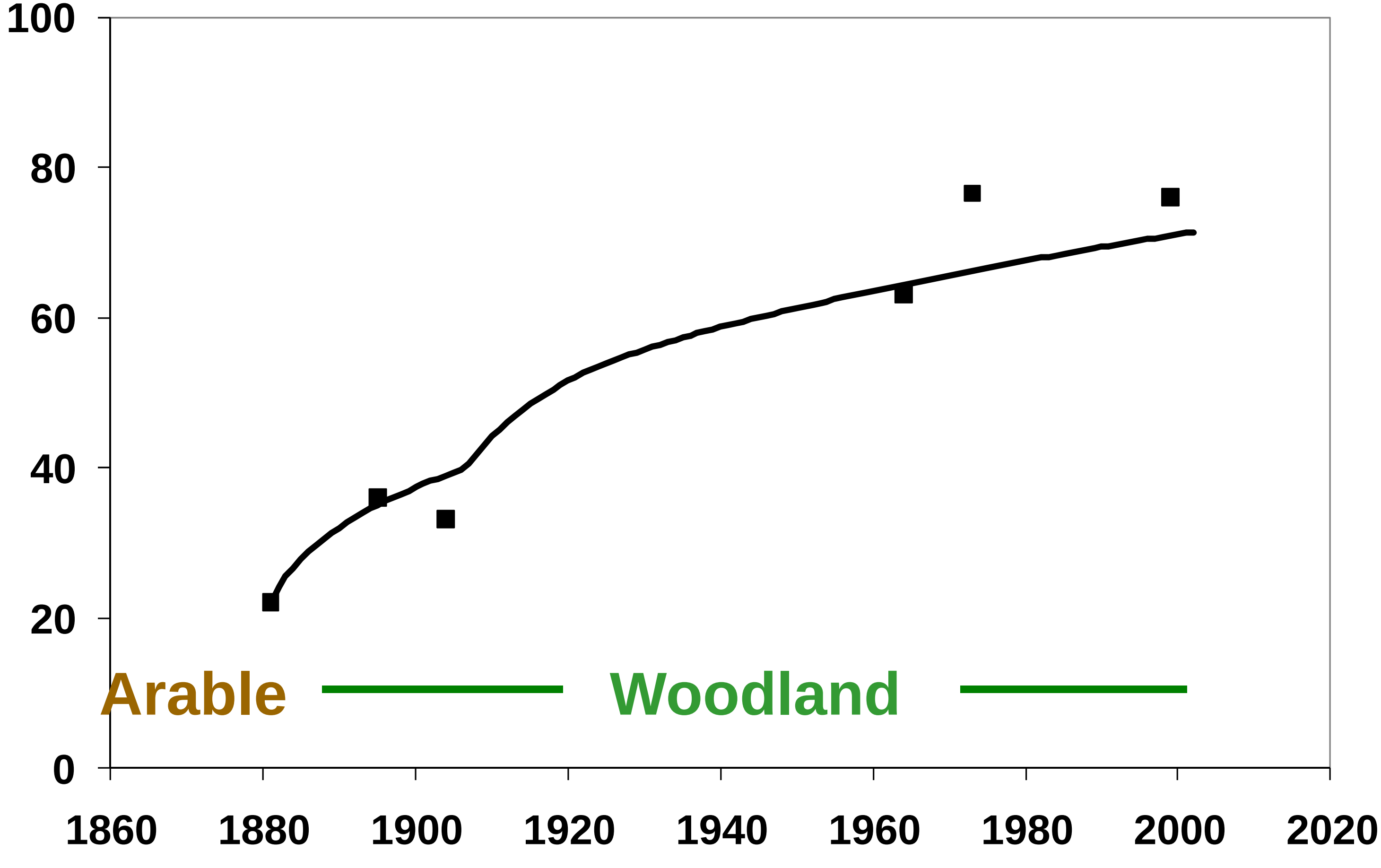
* Johnson *et al*. (2007) *Env. Poll.* **150**: 107-124.

Arable → Forest

- Genuine C sequestration.
- But must be certain that removal of land from crop production *at one location on the planet* does not cause land clearance (deforestation, ploughing grassland, wetland drainage) elsewhere.
- Other GHGs: expect increase in CH_4 oxidation and reduction in N_2O emission provided N deposition low.

Change in soil carbon after the conversion of arable land to woodland by natural regeneration on the Broadbalk Experiment

Data points and model (Roth-C 26.3; solid line) prediction



Biochar


Vol 447|10 May 2007
nature
COMMENTARY
A handful of carbon
Locking carbon up in soil makes more sense than storing it in plants and trees that eventually decompose, argues Johannes Lehmann. Can this idea work on a large scale?
SEQUESTRATION NEWS FEATURE
Black is the new green


ENHANCING SOIL PRODUCTIVITY WITH
CHAR

Biochar: sources and attributes

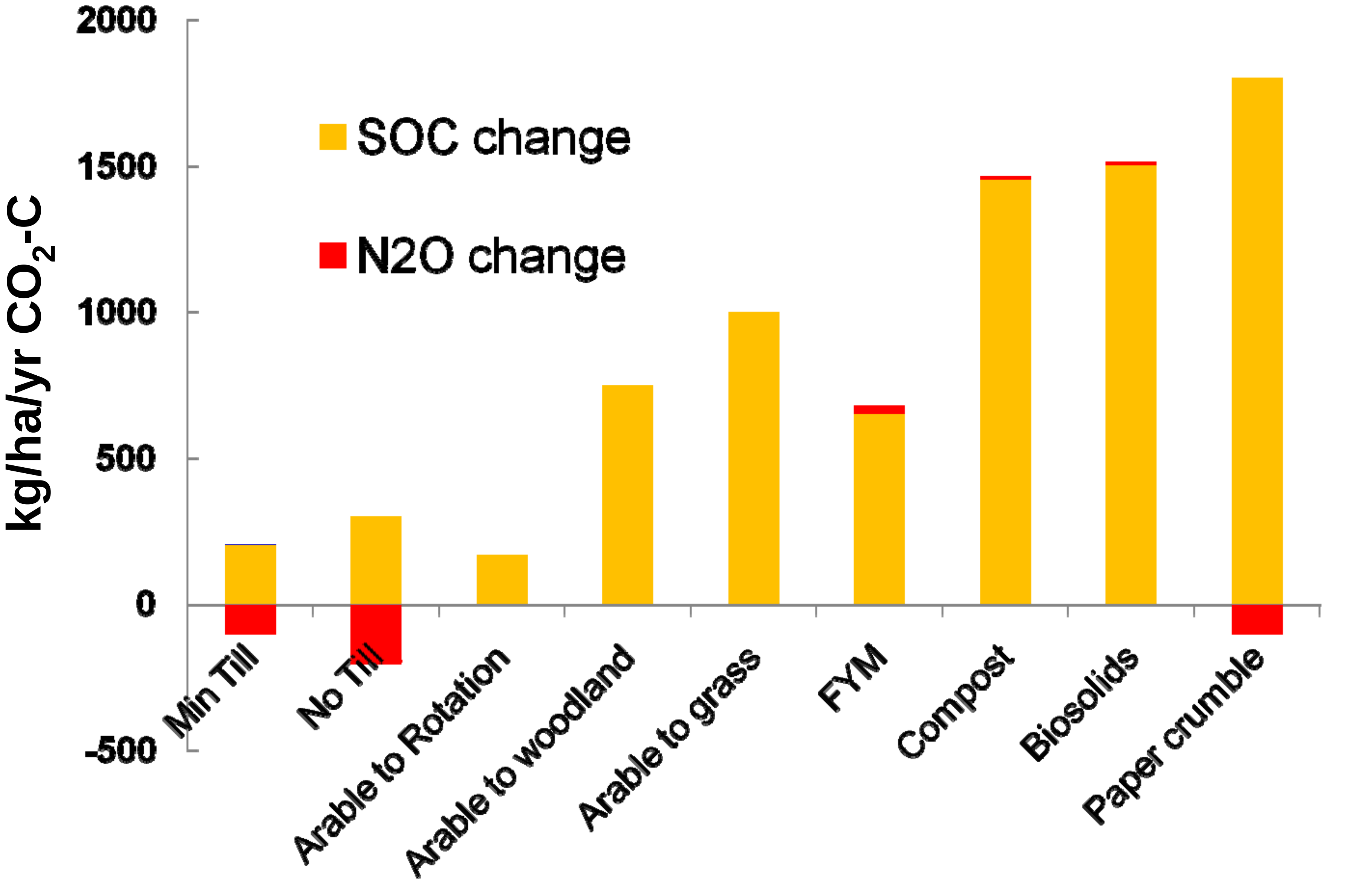
- Organic material burned/pyrolised slowly under limited oxygen
  - Bi-product of bioenergy (pyrolysis of biofuel crops, straw, or wastes)
  - In natural ecosystems from fire
- Highly stable, porous, active surfaces

Biochar: proposed effects on soil

- Near-permanent increase in soil C
- Greater stabilisation of other soil C
- Suppression of greenhouse gas emission
- Enhanced fertiliser-use efficiency
- Improvement in soil physical properties
- Enhanced crop performance
- Increased soil biodiversity

Philosopher's Stone of Climate Change!

C sequestration summary:
Maximum CO_2-C 'savings' from land management options
'Year 1'



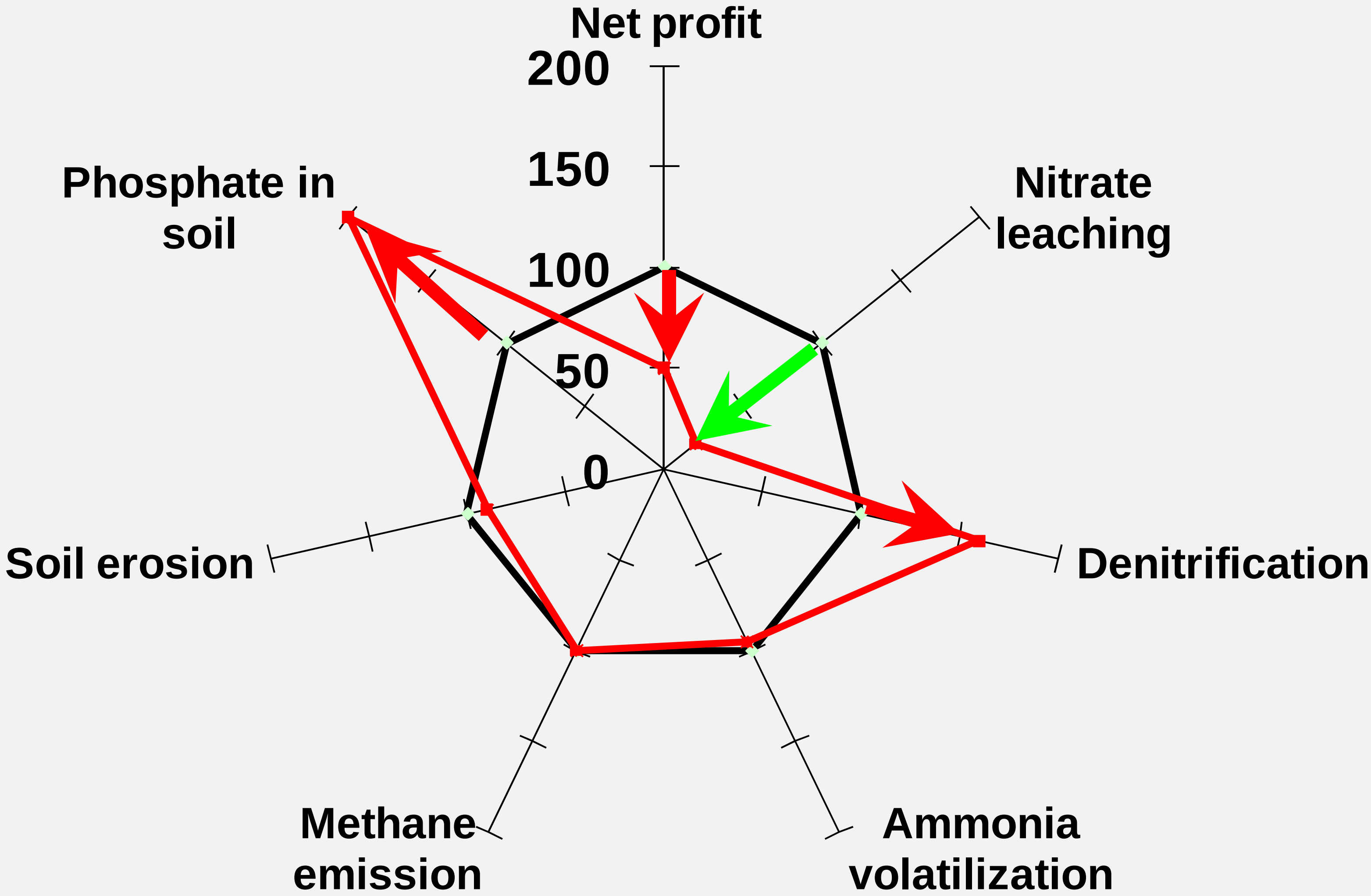
Risks of increased C loss: land clearance for agriculture

- Immediate loss of C from vegetation and longer-term loss of SOC on 1 - 100 year timescale.
- BUT – some conversion is inevitable if we are to feed 6.5 billion people (9 billion soon).
- We currently depend for food supply on past clearances (e.g. Europe, Asia, N. America) – no global understanding then!
- A need for rational decision making on land use – not just short-term profit.
- Integrate global scale thinking (and national scale actions) on food security *and* climate change.

We need integrated solutions

- Avoid impacts of ‘single-issue’ politics and policy
- LCA for integrated solutions

Possible effect of changing farm practice to minimise nitrate leaching



Conclusions

- Not all increases in SOC genuinely mitigate CC.
- Incorporation of organic ‘wastes’ or crop residues does not usually mitigate CC:
  - but benefits for soil quality and functioning;
  - greater CC mitigation from using biosolids and residues for bioenergy production.
- Large GHG emissions from N fertiliser manufacture outweigh any climate change benefit from increased SOC from increased crop residue returns.
- Min-till gives small increases in SOC and other benefits for soil.
- Conversion of arable land to forest or grass ***is*** genuine sequestration, but limited opportunities for this.

Conclusions

- Too much emphasis on soil C sequestration risks less attention to major climate change threats:
  - Land clearance for agriculture (food or biofuels)
  - Other deforestation
  - Wetland drainage
- Priorities:
  - good land stewardship including increased efficiency of N use, reduced tillage, maintaining ‘green’ cover
  - **integrated solutions**

Acknowledgements

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