UK losses of soil carbon – due to climate change?

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Outline

• Potential causes of carbon loss
• Changes that have occurred in UK over the twenty years between samplings
• How we are investigating what is driving the change in soil carbon
• Preliminary results based on simple models
• Work in progress
The National Soil Inventory of England & Wales

The National Soil Inventory was made to obtain an unbiased estimate of the distribution of the soils of England and Wales and of the chemistry of the topsoil (0–15 cm depth)

- Whole of England & Wales sampled at each intersect of a 5 km x 5 km grid – 1979-1983.
- Soil profiles described and topsoil (0-15cm) samples taken
- For each sample organic carbon, pH, metal concentrations and nutrients measured.
- Site properties such as land use, slope, aspect recorded.
Soil organic carbon content c.1980

(a) Original $C_{org}$ (g kg$^{-1}$)

- < 20
- 20 to 30
- 30 to 50
- 50 to 100
- 100 to 200
- 200 to 300
- > 300

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Resampling of NSI

- Proportion of NSI sites were re-sampled:
  - 1994-1996 (cropland and managed grassland)
  - 2002-2003 (forestry, moorland, extensive grazing land)
- Sampling scheme designed to detect changes of organic carbon $\pm 2$ g kg$^{-1}$
Resampling of the NSI

Protocols verified for:

- Original surveyor
- Field sampling – methods and tools
- Site location
- Laboratory analyses
Results from resampling of NSI

Annual change in carbon – grouped by land use

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Results from NSI across all land uses

Equation (1):

\[
\text{Rate of change} = 0.6 - 0.0187 \times C_{\text{org}}
\]

Annual change in carbon (g/kg/yr)

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• Carbon lost from soils at a mean rate of 0.6 gm of organic carbon per kg of soil per year.
• For soils with more than 100 gm per kg carbon rate of loss greater than 2 gm per kg per year.
Estimated annual soil C loss:
- England & Wales ≈ 4.4 million tonnes
- UK ≈ 4.4 x UK / E&W C stock ≈ 13 million tonnes

For comparison:
- UK industrial CO₂ emission ≈ 140 million tonnes
- Reduction since 1990 ≈ 13 million tonnes
Potential causes of carbon losses

**Land use/management**
- Extension of agriculture
  - e.g. grassland and woodland conversion to cropland
- Intensification of land use
  - e.g. drainage, increased nutrient loading, pesticide use
- Non-agricultural land uses
  - e.g. afforestation on wet land, managed burning

**Environmental change**
- Atmospheric
  - e.g. decreased acid rain, increased nitrogen deposition
- Climatic
  - e.g. temperature and precipitation
Mean monthly UK temp and rainfall 1978-2003

(a) Annual pattern

(b) Changes since 1978

- Jan
- Feb
- Mar
- Apr
- May
- Jun
- Jul
- Aug
- Sep
- Oct
- Nov
- Dec
Changes in soil pH between NSI samplings

Original pH

Annual change in pH (over 12-25 yr)
How do we investigate what is driving the change in soil carbon?

- We do not have detailed information on many of the potential drivers of soil carbon change at the NSI sites.

- An alternative approach is to use simple models of soil carbon turnover to evaluate possible explanations for the observed trends based on changes in land management or environmental change including climate change.

- We can reject explanations for the changes that require unrealistic parameters to deliver the measured magnitudes of change.
Soil carbon dynamics

Plant carbon \(\rightarrow\) Soil carbon \(\rightarrow\) Atmosphere CO\(_2\) \\
immobilization \(\rightarrow\) mobilization \\

Soil C accumulates if immobilization > mobilization \\
Lost if mobilization > immobilization
Simple carbon model

Rate of change = \textit{Input} – \( k \times \) organic carbon
\((k = \text{decomposition rate constant})\)

- Assume \textit{Input} & \( k \) changed some time before first sampling – i.e. soils are adjusting to earlier change - \textit{Input} & \( k \) independent of OC, dependant on land use only
- Assume change in decomposition rate, \( k \), (proportional to organic carbon) – i.e. decomposition rate changes in response to climate change
- Assume change in \textit{Input} (proportional to carbon content) – i.e. \textit{Input} changes in response to environmental change

The model fitted to data for each land use class
Simple carbon model: results

Arable and rotational grassland

Permanent grassland

Non-agricultural
The model parameter estimates were assessed against known effects of land use/management change, climate change and environmental change.
Simple carbon model: results

- Estimates of $k$ and *Input* obtained for each land use

- If $k$ changed proportional to OC the large changes required suggest climate change cannot be sole driver

- Large changes in *Input* required suggest environmental changes not a major driver
Initial conclusions

Results so far indicate the dominant driver of soil carbon losses was changes in land use/management, but climate change was responsible for part of the losses, and is likely to cause increased losses in future.
Further work in progress

- More sophisticated models of carbon change are being developed which will represent the whole range of soils in England and Wales.
- These models are being validated using the NSI data.
- These will allow more precise estimation of the contribution of climate change to the change in soil carbon observed in the NSI data.
Acknowledgements

• Funding for the National Soil Inventory of England and Wales came from Defra (Department for Environment Food and Rural Affairs UK)

• I would like to thank past and present colleagues at the National Soil Resources Institute at Cranfield University including Ian Bradley, Guy Kirk, Peter Loveland, Richard Andrews, Ilkka Leinonen and Bob Jones, also Murray Lark at Rothamsted Research.


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