Best Practice for Managing Soil Organic Matter in Agriculture

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Summary report for Defra project SP08016

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1. Introduction

Soil organic matter (SOM) is fundamental to the maintenance of soil fertility and functions, as well as being an important carbon store. However, there is some evidence that soils in the UK may be losing SOM/carbon, probably as a consequence of land-use change; particularly the drainage of peat soils and a legacy of ploughing out grasslands, and this could have implications for climate change. Protecting and enhancing soil organic matter (SOM) levels is a key objective of the draft Defra "Soil Strategy for England", and will have beneficial effects for overall soil quality/fertility, carbon storage and erosion control. This report summarises results from a review of recent research on practices for managing SOM in both 'lowland' (defined as land below the intake wall) and upland (i.e. land above the intake wall) agriculture (Bhogal *et al*., 2009; Worrall & Bell, 2009), where best practices have been identified.

2. Managing SOM in 'lowland' agriculture

Focusing largely on UK studies and reviews, practices that benefit SOM were identified and summarised in a *matrix of management options* (Table 1), taking into account variations in soil type, agricultural systems and cropping/land-use wherever possible. Detailed descriptions of each method are given in Bhogal *et al.* (2009). Table 1 provides an overview of the relative benefits (to SOM and C storage), cost, practicality, likely uptake and environmental impact of each of the methods. Both positive (e.g. a reduction in diffuse pollution, increased biodiversity) and negative (e.g. increased risk of soil erosion or gaseous emissions) environmental impacts were assessed, as there were some examples of 'pollution swapping'. For example, reduced tillage has the potential to *decrease* soil erosion and diffuse nutrient pollution, but could potentially *increase* nitrous oxide emissions.

Two clear 'drivers' were identified for SOM management:

1. *Protection and maintenance* of existing SOM levels for their soil quality and fertility benefits.
2. *Enhancement* of SOM levels for soil carbon storage (to contribute to the mitigation of climate change)

Management practices (methods) could be broadly divided between these two categories, although some of the methods for the protection and maintenance of existing SOM levels could also potentially enhance levels.

- Methods that enhance SOM (and C storage) were largely associated with *land-use change,* typically taking land out of cultivation, thereby reducing SOM oxidation and increasing crop carbon returns, viz;
    - Convert tillage land to permanent grassland
    - Establish permanent woodlands
    - Grow biomass crops
    - Introduce rotational grass
    - Water table management (increase the height of the water table)

  It is envisaged that these methods would most likely be incentivised via Environmental Stewardship (as there is an element of 'income forgone' to the farmer).

Table 1. Summary matrix of the relative benefits/disbenefits of best practice methods for managing SOM in 'lowland' agriculture.

Land use / Method (Soil texture)	Benefit to SOM (C storage)[1]: Tillage Light	Tillage Medium/heavy	Grass Light	Grass Medium/heavy	Organic/peaty	Cost	Practicality	Environmental impact[2] + ve	Environmental impact[2] - ve
Methods that enhance SOM: A. Land-use change									
1a. Convert tillage land to permanent grassland	***	***	n/a	n/a	***	£££[3]	+	↑↑	~
1b. Buffer strips	***	***	n/a	n/a	***	£	+++	↑	~
2a. Establish permanent woodlands	**	**	*	*	**	~ to +£[4]	+	↑↑	~
2b. Hedges, shelter belts	**	**	*	*	**	£	+++	↑	~
3. Grow biomass crops	**	**	*	*	**	~ to +£	+	↑↑	~
4. Introduce rotational grass	*	*	n/a	n/a	**	~ to £	++	↑	↓
5. Water table management	n/a	n/a	**	**	***	£ to £££	+	↑	↓
Methods that maintain existing SOM: B. Reduce soil erosion									
6. i) Cultivate compacted tillage soil	**	*	n/a	n/a	*	£	+++	↑	~
6. ii) Leave autumn seedbeds rough	**	*	n/a	n/a	*	£	+	↑	↓[5]
6. iii) Cultivate across the slope	**	*	n/a	n/a	*	£	+	↑	~
6. iv) Manage over-winter tramlines	**	*	n/a	n/a	*	£	++	↑	~
6. v) Early establishment of winter crops	**	*	n/a	n/a	*	£	+	↑	~
6. vi) Fence off rivers and streams from livestock	n/a	n/a	**	*	*	££	+	↑	~
6. vii) Move feed/water troughs at regular intervals	n/a	n/a	*	*	*	£	++	↑	~

Landuse / Method — Soil type	Benefit to SOM (C storage): Tillage – Sandy/ shallow	Tillage – Medium/ heavy	Grass – Sandy/ shallow	Grass – Medium / heavy	Organic/ peaty	Cost	Practicality	Environmental impact +ve	Environmental impact -ve
6. viii) Loosen compacted soil layers in grasslands	n/a	n/a	✱✱	✱	✱	£	++	↑	~
6. ix) Reduce stocking density	n/a	n/a	✱	✱	✱	£££	+	↑	~
Methods that maintain existing SOM levels and potentially enhance C storage: C. Change tillage practices & D. Increase organic matter additions									
7. Reduced/zero tillage	✱	✱	n/a	n/a	✱	~ to +£	++	↑	↓
8. Establish cover crops/green manures	✱	✱	n/a	n/a	✱	£	++[6]	↑	~
9. Straw/crop residue incorporation	✱	✱	n/a	n/a	✱	£	+++	~	~
10. Encourage use of livestock manures	✱✱	✱✱	✱	✱	✱	~ to +£	+++	↑[7]	↓
11. Import high OC materials	✱✱	✱✱	✱	✱	✱	~ to +£	+++	↑[7]	↓

Carbon storage effectiveness		**Cost**	**Practicality (likely uptake)**	**Environmental impact**
✱✱✱	Very effective	£££ high	+++ high	↑↑ Highly beneficial (impact over large area); ↑ medium/low benefit
✱✱	Moderately effective	££ medium	++ medium	↓ risk of 'pollution swapping'
✱	Some effect	£ low	+ low	~ neutral (no benefit or risk)
n/a	Not applicable	~neutral		
		+£ saving		

[1] The relative benefit to SOM was broadly quantified using C storage estimates where available (see Bhogal *et al.,* 2009 for details).
[2] Environmental impact separated into positive (e.g. reduction in diffuse pollution, increased biodiversity), or negative (e.g. increased soil erosion or gaseous emissions), as in many cases there were clear examples of 'pollution swapping'.
[3] Cost estimates assume conversion to extensive grassland.
[4] Cost high in establishment phase, but potential for long-term income from selling wood products.
[5] Possible increased need for herbicides and slug damage.
[6] Not practical on many medium/heavy soils.
[7] The *overall* environmental benefit will only be positive under 'best practice' management.

- Methods that protect and maintain existing SOM levels (and potentially enhance SOM) could be divided into *3 categories*, viz:
  - Reduce soil erosion and hence soil C losses (9 methods)
  - Change tillage practices to reduce SOM oxidation and erosion (adopt reduced or zero tillage systems)
  - Increase organic matter additions via cover cropping, incorporation of crop residues, addition of livestock manures and importing materials high in OC (e.g. composts, biosolids, paper crumble, industrial 'wastes' etc.).

  It is envisaged that these methods would most likely be delivered via Cross Compliance measures and incorporated into the requirement to maintain soils in Good Agricultural and Environmental Condition (GAEC).

A further 6 potential methods for SOM management were cited by Bhogal *et al.* (2009), but these were largely speculative and therefore deemed to be *insufficiently robust* to promote to farmers/land managers without further investigation and evidence.

A key knowledge gap was the *lack of field measurements* (under UK conditions) of the potential C storage/saving benefits of many of the proposed methods, across a range of soil types i.e*. the evidence base to support policy implementation is weak*.

3. Managing SOM in 'upland' agriculture

The effect of a range of land-uses/management practices on the C budget of peat soils was evaluated using a combination of literature analysis and computer modelling. The following practices were considered and compared with a pristine case: drainage, drain-blocking, managed burning, suppression of wildfire, afforestation, deforestation, grazing removal, re-vegetation, vegetation change and vegetation cutting. The potential for these management practices to improve the C and greenhouse gas (GHG) budget was expressed as a probability based on the number of studies reporting a definitive outcome (Table 2). Table 2 also gives an estimate of the magnitude of the effect (t $C/km^2/yr$), timescale and potential cost.

The results highlighted that *afforestation* would improve the carbon budget of peat soils over that achievable for the same soil under pristine conditions, due to a shift of carbon from soil to biomass. However, the benefit would be limited to the growth phase of the vegetation, unless harvesting and product substitution were considered.

Additionally, the following management practices could also potentially bring a carbon benefit wherever they are possible:

- *Drain-blocking;* this would lead to increases in the C budget, but results suggest that rises in other GHG emissions may also occur.
- *Re-vegetation;* this would improve both C and GHG budgets.
- *Cessation of burning;* current evidence suggests this would lead to improvements in both C and GHG budgets. However, the issue of char production may alter this for some fires.

- *Grazing removal*; this would improve both C and GHG budgets.
- *Afforestation*; this would improve both C and GHG budgets (particularly on mineral soils).

In contrast, the following management/land-uses could potentially bring disbenefits:

- *Deforestation;* this may be constrained depending upon the re-use of the land after deforestation and what use the harvested product is put to.
- *Drainage;* may reduce other GHG emissions but could increase C losses.

There was little direct experimental evidence of the effect of *wildfire suppression, vegetation change* or *vegetation cutting* on the C budget of peat soils.

A key knowledge gap was the lack of studies that considered *complete* C and GHG budgets (particularly for managed environments), as well as a paucity of data on the potential change in C budgets before and after a management intervention.

Table 2. Summary of: effective sample size; probability of success for both carbon budget and greenhouse gas (GHG) benefit (%); magnitude of effect in terms of carbon; the timescale of the effect; and estimated cost of implementation for each management type. The values in the brackets are the variance in the probability estimate. The carbon budgets are expressed relative to the soil, i.e. +ve values express a gain of terrestrial carbon relative to the atmosphere. The timescale of change is given as a default value of 25 years, i.e. the time for *Caluna vulgaris* to achieve maturity, this value maybe lower in some regions of the country. See Worrall & Bell (2009) for details.

Management	Effective sample size	Effective sample size (GHG)	Probability of improvement (carbon)	Probability of improvement (GHG)	**Magnitude of effect (tonnes C/km^2/yr)**	Timescale (yr)	Cost (£/km^2 or/km of ditch) x10^3
Afforestation	9.6	9.4	63 (±19)	81 (±28)	**+253**	Only up to 70 years after planting	?
Managed burning	5.6	4.1	7 (±0.4)	40 (±2)	**-83**	25	12.8 to 20.0
Cessation of burning	5.6	4.1	93 (±0.4)	60 (±2)	**+83**	25	-12.8 to -20.0
Deforestation	0.8	0.3	19 (±14)	14 (±13)	**Depends on re-vegetation and use of harvested products**	?	?
Drainage	12.1	14.7	19 (±1)	47 (±6)	**-5**	25	3
Drain-blocking	10.3	11.3	55 (±11)	34 (±5)	**+5**	25	3
Grazing	3	2.3	65 (±27)	78 (±32)	**-3**	?	?
Revegetation	5.8	6.4	70 (±28)	45 (±9)	**+210**	25	8.8 to 27.0
Vegetation cutting	0	0	50 (±50)	50 (±50)	**?**	25	12.8 to 20.0
Vegetation change	0	0	50 (±50)	50 (±50)	**?**	25	22.3 to 11.0
Wildfire suppression	0	0	50 (±50)	50 (±50)	**?**	?	?

4. Knowledge transfer

All potential management practices (both lowland and upland) were reviewed and revised (as appropriate) at an Expert Workshop held in London on 17th March 2009, by industry, research and policy representatives. Cross Compliance and Environmental Stewardship were identified as key 'drivers of change', with the former most suited to methods that aimed to protect and maintain existing SOM levels; and the latter more appropriate for methods where there was an element of 'income forgone'. Additionally, these methods could be promoted via the provision of farmer advice (e.g. alongside the England Catchment Sensitive Farming Delivery Initiative) and included in future updates of the Code of Good Agricultural Practice.

5. References

Bhogal, A., Nicholson, F.A., Rollett, A. & Chambers, B.J. (2009) *Best Practice for Managing Soil Organic Matter in Agriculture. Manual of Methods for 'Lowland' Agriculture.* Final Report to Defra, Project SP08016. May 2009.

Worrall, F. & Bell, M. (2009) *Best Practices for Managing Soil Organic Matter in Agriculture. Managing SOM in 'Upland' Agriculture*. Final Report to Defra, Project SP08016. May 2009.