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Should organic farmers be rewarded for sequestering C in soil?

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Abstract

The question of whether farmers, and organic farmers in particular, should be rewarded for sequestering C in soils is controversial. A review of the literature on long term experiments comparing organic and conventional systems, demonstrates that soils under organic management tend to have higher soil organic carbon (SOC) contents than conventionally managed soils. But the logistics of designing a system that compensates individual farmers for this ecosystem service are challenging. Agreements would have to be reached on the baseline system used for calculation of relative gains in SOC, values for emissions of other GHGs from soils (e.g. methane and nitrous oxide), the direct and indirect CO_2 *emissions associated with energy use and crop production inputs in the C sequestering system, and emissions associated with sources of SOC imported onto the farm. Alternatively, the evidence for generally higher SOC under organic management could justify an additional payment, for example under the UK Government's Organic Entry Level Scheme.*

Introduction

In general terms, C sequestration is the conversion of atmospheric CO_2 into organic C (C fixation) that is protected or prevented from oxidizing back to the atmosphere. The storage of organic C in soils is one form of C sequestration. While it is acknowledged that the UK will need to adopt a variety of strategies to meet its commitment to the Kyoto Protocol, there is considerable potential for carbon mitigation through changes in agricultural land-use and management that increases soil C (Smith et al., 2000).

Currently, changes in soil C resulting from land use change (LULUCF sector) among four broad categories: forestland, grassland, cropland and settlement, are included within the UK's national GHG inventory (Baggott et al., 2007). Differences in soil organic carbon (SOC) among systems of agricultural production on grassland and cropland, however, are not included in the inventory.

Do organic farming practices increase soil C?

Practices that increase soil organic carbon contents include reduced tillage, ley periods in the crop rotation (e.g. grass or grass/clover crops), the use of organic amendments like compost or farmyard manure (FYM), and increasing biomass production per unit area (in some cases through the judicious use of mineral fertilisers). Organic standards prescribe many of these practices.

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There is a high degree of variability in management practices and soil fertility outcomes, even within specific categories of organic farms (Stockdale and Watson, 2002). Nevertheless, when researchers have compared organically and conventionally managed soils, they have often found that on average SOC contents are higher under organic management. This result was found in paired comparisons of soils from organic and conventional farms in the same region (Armstrong Brown et al., 2000; Drinkwater et al., 1995), and in long-term trials that more rigorously compare organic and conventional systems (Table 1). In these trials, SOC values are frequently higher where organic fertility inputs are used. In the DOK trial at the Institute for Organic Agriculture in Switzerland (FiBL), the plots receiving biodynamically composted manure and slurry at a rate equivalent to 1.4 livestock units per ha (BIODYN 1.4), had the highest SOC relative to the mineral fertilizer treatment (here including clover leys) after 21 years (Fließbach et al., 2007). Raupp and Oltmanns (2006) had similar results comparing composted manure with (CMBD) and without (CM) biodynamic preparations, with inorganically fertilized crops, at three different application rates. After eighteen years, the two higher rates of compost had significantly greater levels of SOC than the inorganically fertilized treatment. In the Rodale Institute Farming Systems Trial (Hepperly et al., 2006) there were significantly higher SOC contents in the organic, legume-based system (LEG) compared to the conventionally fertilized system, even with similar annual returns of crop residues to the soil.

Table 1: Difference in soil C relative to conventional management (∆ C) for organic treatments in several long-term experiments

Experiment	Treatment^z	∆ C t ha^{-1}	Duration of experiment	Reference
DOK trial	BIODYN 1.4	3.82	21 y	Fließbach et al., 2007
	BIOORG 1.4	0.6		
IBR Darmstadt, DK	CM rate 3	3.8	18 y	Raupp and Oltmanns, 2006
	CMBD rate 3	5		
Rodale trial	MAN	10	21 y	Hepperly et al., 2006
	LEG	8		

^{z}BIODYN 1.4 = biodynamic compost and slurry at 1.4 LU ha^{-1}; BIOORG = rotted FYM and slurry at 1.4 LU ha^{-1}; CM rate 3 = composted manure at a total N rate of 140 kg N ha^{-1}; CMBD rate 3 = composted manure with biodynamic preparations at a total N rate of 140 kg N ha^{-1}; MAN = organic manure and legumes as N source; LEG = legumes only as an N source

Calculation of total sequestered C

Carbon sequestration is not just a function of soil organic carbon levels. King et al. (2004) defined total sequestered carbon (TSC) in agricultural systems as a function of soil organic carbon (SOC), direct energy (DE) used on site i.e. to power machinery and operations, indirect energy (IE) used on site i.e. to manufacture and supply fertilizers, agrochemicals, etc., and greenhouse gases (GHGs) other than CO_2 emitted from soils This relationship can be summarized as the TSC equation:

$$\text{TSC (kg ha}^{-1}\text{ yr}^{-1}\text{ CO}_2\text{-C)} = \text{SOC} - \text{DE} - \text{IE} - \text{GHG}$$

Increases in TSC can be achieved by gains in SOC, or by decreases in DE, IE and GHG, or by a combination of these. Literature values for energy usage on-farm and in the production of inputs can be used in the calculation, as well as default values for emissions of N_2O and CH_4 under different management scenarios (King et al., 2004).

The calculation of TSC requires an estimate of the annual rate of change in SOC. According to standard methods of modelling SOC dynamics (first order kinetics), this rate declines with time and eventually becomes insignificant as the soil approaches a new equilibrium SOC content. There is no consensus on how long it takes to achieve equilibrium SOC contents: SOC models like ROTH-C are generally run for 100 years after a perturbation in order to obtain some certainty about the equilibrium SOC contents (Webb et al., 2003), yet King et al. (2004) assumed that gains in SOC were negligible by 10 years after a change in soil management.

The source of the C used to increase SOC levels also needs to be considered. When C is imported from off-site, e.g. as livestock manure or crop residues, there are off-site emissions (OSE) associated with that C source, that need to be included in the TSC equation to get a true estimate of the sequestration benefit of increasing SOC in this way.

Crediting management-related changes in TSC on agricultural land

Changes in SOC due to soil management could be incorporated into the UK Greenhouse Gas Inventory (Baggott et al., 2007). A similar approach to the method currently used to estimate changes in SOC due to changes in land use (e.g. from cropland to grassland) could be adopted to reflect changes to C sequestering practices (e.g. from conventional to organic production). This would require the estimation of rates of change in SOC for different management systems, and an inventory of land areas under improved management. The DE, IE and GHG values used to calculate TSC on a given area of land, are already accounted for in the National Inventory under the Energy, Industrial and Agriculture sectors.

In order to maximise C sequestration in soils, a reward system for C sequestration by individual farmers would be desirable. This would require agreement on the baseline conditions for calculation of TSC. While the UK Greenhouse Gas Inventory uses a 1990 baseline, this may penalize farmers who are already farming in a relatively C-efficient way, as they will find it difficult to further increase their TSC. A better option may be to estimate the maximum potential SOC values for a given soil and climate (SOC_{max}), under optimum agricultural land management, and reward farmers based on their actual SOC contents (SOC_{act}) relative to optimum levels. Separately, emissions from DE, IE and GHG, as well as OSE from imported C sources, could be calculated. While this approach would provide clear incentives to individual farmers to maximize C sequestration, it would require detailed estimates of the maximum potential SOC values for all soil types in the UK, and separate agreements with individual farmers.

The design of a system to reward individual farmers for C sequestration presents logistical challenges. Alternatively, the evidence for generally higher SOC in soils under organic management would support claims for an additional payment, for example under the UK Government's Organic Entry Level Scheme (OELS). Currently, the OELS pays organic farmers £30 per hectare in recognition of the public goods of enhanced biodiversity and reduced pollution that they deliver. Under the OELS, it would be possible to provide recognition of the higher average SOC levels achieved by organic farming, and the ecosystem services including C mitigation, that this provides.

Conclusions

Research results have consistently shown that for similar crops and soil types, organic farming practices which include compost or FYM results in higher levels of SOC than conventional farming practices. Nationally, the C sequestration benefits of these increases could be accounted for in a similar way to the current method of calculating SOC change in the LULUCF sector. At the farm scale the ecosystem services provided by SOC could be recognized by rewarding organic farmers for maintaining high SOC through the existing UK OELS.

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