# Soil carbon and organic farming

## A review of the evidence of agriculture's potential to combat climate change

Summary of findings

Soil Association

# Introduction

**"A large proportion of the mitigation potential of agriculture (excluding bio-energy) arises from soil carbon sequestration, which has strong synergies with sustainable agriculture and generally reduces vulnerability to climate change"**
Intergovernmental Panel on Climate Change, Working Group III, 2007

The UK's Climate Change Act commits our Government to delivering an 80% cut in greenhouse gases (GHGs) by 2050. Perhaps more importantly, scientists are calling for policy-makers to focus on what can be delivered over the next two decades, a critical period in which we must stabilise atmospheric carbon dioxide levels below 400 parts per million to limit global temperature rise to 2°C and avert catastrophic climate change.[1]

Commitments on food and farming have not taken centre stage in the lead-up to the Copenhagen COP15 Summit, but there is growing awareness of this sector's significance. Within the EU, the food we eat represents nearly a third of our climate footprint as consumers.[2]

**One big blind spot remains, both in this country and elsewhere: soil carbon**

When it comes to tackling farming's footprint, all eyes have been on livestock-related methane emissions and nitrous oxide emissions from fertilised fields, or the potential to generate energy from biofuels and the anaerobic digestion of animal wastes. Aspirations are low. The 2020 target for agriculture in the UK's Low Carbon Transition Plan is a voluntary 6–11% greenhouse gas reduction, compared to mandatory 20–40% targets in all other sectors of the economy.

One big blind spot remains, both in this country and elsewhere: soil carbon. Soil carbon sequestration, according to the IPCC's scientific advisors on land use, represents 89% of agriculture's greenhouse gas mitigation potential.[3] Soil carbon losses caused by agriculture account for a tenth of total $CO_2$ emissions attributable to human activity since 1850. However, unlike the carbon released from fossil fuels, the soil carbon store has the potential to be recreated to a substantial degree, if appropriate farming practices are adopted. This would remove large quantities of carbon from the atmosphere every year for the next 20 years at least (until a higher 'equilibrium' soil carbon level is eventually reached). Action to increase soil carbon levels can therefore contribute substantially to the efforts to rapidly cut GHG emissions and avoid dangerous atmospheric $CO_2$ increases.

**Important decisions on agricultural and climate policy are being made without consideration for 89% of agriculture's greenhouse gas mitigation potential**

Furthermore, raising soil carbon levels can make a vital contribution to climate adaptation, by improving soil structure and quality. This will reduce the impacts of flooding, droughts, water shortages and desertification, thereby also improving global food and water security.

So far, soil carbon is largely being ignored by climate policymakers and analysts in the UK, partly due to the inadequacies of the current agricultural GHG accounting systems. Large (1.6 million tonnes a year) ongoing soil carbon losses from the conversion of grassland to arable land are concealed within the 'LULUCF' (Land Use, Land Use Change and Forestry) category of the UK's greenhouse gas inventory, not acknowledged as emissions from agriculture.[4] With the carbon losses from the fenlands also omitted (an additional 260,000tC/yr), this means that the actual figure for UK agriculture's $CO_2$ emissions is more than double the official figure of 1.8 million tC/yr, and $CO_2$ accounts for a quarter of agriculture's current official GHG emissions. In addition, the IPCC guidelines on accounting for soil carbon changes due to agricultural management practices are not being implemented in Europe, which means that all other impacts of farming on soil carbon levels are missing from the GHG accounts. For example, soil carbon losses resulting from the declining proportion of arable farms that use temporary grass leys or livestock manure are not being reported.

There are also major soil carbon impacts of Europe's food and agricultural systems abroad: millions of tonnes of carbon are being emitted from the ongoing conversion of tropical habitats to agriculture in South America to supply soya for the intensive livestock sector and to supply beef in response to the falling UK self-sufficiency in beef (now an annual shortfall of 300,000 tonnes resulting partly from dairy intensification) and from the destruction of high-carbon peatlands in SE Asia to produce palm oil (an ingredient of industrial, processed foods in the UK and other countries).

Soil carbon is also excluded from most 'Life Cycle Analyses' of the climate impacts of farming (such as the 2006 Cranfield University assessment of organic and non-organic farming for the UK Government[5]) and from the current food 'carbon labelling' initiatives.[6] This means that important decisions on agricultural and climate policy are being made without consideration for 89% of agriculture's greenhouse gas mitigation potential.

Critics have been too quick to dismiss soil carbon sequestration on the basis that the rates of sequestration tend to diminish 20 years after a switch to improved practices. But it is the next 20 years that will be critical in policy terms for delivering major greenhouse gas reductions. Moreover, carbon sequestration still continues thereafter, albeit at lower rates, for 100 years or more.

**Action to raise soil carbon levels – through more widespread adoption of organic farming practices and grass-based and mixed farming systems – can make a significant and immediate contribution to greenhouse gas mitigation**

Recently there have been encouraging signs of engagement with the issue at the European level. In September 2009, EU Agriculture Commissioner Mariann Fischer Boel called on European farmers to cut agricultural greenhouse gas emissions by at least 20% by 2020, primarily by storing carbon in the soil.[7] Meanwhile, the UK Government's recently published strategy, *Safeguarding our Soils,* has acknowledged that "preventing emissions from soil and exploring how to increase existing stores of soil carbon can make an important contribution to meeting the Government's emission reduction targets and carbon budgets, introduced by the Climate Change Act 2008."[8] However, action on soil carbon was deferred in favour of a call for more research: "We need better evidence on trends in soil carbon levels and cost-effective techniques for protecting or increasing soil carbon."

This report is a response to that challenge. The evidence it presents suggests that action to raise soil carbon levels – through more widespread adoption of organic farming practices and grass-based and mixed farming systems – can make a significant and immediate contribution to greenhouse gas mitigation.

*This document is a summary of the findings. To read the full report, please see the website address on the inside back cover.*

# Headline findings

"With regard to $CO_2$-sequestration in soils, organic agriculture can achieve high carbon gains through the use of green and animal manures, soil fertility-conserving crop rotations with intercropping and covering cropping, as well as by using composting techniques. In particular, in Northern European countries, conversion from conventional to organic farming would result in an increase of soil organic matter (from 100 to 400kg/ha/year)."
PICCMAT Consortium of EU soil & agricultural scientists, June 2008[9]

▶ Based on a review of the evidence, this report concludes that soil carbon sequestration – achieved through the widespread adoption of organic farming – would substantially reduce greenhouse gas (GHG) emissions and make agriculture more resilient to the effects of climate change.
▶ The soil carbon impacts of agriculture are ignored by current GHG accounting systems, which means that the current GHG emissions of agriculture have been greatly under-estimated, the emissions of organic farming greatly over-estimated, and the real potential of soil carbon sequestration over-looked. According to IPCC scientific advisers, 89% of agriculture's GHG mitigation potential resides in improving soil carbon levels.[3]
▶ A review of all available comparative studies in this report indicates that, on average, **organic farming practices produce 28% higher soil carbon levels than non-organic farming in Northern Europe, and 20% for all countries studied** (in Europe, North America and Australasia).
▶ This represents a soil carbon sequestration rate of approximately 560kgC/year (2t$CO_2$/yr) for each hectare of cultivated land converted to organic farming in the UK, for at least the next 20 years. This would represent 64 million tonnes carbon over 20 years across all UK cultivated land, or 3.2 million tC/year, which would be the equivalent of taking nearly a million family cars off the road.
▶ On this basis, we conservatively estimate that the **widespread adoption of organic farming practices in the UK would offset at least 23% of UK agriculture's current official GHG emissions**.
▶ At a global level, the effects of agricultural soil carbon sequestration are even greater: assuming a higher possible sequestration level of 1tC/ha/year for organic farming best practices (including composting and agro-forestry), we estimate that widespread organic farming could potentially sequester 1.5 billion tC per year, which would **offset about 11% of all anthropogenic global GHG emissions** for at least the next 20 years. (The global impact is greater than in the UK because the ratio of the area of cultivated land to total GHG emissions is much higher).
▶ Soil carbon sequestration through organic farming practices also has the lasting benefit of improving soil structure and quality, because the accumulated carbon is in the organic form of humus. This will improve climate adaptation by reducing the impacts of flooding, droughts, water shortages and desertification, thereby also improving global food and water security.
▶ A review of the scientific evidence on the factors and biological processes of soil carbon accumulation indicates that organic farming increases soil carbon levels by: producing additional sources of organic matter, creating organic matter in forms that are more effective at producing soil carbon, integrating crop and livestock systems, and by increasing the proportion of vegetation cover which promotes the soil's micro-organisms that stabilise soil carbon.

# Let there be grass

▶ Grass-fed livestock has a critical role to play in minimising carbon emissions from farming and this must be set against the methane emissions from cattle and sheep.
▶ This is because grasslands for grazing livestock, whether permanent pasture or temporary grass on mixed farms (which accounts for most UK organic cultivated land), represent vitally important soil carbon stores.
▶ Each year in the UK, 1.6 million tonnes of carbon (representing a hidden additional 12% of the UK's agricultural GHG emissions) are released into the atmosphere because of the net conversion of permanent grassland to cultivated arable land.
▶ According to a recent European Commission report, grasslands have the potential to be sequestering large amounts of carbon on an ongoing basis.
In the UK, the potential sequestration is said to be 670kgC/ha/year,[10] which, if true, would offset all the methane emissions of beef cattle and about half those of dairy cattle.[11]
▶ Advocates of a shift from red meat to grain-fed white meat to reduce methane emissions could therefore find that this has the perverse effect of exchanging methane emissions for carbon emissions from soils and the destruction of tropical habitats (to produce soya feed), as well as having a far reaching impact on our countryside, wildlife and animal welfare.

# Soil carbon and adaptation to climate change

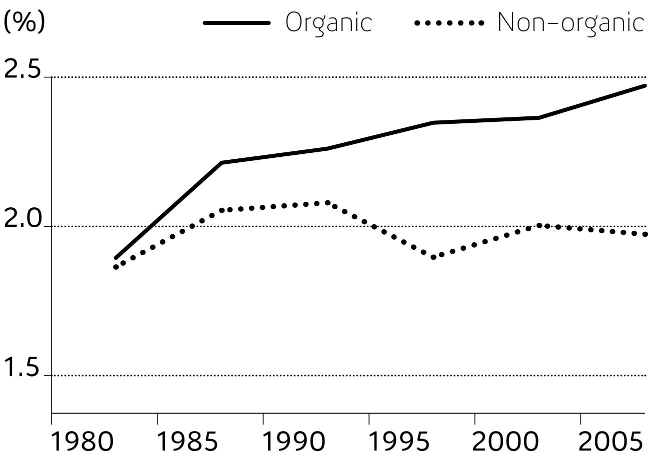
Soil humus levels determine the soil's water-holding capacity[12] and drainage rates. Low soil carbon levels are therefore likely to exacerbate the impacts of climate change, by increasing the risk and severity of droughts, water shortages and surface-water flooding. Conversely, higher soil humus levels should improve all these aspects. For instance:

▶ UK research has found that organic farming uses 26% less irrigation water per tonne of potatoes.[13]
▶ A long-term trial in the US found that in drought years, organic maize crops yielded 33% more than non-organic maize, and organic soya yielded 78% more than non-organic soya.[14]
▶ During torrential rains in 1999, measurements from the same trial found that water capture in the organically managed plots was double that of the non-organic plots.[15]
▶ Improvements in the resistance of agricultural crops to droughts will be particularly beneficial for the food security of drought-prone regions of developing countries.[16]

# Research methodology

This is the largest, most comprehensive and most detailed review of the soil carbon effects of organic farming to date. The Soil Association undertook a review of 39 comparative studies of organic farming soil carbon levels (all available soil sampling studies), covering over 100 individual comparisons from many different countries in temperate regions. This included both controlled trials and farm surveys. The objective was to evaluate the real impacts of current organic farming practices, compared to current non-organic farming practices, using the results of studies that sampled organically and non-organically managed land and to be conservative in all assumptions (unless stated otherwise).

**TOTAL SOIL CARBON CONTENT**



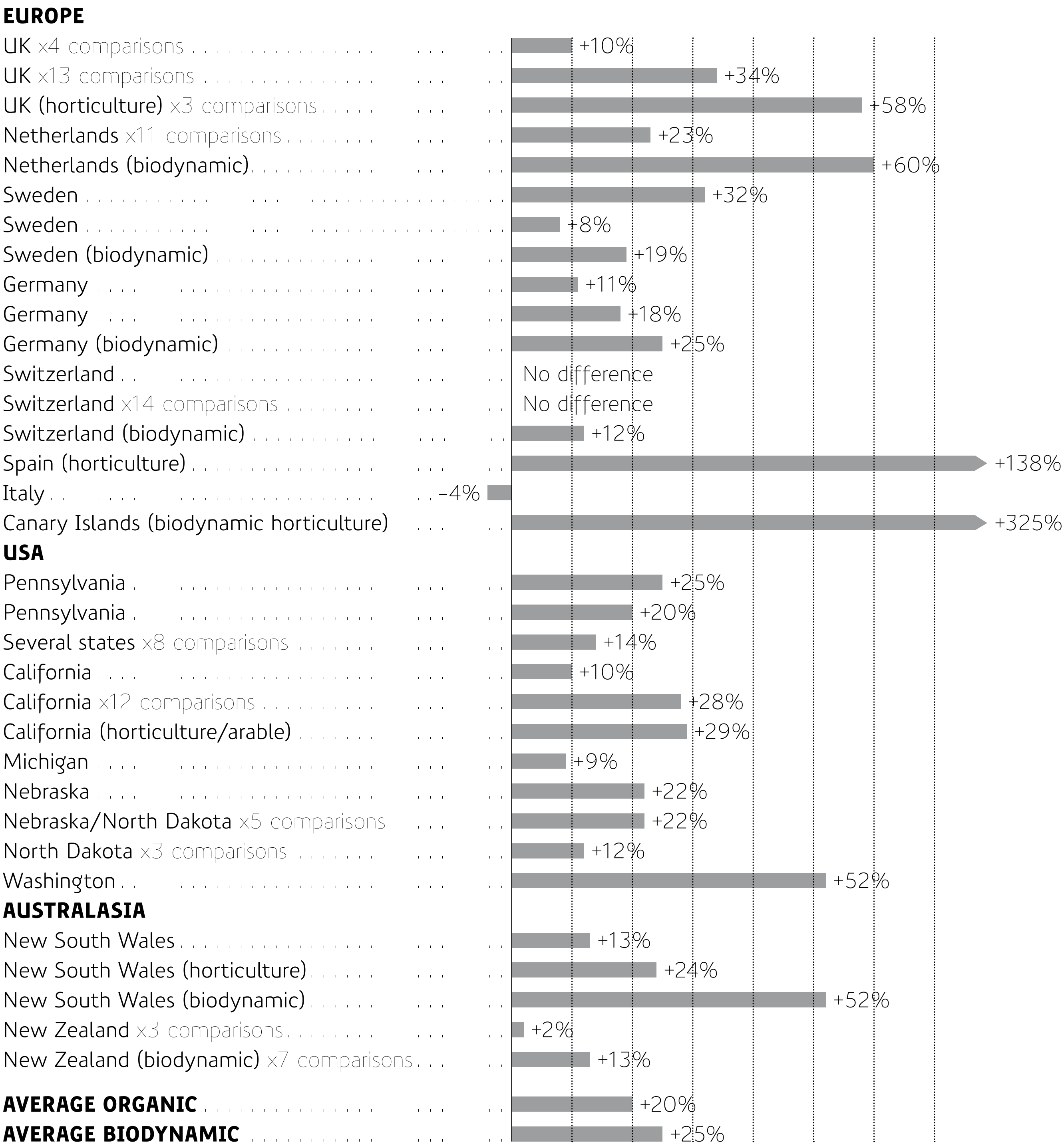

Results of a long-term US comparative trial by the Rodale Institute

The results of the studies were averaged to produce an average percentage difference for organic farming soil carbon levels compared to non-organic farming, (i) for Northern Europe (+28%), and (ii) all studies (+20%). For accuracy, these averages were calculated from the actual data not the percentage differences. A figure for the annual carbon sequestration potential of organic farming in the UK – 560kgC/ha/yr – was then calculated by applying the average +28% increase to official figures on the soil carbon stocks of UK cropland (tC/ha) and dividing this by 20 years to provide an estimated average annual carbon sequestration rate for the UK for 20 years following organic conversion. To be conservative, the +28% figure for Northern Europe was used (instead of the slightly higher figure for the UK alone); this increase was applied to the soil carbon stock data for England (rather than the higher figures for all UK cropland); the increase was only assumed to apply to the top 18cm of the soil (the estimated average sampling depth of the studies, although the IPCC methodology normally applies differences to the top 30cm); and the increase was assumed to be produced over an average period of 20 years (rather than the estimated 15 year average period of the studies; 20 years was used as it is the standard IPCC accounting period).

To arrive at the global estimated sequestration potential, a much simpler and more speculative approach was taken for illustrative purposes, as comparative data was not available for most countries, and using a single soil carbon stock figure would be inappropriate. A carbon sequestration figure of 1tC/ha/yr was assumed to apply to the total global area of cultivated land to give a total sequestration figure of 1.5 billion tonnes of carbon per year. It is assumed that a higher figure than the UK figure of 560kgC/ha/yr is both realistic and reasonable considering the very wide potential of organic farming practices at a global level (eg. using composting and agro-forestry which sequester particularly high levels of carbon).

The +28% and +20% for higher soil carbon levels in organic farming and the UK carbon sequestration potential figure of 64 million tonnes are presented as current best estimates of the soil carbon benefits of organic farming based on the current available data. The global estimate is speculative and intended to be illustrative. As further data becomes available, these estimates are expected to be improved.

**SOIL CARBON LEVELS: ORGANIC FARMING COMPARED TO NON-ORGANIC (SUMMARY OF STUDIES)**



# Soil carbon: the science

We believe the +28% and +20% for higher soil carbon levels in organic farming to be conservative for the following reasons:

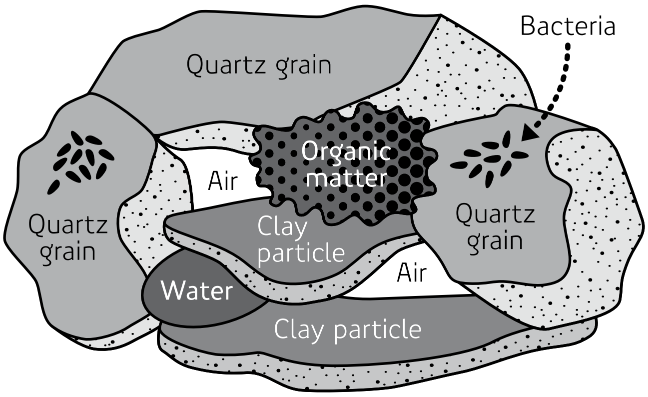
- The averaging was done using only the results of standard organic farming (excluding biodynamic farming) and based on the absolute data not the percentage differences (to avoid any bias from higher differences occurring in lower soil carbon level soils).
- These figures are only based on the differences in the topsoil carbon content (which is all that most studies measure) and they do not include any increases in topsoil depth or subsoil carbon content with organic farming, although the few studies to have looked at these aspects have found increases in these as well.
- The UK estimate does not account for any overseas carbon savings of organic food and farming, including an increase in the soil carbon levels of the large area of overseas arable land that provides feed for the UK's livestock sectors and the farmland used to produce imported foods (these are included in the global estimate, but not in the UK estimate), and a reduced destruction of tropical habitats due to greater use of grass as feed, rather than imported soya and other grains.
- These figures do not account for the increase in agricultural soil carbon storage that would result from the almost certainly greater percentage of farmland that would be in permanent grass with widespread organic farming.
- They only represent cultivated land, and exclude any higher soil carbon levels of organically managed, than non-organically managed, permanent grassland (as found by the three comparative studies to have looked at grasslands).
- They exclude the significant potential for further developing organic farming practices in line with its principles to increase its capacity to build soil carbon, such as by the wider use of green manure crops, composting, and the use of non-agricultural organic matter sources, such as food and paper waste.
- Most fresh organic matter is decomposed in the soil and rapidly releases it carbon as $CO_2$, and only a small proportion of the soil carbon input is converted to humus (stable soil carbon).
- It is often assumed that the main determinant of soil carbon levels is simply the quantity of organic matter inputs to the soil. However, biological factors affect the amount of carbon that is converted to stable soil carbon, and can increase the proportion from a few per cent up to 60%.
- Key to building the soil carbon store is good soil structure and the process of **soil aggregation**, whereby the soil's mineral particles are clustered into 'aggregates' which stabilises humus by encapsulating part of the humus inside the aggregates so that it is protected from degradation.
- **Soil micro-organisms** play a major role in soil aggregation: the soil particles are glued together by the polysaccharide gums produced by soil microorganisms,[17] by the networks of fungal hyphae in the soil,[18] and by the activity of earthworms.[19]
- **Plant roots** are a further key aspect and probably more important than the over-ground part of plants. As well as providing carbon from their biomass,[20] roots supply almost as much carbon to the soil by a continuous release of exudates, root hair turnover and root cell sloughing.[21] Also, the carbon from roots lasts over twice as long in the soil as the carbon from plant stems and leaves.[22]
- Another factor is the **biochemical composition** of the organic matter: (i) the level of resistant compounds such as lignin, and (ii) the carbon to nitrogen (C:N) ratio.[23] Nearly all of the carbon in residues with a C:N ratio higher than about 32:1, such as straw, is lost by microbial respiration.
- Different plant types affect the above properties differently: arable crop residues are relatively poor at forming soil carbon, legumes are better, and grass is very good. **Grass** has many characteristics that promote soil carbon levels: a high root density, resistant biochemicals, fine root hairs that promote

# The impact of current farming practices on soil carbon levels

soil aggregation, and high mycorrhizal fungal levels which increase soil aggregation.

- Organic matter types that have undergone some microbial digestion are also good at producing high, long-term soil carbon accumulation, ie. **farmyard manure (FYM) and compost**.
- The rough proportions of carbon that are converted to soil carbon increases by type as follows: **straw 5–7%**; **legumes 17%**; **FYM 23%**; **compost 50%** (if used without N fertiliser).

**ILLUSTRATION OF SOIL AGGREGATION**




The pore space inside the clump of particles holds organic matter, water and air

Arable soils have the lowest soil carbon levels of all major land types in Europe. There have been several developments in agricultural practices that are likely to have reduced soil carbon levels and are keeping levels low. The main ones for the UK are as follows, and are all associated with the intensification and specialisation of agriculture:

- The abandonment of mixed farming systems with temporary grass alternating with arable crops.
- The reduced spreading of animals manure: only 22% of the UK's cultivated area now receives manure of any kind (including sewage sludge).[24]
- The wide production of liquid slurry instead of solid farmyard manure (with straw), which does not have the same qualities, because of the intensification of livestock production.
- The reliance on inorganic fertiliser, which means farmers are no longer dependent on using organic matter for fertility and which reduces the size of crop root systems.
- The introduction of modern short-strawed cereal varieties, which has reduced not just the amount of straw produced but also the size of crop root systems.
- The ploughing-up of permanent grassland which releases from 23 tonnes (in England) to 90 tonnes (in Scotland) of carbon per hectare.[25]
- A high increase in the numbers of grazing cattle and sheep because of earlier government incentives, which caused over-grazing of UK grasslands.
- The move from grass to grain-fed livestock systems which means there is now a large 'ghost' area of low-carbon arable land abroad supporting the UK's livestock sector and major carbon losses occurring from the destruction of tropical habitats to supply soya feed and a shortfall in beef.
- The production of maize silage for winter cattle feed instead of grass (silage or hay), which causes soil degradation.

# Why organic farming?

The soil carbon benefit of organic farming results from the fact that the system is based on inputs of organic matter to the soil and the decomposition of this by soil microbial activity for releasing nutrients for crop production, instead of using inorganic fertilisers. This process at the same time produces humus (stable soil carbon) and thereby raises the soil's carbon levels.

A review of the scientific evidence on the factors and biological processes of soil carbon accumulation indicates that the key aspects of organic farming that produce these higher soil carbon levels are:

- The production of **additional organic matter sources** on farmland (grass leys, green manure crops), normally without reducing the area of farmland that is in food production.
- The production of more organic matter in **forms that are more effective** at producing humus and raising soil carbon levels (grass, legumes, root systems, composting and farmyard manure instead of slurry and straw), instead of just arable crop residues which tend to be rapidly mineralised.
- The common **integration of crop and livestock production (mixed farming)** which ensures the use of temporary grass in the rotations. It also ensures that much more of the livestock waste is produced in farmyard manure (FYM) form (with straw) instead of slurry, and that much more of the collected manures are applied to the cultivated land.
- The **greater vegetation cover** and less bare soil (use of grass leys, more weeds, green manure/cover crops), which provides a greater and more continuous supply of the root exudates that support the soil's micro-organisms which build the soil carbon store.

# Concerns about soil carbon and organic farming

The full report addresses in detail a number of concerns that have been raised about agricultural soil carbon sequestration and about the soil carbon impacts of organic farming.

- **Reaching equilibrium:** Critics have been too quick to dismiss soil carbon sequestration on the basis that the rates of sequestration tend to diminish 20 years after a switch to improved practices. But it is the next 20 years that are critical in policy terms for delivering major GHG reductions. Moreover, carbon sequestration still continues thereafter, albeit at lower rates, for 100 years or more.
- **Security of soil carbon sequestration:** There is also a concern that any soil carbon gains are insecure and may be lost rapidly if the positive practices are abandoned. This is not a key issue, as the focus should be on improving agricultural soil quality indefinitely. Nevertheless, soil carbon gains seem sufficiently secure: if the practices are abandoned, the half-life of accumulated soil carbon ranges from 10 to 130 years, and if organic farming builds carbon in the subsoil, the gains are even more secure.
- **Additionality:** One concern is whether organic farming produces additional soil carbon or whether the higher levels are largely a result of organic farmers using organic materials from non-organic farms, such as manure. In fact there is relatively little use of non-organic farming materials by organic farmers in the UK, and factors inherent in organic systems explain much or most of the differences in sequestration. Accounting for soil carbon must take account of whether sources of carbon like straw or manure would have been sequestered in any event, as well as of related emissions of GHGs.
- **Ploughing:** A concern that the common use of deep cultivation in organic farming could be a weakness are answered by a number of trials in Europe that show that the depth of cultivation has

no effect on the overall soil carbon levels of organic farming. Ploughing is used to incorporate organic matter into the soil; with sufficient inputs, increases in ploughing depth can even increase topsoil depth.

- **'Min-till' and 'no-till':** Reduced soil cultivation is the main non-organic farming solution commonly put forward for raising soil carbon levels, but its benefits have greatly been exaggerated. According to government scientific advice, the soil carbon benefits are minimal in the UK. Reduced tillage is effective in maintaining soil carbon storage in semi-arid regions where carbon is being lost by erosion and by the use of fallow periods, but otherwise there is no clear scientific evidence that it increases carbon levels over the whole soil profile, and certainly not to the extent of organic farming. Moreover, the carbon is then in a relatively unstable form, and any soil carbon gains may be offset by higher soil N2O emissions.
- **Relationship between soil carbon input levels, agricultural yields and soil carbon levels:** The report challenges a commonly held assumption that agricultural yields are one of the main determinants of soil carbon levels and that the use of inorganic fertiliser increases soil carbon levels (eg. in the US, organic farming yields are similar to non-organic farming, but soil carbon levels are higher). Organic farming produces organic matter sources other than crop residues and also improves the biological conditions for soil carbon accumulation: studies show organic farming can produce two to eight times as much soil carbon per unit of biomass carbon input then non-organic farming.
- **Soil microbial activity:** the higher soil microbial activity of organic farming is a benefit and does not mean that stable soil organic matter is more liable to being broken down. There is a positive association between soil carbon levels and soil microbial levels because it is soil microorganisms that (i) produce the humus, and (ii) protect humus against degradation, by aggregating the soil particles.

# Soil carbon facts and figures

- Soil is a major store of carbon, containing three times as much carbon as the atmosphere and five times as much as forests. About 60% of this is in the form of organic matter in the soil (1,500 bn tC).
- The large size of this store means that soil carbon changes can have significant effects on the level of atmospheric $CO_2$. Each 1% increase in average soil organic carbon levels could in principle reduce atmospheric $CO_2$ by up to 2%.[26]
- Soil carbon losses account for a tenth of all the $CO_2$ emissions by human activity since 1850.[27] However, unlike the losses of carbon from the burning of fossils fuels, the soil carbon store can be recreated.
- The principal component of the soil carbon store is humus, a stable form of organic carbon with an average life-time of hundreds to thousands of years.

# References


1 eg. The UK's Stern Review (www.sternreview.org.uk) warned that unless action is taken within the next 10–20 years, the environmental damage caused by climate change later in the century could cost between 5 and 20% of global GDP every year.

2 Environmental Impact of Products (EIPRO): Analysis of the life cycle environmental impacts related to the final consumption of the EU-25, European Commission, 2006

3 An estimated 89% of the global potential for agricultural greenhouse gas mitigation would be through carbon sequestration. Smith P *et al*, Greenhouse gas mitigation in agriculture. *Philosophical Transactions of the Royal Society of London Series B Biological Sciences* (2008) 363, 789-813. Published on-line 6 September 2007.

4 Soil Association calculation based on data in: Tables 1-1, 1-2 and 1-31, CEH *et al*, July 2008.

5 Williams A, Audsley E, & Sandars D, 2006. "Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities." Main Report. Defra Research Project IS0205. Cranfield University and Defra.

6 For example, the scheme being developed in the UK by the BSI/Defra and Tesco. PAS-2050 (2008) BSI Standards Solutions, Defra and the Carbon Trust. PAS 2050 – assessing the life cycle greenhouse gas emissions of goods and services. http://www.bsi-global.com/en/Standards-and-Publications/How-we-can-help-you/Professional-Standards-Service/PAS-2050

7 15 September 2009, speech by EU Agriculture Commissioner, Mariann Fischer Boel, reported on www.euractiv.com/en/cap/commission-farmers-need-help-cut-carbon/article-185476

8 Safeguarding our Soils: A Strategy for England, Defra, September 2009

9 Ana Frelih-Larsen, Anna Leipprand, Sandra Naumann (Ecologic) and Olivier Beucher(Baastal), 2008, "Background Paper for Stakeholder Consultation Workshop Climate Change Mitigation in Agriculture – Policy Options for the Future June 2008." See PICCMAT project website: http://www.climatechangeintelligence.baastel.be/piccmat/files/PICCMAT_policy_paper_June08.pdf

10 Janssens *et al*, 2003

11 UK methane emissions per dairy cattle per year are 130.8kg from enteric fermentation and from manure. Assuming 2 dairy cattle per ha, this means dairy cattle release: 2 x 130.8 x 21 (conversion factor for methane to $CO_2$) x 12/44 (conversion to carbon equivalent) = 1,498kgCeq/ha/yr of methane. So, UK grassland would give an offset of 670/1498 x 100 = 45% offset. Beef cattle emissions are 39% of those of dairy cattle, per animal. Reference for methane emission data for cattle from page 374 (based on cattle weight 577kg), Annexes of the UK Greenhouse Gas Inventory, 2007: http://www.airquality.co.uk/reports/cat07/0905131425_ukghgi-90-07_Annexes_Issue2_UNFCCC_Final.pdf

12 Humus can hold the equivalent of 80-90% of its weight in moisture, so higher levels increase the soil's capacity to hold water and withstand drought conditions; Olness A, Archer D, 2005. Effect of organic carbon on available water in soil. Soil Science 170:90-101. In addition, the aggregation of the soil particles by humus creates pores throughout the soil, which also holds water.

13 "Irrigation management in organic and non-organic potato production – a case study on the East Anglia region, UK," Soil Association, 2008.

14 Pimentel D, Hepperly P, Hanson J, Douds D & Seidel R (2005). Environmental, energetic, and economic comparisons of organic and conventional farming systems, BioScience.

15 Lotter D, Seidel R & Liebhardt W (2003): The Performance of Organic and Conventional Cropping Systems in an Extreme Climate Year. American Journal of Alternative Agriculture 18(3): pp146–154.

16 Experience in the Tigray province, one of the most degraded parts of Ethiopia, found that organically managed crops are more resistant to droughts and this improves overall yields. For details on this project, see: Edwards, S. (2007): The impact of compost use on crop yields in Tigray, Ethiopia. Institute for Sustainable Development (ISD). Proceedings of the International Conference on Organic Agriculture and Food Security. FAO. See: ftp://ftp.fao.org/paia/organicag/ofs/02-Edwards.pdf

17 1. Haynes *et al*, 1991. Cited by Shepherd *et al*, 2002. 2. Jastrow *et al*, 1998; Tisdall & Oades, 1979. Cited by Rasse *et al*, 2005. 3. Tisdall & Oades, 1982; cited by Wells *et al*, 2000.

18 eg. Haynes & Naidu, 1998. Cited in Shepherd *et al*, 2002.

19 Swaby, 1950; Scullion & Malik, 2000; and Scullion *et al*, 2002. All cited by Pulleman *et al*, 2003.

20 According to this source, the root biomass is generally about 22% of the above-ground biomass for arable crops (ie. 18% of total crop biomass), per unit area (for US conventional cropping systems). The ratio is probably generally higher for organic farming.

21 This suggestion of 'as or almost as much' is based on studies to date, but there is still "great uncertainty" over the size of the contribution of this source of carbon. Rasse *et al*, 2005.

22 An average 2.4-fold greater residence time for root carbon in the soil compared to shoot carbon, for an average 7.5 months, based on *in situ* studies. Rasse *et al*, 2005.

23 "Use of the Carbon:Nitrogen Ratio," SOIL, AGRON 305, www.agronomy.ksu.edu

24 Pages 34, 42 and 45, The British Survey of Fertiliser Practice, 2008. https://statistics.defra.gov.uk/esg/bsfp/2008.pdf

25 Tables 1–23 to 1–26 (note, the units shown should be tC/ha, not kg/m$^2$), page 20, CEH *et al*, 2008.http://www.edinburgh.ceh.ac.uk/ukcarbon/docs/2008/Defra_Report_2008.pdf

26 As the soil organic carbon store is twice the atmospheric carbon level, a 1% increase in the soil organic carbon store equates to 2% of atmospheric C levels. If soil carbon sequestration removes carbon as it is being emitted from other sources, before the sinks have been able to take it up, then presumably the full 2% reduction could occur. This would be far greater than the effect of emissions of carbon, such as by soil carbon losses, because currently the year-on-year atmospheric $CO_2$ increase is only about 40–50% of the amount of C emitted (see Houghton *et al*, 2003). An increase of 40% x 2% = 0.8%.

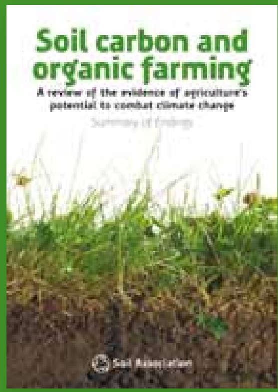
27 Derived from Marland *et al*, 2006; Houghton, 2003; Houghton, 1999. Other greenhouse gases are not included.

# Policy recommendations

**"Many agricultural mitigation options, particularly those that involve soil carbon sequestration (which is 89% of the technical mitigation potential of agriculture), also benefit adaptation, food security and development, referred to as co-benefits. These options involve increasing the levels of soil organic matter, of which carbon is the main component. This would translate into better plant nutrient content, increased water retention capacity and better structure, eventually leading to higher yields and greater resilience. These agricultural mitigation options can be pursued in the context of, and without adverse affects to, national sustainable development processes."**
*Food Security and Agricultural Mitigation in Developing Countries: Options for Capturing Synergies*, UN Food and Agriculture Organisation, November 2009

On the basis of these important benefits for GHG mitigation and climate adaptation, soil carbon sequestration should be maximised by agricultural and climate policies in four main ways:

- Soil carbon impacts should be fully accounted for and considered in climate policy and agricultural GHG accounting systems, in line with IPCC recommendations and including overseas impacts.
- National and global strategies for large-scale soil carbon sequestration should be adopted based on a major expansion and development of organic farming, with a parallel approach to improve non-organic farming.
- Work to define a sustainable diet (as is being championed by the Council of Food Policy Advisors and the Sustainable Development Commission) should take account of the importance of grass-fed livestock in conserving existing soil carbon stocks in permanent grasslands and sequestering carbon in cultivated land via temporary grass leys on mixed farms.
- The major national and global carbon source 'hot-spots' should be also directly addressed. For the UK, this means drastically reducing imports of beef, soya and palm oil, reversing peatland drainage, and returning the cultivated fenlands (lowland peat soils) to rotational arable/grass ley farming.




**www.soilassociation.org/climate.aspx**

The full report is available to download free of charge from the address above

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## SOIL ASSOCIATION

The Soil Association is a membership charity campaigning for planet-friendly food and farming. We believe in the importance of the connection between soil, food, the health of people and the health of the planet. You can find out more about our policy, campaigns and programmes at **www.soilassociation.org**

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