SEVEN WAYS TO SAVE OUR SOILS: SCOTLAND

Introduction

The state of Scottish and UK soils:
Soils in Scotland and across the UK are degrading, and consequently so is the long-term ability of farmers to keep up food production[1]. Compaction and signs of surface run-off are visible in many fields, which can increase the risk of localised flooding[2]. Arable and horticultural soils are losing soil organic matter[3], a crucial component for farm health. Research suggests that while allotment holders are managing to secure soil health, farmers in the same area are losing soil nutrients and organic matter[4].

Things need to change, and fast. Land capable of supporting arable agriculture comprises just 8% of Scotland's land area[5]. All farmers and growers in Scotland should therefore have a common goal to protect, maintain and build soil which is a finite and precious resource.

What is holding farmers back from looking after their own soils?

The problem is partially cultural. Farmers have come to see agrochemicals as the main source of fertility and control for pests and disease. This is not only leading farmers to overlook the unintended consequences of agrochemicals damaging soils, it is also diverting attention from soil health which should be at the heart of farm decision-making. The agrochemical industry has helped perpetuate this culture. It has also debatably diverted research from more innovative farming practices. In particular, there is an increasing realisation that soil life may be the key to crop productivity, but comparatively little research funding is being invested in this area, and huge knowledge gaps remain – although new research is now being undertaken, for example the BBSRC SARISA programme[6], The James Hutton Institute on effective soil function[7], and SRUC's continuing soil research[8].

However, more than just cultural change is needed. Many farmers are at the mercy of short-term leases and the pressure placed on them by their customers to compete with other global suppliers that have lower overhead costs. Consequently, farmers are often forced to focus on the short-term. The result is short rotations and high value but soil-damaging crop systems with quick returns. This is not a way of farming that ensures sustainable future food production and healthy soils.

What action is needed?

Soil is a fundamental environmental resource and should be given the same level of protection as water and air. An EU Soil Directive would have helped achieve this, but for now at least, this is not an option. It is our belief that the UK needs to act itself to save UK soils, while working constructively with EU partners to develop Europe-wide protection.

As a first step we believe this means committing to increase soil organic matter levels. We present here our target for this and seven ways to achieve it.

Our target

The first target of the Soil Association's Soils Campaign[9] is that we increase organic matter in UK arable and horticultural soils by 20% over the next 20 years. The UK and Scottish governments need to commit to this target to restore UK soils to health.

How did we arrive at this target?

For years, scientists have known that there are simple steps farmers can take to increase soil organic matter. Organic farming practices achieve just that. A review of studies from all over the world demonstrates that organically managed soils have significantly higher levels of organic matter – in north-west Europe an average increase of 21% over 20 years. While there have been only three studies in the UK, the difference found here for arable soil was 50%. The study also showed that these gains can be achieved even on farms which do not import organic matter from elsewhere; demonstrating that it is possible on a national scale[10].

Meanwhile the best nationwide data available, the Countryside Survey, shows a different story for most of UK (non-organic) arable and horticultural farmland, with an ongoing downward trend apparent for soil organic matter levels[11].

Reversing this decline in organic matter and starting to increase it will be a challenge, but based on the experience of organic farming, our target for a 20% increase on existing levels in 20 years (1% a year) is realistic and sets out an important goal to aim for. Indeed, many farmers will be able to do better than this depending on their starting point and the available support.

What are the benefits of a 20% increase in soil organic matter?

Increasing arable and horticultural soil organic matter levels by, on average, a fifth over 20 years would improve soil health considerably. It will lead to more fertile soils in the long-term and will provide a wealth of other benefits. The benefits of an increase of a fifth in soil organic matter will depend on the existing levels, soil type and structure. The following are just approximate calculations to give an idea of the scale of benefits:

Water storage, floods and droughts

- Healthy soil reduces the risk of floods – storing as much as 3,750 tonnes of water per hectare, the equivalent of one and a half Olympic swimming pools[12].

- For degrading UK arable soils which can contain as little as 1-2% soil organic matter in total, meeting our target (increasing these levels by a fifth in 20 years) would increase the water holding capacity by between 40-100 thousand litres per hectare or 4-10 litres per m[13].

- This means farmers can play a huge part in reducing the risk of localised flooding, at the same time as making their own farms more climate resilient – not only to floods, but also to droughts. This is vital considering that farmers are likely to face increasingly erratic weather in the future and increasing soil organic matter may help reduce the annual variability in yields.

Water quality

- Healthy soil also protects underground water supplies by neutralising or filtering out potential pollutants. Increasing soil organic matter levels can improve this function[14].

Soil erosion

- Linked to this is the ability for healthy soil to reduce the risk of soil erosion. This occurs as increasing soil organic matter levels reduce the amount of sediment and nutrients washed into rivers. Soil erosion by water has recently been highlighted as a major problem in Europe with the UK contributing 5% to Europe's total[15] despite occupying only 1% of Europe's land area. Research in south-west England found farms had such poorly degraded soils that 4 out of 10 were visibly increasing surface run-off[16].

Carbon sequestration

- Scientific debate continues on how much soil carbon can be sequestered through agriculture. It is likely to be considerable; the International Panel on Climate Change states that 89% of all agricultural emissions can be mitigated by improving soil carbon levels[17].

- An increase of 20% based on the UK average soil carbon density (using the best available data – the 2007 Countryside Survey) would suggest nearly 10 tonnes more soil carbon per hectare could be stored by 2035 – around 0.47 tonnes per hectare every year[18].

- Organic farms in north-west Europe have on average around 20% more soil organic matter than non-organic and demonstrate that meeting our target would result in major carbon gains. The recent meta-analysis found that organic farms (globally) store on average 0.27 to 0.45 tonnes more carbon in topsoil, per hectare per year[19]. Whilst carbon sequestration rates are known to decline in the long-term, these rates have been found to continue for at least 20 years – the most critical time for reducing emissions.

- Even if one takes the lower estimate of 0.27 tonnes more carbon stored in a hectare every year (the average sequestration rate found for zero-input organic farms), extrapolating this across the UK still suggests that around 1.3Mt more carbon

can be stored in UK arable and horticultural soils every year[20]. This is equivalent to the carbon sequestered annually by an area of forest three-quarters of the size of Wales, or to the emissions saved by taking nearly 1 million cars off the road[21]. When you add the additional savings found in terms of reduced N_20 soil emissions and the increased methane uptake (as also found by a meta-analysis comparing organic and non-organic soils[22]) the climate change mitigation potential of shifting arable and horticultural soils towards the standard seen on organic farms amounts to around 13% of current annual UK agricultural greenhouse gas emissions[23]. This far exceeds the current target to reduce emissions by 6% by 2020[24].

The seven ways to save our soils

In order to meet the target for 20% more soil organic matter in the next 20 years, we have set out seven key areas where action is needed. Within each of these areas, there are a wide range of practical measures available to farmers. Given the pressures placed on farmers and land-owners, financial incentives and regulatory change – alongside changes in practice – will be needed.

We therefore propose practices and policies that together could change the future of soils and safeguard future food production in Scotland and across the UK. Some of our suggestions may be more effective than others: some may be easier to implement. What is clear is that there is a wide range of opportunities available and that currently, too few are being implemented.

1 Increase the amount of plant and animal matter going back onto fields

Soil organic matter is an essential element to healthy soils – achieving high levels is the key to soil health. Levels are low or declining on many Scottish farms; we urgently need to work together to reverse this trend by ensuring farms are recycling more plant and animal matter back into soils.

What practices are available to farmers?

- Learn about the additional benefits of animal manure and certified composts; use it in place of nitrogen based fertiliser wherever possible.
- Bring livestock onto arable farm grass leys.

What could the UK and Scottish governments do to help?

- Commit to our target for 20% more soil organic matter in the next 20 years.
- Increase farmer awareness in Scotland about other additional benefits of farmyard manure and certified composts which increase its value above the value of its constituent parts through the FAS programme.

2 Encourage soil organisms – both those that build up soil and those that release nutrients

The current focus on chemical inputs began at a time when we didn't yet understand the importance of soil life. We are now realising how important soil biology is to farming. We need to learn how best to support this life in order to improve our ability to cope with floods and droughts and improve crop productivity.

What practices are available to farmers?

- Increase your own understanding; find out about innovative farmers carrying out farm trials, or even consider taking part yourself. If there is nothing local to you, get in touch with Soil Association Scotland.
- Consider the unintended consequences of agrochemicals before making decisions on their use, and consider ploughing less to reduce the physical impact on soil life.
- If nothing else, increasing soil organic matter, through the other ways listed in this document, can improve your important soil biology.
- Lobby the government to address the lack of research on the importance of soil biology and how it can be improved to benefit farmers.

What could the UK and Scottish governments do to help?

- Address the gaps in chemical testing regulations, so that unintended consequences on soil life are known before deciding on new pesticide approvals.
- Invest in research and development on the role of soil biology in securing crop productivity and carbon and water storage and into how this is impacted by different chemicals and fertilisers, singly and in combination.
- Fund research and development into farming practices required to optimise these benefits.

3 Cover up bare soil with continuous plant cover

You can't see healthy soil; it is covered by plants. Plant roots hold soils together, reducing erosion, and allowing air to penetrate in spaces around roots. Roots also encourage healthier soil communities through plant-fungal interactions. But benefits spread beyond the farm; huge gains can be seen in terms of biodiversity, carbon storage, flood and drought control, and water quality.

What practices are available to farmers?

- Bring vulnerable land into permanent grassland under agri-environment options / ecological focus areas.
- Where appropriate use cover crops, green manures and under-sown crops, with the added benefit of improving soil fertility.

What could the UK and Scottish governments do to help?

- Encourage more permanent grassland and support longer temporary leys, particularly on vulnerable soils.
- Fund research to help farmers choose the right cover crop for the right situation as well as advice to ensure knowledge exchange.

4 Bring more trees onto farmland

Trees have many benefits. They provide livestock with shelter from the elements, they enhance the landscape, and have large root systems that can infiltrate water and help prevent soil erosion.

What practices are available to farmers?

- Plant/ allow trees to grow on vulnerable, steep sided fields and rough grazing.
- Increase your understanding on the value of trees – for example speak to the Woodland Trust Scotland or Forestry Commission Scotland.

What could the UK and Scottish governments do to help?

- Create confidence amongst farmers about the benefits of agroforestry – fund research to quantify the benefits (for livestock shelter, a windbreak for crops and to improve farm climate resilience).

5 Reduce soil compaction from machinery and livestock

Soil compaction is a major problem across the UK – it can lead to increased surface run-off as well as drought stress, fewer grazing days, poor root growth and reduced yields overall.

What practices are available to farmers?

- Do a routine visual assessment to identify levels of compaction on farm and take remedial action.
- A range of alleviation practices are available to reduce compaction risk:
  - Use lighter machinery
  - Adopt controlled traffic farming (arable farmers)
  - Use correct tyre pressure
  - Reduce the number of passes
  - Try out reduced-till/ no till farming
  - Avoid over-grazing
  - Avoid trafficking over and grazing wet land

What could the UK and Scottish governments do to help?

- Continue to raise awareness of the impact that compaction has on overall performance of crops/livestock and on how to avoid, identify and tackle soil compaction. Emphasis should be given to taking the correct action at the right time e.g. not when the soil is wet.
- Strengthen measures designed to prevent soil compaction, needed to meet the standards of Good Agricultural and Environmental Condition (GAEC).

6 Design crop rotations to improve soil health

The current fashion in farming for simple arable crop rotations, financial pressures and the increasing trend for short-term tenancies all put pressure on farmers to make short-term decisions. The result is a drop in food diversity, weeds which we can no longer control and soils which are being stripped of their nutrients. To reverse this we need to ensure farmers are able to design diverse, long-term crop rotations that our soils need.

What practices are available to farmers?

- Many high value crops cannot be grown sustainably in a short rotation, such as potatoes and carrots. Design a longer crop rotation which avoids these problems. Focus on financial margins over the course of a whole rotation, not annual margins.
- Carefully design your crop rotations with more crops varieties and longer gaps before going back to the same crop. Put more emphasis on crops that help protect soils and that build soil organic matter such as legume catch crops.
- Grow crops with different rooting depths to take advantage of the soil's varying nutrient profile.
- Where possible include temporary leys in your rotation, used for grazing by livestock.

What could the Scottish Government do to help?

- Introduce requirements on tenants and land owners to ensure soil health is accounted for in tenancy agreements.
- Invest in research and development to investigate the impact of the increasing trend for short-term land rental and contract farming agreements on the long-term health of soils.

7 Improve soil health monitoring across the UK

Analysing soils is an essential first step to support effective decision-making on soil health, but some farmers neglect to do this routinely.

What practices are available to farmers?

- Undertake routine soil analysis and take appropriate remedial action.
- Test and monitor soil organic matter levels. Definitely do this if you are an arable farmer as you may be most at risk. Apps include the 'SOCiT App'[25] and 'Farm Crap App'[26].

What could the Scottish Government do to help?

- Ensure growers and arable farmers monitor soil organic matter; this could be a part of any planned compulsory soil testing requirements from RPID. Inserting this data onto a producer's SAF could help ease this process.
- Reward farmers doing more to improve soil organic matter above the baseline for their soil type so it becomes something which farmers aspire to improve. Rewards could be directed through AECS.

Support organic farming

Organic farms already practice all seven ways to save our soils. Given that our 20% target for soil organic matter increase is largely based on the average difference between organic and non-organic farms, every farm we encourage to convert to organic production will be a huge boost in reaching this target. Support for organic should therefore be prioritised by all the governments and assemblies in the UK through, for example: enhanced funding for organic production research; better knowledge transfer; and better funding support for organic farming itself in recognition of the public goods organic farming provides. There should be a long-term aim to increase the proportion of organic farmland in the UK. While increases in Scottish organic farmland do need to be driven by the market, growth is potentially being curtailed at present by a lack of support for organic despite a growing demand for organic products.

Summary

- Urgent action is needed to address the state of soils in Scotland and across the UK. Current government policies are not enough.

- In particular, we need to commit to increasing soil organic matter levels in arable and horticultural soils – by at least 20% on existing levels in the next 20 years.

- This will have multiple far-ranging benefits, and can be achieved if both farmers and government address the following seven areas:

    1. Increase the amount of plant and animal matter going back onto fields
    2. Encourage soil organisms – both those that build up soil and those that release nutrients
    3. Cover up bare soil with continuous plant cover
    4. Bring more trees onto farmland
    5. Reduce soil compaction from machinery and livestock
    6. Design crop rotations to improve soil health
    7. Improve soil health monitoring across the UK

- Organic farms already practice all seven of these areas, with soil health being at the very heart of organic practices. Increased support for organic farming should therefore be a key part of the solution and will go some way to meeting our soil organic matter target.

Case study

Lower Smite Farm

Lower Smite Farm is run by the Worcestershire Wildlife Trust and is managed by Caroline Corsie. Percentage soil organic matter levels were low on the farm to begin with – around 2.5% across the farm. Caroline has been using green manures and winter cover crops to improve the soil fertility of the farm and over five years she has managed to increase soil organic matter levels by 20% across the farm. The use of green manures and cover crops has also created rich pollinator habitat. Caroline trades forage cuts of cover crops, green manures and hay for neighbours farm yard manure – a rich and often hard to obtain resource for the farm – and occasionally uses household waste compost. The work undertaken by Caroline has shown that degraded soils can be improved but it takes time, resources and an openness to try new techniques. Lower Smite is an excellent example of what can be achieved and is a valuable resource for other farmers trying to improve their soils in Worcestershire.

Case study

SRUC long-term organic crop rotations trial at Tulloch

In the early 1990s SRUC established a replicated field trial at Tulloch near Aberdeen (Figure 1) to investigate the long-term sustainability of organic crop rotations. This trial is certified by the Soil Association, and compares different rotations:

1) **50% ley rotation** (3 years of grass/white clover followed by spring oats, swedes and undersown spring oats)
2) **67% ley rotation** (4 years of grass/white clover followed by spring oats, and undersown spring oats)
3) **The 67% ley rotation was changed to a stockless rotation in 2007** (grass/red clover, potatoes, undersown spring wheat, undersown spring beans, undersown spring barley, and finally undersown spring oats)

The results show that soil organic matter was maintained where there was livestock. SRUC are interested in what is happening to soil organic matter levels in the rotation without livestock. In soils like these, typical of mixed farming systems in the north-east of Scotland (with a relatively high organic matter content), the focus is on maintaining soil organic matter levels. The data from the trials also highlights the variability in soil samples taken from different locations, and at different times, and the need to look at soil organic matter in the long, rather than the short-term. For further information on these trials see:

Watson, C.A., Baddeley, J.A., Edwards, A.C., Rees, R.M., Walker, R.L. & Topp, C.F.E, (2011). Influence of ley duration on the yield and quality of the subsequent cereal crop (spring oats) in an organically managed long-term crop rotation experiment. Organic Agriculture 1, 147-159.

Taylor, B.R., Younie, D., Matheson, S., Coutts, M., Mayer, C., Watson, C.A. & Walker, R.L. (2006). Output and Sustainability of Organic Ley/Arable Crop Rotations at Two Sites in Northern Scotland. Journal of Agricultural Science, Cambridge 144, 435-447.

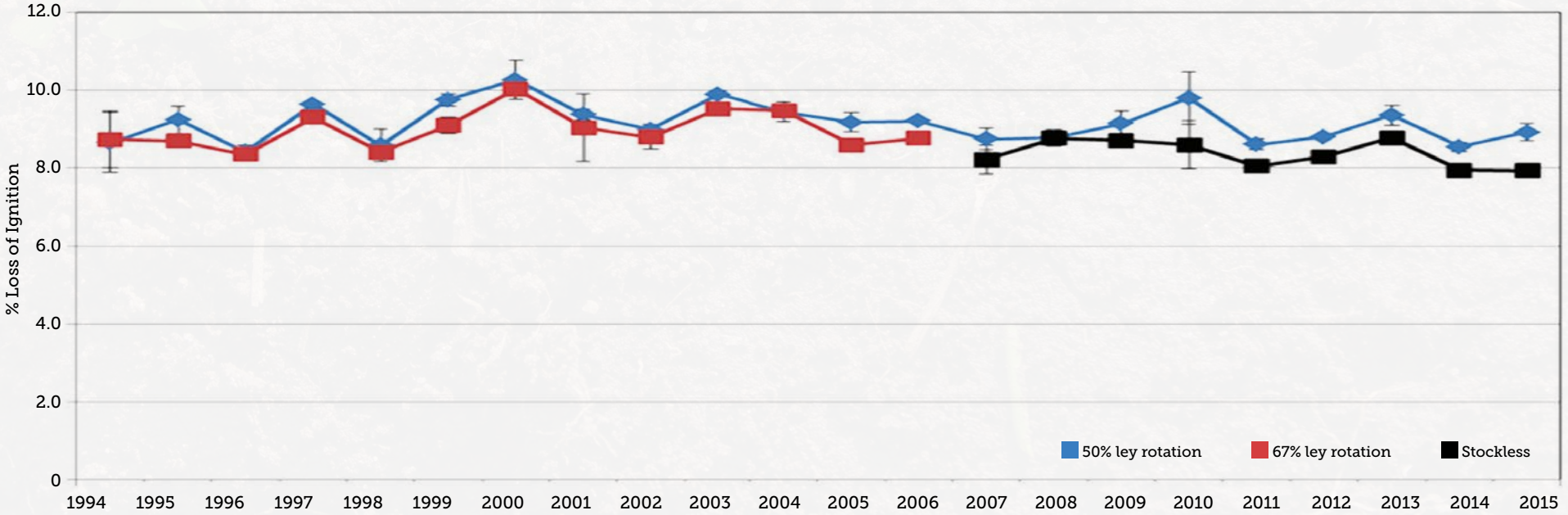
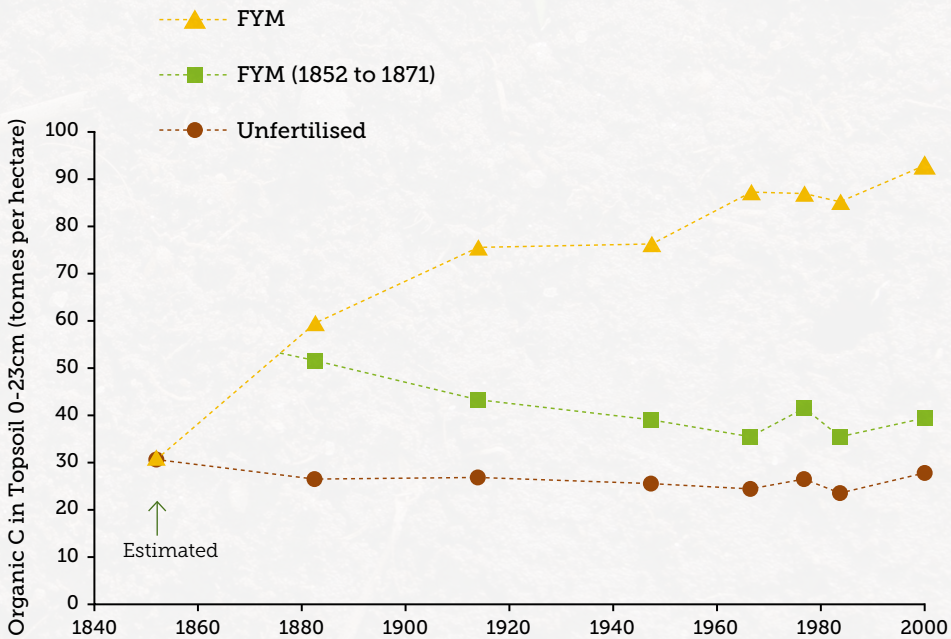


Figure 1: Soil organic matter (measured as loss on ignition) in 3 different organically managed crop rotations at Tulloch, Aberdeen.

Case study

Rothamsted long-term Hoosfield experiment

A long-term trial was initiated by the Rothamsted Research Centre in 1852 and carried on for 164 years – an incredibly long time for a field trial. The purpose was to look at the effects of different practices and cropping systems on soil organic matter and yield. The data from this Hoosfield Spring Barely field trial provides an interesting insight into the impact that applying animal manure can have on soil organic matter levels. For un-fertilised sites, soil carbon – an indication of organic matter levels – has stayed reasonably steady. On sites where farmyard manure has been applied annually however, levels have increased dramatically to around triple what they were originally. What is more, these increases have continued without plateauing, far exceeding the 20 years of gains usually expected. The experiment also found that if manure is no longer applied, levels will soon drop again, but the benefits from the manure are still clear 130 years later.



References

[1] Defra 2009 Soil Strategy for England – 'Our soils have degraded over the last 200 years due to intensive agricultural production. *https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69261/pb13297-soil-strategy-090910.pdf*

[2] Palmer, R. C. and Smith, R. P. (2013) 'Soil structural degradation in SW England and its impact on surface-water runoff generation', *Soil Use and Management,* **29: 567–575** *http://eureferendum.com/documents/sum12068.pdf*

[3] Countryside Survey Soil Report from 2007 *http://www.countrysidesurvey.org.uk/sites/default/files/pdfs/reports2007/CS_UK_2007_TR9-revised.pdf*

[4] Edmondson et al (2014) 'Urban cultivation in allotments maintains soil qualities adversely affected by conventional agriculture', *Journal of Applied Ecology, http://agris.fao.org/agris-search/search.do?recordID=US201400138533*

[5] *http://www.hutton.ac.uk/research/themes/delivering-sustainable-production-systems/soils/land-capability*

[6] *http://www.bbsrc.ac.uk/funding/opportunities/2013/2013-gfs-sarisa/*

[7] Research on soil at the James Hutton Institute *http://www.hutton.ac.uk/research/groups/environmental-and-biochemical-sciences*

[8] http://www.sruc.ac.uk/info/120247/soil_science_and_systems

[9] *http://www.soilassociation.org/soils*

[10] Gattinger et al (2012) 'Enhanced top soil carbon stocks under organic farming', *PNAS,* **109**(44): 18226–18231 Research Institute of Organic Agriculture (FiBL), Switzerland October 2012 *http://www.pnas.org/content/109/44/18226.full*

[11] *The Countryside Survey found decline in soil carbon density (and therefore soil organic matter) between 1998 and 2007 http://www.countrysidesurvey.org.uk/sites/default/files/pdfs/reports2007/CS_UK_2007_TR9-revised.pdf*

[12] European Commission Joint Research Centre European Soil Portal – 'key facts about soil' *http://eusoils.jrc.ec.europa.eu/projects/soil_atlas/Key_Factors.html*

[13] 1% SOM = an additional 20,000 to 25,000 gallons per acre, or at least 225,000 litres per hectare. 0.2-0.4% increase (20% increase on 1-2%) = 45000 to 90000 litres. Laura Byrant (2015) Blog: Organic Matter Can Improve Your Soil's Water Holding Capacity – covers these calculations and the assumptions made *http://switchboard.nrdc.org/blogs/lbryant/organic_matter.html*

[14] European Commission Joint Research Centre European Soil Portal – 'key facts about soil' *http://eusoils.jrc.ec.europa.eu/projects/soil_atlas/Key_Factors.html*

[15] Panagos et al (2015) 'The new assessment of soil loss by water erosion in Europe', *Environmental Science & Policy, 54: 438 – 447 http://www.sciencedirect.com/science/article/pii/S1462901115300654#tbl0015*

[16] Palmer, R. C. and Smith, R. P. (2013) 'Soil structural degradation in SW England and its impact on surface-water runoff generation', *Soil Use and Management,* **29: 567–575** *http://eureferendum.com/documents/sum12068.pdf*

[17] An estimated 89% of the global potential for agricultural greenhouse gas mitigation would be through carbon sequestration. Smith P et al, (2008) 'Greenhouse gas mitigation in agriculture'. *Philosophical Transactions of the Royal Society of London Series B Biological Sciences (2008)* **363: 789-813**

[18] *http://www.countrysidesurvey.org.uk/outputs/soils-report-from-2007* – found the average soil carbon density in Great Britain's arable and horticultural soils in 2007 to be 47.3t C/ha.

[19] Note this is based on global figures. Based on the average difference in carbon sequestration rates between organic and non-organic farms, found in the Gattinger et al (2012) global meta-analysis of comparative studies *http://www.pnas.org/content/109/44/18226.full*

[20] Taking the total croppable area of the UK as 4.8m ha, (*https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/355868/structure-jun2014final-eng-18sep14.pdf*) – an increase of 0.27 mega tonnes of carbon per hectare would mean an increase of around 1.3 million (1296000) tonnes of carbon.

[21] Based on the USA's Environmental Protection Agencies Greenhouse Gas Equivalencies Calculator – *http://www.epa.gov/cleanenergy/energy-resources/calculator.html*

[22] Skinner et al 2014 *http://www.ncbi.nlm.nih.gov/pubmed/24061052* found in a review of 12 comparative studies that organic farms emit the equivalent of 492kg CO_2e less N_20 and take up an additional 3.2kg CO_2e of methane per hectare per year on average.

[23] Based on the croppable area of the UK as 4.8m ha *https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/355868/structure-jun2014final-eng-18sep14.pdf and total current agricultural emissions of 53.7 m CO2e https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/449266/agriclimate-6edition-30jul15.pdf*

[24] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/449266/agriclimate-6edition-30jul15.pdf

[25] *http://www.hutton.ac.uk/news/new-soil-carbon-app-scottish-farmers*

[26] *http://www.soilassociation.org/news/newsstory/articleid/7451/-farm-crap-app-wins-soil-association-innovation-award*

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Report by
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Thanks to
Lillian Kelly, Trevor Mansfield, Liz Bowles, Tim Bevan, Ben Raskin, Emma Hockridge, Peter Melchett, Christine Watson, Robin Walker and Ruth Semple

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