

The role of livestock in sustainable food systems

Soil Association briefing

Executive Summary

- Some scientists, policy makers, politicians and campaigners, including the chair of the IPCC, are calling for people to eat less red meat to combat climate change, because of methane emissions from cattle and sheep - methane is a powerful greenhouse gas (GHG).
- The UK breeding herd has already been allowed to fall by 27% since 1990. As a result the UK, which has some of the most suitable land in the world for beef production, has become a major beef importer.
- IPCC scientists have recognised that soil carbon sequestration represents almost 90% of agriculture's total greenhouse gas mitigation potential.
- New research by the Soil Association based on 39 studies which compared the levels of soil carbon on organic and non-organic farms worldwide, found on average 20% increases in soil carbon under organic farming.
- In Northern Europe soils on organic farms have 28% more soil carbon.
- The carbon sequestered through the adoption of organic farming throughout the UK would offset at least 23% of UK agriculture's greenhouse gas (GHG) emissions.
- This potential to sequester huge quantities of carbon from the air and store it in agricultural soils requires major changes to farming systems, including increasing the area of grassland (especially nitrogen fixing clover) on farms – along with existing hill farms, these areas will produce grass-fed beef, lamb and mutton which will be helping to sequester carbon.
- A theoretical 500 hectare arable farm where no cattle or sheep have grazed since the late 1930s, converted to an organic mixed farming system, would have 250 hectares growing grain and other crops principally for human consumption, along with 250 hectares of grass and clover short term leys.
- Typically the farm might have 220 hectares of grass/clover feeding beef cattle and sheep, and 30 hectares supporting either a free-range pig or poultry enterprise (poultry produce only negligible quantities of methane and free-range pigs only about one-fifth of the emissions from sheep).
- The carbon sequestered under such mixed organic farming systems would be in the range of 660 kg -1 tonne per hectare per year for 20 years, with steadily declining amounts for several further decades. One tonne of carbon is equivalent to 3,666 kg carbon dioxide. An adult beef animal produces 48 kg methane per year from enteric fermentation and 2.74 kg from manure. Using an updated conversion factor of 90, this is equivalent to 2.283 tonnes CO₂. For land sequestering 1 tonne of carbon this gives a net CO₂ 'benefit' to the mixed farming system of 1.383 tonnes CO₂ per hectare per year for the first 20 years after conversion.
- On average arable farms in the UK use 147 kg nitrogen fertiliser per hectare per year. The production of a tonne of nitrogen fertiliser releases 6.7 tonnes of GHGs (in CO₂ equivalent) into the atmosphere. Including these emissions from non-organic arable farms in the comparison reduces the net emissions of CO₂ by 985 kg per hectare per year.
- After taking into account the methane emissions from ruminants, a typical conversion of an all-arable farm from a mixed organic system will deliver an overall net reduction in greenhouse gas emissions expressed in terms of CO₂ per of up to 2.368 tonnes of CO₂ per hectare per annum.

- On climate change and human health grounds we need to eat less meat, but the focus for reduction must be on intensively produced white meat (chicken and pork), and grain fed beef, while we eat proportionately more grass-reared beef, lamb and mutton.

Background

Since the publication of a United Nations report, 'Livestock's Long Shadow' in 2006¹, there has been increasing awareness about the damaging effect on the global climate from the methane emissions emitted by ruminant animals. Many campaigners, scientists like Dr Rajendra K Pachauri, Chair of the International Panel on Climate Change (IPCC), policy-makers like Lord Stern, and politicians have expressed their concern and some have called for dramatic cuts in the number of sheep and cattle as a way of reducing greenhouse gas (GHG) emissions and helping the UK to meet its emissions targets.

These concerns have been re-enforced by Government-funded work at Cranfield University which claimed that the carbon footprint of beef and lamb production was approximately four times higher than that of chicken meat production, and by a range of evidence implicating high red meat consumption in the increased incidence of some cancers, coronary heart disease and even lower sperm counts in Spanish men – entirely the opposite of its past association with male virility.

This paper takes an initial look at the extent to which two important factors have so far been left out of this debate and finds that their inclusion could lead to very different conclusions being drawn about the overall benefit of ruminants and some farming systems that depend upon them. The first of these is the extent to which soil carbon is lost to the atmosphere from some agricultural systems but has the potential to be sequestered from the atmosphere to the soil by others. The second issue is the extent to which food production systems which depend on nitrogen fertiliser are responsible for large emissions of GHGs.

A third issue, explored in the appendix, is the extent to which beef, lamb and other red meats from predominantly grass-fed animals have a very different nutritional composition to that of meat from predominantly grain-fed animals. This provides evidence to support an as yet untested proposition that such meat is more likely to have a positive rather than a negative effect on human health.

Soil carbon

One of nature's major carbon banks, the soil, contains more carbon than all the world's forests and the atmosphere put together. Since 1850 one tenth of the carbon added to the atmosphere as a result of human activity has come from the soil².

The primary cause of this carbon release has been agricultural intensification, specifically the substitution of traditional forms of agriculture which maintained fertility through crop rotation with the use of artificial fertiliser over the last sixty years. Most arable soils have lost over 30 tonnes of carbon per hectare to the atmosphere (about one-third of their original reserves), equivalent to 110 tonnes of carbon dioxide per hectare. Peat soils, such as the Fens in East Anglia, are still losing substantial amounts of carbon every year³

Unlike fossil fuels, which cannot be put back in the ground, it is possible not only to stop the current losses from agricultural soils, but also to rebuild their carbon store by the use of sustainable farming methods. Exemplified by organic farming, these systems sequester atmospheric carbon dioxide through plant growth and lock a proportion of this up each year in the soil as organic matter.

The Inter-Governmental Panel on Climate Change (IPCC) has provided data in Volume 4 of its latest (2006) 'Guidelines for National Greenhouse Gas Inventories' which show that a land-use change from arable to mixed farming is capable of increasing soil carbon levels by 1 tonne per hectare per year for at least 20 years. Analysis by the Centre for Ecology and Hydrology in the UK indicates that after the conversion of cropland to grassland, soil carbon levels will continue to increase for 100-750 years, depending on soil type, with high levels of sequestration in the early decades and progressively lower annual accumulations over time as the soil slowly achieves a new equilibrium. The studies on which these were based did not look at organic farming systems, which include a large number of features and practices likely to increase soil carbon levels still further. Other studies have observed substantial soil carbon sequestration over longer periods and also noted additional advantages in management aspects traditionally found on organic farms, such as the regular application of farmyard manure and use of deeper rooting grasses.⁴

A recent Soil Association report reviewed 39 studies which compared the levels of soil carbon on organic and non-organic farms throughout the world. The average of all studies showed increases of soil carbon in organic matter of 20%, while those in Northern Europe contained 28 % more soil carbon. From the same data, we have calculated that the carbon sequestered through a widespread adoption of organic farming throughout the UK would offset at least 23% of UK agriculture's greenhouse gas (GHG) emissions and probably significantly more than this^{5 6}.

Significantly, IPCC scientific advisers have recognised that soil carbon sequestration represents almost 90% of agriculture's total greenhouse gas mitigation potential. In the UK, the Climate Change Act commits the Government to achieving substantial cuts in GHG emissions over the coming decades. However, although the Government has recently recognised the importance of soil carbon sequestration in relation to both climate change mitigation and adaptation⁷, and pledged to find ways to reduce carbon losses from agricultural soils by 2020, it currently has no significant practical recommendations on how this could be achieved having now recognised that the long-favoured option of reduced tillage will have little or no practical impact⁸.

For further detail on this issue please see www.soilassociation.org/climate.aspx

Reducing Overall Emissions Through Mixed Livestock Systems

One way to enable soil carbon sequestration is to convert cropland into grassland as part of a ley/arable rotation which deploys a leguminous grass ley to build fertility, grazed by ruminant animals to convert the forage into food. This appears to be the only proven method applicable to large areas of farmland that is capable of sequestering substantial amounts of soil carbon, whilst at the same time maximising the production of an adequate range and quantity of food for human consumption.

Since the Second World War, UK agricultural policies have, however, discouraged mixed farming systems and instead encouraged increased specialisation in either livestock production or arable cropping. And with the exception of the very welcome support for organic farming under the Environmental Stewardship Scheme, current agricultural policies are regrettably still taking most farmers in the opposite direction.

For mixed farming systems to reach their full productive and carbon sequestration potential it is necessary for approximately half the land to be under grass (and legumes like clover) and half under arable cropping at any one time. However, unless the grassland is also producing food for human consumption such systems are, by and large, not only uneconomical in agricultural terms but would also fail in terms of

feeding an ever-growing global population with adequate quantities of nutritious food.

In Northern Europe and most other temperate regions, such systems of food production depend heavily on harnessing the ability of ruminants to utilise grass, where the nitrogen produced by legumes provides the principal source of fertility for this carbon building phase of the rotations.

But ruminants are increasingly seen as a major cause of climate change, rather than a means by which it could be partly addressed.⁹ This is principally because they emit large quantities of methane and this tends to be considered in isolation from the total GHG emissions of different food production systems. While there does not yet appear to be a formal Government policy on this issue, the UK breeding herd has already been allowed to fall by 27% since 1990¹⁰.

Britain is ideally suited to beef production, but cutting ruminant numbers in the UK still further would help to meet UK targets for reducing methane emissions on the basis of existing accounting methods. It would though have several major negative consequences. Beef and possibly lamb imports into the UK would increase, and sometimes come from countries where they have a very much higher carbon footprint¹¹. The GHG emissions associated with their production would be allocated to the country producing the beef or lamb, but the overall emissions to the atmosphere would be higher. Fields left vacant would be ploughed for cropping where suitable, leading to significant losses of carbon as carbon dioxide and nitrogen as nitrous oxide¹². Grassland left ungrazed on fields unsuitable for ploughing emits as much methane when it decays over-winter as if consumed by ruminants, while tree planting can produce net carbon losses on certain soils with a significant peat content.¹³

Ruminants have played a crucial role in the maintenance of food production and the development of human civilisations throughout history. We need to recognise the essential differences between those fed predominantly on grass and those fed predominantly on grain, and then reassess the role they could yet play in the development of a sustainable farming future. Advocating the introduction of ruminants onto prime arable land, however, is to propose what for many earnest and concerned people has become the unthinkable. So could we really justify in climate change terms, for example, the return of sheep and cattle to large areas of Britain's most productive cropland, including the wide open fields of East Anglia?

Let's consider a theoretical 500 hectare arable farm where no cattle or sheep have grazed since the late 1930s. To convert this farm to a good mixed farming system, such as that found on the best organic farms, all the land would need to go through a fertility building phase, but after a few years it should settle down into a rotation where 250 hectares is growing crops of grain, principally for human consumption, along with perhaps potatoes and other vegetables, while half is in grass and clover short term leys at any one time. There are likely to be some crops of grain legumes, either peas or beans depending on soil type and other considerations. There will, of course, be capital costs associated with this, because it will need fences to be erected, ideally hedges planted, water laid on to all fields for livestock to drink and in many cases the erection of new buildings for livestock, or modifications to some existing ones. It may even require the building of new abattoirs in some regions.

Typically we might have 220 hectares of the grass supporting a combination of beef cattle and sheep, and 30 hectares supporting either a free-range pig, or a free-range poultry enterprise. Since poultry produce only negligible quantities of methane and free-range pigs only about one-fifth of the emissions from sheep, we can assume that a maximum of 45% of the total farm will be stocked with ruminants at any one time, while the whole farm will be part of a mixed farming system with the ability to

sequester soil carbon on a progressive annual basis over many decades.

We know from published sources how much methane is produced annually from different classes of livestock and how much is released from manures from straw-based and slurry-based systems¹⁴. On farms like our theoretical example, typical ruminant stocking densities are no more than 0.5 livestock units (LU) per hectare over the whole farm, once they have converted to organic.¹⁵

The carbon sequestered under such mixed organic farming systems should be within the range 0.666-1 tonne per hectare per year for 20 years, with a lower level of sequestration continuing for the many further decades^{16 17}. One tonne of carbon is equivalent to 3.666 tonnes carbon dioxide¹⁸. An adult beef animal produces 48 kg methane per year from enteric fermentation and 2.74 kg from manure. Using a 'conversion' factor of 90¹⁹ this is equivalent to 2.283 tonnes CO₂. This gives a likely net CO₂ 'benefit' (3.666 -2.283) to the mixed farming system of up to 1.383 tonnes CO₂ per hectare per year for the first 20 years after conversion.

We also know that on average arable farms in the UK use 147 kg nitrogen fertiliser per hectare per year. During the production of each tonne of nitrogen fertiliser 6.7 tonne of GHGs (in CO₂ equivalent) are released into the atmosphere. If these emissions from non-organic arable farms are included in the comparison there is an additional reduction in the emissions of CO₂ of 0.985 tonnes CO₂ per hectare per year.

It is possible to undertake similar calculations for all grass organic beef or sheep farms which indicates that overall there is an advantage of approximately half a tonne of carbon dioxide equivalent in leaving the land in grass and stocking it with sheep or cattle at up to 1 LU per hectare, compared with ploughing it and growing crops using nitrogen fertiliser²⁰.

Conclusion

After taking into account the methane emissions from ruminants, a typical conversion of an all arable farm from a mixed organic system will deliver overall net savings expressed in tonnes of CO₂ per annum per hectare as follows:

Net soil carbon sequestration:	1.383 tonnes of CO ₂ /annum
Non-use of nitrogen fertiliser:	0.985 tonnes of CO ₂ /annum
Total benefit:	2.368 tonnes of CO ₂ /annum

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With thanks to Gundula Azeez, Patrick Holden and Peter Melchett

Appendix - Nutritional Composition of Forage-Fed Ruminant Meat

A major analysis of the, sometimes contradictory, scientific evidence by the World Cancer Research Fund (WCRF) concluded that high red meat consumption increases the risk of bowel cancer, while high white meat consumption does not. A few individual studies have also found a link with prostate and pancreatic cancer. Widely-accepted concerns that the saturated fats found in red meat increase the risk of heart disease have found their way into the Government's healthy eating guidelines. There has also been research in Spain linking high red meat consumption to low male fertility. None of these negative effects has been established for chicken and other intensively-produced white meat, so far.

One rather bizarre aspect of this issue which has received little consideration is that weekly consumption of beef in the UK fell from 244 grams per person in the early 1950s to 126 grams in the 1990s. In contrast chicken consumption during the same period increased from 19 to 237 grams and has risen further since. Yet this is the very period during which cancer and heart disease has increased dramatically.

This period equates to the major phase of agricultural intensification, when virtually all chickens and a significant proportion of cattle, even in the UK, were brought indoors and fed on a predominately cereal-based diet to increase productivity. Scientists at the Institute of Brain Chemistry and Human Nutrition in London have recently highlighted the fact that more than half the energy in a modern broiler chicken (as well as some organic chickens) comes from fat, whereas 60 years ago, the vast majority of the energy came from protein. Even more significantly though, the proportion of the omega-3 fatty acid, DHA, found at significant levels in grass, has fallen dramatically in chicken meat, which today contains only one-fifth of the level found in wild birds. In contrast levels of the omega-6 fatty acids derived from grain have not fallen, giving a highly unhealthy balance of almost ten times as much omega-6 as omega-3. They associate this with the rise of brain dementia.

Professor Michael Crawford, one of the authors, says that 'Essential fats for the brain are the priority...In biochemical terms the limiting factor for the brain is the omega 3 docosahexaenoic acid [DHA]... to get the same amount of DHA from a modern broiler chicken you need to eat about 3-5 chickens at a cost of over £12 and with 5,000 calories of thrombogenic and atherogenic fats included.' (Crawford, 2009, pers comm).

While a similar trend has occurred with intensively-produced beef and pork, grass-fed beef has an omega 6 to omega-3 ration of just 1.65:1. A very high proportion of beef in recent decades, however, has been produced intensively, in feedlots in the US and many other countries, and in the barley-beef systems pushed by MAFF for so many years. Could this be an explanation for the studies that have found harmful trends associated with high red meat consumption? We have to remember too that the WCRF included pork in their definition of red meat and worldwide a high proportion of pork is produced in the most appallingly intensive conditions.

The beneficial effects of omega-3 fatty acids are, as yet, widely accepted only in relation to cardiovascular disease and it is for this reason that we are advised to eat two portions of oily fish a week, but recent research has shown that Western diets are typically as high as 16:1, omega-6 to omega-3, but that reducing this to:

- 2.5:1 reduced colorectal cancer cells and the risk of breast cancer in women,
- 5:1 suppressed inflammation in patients with rheumatoid arthritis. (Simopoulos, 2008)²¹.

Even the WCRF, which has been at the forefront of the global campaign to reduce the consumption of red meat, has acknowledged that the meat of wild animals has a very different fat profile to that of most farmed animals and may therefore not be linked to

increased cancer risk. However, it has failed to acknowledge that production systems much closer to the wild are likely to produce meat with similar characteristics to wild animals. This is a serious omission, because in the absence of such a recognition economics are driving extensive producers out of business at a much faster rate than intensive ones. Meat and milk from predominantly grass-fed animals have other advantages too: higher levels of beneficial conjugated linoleic acid and many other important micro-nutrients associated with increased well-being.

Notes and references:

¹ Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M. and de Haan, C. (2006) 'Livestock's long shadow', Food and Agriculture Organization of the United Nations

² Houghton, R.A. (1999) 'The annual net flux of carbon to the atmosphere from changes in land use 1850-1990', *Tellus*, vol 52, no 2, pp298-313

³ It has been estimated that about 3 metres of peat has been lost across the fens and that the annual carbon losses still add almost one million tonnes of carbon dioxide to the atmosphere every year.

⁴ Two long-term trials of arable-ley systems described in, "Soil Organic Matter: Its Importance in Sustainable Agriculture and Carbon Dioxide Fluxes," Edward Johnston, Paul R. Poulton, and Kevin Coleman, 2009, Chapter 1, Vol 101, *Advances in Agronomy*, *in press* show that grass leys have positive soil carbon effects on cultivated land. For example, after 36 years, an arable-ley system comprising a three-year grass ley in a six-year crop rotation produced an 18% higher topsoil carbon level than a six-year rotation of five years arable cropping and one year grass for hay (Rothamsted 'ley-arable experiment', 1949-2002, soil with 25% clay content). In another study, after 33 years, a three-year grazed grass-clover ley in a five year rotation produced a 40% higher topsoil carbon level than continuous arable cropping (Woburn 'ley-arable experiment', 1938+, 12% clay soil).

In the 33-year 'Ley-arable Woburn experiment' it was also shown that the positive effects of FYM were greater in an arable-ley system than in a continuously cropped system. This suggests one explanation for the soil carbon advantage noted in many comparative studies of soil carbon under organic and non-organic farming. In this trial, the regular use of FYM at 38t/ha/yr every five years (mean of 7.5t/ha/yr) produced an additional 18% increase (from the starting SOC level of 0.98%) in the topsoil carbon level of plots in an arable-ley rotation, on top of the increase produced by the ley. In comparison, FYM just produced a stable soil carbon level and avoided carbon losses on continuously cropped plots (ending 0.99%). In total, this gave around a 45% higher soil carbon level after 33 years from the use of grazed grass leys plus FYM application (ending 1.44% SOC, instead of 1.26% SOC for grazed grass-clover ley without the FYM), than a continuously cropped system without either grass ley or FYM use.

⁵ Azeez, G. (2009) 'Soil carbon and organic farming. A review of the evidence for agriculture's potential to combat climate change'. Soil Association, Bristol. www.soilassociation.org/climate.aspx

⁶ The overall benefits are likely to be in the region of twice as high because the Soil Association's report was only able to calculate the soil carbon benefits of organic farming to a depth of 18 cm, due to the fact that most available studies did not examine the effects at deeper soil levels. However, of those studies that did study changes in soil carbon in deeper soil layers most (though not all) found the benefits to persist to 30 cm and some right down to 80 cm.

⁷ 'Safeguarding our soils, a strategy for England' 2009 www.defra.gov.uk/environment/quality/land/soil/

⁸ In an accompanying publication, 'Soil Strategy for England Supporting evidence'

<http://www.defra.gov.uk/environment/quality/land/soil/documents/evidence-paper.pdf> Defra scientists recognise that reduced tillage, long seen as intensive arable farming's solution to soil carbon sequestration, has little overall benefit. They cite recent research (pp11-12) which concludes, '*If all arable farms were to convert to zero tillage (assuming this was practical) this could mean sequestering carbon equivalent to only 0.034% of the UK's carbon emissions and reduced tillage is assumed to have only half these benefits. However, even these small gains in carbon might be completely offset by an increase in direct nitrous oxide emissions, or reversed through conventional ploughing which is in the UK generally undertaken every 3-4 years for compaction, weed, disease and pest control purposes even when reduced tillage is used.*'

⁹ The atmospheric concentration of methane has increased from about 700 ppb before the Industrial Revolution to well over 1,700 ppb today. While methane is responsible for only 8% of greenhouse warming globally, it accounts for a much higher proportion of agricultural greenhouse gas (ghg) emissions. In the UK this is officially put at 38%. All ruminants emit substantial volumes of methane while they ruminate, due to the bacterial breakdown of the cellulose in grass. Typical figures are 200 litres per day for an adult beef cow and up to 550 litres per day for a very high yielding dairy cow. Based on research from the US in the 1990s, it is generally accepted that grass-fed cattle produce higher volumes of methane than grain-fed cattle. Despite the higher levels of methane emission associated with high yielding cows, many scientists and policy advisers and even some Ministers have drawn attention to research which appears to show that very high yielding cows nevertheless produce more milk per litre of methane they emit on the basis that even a dry cow on a lower plane of nutrition emits a significant amount of methane.

Reductions in manmade methane emissions are seen as a prime target for ghg action because methane has a relatively short life in the atmosphere of 12-15 years, compared with for example, nitrous oxide which lasts for approximately 150 years. As such, it is argued, reductions in atmospheric concentration of methane now could quickly help to slow the rate of global climate change.

¹⁰ Eblex (2009) 'In the balance? The future of the English beef industry', Eblex report, Milton Keynes, UK

¹¹ Any shortfall in supply for the home market is inevitably made up from increased imports. The UK has moved from being a net beef exporter to a significant beef importer, supplying 20% of the market last year (300,000 tonnes) with imported beef. This simply transfers the methane emissions to other countries GHG budgets. The Greenpeace report 'Slaughtering the Amazon' showed that 80% of rain forest destruction in the Amazon is to clear land for beef production. Currently about 5,000 hectares of the Amazon is cleared every day (14% of worldwide rain forest clearance). At the present time due to regulatory issues, no beef is imported into the EU from Brazil. However, Brazil exports onto the world market and the UK imports beef for other countries which could otherwise supply markets currently supplied by Brazilian beef. Argentina, from which we do import beef, is moving away from traditional grass-based systems towards US-style feedlots, where diets are heavily grain-based.

¹² A Dutch study, Vellinga, Th. V, van den Polo-van Dassel, A and Kuikman, P. J. (2004) 'The impacts of grassland ploughing on CO₂ and N₂O emissions in the Netherlands'. *Nutrient Cycling in Agroecosystems* vol 70, pp. 33-45. Kluwer Academic Publishers, estimates that the combined emissions of CO₂ and N₂O from converting permanent grass to permanent cropping are equivalent to 250 tonnes of CO₂ over about 100 years.

¹³ Fields no longer grazed by sheep or cattle usually get ploughed and converted to crop production, if they are suitable. Over the last 20 years, as beef numbers have declined, approximately half a million more hectares of farmland in the UK has been ploughed and permanently converted to cropland than has been returned from cropland to long term permanent grass. This leads to the loss of soil carbon as CO₂ and the loss of nitrogen as nitrous oxide. The amounts vary according to the initial soil carbon and nitrogen levels being progressively higher in Wales, Northern Ireland and Scotland, than in England, but typically amount to 250 tonnes of CO₂ equivalent over 100 years, with about half of the total being lost during the first 20 years, according to a Dutch study (see ref. 11).

On difficult to farm hill and other land where the removal of grazing animals leads to the abandonment of agricultural management and leaves grass to grow rank and die back naturally over winter, the methane emissions associated with the decaying grass are likely to be just as high as they would have been from ruminants eating the grass

Where trees are planted instead it will take 20 years before the CO₂ sequestered exceeds the CO₂ emissions associated with plantation establishment, and where trees are planted on soils with a high peat content the drying out of peat land can release significantly more CO₂ than the trees take up.

¹⁴ CEH (2008), 'Annexes of the UK Greenhouse Gas Inventory, 1990 to 2007' Centre for Ecology and Hydrology, Edinburgh http://www.airquality.co.uk/reports/cat07/0905131425_ukghgi-90-07_Annexes_Issue2_UNFCCC_Final.pdf Accessed 12 September 2009 p 374.

Summary of relevant data from the Centre for Ecology and Hydrology

Animal type	Enteric CH ₄ kg/head/year	Methane from manure/head/year
Dairy cows	105	25.8 (with slurry systems)
Adult beef cattle	48	2.74
Beef cattle under 1 year	32.8	2.96
Breeding sheep	8	0.19
Lambs	3.2 (over 12 months)	0.076
Pigs (indoor)	1.5	7.06

¹⁵ There are several successful examples of mixed organic farms where the stocking density is below .025 LU per hectare. This is usually achieved by greater use of field legumes, greater use of green manure crops and some cutting and mulching of grass. In contrast stocking densities are typically about 1 LU per hectare on all grassland organic farms and between about 1 and 2 LU per hectare on organic dairy farms, though in the case of the higher stocking levels these are not always true stocking densities because often significant amounts of feed are bought in rather than produced on the farm.

¹⁶ This figure is based on IPCC data from Volume 4, AFOLU; Agriculture, Forestry and other Land Use of its 2006 Guidelines and relates to a clay soil converted from mixed farming with no regular manure applications to mixed farming with regular manure applications.

¹⁷ Greater benefits are likely on soils with a naturally higher organic carbon level. Compared with England, a progressively higher proportion of such soils are found in Wales, Northern Ireland and Scotland.

¹⁸ The 3.666 factor is the molecular weight of CO₂ -44- divided by the molecular weight of carbon - 12.

¹⁹ The current IPCC conversion factor for expressing methane emissions as carbon dioxide equivalent is 21 times over 100 years. French climatologists, however, have argued that for ongoing methane emissions a factor of 81 should be used for 20 years, 57 for 50 years and 39 for 100 and only 21 for 250 years. 'Global warming: the significance of methane' Benjamin Dessus, Bernard Laponche and Henri Le Treut (2008) p6 <http://www.endseurope.com/docs/report3.doc>. We have increased these factors by a further 10% to take account of recent research at the NASA Goddard Institute in the US which found that the global warming effect of methane is 10% higher than previously estimated.

²⁰ All grass organic farms typically have stocking rates about twice as high as mixed organic farms. Some studies suggest that permanent grassland under organic management continues to sequester significant amounts of carbon over prolonged periods. An EU-wide study indicated that permanent grassland in the UK sequesters on average 670 kg C/ha/yr, equivalent to 2456 kg CO₂. 'Europe's Terrestrial Biosphere Absorbs 7

to 12% of European Anthropogenic CO₂ Emissions', by Ivan A. Janssens, Annette Freibauer, Philippe Ciais, Pete Smith, Gert-Jan Nabuurs, Gerd Folberth, Bernhard Schlamadinger, Ronald W. A. Hutjes, Reinhart Ceulemans, E.-Detlef Schulze, Riccardo Valentini, A. Johannes Dolman. Published on-line in Science, Vol 300, 6 June 2003, If we assume the benefit would persist for at least 50 years the methane emissions per hectare would be equivalent to $1 \text{ LU} \times 50.74 \times 57 = 2892 \text{ kg CO}_2$, whereas the carbon sequestered is only equivalent to 2456 kg. However, when comparing an organic all grass farm with a non-organic all grass farm one also needs to include the CO₂ equivalent of the greenhouse gases associated with producing N fertiliser. Application rates on all grass beef or sheep farms have fallen in recent years to about 70 kg/hectare. This is equivalent to 469kg CO₂. If we add 2456 to 469 this gives 2,925 Kg of CO₂. This gives a marginal advantage of 33 kg CO₂. It is necessary to point out however that this compares very favourably with the carbon foot print of much imported beef. If the grassland is ploughed for crop production the CO₂ equivalent of the CO₂ and N₂O emitted will be equivalent to 2,500 kg per year for 100 years (see note 8) and the production of the nitrogen fertiliser applied to grow the crops will be equivalent to 985 kg, indicating that approximately half a tonne less CO₂ ($2456+985 = 3441-2892=549\text{kgCO}_2\text{eq}$) would be added to the atmosphere each year if the land is left in grass and stocked with ruminants.

²¹ Simopoulos, A. P. (2008) 'The Importance of the Omega-6/Omega-3 Fatty Acid Ratio in Cardiovascular Disease and Other Chronic Diseases'.