

An overview of life cycle assessment and carbon footprinting

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The production of any commodity, such as milk or lamb, causes burdens on the environment. These can be diverse, vary in location and apply over different timescales. Climate change is of great importance, but is not the only impact (actual or potential) that is relevant, e.g. we have targets to reduce ammonia emissions under the Gothenburg protocol. We have nitrate vulnerable zones. The Water Framework Directive will introduce more restrictions. It is in our collective interest to reduce the burdens on the environment and yet we still need to produce food. Taking single approaches to mitigating burdens may backfire if the whole production system has not been analysed and quantified.

One approach to this is the application of environmental Life Cycle Assessment (LCA). It is a systematic approach to analysis of a defined output: the functional unit. In its fullest form, LCA considers production and use of commodities (cradle to grave), but it can also be truncated to cradle to gate studies, which is commonly applied to agricultural production. The output of this type of analysis is typically a Life Cycle Inventory (LCI). The LCA method is enshrined in a set of international standards: the ISO 14040 series (BSI, 2006). These describe the basic requirements of LCA, but are not overly prescriptive in many respects.

The aims of LCA are broadly to trace the consumption of resources back to raw materials, to calculate the emissions of unwanted materials into the environment and to allocate these burdens equitably to the functional unit (over stages of production), which is produced within defined system boundaries. The functional unit must be well specified, e.g. 1 m³ of refrigerated, unprocessed milk containing 3.9 to 4.1 % fat, at the farm gate. Raw materials may enter a production system, but almost all are processed in some way, e.g. tractor diesel must include the overheads of crude oil extraction, refining and distribution. Emissions are calculated from individual processes and activities (e.g. burning fuel or ammonia volatilisation from manure) and may be quantified per animal-year, per ha or per MJ energy used. These are then systematically allocated to the functional unit. When co-products are produced, these also receive allocations of burdens, but usually relatively smaller than for the main functional unit.

Diffuse emissions are usually aggregated into potentials for causing environmental harm, e.g. eutrophication, acidification, ozone depletion and of course global warming potential (GWP). These may also be aggregated further into potentials for causing human ill-health and / or ecotoxicity. Disparate abiotic resource usage may also be put onto one scale, either in relation to the element Antimony or the extra energy needed to extract them as their scarcity increases. There have also been efforts made to include factors like biodiversity in an LCA framework, although this is still at an early stage. There is no formal requirement in the ISO 14040 series to include all of these: it depends what the purpose of the analysis is. It is very unlikely, though, not to include energy use and GWP as minima. In much of industry and domestic life, burning fossil fuel and so causing GWP through CO₂ (and other GHG) emissions is very common and the linkage between C based fuel use and GHG emissions is very highly correlated. Hence, the term carbon footprint has been evolved. It broadly represents both resource use and a potential effect on the atmosphere. It gets applied not only to unit quantities of products, but also individuals, cities or countries. But, there is no unequivocal definition of the C footprint and some suggest the term climate footprint is better. It may include gases other than CO₂ and may include the overheads of fuel extraction or just deal with "end of pipe" emissions. In two main areas, the omission of non-CO₂ gases is very misleading w.r.t. atmospheric chemistry: agriculture and refrigeration. About 60% of the GWP from UK wheat comes from N₂O and about half the "Carbon footprint" of refrigeration is stores like Tesco is from refrigerant leakage and the rest from energy use. CH₄ and N₂O play a large role in agriculture, with enteric CH₄ a particular feature of ruminants.

"C footprinting" of products has recently become more formalised through the development of a publically available specification of the British Standards Institution (BSI, 2009). This applies LCA in the "*Specification for the assessment of the life cycle greenhouse gas emissions of goods and services*". It does itself include the term carbon footprint, although it appears in related documentation. It can be used for both cradle to gate and cradle to grave applications. Its aim is to produce an estimate of one environmental impact only and although energy use must have been calculated, it is not required to report it. It also includes many

specific requirements for compliance, such as minimum proportions of primary data that are needed and a prescriptive approach to the effects of land use change. It makes the analyst's job easier in some ways by removing options, but other requirements can be difficult to fulfil. One overall aim is to produce a consistent approach to the subject (and maybe one day with consistent data sources) so that analyses and more comparable than before.

In conclusion, the carbon footprint is a sub-set of LCA as a whole. It is very important in environmental analyses, but it is not everything. Omitting other criteria is unwise for making long-term decisions.

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Livestock, life cycle analysis and the broader view

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"The Answer to the Great Question..."

"Yes..!"

"Of Life, the Universe and Everything..." said Deep Thought.

"Yes...!"

"Is..." said Deep Thought, and paused.

"Yes...!"

"Is..."

"Yes...!!!...?"

"Forty-two," said Deep Thought, with infinite majesty and calm."

Douglas Adams, *Life, the Universe and Everything*

Life cycle analysis (LCA) has proved to be an invaluable tool for measuring the environmental impact of a product or process, across a range of indicators, at a particular point in time. In the case of food, it has given 'snapshot' insights into the relative contributions of particular stages or processes in the food supply chain, and has enabled people to compare the overall greenhouse gas (GHG) intensity of different products and processes. LCA has even been used to compare the nutritional 'value for emissions' of different meals. It has challenged some common sense assumptions, and, importantly, it has highlighted the very significant contribution that the meat and dairy sectors makes to food-related, and indeed to global greenhouse gas (GHG) emissions. This is an important insight, if we are to make a real attempt at tackling the rise in global GHG emissions.

It is, however, important to recognize that LCA is only a tool, and the insights it provides are not 'answers.' LCA can say little about how things might be different *if* things were different, as it were. The insights afforded by LCA (even consequential approaches) are determined by a very limited set of framing parameters - or boundaries - themselves reflecting a particular set of largely economic, business-as-usual assumptions. The food system on the other hand, is at once *dynamic*, shaped by evolving social, economic and ethical mores and *constrained* - by physical, biological and certain moral limits. The relationship between the two is unstable, partly because what is defined as a constraint (limits to available land or productivity, acceptable concentrations of GHG emissions; ethical non-negotiables) is continually being challenged and redefined by technical developments and the changing mores of our day. The numerical answers LCA provides can say little about these complex interactions and so, when they are used in a very narrow fashion to guide policy, they can be dangerously misleading.

This paper explores some of LCA's main limitations in more detail, taking the livestock sector, and its GHG impacts, as the focus. We briefly set out what LCA has to say about livestock emissions, and the various LCA-derived proposals made for reducing these impacts. We then argue that merits of these approaches very much depend on the framework within which they are viewed and are in fact the products of a particular set of economic, social, and moral assumptions; given a different framework of assumptions, different approaches to GHG mitigation from livestock may be considered preferable. To illustrate this, we describe four scenarios for livestock production (based on systems that already exist worldwide), each of which takes as its goal the mitigation of GHG emissions but which sits within a different set of framing assumptions. We look at how successful each scenario might be in achieving reductions while also examining what the moral and social implications, for example with respect to human health or animal welfare, might be. We then look at what approaches might be adopted (themselves reflecting the framing assumptions of that particular scenario) to overcome any negative consequences. We conclude that we need to make sure that the insights afforded by LCA are used not just to help policy makers minimise the damage caused by pursuing a 'lite' version of the status quo, but to enable society to start imagining alternative possible futures.

Greenhouse gas emissions related to livestock in the UK inventory

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Introduction.

The UK is required under the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC) to reduce its Greenhouse Gas (GHG) emissions by 12.5% relative to 1990 levels (baseline year) by 2008-2012. The accuracy of the inventories of GHGs largely depends on the methodology employed to calculate the fluxes but is also influenced by the quality of the activity data required to input in the calculation model. In the case of N₂O, the current UK GHG inventory uses the standard Tier 1 methodology of the Intergovernmental Panel on Climate Change (IPCC), which is generalised and simplified due to restricted availability of country specific data. For CH₄, the methodology is a mixture of Tiers 1 and 2. The latter takes into account country specific data mainly for cattle. Emissions of GHGs from livestock comprise emissions of N₂O from soils (grazed and cut grassland) and manure management, and emissions of CH₄ from manure management and enteric fermentation. In this paper we present a description of the current UK methodology for estimating emissions of N₂O and CH₄ from agriculture and a brief summary of the improvements that are under development.

Methods. The activity data required for calculating the national emissions from both N₂O and CH₄ were compiled from sources such as DEFRA and the governments of the Devolved Administrations (DAs): England, Wales, Scotland and Northern Ireland. These include areas of crop and grassland, fertiliser application rates to crops, numbers of livestock, and, for dairy cattle, milk production and fat content, and an average weight of the animal. The emission factors used are from the IPCC default methodology (Houghton et al., 1996). Following submission, quality checks are performed by AEA Technology. Emissions are calculated for a year and at DA level. Emissions are reported to the UNFCCC and published in National and DA reports (Jackson et al., 2008; Jackson et al., 2009). Data from measurements and modelling are being collected from the literature and new experiments to improve the inventory methodology for the UK.

Results. Agriculture represented 6.8% of all GHG emissions in the UK in 2007 with a total of 43.22 MtCO_{2eq} and was responsible for 73% of nitrous oxide (N₂O) and about 38% of methane (CH₄) emissions in 2007. The results showed that 84% of agricultural emitted CH₄ was enteric and 16% was derived from manure management. Cattle contributed 76% to enteric CH₄ and sheep 22%. Emissions of CH₄ from agriculture are largely dependent on the numbers of livestock and have fallen by 17 % from 1990 to 2007 resulting from a decline in cattle and sheep numbers.

The contribution of livestock to N₂O emissions was 53.1 kt N₂O for 2007 (66% of the total), the individual sources are broken down in Table 1. Improvements to the methodology are currently being carried out by incorporating country specific data from measurements and modelling. This work is on going.

Table 1. Sources of N₂O emissions from the livestock sector

Source	Emission, kt N ₂ O
Direct-Manure management	5.4
Direct-fertiliser applied to grassland	8.2
Direct-Manure application	7.5
Direct-Grazing	13.8
Indirect-fertiliser applied to grassland (leaching+deposition)	5.6
Indirect-Manure applied+manure management+grazing (leaching+deposition)	12.6

Conclusions. The UK methodology is mostly based on a default methodology for calculating emissions of GHGs from agriculture. The results showed that in the livestock sector, animal numbers largely contribute to emissions of CH₄ and that the contribution to N₂O is 66% of the total.

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Carbon accounting for changes in livestock systems

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Introduction.

Climate change is a serious and complex environmental challenge facing UK land managers and wider society. Under the Kyoto Protocol the UK Government is committed to reducing greenhouse gas (GHG) emissions in the coming years. Over the next few months to UK Government will be setting targets for GHG reductions for all sectors of the economy, including agriculture. Accurately accounting for the sources of GHG emissions in a livestock system and understanding management interventions upon them is critical in properly accounting for efforts made by livestock keepers to reduce overall emissions.

Examples.

Some of the important issue for carbon accounting in a livestock system is where the boundary the “system” is and what level of detail is considered in estimating emissions from that system. An example of the impact of detail considered in modelling emissions from a livestock system can be seen in a study reporting the carbon footprint of a mixed Scottish farm (sheep and beef, with forestry as a source of carbon sequestration) using two levels of modelling. The first level of modelling reflected methods used in the national GHG inventory reporting and the second using detailed biological models using farm specific management data and local climate data. The results between the two different models are shown in Figure 1. The farm is in an approximate carbon balance (+/- 2 tCO₂e/hec) , with the processes releasing carbon into the atmosphere (livestock rumination, manure management,

fertiliser use) roughly balanced by processes that remove carbon and store it in the soil and vegetation (carbon uptake by woodland). However, the different footprinting techniques gave different estimates of the net carbon emissions from the system, with the inventory method predicting a net uptake of carbon and the detailed model predicting a net release.

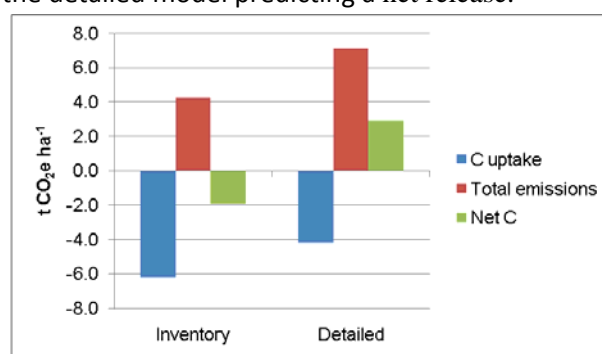


Figure 1. Comparison of models for C footprinting a livestock system

A project funded by the Committee on Climate Change which was to help identify cost effective ways of abating (reducing) greenhouse gases from UK agriculture, forestry, land-use and land-use change. Focussing on issues related to livestock systems, there are many ways that farmers can reduce emissions from their production systems so that they have a positive environmental impact and a positive impact on profitability. The main livestock abatement options target:

- (i) efficiencies with which ruminant animals utilise their diet.
- (ii) efficiencies in livestock systems.
- (iii) efficiencies in manure management.
- (iv) Also considered in the report were grazing/pasture management options.

Using environmental economics methodology (marginal abatement cost curves) In livestock systems an annual abatement of approximately 1.266 - 5.02Mt CO₂e could be achieved in the livestock sub-sector at a cost of <=£25/t by 2022. Assuming the central value, this represents a total of 5% of the GHG emissions from UK agriculture. Additionally, grassland management abatement options have a further abatement potential of 0.64 – 4 MtCO₂e. Assuming the central value, this represents a further 4.5% of the GHG emissions from UK agriculture. The measures needed to achieve this abatement are, in no particular order, included dietary additives, improved genetics in beef systems; current selection, selection for fertility, dietary additives, maize silage in dairy systems, on farm and central anaerobic digestion and range of “better” grassland management. This work highlights that there are cost-effective options for the UK livestock sector that will abate GHGs. These options will also result in a saving to the farm business. The

results have been used to guide policy makers on options available and the feasibility of delivering cost effective GHG abatement for the UK livestock sector. However, this report also highlighted that under current inventory methods only some of the management applied to reduce GHG emissions would be fully (or partially) reflected. This highlights the need to ensure that methods for “evaluating” agricultural systems for the environmental impact can fully account for the relative impact of system/management changes to overall emissions.

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Building carbon footprints from the bottom up: issues of farms, farmers, scale and uncertainty

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Published studies that report the carbon footprints of food items and can be classified into one of three types: modelled, aggregated and empirical.

- Modelled carbon footprints are typically derived from models of particular agricultural systems and/or supply chains .
- Aggregated footprints are based on real farm data collected from a large sample of farms, e.g. national statistical data.
- Empirical footprints are developed from data collected from one or more farms or other actors in the supply chain. These data are then used to construct the carbon footprint for a particular, and identifiable farm system and/or supply chain.

In the empirical approach data are typically collected via a questionnaire which requests details on inputs, processes and outputs on the system of concern, e.g. amount and type of fertiliser applied, electricity and diesel usage, use of plastics, agronomic management, yield and wastes. These data are then manipulated along with relevant emission factors in order to estimate a carbon footprint for that particular farm or food item.

Each of these methods has advantages and disadvantages and they serve different needs. One of the main disadvantages of the first two approaches is that they do not normally explicitly account for the variability that occurs within a farm over time and across similar farms in a region.

In addition to variability, carbon footprints can be subject to several sources of uncertainty. These arise from the representation of the farm system in the 'footprinting model' and in the emissions factors used in the calculations. These uncertainties are common to all three methodologies, but to date none of the carbon footprints developed for UK based food supply chains explicitly define this uncertainty.

In this paper we will discuss our experiences of in calculating empirical footprints. We discuss issues of collecting data from farmers and others in the supply chain, we will consider the impact of spatial variation on the carbon footprints of similar farms (e.g. sheep farms on different soil types) and we will demonstrate the level of variation in the footprint of individual dairy farms.

Towards the end of our paper we will argue that 'empirical footprints', developed with farmers from the bottom up offer advantages to farmers, scientists and policy makers. We will also argue that using single figures to represent the footprints of all similar farms across a region may not be helpful to the businesses of the farmers or to the consumers of their products.



The application of life cycle analysis in the marketing of milk

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We are all paying more attention to where our food comes from and how the animals and natural resources are treated that provides that food.

British dairy farmers have a great story to tell about the high standards of animal health and welfare on our farms and how we are rising to the challenge to acknowledge the importance of the environment. The provision of the right insight and expertise to protect and promote image of dairy and dairy farming is crucial. DairyCo, through its Farming Information Centre, provides factual information about dairy farming to media, consumers and to the dairy industry.

Amanda Ball who heads up this initiative for DairyCo will share the latest consumer insight to show the extent to which our environmental credentials are likely to influence purchase decisions for dairy.



Collaboration on a Global Basis can work – The Dairy Industry example

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Dairy products promote the good health and wellbeing of people in all countries of the world. The global dairy industry helps to sustain the lives of people and their communities, through the supply of products that deliver essential nutritional building blocks and through the provision of employment in both rural and urban communities.

The global dairy industry is a user of natural resources. At the same time it has a long history of providing stewardship of the land, air and water. The three dimensions of economic, environmental and social sustainability underpin a common approach by the industry, even though expressions of the concept of sustainability may vary. (A Global Dairy Agenda for Action – Climate Change September 2009)

The publication of the FAO's Livestock's Long Shadow report in 2006 has challenged livestock industries throughout the world. Though often misreported in consumer press, the report has been a catalyst for many to act from a range of perspectives.

With reference to this report and the ongoing climate change negotiations, the world dairy sector has collaborated to move forward positively in acting to better understand and reduce the emissions of green house gases emanating from the production of milk and dairy products.

The Sustainable Agriculture Initiative is just one of many dairy industry organizations who are now joining together to meet the challenge head on, not just with words, but demonstrable actions that contribute to a better understanding of the issue and the seeking of consensus in the application of measuring and mitigation systems.

Brian Lindsay will provide an update on relevant existing work programmes and initiatives that will move the sector closer to its identified goals as a responsible food producing industry.

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Ensuring Consistency in assessment of product carbon footprints

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Product Carbon Footprinting is a relatively new phenomenon, but is rapidly gaining wide acceptance, with a growing number of companies wanting to measure and publicise their product carbon footprints.

The Carbon Trust has been leading developments to formalise the approach to product carbon footprinting with the publication by BSI of the PAS 2050 in October 2008, which was jointly sponsored by the Carbon Trust and Defra. While the PAS 2050 is the first standard to define a methodology for product carbon footprinting, it is based on over 30 years of development in the field of Life Cycle Assessment.

As more organisations engage in measuring their product carbon footprints, the challenge is that this is done using a consistent and comparable approach. Where public statements and reduction claims are made concerning product carbon footprints it is important that these are done in a consistent manner with common assumptions and methodology, in order to maintain credibility and avoid accusations of “greenwash”. The Carbon Trust has developed a toolkit for companies and organisations to develop product carbon footprints in a comparable manner, using common assumptions and common standard secondary emissions factors. This toolkit, Footprint Expert™, encapsulates the Carbon Trust expertise and knowledge in this area. The Carbon Trust also offers a consistency certification service, to certify that companies have measured their product carbon footprints according to the methodology of PAS 2050 and to the guidelines in Footprint Expert™.

For specific sectors it is necessary to develop product sector guidance, and this is particularly relevant for ruminant agriculture. The Carbon Trust has worked with practitioners to develop specific guidelines on milk and dairy production. The guidelines for the measurement of milk product carbon footprints to farm gate are published in Footprint Expert™ and these are being developed further with Dairy UK to cover processed dairy products including cheese, butter and yoghurt.

In conclusion, despite the relative infancy of product carbon footprinting, it is both possible and necessary for continuing efforts to develop consistency in measurement and communication of product carbon footprints.

