INTERNATIONAL UNION OF FOOD SCIENCE & TECHNOLOGY

IUFoST Scientific Information Bulletin (SIB)
April 2010

Life Cycle Analysis and Carbon Footprinting with respect to Sustainability in the Agri-food sector

Introduction

Environmental concerns are driving business and policy changes in both Europe and in many parts of the world (Stern, 2006). Global warming, also referred to as climate change, is the principal environmental issue of concern because of its effects on changing climates for growing food globally. It is increasingly accepted that the change in climate over the last 100 years is due to an increase in atmospheric concentrations of greenhouse gases and that anthropogenic sources are playing a major role in these increases. Implications for agricultural systems in most growing regions of the world are substantial.

Businesses are starting to take responsibility for measuring and reducing the potential global warming impact of their activities. This requires an understanding of the life cycle greenhouse gas emissions (GHG) involved in the manufacture of a product or from a business (PAS 2050, 2008; Wiltshire *et al.*, 2008). This understanding can help a business to set strategies for decreasing emissions of greenhouse gases, which usually leads to decreased costs.

A key commercial driver for businesses to reduce GHG emissions is the growing need to satisfy customer demand for products from 'sustainable sources'. This is leading businesses to consider the other environmental and social impacts of their activities, in addition those associated with emissions of greenhouse gases. Large food producers and retailers are undertaking life cycle assessments (LCA) that cover a range of environmental impacts for the lifecycle of their products. This requires a study of all stages in the production of a unit of food, and includes production of raw materials, the manufacturing process, transport and distribution, retail, consumer use and waste disposal. In a food context, this includes farming activities, packing, transport to market, retail, in-home preparation and consumption, and waste disposal at all stages of the life cycle.

In addition to business drivers, there are policy and legislative drivers for decreased greenhouse gas emissions and sustainable development (IPCC, 1997 & 2006). For example, the new UK Climate Change Bill has set a target for an emissions decrease of 80% by 2050. At an EU level, the European Commission has a policy called Integrated Product Policy (IPP), which promotes sustainable development through:

- Life-cycle thinking
- Working with the market (to reward companies that are innovative, forward-thinking and committed to sustainable development)
- Continuous improvement (IPP requires producers to constantly look for potential improvements)
- Stakeholder involvement

- A mix of instruments (includes economic instruments, substance bans, voluntary agreements, environmental labelling and product design guidelines)

Assessing the GHG emissions arising from the manufacture of a food product has recently been the subject of a UK initiative that resulted in a new publication referred to as PAS 2050 (Publicly Available Specification for the assessment of the life cycle greenhouse gas emissions of goods and services). This document, recently published by the British Standards Institution (BSI, 2009) is based on existing internationally accepted standards and is under consideration as a seed document for a new international standard.

Life Cycle Assessment (LCA)

LCA was developed to study the environmental impacts arising from the production, use and disposal of products or services of all kinds (Andersson *et al.*, 1994; Roy *et al.*, 2009). LCA provides a mechanism for investigating and evaluating impacts that arise throughout the "product system" that extends from extraction or production of basic materials, through processing, packing, distribution and retail to product use (e.g. home cooking and consumption of food) and management of wastes (e.g. disposal of packaging or vegetable peelings). LCA analyses chains of connected activities systematically to account for all inputs and outputs that cross the specified boundaries of this "product system". LCA assesses the environmental consequences of the operation of the product system in a two step process:

- Firstly by developing an inventory of the flows (principally flows of substances) that occur between the system and the environment (see Figure 1) when the system operates to produce one unit of output.
- Secondly by using environmental science models to quantify the effects on the environment associated with the flows in this inventory

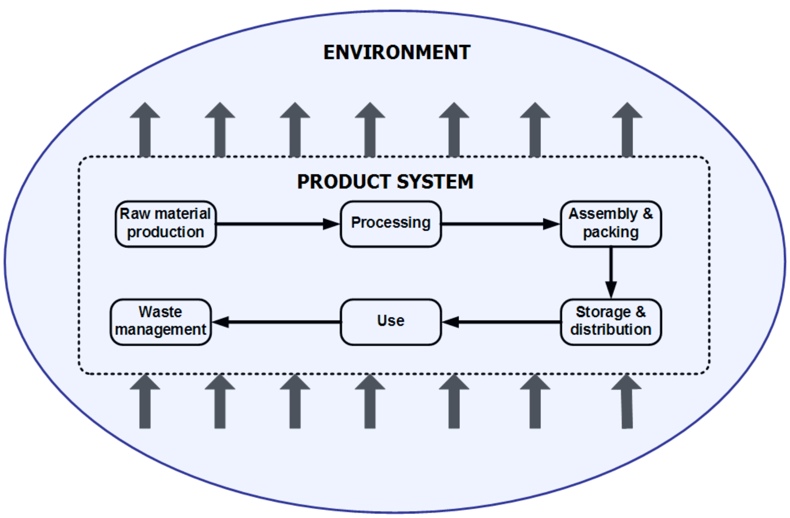

Figure 1: Product systems and the environment

In conducting a LCA on a specified product system all inputs to the system are ideally traced back to primary resources, so for example the impacts of electricity generation are not only those of power station operation and electricity transmission, but include extraction of primary fuels like coal, oil and uranium and the burdens of refining them. All outputs from the system are ideally followed forward through subsequent processing until residual substances and energy enter the environment (so waste is followed through the transformations that take place in the landfill or incinerator). LCA considers impacts on all environmental media – air, water and land.

The LCA process has become standardised. The ISO 14040 series contains the main standards applicable to LCA. BS EN ISO 14044:2006 describes the four main elements of an LCA study as being:

1. Goal definition and scoping (defining the product system and other aspects of the LCA)
2. Life Cycle Inventory development (compiling the inventory of relevant inputs and outputs)
3. Life Cycle Impact Assessment (evaluating the potential impacts associated with the inputs and outputs identified in the life cycle inventory)
4. Interpretation (interpreting the results in relation to the objectives).

Other standards, at national and international level, exist to provide guidance on the application of LCA to particular classes of products (e.g. CEN TR 13910 for packaging) or to the study of particular environmental issues (e.g. PAS 2050 for the assessment of greenhouse gas emissions in product systems), or to prescribe ways of consistently carrying out LCAs to generate results in the standard format of "Environmental Product Declarations" (EPDs). PAS 2050 is a UK standard (Publicly Available Specification) produced by collaborative work between the British Standards Institution (BSI), Carbon Trust and Department for Environment, Food and Rural Affairs (Defra). It is intended to be used for all goods and services and is not designed specifically for agricultural or food production. PAS 2050 is available as a pdf document from BSI (http://www.bsi-global.com). An ISO standard covering the same topic is under development (ISO14067).

Some further detail about the content of each of the four elements of LCA listed above is now provided:

Goal definition and scoping
This involves clearly establishing the objectives of the study (for example "compare alternative packaging systems for yoghurt sold in the UK market, taking into account current UK waste management arrangements") and an appropriate "functional unit" that quantifies the output from all product systems in the study (so, in the yoghurt packaging example, this might be packaging for 250g of yoghurt available to the consumer). The scoping element of an LCA then involves defining the boundaries of the product system(s) that are being studied (e.g. is the ink used to print on the packs included, etc.?), specifying the processes within the system to a sufficient level of detail that relevant data can be collected. The way in which later stages of the LCA will be conducted is also established (e.g. establishing which environmental themes or "impact categories" are of interest).

Inventory development
This involves collecting, and then connecting, data characterising all the processes in the product system(s) being studied. The data characterising any process is an inventory of flows for that process. When data is collected directly it is collected for a chosen time period, which should ideally be long enough to encompass the "natural" variability of the process. When sets of data are published, the flows are often normalised to the quantities associated with one unit of product.

Data for use in LCA can be obtained from various sources: individual operators, trade associations, compiled databases, previous LCAs are all commonly-used. Not all data is suitable for use in every LCA; for example if a study has the objective of investigating 1 tonne of potatoes produced in average UK conditions between 2000 and 2005, then data describing a single farm is inadequate for the purpose.

Because many processes (whether industrial or agricultural) produce more than one product, it is often necessary to assign part of any set of collected data to the particular product of interest. This is known as allocation and there are various options for carrying it out (e.g. one could divide the energy and water used in a cheese-making process between the cheese and the whey on the basis of the relative quantities of each produced or on the basis of the relative values of the two outputs). The application of different allocation methods leads to data being divided between joint products in different ratios. Since this ultimately affects the results of the LCA, it's useful to seek consistency in the way any allocation is done.

Impact assessment
LCA is focused on environmental impacts, and covers a range of environmental impact categories to which we return below. The pursuit of "sustainable" consumption and production also requires the control of (desirable and undesirable) social impacts. This is to some extent implemented through the Corporate Social Responsibility (CSR) activities of major businesses; there is however a parallel analytical tool to LCA - Social LCA – which has

been developed relatively recently. General guidance for the conduct of Social LCAs has been developed under the auspices of the UNEP-SETAC Life Cycle Initiative (Benoît and Mazijn, 2009).

This scope of this bulletin is limited to environmental LCA. For that technique, the main environmental impact categories relevant to the agri-food sector are as follows:

Global warming

A global warming potential assessment is sometimes referred to as a carbon footprint. The most common method of quantifying the "impact" is to convert all greenhouse gas emissions in the inventory (except for emissions of CO_2 derived from carbon taken up by plants in the "recent" past) into quantities of carbon dioxide equivalents (kg CO_2e) using factors (global warming potentials) published by the Intergovernmental Panel on Climate Change (IPCC). This is the method described in PAS 2050. Some global warming potential (GWP) values are shown in the table below (Table 1). PAS 2050 contains a more complete table that includes gases used in refrigeration, solvents and packaging. It is apparent from Table 1 that a process releasing nitrous oxide has the potential for much greater global warming impact than one releasing carbon dioxide (Wiltshire *et al*., 2008; Tucker *et al*., 2008)

Table 1: Relative Global Warming Potential (GWP) of the main greenhouse gases of relevance to the food industry

Greenhouse gas	**Formula**	**GWP**
Carbon dioxide	CO_2	1
Methane	CH_4	25
Nitrous oxide	N_2O	298

Eutrophication

Eutrophication refers to the accumulation of excess nutrients (particularly phosphorus and nitrogen) in water bodies and on land. Agricultural activities are important sources of these nutrients, for example nitrate (NO_3) and phosphate (PO_4) leaching to water, and ammonia (NH_3) emissions to air. A consequence of nutrients leaching into watercourses is the prevalence of algal blooms in rivers and lakes. These obstruct waterways, are unsightly, and deplete oxygen as the algae decompose. Eutrophication potential is commonly quantified in units of phosphate equivalents (Guinée *et al*., 2002). The results of impact assessments such as this are referred to as "impact potentials" because the actual effect of any amount of nutrient released will depend on where that release occurs and on the properties of the receiving environment. Such local considerations are normally omitted from LCAs.

Acidification

Acidification quantifies acid-gas releases from the system and/or the subsequent damage they cause. In this case, impact potential is often quantified by converting all acid-gas emissions into equivalent amounts of a single acidic substance, hydrogen ion (H^+) or sulphur dioxide (SO_2).

Abiotic resource use

This captures the extent to which the activities in the product's life cycle contribute to the depletion of non-living resources, essentially fossil and mineral resources. Several assessment methods are available, since the "environmental impact" of mineral or fossil resource use is somewhat difficult to define. The widely-used CML

(CML is the Centre for Environmental Sciences, Leiden University) method (Guinée *et al*., 2002) relates all abiotic resource use to extraction of a single substance (antimony) on the basis of the relative abundance of different resources.

<u>Pesticide use/ecotoxicity</u>

Impact assessment of ecotoxicity in LCA is complicated by the fact that not all toxic chemicals have the same mechanism of action (whereas all greenhouse gases do). There is also a large (and to some extent evolving) number of substances that can contribute to the impact category, ranging from metals, through persistent organic pollutants to pesticides. Commonly used methods relate the toxicological potency of substances to that of a reference substance (e.g. 1,4, dichlorobenzene as in Guinée *et al.*, 2002) or compare the "critical volumes" of water or soil needed to dilute the amounts of substances expected to be present in specified environmental compartments following unit releases (Wenzel *et al.*,1997; Hauschild and Wenzel, 1998).

<u>Land use</u>

Activities throughout the food chain occupy land and use water, although agricultural activities are perhaps most significant in both respects (agriculture is widely reported to account for some 70% of global freshwater use).

Land occupancy is recorded in some LCAs and LCA databases, and can be used as an indicator of the extent to which this finite resource is utilised for the function being considered. However, there is as yet no widely agreed method for quantifying the impacts (e.g. the effect on ecosystems in terms of their biodiversity) associated with different types of land use. The assignation to individual products of impacts associated with changes in land use has also received some attention with one approach (for greenhouse gas emissions) being established in PAS 2050; this is an area in which further development seems likely.

<u>Water use</u>

A similar situation applies to water use as applies to land use. While the impacts of water use are of increasing interest to stakeholders (not least because of the effect of global warming on rainfall patterns), there is as yet no well-established Life Cycle Impact Assessment (LCIA) method for the environmental impacts associated with water use. In our opinion, two obstacles in particular have hindered emergence of a quantitative method to connect water use to its environmental significance. The first is that the significance of any water consumption is highly location-dependent in terms of its implications for the water resource base, and LCA is a rather location-insensitive method in its current form. The second is that the impacts arising from any water consumption depend on a number of other factors associated with that use, such as where, and in what condition the water is returned to the environment. Water footprinting has emerged as a means to provide some indication of the water demands of different crops and products, but does not, in its current form, succeed in addressing these issues. Note that some of these issues are dealt with in the IUFoST Scientific Information Bulletin on Water in Food and Farming SIB.

Even if one uses a more sophisticated approach than the water footprint (e.g. in the way proposed by Pfister *et al*., 2009), incorporating water use into LCA will only provide pointers towards areas worthy of more attention. Reducing water stress involves not just the efficient use of water, but also management of incident water (e.g. using techniques such as rainwater harvesting) to make water available for human use and ecosystems when it is needed.

Interpretation

The interpretation stage of an LCA is very important. LCA is a modelling technique and it is crucial that not only are the results reported, but that the constraints imposed by the nature of the modelling exercise are understood and also reported.

Interpretation, therefore, normally includes consideration of the influence on the results of the different assumptions made and the quality of the data used. A discussion of the uncertainties associated with these aspects is important, as is an exploration of the effects of those uncertainties on any conclusions. This can be done using statistical techniques or through systematic “sensitivity analysis” (or using both).

Critical review is valuable to identify weaknesses and errors that have been overlooked by the LCA practitioners doing the study. It has been used extensively to improve the credibility of LCAs. Indeed, ISO14044 stipulates that any LCA intended to support “comparative assertions intended to be disclosed to the public” must incorporate a critical review if it is to be incompliance with the Standard.

Carbon footprint of food and interaction with other impacts

One of the most important LCA impact factors for today is the effect of an activity on global warming and the food industry is a major global contributor to this impact. Estimates of the contribution of agriculture to global GHG emissions vary from 10 to 32% (Garnett, 2008) depending on the inclusions (e.g. whether or not land use change emissions are included) and also reflecting large uncertainty. Food related emissions in the UK, including consumption, have been estimated at 18.5% of total UK emissions (Garnett, 2008).

The focus on GWP and efforts to minimise this impact, could lead to changes in other environmental impacts, often beneficial, but not always. For example, increased yield of a crop by better management and more efficient use of resources can improve the carbon footprint of the produce, but may require extra water use. If this occurs in a locality where water is scarce, or where there are fragile aquatic ecosystems, there may be negative environmental impacts alongside the improvement in GWP. It is important that other impacts are not ignored and that there is an overview of the main environmental impacts to avoid unintended consequences.

The application of carbon footprint assessment methods to food

<u>Processes</u>
The food life cycle can be highly complex, with multiple processes. For a food product, there may be a production process for nitrogen fertiliser, another for growing a crop or producing an animal for meat, another for making a ready meal, another for retail, and another for meal preparation. To arrive at a carbon footprint (or to carry out a more comprehensive LCA) it is practical to perform separate assessments for each process, with some processes providing raw materials for processes further on in the life cycle. In some cases there may be published carbon footprint values or LCA datasets available for raw materials, and provided that these were calculated using a method and data consistent with the main assessment, this can avoid un-necessary work.

<u>Assessment boundaries</u>
In primary food production the boundaries of an assessment are sometimes less obvious than in other industries. Agriculture has production cycles, in which some co-products are inputs to the same system (e.g. animals for breeding) or to other systems (e.g. manure). There are different ways in which these cycles could be interpreted for assessment of GHG emissions. For example, emissions from the manure after application to land could be ascribed to the animal system that produced the manure, or to the crop that benefits from the nutrients. These cycles require careful consideration to allow the boundaries of the assessment to be defined.

<u>Mass balance</u>
Another peculiarity of primary food production is that mass balance calculation is difficult and not as useful as in a factory process. Mass balance involves checking that the total quantities of materials entering and leaving a process are the same, and helps to ensure that all materials are fully taken into account. In primary production of food there are several mass flow streams that are not fully controlled by the owner of the process and involve exchange with the wider environment. For example, plants and animals exchange water with the soil and atmosphere, and similarly, dry matter accumulates through photosynthesis and is lost by respiration. These are generally not easy to quantify and extensive interactions with soil and atmosphere are involved.

<u>Allocation of emissions to co-products</u>

Where two or more products can be produced from a unit process, they are considered co-products only where one cannot be produced without the other being produced. A co-product is not the main product and usually has a lower value. The issue regarding GHG assessments of co-products is one of the most complex within PAS 2050. Some LCAs use economic value to allocate CO_2e between co-products, which is also the approach adopted by PAS 2050. The argument for using economic value derives from the original purpose of an activity, which is to manufacture the main product.

For example, in cheese manufacture (Wiltshire *et al*., 2009) the main product is cheese, while whey powder, whey butter and grated cheese are considered as co-products. By applying economic allocation, the higher value of cheese compared with the co-products means that most of the CO_2e is attributed to the cheese. The mass balance approach would result in the opposite, with the heavier co-products taking with them much of the CO_2e, leaving the cheese with a low carbon footprint. Allocation of emissions for the co-products in the cheese example from Table 2 resulted in 77.1% of emissions to cheese, 20% to whey, and 2.9% to grated cheese.

Although it makes sense to go with economic value, the disadvantage is that relative economic values of products and co-products can be variable. This requires the prices to be averaged over an appropriate growing season, which is often a year. If co-products are not sold but subject to further processing in situ, identifying appropriate price information can also be difficult.

Problems for complex foods

Complex manufactured foods can have many ingredients, which in itself is not a barrier to carbon footprint assessment, but it can make the task larger. A greater problem is that many complex foods are manufactured for a period of unknown time, which can be short, perhaps only a few months. The carbon footprint assessment could take as long as the production period, rendering the assessment of no use. A third problem is that large numbers of manufactured products are often made in the same factory and usually it is difficult or impossible to accurately separate energy use, and sometimes ingredient use between products. These problems make assessment of complex foods challenging and should be considered before an assessment is started.

Data sources for carbon footprint assessments

PAS 2050 discusses primary activity data and secondary data as the sources for GHG assessments. Primary activity data are quantitative measurements of activity from a product's life cycle that, when multiplied by an emission factor, determine the GHG emissions arising from a process. These are the preferred sources because the company involved in manufacture has some degree of control over their capture. Secondary data are obtained from sources other than direct measurement of the processes (e.g. a CO_2e value for plastic packaging). It is also likely that primary activity data are more accurate than secondary data because they are taken specifically for the purpose.

Agriculture differs from many industries in that primary data (activity data directly from the product life cycle) are often unavailable for some parts of the production process. For example, it is not practical to directly measure emissions of non-CO_2 gases from soil or animals, so estimates are used based on approaches published by the IPCC (2006). Another example occurs when agricultural commodities are bought on a market that does not provide traceability to the precise production source. In this case, assumptions must be made and a generalised production system assessed using secondary data (e.g. industry averages for the country of production).

For the cheese example (Wiltshire *et al*., 2009), mentioned above (see Allocation of emissions to co-products), primary activity data supplied by the manufacturer were used for:

- Product unit composition
- Mass flow rates of product and waste
- Onsite energy consumption
- Water and utility use
- Distances for transport of raw materials

Secondary data sources were used for obtaining GHG emissions from:

- Electricity and natural gas supply (Defra, 2008)
- Transportation of materials to the factory (Defra, 2008)
- Water (Water UK, 2006)
- Plastic and carton packaging materials (Plastics Europe, 2005; Anan, 2006)

Variation in carbon footprint values between food types

There are now numerous publications freely available on the internet that quote carbon footprint values for food products (e.g. Tate & Lyle, British Sugar, fat Tire Amber Ale). In addition, web sites such as www.climatefruitandwine.co.za contain guidance on how carbon footprints can be calculated. Commercially-funded studies can be used to label products, but often have some degree of confidentiality (e.g. detailed ingredient lists for complex food products are usually confidential but are needed to assess a carbon footprint). Some of these have used the procedures defined in PAS 2050 although the calculation procedures are not always clear. Other publicly funded studies can provide useful indications of the size of impacts and how these vary between products and within production processes. For example, a recent Defra-funded project (Defra ref. FO0404) explored the validity and suitability of the methods described in PAS 2050 for food products (Wiltshire *et al.*, 2009). Results of this work show how GHG emissions vary between different types of product.

Food commodities with low emissions (less than 1 kg CO_2e/kg or L) tended to be crop commodities with high yields and low inputs, such as apples (0.066-0.10 kg CO_2e /kg), potatoes (0.12-0.16), spring onions (0.23), animal feed crops (0.0043 to 0.74), carrots (0.35), UK conventional tomatoes grown using 'waste' heat (0.39), wheat (0.40-0.74), and onions (0.42-0.59). These GHG data were used to calculate GHG emissions for manufacture of the food products in Table 2.

Table 2: Summary of manufactured food products GHG emissions per kg product and per functional unit (FU)

Food product	kg CO_2e / kg or L	kg CO_2e / FU	FU
Tea bags	4.1	4.1	1 kg (320 tea bags) in a carton
Cocoa powder	210	21	100 g glass jar
Granulated sugar (from cane)	0.87	0.87	1 kg paper bag
Fresh pineapple	1.3	1.8	Whole pineapple, 1.35 kg
Beef cottage pie	7.6	3.3	Single chilled ready meal, 434.9 g
White loaf of bread	0.73	0.60	827 g loaf in plastic bag
Packed mild cheddar cheese	9.8	4.9	500 g plastic pack
Cox's apple juice	1.6	1.2	75 cL glass bottle
Jaffa cakes	2.5	0.42	165 g packet
Duck in Hoisin Sauce	2.0	0.88	Single chilled ready meal (430 g inc packaging)
Lamb shanks and roasted potatoes	19	25	Single chilled ready meal (1,300 g inc packaging)
Thai chicken pizza	3.5	1.6	1 pizza (460 g inc packaging)

Two of the manufactured products also had GHG emissions less than 1 kg CO_2e/kg: a white loaf of bread (0.73) and granulated sugar from cane (0.87).

Food commodities with medium emissions (between 1 and 5 kg CO_2e/kg or L) tended to be high yielding livestock products such as milk (1.2-1.4 kg CO_2e/L), or manufactured products such as apple juice (1.6), duck in Hoisin sauce ready meal (2.0), Jaffa cakes (2.5), Thai chicken pizza (3.5), chicken meat (3.1-4.4), duck meat (4.1), and tea bags (4.1).

Food commodities with high emissions (over 5 kg CO_2e/kg or L) tended to be livestock products and highly manufactured foods such as pig meat (5.5-9.9 kg CO_2e/kg), beef cottage pie ready meal (7.6), packed mild cheddar cheese (9.8), beef (10-40), lamb shanks and roasted potatoes ready meal (19), lamb (27-39), and cocoa powder (210). The cocoa assessment was the only assessment for which land use change was relevant, and this was the major source of emissions (98%). This dominated the emissions for the processed product, as well as for the agricultural commodity.

Uses of carbon footprint assessments

Carbon footprint assessments can be used in many ways, for example, to:

- Inform strategies for decreasing a carbon footprint
- Satisfy customer and/or investor demands
- Compare alternative production methods
- Define industry benchmarks
- Identify 'hotspots'
- Encourage best practice
- Improve business performance (e.g. through energy saving or competitive advantage)
- Label a product with an emissions value.

Identification of 'hotspots' is invariably a useful result of carbon footprint assessment. Hotspot is a term used for any part of the production system with high emissions. Identification of hotspots helps the formulation of improvement strategies by focussing attention on the largest sources of emissions.

Strategies for decreasing a carbon footprint must focus on more than just the inputs. Fewer and more efficiently produced inputs (e.g. less energy use and use of energy from a renewable source) can decrease a carbon footprint, but the outputs are also important. For example, if crop yield can be increased without an increase in inputs then the carbon footprint per unit of product output will be decreased. This goes further than consideration of the main product, as increases in co-product outputs will also be of benefit. For primary food production this can be a complex issue because of the intricate relationships between the production processes and the soil, water and atmospheric environments. Maximising use of a crop plant can help to spread the carbon 'costs' across more product(s), but will result in less return of organic matter to the environment. There is a trade-off when it comes to use of roots because it usually 'costs' carbon emissions to get the roots out of the soil (direct soil emissions could be increased, and more energy may be needed) and the benefits of carbon cycling and/or sequestration in soil will be decreased. It is important to consider these issues on a case-by-case basis.

There is much debate about the value of labelling, with different views within the food industry, but this is not considered further here.

In the food industry, primary production (agriculture and horticulture) of raw materials for food manufacture usually is responsible for the largest share of emissions. For example, the agricultural component of the carbon footprint of a beef cottage pie is approximately 50%, even when retail, home use and waste disposal are included in the total (Wiltshire *et al*., 2008). However, there are exceptions, and apple juice is one, with around 16% of emissions from primary production.

Within primary production, hotspots can include:

- Manufacture of raw materials, especially nitrogen fertilisers
- Direct, non-CO2 emissions (e.g. methane from cows, nitrous oxide from soil)
- Energy use for heating (e.g. glasshouses) and/or cold storage
- Land use change
- Waste disposal.

Figure 3 presents two examples of processes that release non-CO_2 gases with high GWP (Wiltshire *et al*., 2009). Wheat has high emissions from soil processes, and beef cattle have high emissions of methane from enteric fermentation. In the case of emissions from beef production, the raw materials value in Figure 3 (45.5%) includes soil emissions from growing crops for animal feed.

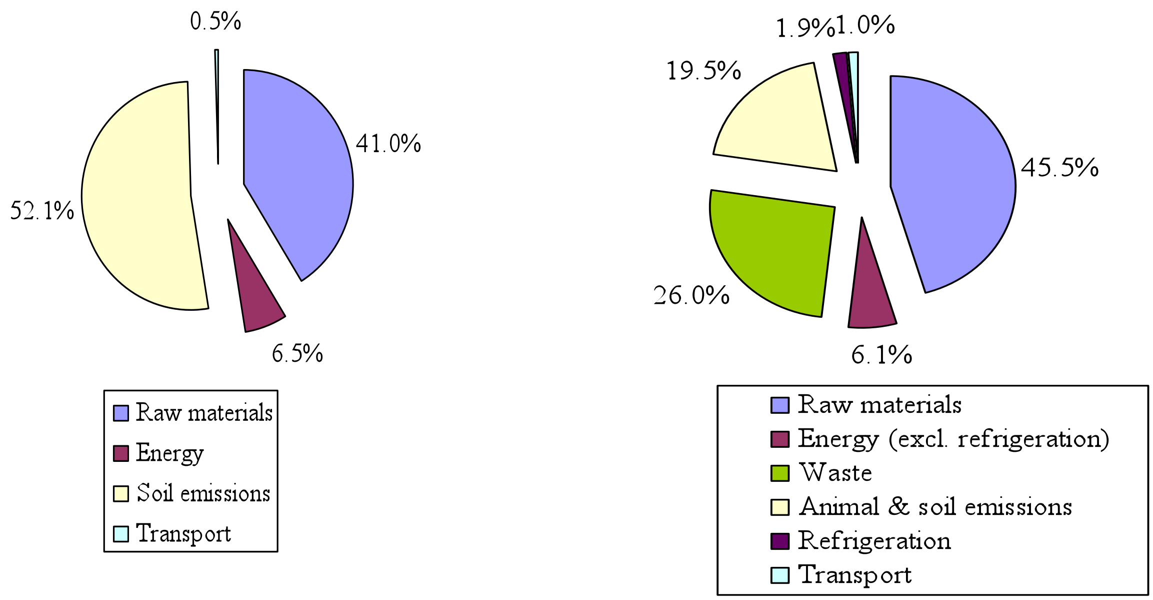

Figure 3: Greenhouse gas emissions of wheat (left) and beef (right), as a percentage of the totals, showing the large contributions of soil and animal emissions, which are mainly nitrous oxide and methane. Source: Defra project FO0404.

Nitrous oxide (N_2O) has a GWP of 298 times that of carbon dioxide and is released into the atmosphere during production of nitrogen fertilisers and by soil processes following application of nitrogen fertilisers. Methane has a GWP of 25 times that of carbon dioxide and so this can lead to cattle products such as beef and milk with high carbon footprint values. These direct emissions from agricultural systems are difficult to control because often mitigation measures result in lower yield, which can increase a product carbon footprint. Research is being undertaken to farm cattle in conditions that minimise the release of methane, and to grow crops with lower N_2O emissions.

Conclusion

In conclusion, LCA and carbon footprinting can provide valuable insights into the life cycles of food products and their environmental significance. As with other analysis techniques that use modelling, it is necessary to make certain assumptions to obtain the quantitative results that both techniques generate. It is important to be aware of these assumptions and of the inherent uncertainty in some underlying data when using LCA results and carbon footprint values. Although that can restrict their applicability for comparative purposes, it does not prevent their use in focussing improvement efforts and selecting more promising improvement options from those available.

References

Andersson, K., Ohlsson, T. and Olsson, P. (1994). Life cycle assessment (LCA) of food products and production systems. Trends in Food Science & Technology, 5 (5), 134-138.

Anon. (2006). "European Database for Corrugated Board Life Cycle Studies". European Federation of Corrugated Board Manufacturers. www.fefco.org

Benoît, C. and Mazijn, B. (2009). Guidelines for Social Life Cycle Assessment of Products. UNEP-SETAC Life Cycle Life Cycle Initiative.

BSI (2009). PAS 2050: Publicly Available Specification for the assessment of the life cycle greenhouse gas emissions of goods and services. www.bsigroup.com.

BS EN ISO 14044:2006, Environmental management – Life cycle assessment – Requirements and guidelines, Clause 4.3.4.3.

Defra (2008). Guidelines to Defra's GHG Conversion Factors - Annexes updated April 2008 http://www.defra.gov.uk/environment/business/envrp/pdf/ghg-cf-guidelines-annexes2008.pdf

Garnett, T (2008). Cooking up a storm. Food, greenhouse gas emissions and our changing climate. Food Climate Research Network, Centre for Environmental Strategy, University of Surrey. http://www.fcrn.org.uk/frcnPubs/publications/PDFs/CuaS_web.pdf (accessed 17 November 2009).

Guinée, J.B. (Ed.), M. Gorrée, R. Heijungs, G. Huppes, R. Kleijn, A. de Koning, L. van Oers, A. Wegener Sleeswijk, S.Suh, H.A. Udo de Haes, J.A. de Bruijn, R. van Duin and M.A.J. Huijbregts (2002). Handbook on Life Cycle Assessment: Operational Guide to the ISO Standards. Series: Eco-efficiency in industry and science. Kluwer Academic Publishers. Dordrecht.

Hauschild, M.Z. and Wenzel, H. (1998). Environmental assessment of products. Vol. 2 - Scientific background, 565 pp. Chapman & Hall, United Kingdom, Kluwer Academic Publishers, Hingham, MA.

IPCC (1997). Revised 1996. IPCC Guidelines for National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change (IPCC), IPCC/OECD/IEA, Paris, France.

IPCC (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change (IPCC), IPCC/OECD/IEA/IGES, Hayama, Japan.

Pfister, S., Koehler, A. And Hellweg, S. (2009). Assessing the Environmental Impacts of Freshwater Consumption in LCA Environ. Sci. Technol. 43 (11), pp 4098–4104.

Plastics Europe (2005). Reports by I Boustead. "Eco-profiles of the European Plastics Industry LDPE FILM EXTRUSION, Polyethylene Terephthalate (PET) Bottle grade, PET FILM. www.plasticseurope.org

Roy, P., Nei, P., Orikasa, T., Xu, Q., Okadome, H., Nakamura, N. and Shiina, T. (2009). A review of life cycle assessment (LCA) on some food products, Journal of Food Engineering
90 (1), 1-10.

STERN REVIEW (2006): The Economics of Climate Change. HM Treasury.

Tucker, G., Wiltshire, J. and Fendler, A. (2008). Carbon footprint of British food production. Food Science & Technology, 22(4), 23-26.

Wiltshire, J.J.J., Fendler, A., Tucker, G. and Wynn, S. (2008). The contribution of primary food production to lifecycle greenhouse gas emissions of food products. Aspects of Applied Biology, 87, 73-76.

Wiltshire, J.J.J. et al. (2009). Scenario building to test and inform the development of a BSI method for assessing greenhouse gas emissions from food. Technical annex to the final report to Defra, Project Reference Number: FO0404. http://www.defra.gov.uk

Water UK (2006). "Towards Sustainability 2005-2006. UK Water Sustainability Indicators 2005/6". www.water.org.uk

Wenzel, H., Hauschild M.Z. and Alting, L. (1997). Environmental assessment of products. Vol. 1 - Methodology, tools and case studies in product development, 544 pp. Chapman & Hall, United Kingdom, Kluwer Academic Publishers, Hingham, MA.

Websites

Tate and Lyle carbon footprint
http://www.tateandlyle.com/TateAndLyle/social_responsibility/environment/default.htm

British sugar carbon footprint
http://www.silverspoon.co.uk/home/about-us/carbon-footprint

The carbon footprint of fat tire amber ale, The climate conservancy.
http://www.climateconservancy.org/cca_fattire.pdf

UK Defra carbon footprint study on a cottage pie ready meal
http://www.defra.gov.uk/foodfarm/food/pdf/cottagepie.pdf

South African Fruit and Wine Carbon Calculator
www.climatefruitandwine.co.za

LCA research at the Center for Environmental Sciences, Leiden University
www.cml.leiden.edu/research/industrialecology/

The European Commission's Directory of LCA services, tools and databases
http://lca.jrc.ec.europa.eu/lcainfohub/directory.vm

Department Life Cycle Engineering – LBP. University of Stuttgart
http://www.lbp-gabi.de/30-0-Startseite.htmlenglish/index_e.html

The European Commission's LCA database ELCD (free of charge)
http://lca.jrc.ec.europa.eu/lcainfohub/datasetArea.vm

Australian Greenhouse Friendly products and services
http://www.climatechange.gov.au/government/initiatives/greenhouse-friendly/products.aspx

Prepared by Gary Tucker, Chris Foster and Jeremy Wiltshire on behalf of, and approved by the IUFoST Scientific Council. Dr. Gary Tucker is with the Campden BRI, Department of Baking & Cereal Processing, Chipping Campden, Glos., GL55 6LD, UK. Chris Foster is with EuGeos Limited, 387 Park Lane, Macclesfield, SK11 8JR UK. Dr. Jeremy Wiltshire is with ADAS UK Ltd, Boxworth, Cambridge, CB23 4NN, UK.

The International Union of Food Science and Technology (IUFoST) is the global scientific organisation representing over 200,000 food scientists and technologists from more than 65 countries. It is a federation of national food science organisations linking the world's food scientists and technologists. IUFoST has four regional groupings: ALACCTA representing Central and South America, EFFoST representing Europe, WAAFoST representing Western Africa and FIFSTA representing the countries in the ASEAN region.
IUFoST Contact: J. Meech, Secretary-General, IUFoST, P O Box 61021, No. 19, 511 Maple Grove Drive, Oakville, Ontario, Canada, L6J 6X0, Telephone: + 1 905 815 1926, Fax: + 1 905 815 1574, e-mail: jmeech@iufost.org