POSTER SESSION B
LCA and Footprinting

Challenges in the comparability of carbon footprint studies of food products

Hannele Pulkkinen[1,*], Juha-Matti Katajajuuri[1], Jouni Nousiainen[1],Frans Silvenius[1]

[1]MTT Agrifood Research Finland, Food Research, Sustainable Bioeconomy

ABSTRACT

The interest to make comparisons between carbon footprint studies is growing. Comparisons are made between studies of same products but also between product categories. Yet, the comparability of studies is questionable. This paper presents the results of comprehensive reviews on milk and bread LCA studies. Some hotspots, but no one factor, as causes for differences between studies, were possible to be identified. Most probably methodological choices, agricultural production circumstances, production technologies and data quality contribute together to the differences. Major problem within this type of review is the lack of transparency and missing or incomplete references in studies to trace in practice calculations as far back as needed. Documentation must be developed to allow reproducibility and credible comparisons. In addition, harmonization needs to be guaranteed at the product category level, as the pressure to communicate these issues is growing.

Keywords: Life Cycle, Comparability, Carbon footprint, food, methodology

1. Introduction

Many LCA or carbon footprint studies of different food products have been carried out in the last 10 years. Academic or not, most of them are not comparable at the moment, but they are still used for different kind of comparative purposes. The Finnish "Climate Count and Communication" –programme is investigating and developing best practice national methodology and calculation rules and tools for the Finnish food industry to assess environmental impacts of food products in comparable way.

As part of the programme reviews on scientific articles and in smaller extent also other research papers presenting LCA results was conducted. The aim of this review was to identify major reasons to the fact that different studies for same type of food products give different results with large range, and how carbon footprint studies could be made more comparable.

The reviews were made on studies of milk, bread, pork and rice. This paper concentrates on milk, but also main findings on bread are presented. Methodologies and calculations used were scrutinized, reviewing also the articles' references when possible. Parameters and methods were compared to similar cases to prove their suitability or to find discrepancies.

2. Methodological review

The carbon footprints obtained for similar food products between different studies varied remarkably. The results of raw milk varied between 0.4 to 2.7 kgCO_2-eq. / kg milk. Additionally, FAO (2010) found in their resent study even larger range for carbon footprints when data from developing countries and all continents were included. The major variations for milk results seemed to be caused by different general methodological choices and different coefficients and equations for emissions etc. used in practice. The results of bread vary from 0.5 to 3.4 kgCO_2-eq. / kg bread, and the main differences were caused by system boundaries,

* Corresponding Author e-mail: Hannele.Pulkkinen@mtt.fi

production type of electricity and direct N_2O emissions from soil. Surprisingly, large carbon footprint ranges exist even for basic, only slightly processed products such as bread wheat. Climate conditions explain variation in the results of cultivated products to some extent, but also considerable differences can be tracked to used methodologies.

2.1. Bread

Lack of scientific life cycle assessment studies caused major limitations to the review. Only one scientific article, Narayanaswamy *et al.* (2005), was found on bread's whole life cycle. Two other studies, namely Andersson *et al.* (1999) and Braschkat *et al.* (2003), reported production and some transports in addition to cultivation. More studies were found on wheat production, and one, Sundkvist *et al.* (2000), which was partial LCA study and compared different production methods of bread excluding cultivation phase.

Because the lack of scientific studies found, the review included also few non-scientific articles or climate declarations published by bread producers and others, namely Hirschfeld *et al.* (2008), Lantmännen (2009), Allied Bakeries (2009), LRF (2002) and Brödinstitutet (2009). The scientific articles on cultivation of wheat were Biswas *et al.* (2008), Brentrup *et al.* (2003), Charles *et al.* (2005), Meisterling *et al.* (2008) and Williams *et al.* (2006).

The scope of studies varied, and some studies were not suitable for the review, because of made methodological choices, especially on system boundaries. Few times approximated defaults were used, and for example in the Australian study of Narayanaswamy *et al.* (2005) the direct nitrous oxide (N_2O) emissions from soil were incorporated from US data.

Lack of transparent reporting was a major obstacle for analysing studies. Few of them used kilograms of bread as their functional unit. But it remained unclear in few studies how much wheat is used for one kilogram of bread. Different studies include different phases of life cycle and report diversely aggregated emissions, which means comparisons can only be made on overlapping phases and therefore makes the comparisons very difficult. The inclusion of other ingredients to the analysis also varied remarkably, and sometimes the shares of different ingredients were not documented, nor their share on the total emissions.

Cultivation, including the manufacture of its inputs, is clearly the most important hot-spot of the production chain of ordinary wheat bread. Its share of the total GHG emissions from cradle to bakery gate varies approximately between 60-90%. Unfortunately the amount of studies reporting well one particular issue is always limited and therefore making robust conclusions is very difficult. In fact, no factor could be identified to cause alone major variations in the emissions of the cultivation phase between studies. The emissions for cultivation of one kg of wheat are mainly 0.2-0.4 kgCO_2-eq. Three major differing studies are present: Williams *et al.* (2006), Narayanaswamy *et al.* (2005) and Andersson *et al.* (1999) for which no explanation can be given as reporting is too general.

In the milk studies it was common to use national emission factors (EF) for emissions from livestock and manure management, but in the bread articles scientists have applied international IPCC (1996) default EF of 1.25% in all studies, except in Biswas *et al.* (2008), for direct (N_2O) emissions from fertilizer application to soil. It is most probably used, as no national EF have been published by the time of writing these articles. However, it is known that major differences in soil emissions are reality, and therefore, it does not seem justified to compare cultivation between different countries if only international defaults are used. Highlighting also the fact that the largest part of emissions seems to come from the N_2O-emissions, in these studies 60-80% of all emissions from the cultivation phase, the use of a default reduce the value of making comparisons between studies as soil is one of the two main N_20 sources along with fertilizer production. The only exception using national EF is the study of Biswas *et al.* (2008), and, indeed, using a factor of more than twenty times lower than the default, but still an approved one at least to Australian National Inventory Report of IPCC, they find N_2O-emissions of only 21% of the cultivations' emissions.

Not enough comparable studies with detailed reporting were found to prove that the emission factor of electricity would cause differences on the emissions of processing phases. Still, some Swedish studies do have a little lower baking and milling emissions, which can be due to low national EF for electricity production because of wide use of renewable energy.

The consumption phase is reported only in few non-scientific studies. Brödinstitutet (2009), Lantmännen (2009) and Allied Bakeries (2009) find large emissions from the consumption phase of frozen products and of products meant to be toasted. Instead, in the study of LRF (2002) a microwave had been used in the consumer phase and thus the emissions of consumption and retail together are much lower than consumption alone in the previous two. In the study of Allied Bakeries the consumption phase was rather large, 23%. Though, again unfortunately, it was not defined what the consumption phase included (toasting, freezing, etc.).

2.2. Milk

For a preliminary research all found 28 papers using LCA for calculating greenhouse gas emissions of milk were looked into. After fast review 10 papers were selected for more detailed study as they had reported their assessment, especially the farm-phase, more carefully than the others. After the preliminary review it seemed that studies, which used consequential approach, find smaller carbon footprints, and the choice of approach certainly affects the result, but for simplicity this review concentrated on attributional studies.

The project concentrated on methane and nitrous oxide emissions as they were expected to cause the main differences between studies. The emissions of the third major greenhouse gas, carbon dioxide, are deriving from more various sources and its variation between studies was less than of the other two gasses, and therefore it was supposed that no one emission source is of major importance to the emissions of the whole life cycle.

The real differences in the greenhouse gas emissions were tried to find out by separating the often aggregated emissions to different emission sources. Most of the articles followed more or less the IPCC 1996 or 2000 guidelines and their division, but some reported aggregated emission without explanations on details, and consequently made comparisons of a certain stage impossible. In the case of methane emissions the importance of the two important sources, enteric fermentation and manure, were quite possible to track, but in the case of N_2O-emissions only one study reported the emissions from different sources directly.

Although it is important to document how different emissions are calculated, it would be a good practise to divide the resulted emissions directly to different sources to make comparisons easier. Even when the documentation on calculations seems to be well made, one missing but essential parameter could have made comparisons impossible.

As already noted by Basset-Mens (2008), the most important life cycle phases are most often included in the studies. Generally few emission sources are clearly more important than the others in milk production: enteric fermentation for methane, soil for direct nitrous oxide and manure for both gasses.

Difficulties arise soon after one looks more carefully the different studies. Even if some emission sources are explained and reported very carefully, the same study might ignore completely the reporting of another important general data and thus make it impossible to calculate more specific numbers. For example even when the ratio between concentrates and forage and gross energy intake are important factors determining the milk production capacity and enteric fermentation emissions and thus footprint of milk, also their reporting was occasionally very poor.

Most of the studies used national emission factors at least partly in their inventory instead of the IPCC defaults. This can seem to make comparisons between studies more difficult but, in reality, most of these used factors can be thought to describe better than the defaults the different national and/or regional circumstances, and therefore deliver more accurate results. In these studies too general references to the data source articles without stating which parameters were really picked from them caused severe problems.

The ten different studies used several different methodologies to calculating enteric fermentation: a country-specific method for New Zealand, Canada, Germany and the Netherlands according to IPCC Tier 2 methodology, Kirchgesser (1991) methology, Mitscherlich equation, and OVERSEER nutrient budget model. To find out if using a certain methodology will affect the results, the methane emissions were calculated in four alternative ways using values of Finnish dairy cattle. The methodologies compared were Kirchgessner, IPCC (2000), Yan and the Finnish methodology by Agrifood Research Finland. It seemed that different methods do give somewhat diverse emission levels per cow per year, but when comparing the result per one kg of milk, the differences were rather insignificant.

In these milk studies there seemed to be strong negative correlation between milk yield and methane emissions per kg of milk, but when comparing yield and total emissions per kg of milk, no correlation is found. Though, it can not be said that lower yields would certainly lead to higher emissions, instead, the relationship between total methane and nitrous oxide emissions during the whole life cycle is highly complex.

It is clear that production types, feeding methods and animal breeds are causing real differences in emission levels even if tracking the magnitude of their impacts is difficult. It seems though justified that Tier 3 calculations as identified in IPCC (2006) guidelines are used to demonstrate these differences, but in the same time it naturally makes it more difficult to evaluate different studies without investigating all national methodology documents.

Calculations were also made to see if the manure management system affect directly to the emissions. Using the IPCC methodology, as in most of these studies, it was concluded that there is only clear trade-off between nitrous oxide and methane emissions when choosing between liquid and solid storage while the total emissions remains quite the same.

Nitrous oxide emissions were much more difficult to track. A lot of effort was put to recalculate the emissions from three major sources, namely manure management, manure applied to field and direct emissions from fertilizer application to soil. But only in four studies this was possible to some extent and in most just one source was adequately documented. Table 1 gives a good overview how diversely the emissions from different phases are possible to review after some disaggregations. Reporting in these articles was less comprehensive and these are already the articles of better accuracy.

Table 1: An example of the level of reporting in milk LCA studies on emission sources

	Study 1	Study 2	Study 3	Study 4	Study 5	Study 6	Study 7	Study 8
Direct N2O-emissions from manure management		x	x		x	x		x
Direct N2O-emissions from synthetic fertilizers	x	x	x	x		x	x	x
Direct N2O-emissions from manure application		x	x	x		x		x
CH4-emissions from manure management	x		x		x	x	x	x
Enteric fermentation emissions of dairy cows	x	x	x		x	x	x	x
Enteric fermentation emissions of heifers	x	x	x		x	x	x	

3. Conclusion and future recommendations

Even after carrying out a detailed analysis on carbon footprint studies, it is only possible to give general explanations for the wide differences in their results: 1) the methodological choices, such as selection of allocation methods and system boundaries, are different in studies, 2) the circumstances of production (climate, soil etc.) varies between countries/regions, which in addition to the real differences, might also lead to diverse emissions modelling approaches, 3) the production methods/technologies are different, and 4) the data quality and the level of primary and secondary data varies between studies. Even when the applied standardised methodology (ISO etc.) appears to be similar in the studies, its practical implementation and calculation routines seem to differ.

From transparency and reproducibility point of view, serious shortcomings were found in the reporting of data sources and calculation methods in these scientific articles, not to mention in the conference proceedings. No specific factor was identified to create alone clear differences between studies, and most obviously many factors contribute together for the wide range of carbon footprints. Only a long list of possible factors could be created for different food products as the documentation level of the studies still remains inadequate. Because in the future, there is a need to reach better comparability between different LCA results, there have to be also more comprehensive reporting on studies made.

In order to improve the comparability of results, common, harmonized calculation methods and globally accepted product category rules have to be developed. International standardisation and harmonisation is needed not only in the general LCA standardisation level but also in more practicable product category level, especially now when consumer communication of carbon footprints of food products is becoming common practice worldwide. But as PCRs are becoming available with increasing speed, it should be guaranteed to keep them harmonized at some level. We can not either allow to have PCR for every single product. It should be also avoided to have several overlapping PCRs from which a company can choose the one which makes its products look most environmentally friendly, or which causes growing trade cost to industries.

4. References

Allied Bakeries (2009): Allied Bakeries Kingsmill product carbon footprint. See: http://www.sustain.co.uk/media/94501/allied%20bakeries.pdf.

Andersson K., Ohlsson T. (1999): Life Cycle Assessment of Bread Produced on Different Scales. *The International Journal of Life Cycle Assessment*, 4(1), pp. 25-40.

Basset-Mens C., Ledgard S., Boyes M. (2007): Eco-efficiency of intensification scenarios for milk production in New Zealand. *Ecological Economics*, 68(6), pp. 1615-1625.

Basset-Mens C. (2008): Estimating the carbon footprint of raw milk at the farm gate: methodological review and recommendations. Proceedings of the 6th Int Conference on Life Cycle Assessment in the Agri-Food Sector. Zurich, Switzerland, November 12-14 2008.

Biswas W. K., Barton L., Carter D. (2008): Global warming potential of wheat production in Western Australia: a LCA. *Water and Environment Journal*, 22(3), pp. 206-216.

Braschkat J., Patyk A., Quirin M., Reinhardt G. A. (2003): Life cycle assessment of bread production - a comparison of eight different scenarios. Life Cycle Assessment in the Agri-food sector. DIAS report. Animal Husbandry. No: 61.

Brentrup F., Küsters J., Lammela J., Barraclough P., Kuhlmann H. (2004): Environmental impact assessment of agricultural production systems using the life cycle assessment (LCA) methodology. *European Journal Agronomy*, 20(3), pp. 265–279.

Casey J.W., Holden N.M. (2006): Greenhouse Gas Emissions from Conventional, Agri-Environmental Scheme, and Organic Irish Suckler-Beef Units. *Journal of Environmental Quality*, 35, January-February.

Cederberg C., Flysjö A. (2004): Life Cycle inventory of 23 dairy farms in South-Western Sweden. SIK rapport 728. The Swedish Institute for food and biotechnology.

Charles R., Jolliet O., Gaillard G., Pellet D. (2006): Environmental analysis of intensity level in wheat crop production using life cycle assessment. *Agric. Ecosyst. Environ.* 113(1-4), pp. 216-225.

FAO (2010): Greenhouse gas emissions from the dairy sector. FAO, Animal Production and Health Division, pp. 1-96.

Haas G., Wetterich, F., Köpke, U., (2001). Comparing intensive, extensified and organic grassland farming in southern Germany by process life cycle assessment. *Agric. Ecosyst. Environ.*, 83, pp 43–53.

Hirschfeld J., Weiß J., Preidl M., Korbun T. (2008): Klimawirkungen der Landwirtschaft in Deutschland. Diskussionspapier des IÖW IÖW 186/08.

IPCC (1996): Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Workbook. Volume 2. Intergovernmental Panel on Climate Change.

IPCC (2006): IPCC Guidelines for National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change.

Kirchgessner M., Windisch W., Müller H.L., Kreuzer M. (1991): Release of methane and of carbon dioxide by dairy cattle. *Agribiological Research*, 44.

Lovett D.K., Shalloo L., Dillon P., O'Mara F.P. (2006): A systems approach to quantify greenhouse gas fluxes from pastoral dairy production as affected by management regime. *Agricultural System*, 88, pp. 156-179.

LRF (2002): Maten och Miljön: Livscykelanalys av sju livsmedel. Lantbrukarnas Riksförbund.

Meisterling K., Samaras C., Schweizer V. (2009): Decisions to reduce greenhouse gases from agriculture and product transport: LCA case study of organic and conventional wheat. *Journal of Cleaner Production*, 17(2), pp. 222-230.

Narayanawamy V., Van Berkel R., Altham J., McGregor M. (2005): Application of life cycle assessment to enhance eco-efficiency of grains supply chains. p. 1–16. Proceedings Australian Conference on Life Cycle Assessment, 4th, Sydney, Australia. 23–25 Feb. 2005.

Schenck R., M. Ostrom, D. Granatstein, K. Painter, C. Kruger (2008): Life cycle assessment of wheat grown in Washington State. Proceedings of the International Conference on Life Cycle Assessment in the Agri-Food Sector. Zurich, Switzerland, November 12-14 2008.

Sundkvist Å., Jansson A-M., Larsson P. (2001): Strengths and limitations of localizing food production as a sustainability-building strategy — an analysis of bread production on the island of Gotland, Sweden. *Ecological Economics*, 37(2), pp. 217-227.

Thomassen M.A., van Calker K.J., Smits M.C.J., Iepema G.L., de Boer I.J.M. (2008): Life cycle assessment of conventional and organic milk production in the Netherlands. *Agricultural Systems*, 96(1-3), pp. 95-107.

Vergé X., Dyer J.A., Desjardins R., Worth D. (2007): Greenhouse Gas Emissions from Canadian dairy industry in 2001. *Agricultural Systems,* 94, pp. 683-693.

Williams A.G., Audsley E., Sandars D.L. (2006): Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities. Main Report. Defra Research Project IS0205. Bedford: Cranfield University and Defra.

Woitowitz A. (2007): Auswirkungen einer Einschränkung des Verzehrs von Lebensmitteln tierischer Herkunft auf ausgewählte Nachhaltigkeitsindikatoren.

Putting allocation into effect for carbon footprints of composed feed products

Tommie Ponsioen[1,*], Hans Blonk[1]

[1]Blonk Milieu Advies (Blonk Environmental Consultants), Gouda, the Netherlands,

ABSTRACT
Economic allocation, rather than allocation that is based on physical characteristics, is generally applied as the most adequate method for dividing upstream greenhouse gas emissions between co-products with different applications (mainly feed, food, fibre and fuel). However, economic allocation can be applied in several ways, depending on data availability. We argue here that for calculating the carbon footprint of composed products, the price definitions for economic allocation should be applied consistently, because this could have a large effect on the results. Therefore, we analysed the effects of using different price definitions on the carbon footprint of animal feed raw materials and of feed concentrates. This resulted in recommendations for using annual average country or region specific off-factory or commodity prices over a period of five years, and consistent use and clear communication of the allocation level (based on finished or unfinished co-product prices).

Keywords: Economic allocation; Carbon footprints; Composed products; Feed concentrates,

1. General information

Economic allocation, rather than allocation that is based on physical characteristics, is generally applied as the most adequate method for dividing upstream greenhouse gas emissions between co-products with different applications (Guinée *et al*., 2004). However, economic allocation can be applied in several ways, depending on price definition and data availability. In this paper, we discuss several choices for using different types of prices:

- actual prices or periodical prices,
- off-factory prices or commodity prices
- prices of unfinished co-products or final co-products.

Under commodity prices, we include transport (CIF price, which means the price as delivered at the frontier of the importing country including insurance and freight charges, or FOB price, which means CIF price less the insurance and freight charges for export). Unfinished co-products are products as they are after separation from the other co-products (for example, wet beet pulp) and finished co-products (off-factory) are products as they leave the factory (dry beet pulp). Figure 1 shows a schematic example of the production chain of two co-products and the various states of the products.

Composed products, such as feed concentrates, can consist of many co-products. We argue here that for calculating the carbon footprint of composed products, the price definition for economic allocation should be applied consistently, because of the possible large effect on the results. Therefore, we analysed the effects of using different price definitions on the carbon footprint of animal feed raw materials and of feed concentrates.

* Corresponding Author. e-mail: tommie@blonkmilieuadvies.nl

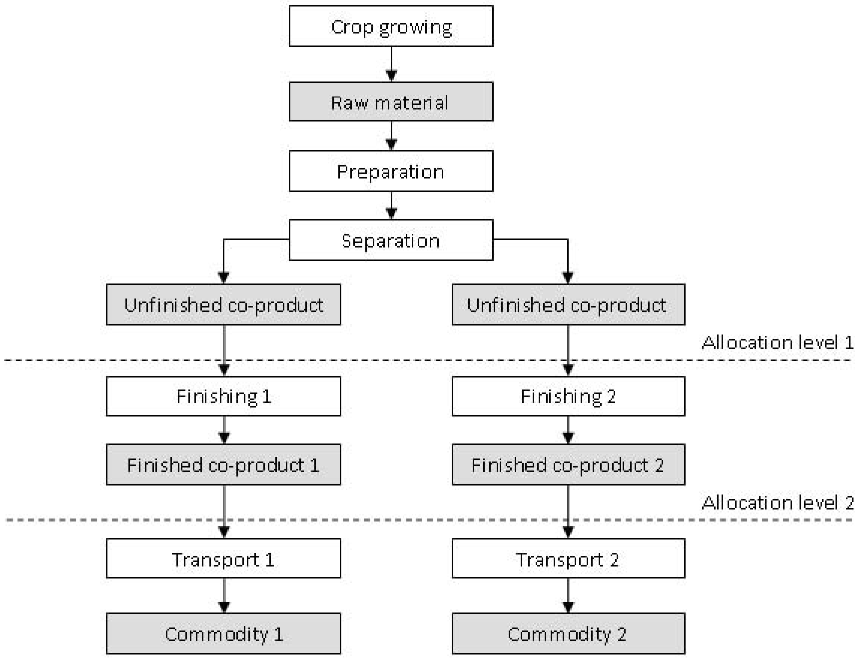

Figure 1: Schematic example of two agricultural commodities from co-production, with two different levels at which allocation of upstream greenhouse gas emissions can be applied (grey boxes represent products, white boxes represent processes and activities, and arrows represent material flows)

2. Methods

We chose to analyse the effect of price fluctuations on the allocation fraction of co-products for three different cases: 1) soybean oil and meal, 2) sunflower seed oil and meal, and 3) rapeseed oil and meal. We assumed mass balances did not change over time, with 0.2 kg soybean oil and 0.8 kg soybean meal per kg soybeans, 0.4 kg sunflower seed and rapeseed oil, and 0.6 kg sunflower and rapeseed meal. We used annual average prices between 1998 and 2009 and averaged the annual allocation fractions over five years. The price data were taken from FAO (2010). Table 1 shows the price type per co-product.

Table 1: Co-products and price type for analysing price fluctuations

Co-product	Price type
Soybean oil	Dutch FOB ex-mill
Soybean meal	Pellets 44/45% Argentina CIF Rotterdam
Sunflower seed oil	FOB Northwest European ports
Sunflower seed meal	Pellets 37/38% Argentina CIF Rotterdam
Rapeseed oil	Dutch FOB ex-mill
Rapeseed meal	34% FOB Hamburg ex-mill

For the analysis of the effect of using off-factory or commodity prices, we could not find publicly available off-factory prices to use in this paper. Therefore, we used commodity prices in different countries, from which we could deduce how large the effect would be on calculating allocation fractions based on off-factory or commodity prices. We used the case of soybean meal and oil in the USA, Brazil, Argentina and Hamburg. The price data were taken from USDA (2010).

The analysis of either applying economic allocation at the moment a product is separated into different co-products or at the moment the co-products leave the factory could not be applied to actual data, because prices of unfinished co-products were not available. We therefore calculated two scenarios for price deduction in the case of soybean meal and oil. The first scenario is to assume the prices of finished and unfinished co-products are the same; the second scenario is to reduce the prices of the finished co-products by the relative energy use in the finishing processes of all co-products (based on energy use in Sheehy *et al.*, 1998). The latter scenario does not result in realistic absolute prices, but we believe that it does give realistic relative prices to calculate the allocation fractions. We also analysed the effect of allocating upstream emissions of cheese production at different moments on the carbon footprints of cheese and whey powder. In the base scenario, we allocated when the products leave the factory. In the alternative scenario, we allocated before cheese storage and whey drying. Data for energy use was based on Wang (2008), Ramírez *et al.* (2006) and Dijkstra *et al.* (2001). Price data for calculating allocation fractions was based on LEI (2010) and LTO (2010). The carbon footprint of raw milk was based on own calculations.

3. Results

Figure 2 shows average annual and five-year commodity prices of soybean oil and meal, sunflower oil and meal, and rapeseed oil and meal, and the resulting allocation fraction for the meals. Especially in the case of rapeseed meal and oil, the allocation fraction for meal fluctuated between 0.35 and 0.2 when using annual commodity prices between 1998 and 2008 and the five-year average allocation fraction decreased from 0.3 (1998–2002) to 0.23 (2004–2008).

Figure 3 shows the results of calculating the allocation fraction of soybean meal with soybean meal and oil prices in different countries. The difference between the allocation fractions of soybean meal from the USA and Western Europe (Hamburg prices) does not differ much, but those of soybean meal from South American countries are about five per cent less.

Allocation when a product is separated into different co-products rather than when the co-products leave the factory results in minor differences in the carbon footprints of soybean meal and oil (Figure 4, scenario 1). However, when correcting the prices of the unfinished co-products based on the relative energy use for finishing the products, the carbon footprint of soybean meal is about five percent lower and that of soybean oil is about ten percent higher (Figure 4, scenario 2). Figure 5 shows the results of the cheese and whey powder case study. The carbon footprint of cheese is six percent higher and of whey powder 32 percent lower when allocating before cheese storage and whey drying.

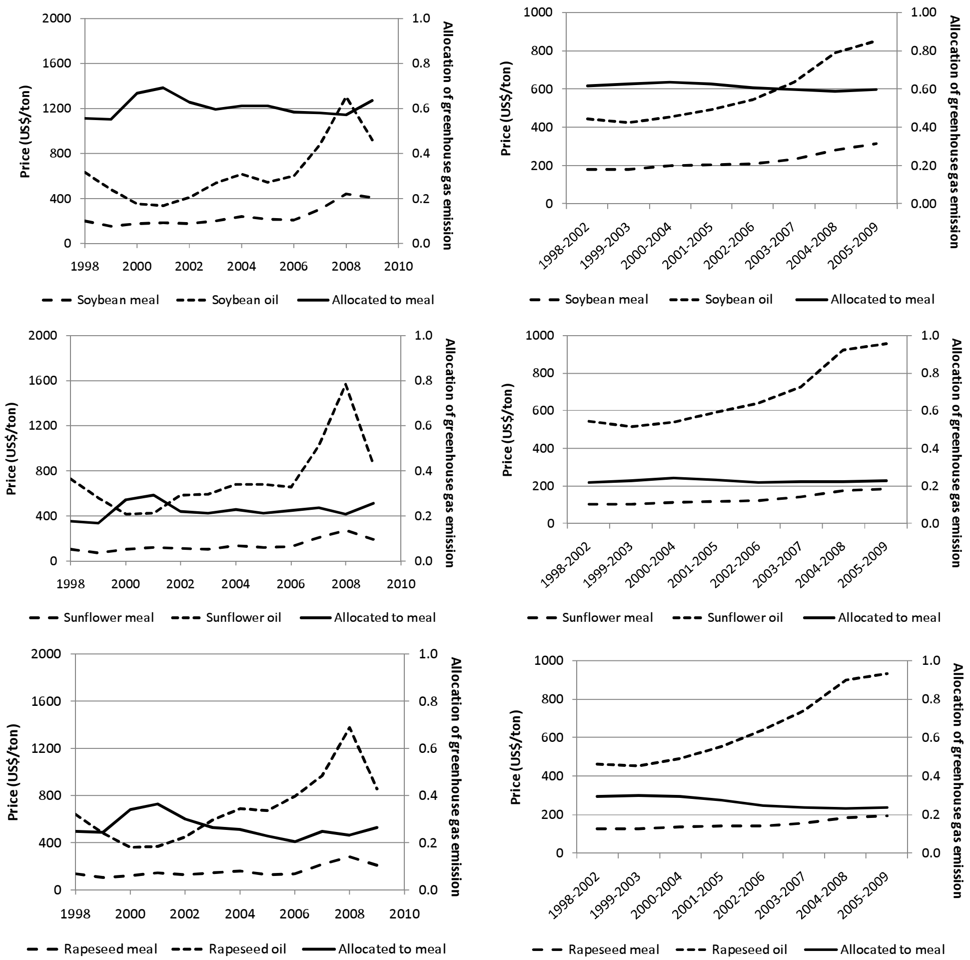

Figure 2: Average annual (graphs on the left side) and five-year commodity prices (right side) of soybean oil and meal, sunflower oil and meal, and rapeseed oil and meal, and the resulting allocation fraction for the meals

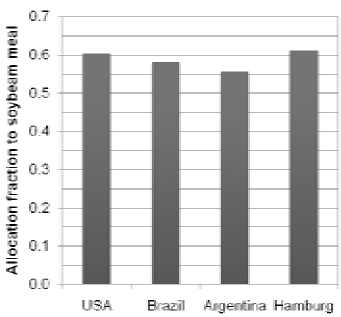

Figure 3: Average allocation fraction to soybean meal calculated with prices between September 2004 and August 2009 from the USA, Brazil, Argentina and Hamburg

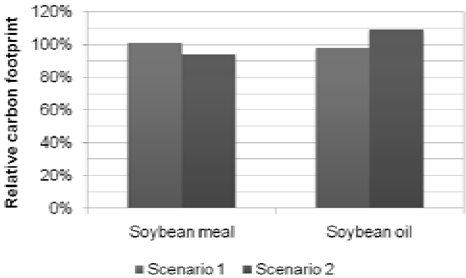

Figure 4: Relative carbon footprint of soybean meal and oil in two allocation scenarios compared to allocation at the factory gate; scenario 1 is allocation when a product is separated into different co-products rather than when the co-products leave the factory; scenario 2 is correcting the prices of the unfinished co-products based on the relative energy use for finishing the products

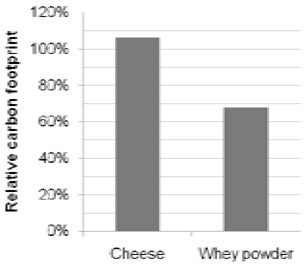

Figure 5: Relative carbon footprint of cheese and whey powder, allocating upstream emissions before cheese storage and whey drying compared to allocating when leaving the factory

4. Discussion

We analysed three different options when applying economic allocation. The first option was using allocation fractions based on annual average prices or averaging the allocation fractions over five years. Because a carbon footprint should give information about the actual situation, recent data based on annual averages would be most relevant. However, the results show that this would mean that the carbon footprint can change considerably over the years, solely because of price fluctuations. This would make a comparison between carbon footprints of products produced in subsequent years problematic. We think that it is important that economic allocation represents a (socio)economic value and not a short term market value. A period of five years is short enough to represent the actual situation, and the results show that price fluctuations have a minimal effect on five-year average allocation fractions.

The second option that we analysed was whether differences in prices between countries affect the allocation fractions. The results from the case study with soybean meal show that this effect is at most five percent. We expect from this analysis that when the distance between two countries is small, the allocation fractions will not differ significantly. Also, we do not expect large differences between allocation fractions based on off-factory and commodity prices within a country, except for co-products that have low off-factory prices compared to the commodity prices due to a large share of transport cost in the price, such as soybean hulls (when not mixed in meal), brewer’s grain, beet pulp and citrus pulp.

The third option was to allocate upstream greenhouse gas emission to unfinished co-products rather than allocating to off-factory co-products. For some unfinished co-products, price data may be available because the co-products are finished by another company or they are used in their unfinished form (for example wet whey for dairy cows), but for other unfinished co-products such prices do not exist (unfinished soybean oil and meal). Therefore, it is not always possible to calculate the difference between economic allocation with unfinished or finished co-products. To circumvent this problem, we suggest a price correction for unfinished products based on the relative energy use for finishing the co-products. When different mixes of energy sources are used for the different finishing processes, we suggest translating the energy use from physical units to monetary units. With this price-correcting method, we found that the carbon footprints of the co-products based on allocation of finished and unfinished co-products are very different. When a large part of the energy is used for drying one of the co-products and the value of that co-product per unit dry mass increases considerably – as is the case of whey powder – the carbon footprints of that product when allocating before or after drying can differ enormously. Moreover, energy efficiency for drying may vary between factories, which would result in large differences in the carbon footprint of whey powder when allocating before drying. Therefore, we suggest consistent use of one method and stating which allocation level is used when presenting a carbon footprint, especially when it concerns a composed product such as animal feed.

5. Conclusions

Based on the analyses in this paper, we recommend:

- the use of a five-year average allocation fractions that are calculated with annual average prices,
- the use of country or region specific commodity prices or the use of off-factory prices in cases with co-products that have relatively low prices, and
- consistent use and clear communication of the allocation level (based on finished or unfinished co-product prices).

6. References

Dijkstra J.W., Rouwen W., Sluimer P., Verdurmen R. (2001): Geavanceerde gasturbinecycli in de brood- en banket- en in de zuivelindustrie. ECN-C-01-076 (In Dutch).

FAO (2010): Faostat website. http://faostat.fao.org accessed: March 2010

Guinée J.B., Heijungs R., Huppes G. (2004): Economic Allocation: Examples and Derived Decision Tree. *International Journal of Life Cycle Assessment*, 9(1), pp. 23-33.

LEI (2010): Binternet website: http://www.lei.wur.nl/NL/statistieken/Binternet/. LEI-WUR, The Hague, Netherlands.

LTO (2010): LTO Nederland website: http://www.lto.nl. The Hague, Netherlands.

Ramírez C.A., Patel M., Blok K. (2006): From Fluid Milk to Milk Powder: Energy Use and Energy Efficiency in the European Dairy Industry. *Energy*, 31, pp.1648–1668.

Sheehan J., Camobreco V., Duffield J., Graboski M., Shapouri H. (1998): Life Cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus. USDA and USDE.

USDA (2010): Oilseed: World Markets and Trade. USDA, Foreign Agricultural Service, Circular Series, FOP 2-10, February 2010

Wang L.J. (2008): Energy Efficiency and Management in Food Processing Facilities. CRC Press, Taylor & Francis Group, LLC, Boca Raton, FL, USA.

Development and harmonisation of a Finnish methodology for the calculation of carbon and other footprints for food products

Juha-Matti Katajajuuri*, Hannele Pulkkinen, Merja Saarinen, Frans Silvenius, Pauliina Nurmi

MTT Agrifood Research Finland, Biotechnology and Food Research, Sustainable Bioeconomy

ABSTRACT

Approximately 15% of the greenhouse gas emissions of consumption stem from household food purchases. This figure increases when all environmental impacts and all activities related to food consumption are taken into account. Despite the fact that past and current LCA studies for both similar and different kinds of food products are not comparable, results of the various studies are used as a basis for product comparisons, and even for consumer communication, as well as for improving supply chains. Reliable and comparable data on the environmental impacts, and particularly climate change potential of food products are needed more than ever. The long-term goal of this "Finnish Foodprint" programme and subprojects is to mitigate climate change and other environmental problems through influencing consumer behaviour, and particularly through the development of food supply chains. The project specifically investigates current LCA, problematic parts of footprinting methodologies and best practices, and develops harmonised science-based, practical methodologies and calculation guidelines and tools, to enable valid and reliable comparisons of carbon and other footprint data on food chain processes that will be easy to update.

Keywords: LCA, footprint, methodology, carbon footprint, harmonisation

1. Introduction

Approximately 15% of the greenhouse gas emissions of consumption stem from household food purchases, and this share increases to a substantial 25% when other factors directly related to consumption, such as food preparation and preservation, journeys to the shops and meal services, are included. The contribution of food consumption to other environmental impacts, such as eutrophication and acidification, is even higher (Seppälä et al., 2009). Environmental impacts of food production and consumption have been studied in Finland since 1998 (see e.g. Katajajuuri, 2008, 2009, Katajajuuri et al., 2003, 2005, 2009a, 2009b, Kauppinen et al., 2009, Kurppa et al., 2009, Usva et al., 2009). Despite the fact that past and current LCA studies for similar and different food products are not comparable with each other, the results of various studies are nonetheless used as a basis for product comparisons and even for consumer communication, as well as for improving supply chains.

Numerous international and national initiatives are currently developing standards and protocols for calculating carbon footprints. They are mainly attributional approaches, but some differences exist. The main challenge is that they are all (ISO 14040, WRI/WBCSD GHG protocol, PAS 2050, etc.) too generic and are consequently implemented in diverse ways. They refer to more specific product category rules (PCR), but few currently exist, and are of variable quality. Futhermore, with current PCR progression, it is likely that different

* Corresponding Author e-mail: juha-matti.katajajuuri@mtt.fi

PCRs are developed differently across regions, and possibly even countries. Harmonisation is unlikely to prevail if current trends continue.

The public are concerned about climate change, and a number of Gallup polls have revealed an unprecedented desire of people to work for climate change mitigation. This is the reason why reliable and comparable data on the environmental, and particularly climate, impacts of food products, are needed more than ever. The challenge being faced is that the average citizen, despite all efforts, still lacks the knowledge or even the correct perception of the burden placed on the environment by the production, procurement, preservation and preparation of food products, or the impacts of food wastage. Furthermore, the information sought by the public is needed also for continuous improvements of food supply chains.

While international harmonisation of standardisation and PCRs are under development, the Finnish Foodprint programme aims to harmonise calculation methods and communication of footprints at least in the Finnish food sector, taking care that international developments and best practices are taken into account in developing Finnish methodologies.

2. Outline of the Finnish Foodprint programme

The “Foodprint”, Footprint of Food, research programme started in late 2009 following the initiative of active Finnish food companies who had faced the complexity and challenges of producing and communicating different footprints of food products for various purposes. The programme is planned to be completed in May 2012, and is funded by the Finnish Funding Agency for Technology and Innovation (Tekes) and participating companies.

The programme consists of one public project and three company research and development projects, as presented in Figure 1.

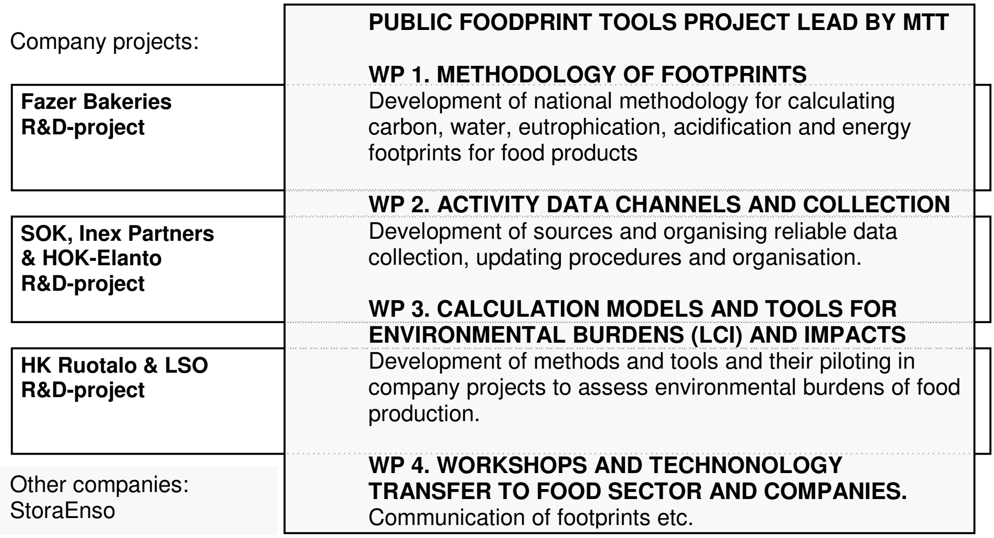

Figure 1: Overview of Finnish Foodprint programme

The Public Foodprint tools project comprises 4 work packages, presented briefly in Figure 1. WP 1 is similar to the previously mentioned international standards and aims at describing a generic methodology and requirements for food products. Other work packages will be more detailed concerning data collection, data quality requirements, actual tools to assess environmental burdens in agriculture etc. Some specific characteristics are described in the following chapter.

3. Foodprint methodology and data quality issues - examples

Initially all current and draft standards were carefully assessed and methodological problems and variations between them reviewed. Thereafter the following topics were identified and chosen for detailed discussion and evaluation during the first phase of the project.

Concerning attributional vs. consequential modelling approaches, it was decided to choose the attributional approach to allow comparability of footprints and to create as concrete modelling backbone for companies as possible. Main issues under discussion in this initial phase of the project include:

- Primary vs. secondary data sources? Consideration of other data quality requirements? There is a need to specify more carefully what is meant by primary and secondary data in practice in different situations. Concerning possible requirements of primary data: is a single good sample sufficient and what is a good sample, and how many years should be taken into account considering agricultural issues? How updating of secondary data and/or defaults will be conducted?
- System boundaries:
    - Whether to include the consumer phase or not.
    - The contributions of production of machinery (e.g. tractors) are to be studied in the public project to determine whether they should be included into the Finnish guideline or not.
- Allocation procedures? How far is possible to go in avoiding allocation using an attributional approach? When allocation is needed, clear allocation rules need to be fixed, which would be principally same for all product categories. When this is not reasonable, exceptions from fixed rules are considered and some guidelines will be produced to assist selection of the corresponding allocation method.
- Verification of activity and emissions data – not yet initiated.
- Different land-use impacts (carbon storage, sequestration, soil carbon change, land conversion) - not yet initiated.
- Water footprint. Specific methodology development work has begun particularly for water footprint.

All the following impact categories (footprints) are included in this programme: climate change, acidification, eutrophication, water footprint and primary energy.

In cooperation with this Footprint Tools and other projects also methodology development and implementation is carried out. One of the specific topics in methodology improvement is to develop as reliable and realistic values as possible for N_2O emissions from agricultural soils, which take into account the particular characteristics of climate conditions in Finland.

Emissions of N_2O from agricultural soils to the atmosphere are traditionally calculated in many countries based on IPCC methods, and can be calculated using e.g. the default emission factor of the IPCC (0.01kg N_2O-N per kg applied N) (IPCC 2006). With a fertilizer application rate of 100kg N ha-1 this would generate average annual emissions of 1.0kg N_2O-N for cereals.

However, in the emission measurements made in Finland, the average emission rate of cereals on mineral soils was 3.1±1.7kg N_2O-N ha-1 year-1 (manuscript in preparation). The measured emissions include the effect of crop residues and other "background" emissions whereas the default emission factor only considers the effect of fertilization. However, even with this difference taken into account, the default emission factor appears to underestimate the flux. On the other hand, the default emission factor is better suited to estimating the flux from grass cultivation. A typical fertilizer application rate for grass can be 200kg N ha-1, which would give an emission of 2kg N_2O-N ha-1 year-1 while the measured fluxes have been 1.8±1.5kg N_2O-N ha-1 year-1.

The field data were so variable however that it was not possible to obtain equations based on the added N (or other environmental factors) for both cereals and grass from the dataset that contained 330 values for annual flux. Thus as a result, to reflect the national conditions better, it is planned to start to use these measured average values for cereals and grass in estimating the emissions of N_2O associated with cultivation.

4. References:

PAS 2050 (2008): PAS 2050. Specification for the assessment of the life cycle greenhouse gas emissions of goods and services. British Standards Institute, pp 1-43.

ISO 14040 (2006): ISO 14040:2006. Environmental management – Life cycle assessment – Principles and framework. International Organization for Standardisation. International Standard, Second Edition, July 2006, pp.1-20.

Katajajuuri J.-M, (2008): Ruoan ympäristövaikutukset. (Environmental impacts of food) *Futura* 3/2008, pp. 38-46. ISSN 0785-5494.

Katajajuuri J.-M. (2009): Climate impacts of food products and meals. Climate Smart Conference, Lund, Sweden, 23-34 November 2009, 3 p. www.se2009.eu/en/meetings_news/2009/11/23/climate_smart_food

Katajajuuri J.-M., Kurppa S., Nissinen A., Usva K., Virtanen Y., Grönroos J., Voutilainen P. (2009): Environmental impacts of different food products and their contribution to the environmental impacts of Finnish consumption. In: Programme book of 15TH LCA Case studies symposium, SETAC, 22-23 January, 2009, Paris. pp. 124-125. http://lcapoznan.setac.eu/embed/LCA/ProgrammebookAndErrataSheetReduced.pdf

Katajajuuri J.-M., Tuhkanen H.-R., Voutilainen P. (2005): Contribution of life cycle stages to the global warming potential of food products. In: Innovation by life cycle management LCM 2005 International conference: Proceedings, September 5-7, 2005, Barcelona, Spain. P. 414-418

Katajajuuri J.-M., Virtanen Y., Voutilainen P., Tuhkanen H.-R., (2003): Life Cycle Assessment Results and Related Improvement Potentials for three Different Kinds of Foodstuff. In: International conference on: Life cycle assessment in the agri-food sector : October 6-8, 2003, Horsens, Denmark. P. 222-225.

Kauppinen T., Katajajuuri J.-M., Pesonen I., Kurppa S. (2009): Carbon footprint of food maintenance in Finnish households. In: Editors Marileena Koskela, Markus Vinnari. Future of the consumer society : proceedings of the conference "Future of the Consumer Society" 28-29 May 2009, Tampere, Finland : FFRC eBook 7/2009. Turku: Finland Futures Research Centre, Turku School of Economics. p. 171-176. www.tse.fi/FI/yksikot/erillislaitokset/tutu/Documents/publications/eBook_2009-7.pdf

Kurppa S., Grönroos J., Hyvärinen H., Katajajuuri J.-M., Kauppinen T., Mäkelä J., Nissinen A., Nousiainen J., Saarinen M., Usva K., Viinisalo M., Virtanen Y. (2009): Environmental impacts of a lunch plate - challenges in interpreting the LCA results. In: Editors Marileena Koskela, Markus Vinnari. Future of the consumer society: proceedings of the conference "Future of the Consumer Society" 28-29 May 2009, Tampere, Finland: FFRC eBook 7/2009. p. 185-193. www.tse.fi/FI/yksikot/erillislaitokset/tutu/Documents/Publications/eBook_2009-7.pdf

Seppälä J., Mäenpää I., Koskela S., Mattila T., Nissinen A., Katajajuuri J.-M., Härmä T., Korhonen M.-R., Saarinen M., Virtanen Y. (2009): Suomen kansantalouden materiaalivirtojen ympäristövaikutusten arviointi ENVIMAT-mallilla SY20/2009 (Environmental impacts of material flows caused by the Finnish economy). Suomen ympäristö 20/2009, 134 s. Suomen ympäristökeskus (SYKE). URN:ISBN:978-952-11-3460-9, ISBN 978-952-11-3460-9 (PDF). (In Finnish)

Usva K., Saarinen M., Katajajuuri J.-M., Kurppa S., (2009): Supply chain integrated LCA approach to assess environmental impacts of food production in Finland. *Agricultural and Food Science*, 18(3-4), pp. 460-476.

WRI/WBCSD (2009): Product Life Cycle Accounting and Reporting Standard. Review Draft for Stakeholder Advisory Group. World Resources Institute, World Business Council for Sustainable Development. November 2009, pp.1-112.

Integrated assessment of sustainability of the home-made production of beer: comparison of the methodologies of Life Cycle Assessment and *Bilan Carbone®*

Katia Zavaglia[1,*] Yvan Deloche[2]

[1] SiTI Istituto Superiore sui Sistemi Territoriali per l'Innovazione
[2] CRitt Centre Règional D'Innovation et de Transferts De Technologies

ABSTRACT

It's now widely recognized the importance of assessing the environmental impacts associated with food production. Even the production of homemade beer, strong growth in Europe and Italy at the top for the number of producers, is affected by the growing demand for naturalness and sustainability by consumers. Research activities were then developed in order to achieve these expectations, with different actions in the production chain, with particular attention to the issue of finding the raw materials, logistics and distribution, packaging and labeling. In this area, in the Alcotra project FASST, assessment of the sustainability of the production of homemade beer was carried out. In particular Life Cycle Assessment and the methodology of *Bilan Carbone®*, codified by French Agency for Environment and Energy, have been applied. The application of LCA and *Bilan Carbone®* were important actions of exchange of know-how between the project partners, to highlight elements of contact and possibilities of improvements.

Keywords: bilan carbone, greenhouse emissions, LCA

1. Introduction

Nowadays it's clear understood that the environmental impacts related to agricultural activities are intrinsically linked to food security both locally and globally. The agricultural production and the change of the land use are activities with a relevant contribution to global climate change (IPCC). The use of fertilizers, for instance, causes the release of pollutant in the soil; moreover these emissions must be added to the impacts generated by the processing of land, the preparing of food, the production of packaging and, last but not least, the transport operations.

Therefore it's evident the importance to apply in this sector tools to improve safety and environmental performances of the products. Among these instruments, in Italy environmental certifications are widely applied in food industry; the food sector is the third in number of registrations EMAS (EcoManagement and Audit Scheme), with more than 105 organizations registered a total of 800 (Emas).

In Italy between the tools of environmental management the application of the methodology of Life Cycle Assessment (LCA) is growing in agriculture and food sector. This occurs because the methodology is recognized as a potential environment marketing tool and it can support to improve environmental performances of the products. Through the LCA study performed on the product, it's possible to identify the consumption of resources and energy and the environmental impacts generated throughout the life cycle, from the extraction of raw materials, through the process of production, distribution and use until the end of life, in

* Corresponding Author. e-mail: katia.zavaglia@polito.it

a perspective that goes beyond the gates of the company. Therefore Life Cycle Assessment can become a complementary tool for environmental management systems (EMS).

Similarly in France the interest in evaluating, monitoring and management of environmental impacts of agriculture and food sectors has grown significantly. Research activities and environmental management tools have spread significantly in the recent years. Among these tools, the *Agence de l'Environnement et de la Maîtrise de l'Energie* (ADEME) has developed the method *Bilan Carbone*® (explained below), whose use is growing in all sectors and particularly in agriculture and food industry.

For the above reasons, in the project *Filière Alpine Senteurs Saveurs Transfrontalière* - FASST- ("Scents and flavors cross border Alpine products chain"), Life Cycle Assessment and Bilan Carbone® were applied to the sector of homemade beer production (both in Italy and in France). FASST is a project of cross-border cooperation between France and Italy (Alcotra 2007-2013). The project lead partner is the *Université Européenne des Saveurs et des Senteurs* (UESS), the project partners are the *Office national interprofessionnel des plantes à parfum, aromatiques et médicinales* (Onippam, now called France Agrimer), the Italian research Institute SiTI (*Istituto Superiore sui Sistemi Territoriali per l'Innovazione*), the Italian scientific and technological park for the Agro Industry Tecnogranda and the *Centre Régional d'Innovation et de Transfert de Technologies* (CRITT, French center of innovation and technology transfer) in the Region of Provence Alpes Cote d'Azur (PACA).

The FASST project is therefore developed in the chain of Scents and Flavors (aromatic and medicinal plants and the manu-facture of perfumes, cosmetics, aromatic and agri-food products) which is present along the Mediterranean coast, particularly along the cross border region France - Italy (PACA region - Piemonte).

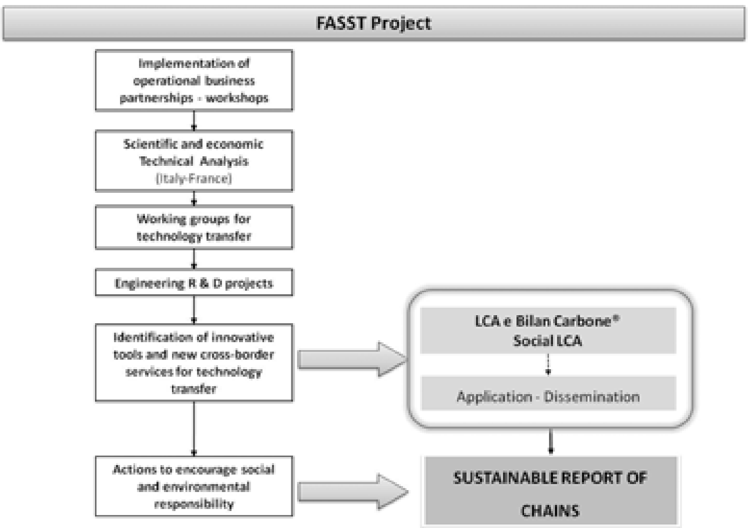

Figure 1. The role of Life Cycle Assessment and *Bilan Carbone*® in the FASST project.

2. Assessment tools: Life Cycle Assessment and *Bilan Carbone*®

In the FASST project the application of Life Cycle Assessment (LCA) and *Bilan Carbone*® and their dissemination have been used for the evaluation of the environmental impact of agri-food chains and for the enhance of performance improvement.

These applications are in a specific work package of the FASST project: identification of innovative tools and new services. They also support actions to encourage social and environmental responsibility for the preparation of Sustainability Reports and to enhance the agri-food sectors and territories and their competitiveness.(fig. 1).

2.1 Life Cycle Assessment

The Life Cycle Assessment study was developed in order to detect the resources and energy consumption and environmental impacts from the entire life cycle, from extraction of raw materials and cultivation of natural raw materials, through the process of production, distribution, use and end of life of the product in a perspective that goes beyond the gates of the company.

One of the main applications of LCA in terms of visibility and marketing company will be the preparation of Sustainability Reports. In particular, LCA is a part of the activities which aim at identifying economic, social and environmental values for the operators, in order to promote the development of Sustainability Reports of the chain and the territories.

The application of Life Cycle Assessment was realized in accordance with the requirements of reference standards:

- EN ISO 14040. Environmental Management-Life cycle assessment-Principles and Frame work (ISO, 2006);
- EN ISO 14044. Environmental Management-Life cycle assessment-Require-ments and guidelines (ISO, 2006).

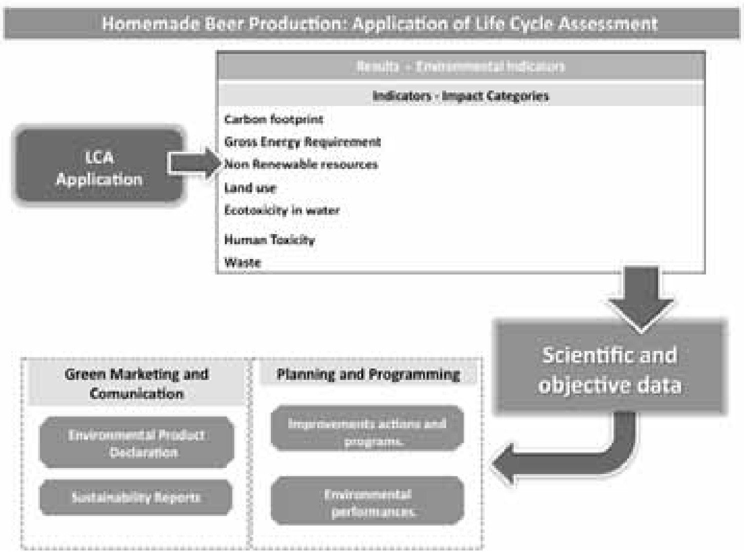

Figure 2. Homemade beer production: LCA application in the FASST project.

2.2 The *Bilan Carbone*® methodology

The *Bilan Carbone*® is a method that has been developed by the French Environment and Energy Control Agency (ADEME) for assessing the greenhouse gas emissions of an activity or a territory by using data easily available. ADEME is a public corporation under the joint supervision of the French Ministry for Ecology and Sustainable Development and the Ministry for Higher Education and Research. It takes part in the implementation of the public policies in the fields of the environment and energy.

Bilan Carbone® methodology is compatible with the standard ISO 14064, the GHG Protocol initiative and the terms of the Directive 2003/87/CE establishing a scheme for greenhouse gas emissions allowance trading within the European Community.

The *Bilan Carbone* ® is a tool increasingly popular in France for the assessment of global emissions of CO_2 of products, systems, services and even manufacturing sites. Its application, allowed only to authorized parties, is considered crucial to the process of "labeling- information environmental" of products, which will become mandatory in France at the beginning of 2011.

The greenhouse gases that are taken into account by the Bilan Carbone® method are:

- CO_2;
- CH_4;
- N_2O;
- Fluorinated hydrocarbons (HFC – PFC – SF_6).

In order to convert the available data in a company to greenhouse gas emissions, *Bilan Car-bone*® method gives emission factors, provided by French and European databases. It may reflect a single process or set of processes. For example:

- Single process, combustion of one litre of gasoline
- Set of processes, production of one kilogramme of wheat flour.

Bilan Carbone® asses the greenhouse gas emission from cradle to grave (fig. 3).

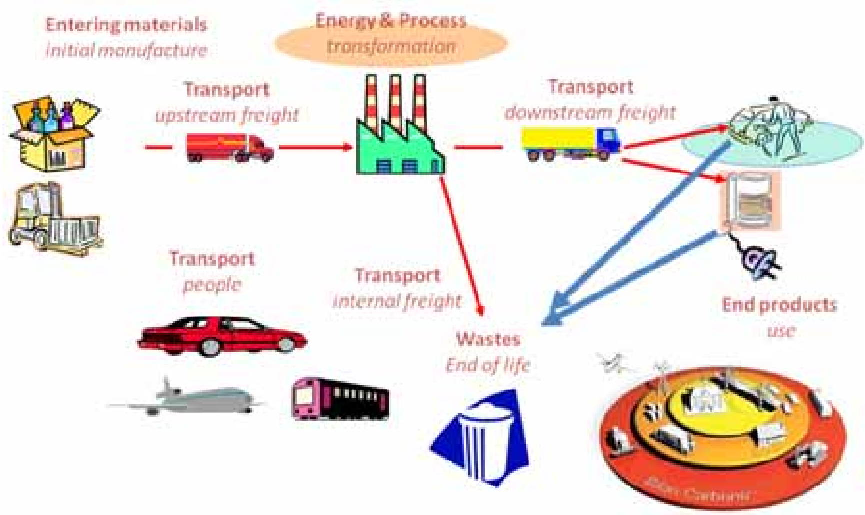

Figure 3. *Bilan Carbone*®: scheme of application and boundary of the system under study.

3. Application of LCA and *Bilan Carbone*® to the case study

The planned activities are summarized in Table 1. The project is currently under development and it will finish at the end in July 2010; some of the following steps have already been implemented and others are still ongoing.

The methodologies of LCA and *Bilan Carbone*® are characterized by the following main activities:

- Definition of the boundaries of the system (geographic and temporal) and the functional unit;
- Data collection and creation of the model of the system under study;
- Calculation with software and use of databases;

- Impact assessment (calculation of emission of CO_2 equivalents for *Bilan Carbone®* and LCA impacts);
- Interpretation and Reporting.

Table 1. Application of LCA and *Bilan Carbone®*.

Activity description	Objectives, expected results and documents
Preparation and definition of LCA questionnaire for data collecting.	- Specific LCA questionnaire.
Literature Analysis: economic and technical aspects; LCA application in agri-food sector.	- Technical and socio-economic aspect; - Classification of the chain; - LCA studies on the agri-food sector.
Goal and Scope definition (geographic and temporal boundaries, functional unit, data, allocation criteria).	- Identification of geographical and temporal boundaries; - Definition of a sample of firms to be involved in the LCA study; - Identification of the functional unit; - Input data and critical analysis; - Allocation criteria.
Life Cycle Inventory (Analysis of inventory through the completion of questionnaires) and data collection *for Bilan Carbone®*.	- Creating LCA data base of the sector; - LCA Model; - *Bilan Carbone®* data collection; - Input-output tables.
LCA and *Bilan Carbone* ®calculation.	- Application of LCA (UNI EN ISO 14040-14044) and Results of the inventory; - *Bilan Carbone®* Calculation
Life Cycle Impact Assessment. *Bilan Carbone* ® assessment.	- Definition of methods and impact categories (specific and useful for the reporting and the preparation of sustainability reports); - Environmental and energy impacts. - Calculation of greenhouse gas emissions.
Life Cycle Improvement (interpretation of results and suggestions for improvement). Interpretation of *Bilan Carbone®* results.	- Identifying critical areas-phases; - proposals for improvement, LCA-*Bilan Carbone®* analysis and comparisons; - Discussion of results and their analysis.
Writing reports.	- Sustainability Reports.

The methodologies has two differences to notice :

- The determination of the improvement actions (“*action de réduction*”) is a full part of the *Bilan Carbone®* methodology;
- The *Bilan Carbone®* methodology has been designed to assess the impact of a company as a whole; it doesn’t define any allocation rules if the company produce different products and wants to determinate the impact of one product only.

However the activities of data collection, calculation, impact assessment and interpretation require a different time for their development. In particular, Bilan Carbone® can be achieved faster than LCA and can provide preliminary results, even after one day of data collection (in the case of simple system).

The case studies are two small business enterprises (one is a French company and one is an Italian company) of the homemade beer sector. The companies realize the beer production in a similar way: the raw materials (mainly agricultural products and water) are mixed and sent to various processes, which end with the packaging. The products are then sent to recipients via various modes of transport. It is rather simple systems characterized mainly by the use of agricultural products, water and energy use for the equipments and machinery.

For these reasons, the production plants are small and don't have significant environmental impacts at the local scale.

The first activities of definition of the boundaries of the system and data collection were completed; creating the model of the system under study and calculation with software and use of databases are now ongoing. The following figure shows the results of the application of *Bilan Carbon*e®.

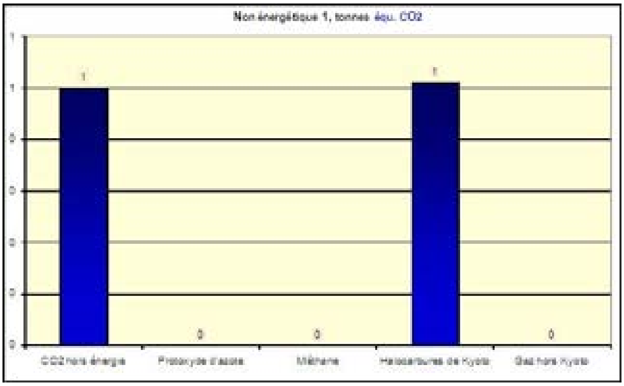

Figure 4. An example of results of the application of *Bilan Carbone*® to the homemade beer production.

4. Conclusions

The Life Cycle Assessment and *Bilan Carbon*e® applied within the European project *Filière Alpine Senteurs Saveurs Transfrontalière* are tools for the research activities and support development of specific tools for "certification" and "sustainability" of sectors and territories. In particular their integrated application will provide scientific and objective in formations for preparing Sustainability Reports.

In the research all the actors of the chain will be involved in order to plan possible actions for improving and promoting sustainable development throughout the production chain.

An important element of the application of LCA and *Bilan Carbone*® in the project FASST is the possibility to assess in a scientific manner as a chain is short in terms of sustainability.

5. References

Agence de l'Environnement et de la Maîtrise de l'Energie- ADEME (2009) : Bilan Carbone® « entreprises » et « collectivités. Guide méthodologique - version 6.0 - objectifs et principes de comptabilisation, ADEME, Paris.

Emas, www.apat.gov.it.

ISO (2006) : UNI EN ISO 14040. Environmental Management- Life cycle assessment- Principles and framework. International Organisation for Standardisation. Ginevra.

ISO (2006) : UNI EN ISO 14044. Environmental Management- Life cycle assessment- Requirements and guidelines. International Organisation for Standardisation. Ginevra.

Outline of the Finnish system of certified Carbon Footprints of food products

Merja Saarinen[1,*], Mikko Hongisto[2], Kirsi Usva[1], Ari Nissinen[3], Juha-Matti Katajajuuri[1]

[1]MTT Agrifood Research Finland,
[2]VTT Technical Research Centre of Finland
[3]Finnish Environment Institute

ABSTRACT

The basic structure of a system called Certified Footprints of Products (CFP system) is outlined. It could produce strict and reliable data needed for generating product-oriented carbon footprints in Finland. Central parts of the CFP system are a national CFP programme, product category rules (PCRs), a chain or actor-wise monitoring plan, validation of the monitoring plan, and reporting and verification of data, and an ICT-system to support data sharing. The system is designed around activity-based monitoring data, and every actor would be responsible for data on its own activities. Linkages to existing environmental management systems are taken into account. The CFP system needs further development prior to full-scale introduction. For the food sector, a new architecture for data acquisition and quality assurance, development of existing mechanisms and consolidation of them in the CFP system are needed. Additional research is also needed regarding emissions from agricultural production.

Keywords: food, carbon footprint, LCA, supply chain management, modularity,

1. Introduction

Different types of climate labels for food products have been increasingly and world wide appeared as a consequence to the increased awareness of climate change. Many of climate labels are based on carbon footprint calculation as an application of life cycle assessment method (LCA). Daily food consumption represents 15-20 % of a total climate change impact of average Finnish consumer (Virtanen *et al.*, 2010). Other, partly proportional more significant environmental impacts are also linked to food, for example entrophication and biodiversity. Some of them are difficult to measure and communicate by product-based tools, such as LCA, as there are not received methods available. Eutrophication is based on material flows, and it typically includes to the LCA studies. Eutrophication impact of food seems to be parallel to climate impact (e.g. Kurppa *et al.*, 2009). Thus, carbon footprint of food does not misguide consumption and production regarding the most relevant material flow based impact, namely eutrophication. However, more spatial impacts may act very differently, and it may decrease significance of carbon footprint as indicator of sustainability.

Existing carbon footprints of foods are based on various kinds of data sources and calculation methods. Therefore they are not necessarily comparable with each other but they may all have their applications and niches. Carbon footprints are often based on general data and doing so they may be comparable on behalf of data quality but they are not strict enough to incite production processes towards low-carbon direction the most effective way. Consumers are able to contribute carbon footprint of his/ her consumption by choosing between different types of food, for example between pork and beef and carrots. This choice can be remarkable. However, choice between the same kinds of products from different producers can also have impact on environment, as there are differently arranged production processes within the same kind of products (Katajajuuri *et al.*, 2007). That is important choice situation as

* Corresponding Author. e-mail: merja.saarinen@mtt.fi

consumers tend to maintain their consumer habits. Only carbon footprint that is based on production chain specific primary data can form a delicate and dynamic tool that offers information for contributing to production processes of existing products.

Not only carbon labels but also various carbon bonus/credit systems for households are currently in use or under development in many countries (Perrels *et al.*, 2009). In addition to the knowledge, they provide means and motivation to promote products and solutions with low greenhouse gas emissions. In order to enable a practicable and credible bonus system for households and comparable product-related information for consumers, development of the underlying product-related information system is critical.

This paper outlines the proposal for the Finnish system of certified carbon footprints of products (the CFP system). The CFP system addresses the challenges of providing reliable, cost effective and up-to-date data to formulate a realistic and systematic information structure that represents the basis of a bonus system for households as well as product-related carbon footprint (Usva *et al.*, 2009a).

2. Outline of the Certified Carbon Footprint of Products -system (the CFP system)

The development of the CFP system was strongly supported by experiences in EU's Emission Trade Scheme (EU-ETS) and empirical LCA-studies. In addition, relevant standards, as ISO 14040, 14044 (ISO 14040 series), 14025 (ISO 14020 series) and specifications were PAS 2050 (BSI 2008) incorporated.

In Figure 1 a scheme of CFP system and its linkages to standards and environmental management systems is described. The CFP system is linked to environmental management systems to emphasize practicality of system for producers alongside with effectiveness of steering mechanism and reliability of information. However, until now CFP system is just a theoretical structure and it needs to be further developed and introduced through application and interaction between different actors.

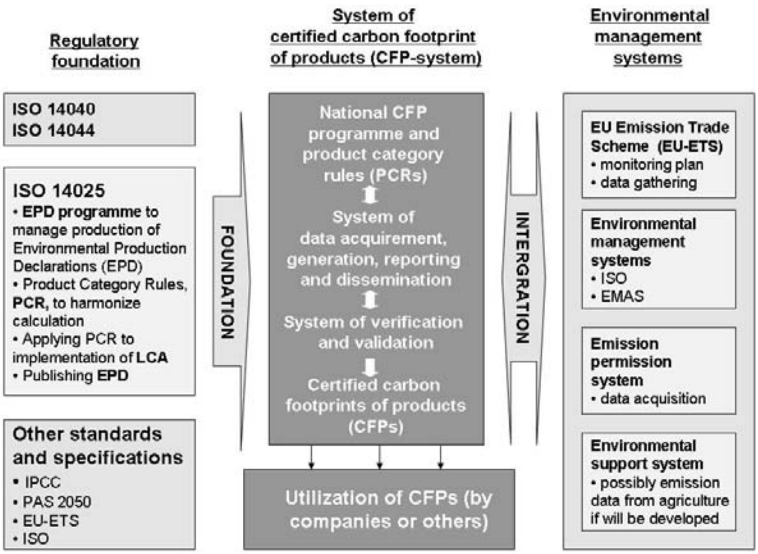

Figure 1: The CFP system and its linkages to general regulations and other environmental management systems.

The CFP system aims to provide representative, reliable and up-to-date information on carbon footprints of products. It truly should provide information at product level. To be feasible it should be cost-effective to society and producers, and acceptable, flexible and user-friendly for producers. The system should allow for gradual improvement of resolution, scope and accuracy of information within the system.

Key elements of the CFP system are 1) utilisation of real monitored process-based activity data, 2) calculation rules at three levels, and 3) procedures for validation, verification, and data dissemination. To tackle some challenges important for food products concept of voluntary emission guarantees and a ceiling level for total product emissions are introduced.

2.1 Utilisation of real monitored process-based activity data

Supporting primary activity data production is a main task for the proposed CFP system. The CFP system is based on responsibility of producers for (carbon) balance area data generation, which is vital for improving environmental performance of product. Balance area can be a farm, for example. In our experience on LCA studies of food products, downstream actors (e.g. farm) are not necessarily enthusiastic about giving information on their activities if upstream actor (processing industry) asks initial data for LCA calculation. This does not mean that downstream actors do not want to improve their environmental performance but it may evidence that improving product chain performance based on that kind of data production structure is not as effective as it could be. We are convinced that if actor is responsible for information on its own activities right from the beginning, and respectively it is recognized that they actually own that information, starting point for co-operation to improve environmental impacts of product are much better. The starting point is more on equal footing.

2.2 Calculation rules at three levels

In the CFP system calculation rules for data production is harmonised at three levels, which form a hierarchy so that the upper level determines the lower level (figure 2). The regulation tools are 1) CFP Programme, 2) Product category rules, PCR, and 3) the Chain Monitoring Plan. The CFP programme and PCR are based on ISO 14025 Standard on environmental product declaration, while the concept of Chain Monitoring Plan has received influence from EU-ETS (EC 2007).

The CFP Programme is the forum where level of harmonisation and details of regulations could be discussed across sector boundaries. The CFP Programme would establish procedures and content for developing the PCRs for different product groups. The CFP Programme can be established nationally or Finnish activities might be channelled into the Swedish International EPD® -system, for example. Existing EPD systems are, however, not developed well enough for the outlined CFP system. For example data quality requirements should be sharpened.

The main issues to be addressed at PCR level are listed in Figure 2 (ISO 14025). Some of them may be defined already at the CFP Programme level, while others are product group specific. Some of the issues are especially challenging for food, for example variability in emission over time and allocation.

Emissions of agricultural products vary over time because emissions are derived from yield. The yield expectations determine input level, but yields are actually determined by conditions during the season. Consumer preference therefore cannot influence emissions. The annual variation in yields considerably influences total life cycle results of product because agricultural production is the most critical phase of life cycle of food. Consumers are not able to appreciate changes that may occur in a production chain elsewhere than in agriculture, because the climate impacts are confounded with yield level changes. Using a longer time span can obviate this problem. The mean value of three harvests fluctuates far less than annual values, but the use of *a voluntary guaranteed level* may be yet more stable and therefore more consumer-friendly. In a voluntary guaranteed level the producer asserts that emissions of production do not exceed a certain level.

Figure 2: Calculation rules in the CFP system and content of PCR according ISO 14025.

Allocation, in turn, has stimulated scientific discussion and different standards and specifications treat it inconsistently. Anyway, principles are introduced in ISO 14040 Standard (ISO 14040 series). Traditionally LCA studies are geared towards production requirements, but product oriented carbon footprints are supposed to guide consumers. It has to be considered carefully what the effects of different allocation procedures have on consumers, and accordingly how consumer choice influences production. This needs further research.

The most detailed level of calculation rules is at the monitoring plan. The continual data collection and the (annual) emission calculation are described in detail using balance area definition. In an ideal situation it is done in the Chain Monitoring Plan. Alternatively, the monitoring plan can be made separately for particular organisations or production networks. According *the modularity* in the CFP system each company in the production chain produces data on its own activities (balance areas) according to the Monitoring Plan.

2.3 Validation, verification and data dissemination

The Monitoring Plan should conform to the validating system. The results of annual emission calculations, as well as methods for continual data collection and other relevant procedures, would be described in *the annual specific emission report*. This document should be verified. After verification, the results would enter into an emission *database* and then can be used in consumer-oriented applications. *The voluntary emission guarantee of balance area* and *the ceiling level of product* are the published results of the emission calculation. If calculation value for balance area is not under the voluntary emission guarantee value or ceiling level of product, a new increased guarantee value must be defined, e.g. based on findings in the verification procedure. An outline of links in The Monitoring Plan and other key elements of CFP system are described in figure 3.

Procedures of verification and validation should be linked to the environmental management systems that exist in the production chains.

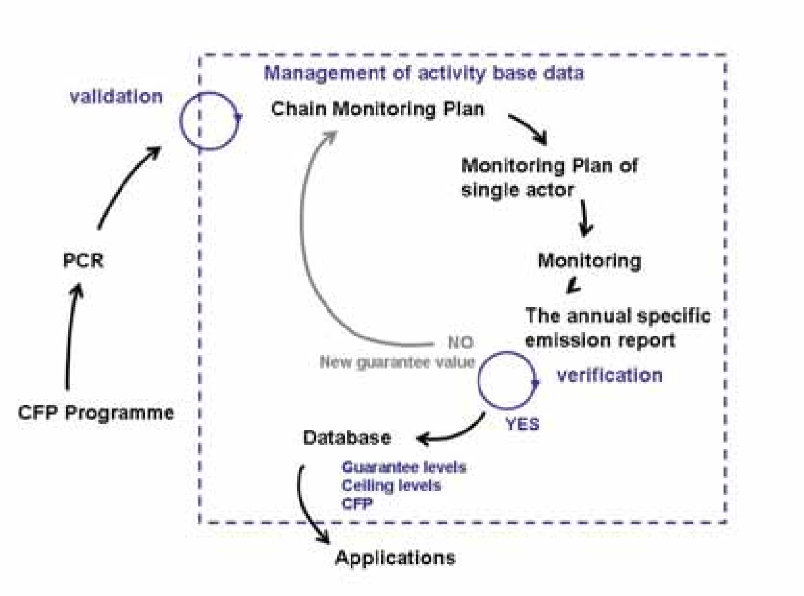

Figure 3: Links of key elements of the CFP system.

3 Discussion - Implementing of the CFP system in the Finnish food sector

For implementing the CFP system for the food sector the entire data production and dissemination system has to be created from scratch. Fortunately some major participants in the food sector, mostly in industry and trade, have a tradition of studying environmental impacts using the life cycle approach (Usva *et a*l., 2009b, Kurppa *et al.*, 2009, Saarinen *et al.*, 2009). However, the majority of actors of food sector are small and middle-sized companies (SMEs), including both farms and industry. It is likely that generation of carbon data will tend to be channelled through central players. So, one impending challenge is to get SMEs to participate in PCR and data production. Development activities and costs are expected to be directed at agricultural production, but the downstream actors (brand owners) might benefit from the lower production costs through lower purchase prices, increased competition and/or possibly higher value of more climate-friendly end products. Attempts should be made to avoid this kind of situation. The system should promote total sustainability and corporate responsibility, and it should be fair and attractive for small actors too.

In terms of the purchase of raw materials from the food industry, the growing challenge is that industrial suppliers (and trade regarding own labels) are in constant flux, and often change rapidly. Use of imported materials makes data acquisition more difficult, which is a basic challenge for manufactures and highlights the importance of traceability as the primary task to encourage business responsibility. In principle, a product with an untraceable production chain could not be included in the CFP system.

Data generation on agricultural primary production needs to be developed for a broad client base by researchers and the agricultural sector, and based on public funding. The R&D work should include at least development of emission modelling, data dissemination methods (linked to traceability) and development of administrative/political steering systems (e.g. environmental support). Most impacts of agricultural production originate from biological processes, and they are not easy to measure and scientific knowledge about them is expanding. For example, land-use and land-use change impacts on CO_2 emissions have been neglected. The (conservative) defaults for N_2O and CH_4 emission are maybe the only present possibility for calculating the carbon footprint of the food products. In the beginning the default values should be as extensive as possible, but from now more specific default values for varied situations have to be defined. In summary, the resolution of emission calculation has to be increased. Regarding an environmental support system based on EU Agri-Environmental Schemes requirement for farmers to produce comprehensive information about their production evidently need to be considered in relation to climate impacts and product-oriented environmental data production.

The CFP system is directed at providing carbon footprints, but a similar system structure could serve also a provision of information on other environmental impacts of products.

4. References

EC (2007): COMMISSION DECISION (2007/589/EC). Establishing guidelines for the monitoring and reporting of greenhouse gas emissions (MRG2) pursuant to Directive 2003/87/EC of the European Parliament and of the Council.

Katajajuuri J-M. (2007): Experiences and Improvement Possibilities - LCA Case Study of Broiler Chicken Production, In: 3rd International Conference on Life Cycle Management, Zurich, Switzerland, 27–29 August 2007, 6 p.

Kurppa S., Grönroos J., Hyvärinen H., Katajajuuri J-M., Kauppinen T., Mäkelä J., Nissinen A., Nousiainen J., Saarinen M., Usva K., Viinisalo M., Virtanen Y. (2009): Environmental impacts on a lunch plate – challenges to interpret the LCA results? Proceedings of Future of the Consumer Society Conference, 28–29 May 2009, Tampere, Finland.

Perrels A., Hongisto M., Hyvönen K., Katajajuuri J.-M. and A. Nissinen (2009): A quick scan of climate policy services and underlying data system approaches – Climate Bonus project report (WP1), VATT Research Reports 143:1

Saarinen M., Mäkelä J., Viinisalo M., Kurppa S. Nissinen A. (2009): Application of lunch plate model for communication of environmental impacts of the consumer’s food choices. Proceedings of Future of the Consumer Society Conference, 28–29 May 2009, Tampere, Finland.

Usva K., Hongisto M., Saarinen M., Katajajuuri J.-M., Nissinen A., Perrels A., Nurmi P., Kurppa S., Koskela S. (2009a): Towards certifies carbon footprints of products – a road map for data production. Climate Bonus project report (WP3), VATT Research Reports 143:2

Usva K., Saarinen M., Katajajuuri J-M., Kurppa S. (2009b): Supply chain integrated LCA approach to assess environmental impacts of food production in Finland. *Agricultural and Food Science*, 18(3-4), pp. 460-476.

Virtanen Y., Kurppa S., Katajajuuri J-M., Saarinen M., Usva K., Mäenpää I., Mäkelä J., Grönroos J. Nissinen A. (2010): Carbon footprint of food – approaches from national input-output statistics and a food portion. *Journal of Cleaner Production*. (submitted)

Carbon footprint of four different Brazilian chicken feed scenarios

Rodrigo Augusto Freitas de Alvarenga[1, *], Vamilson Prudêncio da Silva Júnior[1,2], Sebastião Roberto Soares[1]

[1]Univ. Federal de Santa Catarina, Dept. de Eng. Sanitária e Ambiental, 88040-970, Florianopolis, Brazil
[2]INRA, UMR 1069 Sol Agro et hydrosystème Spatialisation, F-35000 Rennes, France

ABSTRACT

A way to quantify the environmental impacts of a product in relation to global warming is the carbon footprint. This study is a comparison of four scenarios for production of chicken broiler feed in Brazil using this methodology. According to Katajajuuri *et al.* (2008), 36% of broiler's GWP is from feed production. The results of this study show that the worst scenario emitted 739 kg of CO_2 eq per ton of feed at feed factory gate and the best scenario emitted 512 kg of CO_2 eq. The maize production in center-west is the most impacting stage, accounting for 254 kg of CO_2 eq per ton of feed, mainly due to emissions of N_2O and CO_2. From this study, we might see that one single characterization for Brazilian maize and soybeans can lead to misleading results, since Brazilian territory is vast, and different types of soil and farming methods are found.

Keywords: Carbon footprint, LCA, chicken feed, Brazil

1. Introduction

Recently, due to issues related to the global warming impacts, several stakeholders have been researching ways to measure emissions associated with products (goods and services). Some carbon footprint methods are under discussion, basically looking for LCA simplifications, to turn possible to evaluate a large number of products in a short period of time. The concept of carbon footprint originated from Ecological Footprint, created by Rees and Wackernagel in the 1990s. A broad definition would be that the carbon footprint is equal to the amount of GHG emitted directly or indirectly by a person, organization or product (Johnson, 2008).

Carbon footprint is not new, since it was previously used, but with a different name. It is nothing more than a LCA using the IPCC's model as a method of Life Cycle Impact Assessment (Finkbeiner, 2009). The British Standards Institute (BSI), along with Britain's Department for Environment, Food and Rural Affairs (DEFRA) and the Carbon Trust, published in 2008 a guide to standardize carbon footprint of products (goods and services) during throughout their life cycle. It is called PAS 2050.

In the production of broiler chickens, the feed supplied occupies a very important role, since it is what will provide the necessary nutrients for proper growth. The manufacture of feed depends on several technical conditions. Feed ingredients must be of good quality and must meet the minimum standards established by the Ministry of Agriculture. The amount of each ingredient varies depending on the age of the chicken, and its formula should be recalculated if used alternative ingredients (wheat, sorghum, etc.) (Bellaver, 2003). According to Katajajuuri *et al.* (2008), broiler's feed production is responsible for 36% of global warming potential from the entire broiler system (from cradle to retail stores).

[*] Corresponding Author. e-mail: alvarenga.raf@gmail.com

The objective of this study is to evaluate environmentally four broiler's feed production scenarios, each one with maize and soybeans from a different region of Brazil (South or Center-west), using carbon footprint.

2. Methodology

We performed a carbon footprint, from cradle to gate, of broilers' feed. The functional unit was to feed 217,000 chicken broilers from south region of Brazil. Since we considered a feed conversion of 1.86kg of feed for every 1.00 kg of broiler and an average weight of 2.48 kg for the broiler, the reference flow established was 1,000 kilograms of feed ready to be consumed, with 21% crude protein and 3,100,000 kilocalories (kcal) metabolizable energy. The broilers' feed system is composed of seven stages (figure 1):

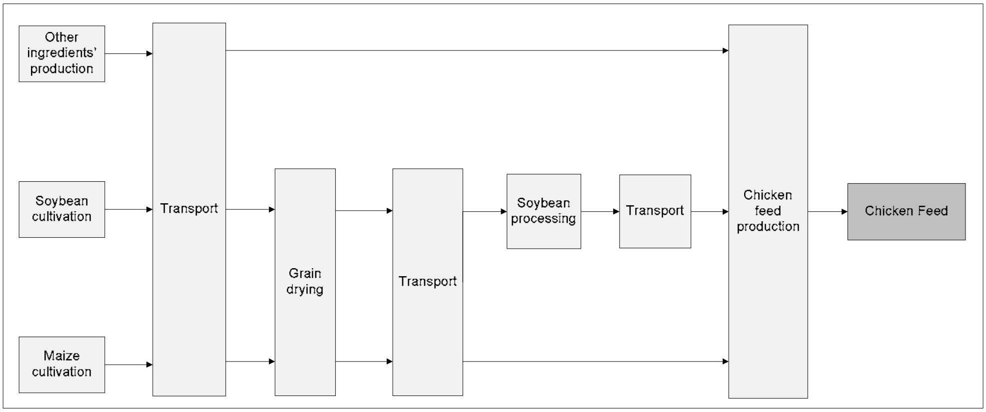

Figure 1: Simplified flowchart of broilers' feed system

We considered that the feed factory was located at Chapeco city (Santa Catarina state). Then, we created four scenarios:

(1) Feed CW–CW: Feed composed with maize and soybean meal from Center-west;
(2) Feed CW–SO: Feed composed with maize from Center-west and soybean meal from South;
(3) Feed SO–CW: Feed composed with maize from South and soybean meal from Center-west;
(4) Feed SO–SO: Feed composed with maize and soybean meal from South.

To make the carbon footprint, we adopted the concept from Finkbeiner (2009), the methodology proposed by (BSI; Carbon Trust; DEFRA, 2008a; b) and used the model IPCC 2007 GWP 100a.

All Life Cycle Inventory (LCI) of this study was done from secondary data. To make the LCI from maize and soybean production stages of each region, we used data from government agencies, cooperatives and database in order to determine the economic costs. Because of that, we established mean values of inputs and outputs for each production system (south and center-west regions). We determined the yield factor for each region by official data from the Brazilian government from the last five years (2003/2004 – 2007/2008). After all, we established the amount of inputs, outputs and the yield of each region, resulting in different environmental impacts for each scenario. For grain drying stage and for soybean processing stage we used data from Marques (2006) and Nguyen (2009), respectively. For the production of other ingredients we used data from Ecoinvent database. For transport and feed production stages, we used (verbal information†), the Google Earth software and the ALL‡ report. When necessary, we used the Ecoinvent database.

We obtained the composition for one ton§ of broiler feed at "Aurora Alimentos", from internal company records. The ingredients are showed in table 1. The quantities were omitted at the request of the company.

Ingredient
Maize grain (dry)
Soybean meal
Tallow mix
Salt
Dicalcium phosphate powder
Limestone
Methionine
L-lysine
Premix
L - Threonine
Colina powder (60%)
Phytase
Rovabio
Anticoccidial
Adsorbent

Table 1: Composition of the broiler feed studied

According to Bellaver (2003), more than 90% of the broiler's feed is composed with maize and soybean meal. In general, the composition of maize varies from 54% to 58% and soybean meal from 32% to 37% of the total weight.

3. Results and Discussion

From Figure 2, we can see that the scenario of broiler feed CW-CW is the worst, with 739 kilograms of CO_2 equivalent (CO_2 eq). The second worst scenario is the SO-CW, with 676 kilograms of CO_2 eq, followed by CW-SO, with 575 kilograms of CO_2 eq, and finally the scenario SO-SO, which is the most environmentally friendly, with 512 kilograms of CO_2 eq.

Evaluating the process regardless of the scenarios, the maize grown in the Center-west, with 254 kilograms of CO_2 eq emitted, is the process with greater environmental impact. Of this amount, 39% are due to emission of N_2O, which is due to the use of fertilizers (chemical and organic) and the degradation processes of roots, organic matter, straw and crop residues. The CO_2 emission contributes with 57% of the value, and this gas is emitted in the sub-processes of deforestation, the production of urea and at the cultivation process due to the use of diesel. Maize from the South region is the second greatest striking process, accounting for 231 kilograms of CO_2 eq. Of this amount, 52% comes from the emission of N_2O. The CO_2 emission contributes 46% of that amount, and the emission of this gas occurs mainly in the production of urea (46%), consumption of diesel (23%) and production of P_2O_5 (13%).

† Interview given by Dr. Sc. Rodrigo S. Toledo, responsible for the Animal Nutrition area of Aurora Alimentos, on October 8th, 200,9 at Chapecó (SC).

‡ Report from *América Latina Logística*'s (ALL) railroads.

§ Thru all the text, ton refers to metric tonnes.

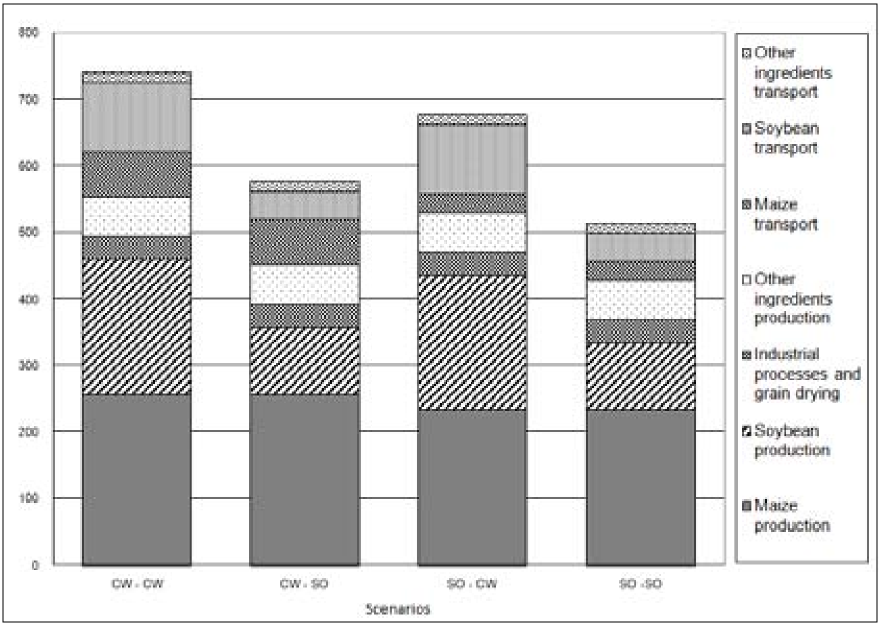

Figure 2: Carbon footprint of four Brazilian chicken feed scenarios, per ton of feed at feed factory gate

Soybeans from Center-west accounted for 203 kilograms of CO_2 eq. Of these, about 33% is from CO_2 emissions due to deforestation, 17% from N_2O emitted at cultivation, 15% from the CO_2 emissions due to consumption of diesel in the process and 10% due to CO_2 emissions due to production of P_2O_5. Soybeans from South region emitted 102 kilograms of CO_2 eq. Of this amount, 33% is due to the emission of N_2O in cultivation, 29% from CO_2 emissions from the sub-process of the diesel consumed in the cultivation and 14% from the emission of the same gas, to produce P_2O_5.

The transport of soybeans from the Center-west region contributed with 103 kilograms of CO_2 eq, in which its vast majority (95%) were CO_2 emissions from transport. From this CO_2 emission, 55% were generated in the road transport of soybean meal, 27% from road transport of dry soybeans and 18% from rail transportation of soybean meal. The transport of maize from the Center-west accounted for 68.28 kilograms of CO_2 eq, and the vast majority (96%) was CO_2 emissions. 67% of it are from road transport and 33% of rail transport. The transport of soybeans from South region emitted 40.65 kilograms of CO_2 eq, and its vast majority (97%) were CO_2 emissions in different types of transport. From that, 69% were from the road transportation of soybean meal, 22% for road transport of dry soybean and 9% from rail transport of soybean meal. The transport of maize from South region emitted 28.81 kilograms of CO_2 eq, and the vast majority (97%) were CO_2 emissions. Of these, 51% were due to CO_2 emissions from road transportation and 49% from rail transportation.

The soybean processing stage released 31.91 kilograms of CO_2 eq. Of these 91% were from CO_2 emissions due to several sub-processes, being the main one natural gas furnace heating (60%). For the feed production, 1.58 kilograms of CO_2 eq was released due to electricity consumption. For grain drying stage, 1.15 kilograms of CO_2 eq was emitted mostly due to the wood burned for energy production.

Despite the fact that the maize and the soybean cultivated in center-west region of Brazil release less dinitrogen monoxide (N_2O) in the atmosphere, the greater emission of CO_2 from fossil origin (due to the higher distance travelled) and CO_2 from land transformation (substance existed in the process 'Provision, stubbed land, BR') make the scenarios that have grains from center-west region have higher carbon footprint.

As shown before, maize production was the most striking process. Although, this might be due to its high contribution on the recipe (54% - 58%). In order to get real conclusions from this study, we performed an evaluation of one ton of maize and soybean (from center-west and south regions), resulting in the following values: 428 kilograms of CO_2 eq from maize from center-west region, 338 kilograms of CO_2 eq from maize from south region, 672 kilograms of CO_2 eq from soybean from center-west region and 337 kilograms of CO_2 eq from soybean from south region. The reasons for these values have already been discussed and will not be repeated here. With this we can conclude that maize production is the most striking stage due to the large amount used in the production of broiler's feed, since the soybean from center-west region appeared to have the highest carbon footprint.

4. Conclusion

We observed that the classification of CW – CW as the worst scenario and SO – SO as the best was not only due to the bigger distance to be traveled (expressed by transportation), but also due to the deforestation, sometimes needed in center-west region of Brazil. Thus, within this scope, we could see that maize and soybean production processes from center-west region release more GHG than the ones from south region, contributing with 125 kg of CO_2 eq, which is more than 55% of the total difference (227 kilograms of CO_2 eq).

From this study, we might see that one single characterization for Brazilian maize and soybeans in the international market can lead to misleading results. The reason for this is that since the Brazilian territory is vast, different types of soil and farming methods are found. Thus, for LCA studies using Brazilian soybeans and/or maize, it is important to know and quantify the environmental impacts from the cradle.

5. References

Bellaver C. (2003): Nutrição e Alimentação. In: AVILA, Valdir Silveira de. Produção Frangos de Corte. Sistemas de Produção 2. Concórdia, SC: Embrapa Suínos e Aves.

BSI, Carbon Trust, DEFRA (2008a): Guide to PAS 2050:2008: How to assess the carbon footprint of goods and services. Londres, Reino Unido.

BSI, Carbon Trust, DEFRA (2008b): PAS 2050:2008: Specification for the assessment of the life cycle greenhouse gas emissions of goods and services. Londres, Reino Unido.

Finkbeiner M. (2009): Carbon footprinting—opportunities and threats. *International Journal of Life Cycle Assessment*, 14(2), pp.91-94.

Johnson E (2008): Disagreement over carbon footprints: A comparison of electric and LPG forklifts. *Energy Policy*, 36 (4), pp.1569-1573.

Katajajuuri J.-M., Grönroos J., Usva K. (2008): Environmental impacts and related options for improving the chicken meat supply chain. Proceedings of the 6th International Conference on Life Cycle Assessment in the Agri-Food Sector. Zurich, Switzerland, November 12-14 2008.

Marques B. d. A. (2006): Considerações Ambientais e Exergéticas na Fase de Pós-Colheita de Grãos: Estudo de Caso do Estado do Paraná. 98p. Dissertação (Mestrado) - Programa de Pós-graduação em Engenharia de Recursos Hídricos e Ambiental - Departamento de Hidráulica e Saneamento, Universidade Federal do Paraná, Curitiba (PR), Brasil.

Nguyen H. T. T (2009): Contraintes environnementales et formulation d'aliments pour la volaille. Rennes, França.

Comparison of LCA and EFA for the environmental account of fruit production systems: a case study in Northern Italy

Alessandro K. Cerutti[1,3,*], Marco Bagliani [2,3], Gabriele L. Beccaro [1], Cristiana Peano[1], Giancarlo Bounous[1]

[1]Department of Arboriculture, University of Torino, Via Leonardo da Vinci, 44 – 10095 Grugliasco (TO), Italy
[2]Department Territory and Environment, IRES (Istutito Ricerche Economico Sociali) Piemonte, via Nizza 18, 10125, Torino, Italy
[3]IRIS (Interdisciplinary Research Institute on Sustainability), University of Torino, via Accademia Albertina 13, 10100, Torino, Italy

ABSTRACT

Although various study cases can be found on the application of environmental indicators in agricultural activities, applications on the fruit production systems are stills rare. In the present study we apply the Life Cycle Assessment (LCA) and the Ecological Footprint Analysis (EFA) at the same commercial nectarine orchard in Piedmont (Northern Italy) in order to highlight the differences both on the results and on the methodological issues. Great care was used to choose an equal boundary setting, to consider an identical schematization of the productive processes and to utilize data referring to the same production stage. In both indicators, the calculation was conducted considering the six orchard stages highlighted by Milà i Canals (2003). The LCA was conducted in compliance with the guidelines and requirements of the ISO 14040 standard series, while EFA calculations were performed by using the methodology and the specific conversion factors implemented by the Global Footprint Network.

Keywords: Orchard management, Fruit production, Nectarine, Life cycle assessment, Ecological Footprint analysis

1. Introduction

Fruit production is considered an agricultural sector with low environmental impacts in comparison to other food sectors when considering the energy in the life cycle per kg of product (Carlsson-Kanyama et al., 2003). On the other hand the use of pesticides is an important key-issue that may increase heavily environmental impacts. As a consequence quantification of the sustainability of fruit production is required to make specific considerations and comparisons. Although a lot of aspects of the environmental accounting methodologies in the agricultural sector are already investigated, still rare are the application of an environmental indicator in fruit production (Gaillard and Nemecek, 2009).

The objectives of this work are (i) to verify the application two different environmental accounting methods to fruit production: Life Cycle Assessment and Ecological Footprint Analysis; (ii) verify the potential of each method to determine the impact of the one-year cultural practices versus the whole orchard lifetime.

[*] Corresponding Author. e-mail: alessandro.cerutti@unito.it

2. Methods

2.1. System description and data sources

Nectarine system and data sources are the same for both LCA and EFA, therefore they are described in one chapter. Specificity of the two different methods are described beyond.

Orchards are complex biological productive systems. In order to obtain reliable environmental assessments in orchards, instead of considered only the one-year field operations, all the impacts related to the entire lifetime of the orchard have to be accounted (Mila i Canals and Polo, 2003; Cerutti *et al.*, 2010). Therefore system boundary includes production of differentiated nectarine farming inputs and their transport to the field, fuel and electricity use during nectarine farming, nursery, orchard installation and destruction (Figure 1).

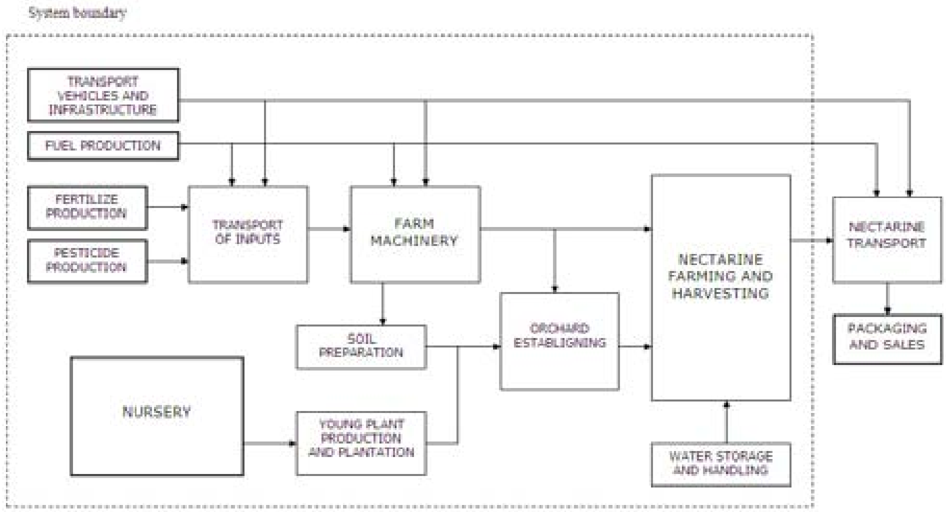

Figure 1: Reference case product system boundary for both EFA and LCA. Bold boxes indicate independent systems related to nectarine production and consumption.

The inventory was based on data from a commercial nectarine (*Prunus persica* var. *laevis* Gray) orchard in Cuneo province, Northen Italy, managed according to the Italian Integrated Fruit Production (IFP) protocol. Impacts and resources use for all of the farming operations were obtained directly on field during years 2008-2009. All other information required (e.g. nursery impacts and resources use) were collected from average agricultural practices provided by COLDIRETTI (Confederazione Nazionale Coltivatori Diretti Piemonte).

As proposed by Mila i Canals and Polo (2003) the productive system was divided in 6 stages (ST) and environmental impacts and resources use for each stage were accounted.

ST1. Nursery stage (accounted for 2 years). This stage was evaluated as the average processes and resources needed to obtain rootstocks, scions and finally young plants.

ST2. The establishment stage (occurs just one time, therefore it was accounted as 1 year). This stage was evaluated as the common practice of removing previous installation and preparing the field for the orchard. Plastic, steel, wood resources and energy for the orchard installation have been added in proportion to the lifetime of the orchard.

ST3. Low yield production due to young plants (accounted for 2 years). This stage includes all the one-year field operation (see ST4) but all impacts and resource use are proportioned to an average production on 12 t ha^{-1} due the youth of the plants.

ST4. Full production (accounted for 13 years). Following information provided from the farmer and considering local pedoclimatic conditions, agrotechniques and cultivar, the average commercial yield for 13 years as been estimated as 18 t ha^{-1}. This stage includes all the one-year field operation, particularly:

- tree management: this category comprises of operations aimed to improve orchard productivity, facilitate harvest and prevent disease proliferation (Mila i Canals and Polo, 2003).
- pest and diseases management: pesticide applications are by air-blast spraying 15 times per season using 56 kg ha-1 of active ingredients diluted in 16000 l of water per ha.
- understorey management: the management of the soil between the rows seeks to prevent competition for water or nutrients with the trees and erosion (Mila i Canals et al., 2006).
- irrigation: trees received water through drip pipe irrigation directly under the tree canopy. This system requires pumping systems that consumes electricity.
- weather damage prevention: hail prevention nets were installed, opened and closed once per season, with two field crossings by hydra-ladder.

ST5. Low yield production due to declining plants (accounted for 2 years). This stage includes all the one-year field operation (see ST4) but all impacts and resource use are proportioned to an average production on 12 t ha^{-1} due the old age of the plants.

ST6. The destruction of the orchard (occurs just one time, therefore it was accounted as 1 year). This stage was principally accounted for machinery and fuel.

2.2 Life Cycle Assessment

The functional unit for analysis is 1ton of nectarine that cross the farm gate to various commercial systems. Analysis was conducted using the software SimaPro 7, with the Eco-indicator 99 H/A (Goedkoop, & Spriensmaa, 2000) method developed by Pré Consultants of the Netherlands[1]. Various authors consider Eco-indicator 99 as one of the major environmental impact assessment method, comprehensive in nature and generating a single numerical value reflecting the composite magnitude of global impact associated with a specific product. We decided to apply the hierarchist perspective because it can be considered generalist and intermediate for most of aspects (Goedkoop, & Spriensmaa, 2000). Impact assessment is carried out to obtain a single numerical value, called Single Score, that can be easily compared to the ecological footprint of the same productive process.

2.3 Ecological Footprint Analysis

EFA is an environmental accounting system that provides an aggregate indicator that is both scientifcally robust and easy to understand by non-experts. Introduced by Rees (1992) and further developed by Wackernagel and Rees (1996), the ecological footprint quantifes the total area of the terrestrial and aquatic ecosystems necessary to supply all resources utilized and to absorb all resultant emissions involved in the production of particular products. Following the standard methodology (Global Footprint Network, 2009) all resources used for the orchard lifetime were converted into bioproductive area by using specific conversion factors available from the Global Footprint Network database (Global Footprint Network, 2006) and further updates (Ewing et al., 2009). When conversion factors were not available, embodied energy coefficients were used to convert data into the equivalent emission of CO_2. The soil occupied by structures was accounted as a built-up land component. The water consumed was accounted as the energy necessary for the irrigation and consequently, as the amount of CO_2 related to that energy.

[1] This method is still valid but just outdated. New works should use ReCiPe (Goedkoop *et al*, 2009) as the more up-to-date LCIA method.

3. Results

Main LCA results are presented figure 2.The main impact category is fossil fuels, that account for 84.91% of all the environmental impacts generated trough the production of 1 ton of nectarine. Other significant categories are respiratory inorganics (9.03%), climate change (3.61%) and acidification/eutrophication (1.02%). All other categories contribute less than 1%. Among the stages involved in peach production, ST4 (operations and resources for production high yield years) has, as expected, the highest contribution to the whole analysis: 61.96%. Characterization analysis permit to underline the amount of each impact category in each production stage. For example the impact category fossil fuel vary from 63.03% in ST1 to 93.08% in ST6; respiratory inorganics vary from 4.81% in ST6 to 22.56% in ST2; climate change vary from 1.16 in ST6 to 10.33% in ST1. Process contribution analysis (EI99 H/A, single score) show the high impact of gasoline use (70.32%), followed by electricity (6.05%), pesticide use (5.39%), N-fertilizer use (4.90%), natural gas use (4.66%). All other process contribute less than 3%.

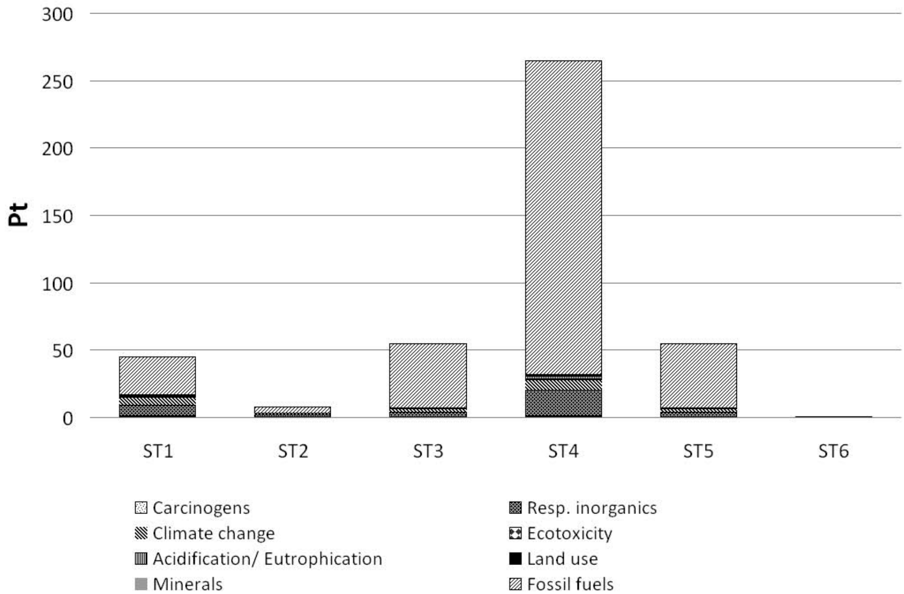

Figure 2: Impact assessment results (weighted values – Eco-indicator 99 H/A) presented in single score histogram. Impact categories that weight less than 0.1% on total pt are not shown.

Main EFA results are presented in figure 3. The total ecological footprint for the case study was 1.20 gha t^{-1} nectarines produced. The major land-component is the carbon-footprint that covers 83.27 % of the whole footprint. Lower contribution comes from the other land-components: cropland (16.37%), forest (0.32%) and built-up land (0.02%). Also in EFA, ST4 present the highest contribution: 63.89% of the overall footprint. The other stages make substantially lower contributions to the overall impact, specifically: ST1=4.83%, ST2=11.59%, ST3=ST5=9.82%, ST6=0.02%. Another interesting result is the comparison between the contribution of each resource used to the overall footprint. The main contribution came from electricity consumption (40.12%), followed by effective soil utilized for production (orchard, nursery and occupied land, 16.39%), diesel consumption (15.25%), plastic for the installations (12.82%) and fertilizers use (6.10%).

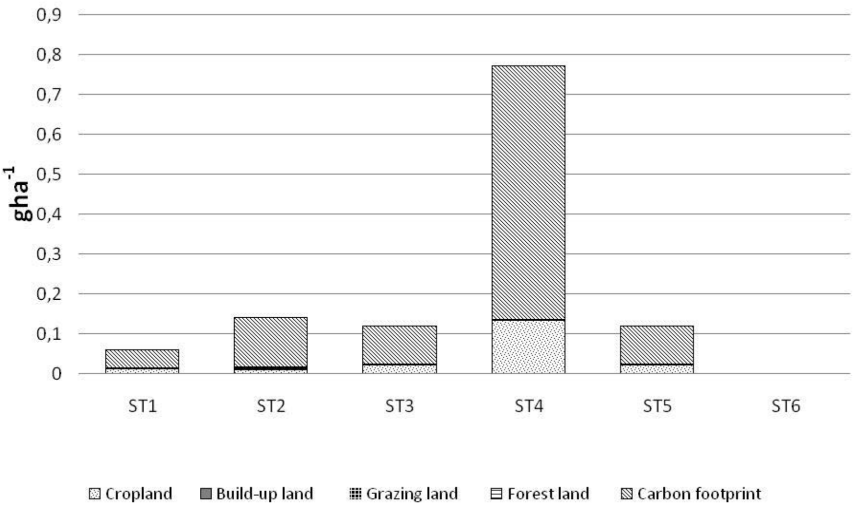

Figure 3: Ecological Footprint of the orchard system for each stage (ST1 to ST6) arranged by land categories. The footprint were accounted as the total gha of that stage divided by the total tonnage of nectarine produced from the orchard across all years.

4. Discussion

The comparison of two different assessment methodology applied to the same productive process permit to discuss both results and methodological issues. First important remark can be done observing figure 2 and figure 3. The results in single score LCA and Ecological Footprint values are strongly comparable. In both analysis ST4 (high yield field operations and resources use) make the major contribution to the environmental impacts of the productive system, particularly 61.96% according to LCA and 63.89% according EFA. Also stages ST3, ST5 and ST6 show similar results in both analysis: ST3 and ST5 contribute each for 12.76% in LCA and 9.82% in EFA, ST6 contribute for 0.16% in LCA and 0.02% in EFA.
Significant differences arise confronting ST1 and ST2. The first stage (nursery stage) is characterized by a relative low quantity of fossil fuel consumption, but a relative high quantity of fertilizers and chemicals products (fitoregulators and pesticides) compared to the orchard stages. As LCA account chemicals products, both for resource use for production and for negative effects when utilized (Van Zeijts et al., 1999; Powers, 2005), ST1 results higher in LCA (10.52%) than in EFA (4.83%). On the other hand the installation stage (ST2) can be considered principally as occupied land, energy as fuel consumption and materials applied to the field such plastics and wood. Those kinds of resources weight more in EFA than in LCA, therefore ST2 results higher in EFA (11.59%) than in LCA (1.82%). This difference in the accounting method in the other stages is balanced by a relative equilibrium of energy consumption and chemical products use, therefore results in overall percentage are strongly similar.

This study reveals that the gaps suggested by other authors (Mila i Canals and Polo, 2003) and evaluated in previous works (Cerutti *et al.*, 2010) can be significant and can be quantified both with EFA and LCA, with little differences. As orchard are not a single year production system (as can be open field crops), the application of an environmental indicator just to the full production year will probably underestimating the real ecological impact, in a variable percentage (in our study about 35% with both methods). More studies are required to verify the average gap for each fruit species; when these data are available, consideration of all stages in the application of LCA, EFA and other ecological/sustainability indicators is strongly advised.

It is interesting to compare the contribution to the total impacts that comes from specific resource used in both assessment. Fertilizers are accounted globally in EFA and divided in N, P_2O_5, K_2O component in LCA, but the total contribution is similar: 8.94% in LCA and 6.10% in EFA. These results are concordant to Mila i Canals *et al.* (2006) which identified fertilizer production and use as responsible for 5–11% of the environmental burdens of fruit production. An interesting difference can be remarked looking at the way to account the energy applied to the system. In EFA the major energetic component is electricity, that covers about 40% of total footprint, followed by diesel consumption (15.25%); but in LCA fuel consumption is responsible for about 70% (process contribution analysis) and electricity for just 6%. This difference can be explained mainly by the normalization/weighting methods of the hierarchist perspective that increase numerically the importance of the fossil fuel consumption (Goedkoop, & Spriensmaa, 2000).

5. References

Carlsson-Kanyama A., Ekstrom M.P., Shanahan H.,(2003): Food and life cycle energy inputs: consequences of diet and ways to increase efficiency. *Ecological economics,* 44, pp.293-307.

Cerutti A.K., Bagliani M., Beccaro G.L., Bounous G., (2010): Application of Ecological Footprint Analysis on nectarine production: methodological issues and results from a case study in Italy. *Journal of Cleaner Production*, 18:771-776

Ewing B., S. Goldfinger, A. Oursler, A. Reed, D. Moore, and M. Wackernagel. (2009). The Ecological Footprint Atlas 2009. Oakland. Global Footprint Network

Gaillard G., Nemecek T., (2009): Editorial to the Proc. of the 6th Int. Conf. on LCA in the Agri-Food Sector, Zurich, November 12–14, 2008. http://www.agroscope.admin.ch. (accessed 07.04.2010)

Global Footprint Network, 2009. Ecological footprint standards 2009. Global Footprint Network, Oakland, CA. Available at: www.footprintstandards.org, (accessed 01.04.09).

Goedkoop, M. and Spriensma R. (2001): The Eco-indicator 99: a damage oriented method for life cycle impact assessment: methodology report. Den Haag, Ministerie van Volkshiusvesting, Ruimtelijke Ordening en Milieubeheer.

Mila i Canals L., Burnip G.M., Cowell S.J.,(2006): Evaluation of the environmental impacts of apple production using Life Cycle Assessment (LCA): Case study in New Zealand. *Agriculture, Ecosystems and Environment,* 114, 226-238.

Milà i Canals L., Clemente Polo G., (2003): Life cycle assessment of fruit production. Cap. 4. In: Mattsson B., Sonesson U., Environmentallyfriendly food processing. Woodhead Publishing Limited and CRC Press LLC, Cambridge and Boca Raton pp. 29–53.

Powers S.E., (2005): Quantifying cradle-to-farm gate life-cycle impacts associated with fertilizer used for corn, soybean, and stover production. Technical Report NREL/TP-510-37500. Midwest Research Institute, Battelle.

Rees W.E., (1993): Ecological footprints and appropriated carrying capacity: what urban economics leaves out. *Environment and urbanization*, 4, pp. 121–130.

Van Zeijts H., Leneman H. Wegener Sleeswijk A.,(1999): Fitting fertilisation in LCA: allocation to crops in a cropping plan. *Journal of Cleaner Production*, 7, pp. 69–74.

Wackernagel M., Rees W.(1996): Our Ecological Footprint: Reducing Human Impact on the Earth. New Society Publishers, Gabriola Island, BC.

Calculation and verification of carbon footprint in agricultural products

Juan A. Polo[*,1], Juan A. Salido[2], Anxo Mourelle[3]

[1] CO2 consulting, General Manager – Madrid, Spain
[2] Det Norske Veritas, Sustainability Services Manager – Iberia - Madrid, Spain
[3] CO2 consulting, CEO – La Coruña, Spain

ABSTRACT

A methodological guide has been elaborated to calculate and verify the carbon footprint of an agricultural product in its life cycle, using as a reference PAS 2050 and ISO 14067. The guide has been tested in five different products: ecological and conventional olive oil, ecological and conventional wine and ecological cherry tomato crate. The verified results allow the producers to improve the knowledge of their processes not just from a environmental point of view, but also in terms of energetic efficiency and, consequently, of economic profitability. The message that these producers can transmit to the society is that they have calculated the emissions associated to their products and that they are committed to reduce them. It is important to emphasize that this project has been developed in a sector, agriculture, where it is not compulsory to communicate these emissions and therefore we are talking about a voluntary declaration.

Keywords: Carbon Footprint, Life Cycle Assessment, Sustainability, Emissions, GHG

1. Objectives

The main objective of this project has been to develop a methodology to calculate the carbon footprint in agricultural products and to calculate this information in five functional units used as pilot products in their life cycles. In this statement are included three concepts that must be defined to understand properly the scope of the job:

A **functional unit** is defined as a quantified performance of a product system for use as a reference unit (ISO 14044:2006, 3.20).

The term **life cycle** includes all the stages of a product system, from raw materials to its end of cycle, including recycling or recovery activities in the case of a B2C scope or to another business, when talking about B2B (ISO 14040:2006, 3.1).

The **carbon footprint** is related to all the emissions of greenhouse gases of a product through its life cycle. This value is calculated using an equivalent unit of carbon dioxide (kg CO2e), where the global potential warming of the gases is included.

From the company point of view the main goals when affording this initiative can be the following ones:

1. To identify opportunities to decrease the carbon footprint of a product both internally and in the customers and suppliers scope: determine which steps in the supply chain have bigger influence from an environmental point of view to reduce them, select among several suppliers using their carbon footprint, choose the layout of the product, etc.
2. To provide the basis and the support related with the external demands of the product environmental results

The company objectives must be concrete, measurable, related to the company strategy and associated to the products characteristics or improvement of the environmental phases

[*] Corresponding Author. e-mail: japolo@co2co.es

specially those that the company can control better. To establish good relations with suppliers will easy the carbon footprint calculation and the accurate of this information. When talking about strategic suppliers the cooperation is especially important, as they contribute with primary information to the life cycle assessment. Once the project is working on is also important to communicate it to all the suppliers to engage them in reducing the GHG emissions.

2. Theoretical framework

The first step in the project calculation is to do a bibliographic review. After doing this review it was decided to use PAS 2050:2008 as the reference to calculate the carbon footprint, as this reference is the only one that combines the life cycle assessment with the calculation of GHG emissions. PAS 2050:2008 is the best analyzed reference to calculate the carbon footprint of a concrete product (functional unit). In this reference there are four main principles (PAS 2050:2008):

- **Relevance**: select GHG sources, carbon storage, data and methods appropriate to the assessment of the GHG emissions arising from products;
- **Completeness**: include all specified GHG emissions and storage that provide a material contribution to the assessment of GHG emissions arising from products;
- **Consistency**: enable meaningful comparisons in GHG-related information;
- **Accuracy**: reduce bias and uncertainties as far as is practical;
- **Transparency**: where the results of life cycle GHG emissions assessment carried out in accordance with this PAS are communicated to a third party, the organization communicating these results shall disclose GHG emissions-related information sufficient to allow such third parties to make associated decisions with confidence.

3. Methodology

The methodology of this project has been done as follows:

- Identification of the context information to calculate the carbon footprint in agricultural products
- Calculation of the carbon footprint
- Evaluation of the result information to improve the company environmental performance
- Communication of the results to consumers and the market

With all this background information, the project was done with these phases:

a) Initial diagnosis:
   - Scope definition
   - International bibliography review
   - Identification of the chosen companies and select the functional units

b) Testing of the protocol
   - Meetings with stakeholders
   - Definition of the calculate methodology
   - Carbon footprint calculation in the chosen products

c) Design and verification
   - Methodological guide edition
   - Results verification and validation of the methodology
   - Communication

Once all the previous information was collected, the next decision was to choose the functional units where test the methodology. These units were the following ones:

- Ecological olive oil in 1 liter glass bottle
- Conventional olive oil in 5 liters PET

- Ecological Pedro Ximenez wine in 0,5 liters glass bottle
- Conventional Pedro Ximenez wine in 0,75 liter glass bottle
- Cherry tomato in 250 gr. PET crate

The calculation methodology proposed for each one of them is resumed in the following scheme:

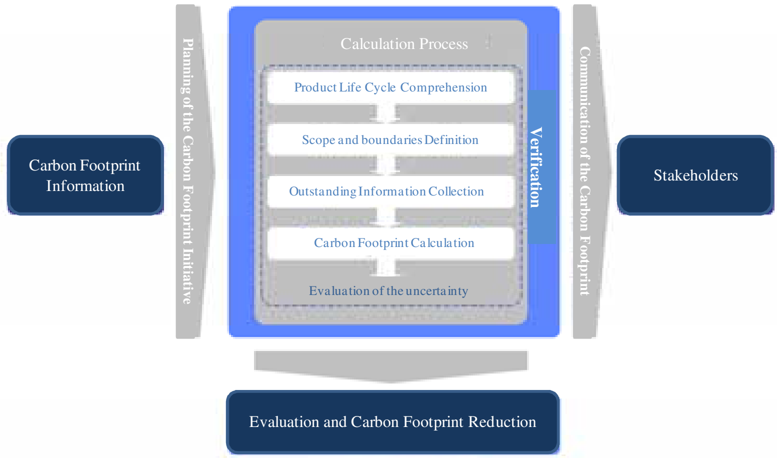

Figure 1: Methodological description of the Project. Source: Own elaboration.

Before analyzing the life cycle of the products within the calculate process, the business model must me selected:

- A business to business model or B2B implies all the emissions from the raw materials of the evaluated business until the output and delivery to the customer who receive the final product (the emissions associated to the transport and delivery): usually this customer is a logistic platform or a manufacturer.
- A whole supply chain is the business to consumer model (B2C): from the raw materials until the disposal or recycling of the wastes.

In this project a B2B model was chosen and it was divided in the following **phases**:

3.1. Product life cycle

After the selection of the business model the next step is the definition of the product life cycle. In order to calculate the carbon footprint it is necessary to understand and to document how the product is obteined, gathering all the information of the different steps. In this case the tool that has been used is the process map, to represent the different transformations of the raw materials to become the final product.

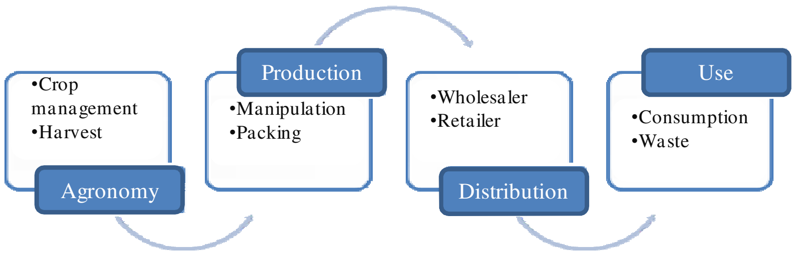

Figure 2: Agricultural production phases. Source: Own elaboration.

In the agricultural product analysis are included the main raw materials (olives to elaborate olive oil, grapes for wine, etc.) and also secondary materials: alcohol, filters, additives, etc.

3.2. Scope and boundaries definition.

According to the business model defined it is necessary to define the scope and the boundaries of the system that is going to be represented in the process map. As this is a critical matter, these boundaries and the exceptions must be clearly determined and explained.

3.3. Outstanding information collection

Once the process map is perfectly defined, the next step is to collect all the data to calculate the emissions.

First it is necessary to identify which data must be collected and where to look for them: contact with suppliers, distances in transport, databases consultation, etc. As a general rule, the emissions calculation is composed of a quantity associated to a unit (fuel consumed) multiplied by an emission factor (grams of CO_2 emitted every kilometer of transport).

The information collection was made for each source, associating a quantified value, and its unit, to every source.

Table 1: Example of data compilation and classification. Source: Own elaboration.

Phase	Environmental Aspect	Source	Unit	Value
Water collection	Fuel consumption	Fuel supplier invoices	Fuel liters	20.115,09
Leaves treatment	Fuel consumption	Distance traveled by supplier multiplied by vehicle emissions	kg CO_2/year	49,2
Plant cover treatment	Fuel consumption	Distance traveled by supplier multiplied by vehicle emissions	kg CO_2/year	13,2

Following PAS 2050:2008 requirements, in this project has been excluded:

- Human energy used in the processes;
- Emissions arisen from the personal transport from their homes to the working place;
- Emissions from animals that work in the production of this functional unit;
- Emissions from capital goods.

3.4. Carbon footprint calculation

Once the previous steps were accomplished, to ease the final report the calculation was tackled separating the production in different steps: agronomy, production, delivery… For some general aspects, such as electric consumption, a global calculation was done because the disaggregation of this information would complicate the scheme. It is useful to distribute the percentage of the emissions in the different steps of the production.

When the global emissions are calculated, the fact that in a factory different products are made must be considered, and all the data must be referred to the concrete functional unit.

3.5. Evaluation of the uncertainty of the calculation

This evaluation in a process with so many steps and different sources of information is quite a hard work. The main strategies used to decrease the uncertainty of the calculations were:

- Substitution of secondary data for primary data, where possible
- To use of well adapted secondary data
- To redefine the process steps by using smaller phases

3.6. Verification

Aiming to reach the necessary transparency and in order to give trust and confidence to the overall results of the project (calculations, boundaries, scope, exclusions,…) it was decided to verify the process by an independent third party (a recognized environmental verifier). The objectives of the verification were:

- To guarantee that the carbon footprint associated to the functional unit was calculated according to PAS 2050:2008 principles and requirements;
- To assure that the data collection, information and calculations were correct;
- To identify improvements and to promote a consistent implementation according with the guide principles.

4. Results.

The result of this Project is the first verified carbon footprint in agricultural products in Spain, following PAS 2050:2008 methodology. It is very important to consider that agriculture is a sector which emissions are not regulated and therefore, the calculation and communication of them is voluntary.

This project has two deliveries: the methodological guide and the final result for the five chosen functional units.

The decision of verify the results by an independent part is justified by the importance of the certainty that this company can contribute with.

The results have been calculated for the five chosen products and therefore, they can not be used for agriculture in general.

Once all the results were calculated and verified, a new brand and logo was created to allow labeling the products (functional units):

Figure 3: Verified CO2 logo

This logo transmits two main messages: a company has calculated and has verified its emissions associated to a functional unit and this company is committed to reduce them.

The results of the calculations of the five functional units verified by Det Norske Veritas (DNV) as independent company are displayed in the next table:

Table 2: Verified results of the carbon footprint. Source: Own elaboration.

	Cherry tomato in 250 gr. PET crate	Ecological P.X. wine in 0,5 liters glass bottle	Conventional P.X. wine in 0,75 liter glass bottle	Ecological olive oil in 1 liter glass bottle	Conventional olive oil in 5 liters PET.
Agronomy	13,45	106,24	51,86	493,89	4589,73
Production	24,9	511,88	611,3	625,08	883,91
Distribution	4,75	10,64	2,42	21,77	21,84
Total gr CO_2 eq	**43,1**	**628,76**	**665,58**	**1140,74**	**5495,48**

5. Conclusions.

To label a product with its carbon footprint may contribute and promote the efforts to decrease the GHG emissions in at least the following ways:

- It can facilitate truthful and reliable information to consumers and to the companies that label their products. It helps consumers to buy in a responsible way.
- The commitment to reduce the GHG emissions has an influence on the supply chain. Some companies are developing strategies with suppliers and collaborators to improve their supply chain.
- Farmers are also committed in the life cycle of a product and they can assume their environmental responsibility, identifying better practices.
- Improve the company image through the differentiation of its product.
- Identify processes with higher emissions, allowing the company to save costs.
- Improve indicators of information related with sustainability which allows the company to reach green credits and those of social responsibility.

6. References

British Standards Institution (BSI), Carbon Trust (2008): Specification for the assessment of the life cycle greenhouse gas emissions of goods and services (PAS 2050:2008).

International Organization for Standardization (ISO) (1999): Environmental labels and declarations — Self-declared environmental claims (Type II environmental labelling) (ISO 14021:1999).

International Organization for Standardization (ISO) (2006): Environmental management — Life cycle assessment — Principles and framework, Requirements and guidelines (ISO 14040:2006, ISO 14044:2006).

International Organization for Standardization (ISO) (2006): Environmental labels and declarations — Type III environmental declarations — Principles and procedures (ISO 14025:2006).

International Organization for Standardization (ISO) (2006): Greenhouse gases — Parts 1, 2 and 3: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions (ISO 14064:2006).

World Business Council for Sustainable Development (WBCSD), World Resources Institute (WRI) (2005): GHG Protocol Corporate Accounting and Reporting Standard.