Developing LCA methodology guide for the food industry

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Abstract In the Foodprint - research programme harmonised methodology for calculating environmental footprints of food is developed in collaboration with the Finnish food sector. Many international standards and guidelines are published but no common approved standard nor communication method evaluating food stuff's environmental impacts are available. In addition they are too generic to give practical instructions to produce comparable LCA studies. International standardisation, developments and best practices on evaluating life cycle impacts are taken into account when preparing national specific guidelines. Some of the most challenging issues in the methodology development, which are also addressed in the project, are described in this paper. These issues are critical as they affect comparability and the magnitude of LCA studies' results. Finnish food sector is actively consulted to ensure practical methodology. Special attention in this paper is given to calculation methods of emissions deriving from land use change.

1 Introduction

The "Foodprint", Footprint of food -research, programme started in late 2009 following the initiative of active Finnish food companies. In Finland few food producers have calculated and are communicating their products' carbon and other footprints based on life cycle assessment. The programme aims to harmonise the calculation methodologies. 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 food, packaging and retail companies.

The programme consist of one public project and three company research and development projects. Figure 1 presents the four working packages of the public project and the entity. 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.

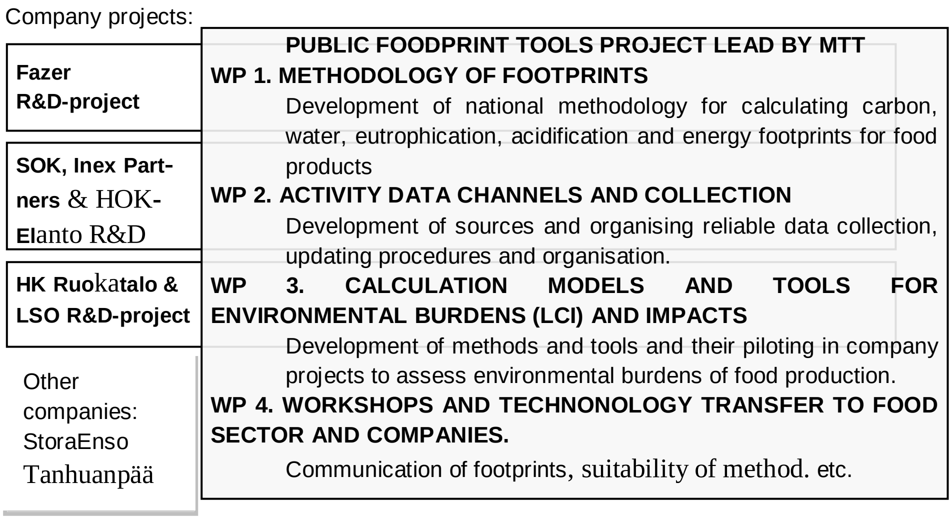

Figure 1: Overview of Finnish Foodprint programme

LCA practitioners often refer to ISO 14040 -standard series [1] or PAS2050 [2], but they are too general to give practical instructions to companies to produce comparable LCA studies. New standards (e.g. ISO 14067 [3], WRI GHG product protocols [4]) are being developed, but also they acknowledge the problem and thus they refer to more detailed product category rules. The problem is that internationally accepted rules do not exist. Furthermore, development of product category rules (PCR) seems to be quite diverse and unharmonised as well. Therefore, MTT and Finnish food industry aim to harmonise methodology and footprint calculations at least in national level.

The methodology is developed largely concentrating on climate impact. Though, acknowledging that also other environmental impacts are important also eutrophication, acidification, primary energy and water footprint/consumption are included.

The programme aims at wider production of good quality supply chain specific data, which is crucial when aiming at development of supply chains. The data collection in the case studies of participating companies is made according to the developed data quality requirements As food production chains are diverse, different ways of collecting data were applied, for example direct anonymous web-based questionnaire and a calculation tool produced for the primary producers. Also, some food producers already have an extensive database on primary production for quality and risk control.

This paper will present some of the most important methodological issues which were addressed in the programme and were developed further to offer practical guidance to companies of the sector. These issues have been discussed with participating companies and are subject to wide national review. Final methodology shall be published in spring 2012, and until then the methodology development will be carried out as iterative process between research, companies and other stakeholders.

2 Some challenging methodological issues briefly

2.1 System boundaries

Variable system boundaries are one of the major causes for incomparable results of LCA. To harmonise methodology and calculation results, detailed instructions are given to different life cycle phases and many clear rules have been established. All life cycle phases from raw material extraction to waste treatment shall generally be included. Different requirements are also made for cultivation and for animal production. Cut-off rules are also applied in the methodology and more detailed instructions for their use are given. This chapter highlights few examples.

Capital goods are excluded from the system boundaries. There is only some evidence that in certain cases they are significant and they are associated with large uncertainties.

Considering the inputs of primary production, in addition to feeds and fertilisers, also liming and fallows of fields between cultivation years shall be included in the system boundaries.

To allow harmonised calculation results it is never allowed to include consumer shopping trips to the final results. It is also not allowed to include emissions from the consumer's cooking phase to the final results. Instead, acknowledging that the latter can have major influence on consumer behaviour, it can be reported separately.

The inclusion of waste management to system boundaries shall be assessed by studying whether or not waste will be used as a major input in a subsequent product system. If waste will be used as an input in a subsequent product system, the waste treatment process shall not be included.

2.2 Data quality requirements

Present data quality requirements, particularly requirements on primary data, in current and draft guidelines are seen insufficient. Therefore, in the proposed methodology more detailed requirements are given separately for each life cycle phase. Detailed instructions are given to each life cycle phase whether data shall be collected directly from a supply chain, or gathered from national statistics, databases etc., and which are adequate data sources. The intention is to harmonise the data requirements from agricultural phase in the guide with the fairly comprehensive cultivation data, which is already collected by primary producers for other purposes in Finland.

To increase the production of good quality data, the guide obligates the use of a worst case default in cases when good data is unavailable. For example if the food producer does not know the origin of a raw-material, the worst emissions found for that raw material in literature shall be used or if electricity production profile is unknown, the worst case default of Finnish production shall be used. The guide also tries to ease calculations by allowing the use of literature data, comparable data of similar raw materials and even mass scaled data on raw materials, when the impact of the input is expected to be low. There are also instructions how to evaluate the representativeness of a sample, and an obligation to reach quantitatively very comprehensive sample when representativeness is unknown or cannot be achieved.

Some facilitation are made with data quality requirements in various life cycle phases, but to reach good quality results, extra requirements are applied for reporting and tightest for a label in a package. For example, it is required to report how large share of emissions is derived from supply chain information, literature sources of comparable raw material, mass scaled information or from worst case defaults. In the case of a label, there is a requirement for the amount of supply chain derived emissions and a requirement not to have too much inferior quality data.

Specific simplification for food production is that the emissions of minor ingredients, less than 5% of the dry matter mass of the product, can be scaled according to emissions of all other ingredients of the product.

2.3 Allocation

Work is underway to develop general principles for choosing appropriate allocation methods for situations where it is not feasible to avoid allocation (e.g. through subdivision). Some examples of allocation situations and comparisons of allocation methods are going to be further explored in R&D projects of the food industry.

2.4 Development of emission factors

New emission factors are also developed. National emission factors for N_2O emissions from agricultural soils derived from field measurements are introduced to describe better national circumstances (manuscript in preparation). This means that new default will give considerable higher emissions to grains and vegetables (outdoor) grown in open fields. New models will also take into account national eutrophication defaults and more detailed model for ammonia emissions is being developed.
Another area of improvement and generation of defaults are national emission factors for different electricity production types. It is proposed to use specific emissions factors related to the actual electricity supplier. This means that when the production profile of the supplier is known, the new national defaults for different production types shall be used.

3 Emissions resulting from Land Use Change

When land is converted from one land use type to another, e.g. forest to cropland, a change in both aboveground and belowground biomass often occurs. In the case of converting an area of forest to cropland, the trees are harvested or burned, while any remaining litter and roots decay over the following years. The burning and decaying of biomass subsequently give rise to emissions of greenhouse gases, such as CO_2, CH_4 and N_2O. By changing the use of the land, the organic matter inputs and outputs can also be affected, which can result in a change of both magnitude and direction of net carbon flux. Carbon dynamics can also vary inside a specific land use type, such as croplands. Factors such as the crop used, the amount of crop, the management practices, and the nature of the soil can affect the carbon fluxes into and out of the ecosystem. Because these fluxes vary largely with conditions, generalizations are difficult to make.

Currently there exist several methodologies for the calculation of greenhouse gas emissions resulting from a land use change, but no methodology has been commonly accepted for use in LCA. The methodologies are mostly based on the change in aboveground and belowground organic matter, and changes in gas (CO_2, CH_4 and N_2O) fluxes resulting from the land use change. There are much fewer methodologies available for the approximation of what land use changes have occurred, and these are based mainly on agricultural statistics. Below is a short overview of methodologies that have been compared and what factors they treat. All methodologies require data on the biomass content of the previous and new land use type, and emission factors for the combustion and decomposition of this biomass. This overview is the first stage towards developing a harmonised methodology which takes also land use changes into account.

3.1 Review of current methodologies

PAS2050 does not include a calculation methodology per se, but ready calculated emissions per hectare for different land use change scenarios in different countries. The emissions were calculated using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Emissions resulting from land use change are to be included in the product's GHG emissions each year for the 20 years following the change in land use. [4]

The 2006 IPCC Guidelines for National Greenhouse Gas Inventories are a set of methodologies for estimating national inventories of greenhouse gas emissions, and it supplies methods for accounting for changes in biomass, dead organic matter and soil carbon stocks, as well as default values (e.g. biomass content and soil carbon stock) for different ecosystems and land use types. [5]

The Dutch Horticulture Protocol is an extension of PAS2050, and the GHG emissions, resulting from land use change, of a product are calculated as the contributions from combusted biomass, loss of carbon sink function, and loss of stored soil organic matter. Each contribution is calculated with a specific equation, and they are summed to give the total GHG impact of the land use change. [6]

The final methodology is based on a concept called the greenhouse gas value of an ecosystem, GHGV, which is defined as the "total benefit of avoiding radiative forcing from GHG's [greenhouse gases] through maintenance of 1 ha of the ecosystem" [7]. The GHGV value takes into account potential GHG emissions from stored organic matter (mainly from above-ground biomass and soil), annual GHG fluxes between ecosystem and the atmosphere (mainly through respiration and photosynthetic assimilation), and the likely emissions resulting from a possible disturbance of the ecosystem. The GHG exchanges between the ecosystem and the atmosphere are accounted for during a multi-year emission time frame of τ_E years. Since the GHG's also remain in the atmosphere for a long time, the climate impact of the potential emissions are also assessed over a multi-year analytical time frame of τ_A years (which is equal to or longer than τ_E).

3.2 Comparison – Effect of Land Use Changes on the carbon footprint of Finnish broiler

To compare the different methodologies, they were applied to an LCA study of Finnish broiler meat [8]. Here, the greenhouse gas emissions from land use change resulting from the cultivation of the feed ingredients were analyzed. Using the average feed consumption per live weight of chicken, 1.78 kg/kg, and the feed composition from the original study, as well as the average agricultural yields from FAOSTAT, the land use requirement per kg of live chicken was calculated. The calculations reveal that only area in Finland and Brazil are used for the cultivation of the feed ingredients. The land use requirements for the feed cultivation and the country of origins are presented in Table 1. The functional unit for the analysis was 1 kg of marinated broiler product. 1.3 kg of live chicken was needed to produce 1 kg of the marinated broiler product.

Tab. 1: Land use requirements of feed cultivation

Crop (Country of Origin)	Land Use (m2/kg product)
Wheat (Finland)	2.94
Soybean (Brazil)	2.25
Oatmeal (Finland)	1.65
Rapeseed (Finland)	1.44

Different land use change scenarios were created to approximate and compare the impacts of land use change on the carbon footprint of the product. The first scenario, *worst case*, is a scenario where all the land required for feed cultivation has undergone land use change in the last 20 years. The second scenario, *FAO case*, is a scenario where the amount of deforestation is calculated with the method presented in the Dutch Horticultural Carbon Footprint protocol using agricultural statistics from FAOSTAT [6,9,10]. The method yields an approximation of the annual change in cultivated area for specific crops, and the fraction of this new area that is newly deforested area. The third scenario, *FAO allocated case*, is a scenario where the amount of deforestation is calculated in the same way as the previous scenario, FAO case, but the greenhouse gas emissions resulting from deforestation in Brazil are calculated using land allocation data from a study by Fearnside [11,12]. The results from the study are that 51% of deforested area eventually ends up as pasture, 5% as croplands, and 44% as secondary forest. The last scenario, *study case*, is a scenario where the annual amount of deforestation linked to soybean cultivation in Center West Brazil, where soybean cultivation is increasing, is approximated using data from a study by Prudêncio da Silva, and is 1% of the total cropland area [13]. This scenario also uses the land allocation data from the previous case, *FAO allocated case*.

The methodologies that are compared consider different amounts and types of variables. Hence, when possible, it was attempted to harmonise and keep alike the values of similar variables from different methodologies, to promote comparability of the methodologies. The values for the biomass variables of different ecosystems used in the calculations are presented in Table 2, and they were collected from various reviews, articles, forest inventories and IPCC defaults. The CO_2, CH_4 and N_2O emission factors for the combustion and decomposition of biomass were collected from IPCC, while data on the annual ecosystem gas fluxes were collected from various studies and reviews [5, 14- 18].

Tab. 2: Biomass variables used for calculations (ton / ha)

Compartment	Amazonian Brazil			Southern Finland	
	Forest	Pasture	Cropland	Forest	Cropland
Aboveground Biomass	306.9[1]	10.7[2]	5[3]	97.6[4]	5[3]
Root Biomass	46[1]	14[5]	1,6[5]	14,6[4]	1,6[5]
Dead Wood Biomass	33.4[1]	0[3,6]	0[3,6]	5.8[3,6]	0[3,6]
Litter Biomass	9.2[1]	5.4[6]	1.1[6]	31.8[7]	1.1[6]
Vulnerable SOM	55.2[8,9]	33.4[8,9]	0[3,8,9]	57.3[9,10]	0[3,9,10]

[1] [19-23], [2] [12], [3] [5], [4] [24-26], [5] [27], [6] [7], [7] [26, 28-30], [8] [31], [9] [32], [10] [33-36]

Tab. 3: Greenhouse gas emissions, over a 20 year emission period, resulting from land use change in Amazonian Brazil and Southern Finland (ton CO2e / ha)

Methodology	Brazil: Tropical Forest to Pasture	Brazil: Tropical Forest to Croplands	Brazil: Tropical Forest to Secondary Forest	Finland: Forest to Croplands
PAS2050	534	740	0	300
IPCC 2006	670	810	470	317
IPCC 2006 (defaults)	571	671	326	290
DHCF	550	569	479	193
GHGV	638	868	568	463

The greenhouse gas emissions resulting from land use change, calculated with the different methodologies, for the two ecosystems (Amazonian Brazil and Southern Finland) are presented in Table 3. The values were calculated using a 20 year emission period (and in the case of the GHGV methodology using a 50 year analysis period) and the biomass variables presented in Table 2 (with the exception of IPCC 2006 (defaults), which used default biomass values from the guidelines).

By using the emissions from Table 3, the land use requirements from Table 1, and the different allocation rules of the scenarios, the emissions resulting from land use change for the broiler product could be calculated. In the *worst case* scenario, 100% of the required land has been subjected to land use change. In the *FAO case* 0% of the land used in Finland has been subjected to land use change, while 19% of the new (3.7% annual increase) soybean area in Brazil has been subjected to land use change. In the *FAO allocated case* the same land use changes percentages were used as in the *FAO case*, but with the land allocation data mentioned earlier. In the *study case* scenario 0% of the land used in Finland and 1% of the required land in Brazil has been subjected to land use change. This scenario also uses the land allocation data from the previous case, *FAO allocated case*. The greenhouse gas emissions resulting from land use change of the broiler product calculated for the different scenarios are presented in Table 4. As can be seen, the results vary both within and amongst the scenarios, which shows that both the acquisition of precise input data (e.g. biomass content) and knowledge over what land use changes have occurred are vital for good results. Compared with the result of the carbon footprint of the marinated broiler product from the original study, 3.6 kg CO2e / kg product, it becomes clear that land use change can have a large impact on the carbon footprint (up to a 6.6-fold increase in the carbon footprint). The *worst case* scenario is though very improbable, but the other scenarios still give, depending on methodology, an increase of around 30% to the carbon footprint.

Tab. 4: Emissions resulting from land use change for the broiler product (kg CO2e / kg product)

Methodology	Worst case	FAO case	FAO allocated case	Study case
PAS2050	17.4	1.17	0.46	0.65
IPCC 2006	17.9	1.28	0.88	1.25
IPCC 2006 (defaults)	17.1	1.06	0.70	0.99
DHCF	12.2	1.41	1.29	1.61
GHGV	23.9	1.37	0.92	1.31

4 Conclusions and discussion

There are many situations in making LCA where decisions are often done case by case. This is major cause for incomparable results. Neither do the international standards nor guidelines give good practical guidance to companies, in particular in the food sector.

The methodology guide to Finnish food sector aims to harmonise the calculations at least in a national level as far as possible. The guideline shall give more specified requirements and better guidance to those difficult methodological issues. These choices are made in workshops together with participating companies and the whole food sector. As land use change emissions seem to affect the results of LCA considerably and as methodology development is still ongoing, major work is being done with selecting and/or developing a method for calculating them.

The work is scheduled to be finished by spring 2012 and until then an open discussion in Finland and in international arena is welcomed. This methodology could also be used as an input for international development of food specific guidelines.

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