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Book of Abstracts

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Objectives of the Meeting

Agriculture and the food sector are responsible for a large share of the environmental impacts and resource use caused by human activity. For certain environmental issues such as the conservation of biodiversity, agriculture is the key driver. For about 15 years now, the Life Cycle Assessment (LCA) method has successfully been used to analyse agricultural production systems and food chains. A variety of inventories, tools and methodical approaches for analysing different food chains have also been developed over this period.

The objectives of the meeting are:

- to show recent developments in terms of methodology, approaches, databases and tools;
- to present applications of the LCA methodology in new case studies or case studies showing new aspects in various food chains;
- to present successful examples of communication of LCA results to stakeholders and their use in decision making.

We are pleased to welcome you to the conference "LCA in the Agri-Food Sector 2008", the sixth conference in a series that started in 1996.

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Assessing freshwater use impacts in LCA

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Keywords: water footprint; water resource; freshwater ecosystem impact; LCA; evaporative use; ecosystem; FEIP; FDP

This presentation describes the main impact pathways related to changes in the amount of water available (i.e. not qualitative aspects), and the relevant flows requiring quantification in the LCI are defined as shown in Figure 1 (Milà i Canals *et al.*, submitted). Although a basic resource for humans, physical access to freshwater seldom leads to effects on human health, and even its availability for most economic activities and future generations is usually secured, with some exceptions discussed in this paper (over abstracted aquifers). On the other hand, freshwater availability for aquatic ecosystems is often reduced due to competition with human uses, potentially leading to impacts on freshwater ecosystem quality.

Freshwater flows requiring distinction in the LCI include evaporative and non-evaporative uses of blue and green water, and land uses leading to changes in freshwater availability are discussed and quantified. Suitable indicators are suggested for the two main impact pathways (namely freshwater ecosystem impact potential, FEIP, and freshwater depletion potential, FDP) and operational characterisation factors provided for a range of countries and river basins. For FEIP, indicators relating current freshwater use to the available freshwater resources (with and without specific consideration of water ecosystem requirements) are suggested. The potential for regionalisation on a country- and river basin- basis is discussed. For FDP, the parameters required for the implementation of the commonly used Abiotic Depletion Potentials (ADP, Guinée *et al.*, 2002) are explored and illustrated; this impact pathway is indeed very region-specific, and only relevant when there is knowledge of aquifers being over abstracted. When water from over abstracted aquifers is used, it may easily dominate the ADP as defined by Guinée *et al.* (2002).

This methodological framework improves the representation of freshwater use derived impacts in LCA. Its application is illustrated with a case study of broccoli production in the UK and Spain and consumption in the UK (Milà i Canals *et al.*, in preparation). This application serves to discuss advantages and potential drawbacks for its widespread use.

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Milà i Canals L, Chenoweth J, Chapagain AK, Orr S, Antón A, Clift R (submitted): Assessing Freshwater Use Impacts in LCA Part I: Inventory Modelling and Characterisation Factors for the Main Impact Pathways. *Int J Life Cycle Ass*

Milà i Canals L, Chapagain AK, Orr S, Chenoweth J (in preparation): Assessing Freshwater Use Impacts in LCA Part II: Case study for broccoli production in the UK and Spain. *Int J Life Cycle Ass*

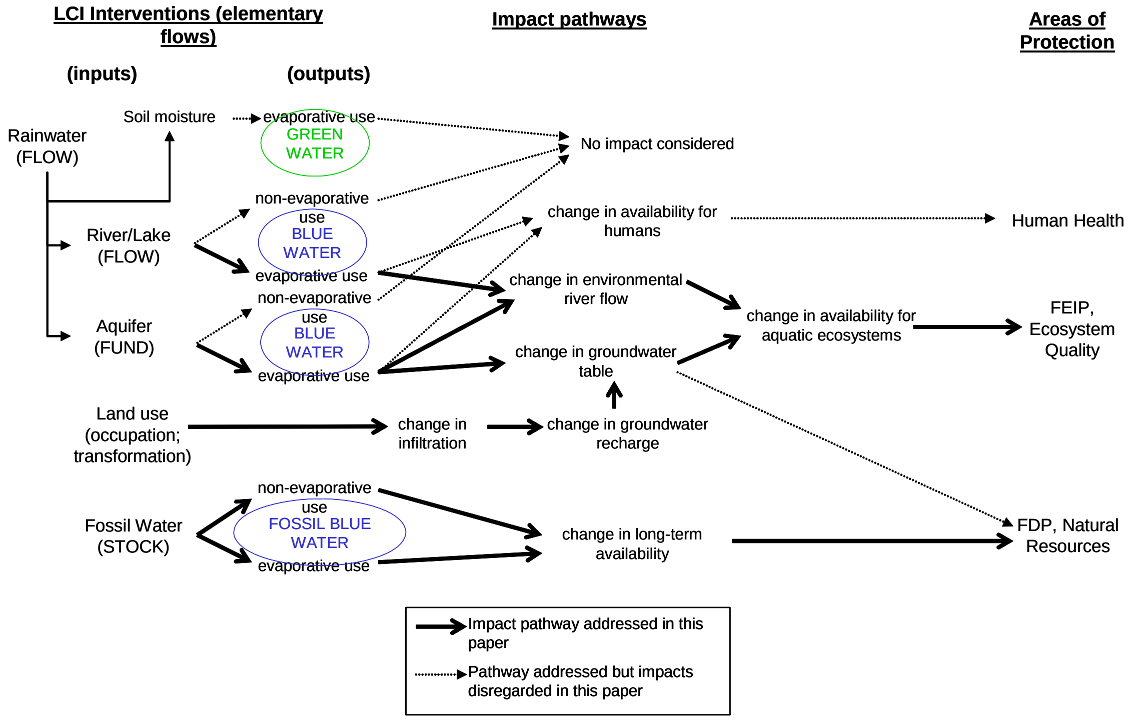

Figure 1: Main impact pathways related to freshwater use. All the pathways are discussed but only those depicted with solid arrows are considered relevant for LCA (Milà i Canals *et al*., submitted).

Regionalised LCIA of vegetable and fruit production: Quantifying the environmental impacts of freshwater use

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Keywords: LCIA, vegetables, freshwater use, regionalisation, Eco-indicator

Many LCA studies of agricultural products neglect the impacts of water use. In this paper we provide a regionalised study based on new inventory data including water use figures for the following agricultural products: Tomatoes, potatoes, cabbage, onions, and peppers. Since water use can cause important environmental impacts originating from agricultural production, we developed and applied a method to assess the environmental damages resulting from freshwater use. Our method is concordant to the framework of the Eco-Indicator 99 method (EI99) and allows the integration into standard LCA studies to show the relevance of water use related environmental impacts. The method is mainly based on global data of annual hydrological water availability and anthropogenic water use as provided in the WaterGAP2 model (Alcamo et al., 2003). We enhanced this model by integrating the effect of seasonal and interannual precipitation variability using data of Mitchell & Jones (2005). On this basis, the damage assessment was performed for separate impact pathways with regard to the three Areas of Protection, as considered in EI99: Resources, Human Health, and Ecosystem Quality.

Because environmental impacts of water use are of high spatial variability, the assessment was performed with inventory data for the agricultural production in seven different countries with different climatic and socio-economic conditions: Switzerland, Spain, China, Greece, Italy, USA and Ethiopia. Region-specific impact factors were developed and applied. The results show that in some countries, such as Switzerland, water use can have rather small impacts when compared to the overall LCIA results. In contrast, environmental impacts due to water use can be relevant or even dominate the environmental damages of agricultural production schemes in regions suffering from water scarcity as shown in Table 1.

An additional focus was given on the land use impacts which are significant when applying the standard LCA methodology on field-grown vegetables. In contrast, water-intensive production systems are usually extremely high-yielding and therefore eco-efficient in terms of land use. Comparative LCA studies may therefore lead to wrong indications if intensive water use applied for irrigation is neglected in the assessment of different production sites and techniques (Table 1).

The results of this work highlight the importance of integrating water use in LCA studies on agricultural products and pinpoint the relevance of regionalisation on the level of the inventory analysis as well as impact assessment. Both aspects are crucial when comparing products on the global market: for decision makers in food supply chains as well as for consumers interested in sustainable consumption.

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Table1: Comparison of impacts due to water use and standard LCA for different crops in different countries according to EI99. Relative damage of water use in percent of results from total standard LCA (upper part) and from Land Use (lower part) are classified as follows: <10% = " -- ", 10-20% = " - ", 20-50% = " +/- ", 50-100% = " + " and >100% = " ++ ".

	Switzerland	Spain	China	Greece	Italy	USA	Ethiopia
				compared to standard LCA (EI99)			
Onion	--	+/-	++	--	--	+/-	+/-
Tomato	--	-	+/-	--	--	-	--
Potato	--	+	+	--	--	+	-
Pepper	--	++	-	-	-	+	+/-
Cabbage	--	+/-	+	-	--	+	+/-
				compared to Land Use (EI99)			
Onion	--	+	++	-	--	+/-	+
Tomato	--	++	++	+/-	+/-	++	+
Potato	--	+	+	--	--	+	-
Pepper	--	++	+/-	+/-	+/-	++	+
Cabbage	--	+	++	+/-	🟩	++	+

Proposing a life cycle land use impact calculation methodology

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Keywords: LCA, Land use impact assessment, bio-diesel, Oil Palm

The Life Cycle Assessment (LCA) community is yet to come to a consensus on a methodology to incorporate land use in LCA. In Peters *et al.* (2004) and García-Quijano *et al.* (2007) our research group presented a methodology based on the ecosystem exergy concept. The ecosystem exergy concept suggests that ecosystems develop towards more effective degradation of energy fluxes passing through the system (Dewulf *et al.* 2008). The concept is argued to be derivable from two axioms: the principles of (*i*) maximum exergy storage and the (*ii*) maximum exergy dissipation. Although still under debate, Dewulf *et al.* (2008) conclude that the ecosystem exergy concepts hosts varied and promising applications (e.g., land use impact assessment).

In this paper we present an improved methodology to assess impacts of human induced land use occupation, in which we make a difference between functional and structural land use impacts (both part of the 'natural resources' area of protection). The methodology follows a dynamic multi-indicator approach looking at mid-point impacts on soil fertility, soil structure, biomass production, vegetation structure, on-site water balance and biodiversity. The impact scores are calculated as a relative difference with a reference system. We propose to calculate the impact by calculating the land quality change between the former and the actual land use normalised by the quality of the potential natural vegetation. Impact scores are then aggregated, as endpoint impacts, in (*i*) structural land use impact (exergy storage capacity) and (*ii*) functional land use impact (exergy dissipation capacity). Soil fertility, biodiversity and biomass production are characterized as structural land use impact. Impacts on soil structure, vegetation structure and on-site water balance are characterized as functional land use impacts. For aggregation of the relative mid-point impact scores no characterization factor is used. In order to fit this impact calculation in the LCA framework the end-point impact scores are multiplied by a LCA component, a component that enables us to report the impact per functional unit (FU). In a case study the proposed method is applied on bio-diesel production from palm oil in Cameroon.

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Integration of biodiversity as impact category for LCA in agriculture (SALCA-Biodiversity)

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Keywords: LCA, biodiversity, indicators, impact assessment, agriculture

Land use is an economic activity that generates large benefits but causes environmental impacts. Biodiversity, in particular, has been and is being endangered by intensive agriculture, forestry and the increase of urban areas and infrastructure. Currently, the necessary integration of biodiversity and/or land use as impact category in Life Cycle Assessment (LCA) methodologies is recognized (SETAC/UNEP LCA Initiative, Milà i Canals *et al.*, 2007). Agroscope Reckenholz-Tänikon Research Station ART developed a method for the integration of biodiversity (organismal diversity) as a midpoint impact category for LCA of agricultural production (SALCA-Biodiversity).

Complex biodiversity in the broadest sense of the Rio Convention cannot be totally measured as such and a single indicator is unlikely to be devised even in agro-ecosystems (e.g. Büchs, 2003). Instead, groups of indicators should be selected that are sensitive to environmental conditions resulting from land use and agricultural management practices, and give as representative a picture as possible of biodiversity as a whole. In the present method, the choice of indicator species groups (ISGs) was made according to the linking of ISGs to agricultural activities, and general criteria such as their habitats and their place in the food chain (Jeanneret *et al.*, 2006). The following ISGs were selected: flowering plants, birds, small mammals, amphibians, snails, spiders, carabid beetles, butterflies, wild bees, and grasshoppers. Furthermore, we distinguished between the overall species diversity of each ISG and the ecologically demanding species (stenotopic species, red list species) in the impact assessment. To estimate the impact of agricultural practices on ISG, inventory data with detailed management options were specified (e.g. quantity of fertilizers, number of insecticide applications). Then a scoring system was developed that estimates the reaction of every ISG to management options taking into account the relevance of specific agricultural activities (e.g. fertilization, insecticide application) and of the habitat (e.g. grasslands, cereals) for the considered ISG. Scores of management options were then aggregated at the field level. The effects of the management options on each ISG as well as the aggregation rules were estimated based on information from the literature and expert knowledge. Furthermore, the impact of land use on biodiversity at farm level can be calculated by aggregating the biodiversity scores obtained at field level under consideration of the semi-natural habitats.

In a specific case study, several scenarios representing field management options for grassland (intensity level) and wheat (cropping system) were calculated (Tab. 1). The results show the dominant influence of management intensity on most ISGs. The range of indicator values is much higher in grassland than in winter wheat. The inflection point of management from which large impacts on biodiversity are to be expected can be derived, i.e. from system (B) to (C) and (C) to (D) in grassland, and from system (B) to (C) in winter wheat. Conclusively, the method allows comparing impact of agricultural systems on biodiversity and shows biodiversity-friendly practices. Furthermore, the method allows integrating biodiversity as impact category in LCA studies in agriculture.

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Tab. 1: Results of SALCA-Biodiversity for grassland and winter wheat systems. Biodiversity scores are given per ha cultivated crop. Scores of grassland system (A) and winter wheat system (B) are set as reference scores. Scores with the same format are considered similar to the reference (95%<score<104%). Scores underlined are considered better than the reference (105%<score<114%). Scores double underlined and bold are considered much better than the reference (score >115%). No scores means no relevance for the considered system.

	Biodiversity scores							
	Grassland				Winter Wheat			
Production systems	A	B	C	D	A	B	C	D
	Overall species diversity							
Aggregated	6.2	6.4	**13.8**	**21.3**	7.7	7.5	8.4	**8.7**
Grassland flora	3.7	3.9	**11.4**	**18.5**				
Crop flora					15.2	15.1	16.0	17.3
Birds	6.4	6.7	**13.8**	**22.0**	5.3	5.0	**6.2**	**6.4**
Mammals	7.3	7.3	**11.1**	**11.1**	4.6	4.6	4.6	4.6
Amphibians	2.1	2.1	**5.2**	**9.5**	1.7	1.7	1.8	1.8
Molluscs	5.4	5.6	5.8	**11.3**	2.2	2.2	2.2	2.2
Spiders	9.1	9.3	**15.8**	**22.4**	8.2	8.0	**10.5**	**10.7**
Carabid Beetles	7.0	7.4	**13.6**	**21.0**	10.9	10.6	11.7	11.9
Butterflies	6.8	7.0	**20.0**	**36.0**				
Wild Bees	7.4	7.6	**18.6**	**23.0**	5.2	4.9	5.0	4.8
Grasshoppers	6.9	6.9	**19.4**	**33.1**				
	Ecocologically demanding species							
Amphibians	0.8	0.8	**2.9**	**4.8**	1.5	1.4	1.6	1.6
Spiders	8.9	9.0	**15.3**	**21.6**	8.0	7.8	**10.3**	**10.5**
Carabid Beetles	7.0	7.3	**13.4**	**20.6**	10.6	10.1	11.2	11.3
Butterflies	6.7	6.8	**19.4**	**36.0**				
Grasshoppers	6.8	6.8	**19.3**	**32.9**				

Grassland systems (hay production):

(A) 5 cuts/year, fertilised with slurry; 11t DM/ha

(B) 4 cuts/year, fertilised with slurry; 9t DM/ha

(C) 3 cuts/year, fertilised with solid manure; 5.6t DM/ha

(D) 1 cut/year; no fertilisation; 2.7t DM/ha

Winter wheat systems:

(A) Conventional production; 5.8t DM/ha

(B) Integrated production – intensive; 5.5t DM/ha

(C) Integrated production – extensive; 4.5t DM/ha

(D) Organic production; 3.5t DM/ha

Swiss Ecological Scarcity Method 2006: regionalised eco-factors of water resource use

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Keywords: life cycle impact assessment, distance to target, ecological scarcity, water resource use

The Swiss Ecological Scarcity method has first been introduced in 1990 and updated a first time in 1997. The most recent 2006 update and extension of the method (Frischknecht et al. 2006, Frischknecht et al. 2008) takes into account the recent developments in Swiss and European (as far as it is relevant for Switzerland) legislation and environmental targets. Furthermore, ISO standard revisions and recent developments in scientific knowledge on environmental effects are also considered where appropriate. The basic principle and main strength of the method, measuring the environmental scarcity with the help of actual pollutants (and resources) flows and maximum allowed (so-called critical) flows, remained untouched. Hence, it is still a distance to political target rather than a damage oriented impact assessment method. The most important changes are mentioned below.

The mathematical representation of the ecofactor was slightly adapted. The characterization step is made explicit. Current emission values are used in the normalization step and thus the weighting factor (current vs. critical flow ratio) is squared. The ecofactor can now be defined according to regional scarcities, if needed and if regional data are available. This principle is used for phosphorus emissions into surface water and for water resource use. The long-term objective of the Swiss confederation of 1 ton CO_2 or 2’000 W per capita regarding CO_2 and energy was interpolated for the year 2030 as a common time horizon of Swiss legislation. In many areas of the world fresh water is a limited resource. Therefore new ecofactors have been introduced, based on varying regional fresh water scarcities. In Switzerland, gravel reserves are steadily decreasing according to the permitted building zones and thus becoming a limited resource. Hence a new ecofactor is attributed to gravel. New ecofactors are introduced for land use. The characterization is based on the impacts of land use on plants' biodiversity. The precautionary principle of the Swiss environmental protection legislation is applied to establish ecofactors of air pollutants benzene, dioxin and diesel particulates. The long-term conservation of soil fertility is applied to establish ecofactors of heavy metal emissions to air and soil. Current results from research allowed to establish an ecofactor (including characterization) for micropollutants (measured as estrogen activity) emitted into water. This is the first time that micropollutants, which are of increasing importance regarding surface water quality, are being considered. Based on the international agreement for the protection of the North Sea, an ecofactor was established for the discharge of radioactive isotope into the sea (including characterization). Bioreactive wastes are assessed based on their carbon content. Until now all types landfilled wastes were assessed based on their volume. The volume is now only used for the underground disposal of nuclear wastes and of hazardous wastes. The new properties of the revised formula are presented on the example of the new eco-factor of freshwater resource use. The major changes in the impact assessment results are highlighted using examples from the agricultural and industrial sectors.

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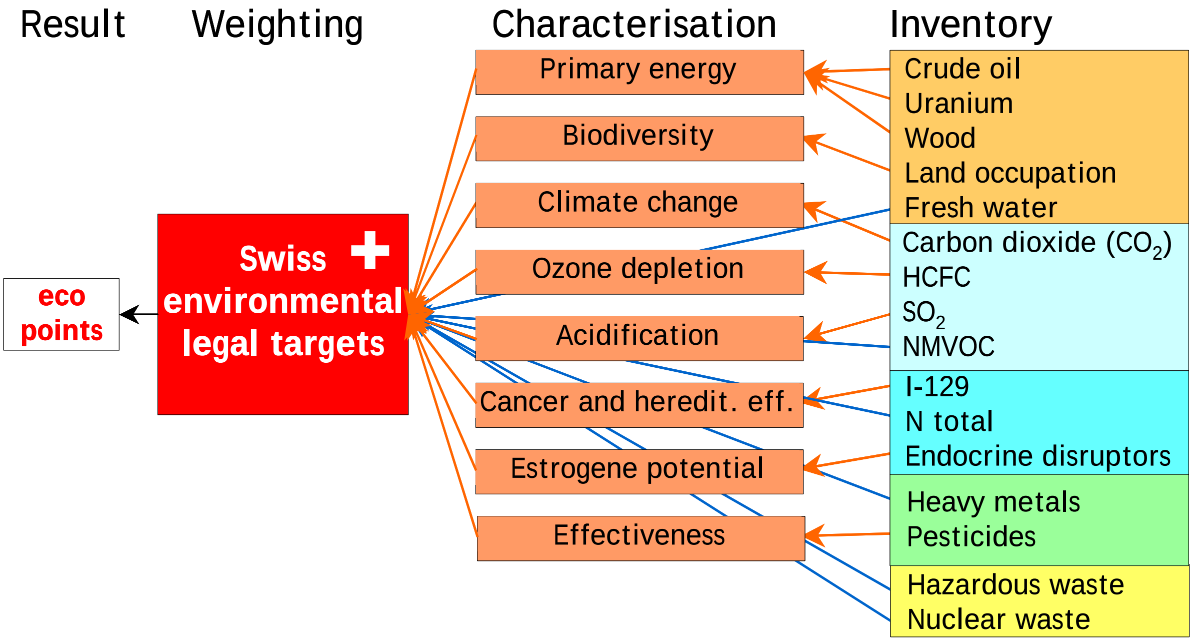

Figure 1: Basic structure of the ecological scarcity method 2006

Assessing land use impacts on biodiversity with an indirect assessment, exemplified with data from boreal forests

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Keywords: LCA, land use, biodiversity, ecoregions, key factors

There is an ongoing debate on how to assess impacts on biodiversity due to land use in LCA. Since total biodiversity is almost impossible to assess directly, several proposals have been presented using various proxy variables and in particular diversity of vascular plants has been focused. This is to a large degree motivated by the relatively good data availability. However, the correlation between diversity of vascular plants and other taxonomic groups is weak, and based on the definition of biodiversity the correlation between number of species and biodiversity is also not clear. Based on this understanding, it is here proposed to use indirect measures on biodiversity and focus on structural key factors known to be important for maintaining biodiversity.

Another question that hardly has been raised in this discussion is the motivation for biodiversity conservation. Even though this might seem superfluous, it is of importance for the biodiversity assessment. If the motivation is to protect as many species as possible, areas with high species diversity (might even include invasive species) should be in focus. If, on the other side, the motivation is to maintain the life support functions in ecosystem, species poor ecosystems could be of equal importance.

The proposal here is based on the idea that it is the ecosystem functioning that is of importance. The assessment is based on a combination of the intrinsic value of the ecosystem of concern and the possibilities for maintaining the biodiversity in the area given present or planned land use. The intrinsic value of the ecosystem is assessed as a combination of ecosystem scarcity and ecosystem vulnerability, measured at the level of ecoregions (cf. Olson et al. 2001). This ensures that the natural distribution of the ecosystems is used and not administrative borders (such as country borders).

The influence from the land use on the natural occurring biodiversity is assessed through an assessment of selected key factors known to be important for biodiversity.

While data on status of the ecoregions is readily available, key factors for biodiversity conservation must be identified and developed for each ecoregion of concern.

The proposed methodology will be presented and exemplified with forestry operations in two different ecoregions. The results show that given the same forestry regime, the impact from land use will be more than 40% higher for forestry operations in the ecoregion ‘Scandinavian costal coniferous forest’ compared to the more widely distributed ecoregion ‘Scandinavian and Russian taiga’. If the forests are transformed to e.g. fields for bioenergy crop, the impact would range from complete devastation of the biodiversity to a reduction of 67% of the present value when the proposed key factors are applied.

A framework for construction of an index will be presented, as well as ongoing work to improve the index in the case of boreal forests.

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Land requirements for food: a consistent set land use data for major food items

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Keywords: Land use, food items, food consumption patterns, footprints

Food production requires vast amounts of land. Research has shown that consumption patterns have a large effect on land required for food. The affluent patterns with meat, vegetable oils, beverages etc. require far more land than the plain menus mainly consisting out of staple foods (Gerbens-Leenes & Nonhebel, 2002). To obtain insights in the way consumption patterns affect land required for food a data set with land required for individual food items was constructed.

The food production system is characterized by the production of main-products and by-products. The production of wheat also generates straw, vegetable oils come with oil seed scrap, sugar with molasses etc. In general these by-products are used somewhere else in the food system as feedstock. A large share of the by-products is used as livestock feed, but molasses, for instance, are also used in the production of alcoholic beverages and as a substrate for the production of Quorn (a meat replacement based on fungi). As a consequence choices made with respect to allocation land use for sugar beet over sugar and molasses are also affecting land required for the production of pork, alcohol and Quorn.

The magnitude of the by-products from food industry is large, it is the largest waste stream available in society and it is completely re-used mainly in livestock feed. Not taking these by-products into account has large impacts on the land required for food as is shown in figures 1 and 2.

We identified the major main-products and by-products in the food system and their use and we allocated land required for the agricultural crop over main-products and by-product on basis of dry matter. With this information we calculated the land requirements for the most important food items consumed in The Netherlands. The land requirements for meat and dairy were derived from Elferink and Nonhebel 2007. They determined land required for meat taking the by-products from food industry into account.

The food consumption patterns consists out of thousands of products, it is obvious that they cannot be determined in detail. We limited our data set to commodities that contributed more than 0.3% to the total nutritive intake (12 kcal per person per day), based on the FAO food supply sheets. This boundary setting implies that vegetables and coffee and tea should be excluded, since their contribution to the daily caloric intake is negligible. However, since these products play an important role in our menus and since earlier research has shown that their land requirements are substantial they were added to the data set. The dataset presented covers 95% of the Dutch consumption on basis of the nutritive value (kcal).

The list only presents commodities (wheat, sugar, potatoes, oil etc.). The land requirements for nearly all food items available in the shops (bread, cake, pasta etc.) can be determined from these data when ingredients are known. The major improvement with respect to land use data published earlier is the coherence of the values between various food items.

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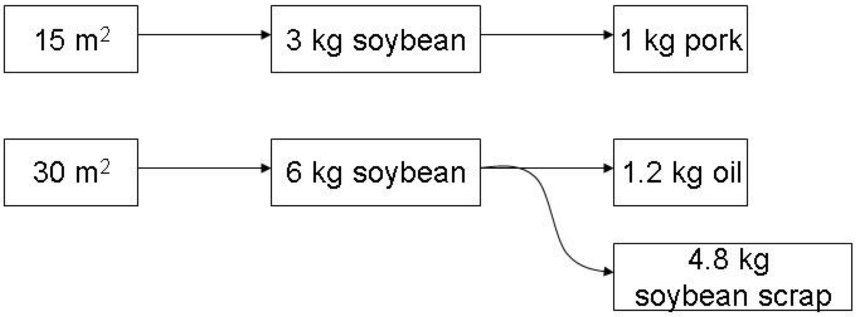

Figure 1 The land requirements for 1 kg pork and 1.2 kg soy bean oil, when re-use of by-products is not considered (45 m^2).

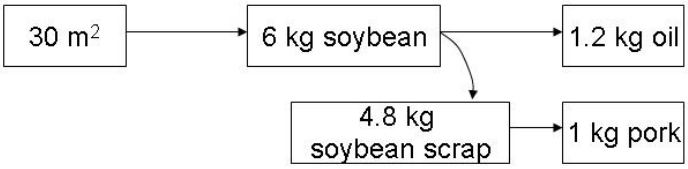

Figure 2. Land requirements for 1.2 kg of oil and 1 kg of pork when re-use of by products is taken into account (30 m^2).

Assessment methodology of the USLE C-factor to include land erosion impact in LCA

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Keywords: LCI, land use impact categories, vegetative cover, agricultural systems

Life Cycle Assessment (LCA) methodology enables the assessment of global environmental burdens derived from all the *history* of a product or a production system, in an objective and measurable way. LCA was initially developed to perform environmental assessments of industrial systems. It was later adapted to agricultural systems, where has received widespread attention. Traditionally, LCA studies take a general approach that is site and temporal independent of the environmental impacts derived from a product or production system. Nevertheless, agricultural systems are closely related to local and temporal aspects, especially water consumption and land use. Moreover, these local indicators are crucial in countries with dry regions like Spain, where soil and water typically represent two limiting resources. Therefore, adjustments to the LCA methodology aimed at including these impacts are key subjects of study.

The Universal Soil Loss Equation (USLE) (Wischmeier & Smith, 1965, 1978) and its updates (RUSLE) (Renard *et al.* 1997) are the quantitative models of soil loss valuation with the greatest agreement at the international level (Cowell & Clift, 2000, Mattsson *et al.* 2000, Muys *et al.*, 2006) to obtain the Life Cycle Inventory (LCI) data. Soil loss tolerance has been proposed as Life Cycle Impact Assessment (LCIA) characterisation factor, as a first approach. USLE and RUSLE predict average soil erosion rates from a rainfall pattern (R factor –rainfall and runoff factor–), a specific soil type (K factor –soil erodibility factor–), a certain topography (LS factor –topographic factor–) and a possible combination of cropping system (C factor –cover and management factor–) and conservation practices (P factor –support practice factor–). Only the USLE C-factor depends on the crop and its management, and, therefore, the measured C-factors are used as a criterion to select one suitable rotation system that reduces soil erosion on site. However, C-factor values have not been calculated in most of the crops and its management practices. With the aim of obtaining new data on the soil protection provided by the vegetative cover of other crop rotations and its management practices, the methodology presented in this paper has been developed to determine USLE C-factors. Crop periodical photographs (per month or per cropstage), specific software for vegetative cover assessment, monthly data of local rainfall and the generic tables of vegetative cover proposed by Wischmeier & Smith (1978) are the parameters needed to apply this C-factor assessment methodology. The information collected with the application of such methodology in the LCI phase could also be useful in the study of other impact categories other than erosion. The creation of an USLE C-factor data set for different crops and places is suggested to constitute an important future line of research in order to include land erosion in LCA studies.

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Product water footprinting: case study involving four complex, highly processed and branded grocery products

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Keywords: product water use, variable supply chain, methodology, interpretation

Freshwater is an alarmingly scarce resource, with more than a billion people in developing nations lacking access to safe drinking water and more than 2 billion people lacking adequate water for sanitation (Bartram, 2008). Additional problems include basin closures (water catchments that no longer flow to the sea due to excessive withdrawals), groundwater overexploitation and the resulting impacts on aquatic biodiversity, riparian and floodplain ecosystems and community economic development potentials. Pressure on freshwater resources is also intensifying rapidly with population growth, continuing economic development, climate change and the anticipated requirements of new bio-fuel crops. Many of these issues are of compelling interest in Australia where water stocks are scarce, highly variable and over allocated.

Traditional water-use analysis has focussed on water withdrawals from rivers, reservoirs, underground aquifers and the like (so-called blue water) by various sectors of the economy (e.g. Foran *et al.*, 2005). Business water accounting has similarly focussed on blue water appropriations on an enterprise or facility basis. These forms of water analysis and accounting have been production rather than consumption driven, have lacked a life cycle (i.e. system) focus and have not taken all forms of water use into consideration (e.g. rainfall intercepted in the root zone by plants and various forms of freshwater pollution).

This context has led to recent attempts to measure the volume of freshwater associated with the production of various good and services. These calculations, largely stemming from UNESCO-sponsored projects in the Netherlands (Chapagain and Hoekstra, 2004), have recently been reported in the popular media in Australia. The problem is that although such water footprinting calculations have the potential to raise awareness of the resource use associated with the consumption of products and services, these calculations are difficult to interpret in terms of environmental and social impact, they are seldom comparable and have the potential to be misleading.

Our research concerns the application of water footprinting methodology to four products manufactured by the multinational food company Mars in their Australian operations: Dolmio® pasta sauce, Peanut M&M's®, Whiskas® cat food and Pedigree® dog food. What distinguishes this work is its focus at the product brand level rather than product category level, as well as the complexity and variability of the associated supply chains. In this presentation we report lessons learned from the abovementioned case studies, highlighting issues in the calculation of water use, particularly in the product use phase and with ingredients which are commodities and those which are derived from semi-natural environments. In addition, we draw attention to issues in the application of product water footprinting for purposes of corporate sustainability reporting and product labelling.

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How do land occupation and land transformation influence the carbon balance of bioenergy?

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Keywords: Bioenergy, Carbon cycle, Land transformation, Land occupation

Both the consumption of resources by an increasing world population and the global trend toward substituting fossil energy sources with bioenergy technologies have placed enormous pressure on the land. However, there is an urgent need to diminish the amount of carbon in the atmosphere to combat climate change. While the use of bioenergy is intended to reduce this carbon flow, the transformation of land raises concerns about additional input of atmospheric carbon. Therefore, decisions on land occupation and its related transformation influence not only the supply of resources but also the global carbon cycle.

The tools currently applied in an environmental analysis, such as assessments of life cycles or ecological footprints, usually evaluate land use as part of two separate scenarios: either being occupied/transformed ((Lindeijer, 2000) or providing (carbon) sink capacity ((Wackernagel and Rees, 1996). However, any type of managed ecosystem acts simultaneously as source and sink. The latter occurs when carbon is stored either in products or in the soil of the occupied land. Conversely, source flows are the losses of soil carbon due to land use activities as well as the consumption of fossil fuels that are required for both those activities and the further production of harvested biomass. The change in carbon levels due to land transformation is the difference between mean carbon stocks during previous and current utilizations of land (IPCC, 2006).

My novel approach entails a methodology that considers the multifunctionality of unsealed land. It is based on two assessments: 1) LCI of the production network to determine environmental performance indicators (e.g., CO_2 mass, the amount of land occupied and transformed per volume unit), and 2) meta-analysis of the available carbon-sink data. In this approach, the functional unit is 1 MJ of energy gained from harvested biomass. Productivity provides the link between this biomass and land occupation because it is calculated as harvested volume divided by the area of land that is occupied. Nevertheless, the nature of the soil carbon cycle and land transformation means that the following allocation problems remain:

1. Land occupation, within the primary production processes, starts after harvesting is completed according to the original land use and ends with the harvesting process that is based on current use. Because changes in soil-carbon levels take time, alterations that are related to land-use activities often exceed the time frame of land occupation, which then overlaps with the carbon processes that are caused by the next occupation.
2. Land transformation is an investment in future occupation, such that carbon changes must be allocated to a projected land use. Therefore, the period of occupation until the next transformation event should be specified.

This proposed approach aims to evaluate new methodology, as well as present a discussion of these allocation problems. It assesses the carbon balance of three bioenergy production systems (wood, grass, and crops) by comparing four occupation options (i.e., close to nature forest, short-rotation plantation, grassland, and cropland) and two transformation options (those of a primary forest and an abandoned agricultural area).

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Ecoinvent-based extrapolation of crop life cycle inventories to new geographical areas

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Keywords: life cycle inventories, agricultural products

Compared to the version 1.3, the version 2.0 of the ecoinvent database (eiV2.0) contains new inventories of agricultural products, in particular for a given crop in various production places (or countries, Nemecek & Kägi 2007). A comparison of the environmental impacts between different production places reveals considerable differences (Figure 1). No simple relationship between inputs and environmental impacts was found except a certain correlation between kg yield/ha and ecoindicator99 points/kg yield and a correlation between N-input/kg yield and non-renewable energy demand/kg yield (Figure 2).

If a crop LCI available in the eiV2.0 has to be established for a country or a region that is not available in the eiV2.0, the question raises how to proceed? There exist several options. The best solution is to collect inventory data specific for the situation under study and to establish a new inventory according to the ecoinvent rules. However, this is often not feasible for lack of resources, or because the dataset is not so important for the considered system. To extrapolate a new crop inventory from existing inventories, we can

- > use an existing eiV2.0 inventory with the most similar site conditions (climate, soil, topography) or management data,
- > apply a correction factor for the differences in yields and production means
- > combine two or more existing inventories by interpolating between them (for example 70% wheat Spain and 30% wheat France).

To perform this extrapolation we have to evaluate the similarity of the cropping conditions between known inventories and a new case. There are two important parameter sets to be considered

- > Site parameters: climate, soil conditions, topography, etc.
- > Management parameters: yield, means of production (machines, fertilisers, pesticides, water, land occupation)

Depending on the type of impact assessment which is the main focus, different parameters are of special importance:
Yield → key factor for land use in ecoindicator99
Diesel input → important factor for energy demand and global warming potential
Nitrogen input: type and amount of fertiliser → important factor for energy demand, global warming potential, nutrient enrichment and acidification
Precipitation: amount and distribution → important for nutrient leaching
Pesticide input → key factor for human and ecotoxicity
Irrigation → important for the energy demand and the water resources

A large variation in production conditions exists between countries and regions, therefore an extrapolation of crop production inventories is problematic in general. An analysis of the site conditions and management practices in the study region and comparison with the regions covered in eiV2.0 is inevitable. Depending on the goal, the considered system, the considered impacts or methods and the particular situation, a certain extrapolation is however possible following the guidelines presented in this contribution.

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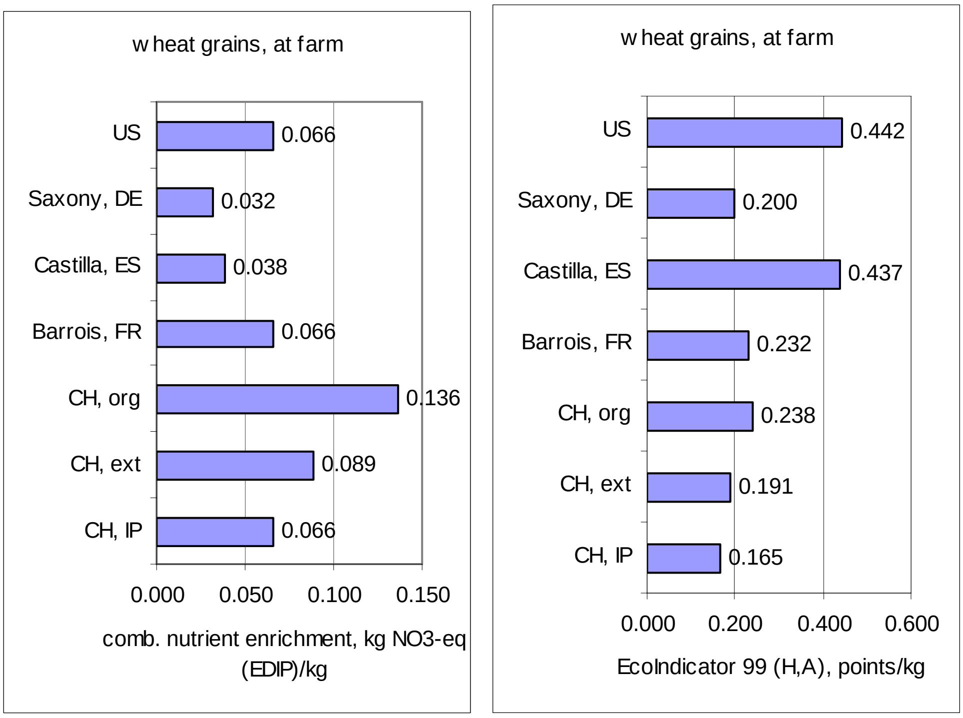

Figure 1: Combined nutrient enrichment potential according to EDIP97 and EcoIndicator99 (HA) points for different wheat production inventories (ecoinvent data V2.0, ecoinvent Centre, 2007).

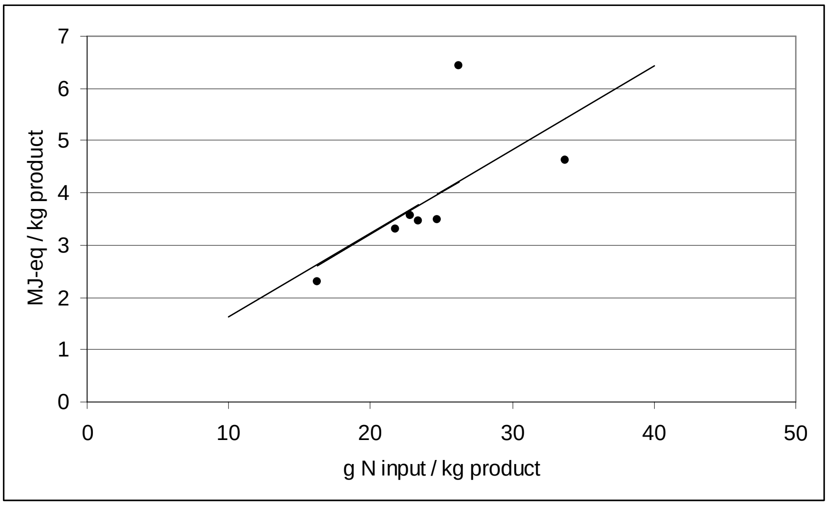

Figure 2 Linear regression between N-input kg N per kg yield and non renewable energy demand MJ-eq. per kg wheat grains for six different wheat inventories from ecoinvent data V2.01 ($r^2 = 0.42$, after exclusion of the outlier $r^2 = 0.95$).

Comparison of life cycle inventories for construction of various greenhouses

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Keywords: inventory analysis, greenhouse, structural materials, protected horticulture

Many life cycle inventory (LCI) databases have been created worldwide (e.g., Curran & Notten, 2006). The creation of original and site-specific inventory data will play an important role in analyzing the current state of the agricultural practices. However, there are few numbers of reports on the inventory data of greenhouses used for protected horticulture besides Russo & Mugnozza (2005). Recent growth in size of greenhouses and corresponding increase in their year-around use make the preparation of LCI data crucial. The objective of this research is to create an inventory database for structural materials of several types of greenhouses used in Japan, and to make a comparative analysis of the environmental impacts that originates in structural materials of greenhouses by using the LCA method.

Four types of greenhouses, i.e., pipe-framed greenhouses (pipe houses), multi-span greenhouses with circular arc roofs (arched roof houses), multi-span high-gutter greenhouses with truss beams (high-gutter houses) and multi-span glasshouses with gable roofs (glasshouses) are chosen for comparative LCI analysis. The representative specifications for each type of greenhouse were selected and common structural materials that are produced based on the Japan Industrial Standard (JIS) were mainly collected for making inventory data. The data sets of unit environmental burden for collected materials were created by the buildup method consulting JLCA-LCA database. As for the transportation stage, the value for emission intensity on producer price basis was cited from 3EID database. The system boundary of the inventory analysis of this study was limited to manufacturing and the transportation of structural materials only. The gross weight, volume or length of each item of the inventory was listed based on the blueprint and the preliminary estimate of real-life greenhouse. A CAD system was also used to prepare the material lists. The emission of environmental burden gases from construction stage of greenhouses were estimated using the inventory database and were generalized in common functional unit; per 1000 m^2 floor area of greenhouse.

In the case of high-gutter houses, amount of CO_2 emission from manufacturing and transportation of structural material is about 16600 kg-CO_2/1000 m^2. The base consists 23% of the total, 67% is from steel materials and 3% is from the aluminium material and 6% is due to transportation. Covering materials consist only 1%. The amount of the emission of NO_x is 26.5 kg-NO_x/1000 m^2 and that of SO_x is 9.9 kg-SO_x/1000 m^2. When considering life of each material, CO_2 emission per 1000 m^2 per year varies from 410 to 1970 kg-CO_2/(1000 m^2·y) depending on the types of greenhouses. Based on CO_2 emission from pipe houses, CO_2 emission from arched roof houses is 0.6 times smaller, 1.5 times greater for high-gutter houses and 2.9 times greater for glasshouses, respectively. The amount of concrete use and life of the plastic covering film mainly influence the emission of environmental burden gases per year. To reduce the gas emission, introducing the concrete-free construction technology and covering materials with longer life are needed. Through this study, it will be expected that inventories of structural materials of greenhouses with various specifications are able to be analyzed comparatively easily by using CAD system.

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Creating Life Cycle Inventories using systems modelling to compare agricultural production alternatives

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Keywords: agriculture, arable, dairy cows, wheat, system modelling

There are many ways suggested to reduce the environmental burdens of agricultural production. Suggestions include reducing fertiliser use, increasing yields or even producing the food elsewhere. Some are hypothetical or have limited experimental data. Sound decision-making requires a comprehensive analysis of the alternatives. We need to know how environmental impacts and land use are changed by long-term widespread use of alternative systems of primary agricultural production for a nation's food. This has become more important as our sources and seasonal consumption of food have diversified and land use for biofuels is increasing.

To ensure that changes are properly accounted and components are linked, the Cranfield University LCI approach uses models of systems and processes to quantify the commodity production at the national level (Williams *et al.,* 2006, www.agrilca.org). A system approach, together with imposing mass balances, ensures that short-termism is not practised. This is very important because the soil provides a large nutrient buffer that can be plundered for several years before yields fall. Comparing typical short-term crop yield response curves with those from the long term experiments at Rothamsted's Broadbalk plots shows this difference (Figure 1). In these experiments, the N supply effectively matches the crop offtake and losses, while maintaining relatively constant soil N pool.

In our approach, long term leaching is calculated from crop rotations using the SUNDIAL crop-soil N simulation model (Smith et al., 1996). The model is run to steady state to ensure that all inputs and outputs are fully balanced. Meta-modelling is then used to calculate leaching and denitrification as functions of yield, fertiliser input, soil texture and rainfall. Machinery inputs are also correlated to soil texture and yield.

Animal production models are used that define industry structures and link outputs, like milk, to the animals' nutritional demands, fertility, productivity, manure and enteric methane production. Increasing numbers of lactations in cows, for example, is associated with reduced breeding overheads, but also a reduced supply of beef from culled cows, which is credited to dairying at a system level. Increasing milk yield or fat concentration increases energy demand and hence feed energy required and manure produced. Total intake is related to body mass, so smaller cows will need to substitute concentrates for forage to meet the same energy demand. Concentrates give lower enteric methane emissions, but generally require more energy for production than forage (Table 1)

In analysing manure use, care is taken to allow for the long-term release of N, which either displaces the need to supply N or increases yields, thereby reducing the need for other land.

System and process modelling provides a highly interactive framework for the analysis. The results of studying proposals for reducing the environmental burdens of food production are instructive. We can clearly demonstrate that the key variable for reducing agricultural production burdens in crops and animals is nutrient utilisation efficiency and not necessarily yield per animal. It is also clear that most alternatives make little difference to the energy required per unit of production: energy out requires energy in.

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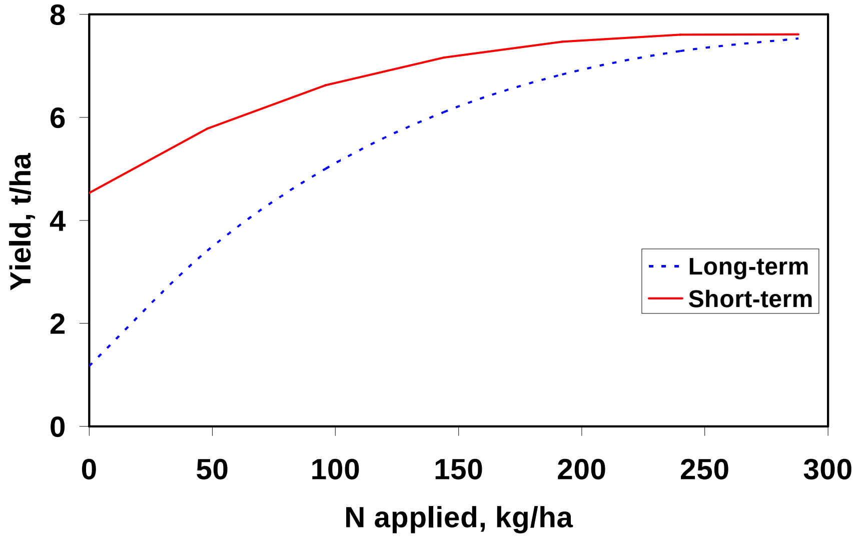

Figure 1. Comparison of yield of wheat versus N fertiliser supply from short and long term experiments

Table 1. Effects of changes in milk production systems on burdens of producing 1 m^3 milk.

	Yield, Litres / lactation	Cow weight, kg	Proportion of concentrates	Primary energy, GJ / m^3	GWP, t CO_2 Equiv. / m^3	NH_3-N, kg / m^3
Current	9,000	650	37%	2.6	0.99	3.5
Yield up 15%	10,400	650	50%	2.6	0.91	3.2
Breed change (typical)	10,400	720	40%	2.5	0.95	3.3
Energy conversion up 8%	10,400	670	39%	2.4	0.89	3.2

LCA and Carbon Footprints in Agro-Food: From Theory to Implementation in the Food Industry

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Keywords: LCA, Carbon-footprint, agricultural production, food industry, GaBi 4, PAS 2050

Agrarian systems are among the most complex production systems. This is because of the important influence of environmental factors that vary in both time and space and may be highly specific to local site conditions. Also the correlation between inputs (of fertilisers, pesticides, agricultural engineering, etc.) to outputs (of harvested crop, gaseous field emissions, leachate, etc.) is extremely complex and often non-linear in nature – in contrast to most industrial production systems. In LCAs or CFs in the agro-sector, classical data collection or enquiry is not possible and the creation of mean values is complicated and may have limited meaning/applicability.

As a consequence, an extensive, non-linear, complex computing model has been developed using the GaBi 4 software tool. This model allows users to carry out LCAs and CFs of agro-production in a very comprehensive way. In addition to accounting for resource inputs required during production of a crop, the model also accounts for storage of renewable energy in the biomass and for CO2 uptake in biomass. On the output side, the most complex aspects of the model relate to developing a robust model of the nitrogen cycle including the emissions of NO3- in water and N2O, NO and NH3 into air for all cultivated species. At the same time emissions from erosion, fire clearing and background emissions (soil emissions that would occur whether a crop was planted or not) as well as the balance of nutrient transfers within crop rotations are consistently realised within this model.

There is growing demand from food companies for information on the environmental performance of food products to assist with producing strategies for developing more sustainable food production systems. As such, the focus of agrarian modelling in LCA and CF has changed over the past five years, shifting from the debate on biofuels to an increasing requirement to better understand the sustainability, especially the carbon footprint, of food supply chains. To assist this, standard methods for the assessment of the lifecycle greenhouse gas emissions of goods and services are under development (BSI PAS 2050, 2nd draft).

LCA and CF approaches can help companies to understand the impacts of their products and also shed light on some of the current debates around issues such as food miles, GM crops, organic farming, deforestation, carbon sequestration, etc. A challenge from an LCA practioner's point of view is to be able to

- cover different locations worldwide (country/site specific) and explain why differences occur
- cover different agricultural production systems (annual and perennial crops, organic vs. conventional etc)
- cover different products and packaging designs
- produce results reliably and quickly
- be easily understandable and marketable – companies want results that can be easily communicated to stakeholders and also want to be able to balance the environmental issues with other areas of concern such as social equality (fair trade, sharing benefits, not exploiting farmers in poor countries, etc.) and affordability (relating to subsidies, competition for land, input costs of fuel and fertilisers, etc.)
- deliver at a reasonable cost.

The Agrarian Model (and the associated databases) developed gives the flexibility to meet these criteria. The presentation will give examples of challenges and gives close insight into some case studies on agro-food production.

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Transport load pattern and exhaust gas emission data from vehicles used in Brazil

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Keywords: transport, emissions, LCA, food, Brazil

In Brazil, transportation of goods is predominantly carried out by road (i.e. trucks). The Brazilian economically active truck fleet (over 50%) is mainly composed by over 10 years old medium trucks. Countless attempts were made at obtaining actual data relative to emissions of pollutants associated with road transport of goods in Brazil. For that purpose, contacts were made with a great number of freight companies throughout the country, in addition to Petrobrás, CETESB and many other organizations and institutions. In spite of all the efforts, these data are not available in Brazil, be it because they are not directly measured, be it because they are treated as strictly confidential information. Only data relative to smoke emission control could be obtained from 2 companies. None of the other pollutants is currently being monitored in Brazil as public data and / or data that could be used for elaboration of LCI. The laws and regulations currently in force only specify limits for new truck engines in standard operating conditions. It is hardly feasible to adapt these figures to the actual running order and conditions of the trucks that circulate on the Brazilian roads today.

Then, a road transportation model for the purpose of LCA studies was developed by evaluating the average amounts of fuel used by each type of truck (light, medium and heavy-duty vehicle), as well as the air emissions of pollutants (CO_2, CO, NO_x, CH_4, particulate, HC, N_2O and NH_3) that result from fuel combustion in diesel engines were estimated based on combustion processes (Madi et al., 1999). This model adopted 1 ton.km as the functional unity in order to analyze the relative contribution of each type of truck. Data collected from 14 Brazilian freight companies contributed to the average amounts of fuel consumed by the different types of trucks. These values were adjusted to the actual load in order to obtain the diesel use per ton.km. The collected data have been used to model the transport by trucks using the PEMS4 software produced by PIRA International.

This model was applied to evaluate the transport of different kind of food in Brazil (green coffee, orange, frozen concentrated orange juice – FCOJ, apples, tomatoes, soft drink, beer, edible oil, mayonnaise, milk, milk cream, etc.), considering the distribution distances from the farms to the co-operatives, industries and port. The same model was also applied to the agricultural machines used at the farms and for off-road vehicles. Validation of transport data against total fuel use was performed. From the results of this study it has been shown that the transport steps have little effect on the LCA of food in Brazil due to the local and/or regional distances travelled from the producer to the co-operatives and port or even to the optimized useful load of the trucks used for the concentrated juice transport (Coltro et al, 2006). So, the main contribution of this paper is to present a transport model that permits to access both the effect of the transport steps and the gas emission of agricultural machines in the LCA of agri-food sector in Brazil.

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SALCA-NO3: How to calculate nitrate leaching within an agricultural LCA?

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Keywords: Nitrate leaching, LCA, eutrophication, crops, vegetables

The intensive cultivation of crops and vegetables causes often important rates of nitrate leaching leading to pollution of the groundwater and eutrophication of surface water. For the establishment of the agricultural life cycle inventory (LCI), ART developed the tool SALCA-NO3 to calculate the nitrate losses in function of the crop rotation, the nitrogen fertiliser regime, the cultivation techniques and the soil characteristics. This LCI method aims at allowing a comparison of the impacts of different crops and cultivation types on nitrate leaching based on easily available input data. The model is designed for typical climatic and pedological conditions in Switzerland and adjacent regions. Minor adaptations based on local expertise allow also an application in a broader European context (Nemecek et al. 2008).

The main tool components are mineralization of the soil organic matter, nitrogen uptake by plants, input of mineral nitrogen fertiliser and seasonal nitrate leaching potential. The base rated of mineralization is based on a standard soil with 2% organic matter and 15% clay and assumes a regular input of manure to the soil. This net nitrogen mineralization is adapted to a specific soil taking into account its clay and organic matter contents, the manure inputs, the intensity and time of tillage and the crop rotation. The nitrogen uptake by plants is modelled with help of a temperature-depending N-uptake function. The plant N-uptake functions have been developed using the simulation model STICS (Brisson et al., 2003) based on the standard N-uptake rates and harvest yields of crops given in the Swiss fertilization recommendations (Walther et al., 2001).

Nitrate leaching is calculated on a monthly basis as the difference between the available soil mineral nitrogen and the amount taken up by a certain crop in the given month. This difference results in the portion of mineral fertiliser prone to leaching. No leaching is assumed during the period of intensive growth of crops, because then soil water balance (precipitation minus evapotranspiration) is negative. The leaching of applied mineral fertiliser is modelled in SALCA-NO3 based on the seasonal leaching risk, amount and the date of nitrogen application and the soil characteristics in a given climate. The tool allows calculating 'typical' amounts of nitrate leaching. It neglects the variation of leaching rates caused by actual (weather) conditions and does not directly consider the immobilisation of nitrogen in the soil and denitrification losses. For considering the above mentioned effects dynamic simulation models like for example STICS (Brisson et al., 2003) or MINERVA (Kersebaum 1989) would have to be applied but they require data which are rarely available in an LCA context.

To be able to take crop rotation effects into account nitrate leaching of a crop is calculated for the period from the harvest date of the preceding crop to the harvest of the investigated main crop. In this way, the effect of the crop rotation is considered in the LCA of a specific crop. Moreover, nitrate leaching of whole crop rotations can be assessed with SALCA-NO3, which is important when farming systems have to be assessed.

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Multi Criteria Analysis on Countermeasures against Livestock Manure Excess Problem in Maebashi City, Japan

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Keywords: Livestock manure, LCA, Material Flow Analysis, Multi-Criteria Analysis, Policy

Japanese livestock farmers have been expanding the farm scale with an imported feed to reduce the production cost and manpower. As a result, a large amount of livestock manure is emitted from each livestock farm without enough utilization because of the lack of their own field for feed production. In the past livestock manure was utilized effectively by most of the farmers as a fertilizer, however, the demand has been decreased recently because of the spread of an imported chemical fertilizer, which is cheaper and easier to handle than manure. Those social reasons have caused the manure excess problem. The oversupplied manure caused river water and ground water pollution and odor problem. To cope with this problem, Japanese government and local authorities proposed some countermeasures with subsidy, such as the promotion of domestic feed production, construction of manure disposal plant like methane fermentation plant, and so on. Those countermeasures are expected to alleviate the manure excess problem. To propose a reasonable policy planning including effective budget allocation, it is necessary to clarify the benefits brought by proposed countermeasures comprehensively and quantitatively. However, the methodology of reasonable policy planning has not established in agriculture because of an absence of database and comprehensive model to discuss the benefits of countermeasures quantitatively in Japan.

In this research, the model for budget allocation to countermeasures was developed to contribute to the establishment of reasonable policy decision-making. The model was based on the multi-criteria analysis[1], which was often applied to the evaluation of public works projects. Multi-criteria analysis mainly includes three phases: scoring phase, weighting phase and integration phase. In the scoring phase the benefits brought by proposed countermeasures were calculated. In the weighting phase the degree of importance of each benefit were quantified by analytic hierarchy process. Finally a single synthetic unit was defined by using score and weight as an evaluation value based on goals-achievement method (Fig.1). To propose a proper budget allocation the evaluation value was maximized in the developed model. The model was applied to Maebashi city, Gunma Prefecture, Japan as a case study. In this study the expected effects of optimised budget allocation was compared with the effects of actual budget allocation of Maebashi in 2005. As a scoring phase the environmental & social benefits expected by countermeasures were estimated based on agricultural material flow analysis and life cycle impact assessment in the developed model (Fig.2).

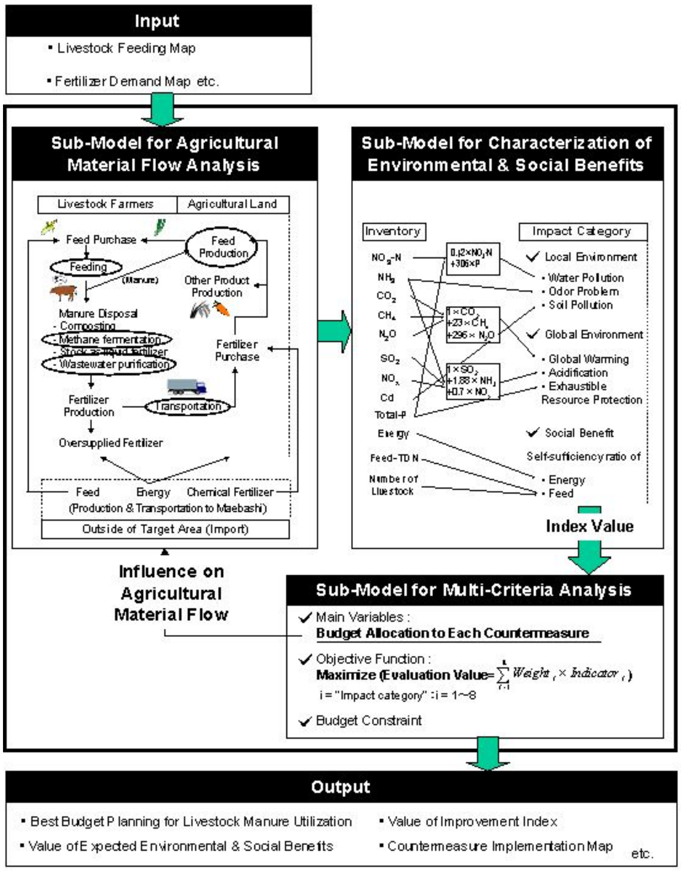

Fig.1 Outline of the Budget Allocation Model

Index of Water Pollution (PO_4-eq) = 0.42× Nitrate Leaching (NO_3- N)
+ 3.06× (Excess Phosphorous (P)
Index of Soil Pollution = Cadmium Input (Cd)
Index of Air Pollution = Ammonia Emission(NH_3)

Index of Feed Self Sufficiency = (Livestock Head / Initial Livestock head) × (Feed-TDN Production / Feed-TDN Demand)
Index of Energy Self Sufficiency = 1 / (Energy Demand – Energy Production)

Index of Global Warming (CO_2-eq) = 1× Carbon Dioxide (CO_2) emission + 23× Methane (CH_4) emission + 296× Nitrous-Oxide (N_2O)
Index of Acidification(SO_2-eq) = 1× Sulfur Dioxide (SO_2) emission + 1.88× Ammmonia (NH_3) emission + 296× Nitrogen Oxide (NO_x)
Index of Exhaustible Resource = 1 / Phosphorous Consumption (P)

Fig.2 Outline of Budget Allocation Model for Livestock Manure Utilization[2]

As a weighting phase the degree of importance of each benefit were quantified by analytic hierarchy process. The result showed that the importance on alleviation of water pollution and increase of food self-sufficiency ratio were relatively large in Maebashi city (Fig.3).

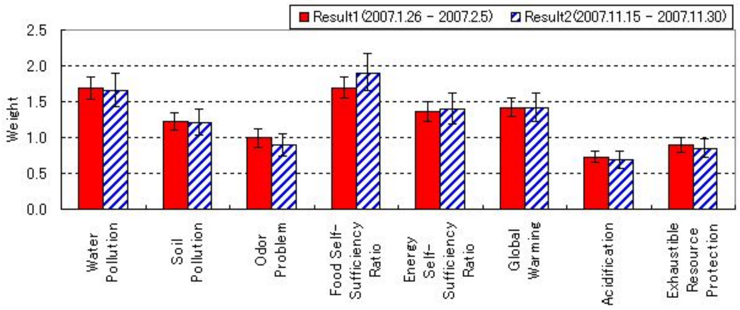

Fig.3 Result of weighting to “Impact category” based on

The result of maximization of evaluation value showed that the Maebashi plan(2005) gave the priority to improvement of local environment (Fig.4). The results also indicated that the combination of feed production project, methane fermentation and livestock reduction was effective to increase social & environmental benefits which were important benefits for residents in Maebashi (Fig.5). However, more discussion about the introduction of “Livestock Reduction Plan” should be done taking into account of consensus building between government and farmers because it has not accepted and introduced in Japan yet.

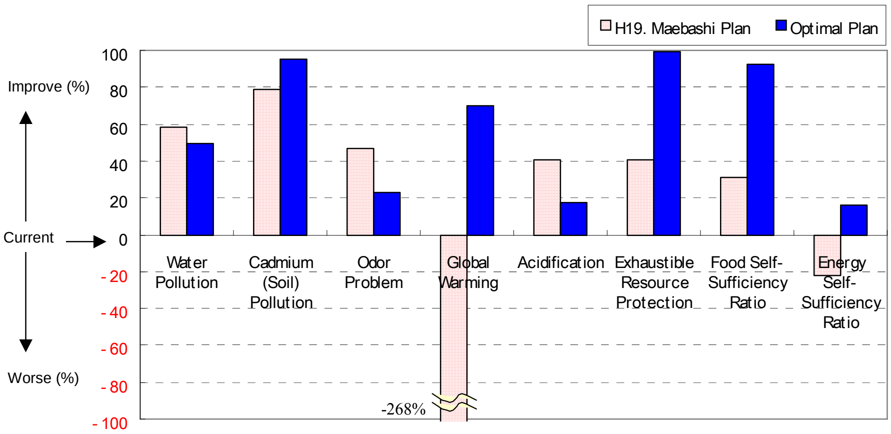

Fig.4 Expected benefits of Maebashi Plan(2005) and Optimized Plan

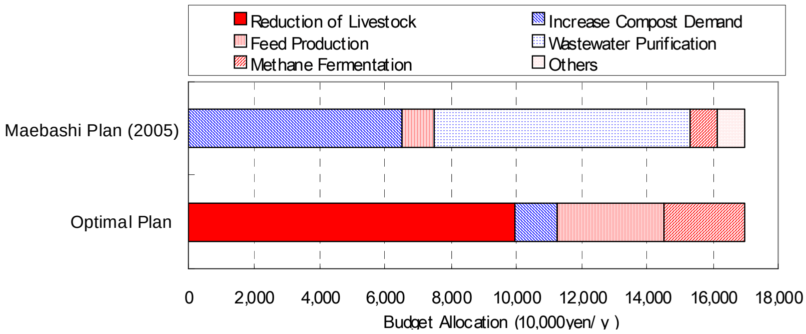

Fig.5 Budget allocation in Maebashi Plan(2005) and Optimized Plan

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Estimating the carbon footprint of dairy products at the farm gate: methodological review and recommendations

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Keywords: Global Warming Potential, Carbon footprint, life cycle assessment, dairy, methodology, harmonisation

The food industry is receiving a growing pressure from consumers, retailers and governments to produce environmentally-friendly products over their whole life cycle. Among all environmental impacts, the Global Warming Potential (GWP) in particular, also called “carbon footprint”, is currently given a stronger emphasis with specific norms being developed such as the UK-based Carbon Trust methodology. In this context, dairy companies for instance, exporting dairy products worldwide are looking at benchmarking the carbon footprint of their products along their whole life cycle using methods able to stand international scrutiny. Dairy products have been the most studied of all food products using the life cycle assessment (LCA) methodology. However, in order to produce reliable comparisons of the carbon footprint of dairy products across countries, the consistency and harmonisation of all assumptions, models and references used across all studies compared need to be checked, especially for the cradle-to-farm-gate stages representing the major contributor to the GWP of dairy products. This paper presents a review of studies on the LCA-based carbon footprint of dairy products from cradle-to-farm-gate. All steps of the LCA methodology in each study have been compiled and compared including goal and scope definition, inventory analysis, impact assessment and interpretation.

Across all studies, the goal and scope is properly defined as well as the studied system and system boundaries. The allocation rules between milk and meat at the farm gate includes no allocation, allocation based on biological causality and for most studies economic allocation. The design of the studied farm systems and their technical data are based on a range of approaches from the survey of a sample of farms to the use of national statistics and database. In all studies, the global warming potentials used are given but differ from one study to the other. Moreover, the detail of the inventory of the greenhouse gases (GHG) is more rarely fully described. Some studies apply the methods used in their national greenhouse gas inventories, while other studies use a mix of specific references on emission factors for dairy farm systems in their countries and IPCC guidelines. Some studies apparently use quite simplified inventory covering only the key aspects such as methane emissions from cows. Finally, the completeness of the analysis in most studies is difficult to check since not all components of the GHG inventory are mentioned.

The level of discrepancy in the methods and assumptions used and the uncertainty on the degree of completeness of the GHG inventories make comparisons across independent carbon footprint studies very questionable. In this particular case study as in all comparative LCA studies, a more in-depth study with all interested parties is required to harmonise as much as possible the methods used and guarantee more accurate comparisons. Finally, the most appropriate methods and references to use across LCA-based carbon footprint studies for dairy products are discussed and suggestions are made.

Sustainable livestock industry: Limitations of LCA methodology

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Keywords: Meat products, animal husbandry, organic meat, allocation, animal welfare.

Increasingly more attention is given to the environmental impact of the agri-food sector. The study “Environmental Impact of Products” (Tucker et al, 2006), commissioned by the European Union, concluded that a fifth of the environmental impact of the European economy can be associated to the sector “Meat and Meat Products”. This paper explores the possibility of using LCA results as input for policy making towards sustainability.

With the subsidy of the Dutch Ministry of Agriculture, the Dutch Consumers Organisation commissioned a life cycle assessment study on 10 regular and organic meat products; including lamb, turkey, chicken, cow and pork. The study was performed by PRé Consultants BV and Blonk Milieuadvies.

Economic allocation is used to model the multiple outputs of crop production for animal feed and the slaughterhouse, in which system expansion is not possible. The assessment of meat products is done using two functional units: 1 kg product and 1 euro.

The Impact assessment methodologies Ecoindicator 99 (Goedkoop & Spriensma, 1999) and CML-IA (Guineé et al., 2002) are used to calculate normalised figures for: energy use, land use, climate change, acidification and pesticide use.. The study includes also a qualitative analysis of the impacts of replacing nutrients and metals from crop producing countries to cattle keeping countries.

When LCA is used to analyse meat production systems, consistently the lowest environmental impact is associated to the most intensive production systems. The reasons for this are, among others: methodologies often do not account for all pesticides and hormones used, data on specific use of pesticides and hormones is often too complex to collect and animal welfare is not considered.

This paper discusses the consequences of applying economic allocation on the LCA results. Furthermore the paper discusses the limitations of the LCA methodology current status as tool to determine criteria for sustainable livestock industry.

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Investigating variation and uncertainty in agricultural production system: examples from Australia

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Biofuels, Variability, Uncertainty, Sugar, Grain, LCA

The biofuels industry in Australia is currently small (<0.5% of total transport fuels). Ideally, any industry expansion would be underpinned by robust science demonstrating sustainability credentials. Given the unintended consequences of rapid biofuels expansion in the USA and Europe, Australian governments have been and continue to be somewhat cautious in developing policy to support expansion.

The greenhouse gas (GHG) emission profiles of biofuels have long been of critical interest to policy makers as a key aspect of sustainability and fundamental to the argument for government support. Life Cycle Analysis (LCA) has been used previously to characterise standard first generation feedstocks (Beer *et al.* 2001; CSIRO, ABARE and BTRE 2003), and these figures were used as policy benchmarks. These GHG profiles differentiated main feedstocks (wheat, C-Molasses, etc) and blends with petroleum products (eg 10% ethanol blend), giving a single emission reduction number for each combination.

However these numbers are outdated, and new approach must be better able to incorporate more explicitly the variation and uncertainty found in feedstock production systems. For example

- existing production systems (such as wheat farming systems in Australia) can have vastly different forms, and the emissions profiles differ substantially according to particular management decisions,
- regional variation from different environments leading to differences in yield, fertiliser and other input regimes.

In addition, there are great sources of uncertainty including

- scientific understanding of the extent and role of nitrous oxide emissions (e.g. Crutzen 2008) and our ability to model them for some systems (e.g. O'Connell *et al.* 2008)
- emergence of novel feedstock sources (such as *Pongamia pinnata*) about which little is known and therefore parameterisation is very uncertain

This paper illustrates our developing approach to these issues in Australia. We have linked crop simulation models to LCAs to better quantify and characterise variation and uncertainty in sugar and grain production systems for biofuel production. Moving beyond 'single value' emission factors will need to be a balance between the complexity of capturing the variation, and the simplicity required to underpin industry and government policy development.

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Results of a Literature Review: Life Cycle Assessment of Agriculture Production

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Keywords: LCA, literature review, farm production

Many LCA studies and data for agriculture production have been published these last years: scientific articles, reports, thesis, conferences proceedings as well as databases. Ecointesys – Life Cycle Systems has performed, together with the ADEME (french EPA), a literature review on LCA of agricultural production. The process of the literature review was the following:

1. Identification of available LCA publications related to agriculture products (130 publications screened, transformed products were not included);

2. Classification by type of productions;

3. Evaluation of the quality and selection of the most interesting studies;

4. Detailed analysis of the reference studies per type of production, comparison and interpretation of the results.

Overall, it is about 30 studies that the authors have selected for the detailed analysis. 17 different productions have been assessed: wheat, barley, corn, rice, rye, salad, tomatoes, carrot, grape, apple, beef, milk, sheep, pork, poultry, eggs and aquaculture. For each of these productions, the references studies have been assessed in details. The studies are described, in particular the scenarios used, the hypothesis, the system boundaries or the allocation procedure. The results of these studies are presented using the following indicators: non-renewable primary energy, greenhouse gases, acidification, eutrophication and land use. Whenever possible, results are interpreted and conclusions are drawn for each production. The influences on the results of important parameters such as the type of production (organic, intensive, extensive), the inclusion of the infrastructure or the feeding scenarios are analysed.

Finally, a synthesis of the results for all agricultural productions studies is proposed, with the main conclusions of the literature review and an identification of the needs for further developments.

This study gives a good state of the art of the LCA studies that have been performed on agriculture production these last years and identify what are the main conclusions for the above-mentioned agricultural production. The study finishes in October 2008 and the literature review will be published by the ADEME at the end of 2008.

The report module “Agriculture and Environment” for the German national environmental accounts

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Keywords: SEEA, environmental and economic accounts, I/O analysis, agricultural sector model

Systems of integrated Environmental and Economic Accounts (SEEA) (United Nations et al., 2003) shall help to quantify and analyse interactions between economic systems and the environment as a basis for policy advice. SEEA constitutes a satellite system added on the national economic accounts. As one element of SEEA, the analysis of material and energy flows, resource use and emissions is an approach at the macro level comparable to LCA methods applied to particular production chains. However, implementation of such systems still suffers from the lack of detailed data on both monetary and physical flows between economic sectors, and within specific sectors. On behalf of the Federal Statistical Office responsible for the German SEEA system (Destatis, 2007), the authors have been involved in an explorative project for disaggregating the agricultural sector as part of the national environmental accounts (Schmidt and Osterburg, 2006). Main objective is a more detailed depiction of specific production activities and main outputs of the sector while maintaining full consistency with data of the national monetary and physical accounts, and to emissions in accordance to official inventories.

Calculations are based on the German sector model RAUMIS (regionalised agricultural and environmental. information system for Germany), which is used for integration of different data sources. The complete and consistent physical data framework describes production processes and input-/output-relations, including data on intermediary products like feed, manure and young livestock. A focus of the analysis is the calculation of total resource use and emissions per product unit, calculated on the basis of the physical and monetary input-output tables. For analysis of multi-input-/multi-output agricultural production systems, allocation procedures are based on monetary I/O-relations. However, methodological approaches are still subject to internal discussions and further developments.

As a top-down approach, SEEA provides aggregated assessments at a rather aggregated level. A topic for further development is to disaggregate the sector data to regions or farm units. Further, system boundaries shall be extended beyond the national agricultural sector, for including imports from upstream industries and from abroad. As the German national environmental accounts actually provide quite aggregated data on inputs, and because SEEA approaches hardly exist in relevant export countries, LCA data could provide an improved basis for this. Also, LCA methods are explored in order to include investment goods in a coherent way into the SEEA approach. As a comparative advantage, the SEEA methods developed for the German agricultural sector provide a complete picture consistent to the official statistical data framework, with options for further disaggregation and extension of the depicted production processes and multi-input-/multi-output analysis.

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LCA of novel products – Application to food processing

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Keywords: LCA, LCA methodology, novel products, food, food processing

Life cycle assessment (LCA) was initially developed to answer questions about the environmental impact of available products and services (Azapagic 1999, Baumann & Tillman 2004, Curran 2004), implying that the product system under study was possible to investigate in detail; however, if new products or processes are to be evaluated several complications occur. So, the aim of this paper is to review the methodological issues that need to be taken into account when LCA is used for evaluating novel products, processes or production from an environmental standpoint, as well as to draw some recommendations related to the best approach when dealing with them.

An initial brainstorming on the identification of methodological issues when applying the standard LCA methodology for the evaluation of novel products allowed the identification of the relevant aspects, on which a literature review was then performed. Periodical meetings took place for discussion of the significant references and an agreed approach, validated through three case studies on the food sector, was defined as result of the procedure.

Five elements were identified as relevant for the specific application of LCA to novel products: type of LCA, functional unit, system boundaries, data gathering and scenarios development. An analysis of the state-of-the-art of the LCA methodology concerning to each of them leaded to the definition of the recommended approach (Table 1):

The recommended approach was validated through three case studies (Table 2), which are all comparative studies, with the common element of including novel products (such as the production of new products from by-products) or novel processes (such as membrane technology or high pressure processing), either regarding the production of food products or the treatment of waste associated to the food industry.

This paper has, in our opinion, helped at cleaning the area of the application of LCA to novel systems, in particular related to food products and food processing that is an area of great development in the last years. The general application of our approach is difficult to assess, however we feel confident regarding the recommendations here proposed and we hope they can be of use for other LCA users.

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Table 1: Summary of the proposed methodology

Element	**Methodological Choice**
TYPE OF LCA	Prospective Attributional LCA
FUNCTIONAL UNIT (FU)	Physical FU (with system expansion) or the inclusion of the economic dimension in the FU
SYSTEM BOUNDARIES	System expansion when possible. Exclusion of those steps that are not affected
DATA GATHERING	Specific data for the foreground system. Average data for the background system checking the suitability of using actual data for that
SCENARIOS DEVELOPMENT	Future perspective of scenarios. Most appropriate method for scenarios development depends on the aim of the study.

Table 2: Validation of the recommended approach

	CS1A: Membrane filtration (Dairy industry)	**CS1B: Membrane filtration (Abattoir by-product treatment plant)**	**CS2: High Pressure processing**	**CS3: By-product (from food processing) treatment**
AIM OF THE STUDY	To compare the production of fermented milk production from condensed milk or using nanofiltered rinse milk	To compare three different combinations of ultra and nano filtration (UF&NF) with the actual treatment of bones and fat from Swedish abattoirs	To compare high pressure (HP) treated tomato salsa with fresh untreated salsa and conventional heat treated salsa	To compare three different treatments for a by-product of the industrial food processing: red cabbage trimmings
TYPE OF LCA	Product Prospective Attributional LCA	Product Prospective Attributional LCA	Product Prospective Attributional LCA	Product Prospective Attributional LCA
FUNCTIONAL UNIT (FU)	Production of 10,000 L of fermented milk, plus a certain amount of feed	Annual processing of raw materials (bones). Results are presented related to the FU and related both to the FU and the total economic profit of the products	1 kg of tomato salsa at the consumer. Results are presented related to the FU and related both to the FU and the price of the products	Processing of 1 ton of red cabbage trimmings
SYSTEM BOUND.	System expansion. Exclusion of identical steps (actual milk treatment)	NO system expansion. Exclusion of identical steps (production of bones and fat)	NO system expansion.	System Expansion. Exclusion of identical steps (production of red cabbage trimmings)
DATA GATHER.	Foreground: Laboratory scale data and scale-up Background: Average actual data from LCA databases	Foreground: Real industrial data Background: Average actual data from LCA databases	Foreground: From salsa industry and HP equipment manufacturer Background: Average actual data from LCA databases	Foreground: Computer modeling and real data Background: Average actual data from LCA databases
SCENARIOS DEVELOP.	Technical what-if scenarios	Technical what-if scenarios	Technical what-if scenarios	Based on expert judgments on profitability

Accounting for biogenic NMVOC emissions in LCA

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Keywords: isoprene, monoterpene, NMVOC, leaves, photochemical oxidation

Isoprene (also known as 2-methyl-1,3-butadiene), an unsaturated C-5 hydrocarbon, is emitted in vast amounts from photosynthesizing leaves of many plant species, particularly by trees. With a global atmospheric carbon flux of approximately 450 million tons of carbon per year, isoprene emissions are a major contributor to the total biogenic volatile organic compound (BVOC) flux of 1,200 million tons of carbon per year. Current interest in understanding the biochemical and physiological mechanisms controlling isoprene formation in plants comes from the important role isoprene plays in atmospheric chemistry. Isoprene rapidly reacts with hydroxyl radicals in the atmosphere. In the presence of nitric oxides (NO_X), the oxidation of isoprene contributes significantly to the formation of ozone, a dominant tropospheric air pollutant. Moreover, isoprene also contributes to the regulation of tropospheric hydroxyl radicals concentration and thus plays an important role in determining the abundance of atmospheric methane, an important greenhouse gas."[1] On a sunny day the isoprene emission of 10,000 trees can be up to 10 kilograms per hour.

So far such biogenic NMVOC emissions are only rarely accounted for in LCA of biomass products. There is a modelling uncertainty due to several influencing factors like type of plant, temperature or irradiation of the sun. Also it has been shown that there is a large seasonal variation with the main emissions soon after budbreak in the summer and quite lower emissions in the winter. No information could be found about the influence of different cultivation intensities (e.g. fields with lower or higher annual yields). And it is debatable whether such emissions should be included because they also arise from non-cultivated biomass areas. Thus, the conclusion of taking them into account would be to reduce the area actually covered by biomass. Nevertheless, according to the today knowledge, these emissions are quite important with respect to the formation of summer smog and thus it is of interest to include them in the LCI.

The NMVOC emissions during plantation of Straw, Miscanthus and Short-rotation wood have been investigated for a life cycle assessment of BTL-fuels (Jungbluth et al. 2007a; Jungbluth & Schmutz 2007).

The presentation focuses on the results for category indicators considering NMVOC emissions for these plants, e.g. photochemical oxidation (Jungbluth et al. 2007b). It can be shown that NMVOC of plants have a large impact on the total impacts in the life cycle if accounted for. Pros and Cons of including such emissions in LCA studies are discussed in the presentation.

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Conceptual framework for considering life cycle and watershed vulnerability analysis in the environmental performance evaluation of agro-industrial innovations (Ambitec-Life Cycle)

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Keywords: environmental performance, vulnerability, Ambitec-Agro, Ambitec-Life Cycle

Since 2001, Embrapa performs impact assessments of agro-industrial innovations with the Ambitec-Agro system (Rodrigues *et al.*, 2003). Ambitec-Agro integrates social and environmental impact indicators in weighing matrices designed to compare the performance of an innovation against other existing technology, focusing the analysis at the innovation-adopting establishment scale. This study presents a conceptual model that aims to expand the scope of the Ambitec-Agro System by including life cycle and watershed vulnerability analyses to the environmental performance evaluation.

The life cycle assessment (LCA) of agro-industrial products is growing up with the development of models that consider emissions from the use of agrochemicals and their impacts on the environment. Although these models and the supporting agro databases were developed to Europe environmental conditions and need to be adapted to the environmental conditions of developing countries, the life cycle thinking can be promptly adopted, allowing the inclusion of other production phases beyond those specific of the agro-industrial establishment.

The consideration of the environmental vulnerability of a natural system that receives emissions related to production, use or disposal of agro industrial innovations is also important, since each system is affected differently depending of its socioeconomic and environmental characteristics. This concept is usually linked to the following factors: systems' exposure to pressures, sensitivity and adaptive capacity. These factors can be studied in a watershed scale to evaluate its vulnerability, considering agro-industrial environmental issues.

In order to develop this conceptual framework, the steps proposed by Malczewski (1999) to the delineation of a multi-criteria decision support model were followed. Figure 2 presents the conceptual framework of the Ambitec-Life Cycle model, showing a sequence of actions that need to be followed in order to plan the environmental performance evaluation of an innovation, to conduct the environmental vulnerability analysis of the watersheds where each life cycle phase occurs, to conduct the environmental performance analysis in each life cycle phase and in the overall life cycle. The framework includes four life cycle phases to the environmental performance evaluation of an agro-industrial innovation as compared with an existing substitute technology: raw material production, technology production, technology use and its final disposal. A set of indicators evaluates the vulnerability of the watersheds where given phases of the innovation and of existing technology life cycles are placed. The vulnerability index enters as a weight to those environmental performance indicators that are related to local or regional agro-industrial issues. The environmental performance evaluation, in a life cycle phase, is carried out by a set of environmental performance indicators that are aggregated in criteria, principles and in a phase index. The values assumed by the environmental performance indicators in each life cycle phase are aggregated in total indicators values, in criteria, principles and in the final life cycle index of an innovation and of the comparative existing technology. This framework provides a broaden view of the environmental performance of an innovation, shedding light on technological improvements along its entire life cycle.

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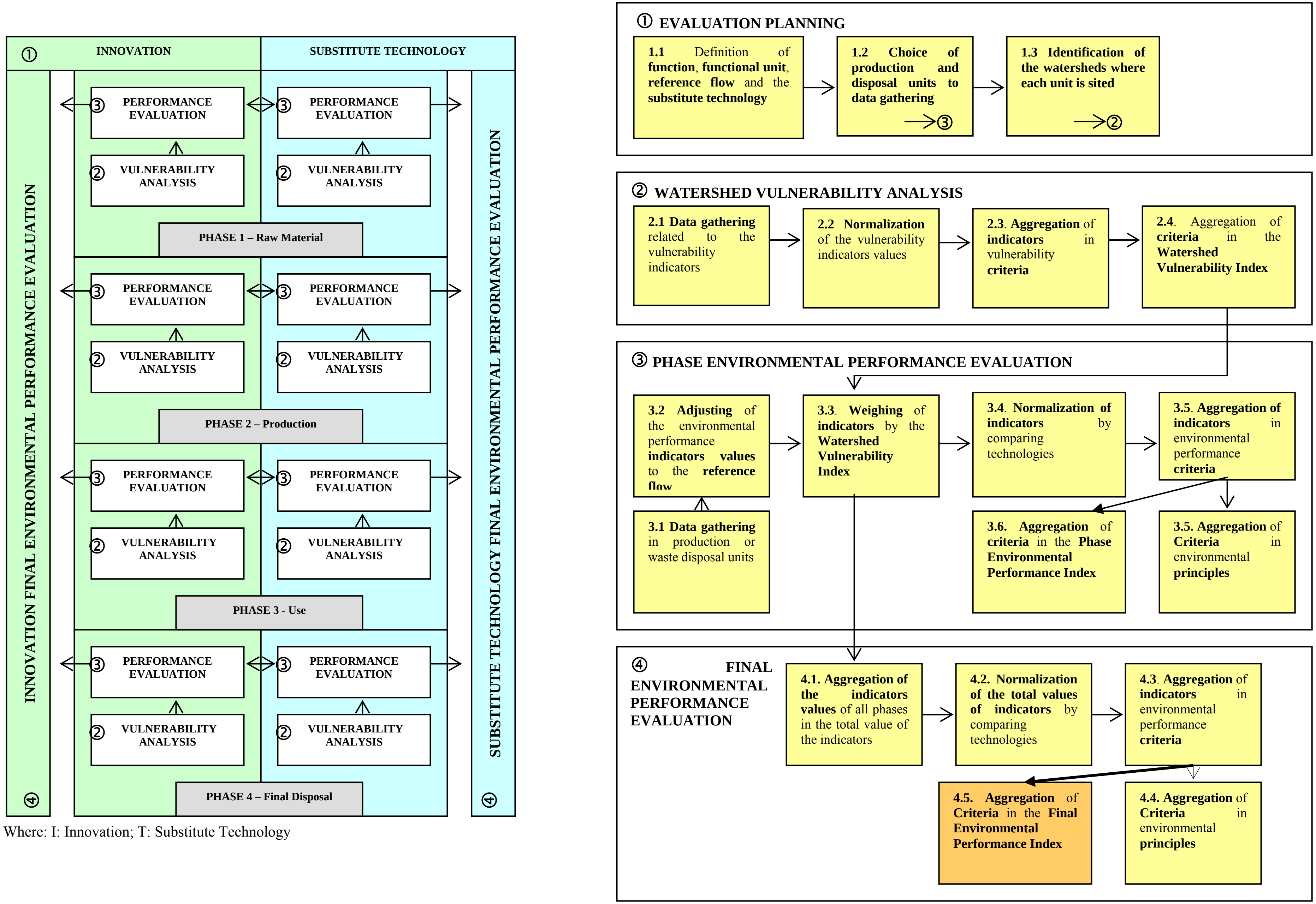

Where: I: Innovation; T: Substitute Technology

FIGURE 1 – Conceptual framework proposed to the environmental performance evaluation of agro-industrial innovation (Ambitec-Life Cycle)

Multicriteria comparison of RA and LCA toxicity methods with focus on pesticide application strategies

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Keywords: LCA, RA, eco-toxicity, human toxicity, pesticide application, ENDURE

Over the last years many Life Cycle Assessment (LCA) models have been developed in order to analyse the toxic effect of chemical substances to environment and human health. Experience shows substantial variation between the models, especially when looking at pesticides in agricultural production systems. For these reasons, we decide in the frame of the European network of competence on pesticides (ENDURE) to compare RA toxicity models SYNOPS (JKI), IPHY (INRA) and PRZM-USES (INRA) and the LCA toxicity models EDIP, USES, IMPACT2002+ and EI99 by a multicriteria analysis. The criteria list is derived from the work of Gaillard et al. (2005). It considers the criteria groups scientific soundness (11 criteria sets), practical feasibility (9 criteria sets) and stakeholder utility (6 criteria sets). this study is focused on scientific soundness (Table 1)

Considering environmental issues, all methods cover the aquatic risk (number of target species and type of indicator) satisfactorily. Looking at the terrestrial risk, the methods EDIP and IPHY partially cover this environmental issue because only one target species and only the chronic or acute risk potential is calculated for single products. On the other hand, IPHY is the only method which considers the risk assessment for beneficial organisms. Looking at human toxicity, the methods SYNOPS, IPHY and EDIP do not cover it sufficiently. SYNOPS does not consider human toxicity at all, IPHY does not consider the risk for farmers and consumers whereas EDIP does not consider the pesticide uptake through water. On the contrary, the methods USES, IMPACT2002+, EI99 and USES-PRZM-USES face this aspect almost entirely. In view of the exposition pathways, EDIP only roughly estimates the fate factors to water, air and soil and therefore shows the lowest value. On the other hand, the methods SYNOPS, EI99, USES and USES-PRZM have the highest value calculating the exposition pathways well founded.

There is an apparent advantage of the RA methods over the LCA methods for the criteria sets coverage of agricultural applicability and coverage of production factor and geographical applicability. The LCA methods can so far only handle a limited number of pesticides. Furthermore they are not detailed enough to consider production management aspects or processes on the field such as incorporation., whereas the RA methods are especially designed for assessing pesticide applications. Looking at the other criteria sets such as the depth of analysis, the integration of processes, the avoidance of incorrect conclusions and transparency, there is no difference between the methods. They all cover these aspects adequately.

The criteria groups practical feasibility and stakeholder utility will be discussed by the authors at the next project meeting in Mid May. The corresponding table can be delivered afterwards and will be available at the time of the conference.

Although first results on scientific soundness show higher scores of RA compared with LCA methods in coverage of agricultural production and coverage of production factors, the LCA methods also show their strength considering the criteria sets environmental issues, coverage of human health, and the ones which deal with the quality of the indicator in term of result and implementation. Therefore, further tests on different case studies are foreseen to better document the ability of each method for an application in agricultural LCA.

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Tab. 1: Overview of the provisional results for the criteria group scientific soundness for the considered toxicity methods. Scale goes from 1 (bad) to 5 (excellent). Each author first filled in the tables for the method he supports

Tab	**Criteria group scientific soundness**	**Score**						
		SYNOPS	IPhy	PRZM-USES	EI99	USES	Imp02	EDIP
1	coverage of environmental issues	3.2	2.6	3.4	3.2	3.2	3.0	2.8
2	coverage of human health	1	1.7	3.75	4.5	4.75	4.25	2.75
3	coverage of exposition pathways	2.9	2.5	3.6	3.1	3.1	2.6	2.1
4	coverage of agricultural production branches	3.83	3.7	3.7	2	2	2	2
5	Coverage of geographical applicability	4.2	*	1.5	1.2	1.2	1.2	1
6	coverage of production factor	3.4	2.6	1.9	1.5	1.5	1.5	1.5
7	indicator type, depth of environmental analysis	4	4	5	4	4	4	4
8	integration of processes	4	4	4	4	4	4	3
9	avoidance of incorrect conclusions linked to calculation method	4	4	4	4	4	4	3
10	avoidance of incorrect conclusions linked to outputs	4	4	4	4	4	4	3
11	Transparency	4	4	4	4	4	4	3

*value still to come

Comparative assessment of the potential impact of pesticides used in the catchment of Geneva lake

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Keywords: Life Cycle Impact Assessment, Comparative Risk Assessment, Ecotoxicological Impact, Pesticides, Multimedia Modeling, Model Evaluation.

Whilst recognizing that pesticides historically appeared beneficial, the harmful side effects of some active substances were rapidly highlighted. The impact of pesticides (and their by-products of degradation) depends on their mode of action, their persistence and capacity to move around different environmental media and the characteristics of environment it is emitted in. In an effort to evaluate and limit the ecotoxicological risk to the ecosystems of pesticide use, during the last years a monitoring campaign on the Geneva Lake (Switzerland) measured approximately 30 pesticides, mainly herbicides and fungicides, in almost all depths and all around the lake (Edder *et al.*, 2007).

The objectives of this research are to evaluate multimedia model predictions against the monitored concentration levels of pesticide in the lake, and to develop a method enabling to set priorities on pesticide use with respect to their ecotoxicological impact on aquatic ecosystem. The cause-effect chain is usually modelled via two intermediary parameters: the fate and the effect factor. The fate factor links a substance emission, e.g. into air, to an increase in concentration in an environmental media, e.g fresh water. The effect factor links this concentration increase to a loss on living species. In this study, the fate factors for pesticides were calculated with the multimedia fate model IMPACT 2002 (Pennington *et al.*, 2005) and compared against empirical fate factors obtained from monitored concentrations in the Geneva lake and the yearly pesticide use for agricultural purpose in the whole water catchment. Results showed a good agreement between both modelled and empirical values for most of the pesticides (Fig. 1). Discrepancies were explained by uncertain chemical properties, particularly half-lives in water (Monolinuron, Difenoconazol), and likelihood of additional pesticide sources coming from industry (Amidosulfuron, Metalaxyl) or urban use (Terbutryn, Propiconazole). Two alternative effect factors were determined based on the Species Sensitivity Distribution (SSD) curves and the Average Mean Impact (AMI) method (Payet, 2004), both based on ecotoxicity data. Results were compared and advantage/disadvantage of SSD and AMI approaches discussed with respect to the goal of comparative assessment vs. regulative risk assessment. Finally the fate and the effect factors were combined into a single assessment method used to compare the potential impacts of pesticides applied into the catchment of Lake Geneva. The final results are provided in the form of a single value for each pesticide, the so called characterization factor (CF), which are easy to understand and can be used to compare the impacts of the pesticide use on the aquatic environment. The CF, when combined with amount of pesticide use, provides a powerful indicator for decision-making, allowing local authorities and farmers to promote good agricultural practices.

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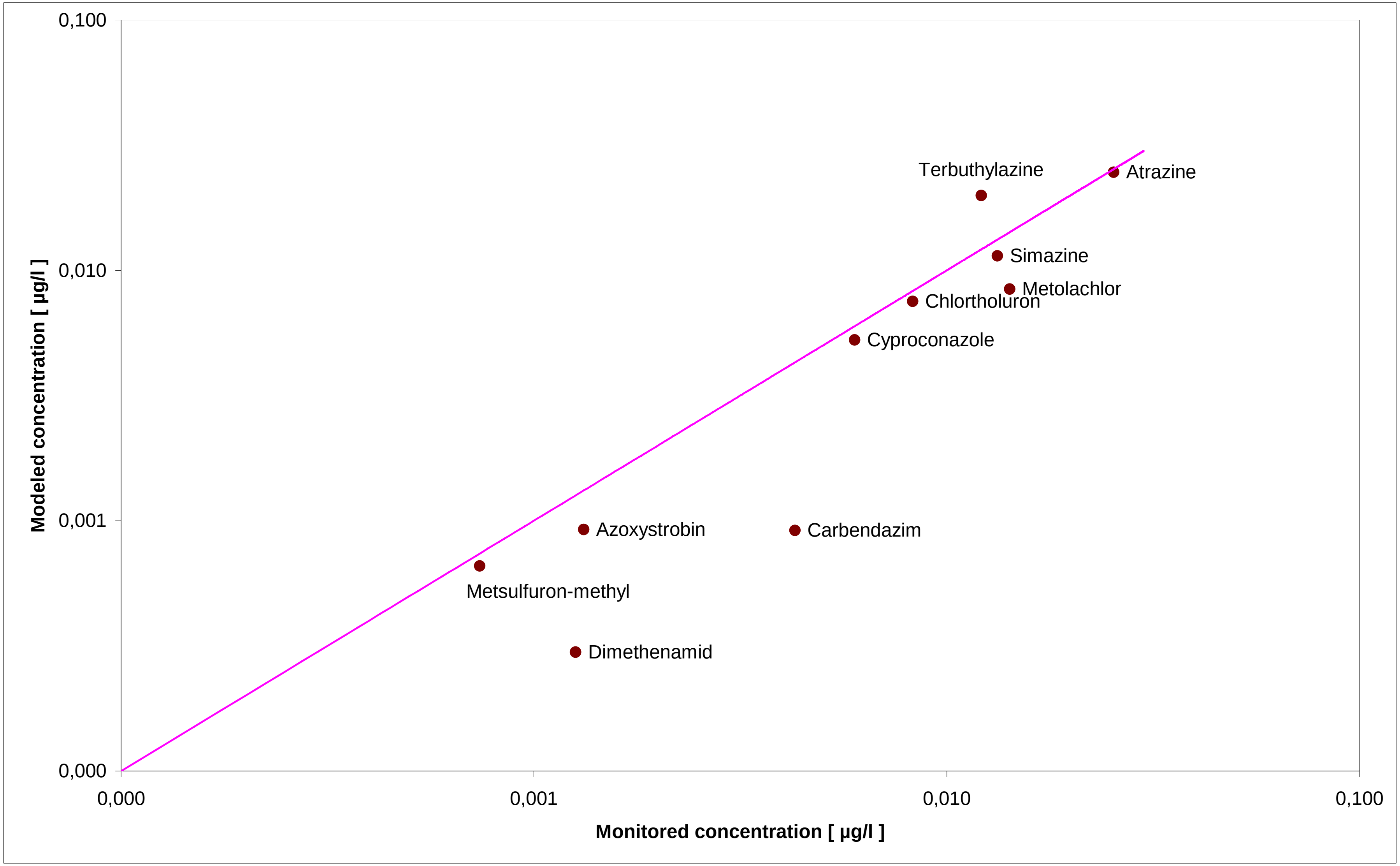

Fig. 1 : Correlation between modeled and monitored concentration of several pesticides applied in the catchment of Lake Geneva.

E*m*ergy as an indicator for Life Cycle Impact Assessment

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Keywords: LCIA, e*m*ergy, biodiversity, water depletion, soil erosion, land transformation

Recent studies pointed out that the first generation of agricultural bio-energy involves a broad array of significant environmental impacts, mainly due to the production of the agricultural crops. Despite this fact, the environmental literature is dominated by a discussion of net carbon offset and net energy gain. Effects related to human health, soil quality, biodiversity, land transformation, water depletion, among others, are recognized to be very important and should be assessed more accurately. Life Cycle Impact assessment methods provide models and data to this aim but still have clear shortcomings for the evaluation of some of the aforementioned effects.

The concept of solar E*m*ergy (solar energy memory), being the solar energy embodied in an energy system or a supplied end-energy (Odum, 1996), can provide a good indicator to evaluate the energy quality, hierarchy and efficiency along the lifecycle related to the energy system studied. E*m*ergy accounting can include the contributions of the earth systems (rain, evapotranspiration, …) and of parts of the technosphere that are often neglected in LCA studies (e.g. services). For these reasons, it can provide the basis for the evaluation of effects on soil quality, biodiversity, land transformation, water depletion, among others (Benetto, 2008). The inclusion of socio-economic effects can lead to the evaluation of the sustainability of bio-energy systems at the regional or national level.

This poster is aimed at providing the concepts and few calculations examples on simple systems for discussion with the LCA community.

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Implications of field and climate variability in the Life Cycle Assessment of slurry application techniques: a scoping study

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Keywords: Life Cycle Assessment, application technique, soil fertilization, nitrogen losses, slurry

The provision of nutrients, especially nitrogen, is a major source of pollution in intensive agriculture. Application techniques have been improved to mitigate the environmental impact of soil fertilization (Sommer and Hutchings, 2001). However, trade-offs have been observed between field emissions (Dosch and Gutser, 1996; Rodhe et al., 2006). The goal of this study is to compare the overall environmental performance between slurry application techniques in various field and climate conditions.

Four application techniques were compared with Life Cycle Assessment: broadcast spreading, band spreading, shallow cultivation and injection. The functional unit is the application of one ton of slurry. Average emission factors for nitrogen losses were calculated from on a literature review for each technique. Field nitrogen losses, i.e. NH_3, N_2O and NO_3, account for most of the acidification, global warming, and eutrophication potentials respectively. Regarding global warming potential, slurry transportation and machinery operation matter little compared to the effect of N_2O emission from the soil. Based on the analysis on the various references, it clearly appeared that the respective advantages of the different application techniques strongly depended on field and climate conditions. As a consequence, a method is proposed to design typical scenarios of application in which the application techniques can be reliably discriminated.

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Environmental impact assessment of reactive nitrogen in the Spanish agri-food sector

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Keywords: ammonia, eutrophication, LCA, multi-criteria analysis, substance flow analysis.

Nitrogen (N) is an essential element in human, animal and plant nutrition, but the presence of large quantities of reactive forms of nitrogen in the biosphere implies environmental problems at global, regional and local levels. Using data from a previous work (Soler-Rovira *et al.*, 2006) on flow analysis of N in the Spanish agricultural and food production system in the time period 1996-2000, in this work we analyze the environmental impact of reactive nitrogen exported from the economic subsystem to water and atmosphere, and the nitrogen left in agricultural soils. We have applied life cycle assessment methodology, i.e. impact categories, characterization factors and normalization values to the results of N flow analysis. The normalised values from LCA have been aggregated using weighting factors from a multi-criteria analysis using analytical hierarchy process (AHP). Impact categories have been ranked at three geographical scales: global, regional and local.

Emissions and flows of reactive N from nine compartments in the economic subsystem of the agri-food sector have been studied: fertilizer industry, agricultural soils, plant production, livestock production, food and feed industry, transport of fertilizers and agricultural and food products, domestic consumption, waste and wastewater management. The environmental compartments have been identified as water, atmosphere and agricultural soils. These receive nitrogen inputs from the economic subsystem and the pressure can be quantified as 505 Gg N y^{-1} of gaseous emissions (NH_3, N_2O and NO_x), 288 Gg N y^{-1} flow to water (nitrate, ammonium and organic N) and 1,278 Gg N y^{-1} of surplus in agricultural soils.

The results of the impact assessment are shown in figure 1. The main impact categories are Eutrophication and Acidification, with a higher importance at regional scale. Global Warming category shows minor weight, and only at global scale. The relative importance of every nitrogen form was studied (table 1), and total N and ammonia were the most important ones. The driving forces that produce those emissions and, consequently, the environmental impact were analyzed using the interrelations established in the substance flow analysis, which showed the links between N sources, processes and sinks. The main source of N is the surplus in agricultural soils, which accounts only 50 kg N ha^{-1} y^{-1}, but produces an important impact when it is considered as an aggregated value. Fertilizers and manure are the main inputs in soils, but the balance with crop uptake differs considering the crop species and farming systems, although vegetables and citrus trees show the higher N imbalances. Besides, there are zones where livestock production is concentrated and structural nitrogen surpluses arise, because they import N in animal feeds. This production is linked to a human consumption of over-recommended quantities of animal proteins. Seventy five percent of ammonia is emitted from livestock production (42% pigs) and the other 25% is from urea-based fertilizers application. These driving forces should be the target for nutrient policy, so national and regional governments have the responsibility of response to these environmental impacts.

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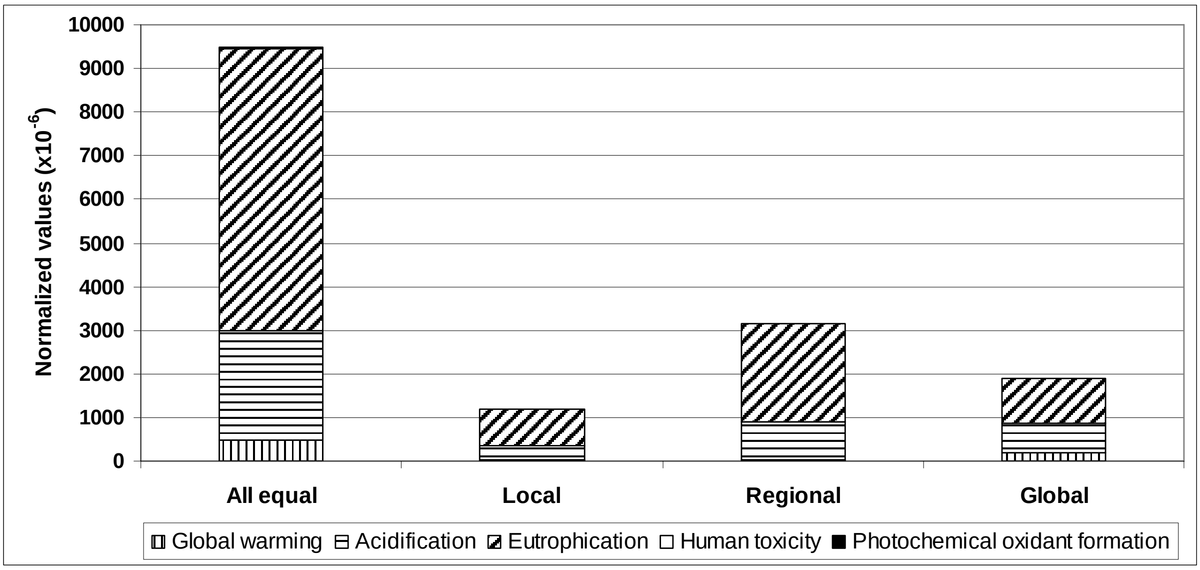

Fig. 1: Normalized and weighted values of the reactive N impact assessment at three levels of scale.

Tab. 1: Contribution (%) of each nitrogen form to total environmental impact.

Scale / Nitrogen form	Local	Regional	Global
N	53	54	42
NH_3	30	31	33
NO_x	10	10	11
NO_3^-	4	4	3
N_2O	2	1	11
Total	**100**	**100**	**100**

Relating life cycle assessment indicators to net farm income for Dutch dairy farms

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Key words: economic sustainability, ecological sustainability, life cycle assessment, dairy farms.

Sustainable dairy production requires farms that are economically viable, ecologically sound and societally acceptable. A good ecological performance of a dairy farm not necessarily implies a good economic or societal performance. To gain insight into a possible "trade-off" between economic and ecological sustainability, we investigated in this study the relation between environmental and economic performance of dairy farms, and their underlying characteristics. To determine such a relationship, however, economic and ecological indicators are required for a relatively large number of dairy farms. An additional aim of this study, therefore, was to investigate whether it is possible to assess the ecological performance of a large group of dairy farms from the Dutch Farm Accountancy Data Network (FADN), using life cycle assessment (LCA). The economic and ecological performance of 119 specialized dairy farms was assessed for the year 2005. The economic indicator used was net farm income per FTE (full time equivalent). Ecological indicators used were: land use per kg FPCM (Fat Protein Corrected milk), energy use per kg FPCM, global warming potential per kg FPCM, eutrophication and acidification potential per kg FPCM or per ha of land. Environmental indicators were based on an attributional LCA and economic allocation was used whenever a multifunctional process occurred.

Results showed that it was possible to perform an LCA for a large group of dairy farms based on FADN. Future LCAs based on FADN can be strengthened by extending FADN data collection with, for example, quantities of purchased products such as bedding material and seeds, mineral nitrogen content of purchased and produced manure, and information on soil content, e.g. phosphorus saturation. Furthermore, it was demonstrated that farms with a high net farm income per FTE had a low on farm and total land use, on farm and total energy use, and on farm and total climate change, expressed per kg FPCM. On the other hand, farms with a high net farm income per FTE had a high on farm and total eutrophication and acidification potential expressed per hectare. Analysis showed that these relationships could be explained by: farm size, Dutch livestock units per ha, annual milk production per cow, purchased concentrates per 100 kg FPCM, and milk urea content. Net farm income per FTE, for example, increases as milk production per ha (results from Dutch livestock units per ha and annual milk production per cow) increases, which explains the relation between net farm income and on farm land use per kg FPCM. Similarly, the relation between net farm income per FTE and global warming potential per kg FPCM could be explained partly by annual milk production per cow and kg concentrates/100 kg FPCM. The variation found in economic and ecological performance among farms shows that there is potential to improve economic and ecological sustainability. The fact that a high net farm income relates to a low global environmental impact (energy use and climate change) but a high local environmental impact addressed the importance of further optimization studies.

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Developing a Methodology to Integrate Private and External Costs and Application to Beef Production

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Keywords: LCA, DALY, environmental valuation, economic value, natural and sown pastures

In this paper we develop a method for integrating Life Cycle Assessment (LCA) with economic valuation, allowing a trade-off analysis between environmental and economic performance. We use an aggregate indicator for the environmental component, namely Eco-Indicator99 (Goedkoop & Spriensma, 2000) from the LCA software SimaPro. Eco-Indicator 99 (EI99) calculates a weighted sum of values in the categories Human Health, Ecosystem Quality and Resource Consumption, converting the value for this indicator to monetary units, and then adding this to market-based private economic costs. An economic value is quite a simplified output, understandable by either a scholar or by a layman and aiding in cost-benefit analysis.

EI99 measures Human Health in DALY – Disability Adjusted Life Years. We use conventional economic valuation of the Value of Statistical Life (VSL) to obtain 74-175 k€/DALY. The quality of this estimate is confirmed by back-converting from DALY to GHG emissions, using the conversion factors in SimaPro, obtaining a valuation range of 16-37 €/ton CO_2. We then use the weight for Human Health in EI99 to obtain an economic valuation for EI99 points: 2.83€-6.71€/point. This gives us a monetary valuation for the other categories.

Using this method, we compare beef production in natural pastures vs. sown pastures. Beef is a valuable product in the Portuguese market. However, its production has considerable environmental impacts. Part of the problem is that steers are usually fed in intensive production systems. This work aims to provide an alternative for steer production, namely using extensive systems. We compare the total costs and benefits (private and environmental) of two extensive animal production systems: (1) natural poor grasslands, and (2) sown biodiverse permanent grasslands. Differences are shown in Fig. 1. Contrary to general belief, we conclude that the latter, although more intensive, are better, and would be even more so if their use of phosphate fertiliser were optimised.

Results are shown in Tab. 1. In this case, though the lower €/DALY value is a third of the higher, this is concealed by the magnitude of the private costs compared to the costs determined by LCA. Private costs are higher in the natural pastures scenario due to the greater area needs, and this is mainly reflected by the fencing costs. Sown pastures have such low private costs because they are more productive. Hence, costs per steer are smaller.

Also, to compare costs for environmental impacts in the Climate Change category with those from other studies we used the EI99's damage values in DALY per kg of CO_2. Despite the differences in the underlying methods, we obtained a range of 16.6 - 39.4 €/ton CO_2eq, which falls near the range of 5 to 22 € per ton of CO_2, provided by NewExt (Friedrich, 2004), and the EU Emissions Trading Scheme value of 26 €/ton CO_2.

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Tab. 1: Values in €/steer.yr for all components considered

	Natural pasture + Feed		**Sown pasture + Feed**		**Sown pasture (11th year) + Feed**	
	Min	***Max***	***Min***	***Max***	***Min***	***Max***
Water	0.6	23	0.6	23	0.6	23
Soil	5.82		4.96		1.34	
Carcinogens	5.88	14.11	13.65	32.77	5.04	12.10
Climate Change	31.32	75.17	-35.67	-85.60	32.07	76.96
Respiratory Inorganics	33.84	81.22	63.75	153.01	29.85	71.65
Other LCA categories	17.39	41.73	26.76	64.24	16.20	38.89
Total external costs	**94.85**	**241.05**	**74.06**	**192.37**	**85.09**	**223.94**
Private costs	**452.27**		**434.02**		**284.22**	
Total	**547.12**	**693.32**	**508.08**	**626.39**	**369.31**	**508.16**

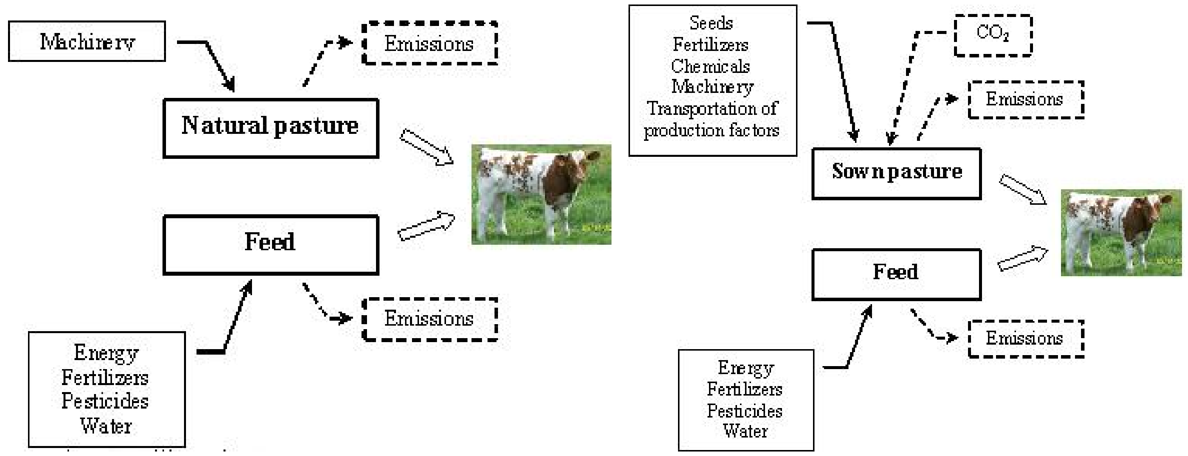

Fig. 1: Steer's life cycle in the natural (left) and sown (right) pasture scenario.

Using LCA data for agri-environmental policy analysis at sector level

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Keywords: SALCA, FARMIS, positive mathematical programming, organic farming, environmental indicators, economic efficiency, life cycle assessment

The Swiss agricultural policy has been implementing a progressive environmental agenda since the introduction of direct payments in 1993. Full cross-compliance was introduced already in 1998 and additional ecological services were stimulated by targeted agri-environmental payments, including payments for organic farm management. Against the background of a limited budget, the considerations on cost-effectiveness play a fundamental role for a further development of the direct payment system (Badertscher, 2004). Therefore, this paper pursues the following objectives:

- explore the suitability of life-cycle assessment data for policy analysis at agricultural sector level
- compare the environmental impacts and costs of different agri-environmental policies

The cost-effectiveness of policy measures on sector level can be assessed quantitatively with an economic modelling approach which takes into account uptake rates, transaction costs, and the environmental effects as three major determinants of a successful agri-environmental measure.

Our analytical approach consists of an economic sector model supplemented with life-cycle assessment data. The economic model FARMIS, is a sector-consistent static-comparative farm group model, which can be used for the assessment of policy impacts both at farm and sector level. The model is primarily based on farm accountancy data, distinguishing between 29 plant production activities and 15 animal production activities (Sanders *et al.*, 2008).

For modelling the environmental impacts of different policies, we link the following data from the Swiss Agricultural Life Cycle Assessments (SALCA) (Nemecek *et al.*, 2005) to the economic data of the farming activities (e.g. wheat and grassland cultivation):

- Primary energy use, in order to determine the potential of the policies to reduce the dependence of agriculture on non-renewable energy
- Eutrophication potential due to nitrogen and phosphorus losses, in order to assess the ability of the policy to reduce the risk nutrient enrichment in sensitive ecosystems
- Habitat quality for 11 different indicator species groups, evaluating the potential of policies to improve biodiversity

The paper will present sector-level cost-effectiveness calculations for selected policies and discuss strengths, limitations and potential applications of this approach.

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Sustainability Solution Space for the Swiss milk value added chain: Combing LCA data with socio-economic indicators

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Keywords: Sustainability, indicators, milk value added chain, LCA, socio-economic indicators

We present the Sustainability Solution Space (SSP; Wiek & Binder, 2005) an approach for assessing the sustainability of the Swiss milk value added chain. Current integrative and indicator-based assessment approaches in agriculture usually have three main shortcomings: (i) there is an overall focus on assessing the ecological aspects of agriculture neglecting to some extent economic and social aspects; (ii) research has so far focused on filling important gaps in knowledge and technology, but has missed to include the step towards utilization and implementation of this knowledge; and (iii) the assessment results themselves are difficult to be implemented in decision-making, as conflicting goals and the interaction between indicators has not been sufficiently considered. We propose that for filling this gap an approach is needed which fulfills *systemic criteria*, i.e., sufficient representation of the system including functional interaction among indicators, which allows to depict goal conflicts; *normative criteria*, i.e., considering the different value perspectives of stakeholders by including them in the process and designing sustainability ranges rather then threshold values; and (iii) *procedural criteria*, i.e. pursuing the assessment in a true transdisciplinary process. We present the SSP and its application for the Swiss milk value added chain. The system is described with a set of 17 indicators, 8 ecological (derived from LCA data) and 9 socio-economic. The sustainability thresholds were obtained through literature research and stakeholder interviews. The relationship among the indicators was developed in a transdisciplinary workshop. The SSP program takes a geometric approach to determine the intersection space corresponding to the satisfaction of the normative ranges while taking into account the functional interactions of the indicators. We show some results of the sustainability solution space for the Swiss milk value added chain and discuss the prerequisites, advantages and shortcomings of the method (Schmid, 2008).

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Life cycle assessment to eco-design a ready to eat dish

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Keywords: life cycle assessment, food product, eco-design, agri-food chain.

The costs and environmental impacts attributed to the sale and consumption of any food product are associated to the type of converted product and its whole agri-food chain: its raw materials, the type and design of used packaging, the necessary manufacture to produce it, its supply chain and retail, consumer's use, etc. Most of those impacts come from the eco-design stage of a product since in that stage the product needs are defined.

In this study, an eco-design pilot experience on a ready to eat dish has been performed as a way to develop more efficient and sustainable agri-food products along its whole life cycle. The final aim of this work is to optimize all stages of the agri-food chain and reduce associated costs and environmental impacts (Zufía & Arana, 2007).

To achieve this, the followed methodology is:

- Complete definition of the product: raw materials (source, transport needs, manufacturing, etc.), manufacture and preservation process, packaging (materials, shape, etc.), preservation needs, retailing, way of final consume and disposal.
- Life cycle assessment of the product using an specific LCA software: definition of the whole agri-food chain and its stages, characterization of all inputs (natural resources, intermediate products) & outputs (emissions to air, soil and water) of each stage, eco-inventory performing and impacts definition and assessment (Andersson *et al.*,1994).
- Identification of most important causes of the main impacts and costs. Location of these aspects within each stage of the whole agri-food chain.

Using this information, a lot of specific improvement measures for the product have been identified. The main kind of measures are: use raw material from nearer origin to reduce transport, plastic packaging substitution to another lighter, redesign the plastic container to a more efficient shape, improve the efficiency of the manufacturing process to reduce wastes, and so on. (De Monte *et al.*,2005).

Identified measures for sustainability have been evaluated from a technical and other product aspects point of view, and selected for the new product to design. As a result, it has been re-designed a new ready to eat dish much more sustainable and environmentally-friendly in its whole agri-food chain (Table 1).

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Table 1. Environmental impacts reductions achieved with the new eco-developed product.

Impacts		**Original product**	**Ecodesigned product**	**% reduction**
Air Acidification	geq.SO_2	107.98	102.85	4.75
Aquatic Toxicity	geq.1,4-DCB	127.66	102.68	19.57
Depletion of the strastosphic ozone	geq.CFC-11	0.0015	0.0012	16.60
Eutrophication	geq.PO43	16.44	15.11	8.14
Greenhouse effect	geq CO2	23748.33	23364.87	1.61
Human Toxicity	geq .1,4-DCB	1376.31	1203.82	12.53
Terrestrial Toxicity	geq .1,4-DCB	36.85	30.03	18.52
Depletion of non renewable resources	yr-1	0.425	0.427	-0.46

How to Reconcile Agronomic and Economic Perspectives in LCA for Agriculture

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Keywords: trade-off, impact-yield plane, impact-income plane, functional unit, stakeholders

Most prior studies using multiple functional units in agricultural LCA have found that the results depend on the selection of the functional units (e.g., Hayashi et al., 2006), and hence, previous surveys on environmental assessment methods applied to agriculture recommend using both area- and product-based environmental indicators (e.g., van der Welf et al., 2007). One way to develop these studies on the multiplicity of functional units is to develop an integrated agronomic and environmental framework based on eco-efficiency and trade-off representation using the relationships between management intensity, yield and environmental impacts (Hayashi et al., submitted). Eco-efficiency representation uses a ratio model, which minimizes the ratio of environmental impact to the yield, and trade-off representation applies an additive model, which maximizes the weighted sum of the yield and the negative of impact (maximization on the impact-yield plane). The framework can be extended more widely by applying the relationships between management intensity, income and environmental impacts. Using the extended framework, we can comprehensively construct area-, product-, and monetary-based environmental indicators. However, the evidence from a case study on the transition phase from conventional to "environmentally friendly" rice cultivation indicates that the results on the impact-yield plane and impact-income plane are inconsistent. Therefore, this paper analyzes the differences between the impact-yield and impact-income planes and discusses how to understand and reconcile the differences between agronomic and economic perspectives.

The results of the transition phase are summarized as follows. (1) No differences in tendency were found when the relative superiority among the production systems using the ratio of impact/yield or impact/income was judged. (2) In contrast, there were differences in the directions of transition between the impact-yield and impact-income planes; the impact-yield plane reveals that there are trade-offs between agronomic and environmental performance and the impact-income plane shows that there are no trade-offs between economic and environmental performance. In other words, by introducing "environmentally friendly" practices farms can improve the economic performance, although the yield levels will decrease. These results necessitate thinking explicitly about stakeholders. (a) If there are no trade-offs on the impact-yield plane due to the increase in yield through the development of agricultural technology (win-win directions in criteria), the land use competition for food production, energy production, residence and nature conservation will be relieved by introducing "environmentally friendly" practices (win-win situations among stakeholders). (b) However, the win-win directions on the impact-income plane in the case study do not imply the win-win situation among stakeholders because product differentiation inevitably involves losers too and there are win-lose directions on the impact-yield plane. This situation implies the existence of a contradiction between public and private interests. Formulation of LCA as multi-participant problems will be necessary for further methodological development.

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LCA+DEA: A proposal for measuring eco-efficiency

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Keywords: LCA, eco-efficiency, food production, scenarios

The interest of our society in decreasing and measuring the environmental impact caused by the production processes is increasing. Nevertheless, establishing the best environmental practices requires to integrate not only the environmental aspects, but also the economic ones. The concept of eco-efficiency embraces these two aspects. Although the eco-efficiency concept is well defined, it is no easy to quantify, and different models have been proposed. The aggregation of the environmental pressures into a single environmental damage index is a challenge of eco-efficiency measurement (Tyteca, 1996).

In this context the model for measuring eco-efficiency of Kuosmanen and Kortelainen (2005) is analyzed and applied to food processing systems. The model integrates both, the economic results of the production process and its environmental impact in an eco-efficiency index. This model has been applied to Mahón-Menorca cheese production, in order to determine the most eco-efficient production techniques. Specifically, 12 production scenarios have been measured using the economic result of the production process and their related environmental impacts, assessed through LCA. Both kinds of measurements are integrated in an eco-efficiency ratio through a model of weightings estimation based on Data Envelopment Analysis (DEA). DEA provides different weightings for each evaluated scenario. The model allows obtaining objective weightings, with independence of individual thought and preference.

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To broaden the perspective of LCA; how the holistic sustainability assessment tool RISE can complement the LCA approach

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Keywords: RISE, holistic, sustainability, assessment, farm level, LCA

While most life cycle assessments (LCA) allow a cradle to grave comparison of single, specific aspects of agricultural production due to the quantifications of stock and energy flows, the sole focus on single, intensely researched aspects may lead to distorted conclusions on the entity of a system. The in depth analysis of the impact an agricultural product or service has on the environment provided by LCAs can be put into a broader perspective by complementing such studies with the more holistic Response-Inducing Sustainability Evaluation (RISE) (Häni *et al.* 2003; Studer *et al.* 2006). RISE provides a benchmarked look at the bigger picture of farming systems based on aggregated indicators. RISE puts social and economic aspects of farming in context with the environmental impact and multifunctional merits produced in agriculture. It is applicable worldwide and farm- instead of commodity-oriented.

RISE is a computer-based tool that allows a holistic sustainability assessment of agricultural production at farm level. It uses the following 12 indicators to accrue one picture: Energy, Water, Soil, Biodiversity, Emission Potential (N&P), Crop Protection, Waste, Economic Stability, Economic Efficiency, Local Economy, Working Conditions and Social Security. Each indicator is determined by various “Driving force” and “State” parameters. The determination of several sustainability indicators (not a single indicator) allows a differentiated appraisal and to pinpoint possible trade-offs. In fig. 1 the principle procedure of a RISE assessment is visualized.

The tool identifies strengths (potentials) and weaknesses with regard to sustainability, hereby providing the farmer with (1) a testimonial and (2) the identification of intervention points for improvement. Repeated evaluations may serve as a holistic monitoring and impact assessment. By evaluating groups of farms, RISE allows for benchmarking and comparisons (spatially and temporally), and for the identification of framework conditions particularly conducive or unfavourable for sustainable production. RISE may thus contribute to improve agricultural production through concrete measures at farm level by improving critical framework conditions and by initiating a change of mindset of the relevant actors in the domain.

RISE has so far been applied on approximately 250 farms in diverse environments in the following countries: Armenia, Brazil, Canada, China, Columbia, France, India, Ivory Coast, Kenya, Lebanon, Mongolia, Poland, Russia, Switzerland, and Ukraine (for references see http://rise.shl.bfh.ch).

The experience with RISE so far has shown that it is an efficient and useful tool to prioritize sustainability issues at farm level. Such findings then often require more detailed and quantitative analysis to fully understand and verify the concern in question. Furthermore, the focus of the analysis should go beyond the system boundary of the farm. Therefore, RISE and LCAs should ideally be seen and used as complementary tools.

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① Interview on the farm

② Data entry into computer program and analysis

③ Visualization of results

④ Feedback to farmers and induction of measures

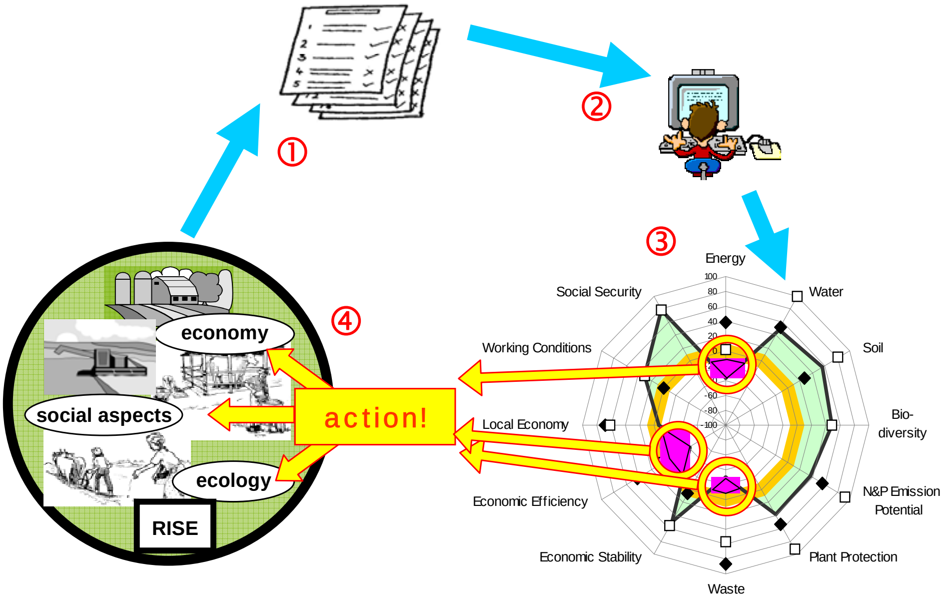

Fig. 1: Principle method for a Response-Inducing Sustainability Evaluation RISE.

Environmental evaluation of cow and goat milk chains in France

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Keywords: cow milk, goat milk, butter, energy use, dairy production chain

We analysed dairy chains in central western France with respect to their environmental impacts using life cycle analysis. This study was conducted in a pilot area, the “Pays Thouarsais”, hosting around 140 dairy cow farms and 70 dairy goat farms. Our work focused on specialised dairy farms, i.e. those hosting no other animal species than either cows or goats: 54 cow farms and 41 goat farms. We evaluated the production of cow milk and its transformation into butter, crème fraîche and skimmed milk, and the production of goat milk. Construction of farm and factory buildings was not included in the analysis, transport of milk between the farm and the factory was included. Temporal coverage was a period of one year, corresponding to the period used in the bookkeeping for the farms and factory. The impact categories used were Eutrophication (EU), acidification (AC), climate change (CC), terrestrial toxicity (TT), non-renewable energy use (NE) and land occupation (LO).

Impacts of milk production in the Pays Thouarsais were assessed for six dairy goat farms (Goat T) and thirteen dairy cow farms (Cow T), and compared to a reference group of 46 dairy cow farms in the Bretagne region in western France (Cow B). Average farm size was 120 ha (Goat T), 161 ha (Cow T) and 59 ha (Cow B). Average use of concentrate feed per year was 546 kg per goat, per cow it was 1703 kg (Cow T) and 804 kg (Cow B); annual milk production was 756 kg per goat, per cow it was 8676 kg (Cow T) and 7758 kg (Cow B). When expressed per ha of land occupied Cow T farms were similar to Cow B farms for EU and NE, while AC, CC and TT were lower for Cow T farms than for Cow B farms (Table 1). Per ha of land occupied, impacts for Goat T farms were similar to Cow B farms for EU, AC and TT, CC was lower for Goat T farms than for Cow B farms, but NE was higher. When expressed per 1000 kg of FPCM and relative to Cow B, impacts for Cow T were 12 –70% higher, and impacts for Goat T were 145 – 263% higher.

We divided the cow milk chain originating in the Pays Thouarsais in four stages: 1) production and delivery of farm inputs, 2) farm operation, 3) transport to and operation of the dairy plant and 4) post-plant transport of products (Table 3). The contribution of impacts associated with farm inputs to total inputs for the milk chain is variable, ranging from 9% for EU to 49% for NE. For all impacts except NE (to which it contributes 15%) farm operation is the dominant stage of the milk chain, its contribution ranges from 65% (CC and TT) to 86% (EU). The actual processing of milk, including milk collection at the farms, varies from 0% (LO) to 8% (CC) and it thus is the stage that contributes least to the impacts evaluated here. The transport of products from the plant to retailers contributes to a variable extent to overall impacts: 0% (LO) to 28% (NE).

The search for options to reduce impacts associated with this milk production chain should neglect none of the four stages. To explore the potential contribution of improvements for the farm operation stage to overall impacts of the milk chain we identified, within the set of thirteen dairy cow farms, the two farms with the lowest values for NE per 1000 kg FPCM and the two farms with the highest values for this impact. Based on the average of each set of two farms we then calculated characteristics for “low energy milk” and “high energy milk” and assessed impacts of milk chains based on these types of milk (Table 3). Results for low energy milk reveal that improvements at the farm stage may have a large potential to reduce impacts of the chain. This holds for NE (-20%), but also for the other impacts, with reductions ranging from 24 – 39%. Conversely, the use of high energy milk leads to increased impacts relative to the average milk scenario. It remains obviously to be seen at what cost farms with high values of NE per 1000 kg of FPCM can reduce their energy use.

Table 1. Mean impacts (1) per 1000 kg fat and protein corrected milk (FPCM) and (2) per ha of land occupied for dairy cow farms in Bretagne (Cow B, n = 46), for dairy cow farms in Pays Thouarsais (Cow T, n = 13) and for dairy goat farms in Pays Thouarsais (Goat T, n = 6).

		Per 1000 kg FCPM			Per ha of land occupied		
Potential impact	Units	Cow B	Cow T	Goat T	Cow B	Cow T	Goat T
Eutrophication	kg-eq. PO_4	6.2	9.3	14.3	40.1	39.0	39.6
Acidification	kg-eq. SO_2	7.3	8.2	16.1	48.2	34.5	47.4
Climate change (100 yr)	kg-eq. CO_2	880	1033	1272	5806	4347	3700
Terrestrial toxicity	kg-eq. 1.4-DCB	1.6	2.0	3.8	10.5	8.2	10.2
Non-ren. energy use	GJ	3.0	5.1	7.9	19.6	21.0	22.5
Land occupation	m^2 yr^{-1}	1530	2431	3481			

Table 2. Impacts associated with the production of 1000 kg FPCM, its transformation and the transport of products produced. Contribution (in %) of farm inputs, farm operation, transport to and operation of dairy plant and post-plant transport of products to total impacts. Average milk is based on data for thirteen farms. Low and high energy milk give total impacts using data for two sets of two farms within the thirteen-farm sample with lowest and highest values for NE per 1000 kg FPCM.

		Average milk					Low energy milk	High energy milk
Potential impact	Units	Inputs	Farm	Dairy	Transport	Total	Total	Total
Eutrophication	kg-eq. PO_4	9%	86%	4%	1%	9.8	6.0	11.6
Acidification	kg-eq. SO_2	19%	73%	1%	7%	8.9	6.3	11.4
Climate change (100 yr)	kg-eq. CO_2	23%	65%	2%	10%	1167	890	1431
Terrestrial toxicity	kg-eq. 1.4-DCB	22%	65%	4%	9%	2.3	2.9	6.9
Non-ren. energy use	GJ	49%	15%	8%	28%	7.9	6.3	10.3
Land occupation	m^2 yr^{-1}	15%	85%	0%	0%	2436	1733	3327

Life cycle assessment of a pilot plant for the must enrichment by reverse osmosis

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Keywords: LCA, must enrichment, reverse osmosis

The enrichment of musts is one of the most spread practices in the wine making process. Today the method of concentration at high temperature is the most common one. It requires great energy quantities and it can affect in a negative way the organoleptic characteristics of the product. On the contrary, reverse osmosis concentration methods are still poorly investigated in the wine making process, mostly with regard to the semi permeable membranes to be used (Baker, 2004) and various aspects such as energy, materials and environment of the plants, also considering the process variables. Moreover these plants offer promising development prospects, if one considers the new OCM wine, approved in december 2008, which considers to progressively eliminate the support to the concentration with the addition of rectified concentrated must.

The University of Bari and Itest, a southern italian mechanical company specialised in the building and set up of wineries, which has developed a reverse osmosis pilot plant for the must enrichment, have carried out a research project financed by the Regione Puglia, whose general goal is to acquire the knowledge necessary for assessing the environmental characteristics of the reverse osmosis plants for the enrichment of musts, which in turn is essential for the optimisation of the development of such plants. It has been agreed that the most suitable application methodology for this study is the Life Cycle Assessment of the product (LCA), standardized by the rules of the series ISO 14040 that can provide useful indications in the case of “Design for Environment” (Notarnicola *et al.*, 2003).

The inventory and impact assessment results show that the use phase, which could be divided in two subphases, enrichment process and cleaning, absorbs most of the direct energy and material consumption and that the preproduction, the production and the final disposal phases have a minor impact which is typical for most of the studies on the life cycle of machines. The research focused on finding solutions to decrease environmental impacts through the identification of the best opportunities to optimize the system under study, going through an improvement assessment. Therefore tests were carried out with the specific goal to identify the machine setup allowing to obtain the best trade off between efficiency and environmental impact during the enrichment of musts. The methodology used for the performance of the experiments is the Design of Experiments (DOE) (Anderson & Whitcomb, 2007).

The results of the led experiments show that, unlike what was deemed by many experts in the field, the processing with the reduced must incoming flow consumed less electric power, it didn’t reduce the quantity of the permeate produced, rather it increased. Further the chemical analysis led on enriched musts and on permeate show a greater efficiency of the concentration operation. The results of the research consent to improve the plants under study and to increase its value added. The research consents also to increase the environmental knowledge in the application field of the reverse osmosis technology with semi permeable membranes in the wine sector.

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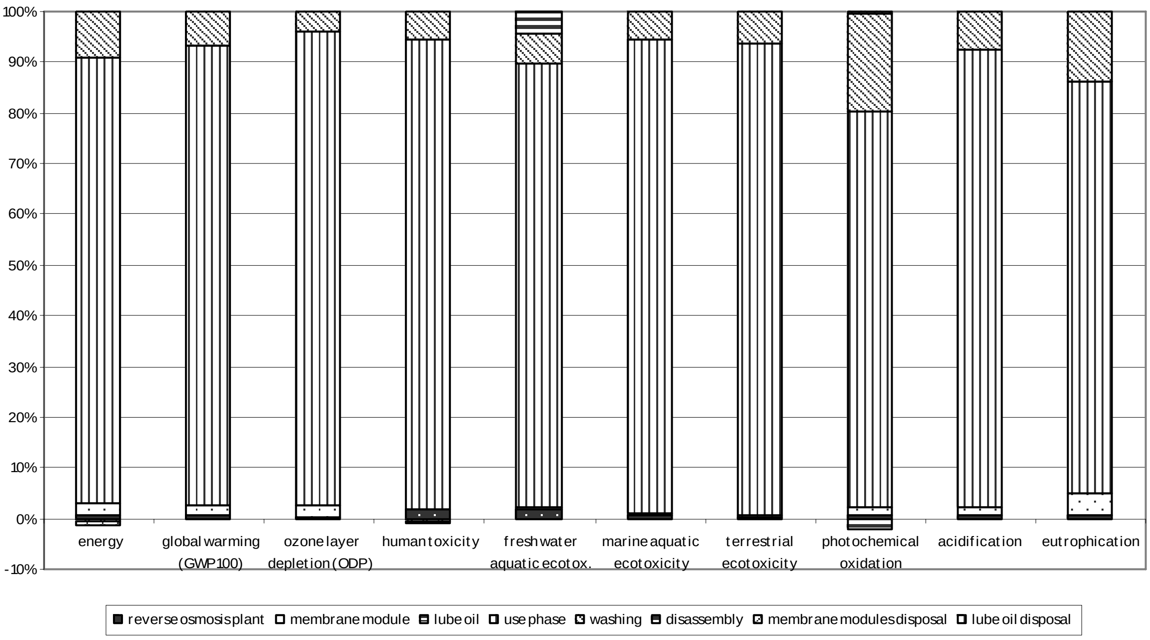

Fig. 1: Characterization of the system per phases

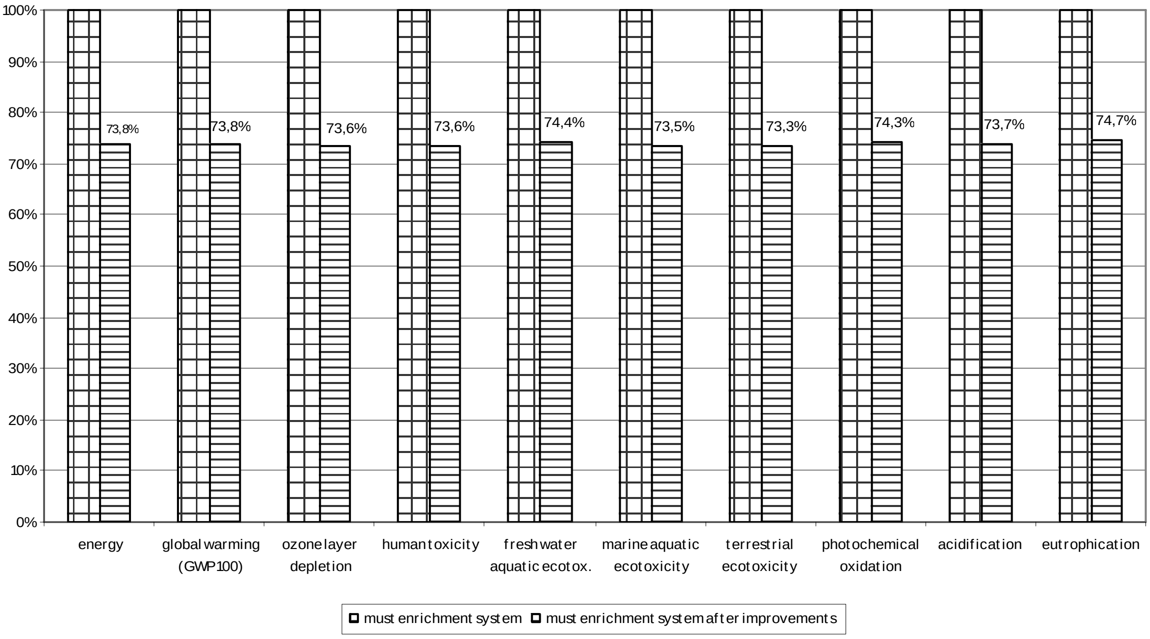

Fig. 2: Characterization of the system before and after the improvements

Relevance of human excretion in LCA of food products. Case study of the average Spanish diet

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Keywords: human excretion, wastewater treatment, nutrient cycle, carbon cycle

The aim of this work is to find out to what extent human excretion, a life cycle phase often excluded from most food LCA studies, is relevant in the context of a person's overall food intake. In order to include all the processes related to human excretion such as metabolism, toilet use, and wastewater treatment, a model recently developed (Muñoz et al., in press) has been used. A case study dealing with the average Spanish diet is carried out, including the whole life cycle of food, with the exception of packaging materials: agricultural and animal production, industrial processing, distribution and retail, home storage and cooking, solid waste management, and human excretion. The average Spanish citizen purchases 884 kg of food and beverages per year, from which we only excluded mineral water (68 kg) and some food items (34 kg) for which inventory data was not available. Due to the lack of specific inventory data for most Spanish food products, the Danish LCA food database (Nielsen et al. 2003) and data from Carlsson-Kanyama and Faist (2000) was used, along with Ecoinvent background data (Frischknecht et al. 2004) for home-related processes and solid waste treatment. Cooking was modelled by defining a hypothetical scenario for each food item, including raw eating, boiling, frying, baking, and microwaving. Human excretion and wastewater treatment was accounted for with the model by Muñoz et al. (in press), which required calculating the average nutritional composition of the Spanish diet, in terms of water, carbohydrate, fat, protein, fibre, alcohol, and phosphorus content. As scenario for wastewater treatment, it was considered that 50% of the wastewater is treated in sewage treatment plants with nutrient removal, while the remaining 50% is subject to secondary treatment.

Concerning Life Cycle Impact Assessment, only three impact categories, namely Global Warming Potential, Acidification Potential, and Eutrophication Potential are assessed (Guinée et al. 2002), along with Primary Energy Use (PEU) as environmental indicator. The results (table 1) show that although food production clearly appears as the main hotspot in the Spanish diet, human excretion, along with further wastewater treatment, is not a negligible process, specially in Eutrophication and Global Warming, where is the second most important source of emissions. On the other hand, the contribution to Acidification is almost negligible (3%) and rather low in Energy Use (8%). These results show that excretion should not be overlooked in LCA studies dealing with diet shifts, since the emissions related to this life cycle phase are different when different food items are considered. Neither should excretion be omitted in attributional studies aimed at identifying the life cycle hotspots of a given food product.

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Tab. 1: Environmental profile of the Spanish average diet, per person and year.

Impact category	Units	Processes						
		Total	Carbon in biomass	Food production & retail	Transport home	Home storage & cooking	Kitchen waste treatment	Human excretion & wastewater treatment
Global Warming Potential	Kg eq. CO_2	1,557	-371	1,277	2	237	32	379
Eutrophication Potential	Kg eq. PO_4^{3-}	11.6		8.8	2.6E-03	0.1	0.1	2.5
Acidification Potential	Kg eq. SO_2	19.8		16.4	0.016	2.7	0.2	0.5
Primary Energy Use	GJ	16.4		9.9	0.040	5.1	0.057	1.3

Sustainability of apple trade in Spain using principal components analysis

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Keywords: aggregated indices, ecological footprint, environmental indicators, life cycle assessment, multivariate analysis.

Spain is a big fruit producer and it has important trade flows with other countries. So, there is a need to assess the environmental and social impacts of intensive agricultural production but also those regarding to international trade. Apple production and trade is a good case study because it accounts for 14% of total fruit consumption in Spain, and 29% of this is imported from other countries. The sustainability of this apple trade may be assessed by an appropriate index that contains a lot of information and that it were easy to understand by the end-users. Principal components analysis (PCA) can be used as an objective approach to build up such index by choosing the indicators that show higher variability within the studied observations and by setting the weights as a function of the explained variance (Soler-Rovira and Arroyo-Sanz, 2003). The aim of this work is to assess sustainability of apples that Spanish consumers can find in the market, and to develop an aggregated index using multivariate analysis of individual indicators regarding economic, social and environmental aspects of apple production and trade.

Twenty most important apple exporters of the world and other 16 countries that have exported apples to Spain in the last 10 years have been selected as the observations set. Environmental dimension was studied searching information about fertilization, irrigation and yield of apple orchards and the distance and transport from production zones to Spain (i.e. FAO, International Fertilizer Industry Association, Water Footprint of Nations, etc.), and carrying out life cycle analysis of agricultural and transport data was done for 1 kg of fresh apples. Global and local scale impacts were calculated weighting the impact categories with a multi-criteria analysis using analytical hierarchy process. Other aggregated indices were calculated: ecological, carbon, energy and water footprints and reactive nitrogen. Economic dimension was analysed at both micro and macroeconomic levels with 12 indicators. Social sustainability was studied at farm and society scale with 8 indicators (table 1). PCA was performed for each set of indicators and a synthetic index was calculated for each sustainability dimension considering the coordinates of each country with the components retained and the eigenvalues obtained in the analysis. The indicators that showed high correlation with each aggregated index were selected and a PC analysis was carried out in order to build up a sustainability index.

Twenty countries showed a positive value of the sustainability index (table 2) and the other had negative values and were below the mean value. Nine countries were in the top of the ranking (e.g. France and Italy) with a low environmental impact, high productivity and good apple prices, while that indicators were worse in the countries located in the bottom of the ranking and with an unsustainable index. Spain and Portugal were characterized by socio-environmental sustainability, due to a low productivity and market share in the economic dimension. Argentina and Chile reach a positive value in economic sustainability, but production and trade impact and low producer prices eroded environmental and social dimensions.

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Tab. 1: Principal component analysis sustainability indicators.

PCs retained	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Eigenvalues	6.63	5.45	3.60	2.90	1.80	1.48	1.16
Variance absorption (%)	23.7	43.1	55.9	66.3	72.8	78.0	82.2
Correlated indicators (loadings)	LCAcrop (0.94) EF (0.93) WaterF (0.93) LCAglobal (0.89) Productivity (0.80) Int. justice (0.64) Income st. (0.62) Yield st. (0.58) Exp. price (0.58)	LCAtransport (0.96) CarbonF (0.96) EnergyF (0.94) Distance (0.85) Nreactive (0.62)	LCAlocal (0.92) m^3/ha (0.92) Fruit diversity (-0.46)	Income trend (0.85) Yield sust. (0.84) Globalization (0.77) Equity (-0.57)	Market share (0.91) Oligopoly (-0.91)	Exports value (-0.83) Food waste (0.81) Export oriented farming (0.50)	Fruit deficit (0.74)

Tab. 2: Values of the aggregated indices for sustainability and environmental, economic and social dimensions of the 36 countries studied. Relative ranking of each country is also shown.

Country	PCA$_{environ}$	Ranking	PCA$_{econ}$	Ranking	PCA$_{social}$	Ranking	PCA$_{sustainability}$	Ranking
Argentina	-1.494	27	0.427	14	-0.980	31	-0.671	22
Austria	3.007	6	0.757	11	0.651	11	1.976	7
Belgium	3.523	3	1.237	9	0.400	15	2.416	4
Brazil	-0.008	21	0.367	15	-0.914	30	-0.846	24
Canada	1.819	13	-0.138	19	0.294	18	1.738	10
Chile	-0.620	25	2.789	1	-2.124	35	-1.151	26
China	-10.708	36	1.512	5	-0.733	29	-3.599	35
Cyprus	-9.614	35	-1.839	34	1.240	1	-3.476	33
Czech R.	2.875	7	-0.366	22	0.112	22	0.849	17
Denmark	1.682	15	-1.060	31	0.773	7	1.147	12
Finland	-1.799	28	-4.149	36	0.285	19	-2.314	32
France	3.875	1	1.987	4	0.147	21	2.769	1
Germany	2.061	12	0.708	12	0.373	16	0.957	16
Greece	1.428	18	-0.722	27	0.853	6	0.754	18
Hungary	-0.451	23	-0.403	23	-1.088	32	-0.684	23
Iran	-4.587	34	0.315	16	0.544	14	-2.147	30
Ireland	3.131	5	-0.524	24	0.162	20	2.183	5
Italy	2.070	11	2.284	3	0.547	13	1.934	8
R. Korea	-3.798	33	-0.189	20	0.667	10	-2.187	31
Latvia	-1.170	26	-3.804	35	-1.873	34	-3.510	34
Moldova	-2.937	32	-1.425	32	-3.063	36	-4.252	36
Morocco	-2.906	31	-1.604	33	0.065	23	-1.751	27
Netherlands	3.619	2	0.838	10	0.696	9	2.513	3
N.Zealand	-0.546	24	1.288	7	0.013	25	-0.924	25
Poland	-0.101	22	1.389	6	-1.744	33	0.221	20
Portugal	0.074	20	-0.548	25	0.623	12	0.646	19
Slovakia	2.138	10	-0.826	30	-0.207	27	-0.054	21
Slovenia	2.861	8	0.147	17	0.029	24	1.423	11
S. Africa	-2.569	30	1.240	8	-0.542	28	-1.985	29
Spain	1.690	14	-0.131	18	0.312	17	1.075	14
Sweden	0.112	19	-0.822	29	0.862	5	1.064	15
Switzerland	3.508	4	0.628	13	0.966	3	2.695	2
Turkey	1.596	16	-0.286	21	0.744	8	1.093	13
UK	2.671	9	-0.817	28	0.970	2	1.810	9
USA	1.437	17	2.357	2	0.950	4	2.096	6
Uruguay	-1.869	29	-0.614	26	-0.008	26	-1.808	28

Veggie versus meat – environmental analysis of meals in Spain and Sweden

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Keywords: LCA, meal, peas, pork, vegetarian

The cultivation, processing, packaging and transport of food contribute significantly to the overall environmental impact caused by man. However, different food products have quite different impacts; and it is commonly stated that production of vegetarian products is associated with far less environmental impact compared to products of animal origin. In this study, the magnitude of the environmental benefit of pea protein compared to animal protein was investigated. Since peas do not only provide protein but also other nutrients like carbohydrates, the functional unit of the study is a complete meal providing 35 g protein and ca 3 100 kJ (the proportion of energy coming from fat, carbohydrates and protein respectively are similar in the compared meals). The main components of the meals are 1) pork produced with conventional cereal and soy based feed, 2) pork produced with feed where soy was replaced by peas and rape seed, 3) a pork sausage in which 10% of the animal protein has been replaced with pea protein, and 4) a vegetarian pea burger. Two countries are explored: Sweden and Spain; i.e. eight meals have been analysed. Data on production of pork, wheat and peas have been collected from Baumgartner *et al.* (2008), data on industrial operations have been gathered from industrial contacts, and data on other materials and transport have been taken from literature and Ecoinvent (2004).

Indeed, the study shows that the vegetarian meal causes significantly less environmental impact than the meals with animal protein; eutrophying and acidifying emissions, as well as green house gas emissions are between 40 to 80% lower. Concerning energy use the picture is however different, the vegetarian meal uses about the same amount of energy as the meals with animal protein, which is due to the energy demanding processing in industry of the pea burgers (mainly from freezing the product – most vegetarian products like sausages and burgers are today sold frozen). Most of this energy is electricity; in Sweden, the electricity mix is based mainly on nuclear and hydropower, so this is why the contribution to global warming was still 50% lower than the other meals despite a lot of energy being used for producing and storing the pea burger (for the Spanish meals, the GWP emissions was 'only' 30% lower for the vegetarian as compared to the meat based meals due to a more fossil fuel based electricity production in Spain). In summary, the environmental benefit of wholly pea based protein in a meal is clear, but there is scope for improving the energy efficiency in the processing and storing of frozen vegetarian products. Moreover, the study shows it is important to look at a complete meal, and also the entire processing chain up to consumption, when comparing the environmental impact of different protein sources.

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Analysis of trends in the drinks sector from an environmental point of view. The case of wine and of mineral water in Spain

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Keywords: Life Cycle Assessment (LCA), Sustainability; Drinks, Food; Wine; Water.

This paper uses Life Cycle Assessment to analyse the European trends in the sector of drinks, mineral water and wine, their environmental repercussions and possible solutions to the problems they generate.

In Europe more than 50,000 million litres of bottled water were consumed in 2007. The phenomenon of bottled waters is fundamentally and typically European. Europe accounts for 75% of the worldwide packaged water market, the United States approximately 20% and the rest of the world 5%. World consumption has doubled in the past 5 years.

Packaging can be made of PET (Polyethylene terephthalate) or glass, which can be re-usable or single use. PET packaging uses PET resin as a raw material, which is preformed by means of injecting and later blown to form bottles. More than 50% of bottles have varying capacities of less than 1 litre, however the 1.5 litre bottle is the most common. The location of the bottling plants is legally required to be next to a spring that fulfils the necessary requirements, both in quality and chemical composition, in accordance with legislation, and in volume.

The paper considers possible improvements to water bottling, and even compares the environmental impact of mineral water consumption to that of tap water consumption.

At the same time, the European wine sector constitutes a very diversified and dynamic sector, in continuous evolution, maintaining the first world position with 45% of the surface area, 60% of production and almost 60% of consumption. Inside the EU, this sector comprises 3.4 million hectares and involves 1.7 million producers manufacturing 6% of the net agrarian production.

The first results point towards a gradual change in the production process of wine. Traditionally wine was elaborated in a sustainable way guaranteeing minimum environmental impact. However, the current globalisation tendencies, involving a higher competitiveness between the wineries, usually lead to less ecoefficient production. The increment in the use of water and plant protection products in the vineyards, the increase in sales of bottled wine as opposed to wine in bulk, the minority use of recycled bottles, the widespread use of industrial cooling equipment in the wineries and the impact associated with transport due to wider commercialisation of wine to distant countries have considerably increased the requirements of energy and origin matters for the whole process.

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The role of flexible packaging in the life cycle of coffee and butter

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Keywords: flexible packaging; brewing; butter; coffee; consumer behaviour; packed goods;

The evaluation of the environmental performance of packaging usually concentrates on a comparison of different packaging materials or types of packaging designs (De Monte et al. 2005, Plinke et al. 2000). Some LCA studies of food include the packaging with specific focus on the contribution of the packaging for the total results (Jungbluth 2000). The consumption behaviour is often assessed only roughly. Broader approaches, which focus on the life cycle of packed goods, including the entire supply system and the consumption of goods, are necessary to get an environmental footprint of the system with respect to sustainable production and consumption.

A life cycle assessment study has been conducted for the full life cycle of two food products: coffee and butter (Büsser & Jungbluth 2008, Büsser et al. 2008). The study looks on the environmental relevance of stages and interdependencies within the life cycle of goods while taking consumers' behaviour and portion sizes into consideration. The impact assessment is based on five indicators: non-renewable cumulative energy demand, global warming potential, ozone layer depletion, acidification and eutrophication.

The most important factors concerning the environmental impact from the whole supply chain of a cup of coffee are the brewing of coffee, its cultivation and production, and the milk production in case of white coffee (Figure 1). The influence of packaging disposal is very small due to the general low influence of packaging in both food systems. In contrast, the brewing behaviour is highly relevant for the environmental impact of a cup of coffee. That applies similarly to the type of heating device – i.e. using a kettle or an automatic coffee machine. Spoilage leads to a significant increase of all indicators. The study highlights that reduction of spoilage and leftovers reduce the environmental impact of a cup of coffee.

The most relevant aspect regarding the life cycle of butter is butter production. For this the provision of milk dominates the results (Figure 2). Another important factor is the consumers' behaviour, i.e. the reduction of leftovers. The impacts of packaging and grocery shopping in the life cycle of butter are low.

This presentation will show that a reduction of relevant environmental impacts can only be achieved if also aspects indirectly influenced by the packaging are taken into account. Thus, the packaging industry should not only aim to improve the production process of their packages, but also to provide packages whose functionality helps to reduce other more relevant environmental impacts in the life cycle as e.g. losses.

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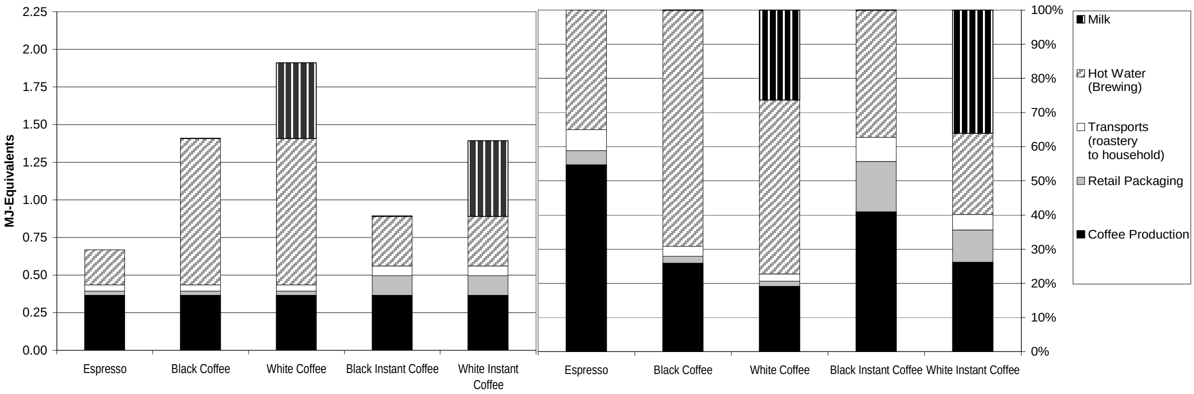

Figure 1: Results of the standard case for a cup of coffee with regard to the non-renewable cumulative energy demand. The absolute values are shown on the left side and on the right side the results are scaled to 100 %.

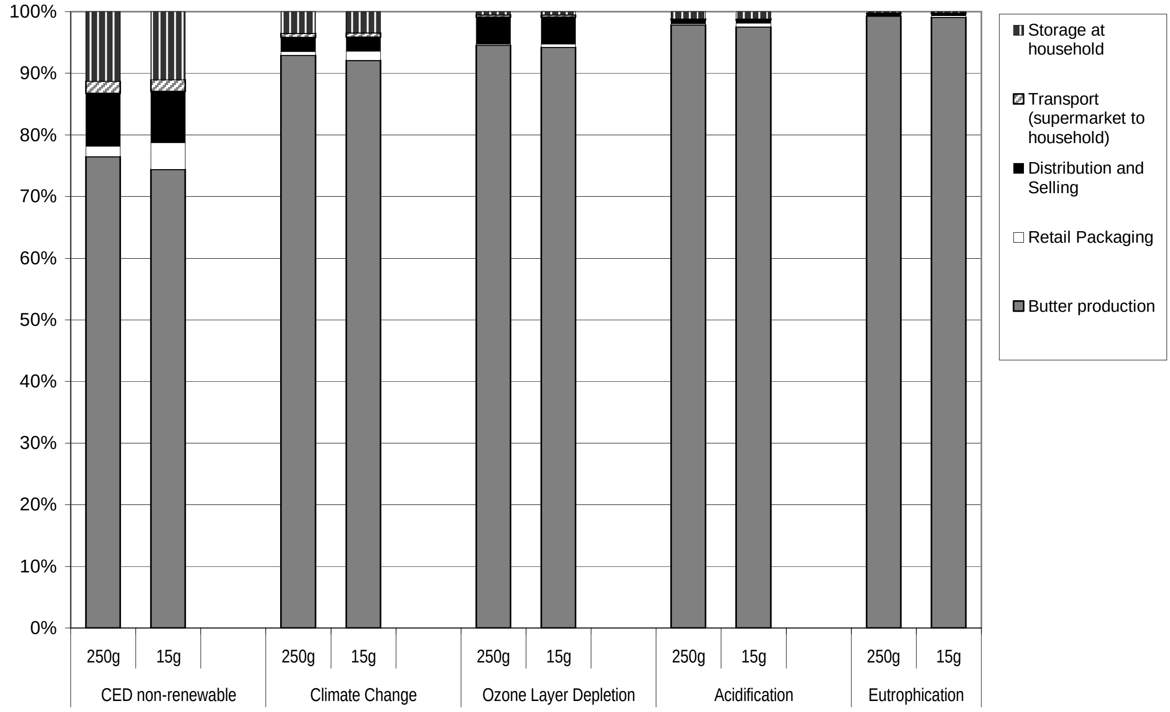

Figure 2: Results of the standard case for 1 kg butter with regard to the selected five indicators. Shown are family portion packs (250g) and small packages (15g). The results are scaled to 100 %.

An Application of Life Cycle Assessment to Pork Processing in Taiwan

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Keywords: Life Cycle Assessment (LCA), Pork Processing

Food resources are one of the human basic goods and materials demand. Hence their relevant product, processing, transportation, consumption, and final waste disposable, will influence the sustainable of modern human society.

Life Cycle Assessment (LCA) was first used as tool and method for assessing or improving product, make chain or environmental pollution load by business activity. In 1970s, after energy crisis, development come out that energy analysis thoughts were main about 'life cycle'. In recent years, the important and its use were transfer to the relevant public affairs such as environmental protection. It was ISO (International Standards Organization) in 1993 list in the requirement for ISO14000 series, and announces relevant standards successively since 1998, in order to be regarded as the basic tool of the environmental protection assessment.

In the past, LCA approaches were applied to the second industry mostly. However, more and more studies concerned about Agri-Food Sector can be found, particular in the some well-developed country, such as USA, UK, Sweden, and Finland et al. In contrast, few researched of LCA applications in Taiwan are concerned about Agri-Food Sector.

Pork, the major meat product in Taiwan, was selected as study example in this study. Pork Processing, one important process in the pork provided was investigated firstly. According to the field survey and data analysis, the following results were found:

(1) Among the four impact category influenced by pork processing, “climate change” category is influenced mostly, and then “resource consume”, “environmental quality”; in contrast, “human beings’ health” is influenced minimally.

(2) The greatest one of impact in climate changes is global warming.

(3) In summary, the electric power generated by coal and oil used in pork processing plant are major impact activity in Taiwan.

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Table1 Compare table of slaughter of resource consumption and litter output (Taiwan vs. Australia)

Resource consuming		Taiwan	Australia
Water		54.17kL/t	7kL/t
Energy	Coal	N/A	53kg/t
	LPG	1.475m3/t	0.8m3/t
	Electricity	5660kWh/t	400kWh/t
Chemical material	Cleaning chemicals	0.425L/t	1.3L/t
	Wastewater treatment chemicals	N/A	0.2kg/t
	Oils and lubricants	N/A	0.2L/t
Package	Cardboard	106.75kg/t	31kg/t
	Plastics	7.01kg/t	1kg/t
	Strapping tape	0.19kg/t	0.7kg/t
Litter			
Waste water	Volume	20.525kL/t	6kL/t
	Land pollution		
	BOD	46.658kg/t	N/A
	COD	67.558kg/t	38kg/t
	Suspended solid	17.4kg/t	13.7kg/t
	Nitrogen	27.5kg/t	1.7kg/t
	Phosphorous	N/A	0.6kg/t
Discard litter	Paunch and yard manure	7.92kg/t	47kg/t
	Sludge and floats	1.16t/t	0.04t/t
	Boiler ash	9.25kg/t	5kg/t
	Cardboards litter	12.25kg/t	0.6kg/t
	Plastics litter	8.22kg/t	0.07kg/t
	Glasses litter	124.17kg/t	N/A
	Strapping tape	N/A	0.01kg/t

Sustainable production of cheese thanks to renewable energy: an LCA of the “Pecorino Toscano DOP” from the geothermal district of Larderello, Italy.

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Keywords: LCA, cheese, sheep milk, sustainability, clean food, geothermal direct use

Since food availability ceased to be a problem for many industrialised countries in the 60s, people began to look for quality on the market. With the development of the organic agriculture, in the early 80s, consumers discovered the healing effects of food. Subsequently, consumer attention focused also on typical local-product markets, with the aim of safeguarding and emphasising the value of the “heritage” of agricultural varieties and gastronomic traditions. In the 90s, the so-called “green consumer” began to make claims for “clean food”, produced in ways minimising environmental impact. “Sustainability” is the concept that can effectively integrate all these different aspects of food production. In order to be “sustainable”, a high-quality food product should be good, clean and even “fair” from an ethical point of view (Croall, 2000).

The international NGO “Slow Food” recognized the district of Larderello as the First “World Food Community” Using Renewable Energy. The district of Larderello is known all over the world for its geothermal resources, that are effectively exploited not only for electricity generation but also for direct heat uses, such as aquaculture, greenhouse heating and food production. Does the use of geothermal heat make the local food production more sustainable if compared to traditional food chains? In our work we use LCA as a tool to assess the environmental burden of the Larderello local food productions. Our study, in particular, investigates the performance of the company “San Martino”, a family-run dairy farm that produces 60.000 cheese rounds per year (especially from sheep milk), by using geothermal steam in cheesemaking for heating and pressing purposes. We performed a “cradle to gate” study, breaking down the production process into phases: milk production at the farm, milking and transportation, cheesemaking phase, cleaning of the equipments, packaging of the cheese. The environmental impact categories are those conventionally used in some ISO 14025-based Environmental Product Declaration schemes: resource and energy used, global warming potential, stratospheric ozone depletion, acidification, photochemical oxidant emissions, acidification and eutrophication. As shown in similar studies (Berlin, 2002), also our analysis identifies milk production at the farm as the phase having the greatest environmental impact.

Because the impact of transportation is significant in a life cycle perspective (Sonesson & Berlin, 2003), another aspect that we verified by way of our LCA relates to the so-called “food-miles”, we propose different scenarios on the delivery to final consumers and use the results of our LCA to determine the “break even point” between the benefits of geothermal steam, in terms of avoided use of fossil fuels, and the impacts of transportation.

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LCA of energy recovery of the solid waste of the olive oil industries

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Keywords: LCA, energy recovery, exhausted pomace, pit, olive oil industries

In the last six years the world average olive oil production has been 2.8 million tonnes, just over 94% has been produced by the Mediterranean countries, notably Spain (39%), Italy (24%) and Greece (13,6%).

From the olive oil industrial process, two by-products are produced: the olive-mill wastewater and the pomace. The first are formed by water contained in the olives and, in some case, by the water added during the process. The solid residue is the pomace (virgin pomace), including pits, from which the residual oil content can be extracted, thus obtaining the crude olive-pomace oil and the de-oiled pomace. The recovery of these byproducts is among the most important objectives for solving environmental problems related to olive oil processing. Moreover, to utilise these by-products is also very important for the profitability for the business operators.

This study focus on the possibilities to use the exhausted pomace and pit as a fuel. According to the Government directive March 8, 2004, the de-oiled pomace could be directed to this use, provided, that it has certain characteristics, and that emissions do not exceed the limits set by legislation. Applying the LCA methodology, this analysis aims to assess the environmental performance of these alternative fuels compared to pellets used in boilers smaller than 150 kW. The assessment will broaden the perspective from only an economical point of view towards also the environmental aspects.

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Environmental performance of Spanish food and beverage industry

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Keywords: eco-efficiency, environmental indicators, factor X, LCA, multi-criteria analysis.

Food and beverage Spanish industry accounts 10% of total European production and its represents 15% of total industry sector in Spain. It plays an essential role in employment and investment in rural areas, as it is the main industrial activity in that zones. In recent years, it has increased the investment in environmental management practices and pollution control equipments, but less than 1% has implemented ISO 14001 standards (MAPA, 2005). Some information is available about environmental performance of food industry, but it is mainly focused on particular sectors or based in single indicators, lacking of an holistic assessment of sustainability and eco-efficiency and their temporal evolution, information that is needed to build up competitiveness. The aim of this work is to develop environmental and eco-efficiency indicators for the Spanish food and beverage industry using LCA, assessing their temporal trend at different scale levels.

Life cycle assessment has been applied using the best available statistical data from the food and beverage industry in Spain from 1995 to 2003 (Spanish Institute of Statistics, European Pollutant Emission Register, Ministry of Agriculture, etc.). Air and water emissions and water and energy use have been considered in the analysis. Normalized values have been aggregated using weighting factors from a multi-criteria analysis using analytical hierarchy process (AHP). Impact categories have been ranked at three geographical scales: global, regional and local (Saaty, 1990). Eco-efficiency has been studied using environmental impact data and gross added value of the industry in that period of time. Factor X analysis has been carried out considering the respective improvement of both environmental impact and added value respect to the base year 1995.

The aggregated environmental impact was higher at global scale than local or regional levels. The main impact categories were Energy use and Global Warming at global scale, while Acidification and Water use were the main important ones at regional and local levels, respectively (figure 1). Electricity was the most important energy source, but also important quantities of oil derived fuels and natural gas were used in the big facilities (MAPA, 2005). The analysis of the emissions showed that carbon dioxide was the most important greenhouse gas, and that its emissions had an upward trend over time. SO_x and NO_x were the gases involved in acidification. Industry has reduced SO_x emissions 70% from 1995, but NO_x has increased 50%, showing a good correlation with CO_2 emissions. Water was an important issue at local level and the Industry has increased water consumption, although water use in this sector was proportionally low compared with other uses as agriculture. Eco-efficiency analysis showed that industry has increased the added value per unit of environmental impact, but improvement factor (factor X) was lower than 1.5 (figure 2). The analysis at local and regional levels showed an increasing trend in factor X, but it was decreasing at global level. So, the indicators targeted in this study and those where food and beverage industry should emphasize to build up sustainability are the reduction of greenhouse and acidification gases and the energy use efficiency.

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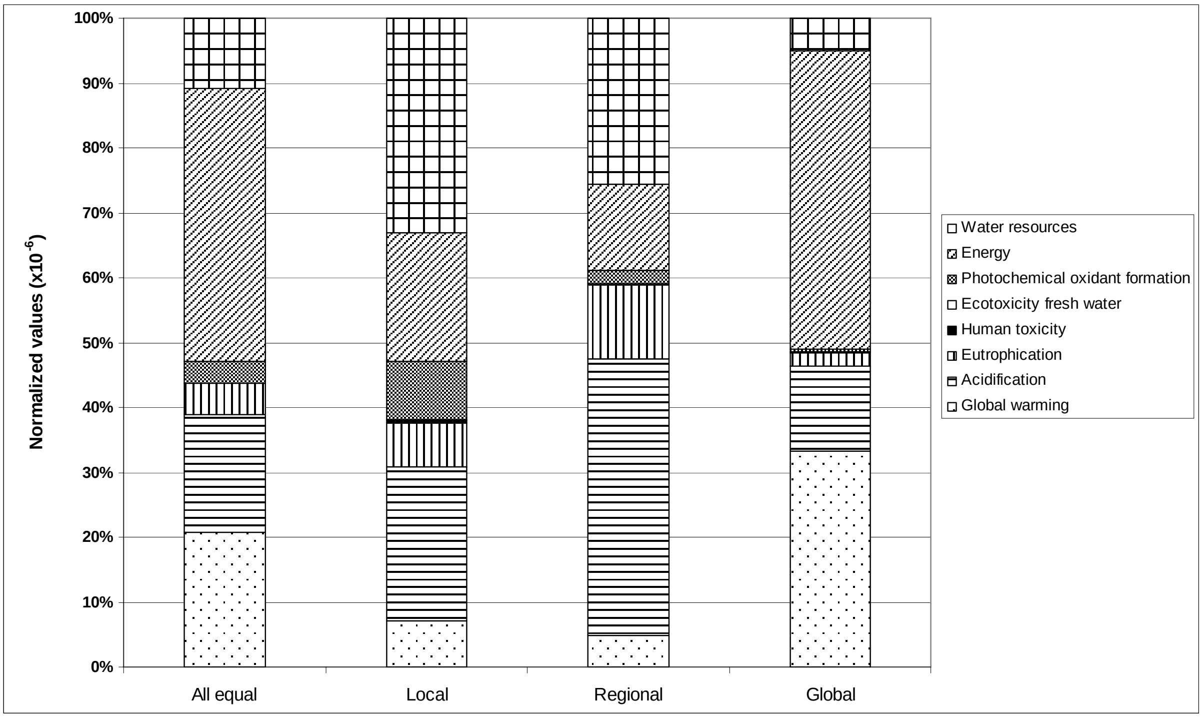

Fig. 1: Normalized and aggregated values of LCA for Spanish food and beverage industry at three scales.

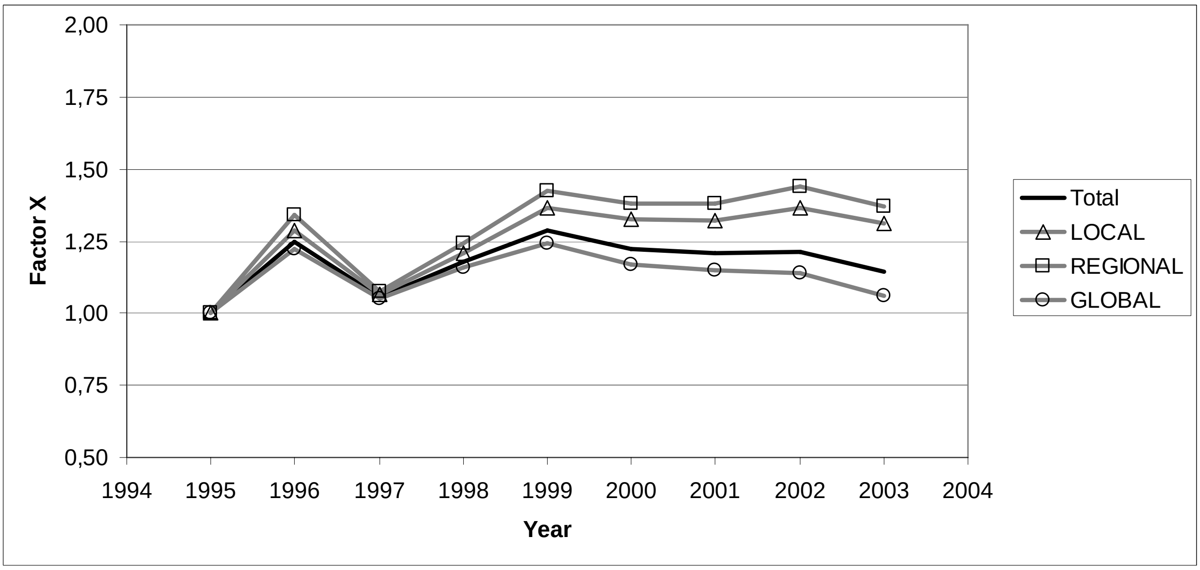

Fig. 2: Temporal trend of factor X eco-efficiency improvement for Spanish food and beverage industry at three scales.

Environmental impact of greenhouse tomato production systems in Colombia using life cycle assessment approach

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Keywords: tomato, environmental impact, life cycle assessment, crop growth modeling

In Colombia, greenhouse tomato (*Lycopersicon esculentum* Mill.) production has been increasing during the last years. Addition of new areas is being associated with technological changes aiming at greenhouse climate improvement in order to reduce technical risks and increase yield and quality benefits. Greenhouse production has caused landscape changes, ecosystems fluxes variations and risings on energy inputs and residue generation. The aim of this work was to quantify and compare the relative intensity of energy demand, resources consumption and pollutants emissions to air, soil and water, as a consequence of actual production systems and the implementation of technological alternatives for greenhouse tomato production. Life cycle assessment (LCA) approach was applied to determine the environmental sustainability of greenhouse tomato production chain, considering 1 kg of tomato in one crop cycle as the functional unit.

In a first phase and using collected data on commercial greenhouses, conventional, organic and hydroponic production systems were evaluated. Afterwards, technological improvement was considered and two greenhouse climate control strategies were evaluated: production system under double layer plastic greenhouse (DP) and DP including heating (HDP). The tomato growth model, Tomgro (Cooman, 2002), was used to determine crop yield and biomass production for climate control strategies. For all the strategies the organic residue management was determined through compost. Potential impact of the infrastructure and its contribution to environmental loads were determined especially for categories: Global warming (GWP100), human toxicity, photochemical oxidation and marine aquatic ecotoxicity. LCA results showed the lowest energy consumption for organic production system, followed by conventional production system and DP, while hydroponic production system with HDP registered the highest energy demands.

The major impact of greenhouse tomato production on the aforementioned categories is related with leaching and plastic residues. Biodegradables residues are of major importance since they lower the impacts for all categories. Fresh water aquatic ecotoxicity and eutrophication are affected by high nutrient emissions. LCA approach and the use of simulation models allowed assessing the environmental impact of actual production systems and the possible effects of technological improvements on commercial production systems.

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LCA of frozen concentrated orange juice: focus on energy comsumption and GWP

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Keywords: frozen concentrated orange juice (FCOJ); food, LCA, Brazil; sustainability

Brazil is the largest world orange producer, with more than 820,000 hectares of cultivated area. The major part of the orange production (70%) is destined for the frozen concentrated orange juice (FCOJ) processing industries, being the FCOJ for the external market (97%) responsible for making Brazil the largest world exporter and producer of FCOJ. The Brazilian citrus sector is responsible for half of the whole orange juice produced in the world and for 80% of the juice commercialized at the international market. The agricultural production showed a growth of 37% in the same period, representing a total of more than 360 million of 40.8 kg orange boxes in the same crop only for the State of São Paulo, the biggest Brazilian producer region (77%). The characterization of the Brazilian orange producers in terms of farm size, cultivated varieties, watering system and tillage practices was published previously (Coltro et al, 2008). The scope of this work was to qualify and quantify the main environmental aspects of FCOJ produced in Brazil in order to establish parameters for the sustainability and a future ecolabelling program for the Brazilian FCOJ. So, the goal of this paper is to present the LCA results for FCOJ focusing on energy consumption at the several steps of this production system and the its GWP.

The LCA of the product was performed according to the ISO 14040 standard series. All information considered in this study were taken up in-depth data collection and evaluation by questionnaires applied on farm and industry level and/or received by mail. The data refer to a production of 9 million orange boxes, 4 million plants in commercial production and an evaluated area that represents 19.5% of the State of São Paulo orange production. Two Brazilian orange producer regions located at the North and South of São Paulo State were evaluated. The environmental aspects relative to the fertilizers production were taken from recognized database and included in the boundary. The functional unit selected for this study was 1,000 kg of FCOJ. Farm specific data along with agricultural and industrial production data have been combined in order to cosntruct a FCOJ production model. The consumption of energy for producing 1,000 kg of FCOJ was 2,720 MJ, being 2,439 MJ due to industrial step, 187 MJ to orange production and 95 MJ to transport steps. Since 80% of the total amount is renewable energy, the GWP of this produtct is only 46,64 kg of CO_2 equivalents. The main contribution to the energy consumption is the industrial step (89%), since it requires a lot of energy for concentrating the orange juice and keep it refrigerated. On the other hand, this industry produces other four co-products with economic value: animal feed, oil essence, aquous essence and limonene. Besides it also contributes to atmosphere water reposition due to the evaporation step. The transport steps contributes with 3.5% of the total energy consumption, the agricultural machines with 1.1% and the fertilizers production with 1.8%. This study supplied important results for better understanding the agricultural practices and the potential environmental impacts of the FCOJ production.

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Life Cycle Assessment of Rice Production in Thailand

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Keywords: life cycle assessment, rice production, green label, rice husk power plant

Rice is the backbone of Thailand economy and the international rice trading has been increasingly important lately. In Thailand it is speculated that rice field is a major source of pollution in several streams. In a global scale, methane from rice field is regarded as a major source of greenhouse gas emissions (IPCC, 2000). Several standards and benchmarks aiming at the quality and productivity of rice products have been established. However, only a few environmental performance benchmarks has been set especially the one that considers the entire life cycle stage of rice production, i.e., Roy et al. (2006). This study is an attempt to evaluate the environmental performance of rice production using life cycle assessment to determine the environmental impact of different stages of rice production. An environmental performance benchmark, which identifies environmental impacts associated with rice production, may show what parts of the life cycle stages where the greatest improvement can be made. This may also improve the value-added of rice and its downstream products.

The major production stages included in the assessment are rice cultivation, rice milling, and transportation both in the rice field and in the rice milling site (Figure 1). The functional unit in this study is defined as the mass of product, e.g., 1,000 kg of unmilled rice. Inventory analysis has been done based on the data surveyed from about 400 farmers in the Northeast of Thailand. Resources and energy used in rice milling were surveyed from 24 rice milling plants. Air emissions, water emission, and waste generation were also surveyed from those 24 plants and a rice-husk power plant. Five major impact categories have been selected in the assessment, e.g., global warming, acidification, eutrophication, energy consumption, and resource depletion. Characterization factors have been applied to convert the emissions/depletions within an impact category to its impact indicator.

The survey shows that in general an average rice milling plant uses 66% of energy from electricity through Thailand grid and 34% from its own rice husk biomass. By these figures, environmental impacts associated with rice production for an average rice field and an average rice milling plant can be identified. The results (Table 1) show that rice cultivation is the primary source of greenhouse gas emission, airborne emissions of acidification causing compounds (N+S), and airborne emissions of eutrophication causing compounds (N+P). Meanwhile, rice milling is the primary source of energy consumption and resource depletion.

In the assessment of rice milling plant according to mode of energy use, it is found that the rice milling plant using only rice husk biomass as the source of energy releases the smallest amount of greenhouse gas followed by the plant using both the energy from electricity through Thailand grid and energy from the plant's own rice husk biomass and the plant using only energy from electricity through Thailand grid, respectively. This rank is also the same for acidification impact in terms of emissions of acidification causing compounds (N+S) and eutrophication in terms of emissions of eutrophication causing compounds (N+P).

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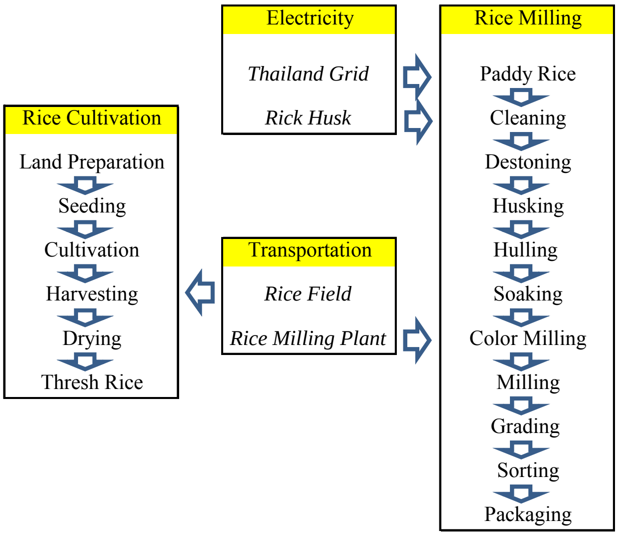

Fig. 1: Boundary of the assessment

Tab. 1: Results of the assessment

Impact Category	Unit	Production Stage		
		Cultivation	Transportation	Milling
Global Warming	kgCO_2-eq	775.85	158.00	30.06
Acidification	kgSO_2-eq	5.00	1.60	0.10
Eutrophication	kgPO_4-eq	2.23	0.45	0.03
Energy Consumption	kWh	-	-	8.60
Resource Depletion	kgSb-eq	-	-	3.95

Brazilian poultry: a study of production and supply chains for the accomplishment of a LCA study

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Keywords: Life cycle assessment; poultry; animal production.

Associated with the strong growth of poultry production in Brazil, environmental impacts caused by this activity appear as a problem. An important characteristic of the poultry-production chain is its spatial decentralization (each phase may take place in different locations within one or several countries). Life Cycle Assessment (LCA) has the ability to analyze systems independent of time and space and the potential environmental impacts associated with a specific product (Basset-Mens 2005). However, the diversity of poultry-production systems and the lack of knowledge about the environmental performance of different systems are factors that render difficult the use of this tool for impact evaluation of poultry production. Thus, it is necessary to perform site-specific studies to adapt LCA tools for Brazilian poultry. This work describes two current supply chains of poultry production in Brazil: the southern system, characterized by decentralized production in small farms with feeds obtained from other states (Spies, 2003), and the central-west system, with feeds produced within the farm and located relatively far from industrial areas. The description emphasizes the environmental aspects and important points for the accomplishment of a LCA study. This study showed that uncertainties in inventory data can appear because of production systems' diversity, the variety of agricultural practices, and the various potential emissions due to these variations. To obtain accurate results, uncertainties in the hierarchical structure, the scope definition, and the sensitivity analysis are main aspects to be considered. Furthermore, the selection of system boundaries should be determined by the choice of indicators.

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Environmental assessment of the Filipino fish/prawn polyculture and comparison with a Thai prawn monoculture using Life Cycle Assessment

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In Asia, aquatic products are the main source of animal protein for the local population, and aquaculture is an ancestral activity. Consequently, aquaculture has to meet several objectives: producing food for an increasing population, providing a source of income, and managing land and water while respecting the environment.

The present article focuses on the brackish water polyculture system of the province of Pampanga in Luzon Island, the Philippines. It is located in an estuary opening onto Manila Bay. Three to four species are associated in this system: tiger prawn *(Penaeus monodon)*, crab *(Scylla serrata or Scylla olivacea)*, milkfish *(Chanos chanos)* and in areas far from the sea, tilapia *(Oerochromis niloticus)*. The production is mainly organised around prawn production, which is the most valuable product. The environmental impacts of the Filipino polyculture system were assessed and compared to the impacts a typical prawn monoculture system in Thailand, using Life Cycle Assessment (LCA). This monoculture system follows the characteristics of an intensive system: it is settled in earthen ponds, with a high stocking density and using an oxygenation system.

The system boundary includes the hatchery stage, rearing (i.e., “growing-out”) and harvest. The impact assessment method used was CML 2 Baseline 2000 (version 2.03). LCA was conducted according to previous studies on aquaculture production (Papatryphon et al., 2004) using the following impact categories: Climate Change Potential (CC), Acidification Potential (AP), Eutrophication Potential (EP), Energy Use (EU) and Land Occupation (LandOc).

The polyculture system was analysed from two perspectives, first by taking into account the four products, then by applying an allocation that focuses on prawns production only. In that view, it was shown that the impacts of polyculture were higher when considering prawns production only than when considering the whole polyculture products, mainly because prawn is the most valuable product among them.

Regarding the comparison between the two systems, the analysis generally shows that polyculture performs better in terms of emissions of greenhouse gasses and acidification, mostly because of the absence of oxygenation systems, and because of the use of natural feeds. However the environmental impacts of polyculture were higher for Energy Use, which are almost 10 times higher than that of monoculture. This results from the low productivity of the polyculture, particularly of its prawns. Land Use was much higher in the case of polyculture than of monoculture.

In our study, LCA appears to be an interesting way to assess the environmental efficiency of the aquaculture systems, and to establish a common database between various systems such as monoculture/polyculture, intensive/extensive systems.

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Environmental performance evaluation of Immature Coconut Substrate using the Ambitec-Life Cycle model

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Keywords: Immature Coconut Substrate, Ambitec-Life Cycle, watershed vulnerability, environmental performance

The Immature Coconut Substrate (ICS) is a product innovation developed by EMBRAPA that acts as a physical support to seedling and to plant production in soilless cultivation. This work presents an environmental performance evaluation of the ICS innovation as compared to an existing technology that is a substitute product to the innovation, namely the Mature Coconut Substrate (MCS).

A specific decision support multicriteria model, Ambitec-Life Cycle, was applied to evaluate the environmental performance of the technologies along each phase of their life cycle, considering the vulnerability of the watersheds where each phase was located. Ambitec-Life Cycle is an expansion of the Ambitec-Agro System, a method applied at Embrapa to evaluate its agro-industrial innovations' environmental and socioeconomic impacts (Rodrigues *et al.*, 2003). The application of the model encompassed four phases of ICS and MCS life cycle: coconut husk disposal, coconut substrate production, coconut substrate use in rose seedling and production, and coconut substrate final disposal (Figure 1). A set of indicators evaluated the vulnerability of the watersheds where given phases of the innovation and of the existing technology life cycles were placed. The vulnerability index entered as a weight to those environmental performance indicators that were related to local or regional agro-industrial issues.

The performance of both technologies was evaluated using three scenarios in order to consider data variability: all indicators assuming average values; indicators assuming their highest values to ICS and lowest values to MCS (most favorable case to ICS), and; indicators assuming their lowest values to ICS and highest to MCS (most unfavorable case to ICS).

The life cycle phases of ICS and MCS were located in four different Brazilian watersheds with similar environmental vulnerabilities indices: Metropolitana, Litoral and Parnaíba, in the State of Ceará, and Baixo Mundaú, in the State of Alagoas. The functional unit adopted was the mass of substrate necessary to the production of one commercial rose of the Carola variety.

In a scale of 0 to 100, the final environmental performance of the ICS along its life cycle, considering the average values, was lower than the one of MCS (Figure 2). In phase 1 (coconut husk disposal), the environmental performance of ICS was much higher than the performance of MCS. In phases 2 and 3 (coconut substrate production and use), the performance of ICS was lower than MCS and, in the last phase, the technologies scored similarly.

Conversely, in the most favorable scenario to ICS, its final environmental performance was a little better than the performance of MCS, implying that data variability, in this work, did not assure best overall performance to neither one of the technologies.

Nonetheless, this environmental evaluation reinforced the importance of taking into account all the phases of a technology life cycle to compare its performance against its potential substitutes, in order to identify opportunities for improvements that benefits its entire life cycle.

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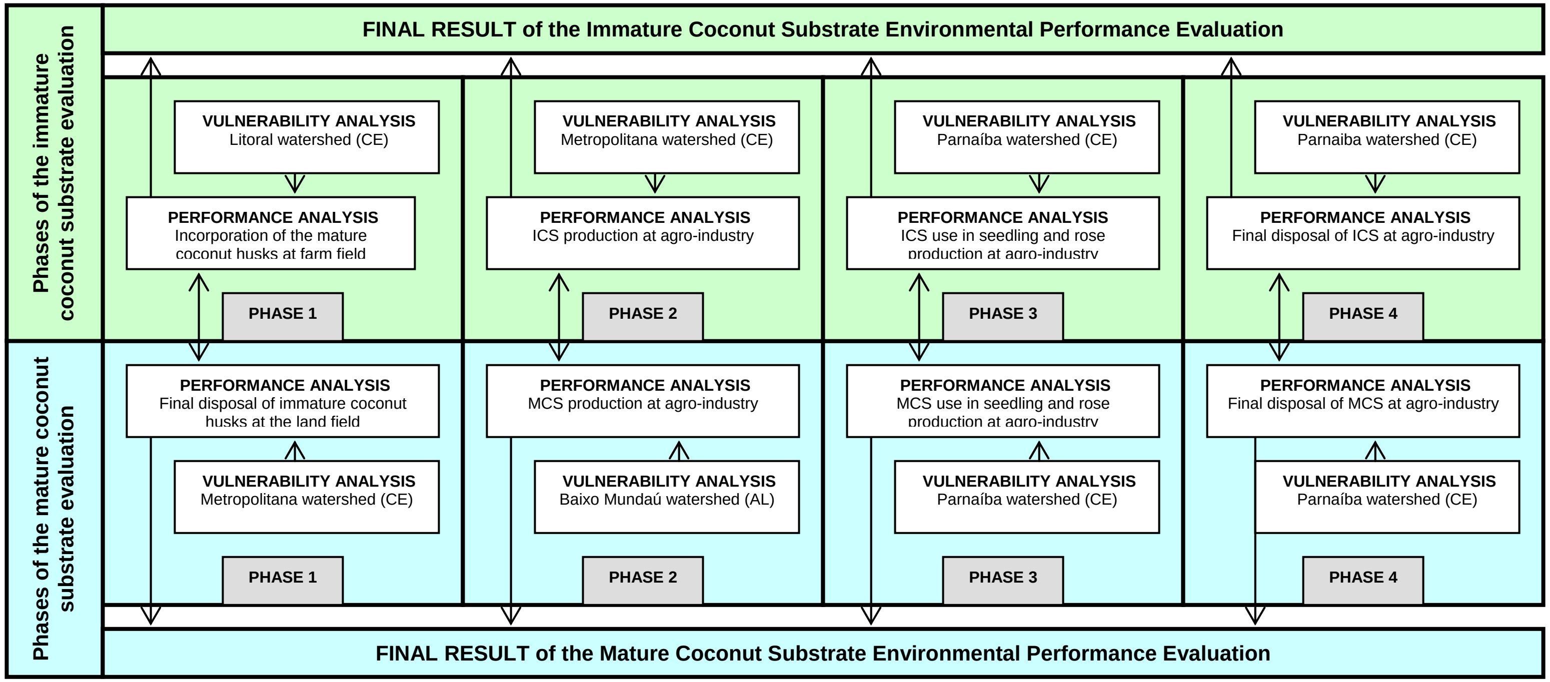

FIGURE 1 – Framework for the environmental performance evaluation of Immature Coconut Substrate in comparison with Mature Coconut Substrate

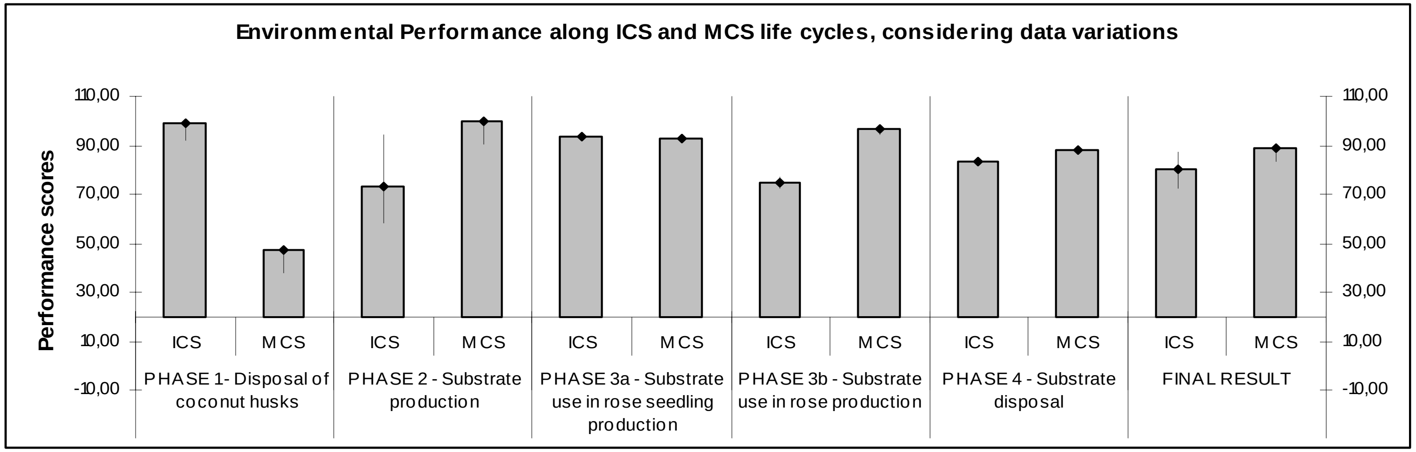

FIGURE 2 - Results of the environmental performance evaluation of ICS in comparison with MCS

Evaluation the energy use and environmental impact on the production of roses of cutting in Colombia using life cycle assessment approach

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Keywords: roses of cutting, environmental impact, life cycle assessment, energy use

The floraculture is a sector of great importance in the Colombian economical development; it represents the second source of currencies inside of the agricultural products of exportation. This sector coated own characteristics of the global market, looking for fulfilling with the quality demands to incorporate tech-nological developments in production and environmental and social regulations; just as aspects of marketing that guarantee the economical competitiveness (Tenjo, 2007). Recently, bonded aspects to the traceability, including energy consumption, emission of gasses greenhouse effect (GGE) and environmental and social impact caused in its production, have won an important space inside the requests of markets and consumers; and because of it, this aspect is considered fundamental in the sector competitiveness (Asocolflores, 2008).

Due to above, it was considered essential to study the use of energy and materials and the potentials impacts related to the growing of roses of cutting, using LCA approach. The objective of its application in the chain of production of roses cutting of Colombian since the extraction of raw material until the arrival to the country of market, was to make preliminaries evaluations contributing to the implementation of this tool and to the development of impact indicators and sustainability in commercial production systems to the market of USA and Europe. The functional unit for the study was defined as the production of a hectare of flower. Initially, it was generated an inventory of the use of energy and resources of three different types of cultivated rose under greenhouse, Dolores and Freedom in soil with fertirrigation to the market of U.S.A and Europe and Titanic in hydroponic medium with open fertirrigation to the market of USA, in a farm located in the Plateu of Bogotá, Colombia; valuing the energy use and some impacts environmental. The determined subsystems in the three different types were: 1) Infrastructure; 2) Machinery; 3) Fertilizer; 4) Phytosanitary manage; 5) Post harvest; 6) residues and 7) Marketing.

Within de most important results, it showed generations of environmental charges of a large impact in the subsystem of marketing, principally influenced by air transport the destination markets. The variety Freedom to the European market generates the greatest impact in this subsystem and mainly in the categories of fresh water aquatic ecotoxicity, ecotoxicity terrestrial, eutrophication and global warming. The comparison of the sown varieties on the soil and hydroponic medium shows a great effect generated because of the Titanic variety cultivated in hydroponic medium with system of open fertirrigation, the greatest contributions of environmental impact of this variety are generated to the categories of eutrophication, fresh water aquatic ecotoxicity, ecotoxicity terrestrial and acidification due to the high use of fertilizers and the lixiviation of mineral salts. As for the energy use it was determined that the biggest consumption is associated to the subsystem of marketing due to the use of fuel and mean of air transport, which represents a 58%.

The results show how the highest environmental impacts and the energy use of the three different types of cultivated roses are associated to the marketing and phytosanitaries subsystems, so is necessary to evaluate the alternative on the increasing of the efficiency of these subsystems. It's important to take into account the application of this methodology of energy quantification and environmental impact on the Colombian flower growing, now that determine the critical points of production and permit generate tools of optimization of the energy use and the resources, increase of the productivity and elements to generate negotiation politics and/or measures of compensation, besides of developing technical arguments to face consumers campaigns such as “Flower Miles”.

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Life cycle assessment of wheat grown in Washington State

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Key words: Wheat, Tillage, Organic, soil carbon, Export

Over the past several hundred years, the production and international trade of wheat has emerged as a central feature in the development of the modern world diet and agrifood system, with historic environmental, economic and social consequences (Friedmann 1994). The USA is the largest exporter of wheat in the world, exporting 28.5 million tons in 2007. Washington State grows 3.5 million tons of wheat annually, around 90 percent of which is exported overseas, and thus represents about 12 percent of USA wheat exports. This is equivalent to the entire export of wheat from Russia.

Growers in Washington are experimenting with different kinds of wheat production to improve farm economic and environmental performance: reduced tillage and organic farming are two new methods currently being tested by different growers. These different approaches imply different impacts. No-till or direct seeding methods typically employ herbicides for weed control, but lower fossil fuel consumption and reduce soil erosion and soil carbon losses. Organic methods eliminate the use of synthetic pesticides, but currently require more intensive tillage practices resulting in increased fossil fuel usage and soil erosion.

Searchinger et al.(2008) recently raised the issue of land-use change induced carbon emissions in the context of biofuel production. This issue has been the subject of a long-term research program on climate-friendly farming in Washington State. We present here the long-term data from surveys on the soil carbon and other indices of soil fertility and soil losses combined with conventional LCA emissions analysis in the wheat fields of Washington State to provide a weighted average ecoprofile of wheat, as well as the ecoprofiles for wheat produced via different production methods.

It is intended that this data be used to support the development of climate-friendly farming programs in Washington State, via outreach to growers and consumers.

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Strawberry and tomato production for the UK compared between the UK and Spain

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Keywords: horticulture, irrigation, tomatoes, potatoes, strawberries, Spain

Comparative Life Cycle Assessments (LCA) were made between the production of strawberries and tomatoes in Spain and the UK. Winter growing conditions are better in Spain so both these crops are imported into the UK "out of season".

The functional unit was 1 t crop, packaged and delivered to a retail distribution centre (RDC) in the UK. One grade of strawberries was considered, but tomatoes were subdivided into loose classic, classic on-the-vine and loose mini-plum.

Comparisons were based on the average burdens over the harvesting season of each crop. The UK tomato season runs from March to October and uses energy for heating and some lighting to extend the season. Direct energy inputs account for about 97% of energy use and greenhouse gas emissions. In Spain, cheaper tomatoes are grown with cheap structures with little direct energy. Direct energy inputs and the indirect inputs for structures both increase as the value of the crop increases. The season runs from about November to June.

Strawberries are produced in Spain using mainly soil-grown fruit in small polytunnels. In the UK, less production uses polytunnels, but more uses containers instead of soil. Heating is rarely used. The UK season is from about April to October and the Spanish from January to June.

Domestic production of strawberries and tomatoes was based on the study of Williams et al. (2006), with some improvements in data quality and modelling. This approach was derived from extensive use of system modelling to underpin the LCA. Mediterranean production was based in the same approach, but with local field data supplied to help define features of the local production methods.

The results were contrasting. Strawberry production took about the same amount of energy in each country, but transport and packaging made Spanish sourced strawberries more energy demanding than UK ones (Table 1). Tomato production, packaging and delivery took 3 to 9 times more energy for UK than Spain production (Table 1). Spanish strawberry production, however, leads to about 1.5 times more eutrophication and used 1.6 times more water. Tomatoes in Spain took 1.5 to 2.5 times more water. Spanish water takes more energy because techniques like reverse osmosis desalination plants is required. Ozone depletion is about 500 times larger in Spanish strawberry production as there is a derogation allowed for using methyl bromide as a soil disinfectant. GWP from UK tomato production is dominated by energy use. The relationships between energy and GWP are more complex for Spanish tomato and all strawberry production because sources N_2O from soil processes become more important.

Packaging and delivery increased energy use for UK tomatoes and strawberries by a few percent, but roughly doubled it for Spanish produce.

The comparisons show mixed effects of growing crops out of the UK's natural growing season. A problem that is common to all crops is the increasing environmental cost of supplying water in areas that have naturally low rainfall. While global warming is often assumed to be of prime concern, this resource limitation can be overlooked.

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Table 1. Main burdens of producing 1 t tomatoes or strawberries in Spain and the UK and delivering to the UK RDC.

	Loose classic tomatoes		**Classic on vine tomatoes**		**Mini plum tomatoes**		**Strawberries ***	
Item	UK	Spain	UK	Spain	UK	Spain	UK	Spain
Primary Energy, GJ	81	17	190	22	162	52	13	23
GWP, t CO_2 Equiv	6.1	0.85	14	1.3	12	3.5	0.73	1.2
Eutrophication potential, kg PO_4 Equiv	0.84	0.52	1.9	0.63	1.6	1.2	2.7	4.1
Acidification potential, kg SO_2 Equiv	7.6	3.7	18	5.9	15	12	6.1	6.5
Land occupation, m^2/a	19	86	45	130	38	180	600	300
ODP, kg CFC-11 Equiv..	0.00029	0.00011	0.00069	0.0033	0.00059	0.0011	0.0030	1.5
Irrigation water, m^3	14	35	34	50	29	67	110	180

* Packaging assumed to be the same as for vine tomatoes.

LCA as environmental improvement tool for products from line caught cod

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Keywords: LCA, autoline fisheries, cod, resource efficiency, product quality, value chain assessment

The demand for protein in the world is increasing. This has led to over-exploration of many wild species such as cod. In this situation it is becoming increasingly important to use fishing equipment and methods that preserve the quality of fish and reduce loss of product. Furthermore the challenge of climate change and the increasing price of fuel mean that it is more important than ever to implement fuel efficient fishing techniques. Scientific research has shown that line fishing gives better quality fish and a lower climate impact than other comparable fishing techniques.

The Norwegian research project “from Seabed to Consumer (www.bunntilmunn.no – Norwegian)” aims at reducing the total environmental impact of fish consumption by demonstrating the quality and environmental performance of line-fished cod and identifying, documenting and implementing improvement measures.

In the project an LCA has been conducted on products derived from the three main outputs of cod processing: Loins, wet-pack, and block. The LCA shows that the impact from the fishing phase is the dominating environmental impact. However, the impacts from the other life stages are considerable, Svanes (2008), Ziegler (2001), Liodden *et al.* (2003). The LCA clearly shows that the focus of improvement measures in the other life stages should be to increase the yield and reduce product loss. The LCA is used together with other scientific tools such as quality analyses, monitoring of conditions in the value chain and activity based costing to identify and choose the best options for improvement.

The LCA identified leakage of coolant as one dominant GHG emission source that could readily be remediated. This was new knowledge for the fishing boat operator and led to a decision to replace with a natural coolant.

The study is based on autoline fisheries that harvest over large parts of the North Atlantic and produce frozen cod. In the coming months research effort will be focused on coastal cod fisheries. Because of the small distances covered these vessels can supply fresh, high quality fish. However the small catches and large distances (from the fishing fields in Northern Norway to the main bulk of consumers in Southern Scandinavia and other markets further south) to consumers pose major challenges.

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Life Cycle Assessment of southern pink shrimp products from Senegal. An environmental comparison between artisanal fisheries in the Casamance region and a trawl fishery off Dakar including biological considerations

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Keywords: artisanal fisheries, by-catch, discard, félé-félé, global warming potential, mujas, *Penaeus notialis*, seafloor impact, southern pink shrimp, trawling

Life Cycle Assessment of two Senegalese seafood products exported to Europe was performed based on the functional unit of one kilogram of product (frozen whole shrimps) plus the accompanying packaging at the point of import to Europe, i.e. transported on a container freighter to Spain. The products are exchangeable on the European market, but the way they reach it from the fishery over processing is very different. One is produced by on-board processing demersal trawlers based in Dakar fishing at sea in FAO catch zone 34 (eastern central Atlantic), is landed and stored before being exported to Europe. The other production chain starts with the fishery in the Casamance river in southern Senegal. Fishing is done to similar extents by the artisanal fishing methods mujas, a fixed trawl set in the deepest part of the river from a canoe, and félé-félé, a type of driftnet managed by three men in a canoe. Major differences between the three fisheries included (trawl, mujas and félé-félé) were shown with regard to catch composition. Each fishing method has advantages and drawbacks from a biological point of view. LCA results showed major differences between the two products with regard to resource use and environmental impact depending on their origin. For the product originating in trawling, fishing was the most important activity in all categories of environmental impact, for the product originating in the artisanal fishery, fishing was most important for the biological aspects, but processing and storage dominated more typical LCA categories like global warming and ozone depletion potential. The main aspects to improve regarding these latter categories in the production chain of the trawled product is the use of fuel and refrigerants onboard, the main aspects to improve in the chain of the artisanal product are the use of energy and refrigerants in the processing plant as well as the energy source used by the plant. Both in the trawl fishery and in the plant processing artisanal shrimps, refrigerants with a high global warming potential are used in considerable amounts. Transportation was in both cases found to be of minor importance. From a biological point of view, spatial regulation of the artisanal fishing methods and possibly the introduction of a mesh size regulation, would be favourable, as would the introduction of selectivity devices in the trawl and mujas fisheries. Increased traceability and labelling is also desirable to make active consumer choices possible.

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Life Cycle Assessment applied to tomato production in the Canary Islands

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Keywords: greenhouse, substrates, transport, environmental impact.

The expansion of greenhouse horticulture in the Canary Islands involves an important economic progress especially in marginal areas. Due to its island condition the commercialization of its products depends strongly on exportation. Nevertheless, greenhouse production and overseas transport are often associated to high environmental impact and perceived as an artificial process, characterized by low nutritional quality of product.

Previous studies have been carried out using LCA to look for the bottle neck of greenhouse horticulture (Antón, 2004; Van Woerden, 2001). They have shown that reducing heating requirements and lighting is a priority if environmental loading is to be limited in Northern countries. On the other hand, transport or distance between production and consumption sites is a key factor in determining the environmental sustainability of food supply chains (Sim et al., 2007). Nevertheless, it is not known the influence of low energy requirements greenhouse and regional (European) transport as the Canary Islands.

The main goals of the present project are to identify the most relevant environmental issues and quantify the environmental impact in order to improve local production and analyze the relative importance of transport in the whole process.

This study was run in Gran Canaria. LCA tool has been applied to identify the environmental burdens associated to tomato production in the Canary Islands and exportation to commercialization to the United Kingdom. Tomato crops are cultivated in low-technology greenhouses, usually a simple locally structure made of plastic film cladding known as *parral* type. In addition, different substrates, rock-wool, perlite or local volcanic gravel, used by the growers have been assessed.

Results show the importance of commercialization process, between 20 and 50% of the total process depending on the environmental categories considered. Almost 25 % of the cumulative energy demand of the whole process is due to commercialization. Nevertheless, there are other processes such as water and fertilizers management, which need to be improved. On the other side, the contribution of this simple local structure to environmental impact was calculated between 6 to 13 % of the whole process demonstrating the interest to maintain local structures such as *parral* type. Another important factor to be considered was the type an origin of the substrates used in soilless culture.

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Simulating the impact of climate change on chickpea *(Cicer arietinum)* production on rainfed environments in northwest of Iran

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Keywords: Climate change, Simulation, yield, yield stability, chickpea.

Different aspects of climate change, such as higher atmospheric CO_2 concentration, increased temperature and changed rainfall all have different effects on plant production and crop yields. In combination, these effects can either increase or decrease plant production and the net effect of climate change on crop yield depends on the interactions between these different factors and specific conditions of crop environment (Ludwig & Asseng ; 2006).

This study evaluated how higher temperature (1,2,3,4,5 and 6 ^{o} C), CO_2 concentration (current and elevated), and 2 different rainfall scenarios affected chickpea grain yield and its stability. Future climate changes were predicted using General Circulation Models (GCM), Goddard Institute of Space Study (GISS) and Geophysical Fluid Dynamics Laboratory (GFDL). Effects of climate change on chickpea grain yield were simulated with Chickpea Simulation Model (CYRUS) using daily weather data values from 1978 – 1995 for rainfed chickpea production areas in northwest Iran (Soltani *et al.;* 2007).

Our simulation results showed that average yields of rainfed chickpea increase by about 26 percent in future climate change conditions in compare with current condition in Northwest Iran. Under the future climate change scenario simulated in this study (2100), warmer temperature and less precipitation would reduce growth period duration and cause earlier maturation. This would helped to avoid all or part of the terminal water deficit condition and better synchronizing of plant growth and soil water supply in rainfed environment.

The results also indicated that future climate change would reduce yield stability and would increase production risks in chickpea production on rainfed environments in northwest of Iran**.**

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Environmental impacts of farms integrating aquaculture and agriculture in Western Cameroon.

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Keywords: fish pond, LCA, polyculture, catfish, tilapia

In sub-Saharan Africa area fish cover 50% of human protein demand. Fish originates mainly from fisheries and is distributed dried or frozen. Fish production in ponds could allow diversification of production in family scale agriculture and can be a source of good quality protein for the local population. Nevertheless, inland fish farming shows a slow development. Although environmental constraints are not a major issue for the local population, we used Life Cycle Assessment to better understand the contribution of fish pond systems to regional sustainable development.

A typology of farms was built based on the level of production of the farm and its ability to obtain inputs to feed the fish. Two of these farms were analysed using LCA. The first one is an integrated pig and fish pond system, owned by a church organisation with ample access to Inputs. The pond is continuously fertilized by pig manure and wheat bran is added for fish feeding. The second one is owned by an independent small farmer fertilised by pig manure and crops by-product. In both cases, the fish production is a polyculture of tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*).

LCA was conducted according to previous studies on aquaculture production using economic allocation and one ton of fish production as the functional unit. The system boundary included the farm process, the feeds and fertiliser production, the harvest of catfish fingerlings, the production of tilapia fingerlings, and the transportation at all stages. Impact categories were: Eutrophication, Climate Change, Acidification, Water Dependence, Energy Use, and Net Primary Production Use.

Two main methodological challenges were identified. The first one is linked to the inventory of pond emissions. Emission estimate based on mass balance calculations for nitrogen and phosphorus differ from emission estimates based on a limited number of water quality measurements, this and implies a high level of uncertainty with respect to Eutrophication. The second challenge concerns the status of pig manure and the way it is taken into account into the allocation.

The main process contributing to impact is the animal manure. Wheat bran is another main contributor to impact, due to its origin and transformation. Impact values are quite high compared to other aquatic productions system due to the low productivity of the system.

Having obtained these first results we propose to increase the number of farms studied and to conduct and experiment in order to identify ways of increasing the productivity of these systems.

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Life Cycle Assessment of Wheat Production Systems within the ENDURE Project

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Keywords: wheat production, production strategy, environmental impacts, ENDURE

One goal of the Endure project (European Network for the Durable Exploitation of Crop Protection Strategies) is to analyse the sustainability of crop protection strategies within Europe. For the case study wheat following regions were selected (Nuts number in brackets): Emilia-Romagna (IT4), Wielkopolskie (PL41), Saxony-Anhalt (DEE) and Denmark (DK0). Data were collected by local project partners. Ten different strategies (different cropping systems or intensities) are considered. The **S**wiss **A**gricultural **L**ife **C**ycle **A**ssessment tool (SALCA) was used for the environmental assessment including the actual production as well as the environmental impacts throughout the production of input factors. The environmental inventories were taken from Frischknecht et al. (2004) and Nemecek & Erzinger (2005). The impacts were calculated using the methods listed in Nemecek et al. (2005) and the method Impact2002+ in addition. The analysis includes the functional units describing intensity of production (per ha*year) and productivity (per kg dry matter yield).

The impact categories linked with the resource management (energy use, global warming potential and ozone formation) are strongly influenced by the field operations and fertiliser use. Both inputs account for about 89-95 % of the energy use (Table 1). The global warming potential (in CO_2-eq) is mainly ascertained by emissions of carbon dioxide related to fossil fuel and energy use in fertiliser production and the direct field emissions of nitrous oxide caused by nitrogen fertilisation. Both climate-damaging gases contribute to 99 % of the global warming potential whereby nitrous oxide alone accounts for 64-82 %. The organic and less intensive production systems perform appreciably better for both functional units (except for Denmark). But concerning the nutrient management (acidification and eutrophication) the organic systems under consideration are disadvantageous due to the previous crop grass clover and the high amount of organic fertiliser. For the production systems with mineral fertilisation the amount, type of fertilisers used and the date of fertilisation contribute mainly to the differences. The results for toxicity are not consistent between the different methods used (EDIP, CML-USES and Impact 2002+), although for all three methods the toxicity is mainly caused by pesticides and the same databases were used to describe the parameters of the active ingredients.

The LCA results for the different regions show that for the resource management in most cases the less intensive systems have lower environmental impacts per ha*year and per kg DM, whereas for the nutrient management these systems show some drawbacks. The results for the toxicity of the systems are not consistent for the different toxicity methods used and are strongly dependent from the active ingredients used. A comparison between the regions is difficult, because of the different data sources. For example, some of the pesticide strategies are based on national statistics, whereas other ones rely on expert knowledge at regional scale.

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Table 1: Overview of the analysed environmental impacts for the different wheat production systems (per ha*year). The results are related to the most intense production for each region for better readability. IT = Italy, PL = Poland, DK = Denmark, GER = Germany; IP = integrated production, Org = organic, Int = intensive, 2 = less intensive than Int, 3 = less intensive than 2; aq = aquatic, ter = terrestrial, hum = human, tox = toxicity.

	DE				DK		IT		PL	
	INT	2	3	OR	IP	OR	IP	OR	INT	OR
Energy use	24737.78	91%	90%	35%	11657.00	77%	16211.30	53%	25728.42	84%
GWP	4490.64	97%	97%	59%	2749.69	92%	2768.59	86%	4864.97	80%
ozone formation	1.37	91%	88%	57%	0.78	101%	1.02	77%	1.31	91%
nutrient enrich.	102.27	98%	97%	162%	113.77	114%	81.26	180%	141.60	82%
acidification	21.69	97%	96%	566%	94.40	75%	28.72	330%	22.61	81%
aq tox EDIP	1058988.36	92%	90%	51%	636765.54	90%	666958.73	85%	1286535.43	88%
aq tox CML	1348.70	12%	3%	2%	65.11	51%	181.00	43%	793.67	10%
aq tox IMPACT	57.15	45%	70%	1%	100.80	0%	114.18	7%	52.67	49%
ter tox EDIP	2296952.30	24%	19%	0%	120016.58	2%	5814.29	54%	466761.21	99%
ter tox CML	42.68	26%	10%	16%	11.89	57%	15.80	235%	22.53	13%
ter tox IMPACT	0.07	74%	74%	427%	0.51	56%	0.01	20300%	0.04	74%
hu tox EDIP	3.66E+09	97%	96%	114%	2.73E+09	135%	2.70E+09	147%	4.96E+09	82%
hu tox CML	824.04	70%	67%	25%	298.57	68%	444.18	63%	834.63	75%
hu tox IMPACT	0.12	82%	78%	525%	1.01	60%	0.08	1456%	0.14	83%

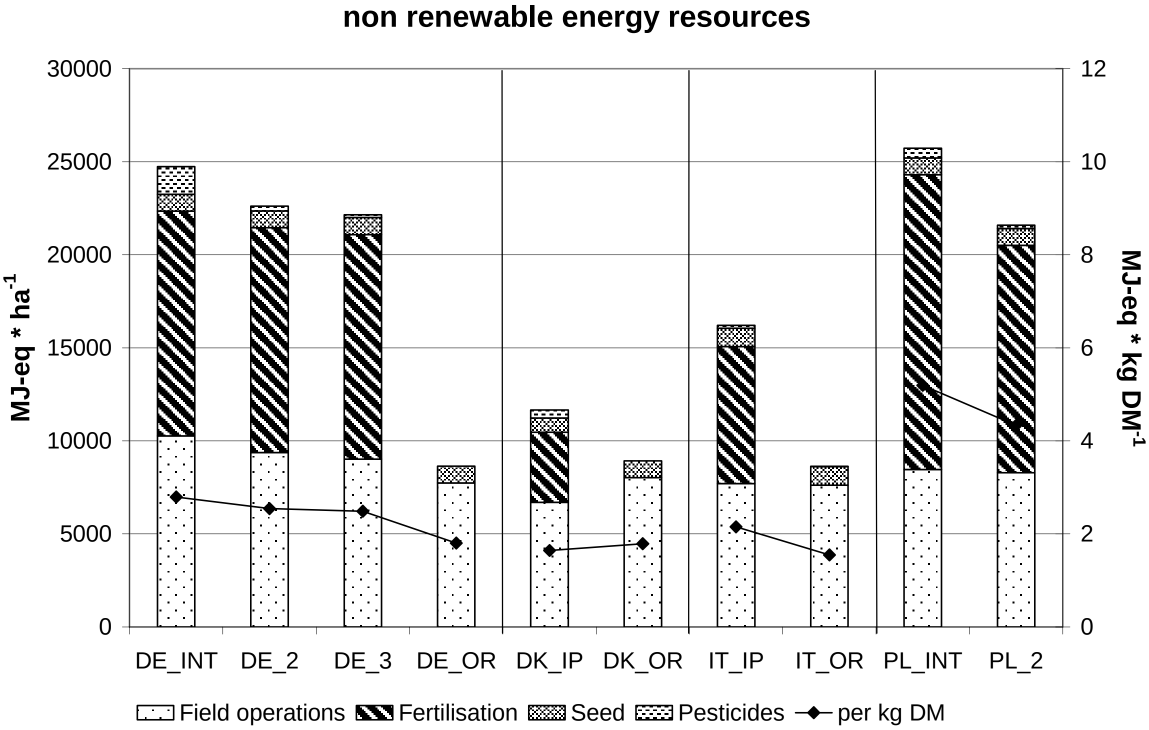

Figure 1: Non-renewable energy input (per ha and kg DM) and contribution of the single input factors to the total energy demand. DE = Germany, DK = Denmark IT = Italy, PL = Poland; IP = integrated production, OR = organic, INT. = intensive, 2 = less intensive than INT., 3 = less intensive than 2.

Life Cycle Assessment of Integrated and Organic Apple Production Systems in Europe

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Keywords: apple production; organic farming, integrated production, environmental impacts, ENDURE

The system analysed encompasses the preparation of the orchard, the production of all inputs, all activities in the orchards and the uprooting at the end of the orchards lifespan. Data were collected by the local partners for the regions Lake Constance (Swiss and German part), Emiglia Romagna in Italy, Lleida in Spain and Rhone valley in France. The productions strategies organic farming and integrated production where considered where possible. The Swiss Agricultural Life Cycle Assessment tool (SALCA) was used for the assessment. It includes the environmental inventories of agricultural inputs, taken from Nemecek & Erzinger (2005) and Frischknecht et al. (2004), methods developed by the Agroscope Reckenholz-Tänikon Research Station (ART) for the estimation of direct field emissions and impact assessment methods listed in Nemecek et al. (2005). The functional units ha*year, representing the function of land cultivation, and dry matter yield, representing the productive function, are considered. Since the life span of the apple production systems are 15 years with different yields depending on the growth level, the results are converted to 1 year for comparison.

The results show the importance of the regional factors on the overall environmental impact. For the energy demand, global warming potential and ozone formation potential, the results generally depend on the field operation intensity, the amount of mineral fertilisers applied and the hail net construction. The irrigation leads to very high figures for these three impact categories in Spain (417 to 583 mm water applied) and France (298 mm water applied). On the contrary, organic production shows lower impacts per ha than integrated production for the same impacts, with the exception of Spain where organic farming has more irrigation (see Fig. 1). The eutrophication and acidification potentials are dominated by ammonia and N_2O emissions losses from the applied nitrogen fertilisers. As the apple production in France uses the largest amount of these fertilisers, the impacts are the highest for this country. Depending on the amount of organic manure applied, organic apple production shows higher values for these two impact categories per ha in the Lake Constance region (Swiss and German part) and lower ones in Italy and Spain. Finally, the environmental and human toxicity figures strongly depend on the active ingredients contained in the pesticides used and on the toxicity impact assessment method considered (EDIP, CML, Impact 2002+). All three toxicity methods show a tendency of lower impacts for organic farming than for integrated production but differ considerably between the regarded regions.

This study shows the overall advantage of organic production over integrated farming in apple production systems when regarding the function of land cultivation (sustaining land use, landscape protection, limited use of basic life resources). From the producer's point of view (per kg dry matter yield), organic farming has higher environmental impacts than integrated production due to notable lower yield per ha.

The results of the life cycle assessment lead to deeper insights and can help to optimise the production systems.

Acknowledgment: The work is supported by the European Network of Excellence for the Durable Exploitation of Crop Protection Strategies ENDURE.

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Table 1: Overview of the analysed environmental impacts of different apple production systems in Europe. The results are related to the Swiss integrated production for better readability. IP= integrated production; OR= organic farming; aqTox= aquatic toxicity, teTox= terrestrial toxicity, hTox= human toxicity

impact category	CH_IP	CH_OR	DE_IP	DE_OR	IT_IP	IT_OR	ES_IP	ES_OR	FR_IP
energy use (MJ)	49848	90%	108%	95%	149%	123%	195%	226%	195%
global warming (kg CO2)	3061	92%	110%	95%	130%	98%	154%	148%	191%
ozone formation (kg C2H2)	2.60	105%	99%	98%	117%	99%	135%	160%	140%
eutrophication (kg N)	18.2	145%	115%	137%	132%	109%	106%	83%	200%
acidification (kg SO2)	28.5	159%	121%	148%	149%	114%	136%	113%	245%
aqTox EDIP (m3 water)	918705	94%	99%	95%	122%	87%	141%	165%	148%
aqTox CML (kg DCB)	4591	24%	29%	32%	266%	24%	121%	12%	140%
aqTox IMPACT (kg TEG)	24740	0.03%	224%	121%	670%	1%	47%	1%	283%
teTox EDIP (m3 soil)	450967464	0.02%	2%	2010%	63%	0.03%	137%	0.07%	7%
teTox CML (kg DCB)	11285	8%	123%	8%	120%	8%	180%	204%	263%
teTox IMPACT (kg TEG)	228856	3%	46%	6%	137%	8%	21%	2%	94%
hTox EDIP (m3 total)	456849	5%	124%	5%	12858%	8%	901%	115%	258%
hTox CML (kg DCB)	15207	34%	118%	36%	117%	37%	160%	481%	267%
hTox IMPACT (kg TEG)	0.115	43%	27%	50%	179%	178%	67%	48%	192%

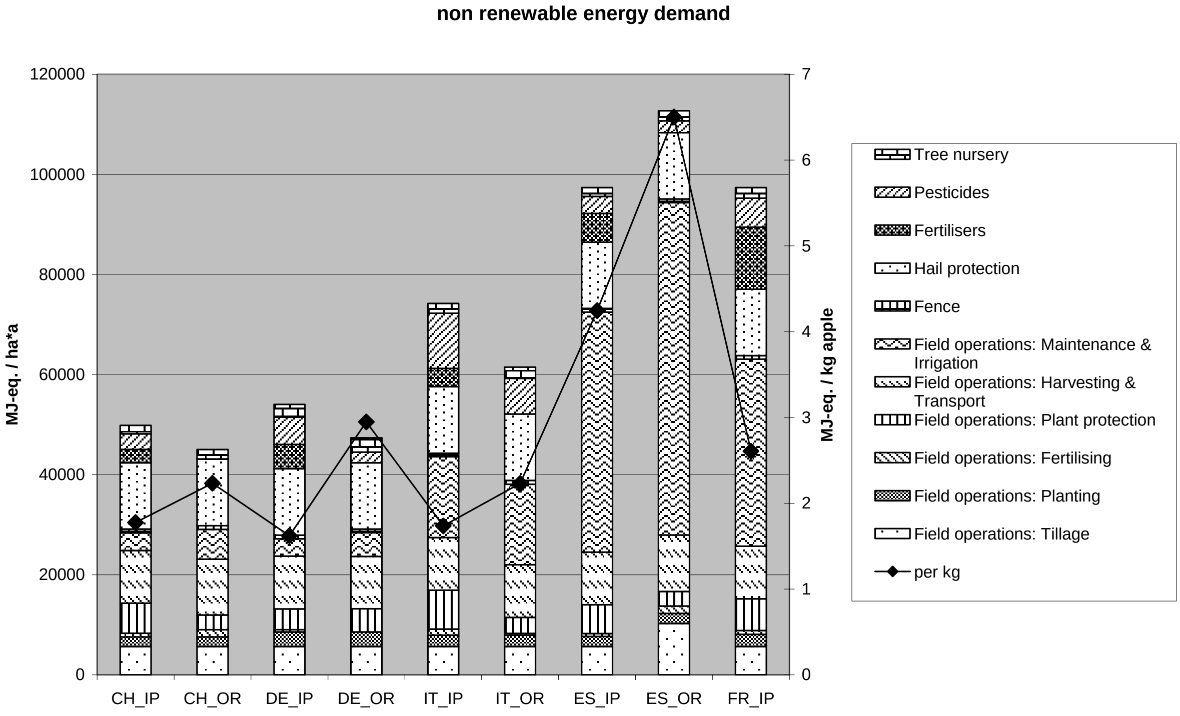

Figure 1: Contribution of various inputs to the total demand of non renewable energy for different European apple production systems in MJ-equivalents per ha*a and per kg yield. Abbreviations: see Table 1.

LCA of the application of compost from organic municipal solid waste in horticulture fertilization

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Keywords: environmental impacts, organic fertilizer, composting plant, horticultural crops

The organic waste composting technologies have been developed during the last decades in response an increasing worry on the amount of waste generated by the society and its treatment or disposal.

In this work, LCA is applied to vegetable crops in a Mediterranean area. The focus is on the evaluation of the environmental impacts related to the application of either compost obtained from the organic fraction of municipal solid waste (OFMSW) or mineral fertilizer. The results could suggest improvement opportunities in the system. Previous studies in this research field have only been focused on a part of the cycle, therefore it does not exist data for the complete cycle. In this project, it is considered a wide system that includes OFMSW obtaining (Cisneros, 2006), production and transport of compost and also the cultivation phase (Audsley, 1997). This last stage includes the extraction, production, use, maintenance and final disposal of the materials, machinery and infrastructures needed to carry out the agricultural operations, irrigation and pesticides application (Figure 1).

Up to now, several crops such as tomatoes, chard or cauliflower, have been grown in the experimental fields, which are situated in open-fields or in greenhouses. The environmental impacts associated to three kinds of fertilizing treatment (only compost, compost and mineral fertilizer, and mineral fertilizer alone) have been assessed for all these crops. The compost that was applied to the experimental fields was class A (with low content in heavy metals) and the mineral fertilizer was potassium nitrate. The functional unit is 1 tone of commercial product, which has been established in order to provide a useful reference of standardization. This allows us to compare the environmental impacts associated to the several crops and treatments.

The preliminary results for tomato crop in open-fields reveal the existence of two stages that are the most impacting ones. Firstly, the management of waste produced during the crop period, especially green wastes. Secondly, the industrial compost production, which highly contributes to the overall impact of the treatments that use it. The main reasons to the overhead impact associated to the compost are the high energy consumption during the industrial production and the great volume of compost needed. Consequently, the compost treatments have higher impacts than the mineral fertilizer ones. However, composting avoids the environmental loads related to the disposal of organic wastes in landfills. If this fact is considered, the difference between treatments diminishes and even it reverses in favour of the compost ones (Figure 2). It has been stated that the application of compost as a fertilizer of tomato crops does not have a negative affect either on production or horticultural quality.

The use of compost for the fertilization of horticulture crops can be an interesting alternative for this by-product, although it would be necessary to propose some improvements for the reduction of the environmental impacts in the industrial composting process. On the other hand, the LCA methodology used in this study considers the compost only as a fertilizer, but there are also a series of local environmental indicators, such as soil quality (organic matter, water content and salinity) or erosion degree, that must also be taken into account.

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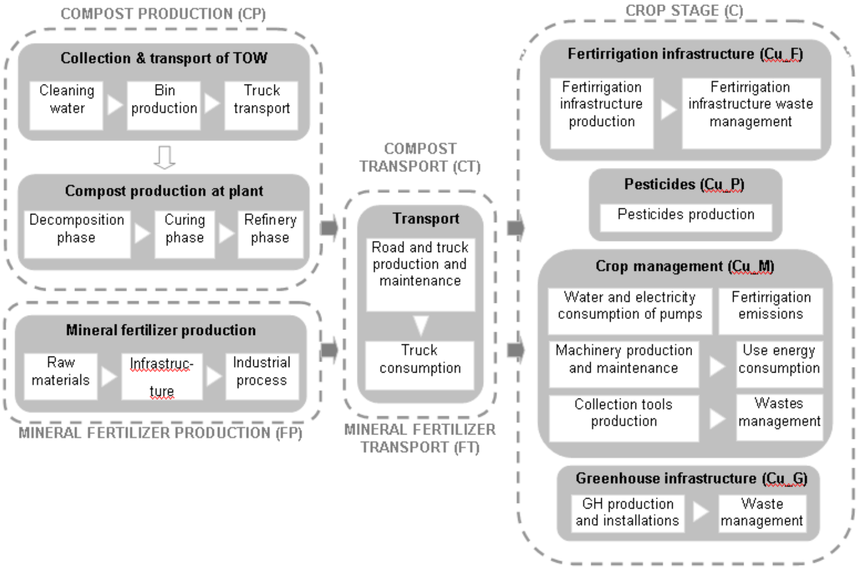
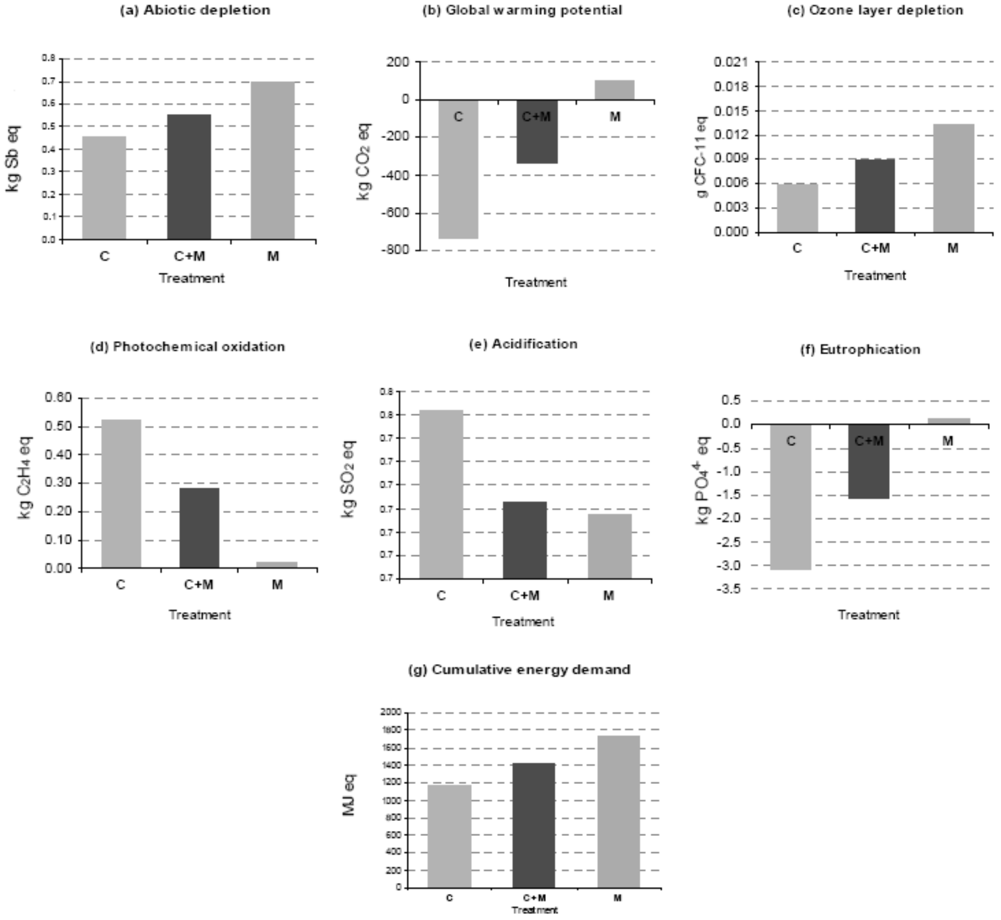


Figure 1: Global system considerate in the environmental assessment for all the crops, the three fertilizer treatments and the two emplacements.



C, compost treatment; C+M, compost and mineral fertilizer treatment; M, mineral fertilizer treatment

Figure 2: Total environmental impacts for open field tomatoes cultivated in 2007, subtracting environmental loads avoided by the non deposition of organic waste in landfill. These results are for 1 tone of commercial tomatoes.

Life Cycle Assessment in plant breeding: an example using porridge oats from the UK

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Keywords: Oats, sustainability, varieties, plant breeding.

The exploitation of plant variety traits offers a means to improve sustainability through improved efficiency of resource use. In order to quantify the impact of different available variety traits a plough to plate life cycle assessment (LCA) of the porridge oat (*Avena sativa* L.) production chain was undertaken and the reduction of inputs associated with phenotypic characteristics which can be modified through plant breeding was assessed. Some of these traits may have attributes which reduce the total environmental impact of the oat production chain and therefore justify their incorporation into a breeding project; in this respect we are proposing to implement “ecodesign” principles to plant breeding: Eco-breeding.

Typically a LCA spans from the extraction of raw materials to the eventual disposal and assimilation into the environment. However agricultural systems present a number of difficulties that within a realistic timeframe inhibit such meticulousness and it is common to present what can be described as a “plough to plate” type LCA. The LCA was constructed using data that corresponds to the most commonly used inputs and processes involved for porridge oat consumption in the UK.

It is clear from this study that plant trait development can have a significant effect on the whole oat production chain. Improvements in yield correspond to the most significant reduction in overall environmental footprint; improvements in yield per hectare have a particularly strong effect on the eutrophication potential and toxicity impacts of the oat production chain. Additionally improvements in cooking efficiency had a significant effect on energy use and impact categories associated with energy delivery.

Few of the traits relevant to this study are immediately obvious and subject to phenotypic assessment. Therefore conventional hybridisation techniques and phenotypic selection may be unsuitable. Advances in molecular markers and other targeted DNA technologies that facilitate non phenotypic assessment could be utilised for this purpose and allow that varietal development be made in conjunction with the whole production chain. Integration of conventional ecophysiological and phenotypic profiling with targeted DNA strategies may be a strong methodology to produce enhanced varieties.

Therefore we have found that improved sustainability in crop production would benefit from an integrated effort stretching from the geneticist to consumer and the use of LCA will be central to the development of more sustainable food production systems.

Crop irrigation with urban wastewaters. LCA case study of tobacco growing in Spanish greenhouses

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Keywords: wastewater, agriculture, tobacco, greenhouse, toxicity, desalination

Spain is a water-stressed country, in which agriculture uses around 80% of the available freshwater resources. For this reason, wastewater reuse in agriculture has a large potential. This work presents the preliminary results of applying LCA to agricultural production of tobacco in a Mediterranean greenhouse, using wastewater for irrigation. The aim of the study is to gain knowledge about the potential impacts of using wastewater for irrigation, as compared to alternative water sources.

Nicotiana tabacum was grown from October 2007 until june 2008 in a experimental greenhouse at the University of Almería (southern Spain). Plant density was set at 8 plants m^{-2}, and two plots, corresponding to wastewater or tap water use, were arranged. Wastewater used for irrigation was not subject to any tertiary treatment, but supplied as taken from the secondary settling tank and transported by truck to the greenhouse, where it was stored. Wastewater samples were analyzed monthly to obtain the concentration of almost 100 emerging and priority pollutants frequently found in urban wastewaters. Total biomass harvested in this 9-month period was 28 kg/m^2 for both wastewater and tap water plots.

The LCA study included all processes involved in agricultural production until harvest, namely: greenhouse infrastructure, seedling development, soil management, fertiliser use, pest management, greenhouse whitening, pump power, and fate of pollutants from fertilisers, pesticides, and wastewater. Wastewater irrigation was compared to the alternative impacts of water produced by desalination (Muñoz and Rodríguez, 2008). The CML 2000 (Guinée et al., 2002) method for Life Cycle Impact Assessment was used, and special focus was put on toxicity of emerging and priority pollutants in wastewater (Muñoz et al., submitted). In addition, soil salinisation potential (Feitz and Lundie, 2002) and soil organic carbon deficit (Milà iCanals et al., 2007) were also investigated. The results show that using desalinated water leads to higher environmental impacts in several impact categories closely related to energy use (global warming, photochemical oxidants, abiotic depletion, etc.), as well as in soil salinisation and aquatic ecotoxicity. On the other hand, wastewater pollutants have an important contribution in terrestrial ecotoxicity, implying a higher impact for the wastewater-irrigated crop. These results suggest several environmental benefits of using wastewater for irrigation in agriculture, although a tertiary treatment should be applied first to minimize the impact on soil of trace pollutants.

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LCA screening indicators applied to a fruit & vegetable data set

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Keywords: LCI, vegetables, fruits, screening indicators

Food consumption is a large part of consumer environmental impact. However, there are few studies assessing the food production system as a whole, because of problems with data collection and inherent variability. Both the European Commission and food retailers are interested in life cycle assessment (LCA) based labeling of food products (Korou, 2008). Some retailers are introducing carbon footprint-based labels, but the LCA community has long recognised that global warming potential alone is not a suitable indicator for agricultural products or systems (Huijbregts *et al*, 2006). The indicators developed for food labeling must be simple, in their data collection requirements and interpretation, and scientifically robust. We use a data set of more than 25 fruits and vegetables developed by the authors (described in a poster) and built upon the ecoinvent 2.01 database, to test a series of simplified indicators.

Global warming potential (GWP) is still an important indicator for food products, especially given high consumer interest. GWP applied to the data set is discussed. A regionalised water use indicator is also tested, which considers both consumptive and degradative use. Similarly, land use indicators are tested and discussed (Canals *et al*, 2007). Additional indicators, including human toxicity, based on USEtox, are also considered. The final mix of indicators, and their respective weightings, will be based on statistical independence and other relevant criteria. Some categories of environmental impact, such as aquatic eutrophication, which are highly sensitive to local conditions, including soil conditions, plant varieties, weather, agricultural machinery, and slope, may be difficult to assess in a generic LCA, however.

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Life cycle inventory for a Brazilian oyster production system

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Keywords: Environmental management; Life cycle assessment; Inventory; Oyster.

This work is about the study of inventory of oysters' system (*Crassostrea gigas*), produced in the city of Florianopolis, Brazil. This city is a leading producer of oysters in the country (80% of all production), exporting to other cities and countries. The methods of production of it are already established and follow the same model throughout the country. This study aimed to raise data of entries and exits at different stages of the life cycle of the oysters, to give grounds for a future analysis through the Life Cycle Assessment. The life cycle of the oyster system was divided in five stages: (a) Seeds production, (b) Oysters' cultivation, (c) Packing, (d) Transportation and (e) Storage and final consumption. All the processes before, as the production of raw materials, and after that (final destination), were ignored. It was also ignored the data of the oysters' growth in the sea because its difficulty of measurement.The inventory used a dozen oysters consumed as a functional unit. The data collection was taken by two ways. First, the primarily data, was by on-site survey. This way was used for most of the data, as the consumption of water, electricity, fuel, polystyrene and ice and the BOD_5 and Solids emitted. The other way, so called secondary data, was taken by studies of published works related to the theme and by the database from the software Simapro 7.1. The secondary data were the quantity of shell residues produced and the air pollutants emitted during the transportation and oysters' cultivation. For simplification, in the Simapro 7.1 database, it was taken only the most significant substances consumed and emitted. The results obtained are presented on table 1. With these results, it can be concluded that there is a high consumption of water (both fresh and salt), and also a high emission of Carbon Dioxide (CO_2), Total Solids (wastewater) and solid waste as shells. The first and third environmental aspects (consumption of water and Total Solids respectively) are essentially due to the stage (a). The second environmental aspect (CO_2) is for the most part due to the stage (d). Finally, the fourth environmental aspect (Solid waste – shells) is mostly produced in stage (e). From these results, it is believable that there is enough information to make the LCA of the Brazilian oyster production system.

Table 1: Final Inventory of the Brazilian Oyster production system

	Environmental Aspect	**Stage**	**Value**	**Unit**
Inputs	Petrol	(b), (d)	50,15	g/dozen
	Kerosene	(d)	40,87	g/dozen
	Water (fresh and salt)	(a), (b), (c)	63.266,83	g/dozen
	Energy	(a), (b), (e)	0,303	kWh/dozen
	Polystyrene	(c)	103,33	g/dozen
Outputs	Total Solids – wastewater	(a), (b)	1.945,92	g/dozen
	BOD_5 – wastewater	(a), (b)	4,00	g/dozen
	Carbon Monoxide (CO) – air	(b), (d)	1,20	g/dozen
	Carbon Dioxide (CO_2) – air	(b), (d)	743,61	g/dozen
	Nitrogen oxides (NO_X) – air	(b), (d)	2,78	g/dozen
	Sulphur dioxide (SO_2) – air	(b), (d)	1,08	g/dozen
	Methane (CH_4) – air	(b), (d)	0,40	g/dozen
	Solid waste – polystyrene	(e)	103,33	g/dozen
	Solid waste – shells	(a), (b), (e)	751,05	g/dozen

LCA of Californian black-ripe table olives

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Keywords: LCA, table olives, Californian style, processing method, black-ripe olives

The cultivation and processing of table olives is an important sector of the Mediterranean agro-food economy, both for its economical and environmental aspects. Previous life cycle analysis highlighted the hot spots of the table olives compartment, with particular reference to Spanish-style green table olives. The cultivation of olives produces different fruits depending on the harvesting period, green and black olives. Green olives are mainly processed according to the “Spanish-style”, whereas for black olives (generally riper) the “Californian method” is used.

This latter process presents similarities with the Spanish-style but some differences occur. In fact, in this method the olives are processed with three solutions of 2% of caustic soda. After each deamarization the fruits are washed with water and at the same time, compressed air is injected. During the last washing, ferrous salts are used to fix the characteristic black colour. Later the olives are further washed to remove these salts. At the end of the process the olives are packed in brine and sterilized.

This study, which use the LCA methodology, aims to quantify the environmental impacts related to the production chain of Californian black ripe olives, underlining the critical points. The analysis of the results will cater a solid base in order to identify suggestions for improvements – i.e. rationalizing energy consumption and materials to achieve savings and benefits. These improvements will arguably be useful not only from an environmental point of view but also from an economic one.

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Sustainable fruit production and consumption: life cycle assessment, environmental indicators and benchmarking

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Keywords: carbon footprint, ecological footprint, energy footprint, reactive nitrogen, water footprint

Consumption drives economic activity and hence the related environmental impacts. Food is one of the key sectors in overall impact and consumers are one of the key actors in defining sustainability. Consumers' choices are driven by price, quality, presentation and other product characteristics, as environmental impact of products. The goal of environmentally sound consumption needs, among other tasks, to resolve the information gap, and thus, LCA is a powerful tool to ensure that. The aim of this work is to develop environmental indicators with LCA of different fruits that Spanish consumers can find in the market, and to benchmark the values with the overall environmental impact of the Spanish Economy.

We have chosen 9 fruits (figure 1) that were available in the supermarkets during the winter season. These fruits were cultivated in different zones (figure 1) and had different packaging (trays, plastic films, bags, etc.). A modular LCA has been developed for 1 kg of fresh fruit, considering three modules: agricultural production, transport and packaging (Jungbluth *et al.*, 2000). Environmental impact of the agricultural module has been calculated with data of crop practices, fertilization and irrigation. Distance from the production zones to Madrid, considering lorry and/or ship transport, were used in the transport module. Impact for packaging module has been calculated using data of the type and quantity of material used. Data from the three modules for each fruit were summed up and a normalized value (world factors for 1995) of life cycle was used as indicator and benchmarked versus the daily LCA value of the Spanish Economy per capita. Water and energy footprint indicator was considered as the volume of water or the quantity of energy used in the three modules per kg of fruit. Carbon footprint per kg of fruit was determined as the quantity of equivalent CO_2 emitted in the modules. Arable and sink of CO_2 forest land were calculated as ecological footprint (m^2 kg^{-1}). Total reactive nitrogen used as fertilizers and emitted as NOx in the modules was computed. Values for the whole Spanish Economy were also calculated for each indicator in order to benchmark each fruit indicator value. The fruit with the highest aggregated environmental impact was custard apple from Spain (figure 1); but banana from Ecuador and pear from Spain also showed high values in the aggregated LCA. The agricultural module contributed with the largest proportion of the total impact (being the main impact categories water resources, energy and eutrophication), although transport was important in fruits produced in distant countries (with energy and acidification as the main impact categories). Packaging module accounted for less than 10% of the impact. When these data were benchmarked with the value of Spanish Economy (figure 2), the environmental impact of fruit production and consumption was low (<20%) for all types considered. The same results were shown by the other indicators, while ecological footprint of vegetable food is lower than footprint of animal food. However, as it was stated in the LCA indicator, water footprint was very high, due to the large quantities of water used in agriculture, especially in zones with a high climate moisture deficit or long crop cycles. This study has developed an indicator (LCA or EF) that could inform to consumers that the overall environmental impact of fruit production and consumption is relatively low, compared with the whole economy, but also it has identified one indicator (water footprint) that could discriminate between types of fruits, and could highlight an important environmental impact at local or regional level.

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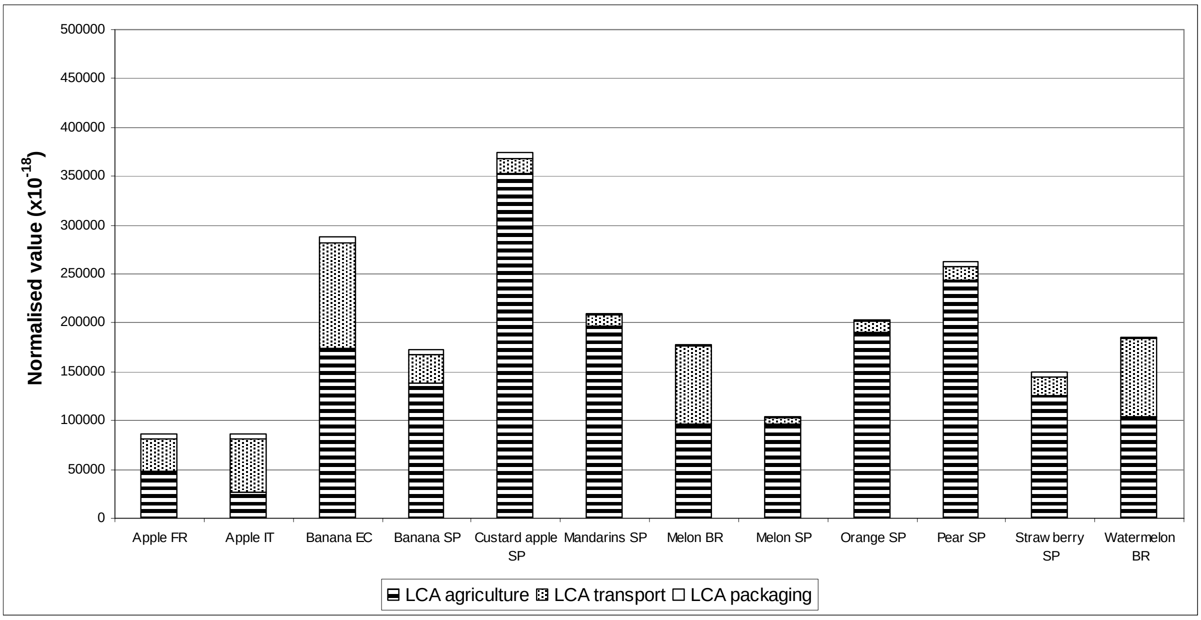

Fig. 1: Normalized values of the modular LCA for 12 types of fruits (Zone of cultivation: BR: Brazil, EC: Ecuador, FR: France, IT: Italy, SP: Spain).

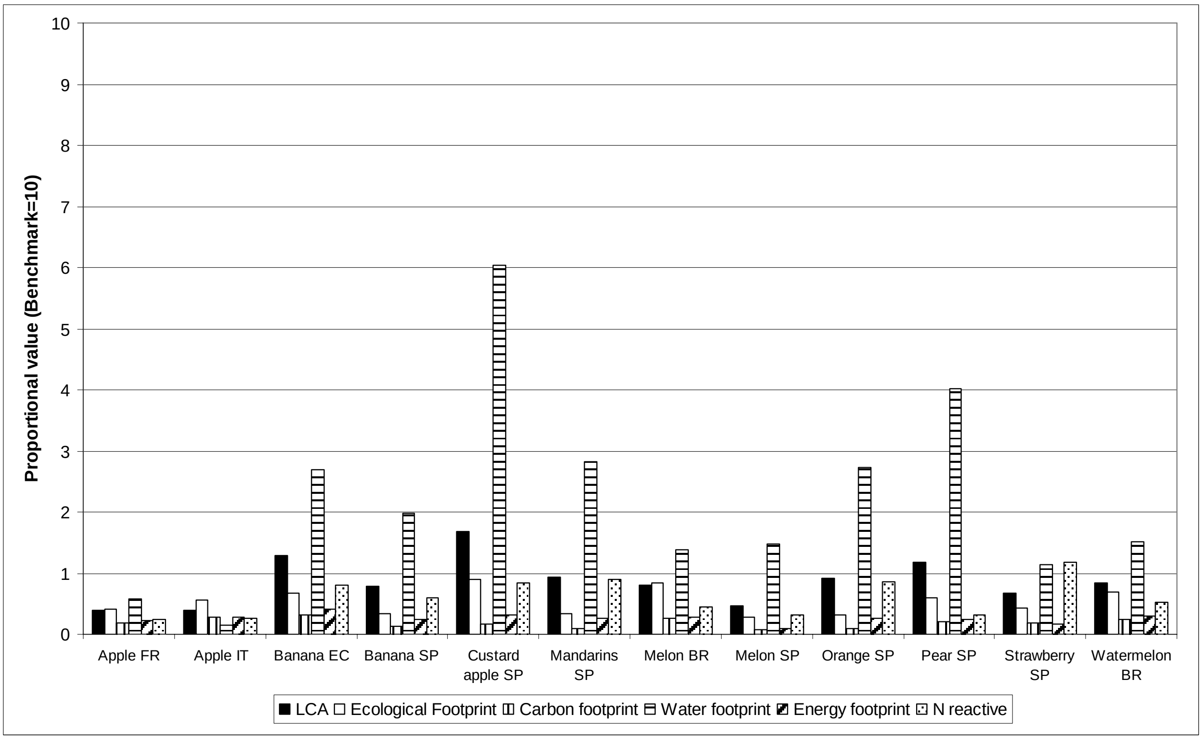

Fig. 2: Proportional values of the environmental indicators respect to the benchmarks considered (Zone of cultivation: BR: Brazil, EC: Ecuador, FR: France, IT: Italy, SP: Spain).

LCI of vegetable and fruit production in different countries

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Keywords: LCI, vegetable production, fruit production, integrated production, organic production

Food consumption is one of the three activities that dominate the environmental impact of personal consumption (Tukker 2006). There are few studies assessing the food production system from a life-cycle point of view, because of scarce data availability and inherent variability. In the present work, the life cycle assessment methodology is used for the environmental assessment of various vegetables and fruits, shown in Table 1. Complete life cycle inventories for these products, including farm machinery work, irrigation, fertilizer, pesticides, seedling production, and transport are presented. Geographic variation is assessed extrapolating from a basic set of data appropriate to Switzerland for vegetables (szg, 2004), resp. to countries of origin for fruits and varying single parameters, e.g. water use (Chapagain, 2004). Sensitive parameters are determined through life cycle impact assessment. The results show that such sensitive parameters are means of transportation and transport distances, regional origin for water use, energy used for greenhouse heating, duration of storage and pesticide use in cultivation.

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Table 1: Analysed vegetables and fruits in different countries.

Vegetables and fruits	Countries
Asparagus, Eggplant, Cauliflower, Fennel, Cucumber, Carrots, Potatoes, Radishes, Celery, Asparagus, Spinach, Zucchini, Onions, Lettuce , Broccoli, Cabbage, Iceberg Lettuce	Switzerland, Spain, Italy, Netherlands, Belgium Morocco, Peru, Mexico, USA, Slovenia, France, Egypt, Germany
Apple, Pear, Melon, Citrus fruits, Kiwi, Strawberries, Avocados, Bananas, Papayas, Grapes, Pineapple	Switzerland, Spain, Italy, France, Greece, Israel, Palestine, Egypt, India, New Zealand, South Africa, Ghana, USA, Mexico, Costa Rica, Caribbean, Colombia, Ecuador, Peru, Argentina, Brazil, Uruguay

Is Globalized Grain Maize Production an Environmental Improvement?

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Keywords: LCA, maize production, globalization, agricultural methods, environmental impact

In this paper we studied the impacts of maize production and transportation. Maize is a very important tradable good, since it is highly used for animal and human food, and increasingly used as a biofuel. We use Life Cycle Assessment (LCA) to analyze the environmental impact of its production and transportation. Using the assessment results, we compare different choices in cultivation methods and locations. We used the aggregation methods Ecoindicator 95 (Goedkoop, 1998) and 99 (Goedkoop & Spriensma, 2000) in software SimaPro 6.0 software with some modifications, namely refining the data for productivity and nutrient leaching. Results were then subjected to an uncertainty analysis.

Our question is: which is the best environmental option for a farmer in Portugal - should he produce grain maize in his farm, buy it from another farm in Portugal, or buy imported maize? The farm used for a case study was Quinta da França (QF). Maize from QF is compared to maize produced by average means from three Portuguese regions and Argentina. Regions are depicted in Tab. 1.

Results in Fig. 1 show that transportation is responsible for an important part of the overall impact. It is so important that it may change significantly the results obtained. In fact, at the farm gate, Quinta da França is not the best option for maize production, when compared with other national regions or Argentina. That is not the case, however, including transportation.

Results change even more if we consider that the QF farmer may optimize its own production, namely using no-tillage techniques, adequate fertilization and irrigation. In that case, QF becomes the location with a lowest environmental impact.

We also concluded that the most important environmental themes in maize production are eutrophication, acidification, greenhouse gas emissions, energy and land use. These themes are usually referred in the literature as significant for agriculture. However, we found a surprising relevant theme in heavy metals. Its impact is due to fertilizers and machinery use.

Even though we used this farmer example in our study, we could also apply it to a bioethanol facility that wanted to use environmental-friendly maize. Should the owner of the facility impose restrictions on nearby producers in order for them to optimize their production, or should he import maize from elsewhere? Our results tell us that small distances for transportation, combined with optimized production, may be the best combination. In terms of policy, it is also the better option, since production conditions are easier to regulate locally than to impose them as a requirement for imports. However, pollution from maize production remains within the country, which may have an influence in international agreements such as the Kyoto Protocol for greenhouse gases. Land opportunity costs should also be addressed in such studies.

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Tab. 1: Maize production technical coefficients, for each production site and method studied

Production zone	Beira Interior (BI)	Ribatejo e Oeste (RO)	Beira Litoral (BL)	QF	QF No-tillage (QF-NT)	Argentina (ARG)
Productivity (ton/ha)	6.5	10.0	10.0	6.5	6.5	8.5
Space occupation (ha/ton)	0.154	0.100	0.100	0.154	0.154	0.117
Market value (€/kg)	0.14	0.14	0.14	0.13	0.13	0.04
N fertilizer (kg/ton)	10.6	21.9	16.5	37.8	37.8	8.1
P_2O_5 fertilizer (kg/ton)	8.6	10.5	7	26.6	26.6	1.1
K_2O fertilizer (kg/ton)	8.6	10.5	7	40.3	40.3	2.7
Irrigation method	Sprinkling	Furrows, gravity	Sprinkling	Furrows, gravity	Sprinkling	Gravity
Water consumption (m^3/ha)	7 200	6 480	8 850	9 000	7 200	2 500
Water consumption (m^3/ton)	1 108	648	885	1 385	1 108	294
Total cost (€/ton)	224.8	157.8	150.5	167.3	-	98.0
Revenue (€/ton)	140.7	140.7	140.7	130	-	42.5
Gross margin (€/ton)	-3.1	54.5	79.8	20.2	-	26.6
Net margin (€/ton)	-84.2	-17.2	-9.9	-37.4	-	-

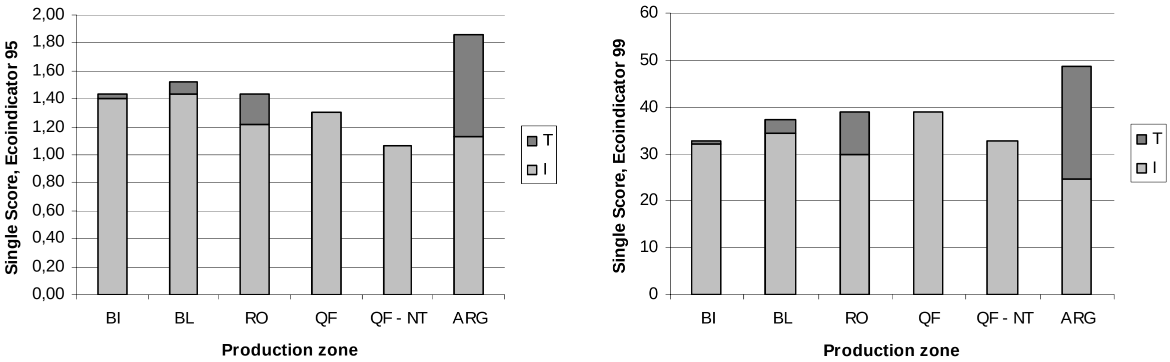

Fig. 1: Impact of maize production in each region with corrected fertilization and considering transportation to QF by road; functional unit: 1 ton of maize. Right: Ecoindicator 95. Left: Ecoindicator 99.

Legend: T – transportation impact; I – ingredient production impact

Organic, conventional or combination? Energy and land use in the contrasting farming systems

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Keywords: LCA, organic farming, environmental impacts, wheat, bioenergy

Organic crop production generally uses less energy per product unit compared to conventional farming (Williams *et al.*, 2006). However, the land requirement for organic crops in Europe is higher due to lower yields. The limited land resources could be utilised more efficiently by increasing yields and integrating bioenergy production into the farming systems (Tuomisto & Helenius, 2008). The optimal system that reduces both energy use and land requirements may consist of a combination of organic and conventional farming practices.

Life cycle analysis was used to assess the energy and land required per tonne of wheat in different stockless farm models including organic, conventional and combined farming systems, both with and without bioenergy production. In addition, whole-farm net energy production, energy balances and land used per unit of food energy were calculated. The combined farming systems were assumed to use only organic fertilisers, but applying pesticides in order to achieve high yields. In the organic and combined models the biogas was assumed to be produced from crop residues, green manure and cover crops. In the conventional farm models *Miscanthus* energy crop was produced over the same land area that was used for green manure crops in the organic and combined models. The combined special model produced both *Miscanthus* and biogas from crop residues, cover crops and imported municipal biowaste. Three different tilling methods and two physical allocation methods were compared.

The results showed that the energy input per tonne of wheat was highest in the conventional systems and lowest in the combined systems. Organic systems had the highest land requirement, while conventional systems and combined special model utilised the lowest land area per tonne of wheat. Those systems that included bioenergy production had the highest net energy production. The lowest net energy and food energy production resulted from the organic model without production of bioenergy, whereas the conventional system without bioenergy production had the highest food energy production.

It was concluded that the energy input and land requirement can both be reduced by combining organic and conventional farming practices when compared to either system alone. The integration of biogas production into farming systems enhances whole-farm net energy production and recycling of nutrients. Further research is being undertaken to assess the wider environmental impacts and economic returns of the systems studied.

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Effect of structural and management characteristics on variability of dairy farm environmental impacts

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Keywords: LCA, dairy farms, Brittany

Bovine milk production generates annual sales of more than €23 billion in France, and approximately 20% of national production comes from the region of Brittany (2004 figures, quid.fr). At the same time, high livestock density in Brittany has contributed to increases in the nitrate concentration of rivers and groundwater there, in some cases exceeding the critical thresholds mandated by the European Union. Thus, as in many regions of the world, decision-makers in Brittany are seeking ways to maintain or increase milk production while reducing the environmental impacts of doing so. We applied Life-Cycle Assessment (LCA) methodology (Guinée, 2002) to dairy farms in Brittany to (1) estimate their potential environmental impacts, (2) characterize differences in impacts between conventional and organic production methods, and (3) identify the production practices or factors with the greatest influence on impacts in order to use them to inform management changes in the future.

We studied 60 specialized dairy farms from all 4 departments of Brittany: 46 conventional farms and 14 organic farms. The input data included information about the following farm characteristics: productivity and management of livestock, crops, and pasture; machinery; organic and inorganic fertilizer use; pesticide use; energy-carrier and plastics consumption; and basic economic performance. LCA calculations were performed with a Microsoft® Excel-based tool called EDEN. For each farm, EDEN estimated farm-gate N, P, and K balances and potential impacts for eutrophication (kg PO_4 equiv.), acidification (kg SO_2 equiv.), climate change (kg CO_2 equiv.), terrestrial toxicity (kg 1,4-DCB equiv.), and non-renewable energy use (MJ). Impacts were compared among farms by standardizing them to two functional units: 1000 kg of milk sold and on-farm plus estimated off-farm hectares utilized (van der Werf *et al.*, in review). The results showed significant differences in the estimated potential impacts of organic and conventional dairy farms and largely agreed with previously published estimates of the effect of production mode on dairy-farm impacts. They revealed, however, great variability in impacts among farms of the same production mode, especially for eutrophication (Fig. 1) and terrestrial toxicity impacts. In the current study, we searched for factors to explain this variability by evaluating relationships within and between sets of input factors and impact estimates with standard statistical analyses.

As expected, some input factors showed strong correlation, such as concentrate fed per dairy cow vs. milk produced per dairy cow and N fertiliser imported per ha vs. pesticide active ingredients applied per ha. Certain potential-impact estimates also showed strong correlation, such as acidification vs. climate change or eutrophication. Two criterion-based regression methods identified 1-7 factors that best predicted each impact, the most important overall being farm N balance, N imported in fertilizer or feed, animal stocking rate, and amount of manure imported. Although the relatively small sample size needs to be increased, these results begin to indicate which management changes could reduce particular environmental impacts of dairy farms the most.

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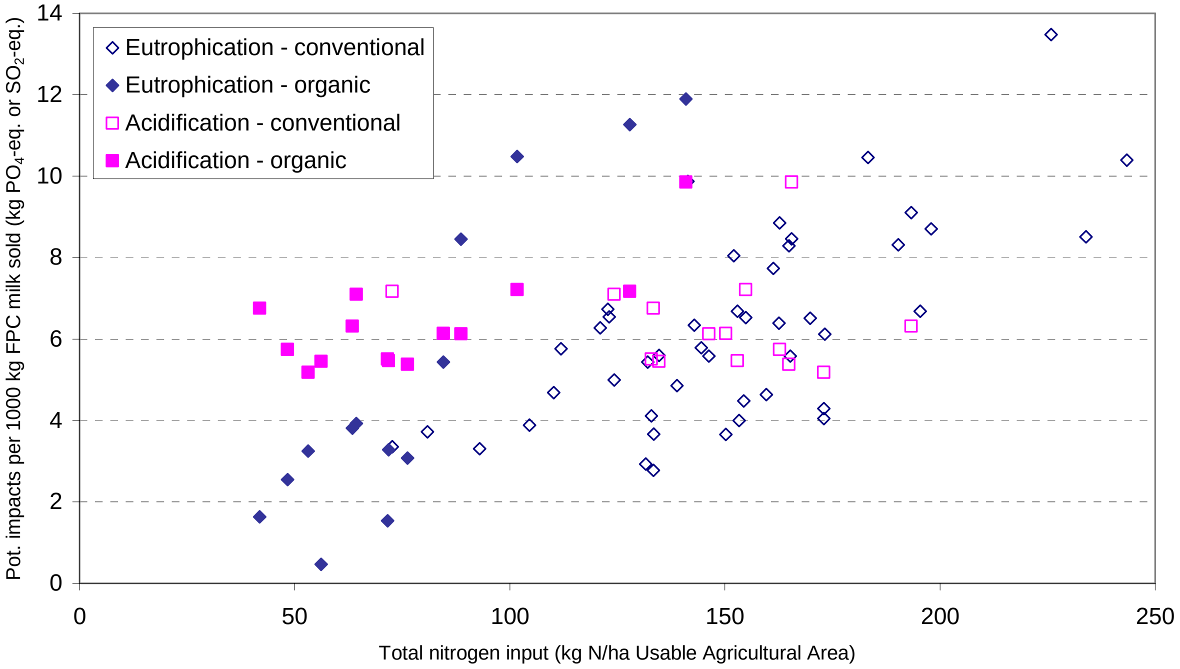

Fig. 1. Potential eutrophication (kg PO_4-equivalent) and acidification (kg SO_2-equivalent) impacts per 1000 kg fat-and-protein-corrected milk sold for conventional and organic farms in Brittany as a function of total nitrogen input (kg N/ha Usable Agricultural Area).

Life-cycle energy and greenhouse gas analysis of a large-scale vertically integrated organic dairy in the U.S.

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Keywords: Organic, milk, GHG, Life cycle assessment, carbon footprint

Agriculture is responsible for nearly seven percent of the total U.S. greenhouse gas emissions; over half of this is from livestock (USDA, 2004). The U.S. organic food sector has consistently grown between 15-20% annually over the past decade. Organic dairy in particular has grown by upwards of 25% in recent years (OTA, 2007). While such growth is in general lauded as an environmental success, there is a great need for systemic benchmarking of the environmental impact of organic agriculture in the U.S. in order to provide guidance for continual improvements in the sustainability of this rapidly growing sector.

This study is the first life cycle assessment (LCA) of a large-scale, vertically integrated organic dairy in the U.S. Aurora Organic Dairy (AOD) is a leading U.S. provider of private-label organic milk and butter, managing over 12,000 milking cows and processing over 84 million liters (22 million gallons) of milk annually. Data collected at AOD farms and processing facilities were used to build a LCA model for benchmarking the greenhouse gas (GHG) emissions and energy consumption across the entire milk production system, from organic feed production to transport of packaged milk. The analysis covers all aspects of milk production (see figure), from growing organic feed, to delivering packaged milk to customers (retail outlets). Overall GHG emissions were 1.7 kg CO_2 eq. per liter of packaged liquid milk. The major GHG contributors include enteric fermentation (28% of total) and feed production (23% of total). The energy consumption for the entire system was 17.3 MJ per liter of packaged liquid milk. Potential strategies for reducing the system GHG emissions are discussed. This energy and greenhouse gas analysis is phase one of a two phase project, to be followed by a thorough sustainability assessment including additional ecological indicators, as well as social and economic indicators.

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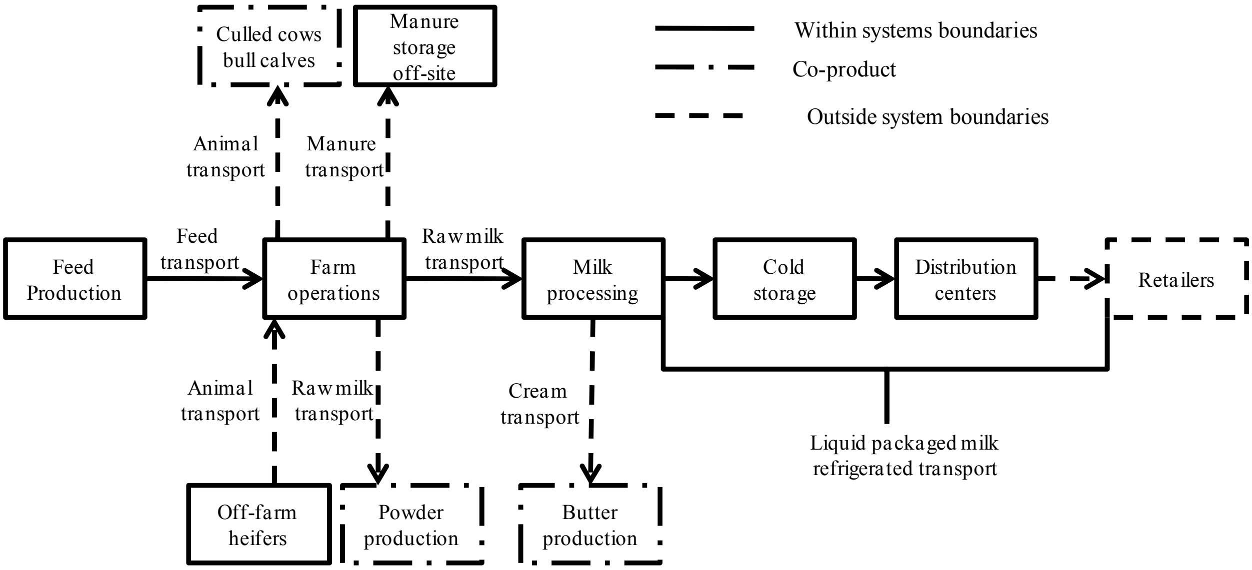

Figure 1: Process flow for organic milk production. Arrows represent physical movement of materials and boxes represent different phases of milk production. Processes accounted for in this study are shown in solid lines while processes not accounted for are shown in dashed lines. Processes (co-products) with upstream burdens allocated away from the liquid milk system are shown in dashed-dot lines.

Meat and milk products in Europe: Impacts and improvements

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Keywords: hybrid LCA, monetarisation, beef, rebound effects, socio-economic assessment, cost-benefit, discounting, consequential LCA

The project – which was presented at the previous LCA-Food conference in 2007 – has now been finalised, and the results can be presented. The overall environmental impact from consumption of meat and dairy products in EU-27 were assessed by the use of hybrid life cycle assessment (input-output data supplemented by specific process data). For the impact assessment, we applied a flexible model that allows results to be presented both in the 14 traditional environmental midpoint indicators (global warming potentials, photochemical ozone creation potential, etc.) and in monetary units (Euro). Specifically for this project, a damage model for aquatic eutrophication was developed.

We found that the consumption of meat and dairy products contributes on average 24% of the environmental impacts from the total final consumption in EU-27, while constituting only 6% of the economic value, see Table 1. For the most important impact categories, the contribution of meat and dairy products varied from 14% (for global warming) to 36% (for nature occupation) of the impacts from the total final consumption in EU-27. The monetarised environmental impacts (externalities) were of considerable size compared to the private costs of the products (from 34% of the private costs for pork to 112% of the private costs for beef). The four main product groups (dairy, beef, pork and poultry products) contributed respectively 33-41%, 16-39%, 19-44%, and 5-10% to the impact of meat and dairy products consumption in EU-27 on the different environmental impact categories. Per kg slaughtered weight, there was a clear difference between the three types of meat, with beef having 4 to 8 times larger environmental impacts than poultry and up to 5 times larger than pork. These differences were less pronounced when comparing the environmental impact intensity (impact per Euro spent) of the three types of meat, where pork generally has the lowest impact intensity (down to 40% of the impact of poultry and 23% of the impact of beef), with the exception of aquatic ecotoxicity where pork production contribute with high copper emissions.

We identified and quantified the improvement options for all processes contributing more than 10% to each of the midpoint impact categories. Rebound effects, synergies and dysergies of the different options were taken into account and we show the importance of rebound effects and interrelationships of the improvement options, as well as market constraints. The environmental impacts were monetarised and a separate socio-economic assessment performed, thus allowing a cost-benefit assessment of the improvements. We also analysed the significance of discounting.

When all the identified environmental improvement potentials are taken together, and rebound effects and synergies have been accounted for, the total improvement amounts to a reduction of 17% for nature occupation, around 25% for global warming and respiratory inorganics, 31% for acidification and terrestrial eutrophication, 43% for aquatic eutrophication, to 68% for aquatic ecotoxicity. Uncertainties and limitations of the study are discussed.

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Table 1. Environmental impact of the total annual consumption of meat and dairy products in EU-27 (the functional unit of the study) expressed in the specific units of each impact category and relative to the impact of EU-27 total final consumption.

Impact category	*1.1.1.1.1.1 Un*	**Amount**	**Coefficient of variance**	**Relative to the impact of EU-27 total final consumption**
Acidification	m^2 UES	9.49E+10	0.9	24.9%
Ecotoxicity, aquatic	kg-eq. TEG water	1.43E+14	2.7	46.6%
Ecotoxicity, terrestrial	kg-eq. TEG soil	6.03E+11	2.7	6.5%
Eutrophication, aquatic	kg NO_3-eq.	8.86E+09	0.2	29.4%
Eutrophication, terrestrial	m^2 UES	3.88E+11	1.2	39.1%
Global warming	kg CO_2-eq.	6.69E+11	0.1	14.2%
Human toxicity, carcinogens	kg C_2H_3Cl-eq.	1.38E+09	2.7	8.0%
Human toxicity, non-carcinogens	kg C_2H_3Cl-eq.	1.14E+09	2.7	6.7%
Mineral extraction	MJ extra	5.26E+09	1.6	5.8%
Nature occupation	m^2 arable land	9.76E+11	1.1	35.8%
Non-renewable energy	MJ primary	8.76E+12	0.1	6.3%
Ozone layer depletion	kg CFC-11-eq.	1.91E+05	1.5	6.4%
otochemical ozone, vegetation	m^2*ppm*hours	6.66E+12	1.7	12.4%
Respiratory inorganics	kg PM2.5-eq.	8.51E+08	1.9	17.7%
Respiratory organics	person*ppm*hours	7.22E+08	2.2	12.8%

Life cycle greenhouse gas emissions from Brazilian beef exported to Europe

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Keywords: Beef production, Brazil, greenhouse gas emissions

During the last decade, Brazilian beef production has gone through a remarkable growth and overall production has increased by over 40 %. The growth has been mainly export driven and in 2004, Brazil became the leading beef exporter on the global market. The pasture area of ~170 million hectares (planted and native) is the base for the country´s beef production and Brazilian beef is promoted as "Natura Beef" on the export market. Despite the great importance of Brazilian beef for global meat production, very few environmental assessments of the production have been reported so far. The purpose of this study was to assess the life cycle greenhouse gas emissions (GHG) of Brazilian beef exported to Europe.

Data on resource use and emissions from Brazilian beef production were collected from statistical sources, recent published scientific literature and through frequent contacts with Brazilian researchers in the fields of agriculture and environment.

The results show that emissions of fossil CO_2 are of minor importance due to very low input of diesel and fertilisers in the production. Also CO_2 emissions due to overseas transports are insignificant. Instead, CO_2 emissions from land use transformation caused by the clearing of forestland to gain more pasture area are important. Since 1995, pasture area has expanded by ~10 million hectares (20 %) in the nine states of the Legal Amazon (IBGE 2007) mainly on earlier forested land. In this part of Brazil, approximately half of the last ten years´ production growth has occurred. Methane emissions (Lima et al, 2007) are relatively high per kg beef due to high slaughter age and long calving intervals for the cows. Nitrous oxide emissions from the manure of the grazing cattle also have a significant contribution to the overall GHG emissions of the beef. Quantified results on GHG emissions will be presented at the conference, but since the study is still on-going, no figures can be included in this abstract.

An important conclusion of the study is that poor pasture management is an important environmental hot-spot in Brazilian beef production. Recent estimations say that more than 25 million hectares of planted pastures can be degraded in various stages, thus leading to low productivity followed by need for new pasture land. The on-going land expansion could be substantially reduced if pasture land were better maintained. Pasture degradation can be prevented by maintenance fertilisation and avoidance of high stocking rates, especially in dry periods (Boddey et al, 2004). Methane emissions can be reduced by improving livestock performance, e.g. by shortening calving intervals.

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Life cycle assessment of biomass from short rotation coppice for energetic utilization

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Keywords: life cycle assessment, short rotation coppice, renewable energy, biomass production, poplar, carbon emission reduction

In order to reach the strict climate goals the European Union has targeted to their members, each member state has to work out its strategy to reduce carbon emissions. Burning wood for producing electricity and heat or converting it into biofuel could play an important role to meet the future energy demand by renewable and low carbon energies. For Germany the wood from forests might not sufficiently meet the increasing future demand. That's why additional sources of wood have to be investigated. One solution might be the cultivation of trees on fallow agricultural lands. In this context the question rises, whether wood from short rotation coppice actually will reduce the emission of green house gases. There is a fear that the cultivation possibly could cause additional environmental burdens, like recently shown for miscellaneous biomass plants (Zah *et al.* 2007). In comparison to other biomass crops poplar cultivation is believed to have fewer negative impacts on the environment because it is perennial and therefore requires less input of fertilizer and herbicides than annual crops. Related to the produced unit of biomass machinery use is also reduced compared to annual tillage.

In order to investigate the mentioned aspects, a life cycle assessment of growing poplar trees on agricultural land was carried out. Data collection and interpretation was accomplished with the help of the software tool GaBi. Factors provided by Guinèe (2002) were used for characterisation.

The cultivation is analysed under different regimes of fertilizer use. The various environmental impacts like global warming potential, eutrophication, acidification, smog and toxicity as well as non-renewable energy use are investigated. Important issues for assessing crop cultivation via life cycle assessment method are discussed. Following the actual debate, assumptions on emission factors for nitrous oxide are taken into consideration. Recently Crutzen et al. (2008) questioned the IPCC default factors and recommended others. Therefore variations of the assessment results by using different emission factors for nitrous oxide are analysed. Furthermore aspects of land use and soil carbon gains or losses are reflected.

Short rotation biomass can be converted into different sources of energy, like Fischer-Tropsch-diesel, electricity and heat. Hence subsequently the potential of wood from short rotation to save carbon is analysed. This is done in comparison to diesel, electricity and heat generated from fossil fuels. As a result it is shown how to use the woody biomass in order to achieve maximal carbon emission reductions.

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The Eco-efficiency of Ewe Cheese Production: Determination and Process Optimization

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Keywords: LCA, eco-efficiency, pastures, ewe cheese, environmental impact, economic costs

In this paper we determine, analyze and optimize the eco-efficiency of ewe milk and cheese production. By comparing the eco-efficiency of milk and cheese, we are able to identify which of the two products has a higher value added per unit of environmental impact caused. We thus determine if it is more efficient to use ewe milk as a raw material for cheese production, or use it for direct consumption.

First, we determined the impacts of the cheese production life cycle, and studied several optimization options. We used the aggregation methods Ecoindicator 95 (Goedkoop, 1998) and 99 (Goedkoop & Spriensma, 2000) in software SimaPro 6.0 to calculate the environmental impacts of each stage. Production stages are shown in Fig. 1. Then, we calculated the costs and revenues of milk and cheese production, so that we finally obtained the eco-efficiency.

We paid special care to animal feed, since our results show that it is the stage with the highest environmental impact. Therefore, we considered that an optimized feed would consist of hay produced with no-tillage and the pastures should be sown, biodiverse, permanent and rich in legumes. Previous work shows that these are an alternative to natural pastures with high environmental benefits (Teixeira *et al.*, 2008). A non-optimized feed, however, incorporates grazing in natural pastures and hay obtained with conventional tillage.

Our final results show that cheese has a higher eco-efficiency (Tab.1). The animal feed stage, where the highest impact stands, is common to both milk and cheese, but cheese has a much higher value added. Transforming milk to cheese has very low impacts if done correctly.

Choosing no-tillage techniques and using sown biodiverse pastures greatly diminishes the global impact. It also provides further protection from erosion, higher primary productivity, and carbon sequestration.

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Tab. 1: The eco-efficiency of ewe cheese and milk production.

Product	Income		Impact		Eco-efficiency (€/Pt)
Milk	1,01	€/L	0,0105	Pt_{95}/L	96,2
Cheese	8,50	€/kg	0,0306	Pt_{95}/kg	277,8

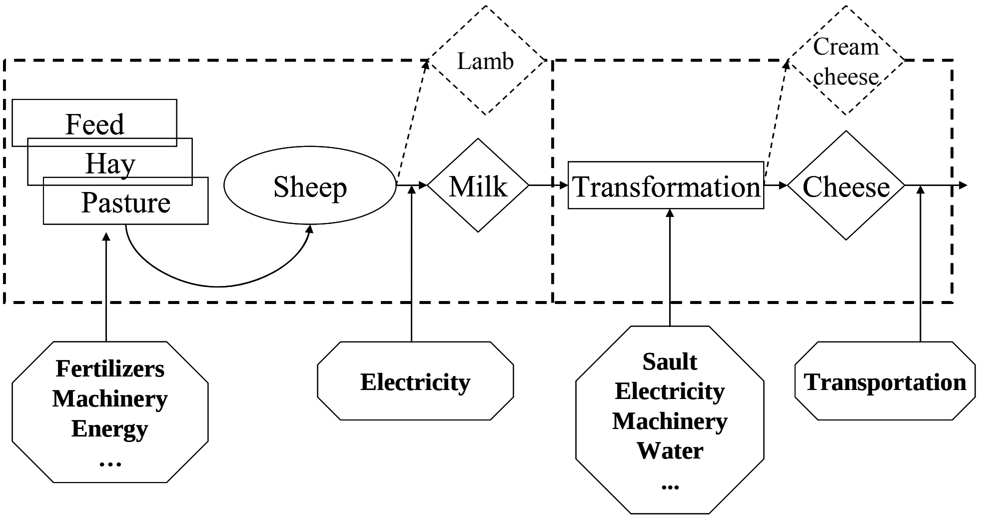

Fig. 1: Cheese production life cycle

Environmental Optimization of Animal Feed for Finishing Beef Calves in Portugal

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Keywords: LCA, beef cattle, animal feed, feed ingredients, feed environmental impact, crop production, feed nutritional value

Most software for animal feed optimization uses a linear programming system which consists on the choice of the quantity of each ingredient. The inputs are the availability of the ingredient, its price, and the intended nutritional value of the feed, which depends on the type of animal. But they do not consider the global environmental impact of the feed as an optimizing parameter. In this paper, we determine the life cycle impacts of typical feed ingredients. We thus build a database which allows us to compute the impacts of most animal feeds, and so optimize their content according to environmental criteria.

This paper is divided in three parts. In the first part, we determine the impacts of the production of each ingredient commonly used in animal feeds in Portugal. We used a Life Cycle Assessment (LCA) method, namely Eco-Indicator 95 (Goedkoop, 1998) and Eco-Insicator 99 (Goedkoop & Spriensma, 2000) in software SimaPro 6.0. Several production options and regions were evaluated for each ingredient. This established our database of ingredient impacts. In the second part of the paper we illustrate the use of this database by determining the global impact of three alternative feeds for beef calves: an optimized grain maize-based feed, an optimized silage maize-based feed and an average national feed. This requires scenarios for transportation of ingredients, industrial processing and transportation to farms. All the impacts from these stages were also calculated in an LCA approach. Finally, the third part deals with the definition of the environmental optimization system we obtain from the two former steps, and its integration with other feed optimization systems.

Regarding results from the first part (Fig. 1), we found that the ingredients with the highest impact are soybeans and barley. In the case of soybeans, used as protein sources, a good substitution option may be found in alfalfa. Alfalfa has a slightly higher impact, and is not transgenic. The ingredients with the lowest impacts are by-products or forages.

As for the application of the impact database to specific feeds (Fig. 2), we were able to conclude that the feed based on silage maize has a generally lower impact. The average feed has a larger content of imported products (corn gluten feed, soy), and therefore transportation impacts are very large. Industrial processing is irrelevant.

Finally, we tried to compatibilize our analysis with standard feed optimization methods. Since optimized feeds must still satisfy the animals' needs, we tested the nutritional characteristics of the feeds, determining which ingredients are environmentally better for each nutritional parameter.

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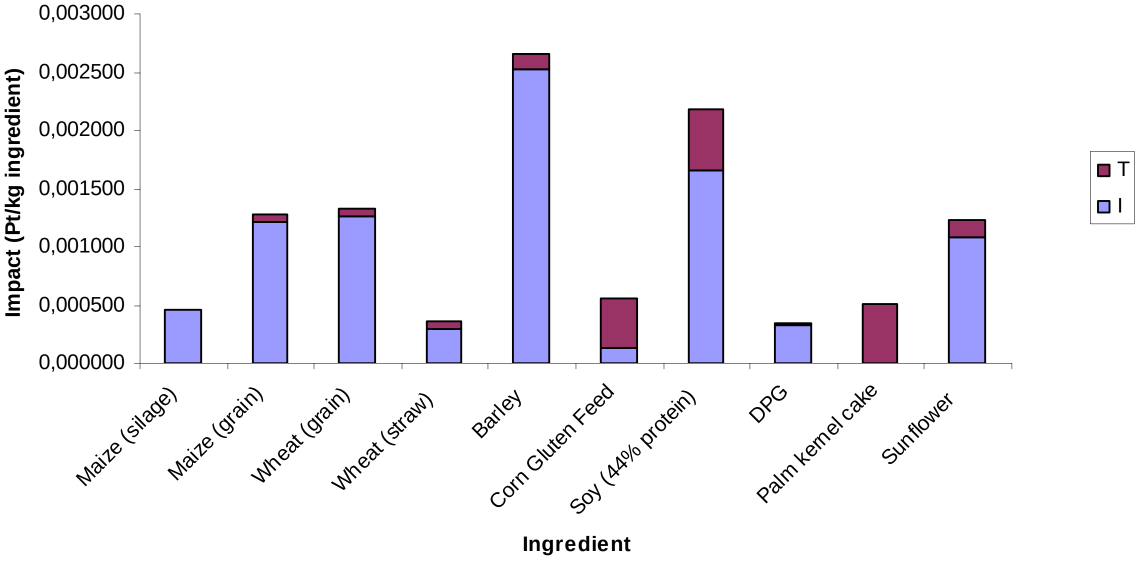

Fig. 1: Unit impact of each ingredient (Ecoindicator 95)

Legend: I – ingredient production; T – transportation from production site to industrial processing facility

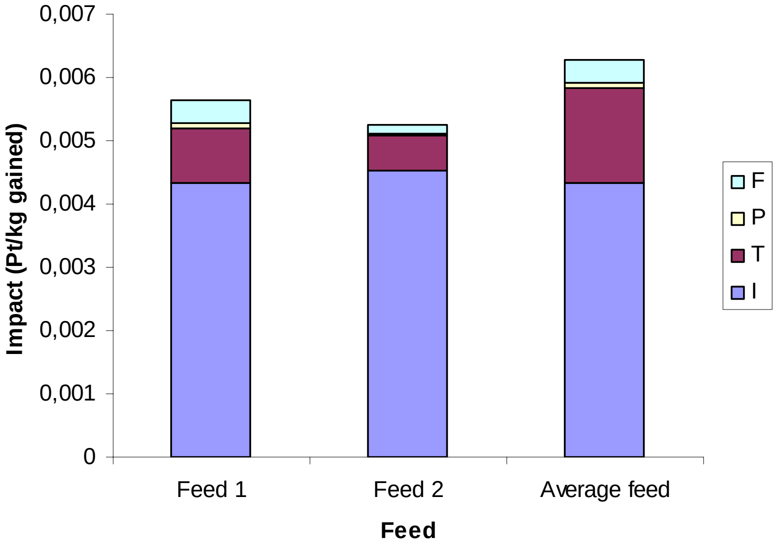

Fig. 2: Overall impact of all feeds (Pt/kg gained), Ecoindicator 95

Legend: I – ingredient production; T – transportation from production site to industrial processing facility; P – industrial processing; F – transportation to animal farm; Feed 1 – grain maize-based feed; Feed 2 – silage maize-based feed

Life cycle assessment of feeding livestock with European grain legumes

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Keywords: life cycle assessment, LCA, grain legumes, soya bean meal, feedstuff, livestock production, Europe

Europe has a high demand for vegetable protein sources. Grain legumes (pulses), such as peas, beans and lupines, would be a suitable alternative to meeting this need. However, only 2% of Europe's arable land is currently cultivated with them, with a downward trend. As a result, 75% of Europe's plant-derived protein demand is covered by imports, mainly as soya bean meal and seeds from North and South America having adverse environmental impacts. Against this background the question arises whether there are environmental benefits from using European grain legumes in livestock production.

Four animal products – pork (Catalonia, Spain, and North Rhine-Westphalia, Germany, chicken meat and eggs (both Brittany, France) as well as milk (Devon and Cornwall, Great Britain) – were assessed in their respective regions using the Swiss Agricultural Life Cycle Assessment (SALCA) methodology (Gaillard *et al.*, 2008). Two feeding strategies were analysed: The standard feed SOY consisting mainly of cereals and soya bean meal and the Grain Legumes Europe (GLEU) alternative, where the soya bean meal was replaced by peas and beans as well as sunflower and rapeseed meal. In some regions additional alternatives, such as use of higher quantities of synthetic amino acids or on-farm feedstuff production, were assessed (Baumgartner *et al.*, 2008).

As an example of the performed life cycle assessment (LCA) case studies, the results for the *Global warming potential (GWP)* of egg production are shown in Fig. 1: The impacts of the GLEU alternative were reduced by 10% compared with SOY, which is considered to be favourable. The main reductions occurred in the process steps Transports (- 31%) and Energy rich feeds (- 11%), but were compensated by an increased use of Protein rich feeds. The main difference though was caused by CO_2-release from Land transformation (- 73%). The overall comparison of the five case studies showed that the substitution of soya bean meal (SOY) by peas and beans (GLEU) did not lead to an overall improvement of the environmental impacts. Clear benefits were shown for the impact categories *Energy demand* and *GWP*. However, there was little effect on the nutrient-driven impacts and the results for the *Ecotoxicity* impact categories tended to be negative (Tab. 1).

In conclusion, the main benefits of introducing European grain legumes in livestock production were found for the resource use-driven impacts. Producing the feedstuffs on-farm lessened the environmental burden further. The results were more determined by the composition of the whole feed formulas than by the replacement of soya bean meal by peas and beans alone. Efforts for improvements should primarily be taken for feedstuff production, as it has a major share in the environmental impacts of livestock production. As a possible measure we propose to integrate environmental criteria into feedstuff models, allowing the optimisation of feed formulas in terms of economic and environmental aspects.

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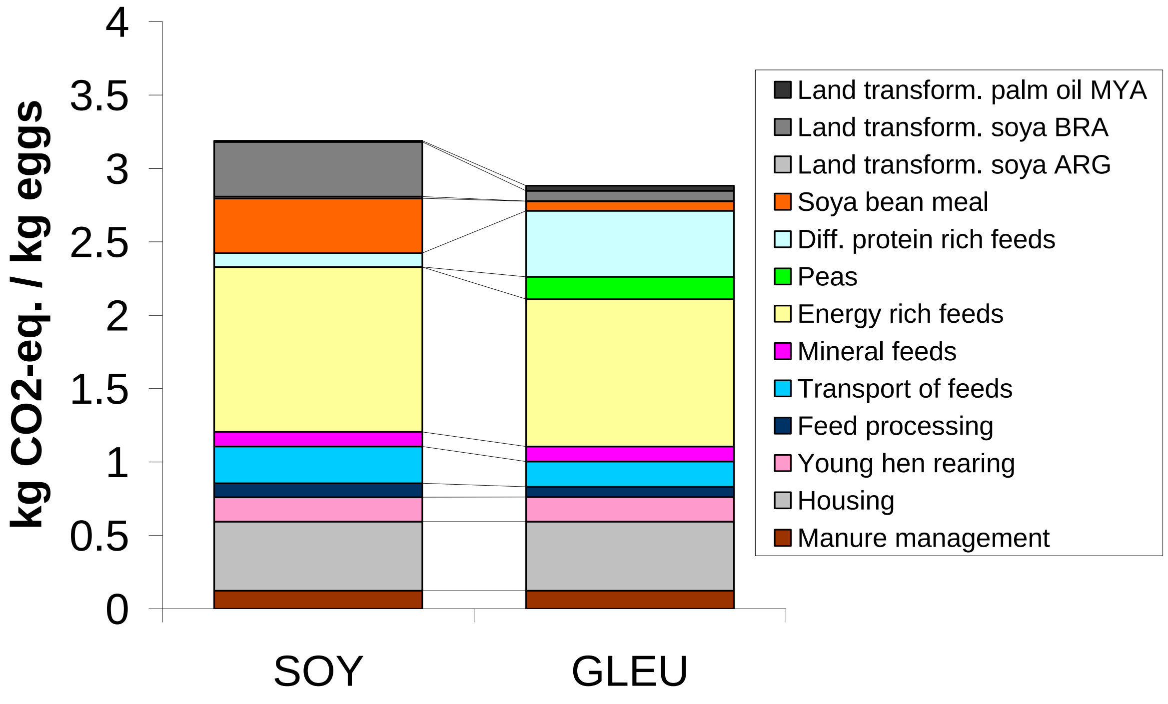

Fig. 1: Global warming potential (100a) for producing one kg of eggs (with egg-shells) in Brittany (BRI) with the two feeding strategies SOY (soya bean meal from overseas) and GLEU (European grain legumes). MYA: Malaysia; BRA: Brazil; ARG: Argentina.

Table 2: Overview of the environmental impacts per kg commodity of all case studies (pork, chicken meat, egg and milk production) of the two feeding alternatives SOY (overseas soya bean meal) and GLEU (European grain legumes). Values are expressed as GLEU in percent of SOY (LW: Live weight; ECM: Energy corrected milk).

Impact categories		**pork**	**pork**	**chicken**	**egg**	**milk**
		North Rhine-Westphalia	**Catalonia**	**Brittany**	**Brittany**	**Devon & Cornwall**
	Reference flows	**kg LW**	**kg LW**	**kg LW**	**kg eggs**	**kg ECM**
Resource use-driven impacts	Energy demand [MJ-eq]	99%	94%	94%	96%	91%
	Global warming potential 100a [kg CO2-eq]	95%	98%	90%	90%	96%
	Ozone formation [g ethylene-eq]	98%	106%	98%	95%	97%
Nutrient-driven impacts	Eutrophication, combined N & P [g N-eq]	93%	117%	105%	106%	102%
	Acidification [g SO2-eq]	98%	98%	98%	100%	99%
Pollutant-driven impacts	Terrestrial ecotoxicity EDIP [points]	96%	126%	125%	123%	97%
	Aquatic ecotoxicity EDIP [points]	111%	127%	89%	124%	82%
	Terrestrial ecotoxicity CML [points]	376%	165%	108%	119%	95%
	Aquatic ecotoxicity CML [points]	176%	105%	104%	113%	95%
	Human toxicity CML [points]	103%	108%	100%	102%	97%

Classification

very favourable	unfavourable
favourable	very unfavourable
similar	

Comparing options for pig slurry management by Life Cycle Assessment

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Keywords: pig slurry, manure management, ammonia, methane

Excess manure from intensive livestock production is a recognised environmental hazard as its mismanagement threatens the quality of water resources and contributes to emissions of NH_3, CH_4 and N_2O. For these reasons, several regulations oblige farmers to search for options to reduce environmental impacts, while remaining productive and economically viable.

In this study we compare several strategies and techniques for excess pig slurry management using Life Cycle Assessment. The strategies tested are (i) the transfer of slurry to crop production regions for its use in substitution of chemical fertilisers and (ii) the treatment of excess slurry in either collective or individual treatment plants. The techniques compared are (i) covering slurry storage tanks with a PVC cap and (ii) different slurry application techniques to cropland: deep and shallow injection, trailing hose and splash plate spreading.

Eutrophication (EU), acidification (AC), climate change (CC) and non-renewable energy use (NE) were the impact categories used for the evaluation. NH_3 volatilised during storage and application of slurry is the main contributor to EU and AC, CH_4 emissions during slurry storage and treatment and N_2O emissions during slurry application were the main contributors to CC. Energy saved by the substitution of fertilisers and energy needed for the treatment of slurry were the main aspects influencing the NE performance of the different strategies.

The transfer of slurry has a better environmental performance than either the individual or collective treatment. Compared to its transfer, the treatment of slurry increases EU and AC by a factor 2 and 1.4, for collective or individual treatment respectively, due mainly to NH_3 emission during the treatment process (solid refuse composting). For CC, individual treatment is the best performing system due to the reduction of transport and slurry storage time. For NE, the transfer of slurry is an energy saving strategy as a result of the substitution of fertilisers, while slurry treatment consumes important amounts of electricity for its aeration.

Covering slurry storage tanks with a PVC cap reduces the EU and AC by 72% with respect to uncovered tanks. CC is not reduced when tanks are covered due to the fact that covers are not airtight and CH_4 emissions depend mainly on organic matter decomposition and not much on wind speed. NE is also very similar for the covered and uncovered tanks.

Technique of slurry application to cropland has important effects on the environmental performance of slurry management. For EU and AC, the deeper the slurry is injected the lower NH_3 emissions are. However, for CC it is the opposite, as N_2O emission increases as slurry is injected deeper. NE is very similar for all slurry application techniques, as the extra energy used for injection is compensated by a greater substitution of fertilisers due to a reduction of NH_3 emission.

An optimal scenario is suggested where the slurry is stored in PVC-cover tanks, transferred for its use in substitution of chemical fertiliser and applied by deep injection to cropland.

Environmental impacts and related improvement options of supply chain of chicken meat

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Keywords: supply chain integrated LCA, poultry, broiler chicken, meat, improvement

The environmental impacts of a typical Finnish broiler fillet product were studied using supply chain integrated life cycle assessment method. All essential production stages from parent stock and production of farming inputs to product distribution and sales in retail stores were included in the assessment. LCA and respective inventory data collection was based on actual production chain processes, between the years 2003 and 2005. The results of the study clearly demonstrated the significance of the environmental releases caused by the primary (incl. broiler chicken houses) production. The majority of the environmental impacts caused by the supply chain originated from the housing of the broilers and the crop cultivation for fodders. These production phases created the majority of the environmental impacts in the each category studied. The impacts accounted for 65 to 85 percent depending on the category.

When the primary energy consumption in the supply chain is considered, feed production and broiler housing accounted together for 41 per cent of all primary energy consumed, followed by the refrigeration of broiler chicken meat in retail stores that accounted for 20 per cent of all primary energy consumed. Broiler chicken production and feeding accounted for 65 per cent of the total global warming potential. This result was not only influenced by the carbon dioxide emissions from energy consumption released in different phases of supply chain, but also by the nitrous oxide emissions (N_2O) from the fertilizer production and use as well as in nitrous oxide and methane (CH_4) that are evaporated in broiler chicken manure handling.

Broiler housing and feed production had the most impact on eutrophication and acidification due to the nutrient run-off and leaching and ammonia evaporated from broiler manure. It is widely known that the control of processes and releases is much more complicated in crop cultivation than in industry, which is due to the field and climate conditions of agriculture. This is also the reason why crop production for broiler chicken was clearly the most influential part (41 %) in the supply chain when the environmental impacts were concerned based on the methodology behind the Finnish Eco-Benchmark (Nissinen et al. 2007). In this approach, the same normalization and weighting factors as used in the Finnish Eco-Benchmark method were used (Nissinen et al. 2007). Eco-Benchmark (EB) takes into account five important environmental impacts (consumption of primary energy, global warming, acidification, eutrophication and tropospheric ozone formation). The most significant environmental burdens from agriculture were those of nitrogen and phosphorus run-off and leaching (33 % of impacts per FU).

To find out what kind of measures could be taken to improve the eco-efficiency of the supply chain, some scenarios were defined together. It is easier to reduce emissions in broiler houses than in fields where the emissions are from non-point sources. At best the emissions could be reduced inhibiting their formation. In this case the quality of litter is in important role. The litter has also a significant role in the health of the broilers. Ammonia emissions could also be decreased reducing them in out-going air together with dust. In our scenario study the heat recovery proved to be efficient way to decrease greenhouse gas emissions. Decreasing the environmental impacts of the broiler houses should be reviewed as a whole, taking air-conditioning, circumstantial factors and heating into account. The results of other scenarios (alternative feeding profiles, alternative fuels in broiler housing) will be presented as well.

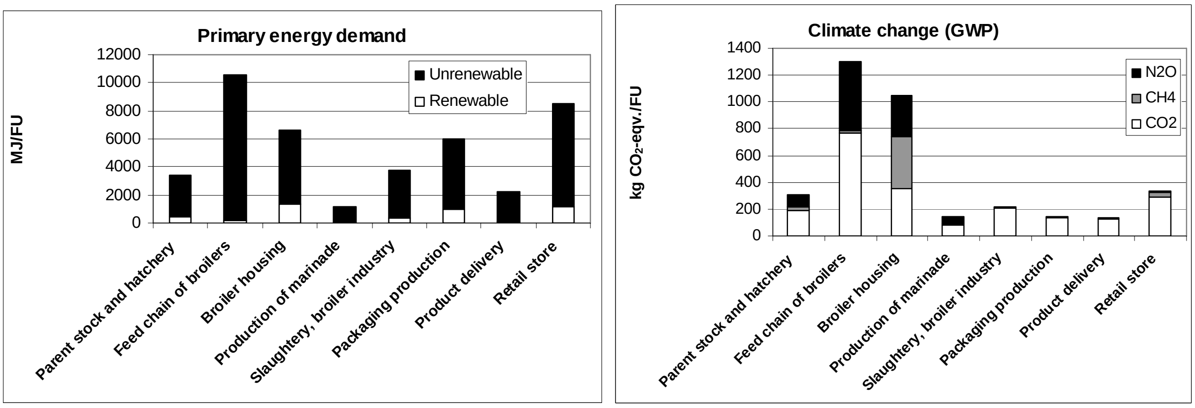

Figure 1. Primary energy demand and climate change impact by life cycle phases in the broiler chicken supply chain (1000 kg product as FU).

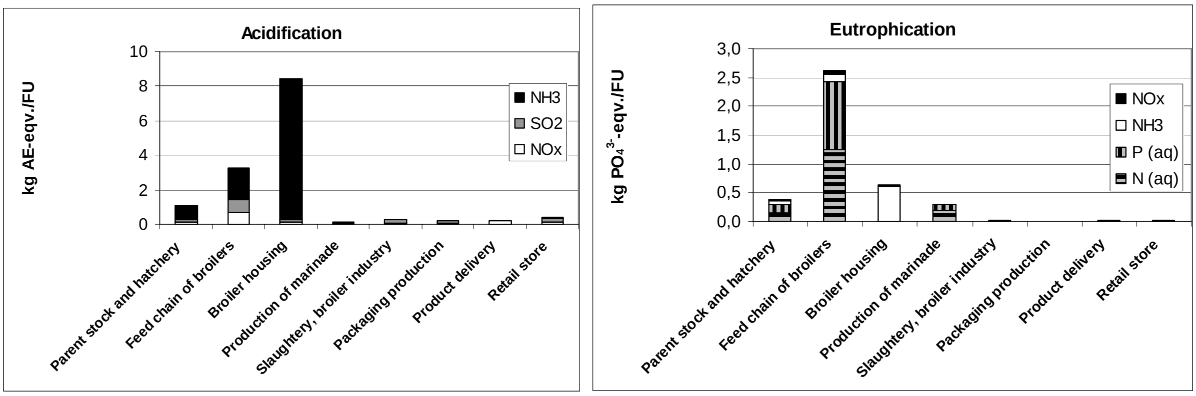

Figure 2. Acidification and eutrophication impact by life cycle phases in the broiler chicken supply chain (1000 kg product as FU).

Environmental hotspot identification of organic egg production

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Keywords: ecological sustainability, life cycle assessment, laying hens, organic eggs

According to the ecological principle of IFOAM[2] "organic farming should be based on living ecological systems and cycles, work with them, emulate them and help sustain them". Experts on organic egg production, however, mention three environmental problems: 1) long transport distances of feed, hens and eggs (Meeusen et al., 2003); 2) a high level of ammonia emission from the hen house (Groenestein et al., 2005) and 3) a high load of nitrogen and phosphorus in the outdoor run, resulting in harmful losses to the environment, such as leaching of nitrate and emission of ammonia and nitrous oxide (Aarnink et al., 2006). Life Cycle Assesment (LCA) was used to quantify the relative importance of these problems, identify hotspots and asses the environmental impact of the organic egg production chain. Attributional LCA and a functional unit of one kg organic egg was chosen based on the aim of hotspot identification. Five environmental impact categories were included: global warming, eutrophication, acidification, energy use and land use. Arable products, eggs and slaughter hens were economically allocated. We interviewed 20 out of 68 Dutch organic egg farmers (>1500 hens) to collect farm data from 2006. Data on transport, feed, rearing and hatching were gathered by conduction interviews with suppliers mentioned by laying hen farmers and from literature. The Life Cycle Inventories of electricity, natural gas, tap water, transport and traction originate from the Eco-Invent V2.0 dataset. For each environmental impact category the impact per kg of egg was split up into four parts of the production chain as well as into one to four compounds (Table 1). We identified a chain-compound combination as a hotspot if it contributed to more than 40% of the total of the environmental impact category. Four hotspots were identified. First, 62% of global warming is caused by emission of nitrous oxide in the feed production chain. Second, 57% of acidification is caused by ammonia emission from the laying hen farm. Third, 47% of energy use is oil used for feed production and fourth, 95% of the land is used for feed production. We identified no hotspot for eutrophication, but feed production contributed most with 37% nitrogen leaching and 26% phosphate accumulation. For the three identified ecological problems we conclude that: 1) Transport is not identified as a hotspot, but contributes 33% to total energy use. 2) Acidification caused by ammonia emission from the organic laying hen farm is identified as a hotspot. 3) Effects of manure deposition in the outdoor run, i.e. eutrophication on the laying hen farm, is not identified as a hotspot. Next to the dimension of quantity, environmental impact also has a time and spatial dimension. These dimensions should be further assessed. We conclude that, except for acidification, optimization options for environmental impact must be sought in feed production and amount of feed input. For acidification, ammonia emission on organic laying hen farms should be reduced. A sensitivity analysis will be executed, to identify powerful production parameters and determine the accuracy of the LCA.

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[2] International Federation of Organic Agricultural Movements

Tab. 1: Preliminary results of the environmental impact assessment in g equivalent per kg organic egg for the environmental impact categories: global warming, acidification, eutrophication, energy use and land use.

Climate Change (g CO_2-eq./kg egg)	N_2O	CO_2	CH_4	Total
Laying hen farm	548	40	71	659
Rearing farm & hatchery	65	9	27	102
Feed production chain	**2475**[1]	534	12	3020
Transport	3	248	7	258
Total	3090	831	117	4038

Acidification (g SO_2-eq./kg egg)	NH_3	NO_x	SO_x	Total
Laying hen farm	**45.7**[1]	2.1	0.0	47.8
Rearing farm & hatchery	5.8	0.3	0.0	6.0
Feed production chain	17.8	1.9	4.5	24.2
Transport	0.0	1.6	0.3	1.8
Total	69.3	5.8	4.8	79.9

Eutrophication (g PO_4^--eq./kg egg)	N-water	N-air	PO_4^-	Total
Laying hen farm	0.0	8.9	2.0	10.9
Rearing farm & hatchery	0.0	0.0	0.0	0.0
Feed production chain	14.4	3.7	10.2	28.3
Transport	0.0	0.3	0.0	0.3
Total	14.4	12.9	12.2	39.5

Energy use (MJ/kg egg)	Oil	Gas	Uranium	Coal	Total
Laying hen farm	0.0	0.3	0.0	0.2	0.6
Rearing farm & hatchery	0.0	0.1	0.0	0.0	0.1
Feed production chain	**5.4**[1]	1.3	0.8	0.7	8.1
Transport	3.5	0.3	0.2	0.2	4.3
Total	9.0	1.9	1.1	1.1	13.1

Land use (m^2/kg egg)	Total
Laying hen farm	0.3
Rearing farm & hatchery	0.0
Feed production chain	**6.1**[1]
Transport	0.0
Total	6.4

Bold [1]:Identified as hotspot because value contributes more than 40% to total of environmental impact category.

Environmental impacts from feeding broiler chicken with European grain legumes: A case study for Brittany (France)

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Keywords: broiler chicken production, grain legumes, protein pea, faba bean, soya bean meal, feedstuff, life cycle assessment, LCA

European livestock production is highly dependent on soya bean imports from overseas. Besides environmental issues, i.e. long transport distances and the deforestation of the rainforest, soya bean cultivation in South America has lately been criticised for its negative social impacts, such as food shortening due to biofuel production and expulsion of small holders due to the increase of cultivated area. Using European grown grain legumes (pulses) for fattening animals seems a viable alternative, especially since only 2% of Europe's arable land is cultivated with them. But what are the environmental impacts of substituting soya with European pulses?

We assessed this question in a case study on broiler chicken production in Brittany (France) using a life cycle approach. Three feeding systems were compared: The standard feed SOY consisting mainly of European cereals and soya bean meal from Brazil and Argentina; the alternative feed GLEU, where soya bean meal was substituted by protein peas and faba beans and supplemented with rapeseed, sunflower, and maize gluten meal; and the alternative SAA, where soya bean meal was replaced by higher quantities of synthetic amino acids in order to improve the nutrient efficiency and supplemented by different protein rich feedstuffs. Additionally, the most common production system, with a shorter fattening length and feed containing higher amounts of soya bean meal (short-SOY) was assessed (Baumgartner *et al.*, 2008).

Compared with the standard feed SOY, the *Energy demand* of the GLEU alternative was reduced by 6%, which is considered to be favourable. For the commonly practised short-SOY variant it was even significantly lower (- 16%) than SOY (Fig. 1). Moreover, using higher amounts of synthetic amino acids in combination with other protein rich feeds (SAA) led to an increased *Energy demand* (+ 9%).

In conclusion, there were benefits from feeding broiler chicken with European grain legumes, especially for the impact categories *Energy demand* and *Global warming potential (GWP)* due to a reduction of transport for protein rich feeds and less CO_2-release from land transformation as a consequence of a strong reduction of soya bean meal use. However, the results for nutrient-driven impacts were similar and for the pollutant-driven impacts there was even a tendency for negative results (Tab. 1). Due to different protein contents soya bean meal could not be replaced by the same quantity of peas and beans. Therefore this replacement led to a change of the composition of the whole feed formulas. Consequently, the results were more determined by the entirety of the changes in the feed formulas and not just by the substitution of soya by other grain legumes. SAA proved to be an interesting alternative having in all impact categories, except for *Energy demand*, similar to very favourable results compared with the standard feed SOY. Higher productivity in the production system resulted in less impacts for most categories with the notable exception of *GWP* and *Acidification*. In most impact categories, the production of feedstuffs accounted for the majority of the environmental impacts. Therefore, this is the process step where measures for improvements should primarily focus on. We suggest the integration of environmental criteria into feedstuff models in order to allow economic and environmental optimisation of feed formulas.

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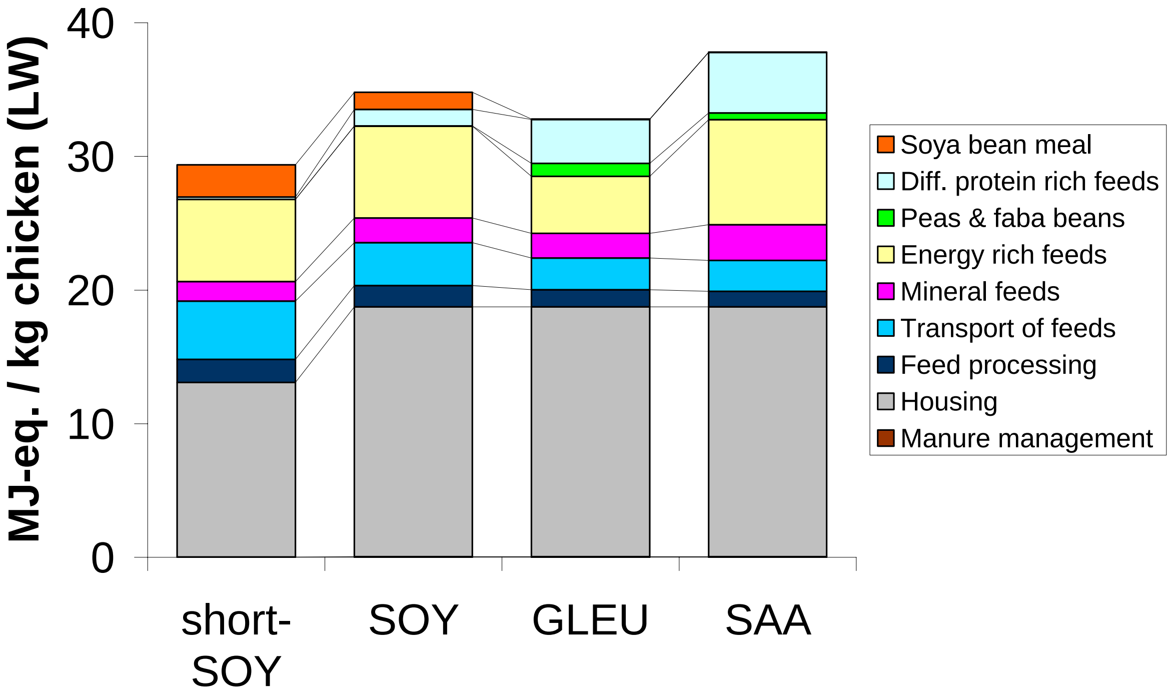

Fig. 1: Demand for non-renewable energy for producing one kg of chicken (live weight: LW) in Brittany (BRI) with the four feeding strategies SOY (soya bean meal from overseas), GLEU (European grain legumes), SAA (synthetic amino acids), and short-SOY (short fattening length).

Tab. 1: Overview of the environmental impacts of broiler chicken production in Brittany. Values are expressed for the functional unit kg chicken meat or as a percent of SOY. Total and relative impact of the four feeding strategies SOY (soya bean meal from overseas), GLEU (European grain legumes), SAA (synthetic amino acids), and short-SOY (short fattening length).

Impact categories		**SOY**	**short-SOY in % SOY**	**GLEU in % SOY**	**SAA in % SOY**
Resource use-driven impacts	Energy demand [MJ-eq/ kg chicken]	3.48E+01	84%	94%	109%
	Global warming potential 100a [kg CO2-eq/ kg chicken]	3.12E+00	106%	90%	91%
	Ozone formation [g ethylene-eq/ kg chicken]	7.93E-01	97%	98%	97%
Nutrient-driven impacts	Eutrophication, combined N & P [g N-eq/ kg chicken]	5.38E+01	101%	105%	98%
	Acidification [g SO2-eq/ kg chicken]	5.60E+01	112%	98%	97%
Pollutant-driven impacts	Terrestrial ecotoxicity EDIP [points/ kg chicken]	2.59E+00	78%	125%	71%
	Aquatic ecotoxicity EDIP [points/ kg chicken]	2.03E+00	100%	89%	64%
	Terrestrial ecotoxicity CML [points/ kg chicken]	2.75E-01	62%	108%	44%
	Aquatic ecotoxicity CML [points/ kg chicken]	7.55E-01	65%	104%	59%
	Human toxicity CML [points/ kg chicken]	1.04E+00	79%	100%	98%

Classification

very favourable	unfavourable
favourable	very unfavourable
similar	

Environmental Impacts of Alternative Uses of Rice Husk for Thailand

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Keywords: LCA, rice husk, environmental impact, Thailand

Thailand is one of the largest rice producing countries in the world. In recent year, the nation produces about 29 million tonnes annually (Office of Agricultural Economics 2006). Rice husks, which are a by-product of rice production, account for 23% of total paddy weight. Being bulky, the husks cause significant disposal problems for the rice mill owners. Furthermore, the methane gas that is released when the husk is fermented by micro-organisms is thought to contribute to global warming. Also, rice husk is one of the potential biomass sources in Thailand. The Thai government has encouraged the use of biomass fuel to help reduce global climate change and reserve fossil fuel resources. One of the ordinary uses of rice husks has been as a source of energy within the rice mills. However, there were still surplus rice husks from the process after being used in paddy drying and milling (The EC-ASEAN COGEN Programme 1998). More recently, rice husks have been put to use within the industrial sectors such as electricity generation, cement manufactory, agriculture etc. Although there are many alternative ways of rice husk utilization, the environmental impacts of these have not yet been widely investigated within the Thai context.

This study compares the environmental impacts of different rice husk use pathways, i.e. use in power generation, cement manufacture and cellulosic ethanol production. A consequential LCA method has been taken in comparing the options with system boundary expansion. As a result, compared to the conventional systems such as the Thai grid production, ordinary Portland cement and petrol production, using rice husks in the three systems investigated cause lower impacts on fossil fuels consumption and climate change. However, the impact on other indicators investigated is higher than that of those conventional production systems. The most favourable option for a disposal of the rice husk ash produced from power generating production is using it in light weight concrete block production as it causes less impact on all indicators analyzed. The most environmentally favourable rice husks use system with regard to fossil fuels consumption and climate change is the use in power plant.

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Maize production in Portugal for Bioethanol use: an Environmental and Energy Assessment

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Keywords: bioethanol, maize, Life Cycle Assessment, greenhouse gas emission, energy

In this paper we discuss the environmental and energy viability of the production and use of bioethanol as a substitute for gasoline. In Portugal, the most likely crop to be used as raw material is maize due to the high area dedicated to its production (INE, 2007) as well as the conversion ratio to bioethanol.

Our main innovation is the fact that our study does not just compare the production and emissions of the two fuels by themselves, but also the consequences regarding land use. Our study thus considers two plausible land occupations for the same area: maize, which is used for bioethanol production, and sown irrigated pastures (SIP). SIP are direct competitors of maize crops, in which there is direct grazing by cattle. When maize is used for feeds, cattle are produced intensively in stables. However, if SIP are installed instead of maize, there is no ethanol production, and thus no gasoline is replaced. Figure 1 is an illustration of the two scenarios analyzed.

In the scenario that considers the maize production we analyzed two different land managements: no-tillage and conventional tillage. In the SIP scenario we also considered the presence and absence of carbon sequestration.

We analyzed both scenarios in a Life Cycle Assessment approach, using software SimaPro. An LCA starts with a systematic inventory of all emissions and all raw material consumption during a product's entire life cycle that are compiled in a list which is named the impact list. The impacts are sorted by the effect (classification) and organized in impact categories (Goedkoop, 1998).

Our results show that overall the most favourable scenario is SIP installation with the continuation of the use of gasoline. The difference between the two scenarios is especially high considering SIP carbon sequestration. However, the use of bioethanol always reduces total energy expenditure in relation to gasoline. Therefore, we concluded that the production and use of ethanol, is not, in the context of our study, a favourable choice in terms of greenhouse gases, but it is as an energy policy.

As results verification, we studied the most common case in the literature, which is a simple analysis of bioethanol production and use, disregarding the alternative land use. Our results are similar to Pimentel's (2003). We show that the energy necessary to produce ethanol is more than that which ethanol contains. However, this conclusion is also valid for gasoline. Regarding greenhouse gas emissions, and similarly to the results highlighted by the U.S. Department of Energy, we show that ethanol thus becomes favourable. Therefore, we conclude that the consideration of alternative land uses is critical to the conclusions obtained.

Regarding all the other categories it must be noted that the only category for which the maize scenario is favourable is the ozone layer depletion. Considering the acidification category, the maize scenario is favourable or not, depending on the study conditions. For all the other categories the SIP scenario is always favourable.

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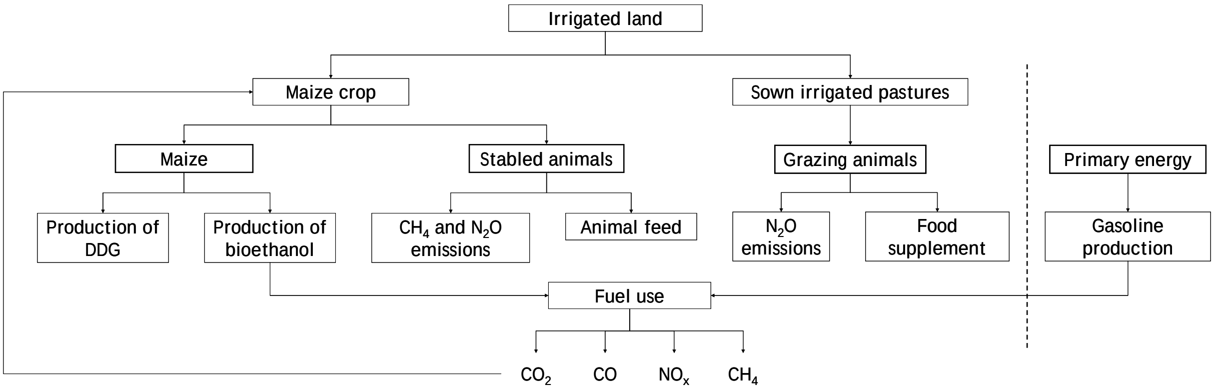

Figure 1 – Illustration of the two scenarios analyzed.

Consequences of increased biodiesel production in Switzerland: Consequential Life Cycle Assessment (CLCA)

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Keywords: CLCA, system expansion, biodiesel

The direct environmental impacts of biodiesel have been investigated extensively in various attributional Life Cycle Assessment (LCA) studies on a local and on a global scale (Zah et al, 2007). However, little knowledge exists with respect to the indirect local and global consequences. But, the production of biodiesel is strongly intertwined with other uses of land like nature conservation, supply of food and production of biomaterials. Moreover, the increased production of biodiesel causes additional co-products such like oil meals and glycerine, which affect the production of alternative products on the world market. For a sound assessment of the total environmental impacts of producing biodiesel, it is therefore necessary to address also indirect impacts, which take place outside biodiesel´s value chain.

The Consequential LCA method was applied in order to take account of possible indirect impacts (Ekvall & Weidema, 2004). In contrast to attributional LCA, the consequential approach uses system enlargement to include the marginal products affected by a change of the physical flows in the central life cycle. This implies that the inputs and outputs are entirely attributed to biodiesel production and the product system is subsequently expanded to include the marginal products affected, i.e. a) the alternative appropriation of the crop displaced and b) the consequences induced by co-products (rape meal and glycerine) (Schmidt, 2008). In order to determine the environmental impacts of a specific consequence predictive “what-if scenarios” have been developed in co-operation with the Federal Office of Agriculture (FOAG) Switzerland (Tab. 1). The scenarios refer to the expected consequences if one percent of the current Swiss diesel consumption should be substituted by rape methyl ester (RME). The environmental impacts were assessed by means of characterized CML indicators, land occupation and the Swiss method of ecological scarcity (UBP 06).

In general, most of the analysed scenarios show higher environmental impacts than the fossil reference as regards both GHG emissions and the overall environmental evaluation (Fig. 1). However, if the additional/avoided emissions from land transformations are taken into account the GHG emission of all analysed scenarios would decrease. In this perspective, increased RME production in Switzerland avoids the production of soybean meal and the related deforestation of rain forest and the transformation of savannah in Brazil. In sum, the environmental impacts of an increased RME production in Switzerland rather depends on the environmental scores of the marginal replacement products on the world market, than on local production factors. If, for example, barley instead of wheat is displaced by increased rape cultivation in Switzerland, the environmental scores of RME production decrease. Otherwise, if the possible marginal product on the world market for protein meal would switch from soybean meal Brazil to soybean meal USA, the environmental impacts of all analyzed scenarios would increase significant. The potential of domestic biofuels is limited today and will remain so in future. From a long-term environmental perspective it would therefore seem wise, to focus the production of biofuels on feedstock decoupled from the global food and feed markets. Examples are biogenic waste or non-edible energy crops that grow specifically on degraded land.

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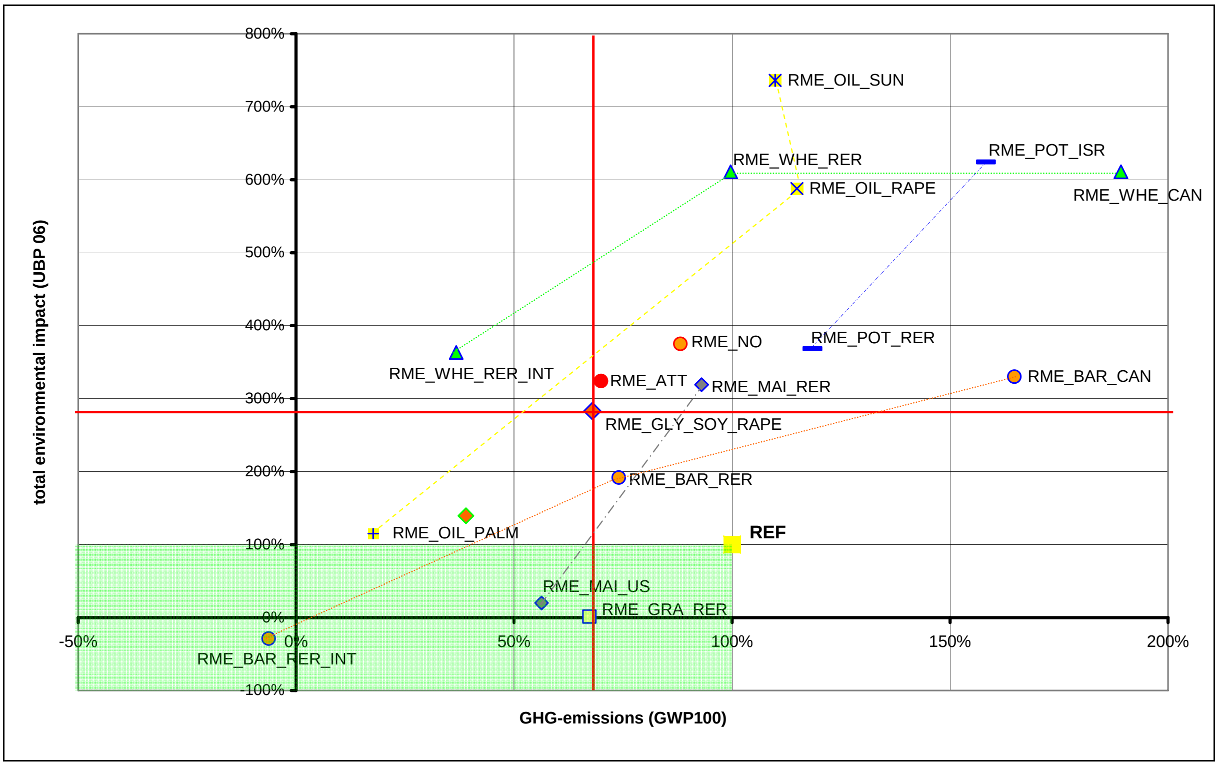
Table 1: Predictive "what-if scenarios" analysed. Each branch of consequences is analysed down-the-line and compared with the fossil equivalent by means of the functional unit (38,3 GJ energy at regional storage in Switzerland) (source: according to FOAG).

Scenario	System delimitation	Increased RME production in CH is met	Consequence	Compensation	in country	by	Scenario-Label
(0): Diesel is imported	attributional	-	-	-	-	-	REF
(1): Domestic RME production	attributional	-	-	-	-	-	RME_ATT
	no allocation	-	-	-	-	-	RME_NO
	consequential	(1.1) at the expense of other crops (displacement)	less grass	import hay	Europe (RER)	expansion	RME_GRA
			less potatoes	import potatoes	Israel (ISR)	expansion	RME_POT_IS
					Europe (RER)	expansion	RME_POT_RER
			less barley	import barley	Europe (RER)	expansion	RME_BAR_RER
						intensification	RME_BAR_RER_INT
					Canada (CAN)	expansion	RME_BAR_CAN
			less wheat	import wheat	Europe (RER)	expansion	RME_WHE_RER
						intensification	RME_WHE_RER_INT
					Canada (CAN)	expansion	RME_WHE_CAN
			less grain maize	import grain maize	Europe (RER)	expansion	RME_MAI_RER
					USA (US)	expansion	RME_MAI_US
		(1.2) at the expense of the available rape oil	less rape oil	import rape oil	Europe (RER)	expansion	RME_OIL_RAPE
				import sunflower oil	Europe (RER)	expansion	RME_OIL_SUN
				import palm oil	Malaysia (MY)	expansion	RME_OIL_PALM

Figure 1: Two-dimensional representation of GHG-emissions and total environmental impacts of the scenarios analyzed. Values are relative to the fossil reference. Scenarios in the green area show better evaluation results than the reference system in respect of both criteria, meaning lower GHG-emissions and lower overall environmental impacts. The difference of a respective scenario to the red lines is the environmental difference between domestic and foreig crop production (source: my own depiction).



Effect of Canadian Bioenergy Production from Agriculture on Life-Cycle Greenhouse Gas Emissions and Energy Use

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Keywords: LCA, Canada, biofuel, energy, greenhouse gas, agriculture, crops

For greenhouse gas (GHG) mitigation and rural development reasons, Canada has policies in place to increase biofuel production using feedstocks from agriculture. To answer the question if bioenergy policies are sensible from an environmental perspective, life-cycle analysis (LCA) was used to determine the impact of selected potential future bioenergy policies on greenhouse gas emissions and energy use for bioenergy products in Canada. Future scenarios of bioenergy demand for 2017 were developed and then input into an economic model for Canadian agriculture. Scenarios included from less than 5 to about 20% of Canada's fossil fuel use for vehicle transportation and coal-based electrical generation being met with bioenergy from agricultural feedstocks (grain, crop residues, coppiced tree plantations, and/or grass). The economic model predicted the equilibrium solution of resource allocation within agriculture that maximized economic surpluses. Based on a LCA of individual activities, the GHG emissions and energy inputs for all agricultural production and processing of agricultural products were totalled for the country. Therefore, our LCA considered the impacts of bioenergy demand on the entire agri-food sector including the economic interactions between competing uses for land and grain.

The life-cycle emissions of GHG for primary agriculture, excluding land C stock change and substitution of fossil fuels with biogenic energy, drop 2 to 5% in all bioenergy scenarios because the production of livestock is reduced. Bioenergy especially competes with beef cattle production for land and grain. A more complete LCA would have to consider whether the drop in livestock production coincides with a change in diet away from livestock products to determine if that GHG emission reduction is actually a net benefit at the global scale. Off-farm transportation GHG emissions are also reduced slightly as bioenergy feedstocks travel less distance overall than grains or livestock destined for food. Considering only the substitution effect of bioenergy for fossil energy, the life-cycle GHG benefits are as large as 2.2 tonnes of CO_2 equivalent per tonne of oil equivalent of bioenergy. However, when considering C stock change on land, particularly from the breaking of grassland and forestland to increase the cropland area, then these GHG benefits could disappear if plausible land-use change occurs within Canada. To provide a more complete LCA, more research is required into relating economic forces to the amount of marginal land currently in forest or grassland that is subject to conversion to cropland. Also important is accurate estimation of the effect of crop residue removal for bioenergy on soil carbon and use of nitrogen fertilizer.

Dedication of about 10% of Canada's agricultural land to feedstock production provides equivalent energy to that used by the entire agri-food sector so the energy balance is highly favourable.

Comparative Life Cycle Assessment of biogas scenarios for Luxemburg

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Keywords: biogas, LCA, Luxemburg

The use of biomass as a CO_2-neutral energy source is an important means to achieve Luxembourg's commitment under the Kyoto Protocol, i.e. 28% cut in greenhouse gas emissions by 2008-2012, as compared to the level in 1990. In addition Luxembourg has committed itself to an increased share of electricity produced from renewable sources (directive 2001/77/EC) from 2.1 % in 1997 to 5.7% by 2010. Given the limited potential of other renewable energy sources (wind, hydroelectricity), the use of biomass and especially biogas is an interesting possibility to diversify the panel of alternative energy sources, as well as the market for agriculture, due to its versatile applications.

Based on the results of a potential study for the biomass development in the Greater Region (RUBIN, Interreg III project) and on the evaluation of innovative energy crop conversion technologies (e.g. dry monofermentation of energy crops), a comparative LCA was carried out in order to compare a few among the most promising scenarios of biogas development in Luxembourg.

The scenarios studied are listed in table 1. The methodology adopted for the LCA is in accordance with the ISO 14040-14044 standards (ISO, 2006). The comparison of different functional units (e.g. transportation as compared to heat and electricity production) is done according to the net credit (or avoided impact) that is expected thanks to the substitution of concurrent systems (such as standard petrol fuelled transportation), as in Zah *et al.* (2007). The LCA modelling was done using Umberto 5.5 and Ecoinvent 2.0 database with extended parameterization. Uncertainty (Monte Carlo) and sensitivity analysis (including different biogas uses, e.g. heat from CHP, dynamic effects etc) focusing on pollutant emissions, parameters and allocation choices, and several valuation methods are being used in order to check the consistency of comparison results.

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Table 1: bioenergy scenarios studied.

Input material	Process	Product	Transformation	Use
Energy crops	Dry monofermentation	Biogas	Purification, (upgrading with LPG) and injection in natural gas grid	CHP
Energy crops	Dry monofermentation	Biogas	Purification and compression to 250 bar	Fuel for car transportation
Manure+ Energy crops	Wet co-fermentation	Biogas	(Purification)	CHP
Wood	Gasification	Biogas	Purification	Fuel for car transportation

The use of agricultural area as energy plantations: A method to compare electricity, heat and fuel production

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Keywords: basket of benefit, decision tool, energy crops, life cycle assessment

The importance of the cultivation of energy crops in Germany is increasing more and more, as the demand for renewable energy is growing. Competition among different usages for agricultural area demands a far-seeing and optimized land use management.

Studies and statistical data about the production of energy per hectare in Bavaria and Germany indicate that producing heat with energy crops results in the highest energy yields per hectare, whereas those of biofuel crops are lowest. However, as perennial cultivation systems for heat production (short rotation coppice, miscanthus) are not yet established in practise, and as these crops occupy their cultivation area for several years or decades, their role in the near future is uncertain. Apart from that, the only possibility to replace fossil transportation fuels by renewable energy is the production of fuels from biomass. Furthermore, energy balances of biogas can improve considerably when not only electricity but also the co-generated heat is used. Therefore, biofuels and biogas presumably will have their share in the Bavarian "bioenergy mix" also in future.

This study aims at comparing environmental impacts of electricity, heat and fuel production on Bavarian farmland, three energy types which cannot easily be compared to each other. So far, a lot of life cycle assessment (LCA) studies have been carried out in the bioenergy sector. The majority of these studies focuses upon one energy type. Due to different goal and scope definitions, a comparison between the results of these studies is difficult (cf. SRU 2007). In the present study, the "basket of benefit" method – an LCA approach known as a decision tool from the waste management sector – is applied (Grassinger & Salhofer 1998). The approach is based on the fact that only one or two of three energy types – electricity, heat, or fuel – can be produced on a certain area or by a specific crop species (e.g. wheat to be used for combustion, biogas, or ethanol). The other two energy types have to be supplied by conventional (fossil or other renewable) resources. The environmental impacts of this conventional energy thus have to be added to those of bioenergy production. This results in different "baskets of benefit" for each crop species with exactly the same energy content, electricity being derived from biomass in one basket, heat from biomass in another basket, and fuel from biomass in a third basket (figure 1). The environmental impacts of the production of electricity, heat and transportation fuels on a certain area or by a specific crop can thus be compared to each other. On the poster, first results for different impact categories and crop species are presented.

The considered crop species will be assigned to the different agricultural production regions in Bavaria. Special focus lies on the comparison of annual and perennial energy crops. The results of the "basket of benefit" method will be part of a decision matrix for land users and politicians to support decisions about the most appropriate energy crop mix for a specific region.

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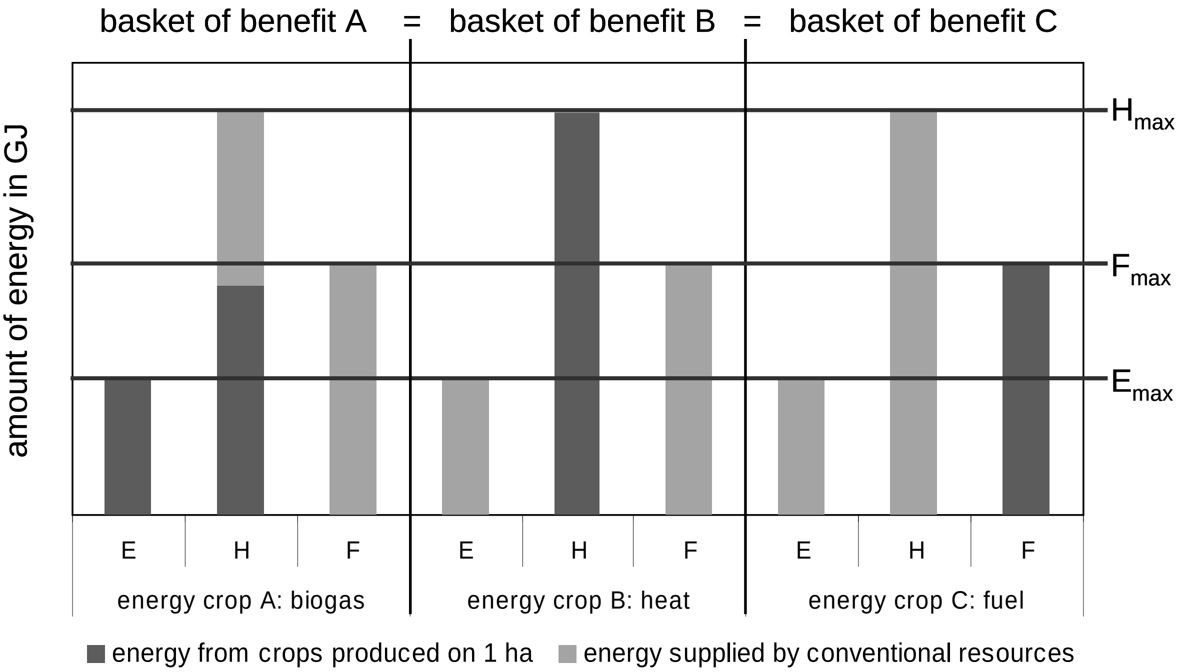

Figure 1: Illustration of the "basket of benefit" method (E: electricity, H: heat, F: fuel). The amount of energy supplied by conventional (fossil or other renewable) resources is the difference to the maximum amount of bioenergy from 1 ha.

Sustainability Assessment of common used plastic products in the EU

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Keywords: Agriculture Plastic Waste (APW), Sustainability Assessment, LCA, economic / social assessment

Agriculture Plastic Waste (APW) generates about 615.000 tons of waste per year in Europe. This presents a serious challenge concerning the production of the plastic as well as the disposal or recycling of the materials.

For addressing especially the specific issues of APW the European Commission funds a project called “Labelling Agricultural Plastic Waste for valorising the Waste Stream (LABELAGRIWASTE)”. In the consortium partners from Belgium, Cyprus, Finland, France, Germany, Greece, Italy, and Spain are working together on developing a labelling scheme for European APW.

The University of Stuttgart, department of Life Cycle Engineering is in the LABELAGRIWASTE project responsible for the sustainability analysis. First of all, in order to identify the environmental impact of the main agricultural plastic products, a Life Cycle Assessment (LCA) over the whole life cycle of APW in Europe is performed. The LCA is done before the development of a labelling scheme starts to examine the different life cycles of the most commonly used products in agriculture in Europe. In a second step a sustainability assessment is performed for the field tests that are conducted during the course of the project to develop a labelling scheme. Field tests are carried out in Spain, Italy, France and Greece in order to test different possibilities of a labelling scheme. The overall objective is to come up with a “best available technique” for the labelling scheme. In order to guarantee, that the developed scheme is not only feasible from a pragmatic and technique point of view, a sustainability analysis is conducted. That means, within the same system boundaries as for the environmental LCA, social and economic data is gathered and analysed. In order to analyse the environmental effects, the impact categories Global Warming Potential (GWP), Acidification Potential (AP), Eutrophication Potential (EP), Photochemical Ozone Creation Potential (POCP) and additionally the Primary Energy use are chosen. Regarding the social issues parameters like the number of employees (full-time equivalents), number of female employees (full-time equivalents), share of all employees between the different qualification levels and rate of lethal/non-lethal accidents in the company are gathered to model social effects using the method of Life Cycle Working Environment (LCWE). For the economic analysis the production costs and the production selling prices are relevant parameters for each process step to model the economic effects for every single process with the method of Life cycle Costing (LCC).

The poster presents a sustainability assessment of one field test. Results concerning the environmental, social and economic issues of labelling agricultural plastic will be shown.

Development of a complete biogenous insulating material

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Keywords: LCA, insulating material, biogenous, hemp, natural fibre

Building with renewable resources is constantly gaining in significance throughout our society. In order to guarantee a healthy environment, more and more people use natural building materials instead of conventional products. However, the question arises, if the building materials made from renewable resources are indeed more sustainable than conventional building material.

The "Deutsche Bundesstiftung Umwelt" (German Environmental Federal Foundation) funded from 2005 to 2007 the project "Development of a complete biogenous insulating material". The objective of this project was to develop a 100 % biogenous hemp insulating material. Therefore, during the course of the project, bicomponent-polyester supporting fibers made of fossil resources in the hemp insulating material should be replaced by biogenous polymers with biodegradable characteristics. Apart from the technical development of this insulating material, its sustainability was examined with the method of Life Cycle Assessment (LCA). Within the project the new insulating material could be successfully found. The bicomponent-polyester supporting fibre made of fossil resources could be replaced by a bicomponent fibre of polylactid acid, basing on corn. Furthermore, the existing production process for the conventional product as well as the process for the new developed product could be optimised in order to reach a better environmental performance.

The consortium consisted of the Fraunhofer Institute for Chemical Technology (Fraunhofer ICT) - responsible for the project coordination and the technical support, the SME BAFA GmbH - responsible for the growing of the hemp and the preparation of the hemp fibres, the SME Hock GmbH & Co. KG - responsible for the marketing of the new developed insulating material, NAPRO GmbH & Co. KG - responsible for the production of the insulating material and the University of Stuttgart, department of Life Cycle Engineering – responsible for the conduction of a design accompanying Life Cycle Assessment, modelling of reference insulating materials and the comparison with the designed insulating material. In order to analyse the environmental effects, the impact categories Global Warming Potential (GWP), Acidification Potential (AP), Eutrophication Potential (EP), Photochemical Ozone Creation Potential (POCP) and additionally the Primary Energy use were chosen.

The poster will present the results regarding the environmental performance of the new developed hemp insulating material compared to the conventional hemp insulating material.

Life cycle assessment of non-food energy crops

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Keywords: miscanthus, short-rotation wood, willow-salix, biomass-to-liquid

Conversion processes for so called second-generation biofuels are developed in the moment by different companies and research institutes. This type of processes is also known as BTL (biomass-to-liquid). The biomass input might be quite variable ranging from agricultural residues like straw over forest wood to energy crops like miscanthus or short-rotation wood. A possible advantage of such processes is the use of non-food energy crops. Several such conversion concepts and biomass inputs have been compared from an environmental point of view. Straw, Miscanthus and Short-rotation wood have been investigated as biomass inputs for the assessment. The analysis includes all stages during the life cycle: the production of pesticides and fertilizers, the necessary transports, the conversion of the biomass to fuel and all emissions in the life cycle are investigated. So far the agricultural experience with such crops is only limited. Thus, the production practice has been modelled with different scenarios (Jungbluth et al. 2007a; Jungbluth & Schmutz 2007).

The presentation focuses on the comparison of different biomass feedstocks for BTL-production plants (Jungbluth et al. 2007b). But, these crops can also be used in other types of processes e.g. SNG (synthetic natural gas) or heat and power production. There are some differences for the abiotic depletion, global warming, POCP (non-biogenic) and acidification with the lowest figures for straw and the highest for short rotation wood (willow-salix or poplar). Category indicator results for eutrophication are highest for the production of miscanthus. Wheat straw shows quite lower figures for some category indicators due to the allocation approach used in this study. This changes if another allocation approach is chosen as analysed in a sensitivity analysis. Wheat straw shows the highest yields of dry matter per year and hectare due to the allocation between straw and grains. Only a small part of the land use for the wheat field is allocated to the straw and the rest is allocated to the wheat grains. Miscanthus has higher yields than short-rotation wood and thus a lower result for the land competition.

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Soybean biodiesel chain evaluation using life cycle approach

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Keywords: soybean biodiesel, life cycle approach, energy balance, biofuel chain

The introduction of biodiesel in Brazil is mainly motivated by the possibility of economic and social development for the country, with employment and income generation, as well as environmental benefits due to replacement of fossil fuels by renewable resources. Although biodiesel has great government incentive, there are doubts about its economic viability and real benefits. The government plan includes manufacturing of this fuel from different crops such as palms, castor beans, peanuts, soybeans, coconuts, cotton and sunflower. However, due to the huge volume of soybean production in the country (58.7 million tonnes in 2007/08), approximately 80% of the total biodiesel volume is produced starting from this source.

The objective of this study was to evaluate the soybean biodiesel chain in relation to its technical and economic aspects using a life cycle approach, including stages from agriculture, oil extraction and oil transesterification to obtain biodiesel. Data was collected from five farms located in São Paulo State and one industrial unit that produces soy methyl ester from soybean oil. The total production of these farms was 2,000 tonnes in 2006/07, with a weighted average yield of 3200 kg/hectare. Oil extraction was estimated using mainly statistical data from the Brazilian industry sector.

A favorable fossil energy ratio of 3.0 was found for soybean production. This result means that 1MJ of fossil energy is consumed to generate 3 MJ of renewable energy. This balance has been achieved with an mass allocation of 18% of total input for the oil production itself and 82% to obtain soybean meal, a valuable co-product of this productive chain.

Although biodiesel has been introduced to reduce dependence on fossil fuels, biodiesel production processes consume diesel which is used in agricultural machinery and transport. So, the reduction in diesel consumption is lower than the 3% of blended biodiesel added to diesel.

Biodiesel introduction in the Brazilian energy matrix has significant potential environmental impacts such as land use, land transformation and emissions to air and water. Therefore, although it has a renewable origin, biofuel also has an environmental cost, but different to that of fossil fuels.

In particular, the introduction of biodiesel from soybeans produces the benefit of high protein meal of great economic value as an ingredient in animal feed. As a consequence, it has a direct link with meat production for human consumption. So, it is clear that both product (biofuel) and co-product (protein meal) already have established markets. This fact is of extreme importance because the protein meal mass is about 4.4 times the biodiesel, and its maximum use is necessary both from the environmental and economic point of view. Glycerin generated in the process, (approximately 11% of biodiesel mass) is not consumed in the internal market, although there are several developments for new viable uses. Soybean is not considered as a suitable crop for small farmers as it requires a high mechanization level and large extensions of land. On the other hand, the introduction of biofuel increases employment in all the productive chain.

The findings of this study show that different aspects of this productive chain must be considered to support important government policy decisions.

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Fossil energy savings potential of sugar cane bio-energy systems

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Keywords: Fossil energy; Bio-energy; Sugar cane; Ethanol; Renewable electricity

One important rationale for bio-energy systems as well acknowledged in literature is their potential to save fossil energy sources (coal, natural gas and oil) which are being rapidly used up. Promoting a conventional sugar mill where the primary product is sugar as a food to develop into an efficient bio-energy process plant would contribute to fossil energy savings. This can be achieved via the extraction of renewable electricity and ethanol substituting for fossil electricity and gasoline, respectively. This paper examines the Thai sugar industry case study and evaluates scenarios that will lead to increased fossil energy savings using a life cycle approach. The three main segments included in sugar cane bio-energy systems are sugar cane farming, sugar milling and ethanol conversion. Positive results have been found for the two options at hand. The first one is to efficiently extract energy in the form of electricity from cane residues e.g. the excess bagasse and trash which are currently not used at their full values. The second proposes to modify/convert a sugar mill to a so-called bio-refinery where molasses or even sugar juice is used for ethanol production. The magnitude of fossil energy savings potential however is determined by two factors. First is an integration of sugar milling and ethanol conversion so that the surplus bagasse available from sugar processing can be used for molasses ethanol instead of fossil fuels e.g. coal. This is considered since most of molasses ethanol distilleries in Thailand currently are not integrated with or annexed to sugar mills. The second factor considers a sustainable utilization of spent wash as a bio-energy resource rather than a waste to be treated in open anaerobic ponds/lagoons from where CH_4, a potent greenhouse gas, is emitted. As oil reserves are predicted to fall short far more rapidly than the two other fossil energy sources e.g. coal and natural gas, fossil oil savings from ethanol production are acknowledged. The largest savings potential achieved with extracting ethanol from sugar juice versus current practice in sugar industry in Thailand amounts to 2,400 MJ or about 60 L oil equivalent per tonne cane. The annual Thai cane of 40 million tonnes for sugar export if shifted to ethanol production would help the country save approximately 20 million barrels of oil a year. In general, promoting biofuels as alternatives to petroleum-based fuels e.g. gasoline and diesel can result in both fossil energy and GHG savings. However, reduced sugar export from Thailand may induce increased GHG emissions due to land use change in sugar importing countries. The main sources of GHG emissions from such a change of land use are losses of carbon stored in native soil and plant biomass which are referred to as "carbon debt". In order to make cane ethanol fully accepted as a climate friendly bio-energy resource, a certain period for the carbon debt to be repaid is needed as shown in another study published earlier. The results of this study with reference to those on GHG issues would serve as a useful guidance to formulate strategies for optimum utilization of bio-energy resource while maximizing its benefits.

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LCM in agriculture: enhancing the self-responsibility of farmers

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Keywords: LCM in agriculture, communication of LCA-results, LCA on farm-level

Farming shapes many regions in Europe and often plays a great role in the environmental impact of food chains. In most European countries governments try to limit the harmful impacts of agriculture on the environment by enacting regulations and bans. Indeed, such initiatives enable to implement minimal environmental standards. On the other side, such laws have the disadvantage to deprive the farmers of their self-responsibility - they just carry out and do not decide themselves. Consequently, other tools are required in order to further improve the environmental performance of farms.

Life cycle management could form such an instrument. Thereby it is essential that the farmers understand the instrument of life cycle assessment. But how can these inherently complex topic be communicated to non LCA experts? In a pilot project with 200 farmers we are analyzing where the major impacts on the environment of a farm in real situations occur in such a way that individual measures can be taken. Therefore we are developing a concept on how to communicate life cycle assessment results to farmers. On developing the feedback we could draw on experiences gathered in a previous project in which we had elaborated feedbacks about LCA-results for four farmers. Based on the positive feedbacks of those farmers we developed the effective concept.

For a maximum explanatory power we chose to analyse five environmental impacts relevant for agriculture: energy demand, global warming potential, eutrophication and aquatic and terrestrial ecotoxicity (Figure 1) and expressed the LCA results at farm level and for the main production branches. Thereby we compare each real farm with a so-called model-farm (i.e. a theoretical farm representing the mean environmental impact for the type of farm analysed). The first results indicate a wide variability not only between the different types of farms, but also within a single type of farm (Figure 2), bringing a high potential for environmental improvement in light. The major explanatory factors are the choice of the cultivated crops, the type of animals and the amount of external purchases. The variability observed within one type of farms makes the comparison between the real farm and the model-farm difficult. Nevertheless, our results allow us to identify which means of production contributed most to an environmental impact and give the farmers important hints about their environmental profile. In addition, the LCA results are confronted with economical figures as well as with production parameters like the output of digestible energy. This allows us to balance environmental impacts with aspects of income generation and physical productivity and thereby enhances the farmer’s readiness to consider environmental impacts as an important key issue.

In order to improve the understanding of the results we are holding large-scale workshops with the farmers. The workshops showed that the LCA feedbacks provoke serious reactions, especially in case of rather negative results. Some figures are hardly to be traced back to clearly defined causes and the possibilities for the farmers to react in a direct and efficient way are restricted. On the other hand, most of the farmers proved willingness to deepen the analyses of the feedback and agreed with the necessity of LCM on farms. In the following two years we will further improve the feedback, i.e. in the domain of benchmarking.

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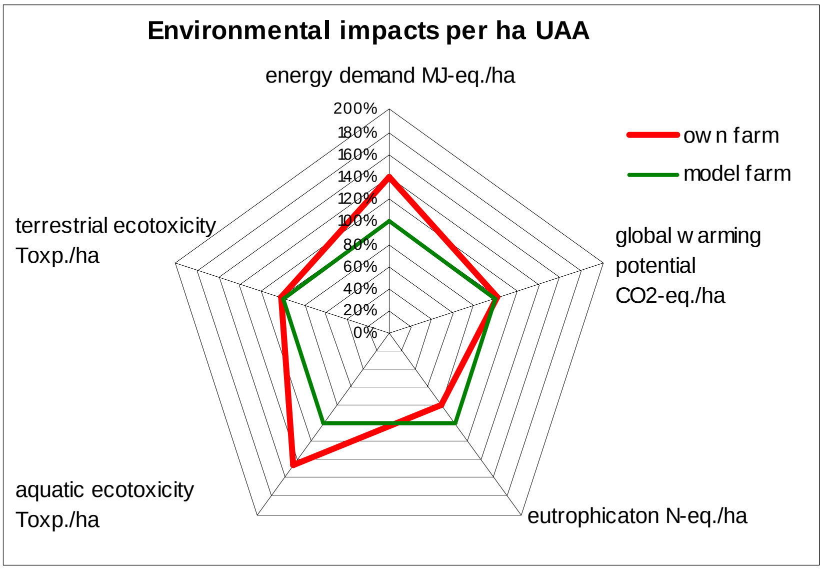

Figure 1: Overview of the environmental impacts per ha UAA: a dairy farm in comparison with its model-farm. Deviations to the centre of the diagram show a smaller environmental impact and are to be valued positively, whereas deviations to the outwards of the diagram imply higher impacts.

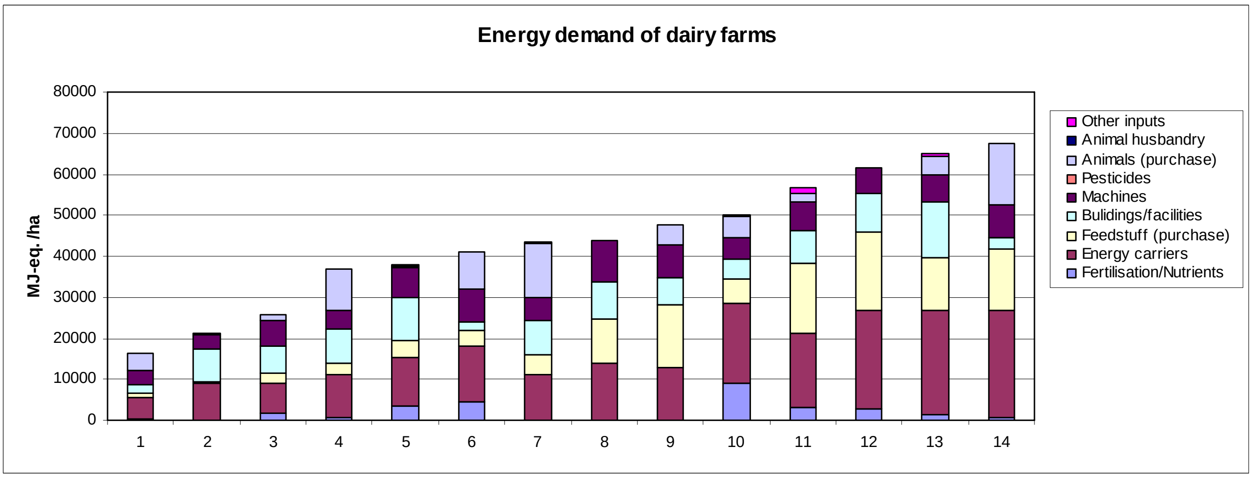

Figure 2: Energy demand per ha usable agricultural area (UAA) of fourteen different dairy farms. Between the lowest and the highest energy demand there is a factor 4.

A simplified tool for ISO type III Environmental Product Declarations in the agricultural sector

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Keywords: Life Cycle Assessment; SMEs; Environmental Product Declaration (EPD); Eco-label, Simplified LCA

Environmental life-cycle-based labels are effective tools to provide consumers with information on the environmental performance of products and services and to increase their environmental awareness. In particular ISO type III Environmental Product Declaration (EPD) allows communicating the results of an LCA study and adding other significant environmental information that are not captured by the LCA study. It can be used also for communications within the supply chain and in green public procurement to provide customers with quantitative environmental information about the product. Even if different systems and programmes have been developed all over the world, the diffusion of the use of EPDs at SMEs is quite difficult due to complexity and costs of the EPD preparation and certification process. This aspect can be a problem for the agricultural sector especially in Italy, where small family-enterprises prevail. Simplified tools and methodologies are then necessary to save time and resources, without neglecting the scientific aspects of the problems. In the framework of the LIFE-Environment project "Ecoflower Terlizzi - Demonstration project for the Environmental Product Declaration: the flowers of Terlizzi and the local eco-label", funded by the European Commission (LIFE ENV/IT/000480), this problem was faced on the basis of the authors' experience in the development of simplified tools for SMEs. Main results obtained were providing flowers' producers with a simplified LCA tool according to the ISO 14040 series and implementing a new approach to the environmental product declaration, which led to the proposal of a simplified EPD programme, whose compliance with the ISO 14025 standard is certified by a third party. Starting from a first version of an on-line tool for screening LCA, eVerdEE, available at www.ecosmes.net and designed for the manufacturing industry (Zamagni *et al.,* 2005), a second version was developed suitable also for applications in the agricultural sector. The database, which already included general LCIA (Life Cycle Impact Assessment) data, i.e. impact assessment data of the commonest processes (energy, packaging, materials, transport) and specific LCIA data, i.e. impact assessment data of processes collected during product chain studies, was enlarged with new datasets concerning the flowers life cycle. Next step was to verify that the methodological simplifications introduced (life cycle model, system boundaries, selection of elementary flows to be recorded, characterization methods used) did not significantly change the impact assessment results: this has been done by comparing the eVerdEE results with those of the detailed LCA studies (Russo *et al,*. 2007) performed by University of Bari, partner of the project. The comparison was satisfying and allowed validating the proposal of simplified scheme of EPD process based on the eVerdEE tool. To improve the tool features also a software procedure, linked to eVerdEE and suitable for the PCRs developed for flowers production, was implemented for the automatic preparation of the EPDs. In this paper the methodological approach adopted and the possibility of extending this approach to other applications in the agricultural sector will be presented and discussed, together with the characteristics of the automatic EPD procedure.

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Beef of local and global provenience: A comparison in terms of energy, CO_2, scale, and farm management

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Keywords: Ecology of scale, beef, energy, carbon dioxide, farm management, intensity

Food of local origin is often said to be eco-friendly, just because of its small transport distance. At the same time, global transport is quite often equated with high energy turnover, without asking for the means of transportation. But the specific energy turnover decreases with increasing size of the transportation unit. Regarding ecological impacts, the energy turnover is one of the most important matters, and closely connected to CO_2-release.

Former case studies on different food items – juices, lamb meat, apples, and wine – have demonstrated that the specific ecological impact depends rather on business size than on transport distance (Schlich, 2008). Similar to economics, it is ecologically reasonable to organize the process chains for food production and delivery under consideration of an efficient business size.

At first sight, our recent case studies as to investigate global beef compared to beef of local provenience support previous conclusions. German beef which is delivered from intensive but rather small scale stock breeding turns out to be burdened with high specific energy turnover, causing significant CO_2-release as well (Hardtert, 2008). Argentine beef which is extensively bred on a large scale, and then shipped round the globe by cargo ship and truck, surprisingly proves to have much lower energy turnover and CO_2-footprint despite the global marketing distance (Krause, 2008).

The particular analysis of energy data obtains more detailed information: First of all, the data prove the main impact of the intensive breeding management which is common at most German farms, because of landscape, population density, and settlement structure. The small distance from farm to point of sale cannot compensate the high efforts of energy for intensive stock-breeding and small transport units. Secondly, the global transport of Argentine beef - by means of reefers on cargo ship and truck - burdens the energy balance much lower than presumed by public opinion.

The case studies of beef demonstrate a declining relation of the specific energy turnover and the business size. Small units require more efforts per food item compared to bigger enterprises. This is proven for delivered energy, for CO_2-release, and for primary energy as well. Additionally, the researched data indicate a minimum business size as break even. All these results correspond to the theory of “Ecology of Scale”.

Finally, the research results permit an extrapolation of data in order to compare intensive with extensive stock-breeding. Here, it is evident that a broadly change to extensive farm management of breeding cattle in Germany would be much more advantageous in terms of energy and carbon footprint. At the same time, extensive cattle breeding instead of intensive livestock farming would face severe disadvantages regarding the efficiency of land use. Additionally, such paradigmatic change of farm management would significantly reduce the degree of self-sufficiency for beef in Germany.

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Analysis of the current food model. Opportunities for and threats to local food. A Spanish case study

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Keywords: Local production; Sustainability; Food; Ecoefficiency; Ecolabelling.

The activity of the food sector is strongly linked to the behaviour of the private consumer. Agri-food companies are in continual technological modernisation, facilitating the incorporation of more energy-efficient technology, and the energy generation from waste.

Historically, in Spain the 33,000 companies that make up the food sector represent around 8% of the final energy consumption. The tendency towards globalisation in the sector, with a sharp increase in the import and export of finished or semi-finished products, and the increase in consumption of ready-made and frozen products mean that the energy invested in the products is greater and the environmental impact grows.

The degree of specialisation in the different geographical zones due to climate, labour, land quality or water availability mean that there are products that reach a high degree of ecoefficiency following the current model of food chains.

The paper analyses the current trends of the food sector in Europe compared with the historical perspective. The current and future degree of sustainability is analysed using Life Cycle Assessment. The shopping basket of the average Spanish citizen has been used as a functional unit, which is compared with the situation that would be obtained with a high level of consumption of local food, or if packaging were reduced or even if another type of packaging were used. That is, this case study compares the results of the so-called "food miles" (Smith et al, 2005) with those obtained with "local food" defended by authors such as Morgan et al, 2006 or Norberg-Hodge, 2002.

The economic assessment and the current indications in prices as a tool to persuade shoppers away from certain products that create more pollution are also analysed. There is currently a paradox in that many of these products are the most accessible as opposed to those that are more environmentally friendly or local products, which are more expensive. The ecolabelling of food products, as is already happening with energy certification for buildings or electrical appliances, may be a discriminatory sign against certain less desirable products.

The results presented in this paper may serve to orient energy efficiency or greenhouse-gas emissions policies in the Spanish and European food sector.

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Greenhouse Gas Assessment of Ben & Jerry's ice-cream: communicating their 'Climate Hoofprint'

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Keywords: carbon footprint, communication, decision making, manufacturing industry, LCM

There is an expectation within many Non-Governmental Organisations (NGOs) and businesses that consumers will soon demand products with lower carbon footprints (Carbon Trust, 2006). However, calculating these footprints precisely presents many methodological challenges. In addition, concepts like "carbon equivalents" are not readily understood.

The ice-cream makers "Ben & Jerry's" (B&J's) strive to be socially and environmentally responsible; in this vein, one of the initiatives the company has recently launched is a 'climate neutral' programme. This follows the strategy described here:

1) Minimise Greenhouse Gas (GHG) emissions across the ice-cream value chain
2) Use renewable energy sources wherever possible
3) Quantify the GHG emissions of B&J's ice cream production in Europe, from cradle to home
4) Purchase carbon credits to offset the remaining GHG emissions

An annualised LCA of the European production was conducted to estimate the GHG impact of the European supply chain for ice cream (cradle to home), and thus the carbon offsets required. A contribution analysis allowed for the identification of supply chain hotspots: e.g. frozen storage at retail.

When applying LCA approaches in the agri-food sector, it is common practice for a single figure for GWP to be calculated; in fact, this fails to acknowledge the range of likely outcomes (mostly due to data variability). In this study, high and low scenarios were considered in an attempt to recognise the range of behaviours and practices which occur along the value chain. However, recognising the need for certainty (a single number!) in decision-making, the average of this range was considered, determining the estimate offset figure for 2008. To facilitate communication, LCA terminology was "translated" into language that is more accessible for those unfamiliar with the field. For example, the term "Climate Hoofprint" (the icon of the brand is a cow) was coined by Ben and Jerry's (2008).

Whilst this study provided information necessary for certain decisions and communication activities (e.g. carbon offsetting and identification of collaborative activities in the supply chain for GHG reduction), analysing a product from the perspective of a single issue generates a mismatch with the business need for information to support multi-dimensional decisions. For example, the need to simultaneously consider criteria such as biodiversity and land use issues, fair trade opportunities and import tariffs as well as GHG emissions.

There are some obvious actions to be taken by the brand in the management of the GHG impacts of their owned operations, but when taking the step to become carbon neutral some questions arise: How many carbon credits do you buy when you have a range of results? Is it possible to offset indefinitely with inevitable rises in the cost of carbon credits? Should offsets be purchased for both direct and indirect emissions?

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Home-grown versus imported organic apples – energy requirement and CO_2 balance

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Keywords: apple, food chain, fruit, organic growing, primary energy requirement, transport

The import of organic fruit and vegetables has been criticised as “non-organic”, i.e. wasteful in terms of resources which contradicts the rules of the international organic association IFOAM. In organic fruit growing particular emphasis is on the larger mechanical e.g. weeding and spraying input associated with lower yields per acreage compared with conventional fruit growers.

Apples are chosen as an example, since they can be consumed fresh or stored 3-6 months depending on variety. After 5-6 months storage, stored regional organic apple fruit compete with the first imports of fresh organic apple fruit from the Southern hemisphere. This contribution compares the energy requirement and CO_2 efflux for organic cv. ‘Braeburn’, which were either organically grown in Jork, Altes Land with those imported from overseas for sale in the Rhein-Ruhr region with 8 million people in April. This study was also initiated by new energy data, which became available for organic apple growing last year, and concern of organic growers in the Altes Land in 2007.

The primary energy requirement is calculated for organic cv. ’Braeburn’ apple picked mid October in Jork, Germany with subsequent five-months on-site CA storage at 1°C until March. This was compared with apples of the same cultivar grown organically in a Southern hemisphere summer in Hawke’s Bay, Northland, New Zealand, which were picked in March with subsequent 30 days sea cargo over 23,000 km from Napier, New Zealand to Antwerp.

Organic apple cultivation required a primary energy input of 1.22 MJ/kg fruit, assuming a 25 t/ha harvest. CA storage of apples in the Northern hemisphere winter consumed 1.03 MJ, which compares favourably with 6.62 MJ/kg for overseas shipment from New Zealand which is in marked contrast to a recently (2008) published report from New Zealand (http://www.scoop.co.nz). The considerably smaller energy required for organic domestic produce is discussed with respect to local employment, countryside issues and other parameters used in life cycle assessment.

Environmental impacts of different food products and their contribution to the environmental impacts of Finnish consumption

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Keywords: communication, LCA, food, agriculture, comparison, consumption

Life cycle assessment (LCA), in communication of environmental impacts of different food products in the context of sustainable consumption, is challenging due to the need of understandable and meaningful results for citizens. The results obtained in recent Finnish LCA studies (marinated broiler chicken, hard cheese, oat meal, rye bread, cheese gratinated potatoes, beer and cucumber) (e.g. Katajajuuri et al. 2003, Katajajuuri et al. 2005, Katajajuuri et al. 2008) made possible to compare magnitudes of environmental impacts of different foodstuff. Typical daily consumption of the products was chosen as a functional unit. LCA case studies were carried out by using similar methodology and system boundaries: all stages from the production of farm inputs to retail stores were included, as well as cooking of oatmeal and gratinated potatoes.

Results were presented by the environmental impact categories and also aggregated based on the methodology behind the Finnish ‘Eco-Benchmark’ (EB) (Nissinen et al. 2007). In the LCIA phase, site-dependent characterization factors were used for aquatic eutrophication and acidification. Other environmental impact categories included in the EB were primary energy demand, global warming potential and tropospheric ozone formation. Based on the aggregation of these environmental impacts, the daily consumption of cheese (30 g/day/person) creates ten times as much environmental impacts as the daily consumption of cucumber (22 g), marinated broiler chicken meat (40 g) two times more compared to the rye bread (83 g), and cheese three times as much as marinated broiler chicken meat. The contribution of different food products to the environmental impacts of Finnish private consumption, based on the methodology behind the Finnish ‘Eco-Benchmark’ (EB) and Finnish IO tables (Nissinen et al. 2007)., is also presented in figure 1.

Contrary to other countries also eutrophication is important impact category in Finland, where the Baltic Sea and inland waters are sensitive to nutrient releases. This can be seen when environmental impacts of products were evaluated and demonstrated. Comparisons could also be carried out in environmental impact category level or based on kg of products.

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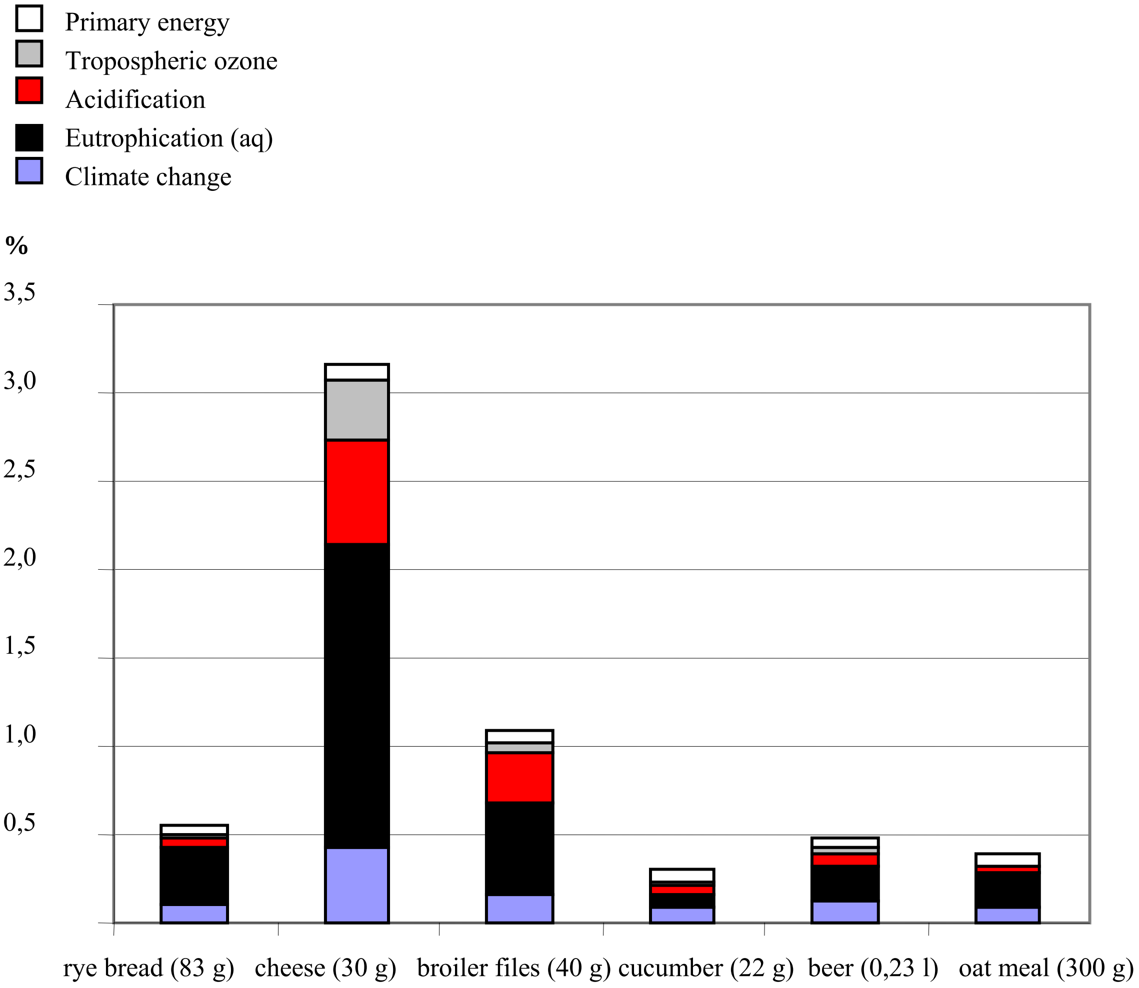

Figure 1. Contribution of typical consumption of different food products to environmental impacts of private consumption in Finland. For impact classes and weighting see Nissinen et al 2007.

Coupling of national environmental impacts and consumers' food choice - ways to communicate informed decisions on lunch table

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Keywords: LCA, food, consumption, environmental impact, consumer choice, input-output

This project pursues the implementation of Finland's national programme for sustainable consumption and production, called "Getting more from less", drafted by the committee of the Ministry of the Environment and the Ministry of Trade and Industry, in 2003.This research project is built up on previous LCA research projects, research on national input-output statistics and the development of the eco benchmark for the Finnish household consumption.

The specific objectives the whole project has been:

1. To develop a method for assessing environmental impact for household consumption. A method would be based on combination of LCA information at micro (segmented consumption of a household) scale and sectoral input-output analysis on macro (national economy) scale.
2. To answer to following questions: What are the actual environmental impacts of various segments of consumption in relation to food? How well do the total environmental impact data assessed by LCA, based on major segments of food consumption, meet with the total environmental impact data assessed on basis of national input-output statistics?
3. On the basis of consumption profile assessments, to produce information about how to develop communication and education of future consumers towards environmentally more responsible consumption choices. The information is directed to both consumers and administration. The final aim is to a knowledge base for households to help their decision making for environmentally responsible consumption.

In this study information from national input-output statistics has been combined with information produced with the help of the standard theoretic farm account models and these further combined with LCA information of major segments of food products. In this way, an account model is being built, by which total environmental impact of the total production - consumption processes of food economy can be assessed. The spatial variability of impacts of production can be assessed, and the impacts of various segments of food consumption, as well. To enable environmentally informed decisions of food consumers, we have built an exemplification of lunch plates representing variable balances between food components of different origins (plant vs. animal, national vs. global origin).

The project has started on August 2006 and will continue to end of June of 2009.

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LCA of Imported vs. Domestic vegetables in the UK

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Keywords: global vs. local supply chain; vegetables; cradle-to-grave; LCA

Life Cycle Assessment (LCA) studies have been performed as part of a project comparing the environmental impacts generated for the delivery to UK consumers of vegetables produced in different countries. Three case studies are presented: broccoli from the UK and Spain; lettuce from the UK, Spain and Uganda; green beans from the UK, Uganda and Kenya (Milà i Canals *et al*. 2008).

Such results allow detecting the environmental hotspots in the life cycle of the assessed vegetables, as well as the likely environmental preference for different supply options. The study specifically addresses the seasonality of fresh vegetables, and compares produce that may be on the market shelves at the same time of the year. In addition, a picture of the variation of environmental impacts associated to the same or similar products through the year is offered.

This study confirms that working with ‘food miles’ as an indicator of environmental impacts for food products is potentially misleading: imported produce may have lower environmental impacts than domestic produce supplied off-season through increased storage and/or produced using enabling technologies such as heated and lit glasshouses. On the other hand, produce imported by air shows clearly higher environmental impacts than off-season domestic produce (at least in the case of lettuce and green beans), although for certain impact indicators such as land use, water use and pesticide use the result are not so clear-cut. However, it needs to be highlighted that LCA results only deal with environmental impacts, and do not address other important aspects considered in the project, such as farmers’ health and effects on the local economy.

Besides, there is considerable variation in the results from different farms producing the same product. This suggests that any single figure defining a crop (e.g. a value for the ‘carbon footprint’ of 1 kg green beans) is bound with significant uncertainty. Post-farm stages, and particularly home storage and cooking, have shown to contribute significantly to the final impacts. Variations in these stages have not been modelled in detail, but are likely to be very high due to alternative consumer behaviour (e.g. cooking for more or less time, with different kitchen appliances, etc.). This is particularly true for products that are often cooked (i.e. not so relevant for products that are eaten raw, such as lettuce). Indeed, the home stage may dominate the results in the case of cooked vegetables.

Soil Organic Carbon (SOC) has been used as an indicator of soil quality, and potential changes to SOC linked to different land uses have been compiled along the whole life cycle of the products assessed. The results show that, contrary to common assumptions in several life cycle impact assessment methods, stages different than cropping (mining for kerosene production) may dominate the impacts related to land use, even if cropping still dominates the amount of m^2year.

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LCA Italian network: works in progress of the Food and Agro-industry Working Group

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Keywords: Italian LCA Network, food, agro-industry, working group

The Food and Agro-industry Working Group has been set up in the framework of the Italian LCA Network and, together with the others working groups, it represents the operative body to carry out research and to identify opportunities for the food companies involved in the application of LCA and LCA-based tools. The working group started the activities in January 2008 and, after two meetings, Bari and Pescara, it accounts over fifty members. The activities until now have been focused on the mapping of the Italian food and agro-industry LCA studies and Italian research groups and institutions involved in LCA of these sectors, in order to know which are the more studied foods (and no-food agro-industrial), who has done what, which are the most common methodological problems and which are the most common problems in the data collection and in the impact assessment factors to use. Since the beginning of May the working group has been shared in 5 sub working groups relative to five typical Italian food sectors: vegetable oils, wine and spirits, cereals and derivates, zootechny and fishery products, no-food (biomass for energy in particular). The main aims of the sub working group are the definition of the stat-of-the-art in the application of the LCA to these sectors, the involvement of all the stakeholders of the relative food chains and the identification of solutions to the most common methodological/data problems of the LCA of these sector are. Aim of the paper is to show the ongoing activities of the working group and of the relative sub working groups and their middle and long period objectives.

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Life cycle assessment in the cherries food chain

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Keywords: LCA, cherries, agricultural inventory

Cherries production represents an important agricultural productive sector in Puglia, a region of the South of Italy, since it covers more than the 55% of the whole Italian cherries harvested area and about the 35% of the Italian output. Italy and Germany are the main European cherries producers. After a long period of decrease, in the last years, the world harvested area and the total production of cherries is highly increasing due to a un renewed interest of consumers for this fruit, to an increase in the uses of manufacturing industries but also to the economic incentives to its setting up present in various regions. However, this cultivation many times is mixed with other cultivations and only in some regions it takes on the character of specialization; this fact considerably affects the energy consumption and the environmental impact per hectare (Godini *et al.*, 1996).

In this paper the production supply chain of cherries has been analyzed in order to assess its environmental profile. In particular, different phases have been analysed: the agricultural operations (Notarnicola & Spada, 1996) and the transformation system which gives two intermediate products for the food manufacturing industries such as the cherries in SO_2 and the cherries in alcohol (Notarnicola & Proto, 1984). The methodology used is the Life Cycle Assessment (LCA), as stated by the ISO 14040 rules.

The results put in evidence that, as in other food systems, the agricultural phase scores worst in almost all the impact categories than the transformation one and that the cherries in SO_2 system has a better environmental profile compared to the that of the cherries in alcohol. It is interesting to note that, above all in the cherries in alcohol system, the gap, in terms of environmental impact, between the agricultural phase and the industrial one is very low if compared with the results shown in the studies of other food products of our region such as wine, extra virgin olive oil and pasta.

The results of the research show that different environmental improvements could be searched in the specialization of the cultivation, in a higher efficiency of the transport system and in the recycling of some solutions (like the hydro-alcoholic one) in the examined systems.

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Tab. 1: Inputs and outpus of the cultivation of 1 ha of cherries orchard

Material	**Typology**	**Quantity**
Inputs		
Water		1051.5 m^3
Fertilizers	NPK (12-12-17)	562.5 kg
Pesticides	Copper sulphate	12.5 kg
	Insecticide (dimethoate)	62.5 mL
	Insecticide (imidacloprid)	0.25 kg
Lube oil		5.79 L
Gasoline		30.74 L
Diesel		215.98 L
Outputs		
Cherries		8000 kg
Wood		2440 kg

Tab. 2: Inventory of the transformation phase of 10000 kg of cherries

Material	**Typology**	**Quantity**
Inputs		
Cherries		10000 kg
Hydro-alcoholic solution		6661.1 kg
SO_2 solution		692 kg
Water		11.1 m^3
Electric energy		141.1 kWh
Outputs		
Cherries in SO_2		1500 kg
Cherries in Alcohol	Diameter >17,2 mm	4628.4 kg
	Diameter <17,2 mm (without stone)	1944.3 kg
Physiologic loss	(water)	994.8 kg
Waste		189.3 kg
Stone		343.1 kg
Leaves, stalks, broken cherries		400 kg
Waste water		11.1 m^3

LCA applied to some products belonging to the food sector

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Keywords: LCA, climate declaration, pasta, bakery, dairy, milk.

Life Cycle Assessment (LCA) was applied to some food chains belonging to different sectors of Italians typical products such as pasta, bakery and dairy production systems. All projects were sponsored by well known industries and big retailers that are considering the opportunity to use the results to improve their eco-efficiency and to communicate to the public domain by means of advanced environmental claims&labels tools.

For this reason, all projects have been split into two levels: a first level, in which results describing the environmental life-cycle burdens are mainly used for external communication activities and a second level in which results are used for research and product development purposes.

The systems have been described by using specific data when available; generic data have been used in accordance with the International EPD System requirements. Generic data come from the Boustead Model Database as well as from other sources such as the International Journal of LCA.

This paper is addressed to highlight hot spots of each project and to present the most important results of the LCA application.

Finally, the Granarolo Environmental Product Declaration (EPD) as well as the Climate Declaration of high quality PET bottled milk is presented and discussed as case study.

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Eco-standardization of frozen vegetable and fruits industries in Chiang Mai province

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Keywords: Eco-standardization, Eco-production, Life cycle assessment, Frozen food, Energy management, Environment management

With Thailand’s tropical climate, a wide variety of fresh fruits and vegetables are available all year round. The abundance of fresh product provides a tremendous opportunity for the country to export its fruits and vegetables to other countries which constitute an important part of diets in cold climate countries during cold season. Therefore, Thailand has become a significant source of fresh and frozen fruits and vegetables around the world. It is expected that the frozen vegetables and fruits can respond to a new trend of health-conscious consumers. Also, non-GMO products can increasingly penetrate European and Japanese markets. Especially, the economies of Asian countries like China and Vietnam, the important markets for frozen fruits and vegetable, and demand is expanding.

However, the production and consumption culture is changing. The increasing of the global problems, such as pollution and waste problems, high energy consumption and so on, are now of interest. Therefore, the energy and environmental management are needed in order to promote and demonstrate the good practice for the frozen fruit and vegetable industries.

The study focuses on the Eco-Standardization of frozen vegetable and fruit industries in Chiang Mai province, in the northern part of Thailand. The objectives of the study are to make awareness of environmental impact of the industry and to improve the efficiency in the energy and material consumption. The standard requirements were then applied to 6 voluntary factories, covering 4 significant issues, i.e., energy and environmental policies, good agricultural practice, energy and material consumption, waste management and corporate social responsibility.

As the results, the improvements were implemented to each voluntary. This leads to a more environmentally friendly outcome and hence leads to a more sustainable society.

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Practical application of results from LCA of root vegetables and leaf vegetables

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Keywords: LCA, organic vegetables, resource efficiency,

Production, storage, packaging and distribution of vegetables and fruits in Norway is challenging, largely due to the small population and large land area, but also due to climate conditions. The challenges are even greater for organically grown products which still have a low turnover despite the Norwegian Governments aim that 15 % of food consumption and production should be of organic food by 2015 while in 2007 only 0,64 % of Norwegian food consumption was organic(Department of Food and Agriculture (2006)). Only 6 % of the population regard themselves as “organic consumers (Haegeland 2006). An investigation carried out in 2006 (Opinion Market Research) showed that 72 % of Norwegian consumers wanted to increase consumption of organic food, 85 % felt that organic food was more healthy than conventional and 56 % said that organic food tasted better than conventional. From talks with actors (retailer COOP, wholesaler Nordgroent) in the market we have found that the largest barriers to increased consumption of organic food are: High price, low availability and low product quality. The “Ecofruit” research project aims to increase consumption of organic fruit and vegetables while increasing resource efficiency and minimalizing environmental impact.

Life Cycle Impact Assessment in combination with analysis of cost distribution in the value chain, analysis of quality characteristics, monitoring of conditions in the value chain and other practical investigations (such as temperature measurements during transports) in the field has been carried out for a number of organically grown leaf and root vegetables. The aim is to gain as complete picture as possible of the economical and technical improvement potential in the value chain. The project is carried out in close cooperation with growers, transporters, wholesaler, retailer COOP, packaging producers and other actors in the value chain.

Preliminary results show that leaf and root vegetables represent opposite situations in terms of environmental load (see figure 1 and 2). For leaf vegetables the packaging is responsible for a large part of the environmental impact, whereas for root vegetables the growing phase and cool storage is most important. For leaf vegetables the problem of loss of product in distribution and storage also has a big impact on environmental performance.

One important aim of the project is to increase consumption of organic fruits and vegetables. In order to achieve this goal, consumers must perceive the products to be of high quality and to be a good choice for the environment. In this project we have f ex tested several lettuce packaging materials to see which would best keep product quality. We have also evaluated the option of communicating LCA results of individual products directly to the consumer to display environmental efficiency of the products. However it can be problematic to publish results directly to consumers. Using our data it could seem vise to recommend consumption of more root vegetables like carrots and rutabagas and less light vegetables like lettuce. However such advice is misplaced because the function (and amount used) of carrots and lettuce is different. Hence this project will search for other ways of communicating LCA results to the general public.

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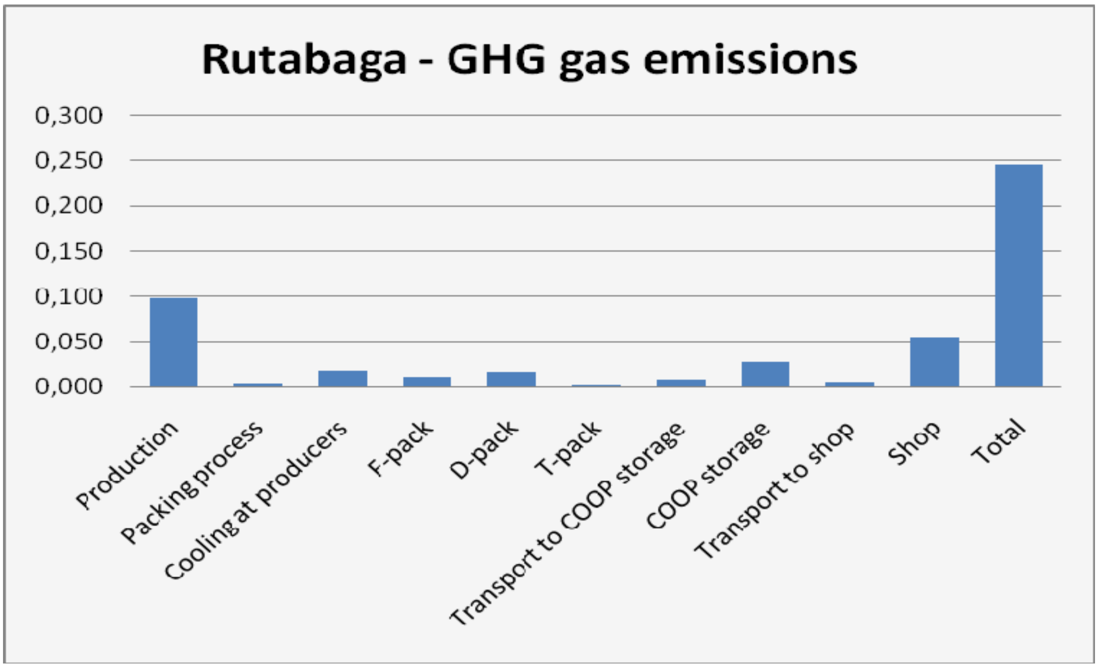

Figure 1. Greenhouse gas emissions of rutabags (Brassica napobrassica) in the value chain (#) (#)Temporary results, not verified yet

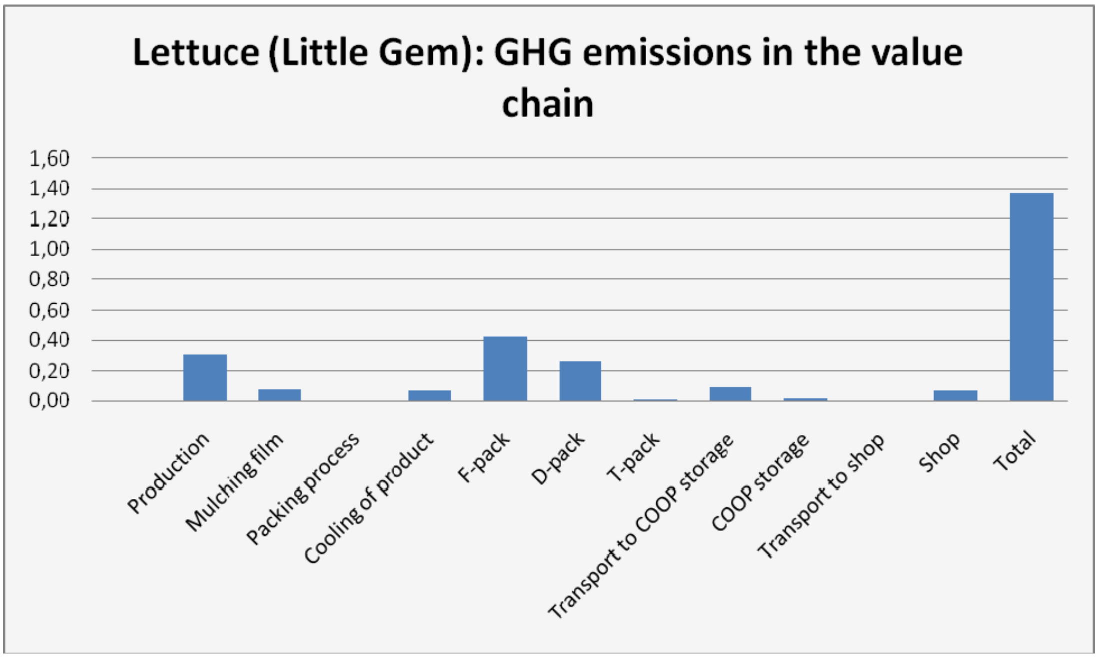

Figure 2. Greenhouse gas emissions of lettuce (Little gem, Lactuca Sativa var. langifolia) in the value chain (#). (#)Temporary results, not verified yet

Zero Impact: A Methodological Proposal to an Environmental Impact Offset Scheme

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Keywords: LCA, impact offset, environmental themes, shadow project

There are several schemes for carbon emissions compensation. However, environmental problems are not exclusively due to climate change. Other global and regional issues must be addressed, and no product can claim to have no impacts unless it also regards other themes in its voluntary targets.

The best environmental performance that products can demand is to be environmentally neutral. However, all activities have (negative) impacts, and process optimizations are limited by physical (thermodynamic) or economic constraints. Therefore, the only option to achieve neutrality is to offset the remaining impacts after all improvements were made.

In this paper we propose a methodology to reach the environmental neutrality of products. We named this scheme *Zero Impact*. Our method consists of three stages: (1) impact assessment, (2) definition of reduction and compensation projects, and (3) implementation of projects.

In the first stage we define the studied product (or activity) and its life cycle, including system boundaries and functional unit. Then, we use a Life Cycle Assessment (LCA) approach to determine its impacts in each environmental theme. The next stage is the determination of how those environmental impacts will be offset. *Zero Impact* follows a hierarchical approach: reduce emissions, compensate emissions in the same environmental theme in the same region where impacts are caused, compensate emissions in the same environmental theme elsewhere, compensate emissions in other environmental themes in the same region, compensate emissions in other environmental themes elsewhere. When we need to convert impact in one theme to another, we use aggregation methods such as the Eco-indicator (Goedkoop, 1998; Goedkoop & Spriensma, 2000). Finally, we determine and implement compensation projects. The projects in each theme are evaluated according to economic criteria, namely the *shadow project* methodology (Perman *et al.*, 1996). This ensures that the less expensive projects for a given environmental target are always implemented first.

The first trial implementation of this concept was carried out for the Portuguese electricity company, EDP. EDP decided to compensate all the impacts of its monthly receipt sent to consumers. The impacts of all production stages, namely paper production, printing, and mailing, were accounted for using LCA software SimaPro 7.0. Then, some impact reduction measures were chosen (switching to a lighter type of paper), and the rest of the impact was compensated via projects implemented in Portuguese farms. These were the least expensive and those with highest direct environmental effects.. Only agricultural firms with some for of sustainability certification were included in the project, to guarantee external control on the outcome of the activities.

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