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Book of Abstracts

8TH International Conference on

Life Cycle Assessment in the Agri-Food Sector

LCA FOOD 2012

October 1-4
2012
Saint-Malo
France

INRA

LCA FOOD 2012

8TH International Conference on Life Cycle Assessment in the Agri-Food Sector • Saint-Malo, France • October 2-4, 2012

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BOOK OF ABSTRACTS

8TH INTERNATIONAL CONFERENCE ON

LIFE CYCLE ASSESSMENT IN THE AGRI-FOOD SECTOR

OCTOBER 1-4, 2012 • SAINT-MALO, FRANCE

Editors: Michael S. Corson, Hayo M.G. van der Werf

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Welcome

Soyez les bienvenus à LCA Food 2012 à Saint-Malo, France !
Welcome to LCA Food 2012 in Saint Malo, France!

"Towards Sustainable Food Systems"

The LCA FOOD conference series is the world's premier scientific and technical forum on Life Cycle Assessment in the agri-food sector. We hope that you will find the conference interesting and enjoyable and that you will "harvest" new ideas and contacts. Your input to the conference will contribute to its success.

The previous conferences in this series took place in Brussels (1996, 1998), Gothenburg (2001, 2007), Horsens (2003), Zürich (2008) and Bari (2010). This year, for the first time, the conference takes place in France. It has been organised by INRA, the French National Institute for Agricultural Research, with the support of ADEME, the French Environment and Energy Management Agency.

Objectives of the conference

The production, transformation, distribution and consumption of food and drink contribute strongly to human prosperity and health. However, the food and agriculture sector also contributes a large part of the environmental impacts caused by human activities. Because these impacts, in particular climate change and biodiversity loss, need to be reduced urgently, a shift towards sustainable food systems is essential.
Over the last two decades the Life Cycle Assessment (LCA) methodology has been developed and applied in the agriculture and food sectors to quantify environmental impacts and assist decision making. In recent years, LCA in the agri-food sector has developed rapidly, in particular for sustainability assessments of agricultural systems and their products, and for guiding consumers toward sustainable food-consumption patterns (e.g., via eco-labelling).
LCA Food 2012 will serve as a global forum in which to share recent developments in LCA methodology, databases and tools, as well as applications of LCA to food-production systems and food-consumption patterns. All of this will contribute, we hope, to achieving the 2012 conference motto: "Towards Sustainable Food Systems".

From the 362 abstracts submitted, the conference is scheduled to have 121 oral presentations and 183 posters, and at the time of writing, we expect more than 420 participants from at least 42 countries. In addition to this book of abstracts, which contains 2-page abstracts for most oral presentations and posters, you will find 6-page papers for most oral presentations, along with the poster abstracts, in the conference proceedings, provided as a PDF file on the memory stick in your conference beach bag.

We want to thank the authors for their presentations and posters. We are very grateful to the 23 members of our scientific committee for their efforts in reviewing the abstracts and selecting the papers for oral presentations. We warmly thank our sponsors for supporting the conference. Last but not least, we want to thank our indefatigable INRA colleagues of the organising committee for their essential contribution to the success of the conference.

We hope you will appreciate the scientific and technical content of the conference, contacts with participants, the French and Breton cuisine during the lunches and Gala Dinner, and the city of Saint Malo and its seaside. We are delighted to welcome you to this beautiful region to join the rapidly growing LCA Food community and hope you will meet old friends and make new ones.

Michael Corson
LCA Food 2012 co-chair

Hayo van der Werf
LCA Food 2012 co-chair

LCA Food 2012 Committees

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8TH International Conference on
Life Cycle Assessment in the Agri-Food Sector

LCA FOOD 2012

1-4 October 2012 • Saint Malo, France

PROGRAMME

INRA

Programme Overview

Monday, October 1st			
16:00 - 18:30	Participant arrival and registration		
18:30 - 20:30	*Welcome reception : cocktail and buffet*		

Tuesday, October 2nd			
08:00 - 08:50	Participant arrival		
08:50 - 09:10	Opening session		
09:10 - 11:10	Keynote session		
11:10 - 11:40	*Break*		
11:40 - 13:00	Parallel session 1a	Parallel session 1b	Parallel session 1c
13:00 - 14:30	*Lunch*		
14:30 - 15:50	Plenary session 1		
15:50 - 16:20	*Break*		
16:20 - 16:50	Poster session A		
16:50 - 18:30	Parallel session 2a	Parallel session 2b	Parallel session 2c

Wednesday, October 3rd			
08:30 - 08:50	Opening of the Conference Centre		Quantis Workshop *Amphithéâtre Maupertuis*
08:50 - 10:30	Plenary session 2		
10:30 - 11:00	*Break*		
11:00 - 13:00	Parallel session 3a	Parallel session 3b	Parallel session 3c
13:00 - 14:30	*Lunch*		
14:30 - 15:50	Plenary session 3: Food		
15:50 - 16:20	*Break*		
16:20 - 16:50	Poster session B		
16:50 - 18:30	Parallel session 4a	Parallel session 4b	Parallel session 4c
19:30 - 24:00	*Congress Gala dinner*		

Thursday, October 4th			
08:30 - 08:50	Opening of the Conference Centre		GaBi Workshop *Amphithéâtre Maupertuis*
08:50 - 10:30	Parallel session 5a	Parallel session 5b	
10:30 - 11:00	*Break*		
11:00 - 13:00	Parallel session 6a	Parallel session 6b	Parallel session 6c
13:00 - 14:30	*Lunch*		
14:30 - 16:10	Parallel session 7a	Parallel session 7b	Parallel session 7c
16:10 - 16:40	Conference Closure		

Friday, October 5th	
08:30 - 14:00	Optional tour of Mont Saint-Michel or Dinan/Dinard
09:00 - 16:30	3rd International ecoinvent Meeting

Room color code:

- Auditorium Châteaubriand (pink)
- Rotonde Surcouf (blue)
- Amphithéâtre Maupertuis (yellow)

GENERAL INFORMATION

General Information

Conference venue

The conference takes place in the Palais du Grand Large, 1 Quai Duguay Trouin, 35400 Saint Malo, France. Tel. +33 2 99 20 60 20. Smoking is prohibited in the conference centre.

Registration

The registration fees include:

- Admission to all conference sessions, poster sessions and the exhibition area
- A conference beach bag, including this book of abstracts, your badge, an electronic version of the proceedings on a memory stick, the conference programme, a list of participants, a conference mug, and an INRA pen.
- Welcome reception: cocktail and buffet on 1 October, 18.30 hours
- Lunches: 2, 3 and 4 October, 13.00-14.30 hours
- Gala Dinner: 3 October, 19.30-24.00 hours
- Refreshments during session breaks
- Access to the Quantis and PE International workshops

Upon registration you will receive a badge to be worn during the conference.

The Young Researcher Wall

LCA Food 2012 is happy to offer Ph.D. students and other young researchers an opportunity to connect with research institutes and private companies by publishing their CVs on the conference web site as well as during the conference on the Young Researcher Wall, located at the entrance of the Salle du Grand Large (level 1). Research institutes and private companies can also publish their job offers on our web site and on the Young Researcher Wall during the conference.

Oral presentations

Plenary-session presentations will occur in the Auditorium Chateaubriand (level 0). Parallel-session presentations will occur in the Auditorium Chateaubriand and two rooms on level 2: Rotonde Surcouf and Amphithéâtre Maupertuis.

Ideally, presentations should not exceed 15 minutes in length; timekeepers will sound a bell to indicate when 2 minutes remain. Any time remaining in the presentation slot will be available for questions. Timekeeping will be strict to allow participants to switch between sessions.

For those who have not sent in their presentation before the conference, please give it to Thierry Trochet in the Preview Room in Salle Charcot (level 1) the day before the presentation is scheduled.

Poster sessions

Posters should be put up in the Salle du Grand Large (level 1) on October 2 between 7.00 and 8.50 hours and stay up for the entire conference. Posters have been grouped according to topic. Two poster sessions have been scheduled: session A on 2 October, 16.20-16.50 hours, and session B on 3 October, 16.20-16.50 hours. Poster authors should stand next to their poster during the session in which their poster has been scheduled.

Exhibition booths and Breaks

Sponsors have exhibition booths available to present their products and services in the Rotonde Jacques Cartier (level 1), where refreshments will be served during morning and afternoon session breaks.

Lunches and Gala Dinner

Lunches will be served from 13.00-14.30 hours in the Espace Lammenais (level 3). Special food requirements (vegetarian, fish) expressed during online registration have been taken into account. Those who registered their desire for a special meal should be sure to wear their badge during the meal so they can be identified by the wait staff. Persons having other requirements (e.g. vegan, allergies) should inform wait staff.

The Gala Dinner will be served on 3 October from 19.30-24.00 hours in the Espace Lammenais.

Internet access

Six computers with Internet access are available in the Salle Bouvet (level 1). Internet access via wifi is available on levels 1 and 2. A password is not required.

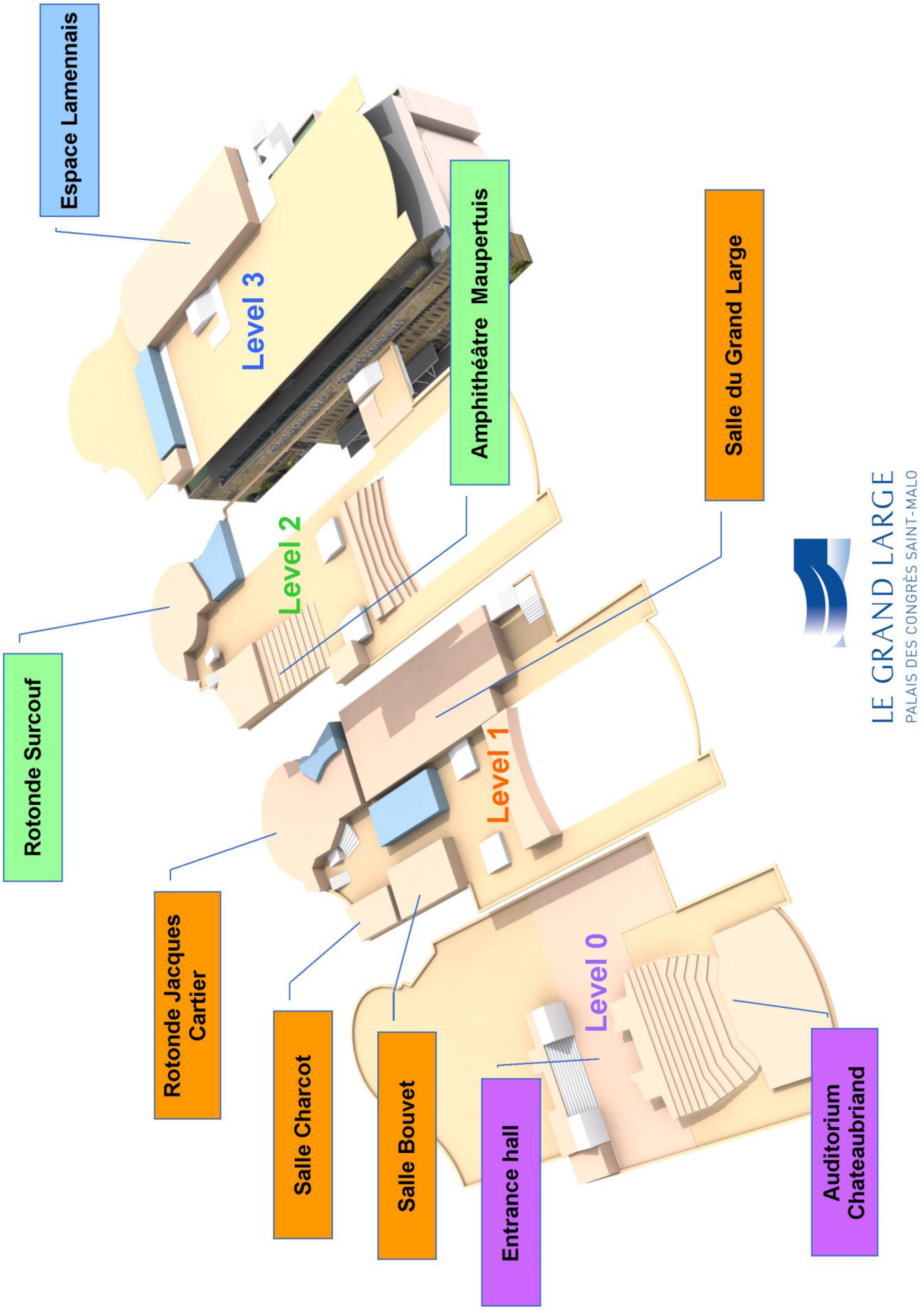
Cloakroom

On Thursday, 4 October, a staffed cloakroom will be available on level 0 to keep your luggage.

Questions?

The members of our local organising committee will be happy to answer any questions you may have. They wear pistachio-green T-shirts with the LCA Food 2012 logo on the back. In the Salle Charcot (level 1) you will find conference secretaries Karine Derrien and Maryvonne Pertué for administrative matters (e.g., attendance certificate).

Conference Centre Map



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TUESDAY, 2 OCTOBER

KEYNOTE SESSION

PARALLEL SESSION 1A: WATER FOOTPRINT

PARALLEL SESSION 1B: TOWARDS LIFE CYCLE SUSTAINABILITY ASSESSMENT

PARALLEL SESSION 1C: ECODESIGN AND ENVIRONMENTAL MANAGEMENT

PLENARY SESSION 1: FOOD

PARALLEL SESSION 2A: LAND USE

GROUP 2, SESSION A: CARBON OR WATER FOOTPRINTS, SOIL, BIODIVERSITY

GROUP 3, SESSION A: LABELLING, CONSUMERS, DIET

POSTER SESSION B - WEDNESDAY, 3 OCTOBER, 16.20-16.50

GROUP 4, SESSION B: CROP PRODUCTION SYSTEMS

ORAL SESSIONS

Sustainable food, a component of the green economy

Dominique Dron

Interministerial Delegate and General Commissioner for Sustainable Development, Ministry of Ecology, Sustainable Development and Energy, Paris, France

From the French perspective, the green economy has both economic and environmental but also social objectives. Agriculture is at the crossroad of various environmental challenges and involves living organisms. Sustainable agriculture calls for new public policies which mobilise both consumers and producers. The proposal for environmental labelling of products aims at launching signals to these different stakeholders to redirect their practices towards a low-carbon economy with low use of natural resources and pollution.

Research priorities for sustainable agri-food systems and LCA

Jean-François Soussana

INRA, Paris, France, E-mail: *jfsoussana@paris.inra.fr*

Recognising that research for sustainable agri-food systems will be essential to meet global and European challenges in the coming decades, European countries participate in two Joint Programming Initiatives (JPIs): Agriculture, Food Security and Climate Change (FACCE) and Healthy Diet for Healthy Life (HDHL). Mission oriented research agendas have been developed and are focused on delivering key outputs. For FACCE: i) to sustainably intensify European agriculture, ii) to operate agriculture within greenhouse gas, energy, biodiversity and contaminant limits and iii) to build resilience to climatic change in agricultural and food systems. For HDHL: i) determinants of diet and physical activity, ii) developing healthy, high-quality, safe and sustainable foods, iii) diet-related chronic diseases. The role of life cycle assessment (LCA) in the context of these research priorities is discussed. Bridging natural capital, on the one hand, and health issues, on the other, with the assessment of the life cycle may lead to breakthroughs in the sustainability assessment of food systems.

Three perspectives on sustainable food security: efficiency, demand restraint, food system transformation. What role for LCA?

Tara Garnett

Food Climate Research Network, Environmental Change Institute, University of Oxford, E-mail: *taragarnett@fcrn.org.uk*

Achieving food system sustainability is a global priority but there are different views on how it might be achieved. Broadly three perspectives are emerging, defined here as: efficiency oriented, demand restraint and food system transformation. These reflect different conceptualisations on what is practically achievable, and what is desirable, underpinned by different values and ideologies about the role of technology, our relationship with nature and fundamentally what is meant by a 'good life.' This paper describes these emerging perspectives and explores their underlying values; highlights LCA's role in shaping these perspectives; and considers how LCA could be oriented to clarify thinking and advance policy-relevant knowledge. It argues that more work is needed to understand the values underlying different approaches to the food sustainability problem. This can shed light on why stakeholders disagree, where there are genuine misunderstandings, and where common ground is possible and ways forward agreed.

Challenges for LCA in the agri-food sector; perspectives from Thailand and Southeast Asia

Shabbir H. Gheewala

The Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi, Bangkok, Thailand, Center for Energy Technology and Environment, Ministry of Education, Thailand, E-mail: *shabbir_g@jgsee.kmutt.ac.th*

Agriculture and agri-food industries are very important sectors in many Asian countries, especially in Southeast Asia. Thailand, an emerging economy, is a large producer and exporter of agri-food products. Life cycle assessment (LCA) has been used increasingly in the agriculture sector though much still remains to be done. This paper outlines the brief historical development of LCA in Thailand focusing particularly on the agri-food sector. The development process and status are described pointing out also the areas that need further development. Challenges for database development as well as methodology development are identified. The status of the development of LCA in the agri-food sector in some other countries in the region is also summarised along with the development of a regional initiative in this area.

The yield performance of organic agriculture

Verena Seufert[1,*], Navin Ramankutty[1], Jonathan A. Foley[2]

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Organic agriculture is often proposed as a solution to the challenge of producing sufficient food in a sustainable way. However, organic agriculture is also criticised for its purported lower productivity compared to conventional agriculture. Here we use a comprehensive meta-analysis to examine the relative yield performance of organic and conventional farming systems globally. Our analysis of available data shows that, overall, organic yields are typically lower than conventional. The yield difference varies, however, depending on site and system characteristics. Under certain conditions – i.e., with good management practices, particular crop types and growing conditions – organic systems can nearly match conventional yields, while under others it currently cannot. To establish organic agriculture as an important tool in sustainable food production, the factors limiting organic yields need to be more fully understood, alongside assessments of the many social, environmental and economic benefits of organic farming systems.

ENVIFOOD Protocol: launch of the collectively-agreed sectorial methodology for assessing the environmental performance of food and drink products in Europe

Camillo De Camillis[1,*], Jean-Christophe Bligny[2], David Pennington[1], Balázs Pályi[3], Christian Bauer[4], Urs Schenker[5], Henry King[6], Lars Lundquist[5], Nicolas Martin[7], Nicole Unger[6], Laura Draucker[8], Øyvind Vessia[9], Coen Blomsma[10], Nathan Pelletier[1], Hans Blonk[11], Rudi Sueys[12], Anna Papagrigoraki[13], Pascal Gréverath[14], Herbert Aichinger[15], Jean-Pierre Rennaud[16]

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The views expressed in this paper are personal and do not necessarily reflect an official position of the European Commission.

Lack of consistency in both the substance and application of methodologies and guidelines for assessing and communicating the environmental performance of food and drink products has the potential to confuse consumers and other stakeholders involved in the food and drink supply chains. Furthermore, it poses an unnecessary burden on those organisations requested to evaluate the environmental performance of their product according to several different methodologies.
In order to address this issue, business associations and other food supply chain partners have involved the European Commission in establishing the European Food Sustainable Consumption and Production (SCP) Round Table. Since 2009, Round Table members have been working together on a commonly-agreed and science-based framework for assessment and communication of the environmental performance of food and beverage products in Europe. The first milestone was reached in 2010 when Round Table members agreed on a set of principles to guide working groups in harmonising relevant approaches for assessment and communication. On this basis, the Round Table Working Group 1 reached agreement on key methodological aspects for environmental assessment at a scientific workshop in 2010. A detailed analysis of relevant data, methodologies and guidelines for assessing the environmental performance of foods and drinks was conducted following the 2010 workshop. This analysis identified aspects of Life Cycle Assessment (LCA) practice where existing methodologies agree, as well as inconsistencies among existing approaches. A second workshop was organised in 2011 to reach consensus on the outstanding inconsistencies. Remaining unresolved issues were further discussed within Working Group 1, leading to the release of an advanced draft of what will be the future Round Table methodology for environmental assessment named the ENVIFOOD Protocol. A public consultation scheduled during the last quarter of 2012 will be followed by the publication of the ENVIFOOD Protocol in 2013. In conjunction with its publication, the ENVIFOOD Protocol will be tested through a range of pilot studies and the feedback used for refining the guidance.
The ENVIFOOD Protocol provides guidance to support those environmental assessments of food and drink products in Europe conducted in the context of:

- Business-to-business as well as business-to-consumer communication (focus of the Round Table Working Group 2)
- The identification of environmental improvement options (focus of the Round Table Working Group 3).

This paper gives a general overview of the process to arrive at the ENVIFOOD Protocol. The paper also illustrates possible next steps of the Round Table Working Group 1. Round Table members are, in fact, discussing how to develop and adopt Product Category Rules (PCR) in line with the ENVIFOOD Protocol. In parallel, Round Table members are also discussing how to obtain adequate data for assessment and streamlined tools. The establishment of the ENVIFOOD Protocol and PCRs will allow the development of user-friendly and affordable tools for assessment and communication of environmental impacts, thus reducing the burdens of undertaking such assessments, in particular for SMEs.

Water footprint of pastoral farming systems in New Zealand

Marlies A. Zonderland-Thomassen*, Stewart F. Ledgard, Mark Lieffering

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Global livestock production has a major challenge ahead in securing food production without increasing the environmental burden. Globally, a key agricultural system is dairying and New Zealand (NZ) is the world's largest dairy exporting country trading at least 95% of the 16,500 million litres of milk that was processed in NZ in 2010, equal to 26% of NZ's total export revenue. Sheep and beef farming is also dominant in NZ agriculture. Red meat and related products contributed NZ$6.5 billion or 15% of NZ's total export revenues in 2009. A need exists to assess the impacts of water consumption associated with NZ livestock products along the whole production chain. A literature review showed various water footprint (WF) approaches exist or are under development (Bayart et al., 2010; Berger and Finkbeiner, 2010). For the red meat and the dairy supply chains, both water quality and water quantity are relevant.

A WF approach compliant with Life Cycle Assessment (LCA) principles was used to assess the stress-weighted WF following Ridoutt et al. (2010), as well as the eutrophication potential (EP) of NZ dairy, beef, and sheep farming systems. We used nitrate and phosphate loss when computing the water quality indicator EP, while excluding gaseous emissions, as preliminary results showed that ammonia and nitrous oxide emissions dominated the EP which is questionable for NZ conditions. For sheep and beef farm systems, survey data from seven representative types from throughout NZ were used. For dairy farm systems, data from the two contrasting regions of Waikato (North Island, non-irrigated, moderate rainfall) and Canterbury (South Island, irrigated, low rainfall) were used.

The cradle-to-farm-gate life cycle required for the production of milk, beef, and sheep meat were analysed; from the production of inputs to products leaving the farm-gate, i.e. excluding transport or processing of raw milk or animals. Water abstraction and consumption associated with the production of machinery, buildings, and medicines were excluded.

The stress-weighted WF of NZ beef (excluding beef from culled dairy cows) was 0.2 L H_2O-eq/kg live weight (LW). Blue water losses from the grazed system were low and consequently the main losses were associated with bull calf rearing (57%) and evapotranspiration from irrigated pasture (36%). The stress-weighted WF of NZ sheep meat was 0.1 L H_2O-eq/kg LW.

The EP of NZ beef (excluding beef from culled dairy cows) was 12.2 g PO_4^{3-}-eq/kg LW. The EP of NZ sheep meat was 4.9 g PO_4^{3-}-eq/kg LW. Nitrate and phosphate loss at the farm (71% and 75% respectively) and the eutrophying pollutants to waterways associated with the production of artificial fertilisers (20% and 22% respectively) dominated the EP.

For dairy farm systems, the stress-weighted WF was 0.01 and 7.1 L H_2O-eq/kg fat-and-protein-corrected milk (FPCM) for the Waikato and Canterbury farm systems respectively. Water consumed by irrigation dominated the WF of the Canterbury dairy system, whereas water consumed for hydroelectricity supply was a hotspot in the WF of the Waikato dairy system. The EP was 1.9 g PO_4^{3-}-eq/kg FPCM and 1.5 g PO_4^{3-}-eq/kg FPCM for the average Waikato and Canterbury dairy farm systems respectively.

We concluded that the stress-weighted WF is a good indicator to assess freshwater availability and EP is a good indicator of water degradation impacts mainly resulting from leaching of eutrophying pollutants to waterways. New Zealand has regions with low water stress, although seasonal droughts can occur in many areas. The impact of NZ pastoral farming on freshwater availability can be reduced by practices that increase water use and feed conversion efficiencies, increase the use of non-irrigated feed supplements, as well as reduce irrigation needs. The impact of NZ pastoral farming on water quality can be reduced by efficient nutrient management. Other water quality impacts of pastoral farming are relevant to consider in future studies, e.g., the impact of microbial pollution on waterways.

References

Bayart, J-P., Bulle, C., Deschênes, L., Margni, M., Pfister, S., Vince, F., Koehler, A., 2010. A framework for assessing off-stream freshwater use in LCA. International Journal of LCA 15, 439-453.

Berger, M., Finkbeiner, M., 2010. Water Footprinting: How to address water use in Life Cycle Assessment? Sustainability 2, 919-944

Ridoutt, B.G., Williams, S.R.O., Baud, S., Fraval, S., Marks, N. 2010. Short communication: the water footprint of dairy products: Case study involving skim milk powder. Journal of Dairy Science 93, 5114-5117.

Water footprint accounting of organic and non-organic strawberries including ancillary materials: a case study

Manzardo Alessandro*, Anna Mazzi, Monia Niero, Sara Toniolo, Antonio Scipioni

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Climate Changes, world population growth and economic development heavily affected accessibility to freshwater resources in the last decades (UNESCO, 2006; Rockstrom, 2009). To support the definition of strategies to better manage these resources, the methodology of Water Footprint has been developed (Hoekstra, 2011). Latest development of this methodology is focused on product water use impact assessment within the framework of a more comprehensive Life Cycle Assessment (LCA) (ISO 2006, ISO 2011).

Many studies on food and agricultural products have been published assessing the water footprint indicator but only a few include ancillary materials and processes that are usually considered in LCA studies (Ridoutt et al., 2009; Milà i Canals et al., 2010).

In this paper the Water Footprint of a 330 g strawberry jam produced and sold in Italy is presented. The objectives of the research were: 1) to compare the water footprint accounting of two different farming: organic and traditional strawberry production at the same production site; 2) to determine if the contribution of the ancillary materials and processes (such as packaging and transports) to the overall product water footprint is relevant. A cradle to gate perspective has been adopted. Results have also been characterised using Water Stress Index (Pfister at al., 2009). Primary data have been collected directly from the producers and suppliers for most of the processes and materials considered.

The result of the quantification is reported in Table 1. In this case study organic farming resulted to be more water intensive then the non-organic one because of the different yield. The contribution of ancillary materials and processes resulted to be over the 10% of the overall product water footprint (Fig.1). These results demonstrate that, to support the choices and decisions in the field of water resources management, is not sufficient to limit the evaluation to the product itself but it is necessary to consider also ancillary process as they can have relevant contribution to the overall product water footprint.

References

Hoekstra A. Y., Chapagain A.K., Aldaya M.M , Hoekstra M.M.M., 2011. The water footprint assessment manual: Setting the global standard. Earthscan.

ISO (International Organization for Standardization), 2006. ISO 14040: Environmental management - Life cycle assessment - Principles and framework. Switzerland, Geneva.

ISO (International Organization for Standardization), 2011. ISO/WD2 14046: Water Footprint requirements and guidelines. Switzerland, Geneva.

Ridoutt B.G., Eady S.J., Sellahewa J., Simons L., Bektash R., 2009. Water footprinting at the product brand level: case study and future challenges. J. of Clean. Prod. 17 (13), 1228-1235.

Milà i Canals L., Chenoweth J., Chapagain A., Orr S., Antón A., Clift R., 2010. Assessing freshwater use impacts in LCA, part 2: case study of broccoli production in the UK and Spain

Pfister S., Koehler A., Hellweg S., 2009. Assessing the environmental impacts of freshwater consumption in LCA. Environ. Sci. Tech. 43 (11), 4098-4104.

Rockström, R., Steffen, W., Noone, K., Persson, A., Chapin, F.S., Lambin, E.F., Lenton, T.M., Scheffer, M., Folke, C., Schellnhuber, H.J., Nykvist, B., de Wit, C.A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P.K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R.W., Fabry, V.J., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P., Foley, J.A., 2009. A safe operating space for humanity. Nature 461, 472-475.

UNESCO-WWAP (United Nations Educational Scientific and Cultural Organization-World Water Assessment Programme), 2006. Water: A Shared Responsibility: The United Nations World Water Development Report 2.

Table 1. Water Footprint of 330 g of strawberry jam.

Process	Water Footprint accounting (l/functional unit)	Water Footprint (l/functional unit)
Primary Packaging	7.0	1.1
Transport and secondary packaging	20.8	6.3
Production	9.0	3.0
Farming	200.5	78.0
Total	**237.3**	**88.4**

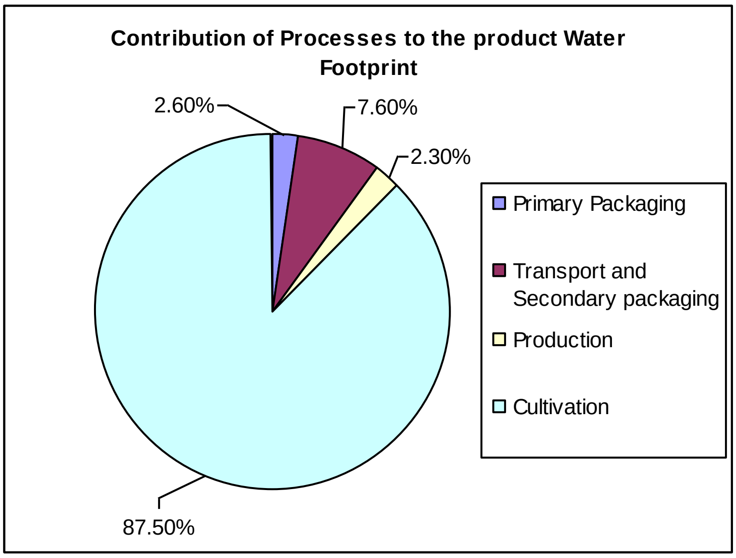

Figure 1. Contribution of different processes to the overall product Water Footprint.

Water footprint of cradle to farm gate milk production in the U.S.

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Dairy and agriculture are water intensive activities and water use impacts can vary widely depending on region, crop irrigation and type of crop. Irrigation can account for up to 90% of water withdrawn from available sources. Of these irrigation withdrawals, approximately 15% to 35% world-wide are estimated to be unsustainable (Siebert et al. 2010a; Wada et al. 2010). As competition for water resources from other sectors continues to increase, there is a demand for agriculture and dairy industries to improve efficiency of water use. On a dairy farm, water use is mainly associated with irrigation, and may account for up to 90% of on farm water use.

The objective of this project was to assess the water related issues ("water footprint") associated with U.S. dairy production. This information is an important stepping stone to identify potential ways to address and reduce water related issues associated with U.S. dairy production. This work was commissioned by the Innovation Center for U.S. Dairy and completed by a consortium of institutions with expertise in dairy and water topics (Quantis, University of Michigan, CIRAIG, University of Arkansas).

Building upon work in progress within the UNEP-SETAC Life Cycle Initiative on water footprinting, a framework was developed by Quantis which integrates a comprehensive state-of-the-science compilation of methods, addressing major issues related to water use in life cycle assessment (LCA).

Extensive data at the state level concerning crop irrigation and production in the U.S. was obtained from the 2008 Farm and Ranch Irrigation Survey (USDA NASS 2010a) and 2007 USDA Census of Agriculture. Key lessons from the spatialised assessment of on-farm water use impacts are that: (1) feed dominates the water stress assessment for milk production to farm gate; (2) irrigation requirements and impact on water use (based on the water stress of the state) varies widely by location, thus regionalisation is an important factor when evaluating water stress assessment; (3) the national water stress assessment of feed due to milk production is dominated by a few U.S. states with a combination of high water stress (high irrigation requirements) and high crop production such as the South-West.

References

Siebert, S., Döll, P., 2010a. Quantifying blue and green virtual water contents in global crop production as well as potential production losses without irrigation, Journal of Hydrology 384 (3-4): 198-217.

Wada, Y., van Beek, L.P.H., van Kempen, C.M., Reckman, J.W.T.M., Vasak, S., Bierkens, M.F.P., 2010. Global depletion of groundwater resources, Geophysical Research Letters 37 (L20402). DOI:10.1029/2010GL044571.

USDA NASS. 2010a. Farm and Ranch Irrigation Survey: Volume 3 • Special Studies • Part 1. 2007 Census of Agriculture. Washington, DC, USA: United States Department of Agriculture.

USDA NASS. 2010b. USDA/NASS - Data and Statistics - QuickStats 2.0. http://quickstats.nass.usda.gov/.

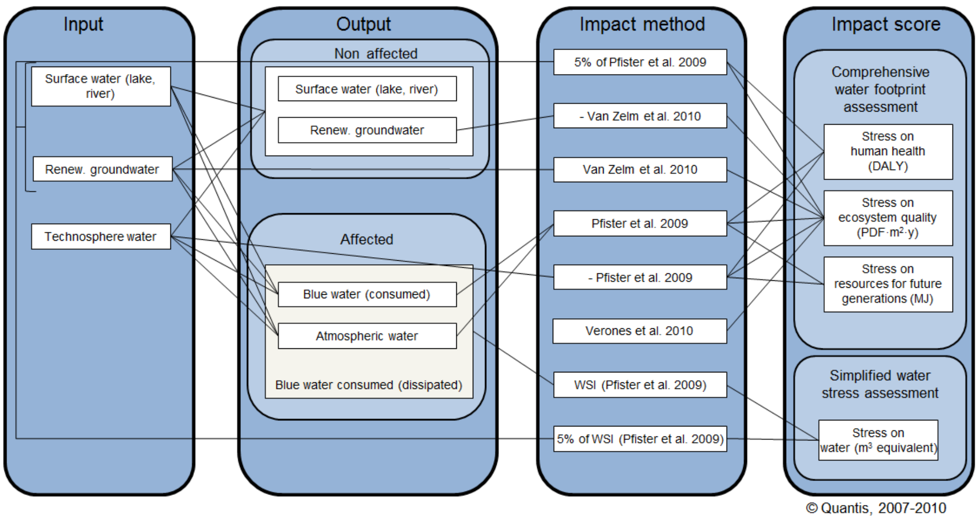

Figure 1. General framework for water use impact assessment for feed production and on-farm water use (grey water not included in the water use part of the study)

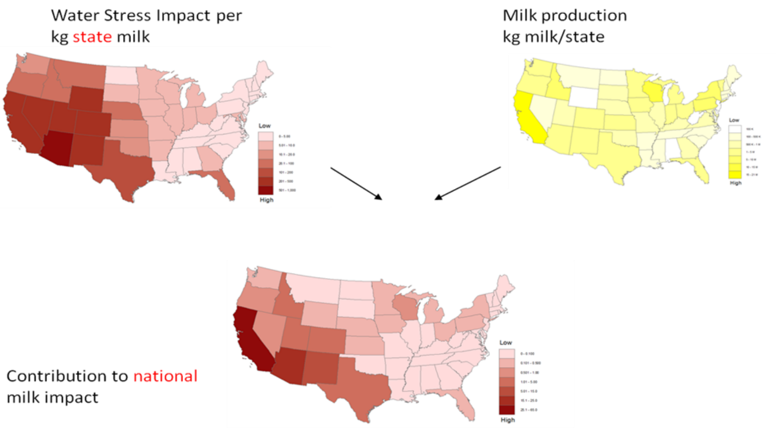

Figure 2. Water stress assessment of corn grain and milk production in the U.S., combined to give the contribution to impact of milk at the national level

Monthly characterisation factors for water consumption and application to temporally explicit cereals inventory

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Relevance of spatial resolution for assessing water consumption and related impacts of plant has been highlighted in previous research (e.g. Pfister et al., 2011). However, the temporal dimension of crop cultivation and related impacts has been neglected, although different crop options can shift irrigation water consumption within a year and hence lead to higher or lower water stress in the region. Furthermore, in some regions temporal dimension is crucial, especially in cases with high variability of water availability. Consequently, annual assessment might be misleading in guiding crop choices within and among different regions. Temporal resolution is therefore essential for proper LCA of crop production.

We developed water stress index (WSI) on a monthly basis for each watershed, based on the approach of Pfister et al. (2009). In a second step, crop water footprints (WFP) are calculated by multiplying monthly WSI ($WSI_{monthly}$) with monthly crop irrigation water requirements (IWR) modelled on high spatial resolution following the approach described in Pfister et al. (2011). The IWR are related to kg crop through location-specific attainable yields (Fischer et al. 2000).

The original, annual WSI includes a term for temporal variability of water availability in order to account for increased pressure in watersheds with unstable water supply over time. This factor has been excluded as it is explicitly covered by applying monthly WSI. Only the inter-annual variability is accounted for by the geometric standard deviation (s^*_{year}) of annual precipitation data during the "climate normal period" (1961-1990) within each river basin. Consequently the WSI function of each watershed is adjusted to:

$$WSI_{monthly} = \frac{1}{1+e^{-9.8 \cdot WTA^*_{monthly}}\left(\frac{1}{0.01}-1\right)} \qquad \text{with} \qquad WTA^*_{monthly} = WTA_{monthly} \cdot s^*_{year}$$

$WTA_{monthly}$ is the monthly withdrawal to availability ratio. It is determined by aggregating 0.5 arc-degree model data by Fekete et al. (2002) to watershed level and adjusting the results by comparing the annual data with the data from WaterGAP Alcamo et al. (2003).

Fig. 1 shows the results of applying $WSI_{monthly}$ to monthly IWR of wheat production ($WFP_{monthly,\ wheat}$) in contrast to the annual assessment using the original WSI ($WFP_{annual,\ wheat}$): while the global pattern of water stress induced by wheat production does not change dramatically (Fig. 1A/1B), the ratio of the two results indicates clearly the relevance of temporal resolution (Figs. 1C, 2). As both, water consumption and water stress is heavily depending on the growth period, the developed $WSI_{monthly}$ are crucial to determine optimal crop selection and growth periods of crops regarding water resources. In Figure 1D the difference of crop growing period is shown for the case of rice vs. wheat at the example of Europe: Wheat has a significantly lower water footprint when assessed on monthly basis for arid regions, where it is grown as a winter crop with lower water stress. For rice which is grown during summer this effect is not observed and the differences between annual and monthly assessment are minor. The boxplots (Fig. 2) indicate the strong correlation but show relatively high variability in regions with average water footprints, especially for wheat.

References

Alcamo, J., Doll, P., Henrichs, T., Kaspar, F., Lehner, B., Rosch, T., Siebert, S., 2003. Development and testing of the WaterGAP 2 global model of water use and availability, Hydrolog. Sci. J., 48 (3), 317-337.

Fekete, B.M., Vorosmarty, C.J., Grabs W., 2002. High-resolution fields of global runoff combining observed river discharge and simulated water balances, Global Biogeochem. Cycles, 16 (3): 15-1 to 15-10.

Fischer, G., van Velthuizen, H., Nachtergaele, F., Medow, S., 2000. Global agro-ecological zones. FAO and IIASA, http://www.iiasa.ac.at/Research/LUC/GAEZ/index.htm, Accessed August 3, 2009.

Pfister, S., Bayer, P., Koehler, A., Hellweg, S., 2011. Environmental impacts of water use in global crop production: hotspots and trade-offs with land use. Environ. Sci. Technol., 45(13), 5761-5768

Pfister, S., Koehler, A., Hellweg, S., 2009. Assessing the environmental impacts of freshwater consumption in LCA. Environ. Sci. Technol., 43, 4098-4104

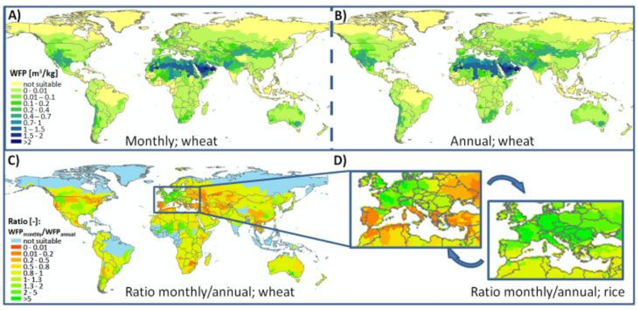

Figure 1. The maps represent the water footprint (WFP) analysis of wheat production based on temporal explicit, monthly (A) vs. annual average assessment (B). The differences are further visualised by the ratio between the two approaches (C). This better indicates the divergence that is quite significant in many places. To illustrate the relevance of crop choices and temporal resolution, we compared wheat to rice (D). This shows clearly how wheat and rice feature different or even opposite effects of temporal resolution on WFP: e.g. in Spain, Greece and Italy where wheat is cultivated as a winter crop the monthly analysis reveals much lower water stress, while for rice, a summer crop, this is not observed.

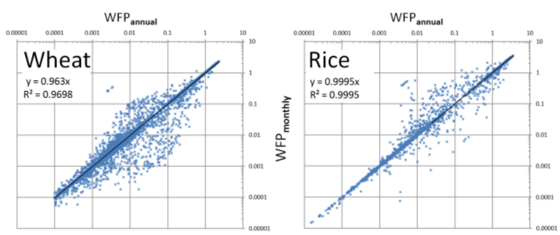

Figure 2. The boxplots represent individual water footprint values for wheat and rice production based on annual (WFP_{annual}) and monthly assessments ($WFP_{monthly}$) for each watershed. The linear regression indicates that monthly WFP are generally lower than WFP_{annual} for wheat, and quite consistent for rice. Also the variability is much higher for the case of wheat, WFP_{annual} revealing the importance of temporal explicit WFP. In some cases the difference is almost to 2 orders of magnitude.

Sustainable intensification in winter oilseed rape production – results from an AgBalance™ study

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Sustainability has become a major concern for modern agriculture. The general sustainability debate in agriculture has strongly focused on its environmental impact. As a result, low-input farming practices have been widely regarded as 'more sustainable' compared to intensive production. In order to gain a broader view of the sustainability of intensive farming, an AgBalance™ case study was conducted using winter oilseed rape production in Northern Germany as an example.

AgBalance™, a new holistic method to assess sustainability in agriculture, is based on BASF's Eco-Efficiency and SEEBALANCE Analysis, to which, in consultation with international stakeholders and experts, new indicators specific for agriculture were added. AgBalance comprises up to 70 individual impact indicators, based on a significantly larger number of input data and parameters. It is flexible to address variable upstream and downstream processes, includes all three dimensions of sustainability, environmental, social and economic aspects, in an integrated approach, and is suitable to be applied in different geographic and climatic contexts.

In the case study on winter oilseed rape, the definition of the functional unit is the "production of 1 ton of oilseed rape, cradle to field border, in Mecklenburg-Vorpommern, Germany, product water content below 9%, data from 2008 and 1998." The considered alternatives comprised the average farm practice in Mecklenburg-Vorpommern in 2007/08 compared to 1997/98. The system boundaries were set to include the extraction of raw materials, the production of pesticides, fertilisers, fuels and seed, transports; as well as the primary agricultural production ("cradle to field border").

The study found that the average farm practice in 2007/08 was about 40 percent more sustainable than 1997/98's practice. Higher yields due to new open-pollinating as well as increased use of hybrid varieties, required a more intensive use of fertilisers and plant-protection compounds in 2007/08. Lower variable and fixed costs per customer benefit led to improved profitability by about 30 percent on the part of economy.

Despite the intensified use of agrochemicals, the environmental dimension in total exhibited the most substantial improvement (about 60 percent). Both the improved ecotoxicity profile of the agrochemicals used as well more protected areas increased the potential for biodiversity development in the region concerned. Moreover, due to the more efficient land use, an improvement of the other environmental impact categories such as energy consumption, water use or resource depletion was found. The third dimension, society, remained almost unchanged in the sum of aspects considered

In a scenario analysis, it could be shown that e.g. the use of nitrification inhibitor-based fertiliser use resulted in an additional increase in the sustainability performance compared to the 2007/08 performance. On the part of economy and society, there was no substantial change in the sustainability performance. This indicates that nitrous oxide emissions can be reduced through targeted measures without placing a burden on the overall sustainability of the system. Taken together, this study illustrates that intensification of agriculture can result in a more sustainable production.

References

Kölsch, D., Saling P., Kicherer A., Grosse-Sommer A., Schmidt I, 2008. How to measure social impacts? A socio-eco-efficiency analysis by the SEEBALANCE® method. Int. J. Sustain. Dev. 11, 1-23.

Saling P., Kicherer A., Dittrich-Kraemer B., Wittlinger R., Zombik W., Schmidt I., Schrott W., Schmidt S., 2002. Eco-efficiency Analysis by BASF: The Method. Int. J. Life Cyle Assess. 7, 203-218.

Schöneboom J.C., Saling P., van Gelder R. 2012. AgBalance – Holistic Assessment of Sustainability in Agriculture. Submitted to Int. J. Life Cycle Assess.

Assessment of existing and potential cereal food and non-food uses by combining E-LCA and S-LCA

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In Wallonia (Belgium), roughly 60% of the arable cropped area is dedicated to cereals (DGSIE, 2010). More than a half of the cereal chains are currently turned towards animal feed. Direct human food uses, i.e. milling and brewing, barely reach 10% of the grain production, mainly because of low prices paid for food varieties, less favourable climate conditions and scattered plots of land. Non food uses are growing too, with 16% of the Walloon cereal production converted into bioethanol or biogas (Table 1, Figure 1). Based on a comprehensive description of the Walloon cereal sector, the project "Alternatives for Cereals – in short ALT-4-CER" considers current and future opportunities for food, feed, fuel and fibre uses of Walloon cereal resources (so-called "4F" scenarios) through an exhaustive comparison of sustainable performances of existing and potential conversion chains. Studied cereals are wheat, barley, spelt, grain maize and forage maize. Walloon cereal flow quantification and scenario definition was supported by the consultation of all involved stakeholders of the cereal chain (producers, wholesalers, processors, consumers, and decision makers) in order to ensure a scientific approach based on existing and realistic potential cases. Beside the current baseline situation (2010), historic trends and projections up to 2030 supported the definition of potential 4F scenarios for Walloon cereal uses. Scenarios have been established with contrasting hypotheses: (1) "Business-as-usual" scenario: current trends are extrapolated from the past 15 years; (2) "Strategic" scenario: environmental, economic and social optimisation of current system; (3) "Localisation" scenario: development of new cereal conversion units in Wallonia (added value relocated within the region) and increased autonomy; and (4) "Globalisation" scenario: world demand drives cereal resources outside Wallonia (massive export), and Wallonia focuses on high added-value products (biorefinery, bio-based chemistry) (Fig. 2). Scenarios are now being evaluated regarding environmental and socio-economic aspects through Life Cycle Analyses fed by region-specific data adapted to the local context. Multifunctional systems such as 4F cereal chains involve specific methodological choices regarding functional unit selection, system boundary definition, impact or stakeholders categories. As so, consequential LCA is the relevant option to assess the consequences of possible evolutions in the Walloon cereal sector by providing clues on potential environmental and socioeconomic impacts of the different scenarios. Environmental Life Cycle Analysis (E-LCA) aims at identifying territorial differences regarding the cultivation step in comparison with generic data found in commonly used databases. Beside E-LCA, a Social Life Cycle Analysis (S-LCA) methodology is being elaborated in order to grasp all 3 pillars of sustainable development. This implies the definition of a range of particular and workable indicators. In a later step, environmental and socio-economic assessment results will be integrated thanks to multi-criteria analysis involving once again the stakeholders. The project will help answering key questions raised today by society: "What type of agriculture do we want for tomorrow? Is it ethically, environmentally and economically sustainable to dedicate cereals resources to other uses than human food?".

References

DGSIE, 2010. SPF Economie - Direction générale statistique et information économique – Recensements agricoles de 1995, 2000, 2005, 2007-2010.

Table 1. Production and uses of Walloon cereal resources in 2010

Use	Grain		Forage maize		Straw		TOTAL	
	1000 T FM[a]	%	1000 T FM[a]	%	1000 T FM[a]	%	1000 T DM[b]	%
Food	125	8	0	0	0	0	108	4
Feed	724	46	2601	98	68	11	1544	57
Fuel (ethanol and biogas)	501	32	53	2	0	0	449	16
Fibre (animal litter)	0	0	0	0	547	89	465	17
Export	227	14	0	0	0	0	160	6
TOTAL	**1577**		**2654**		**616**		**2725**	

[a]FM = fresh matter ; [b]DM = dry matter

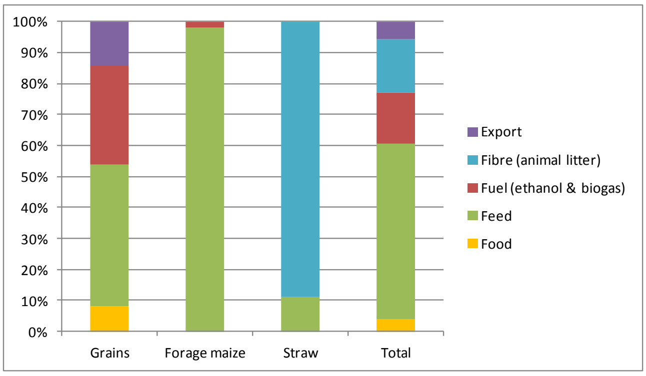

Figure 1. Uses of Walloon cereal resources in 2010.

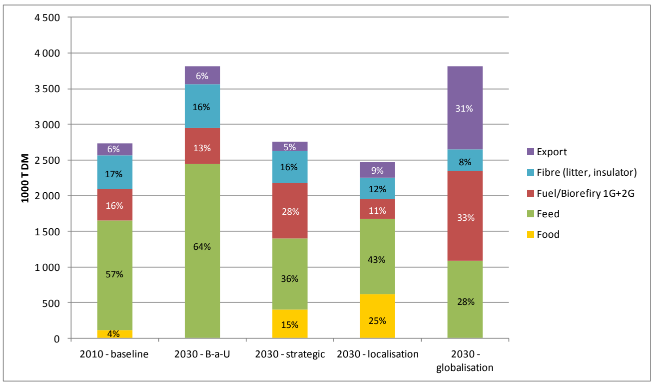

Figure 2. Production and uses of main Walloon cereal resources (wheat, barley, spelt, grain maize and forage maize) in the 4 scenarios (DM = dry matter).

Life cycle costing of farm milk production – cost assessment of environmental impact mitigation strategies

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Agriculture is a significant contributor to environmental impacts. A study by the University of Arkansas [1] showed that 70% of the carbon footprint of US milk occurs at or before the farm gate. Agriculture is also one of the main contributors to water use and land use, as shown by an on-going comprehensive milk life cycle study (University of Michigan, 2011). The goal of this presentation is to present a methodological approach of LCC and an analysis of 3 case studies of milk impact mitigation strategies (Table 1).

Different methods were used to simultaneously assess cost and impact variations. The first one uses cost and impact differences over one year assuming reference situation and scenario are steady-state situations. The second one considers that choosing the scenario will lead the farmer to make new investments and to assess their profitability over their life time. It assesses the net present value (NPV) of the investment, as well as its internal rate of return. We compare those values to the cumulated environmental impact over the same period.

The first case study describes a change of manure management system to a digester for a pilot farm of 1100 cows located in upstate New York. A digester providing electricity reduces the annual carbon footprint of the farm by 17% and increases the annual cost of 2% in a steady state situation. At market conditions, the NPV of the electricity production did not cover the investment and maintenance costs over the lifetime of the digester (Figure 1). We discuss the profitability of the digester, which is highly dependent on additional revenues like grants, Renewable Energy Credits (REC) and/or Carbon Credits. We also discuss the dependability of the cost assessment on the value of the discount rate, and propose an alternate approach to avoid the variability.

The second case study compares the cost and environmental impacts of the production of corn (one of the major dairy feed) in three cases of irrigation. The costs and impacts (water and land use) are quantified in a sample US state for a steady state situation, in 3 cases: rainfed, gravity irrigation, and pivot irrigation. This case study provides perspective on how best to represent the costs and revenues, in term of functional unit or linked to quantities that are more significant to a farmer, such as surface cultivated. Trade-offs between yield and environmental impacts are also discussed.

The third case study focuses on energy saving on the farm. This case study is profitable on an annual basis, and on a cumulated discounted basis. In this third case, the changes do not require a significant capital investment, and they are positive both in term of impacts and in term of costs.

This study couples environmental impacts and costs, providing a general approach to improve the environmental footprint of milk production on a large range of impacts (GHG, water use, land use) with a measure of the financial costs or benefits of the changes.

References

Thoma, G et al., 2010. Greenhouse Gas Emissions from Production of Fluid Milk in the US. University of Arkansas & Michigan Technological University.

Rotz, CA, Corson, MS, Chianese, DS, and Coiner, CU., 2011. The Integrated Farm System Model (IFSM), version 3.4. Agricultural Research Service - United States Department of Agriculture, USA.

Rotz, C.Alan, Hafner, Sasha D., 2011. Whole Farm Impact of Anaerobic Digestion and Biogas Use on a New York Dairy Farm, ASABE meeting presentation.

Table 1. Case studies presented

	Title	Description	Life Cycle Boundaries	Life cycle costing perspective	Impact studied
#1	Digester scenario	change of manure management: from covered slurry without natural crust to a digester	Cradle to dairy farm gate	Dairy farm producer	GHG
#2	Irrigation scenario	Change from rain fed corn grain production to irrigated corn grain production; two alternatives studied: gravity irrigation and pivot irrigation	Cradle to feed producer gate	Feed producer	Water stress Land use
#3	Electrical equipment scenario	Improvement of electricity efficiency of dairy farm lighting and equipment	Cradle to dairy farm gate	Dairy farm producer	GHG

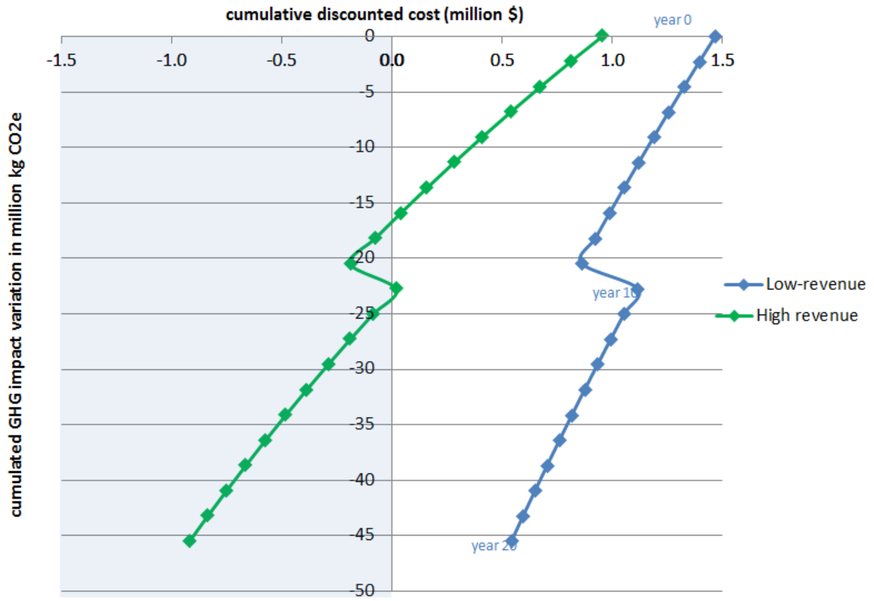

Figure 1. Cumulative impacts and costs of the two digester scenarios over 20 years

Comparing integral sustainability performance of conventional farms with farms focussing on internal recycling of nutrients

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Sustainable milk production systems require economically viable, environmentally sound and socially acceptable practices. We compared sustainability indicators of a group of conventional farms (n=33) with a group of farms aiming at an improved nutrient cycle (INC) on their farm (n=9). INC farms focus on optimising use of on-farm available resource, for example, soil organic matter, nutrients from manure, home-grown feed production and utilisation, in order to minimise use of external inputs (Van Hees et al. 2009). Several studies have assessed the environmental performance of INC farms in the past (Sonneveld et al., 2008). So far, however, no life cycle assessment (LCA) of INC farms has been performed. Moreover, an integral assessment, including environmental, economic and societal indicators has never been performed.

Economic performance was based on net farm income (NFI) and labour productivity. Environmental performance indicators were derived from a cradle-to-farm-gate life cycle assessment, i.e., land occupation (LO), non-renewable energy use (NREU), global warming potential (GWP), acidification potential (AP) and eutrophication potential (EP). Moreover, soil- and water quality were monitored. Societal performance was quantified with payments for ecosystem services, grazing hours and penalties for aberrant milk composition.

Data needed to quantify economic, environmental and societal indicators of farms were derived from the farm accountancy data network (FADN) and the Minerals Policy Monitoring Programme, and analysed for 2008 and 2009. Available site-specific soil information included soil organic matter contents and soil P levels. LCA data was based on Thomassen *et al.* (2009) and additional empirical data, literature or expertise from feed processing companies (Velthof *et al.*, 2010)

Both groups of farms were comparable in terms of farm size, intensity and milk production (Table 1). The proportion of grassland for INC farms was significantly higher (P< 0.05) than conventional farms. The conventional farms only have sandy and clay soils, INC farms have additional to this, a small proportion of peat soil (P<0.05). INC farms positively differ from conventional farms in a lower non-renewable energy use, higher soil organic carbon and receiving higher payments for ecosystem services (all P<0.05), without compromising on their economic performance. However, significant differences between INC farms were limited, despite INC farm follow a farming practice aiming at optimising use of on-farm available resources. Overall, most performance indicators did not show significant differences. High standard deviations indicate that differences within groups are mostly higher than between groups.

References

Sonneveld, M.P.W., Schröder, J.J., De Vos, J.A., Monteny G.J., Mosquera, J., Hol, J.M.G., Lantinga, E.A., Verhoeven, F., Bouma, J., 2008. A Whole-Farm Strategy to Reduce Environmental Impacts of Nitrogen. J. Environ. Qual. 37(1), p. 186-195.

Thomassen, M.A., Dolman, M.A., Van Calker, K.J., De Boer, I.J.M., 2009. Relating life cycle assessment indicators to gross value added for Dutch dairy farms. Ecological Economics 68, 2278–2284.

Van Hees, E.M., Otto, A.A.C., Van der Schans, F.C., 2009. Van Top-down naar Bodem-up. Review van kringlooplandbouw in de melkveehouderij. Centrum voor Landbouw en Milieu, Culemborg.

Velthof, G.L., Van Bruggen, C., Groenestein, C.M., De Haan, B.J., Hoogeveen, M.W., Huijsmans, J.F.M., 2009. Methodology to calculate ammonia emissions by Dutch agriculture. Statutory Research Tasks Unit for Nature & the Environment, Wageningen.

Table 1. Weighted mean and standard deviations (SD) of farm characteristics of conventional farms and farms aiming at an improved nutrient cycle (INC) (average 2008-2009)

Characteristic	Conventional mean (SD)	INC mean (SD)	Sig[b]
Farm land			
Utilised agricultural area (ha)	45.9 (21.5)	50.1 (19.0)	
Grassland (%)	87 (11)	97 (6)	*
Arable land (%)	13 (10)	3 (5)	*
Sandy soil (%)	64 (49)	60 (44)	
Peat soil (%)	0 (0)	1 (1)	*
Clay soil (%)	36 (49)	39 (44)	
Poorly drained land (%)	22 (20)	19 (18)	
Moderately well drained land (%)	75 (21)	79 (17)	
Well drained land (%)	3 (9)	2 (5)	
Animal production			
Cows (#)	69.5 (33.8)	74.8 (35.2)	
Total milk prod. (kg FPCM[a])	553,570 (273,057)	573,525 (255,106)	
Milk prod. per cow (kg FPCM)	7,960 (859)	7,663 (691)	
Milk prod. per ha (kg FPCM)	12,092 (1,537)	11,439 (1,565)	

[a] Fat-and-Protein-Corrected Milk. [b] *:P<0.05; ** P<0.01; ***:P<0.001

Table 2. Weighted mean and standard deviations (SD) of sustainability performance of conventional farms and farms aiming at an improved nutrient cycle (INC) (average 2008-2009)

Indicator	Conventional mean (SD)	INC mean (SD)	Sig[b]
Economic performance			
Labour productivity (minutes labour / kg FPCM)	39 (13)	42 (18)	
Farm income (€ / 100 kg FPCM)	5.71 (6.84)	8.26 (6.54)	
Environmental performance (LCA)			
On-farm land occupation (m^2 / kg FPCM)	0.8 (0.1)	0.8 (0.1)	
Off-farm land occupation (m^2 / kg FPCM)	0.6 (0.3)	0.5 (0.1)	
Total land occupation (m^2 / kg FPCM)	1.4 (0.3)	1.3 (0.2)	
On-farm non-renewable energy use (MJ / kg FPCM)	1.0 (0.3)	0.8 (0.2)	*
Off-farm non-renewable energy use (MJ / kg FPCM)	5.0 (1.0)	4.3 (0.8)	*
Total non-renewable energy use (MJ / kg FPCM)	5.9 (1.0)	5.0 (0.8)	*
On-farm global warming potential (kg CO_2eq / kg FPCM)	0.8 (0.1)	0.8 (0.1)	
Off-farm global warming potential (kg CO_2eq/kg FPCM)	0.6 (0.1)	0.5 (0.1)	
Total global warming potential (kg CO_2eq / kg FPCM)	1.4 (0.2)	1.3 (0.2)	
On-farm acidification potential (g SO_2eq / kg FPCM)	5.7 (2.9)	5.4 (3.8)	
Off-farm acidification potential (g SO_2eq / kg FPCM)	5.0 (1.1)	4.3 (0.8)	
Total acidification potential (g SO_2eq / kg FPCM)	10.7 (3.3)	9.7 (4.0)	
On-farm eutrophication potential (g NO_3-eq / kg FPCM)	32.9 (16.7)	30.3 (20.5)	
Off-farm eutrophication potential (g NO_3-eq / kg FPCM)	45.4 (14.9)	35.1 (8.7)	
Total eutrophication potential (g NO_3-eq / kg FPCM)	78.2 (24.7)	65.4 (26.2)	
Soil Organic Carbon grassland (ton / ha)	152 (40)	186 (42)	*
P-Al grassland (mg / 100 gram soil (0-10 cm))	38 (9)	36 (4)	
Soil Nitrogen Supply grassland (kg / ha)	191 (18)	196 (13)	
Nitrate concentration (mg NO_3^- / litre)	22 (22)	12 (12)	
Phosphorus concentration (mg P / litre)	0.2 (0.2)	0.7 (1.1)	
Societal performance			
Grazing (hours / cow)	2,509 (1,305)	2,006 (1,312)	
Payment for ecosystem services (€ / ha)	24 (46)	166 (175)	**
Penalties for aberrant milk composition (%)	2.4 (3.9)	1.4 (3.1)	

[a] Fat-and-Protein-Corrected Milk. [b] *:P<0.05; ** P<0.01; ***:P<0.001

Environmental improvement of a chicken product through life cycle assessment methodology

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Spain is traditionally one of the major producers of chicken meat in the European Union. In the last years consumers demand has risen to 1.12 million tons accounting one of the highest consumption ratios in the UE (around 24 kilograms per capita), which represents twenty-five per cent of the meat globally consumed in the Spanish market. At the same time, the concern with environmental issues related to meat production, with special regard to acceptable levels of nitrogen and phosphorus, or the contribution of the sector to the emissions of greenhouse gases, may lead to a significant increase in costs in the poultry sector.

From a multidisciplinary approach the project ECOALIM aims to perform the eco-design of a meat product as a way to develop more efficient and sustainable food products throughout its whole life cycle. Four different research centres were involved to investigate innovative technologies and processes in their respective areas of expertise under the common objective of reducing the environmental impact of a food product along various stages of the supply chain. The product chosen for the study was a 600gr tray of sliced chicken breast fillets packaged in modified atmosphere. The most significant impact sources were identified following ReCiPe method for impact assessment. Several potential improvements were proposed, based on a technical and environmental point of view, with special focus on the application of innovative solutions:

- Processing of food industry by-products as valuable ingredients for animal feed.
- Pulsed light technology for water decontamination and re-use in food sector
- Development of a biodegradable packaging for meat products
- Energy and resources reduction in the distribution system by means of improved storage, routes optimisation and reverse logistics solutions.

Once the selected improvements were developed and adapted to the industry, LCA methodology was applied again in order to evaluate the environmental impact of the new food chain. According to LCA results, significant impact reductions were achieved. In the food production stage, freshwater eutrophication and global warming effect decreased 11% and 6% respectively by replacing conventional ingredients with tomato by-products in the poultry diet. Water consumption and wastewater generation was minimised about 15% in the slaughterhouse and meat processing stage through reutilisation alternatives and pulsed light decontamination. Conventional plastic tray and film were replaced with biodegradable materials avoiding up to 20% of greenhouse gases emissions through its life cycle. However eco-designed package showed an increased impact in freshwater eutrophication. Product distribution was also optimised by improving refrigerated storage and logistics. Relevant reductions in electrical and diesel consumption were estimated up to 15% at this phase.

Along the ECOALIM project, LCA methodology has been successfully applied in order to identify critical operations and technologies from an environmental point of view but also to the comparative analysis between processes and alternative technologies. So far, LCA proved to be a useful tool directly involved in the decision making process when optimising food chains from an environmental point of view, but also a considerable option to promote competitiveness, innovation and sustainability through the eco-design of food products.

References

FAOSTAT: Statistical data bank of the Food and Agricultural Organization (FAO) of the United Nations (http://faostat.fao.org)

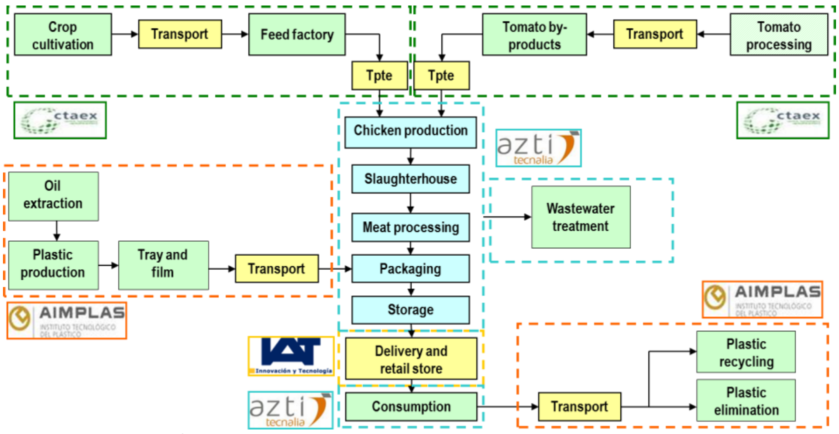

Figure 1. Main flow diagram in chicken breast fillets production

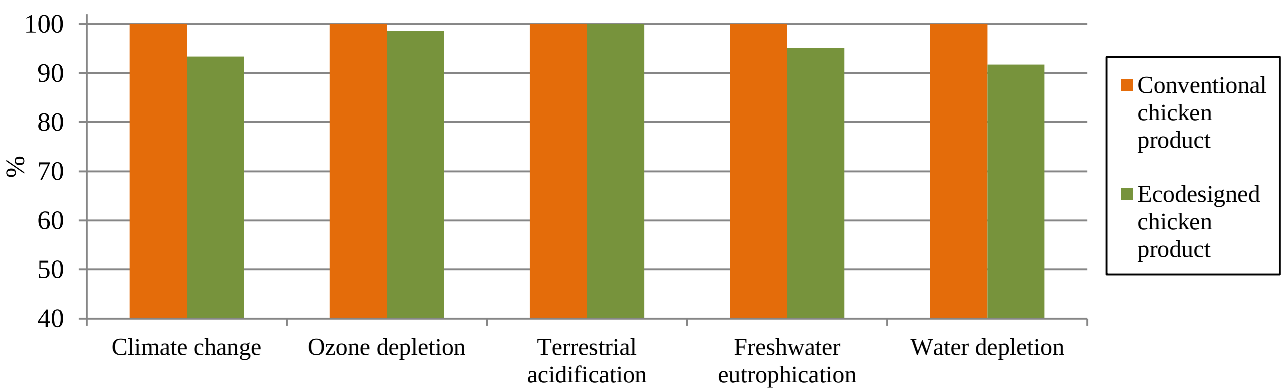

Figure 2. Environmental impacts per FU (600-g tray of chicken breast fillets)

Product-Oriented Environmental Management System (POEMS) in the agri-food sector: main results of the EMAF project

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POEMS is a new framework designed to bring together traditional environmental management systems and tools oriented towards environmental product performances. Despite there still being no standard reference and few studies available in literature, with only one first attempt in the agri-food sector (Ardente et al., 2006), a growing number of organisations are experiencing the need to integrate environmental management systems standards with those ones addressed to the environmental evaluation of products, shifting attention from system/process to product/service.

In this context, the aim of this paper is to present the main results of the Eco-Management for Food Project (EMAF Project) co-funded by the Italian Ministry of Education, University and Research (PRIN No.2008TXFBYT) (EMAF, 2012). Within the EMAF project, a POEMS framework that is specifically tailored for the agri-food industry was designed and implemented. The choice of this particular sector was mainly due to its environmental and economic importance in the European Union (EC, 2006).

The POEMS framework has a modular structure as it is made up of a set of complementary tools that can be applied either individually or as two or more elements integrated, on the basis of organisations' specific requirements and of the objectives they aim to reach: an Integrated Quality and Environmental Management System (ISO 9001 and ISO 14001/EMAS); a simplified methodology of Life Cycle Assessment; guidelines targeted to organisations operating in the agri-food chain for the outlining of the most appropriate environmental label for their products.

Finally, this paper describes the main results of the POEMS framework implementation to different pilot food companies, in order to verify the effective functioning and to highlight the strong and weak points of the POEMS model and of its individual fundamental elements. In particular, various businesses operating in the agri-food sector were analysed, involving businesses of various sizes and with different organisational structures, as in the following:

a) integrated management system in the tomato puree production chain
b) streamlined LCA of the winemaking chain
c) guidelines for ecological labelling in the pasta chain of production
d) POEMS in the olive growing and producing chain
e) POEMS in the coffee production chain.

References

Ardente, F., Beccali, G., Cellura, M., Marvuglia, A., 2006. POEMS: a case study of a winemaking firm in the South of Italy. Environmental Management. XXXVIII, 3, 350-364.

EMAF - Eco-Management for Food Project. Available from http://ww2.unime.it/emaf/ Last visited on 10/02/2012.

European Commission, 2006. Environmental Impact of Products (EIPRO). Analysis of the life-cycle environmental impacts related to the final consumption of the EU-25. DG Environment and DG JRC. Available from http://ec.europa.eu/environment/ipp/pdf/eipro_summary.pdf.

An LCA support tool for management of protected horticultural systems

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Life cycle assessment (LCA) is a useful tool for environmental management. Nevertheless, its methodological complexity hampers its application by non-specialists. The objective of this work was to develop a simple tool to facilitate LCA use by a broad range of users. The simulation tool should be useful to calculate the efficiency of inputs of protected crops and help growers and advisors with options to reduce environmental impacts. The aim was to design an easy-to-use tool with understandable results, to encourage stakeholders in horticulture to simulate environmental assessments. For this purpose, the web platform was chosen to reach a broad range of public.

The methodology used was a simplified LCA, following the principle of "as simple as possible and as complex as necessary". This study was in the context of EUPHOROS project (EUPHOROS, 2008-2012) and was based on reference scenarios analysed in previous tasks, which were representative production systems in different climate conditions in Europe. As a result, three scenarios were considered in this web tool: a multi-tunnel greenhouse with tomato production under Southern European climate conditions and Venlo glasshouses with tomato and rose production under Central European climate conditions. Additionally, users could use the simulation tool for other type of crops, such as vegetable crops with similar agronomic management techniques. The tool is an Excel file structured in four sheets: instructions, input data, total results and detailed results. The environmental analysis can be conducted by following a few easy steps. First step is to select the scenario and to answer a questionnaire with specific data about the production system under analysis. Data refers to greenhouse dimensions, substrate, electricity consumption, water, fertilisers, pesticides, heating, waste and transport. The web tool provides data for the reference scenarios that can be used if users do not have specific data. Some cells include comments or drop-down lists to facilitate data entry. A link to a fertiliser calculator can be used to calculate the total amount of nutrients applied to the crop, one of the main issues in horticultural production systems. Equations were developed to determine materials with major contribution in the structure (plastic, steel and glass) and only require few data concerning greenhouse dimensions. Finally, results can be consulted in results sheets for six midpoint impact categories: abiotic depletion potential (ADP), air acidification potential (AAP), eutrophication potential (EUP), global warming potential (GWP), photochemical oxidation potential (POP) and cumulative energy demand (CED). Results for reference scenarios were included to be used for comparison with user's results. The tool was used to compare a user's situation with reference situation. User's data (Table 1) were for a smaller greenhouse, lower fertilisers' doses and higher yield than reference situation. Results in Fig. 1 show lower contributions to EUP and GWP for user's situation compared with the reference situation, mainly because of lower contributions by fertilisers and the effect of a higher yield, as environmental impacts are referred to a mass functional unit (ton of tomatoes). With this simplified calculator, users can make few changes in inventory data, evaluate easily the effect on results per total production system and per stages and compare with the reference situation.

We can conclude that this web tool is useful to calculate the environmental performance of protected horticultural production systems. Nevertheless, authors recognise that the tool could be strengthened detailing fertilisers and pesticides results or extending the number of reference scenarios. Information for such improvements is available and could be used in future research. In this study, the priority was to contribute to LCA dissemination applied to protected crops with a friendly tool and collecting the opinion of users. The web tool is available at the web site of EUPHOROS project in several languages.

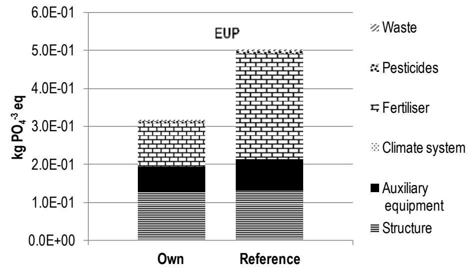
References

EUPHOROS, 2008-2012. Efficient use of inputs in protected horticulture. In: KBBE-2007-1-2-04 SFPT. www.euphoros.wur.nl/UK/.

Table 1. Questionnaire summary of input data sheet, for a tomato crop in a multi-tunnel greenhouse.

Issue	Input	Units	Own data	Reference data
Crop	Crop	name	Tomato	Tomato
	Yield	kg·m^{-2}	20.0	16.5
	Density	p·m^{-2}	1.23	1.23
	Stems per plant	number·p^{-1}	2	2
	Growth period	weeks	52	52
Substrate	Type of substrate	name	Perlite	Perlite
	Substrate life span	years	3	3
	Bag volume	l	30	30
	Plants per bag	number	3	3
Structure data	Span number	number	10	18
	Span width	m	6	8
	Span length	m	60	135
	Roof vents: total greenhouse number	number	10	36
	Gutter height	m	4.0	4.5
	Ridge height	m	4.5	5.8
	Greenhouse walls	material	LDPE	PC
	Greenhouse frame life span	years	15	15
	Greenhouse roof covering life span	years	3	3
	Greenhouse walls life span	years	3	15
Energy consumption	Total greenhouse electricity consumption	kWh·m^{-2}	0.641	0.641
Watering	Water consumption	L·m^{-2}	475	475
	Irrigation system Open/Closed	type	Open	Open
Fertilisers	N	kg·m^{-2}	0.050	0.060
	P_2O_5	kg·m^{-2}	0.035	0.038
	K_2O	kg·m^{-2}	0.135	0.117
Pesticides	Fungicides	kg·m^{-2}	0.00285	0.00285
	Insecticides	kg·m^{-2}	0.00038	0.00038
Heating	Heating	type	No heating	No heating
	Fuel	none	NO	NO
	Fuel consumption	m^3·m^{-2}	0.00	0.00

a)



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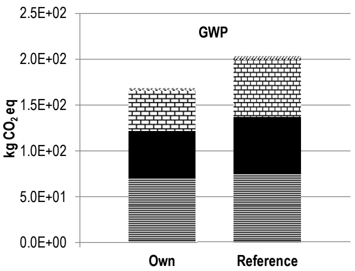

Figure 1. Stage contributions to: (a) eutrophication potential and (b) global warming potential, with own user's and reference data from table 1, per functional unit (t tomatoes).

Environmental impacts of food consumption and its reduction potentials

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Nutrition accounts for about 30% of environmental impacts caused due to the final consumption of Swiss households (Jungbluth et al., 2011b). It is thus the most important consumption sector from an environmental point of view. Therefore, it is necessary to investigate and understand the environmental impacts of food consumption and possibilities for the reduction of environmental impacts.
Several options of reducing environmental impacts have been compared within a general framework. Besides the consumption of food products also reduction potentials for impacts due to energy use in households and private mobility have been investigated (Jungbluth et al., 2011a).
In a first step the share of the environmental impacts related to food consumption has been investigated. Based on a more detailed analysis of this consumption sector, it is investigated, for which percentage environmental impacts can be reduced by a certain change in consumer behaviour. Finally, this estimation is used to estimate the potential reduction of total environmental impacts. The assessment has been made for average consumption patterns in Switzerland and for consumption patterns in the city of Zurich.
For the impact assessment the ecological scarcity method was used as a key indicator (Frischknecht et al., 2009), but the results also were compared for greenhouse gas emissions and energy use.
In this presentation we highlight and compare the reduction of total environmental impacts, if all consumers would:

- Buy locally
- Buy seasonally
- Buy vegetarian
- Buy organic food
- Resign luxury food
- Reduce food wastes
- Reduce obesity to normal weight
- Combine different changes in a healthy and environmentally friendly diet

The highest potential reduction has been calculated for a combination of different measures. Within the healthy and environmentally friendly diet, it is assumed that meat consumption is reduced considerable to two portions of meat a week instead of six. Furthermore, air-transported products are not bought and fruits and vegetables are bought seasonally. With this it would be possible to reduce the environmental impacts of total household consumption by more than 10% (and cut this of nutrition to one third). The most promising single change in behaviour is a vegetarian diet. Just a regional or seasonal choice of products on the other side does not show such a high potential for reducing environmental impacts.
Thus, it has been shown that several relevant issues should be combined in order to develop healthy and environmentally friendly food consumption patterns. Nevertheless, the reduction of meat and animal products is the most important issue from an environmental point of view.

References

Jungbluth N, Itten R., 2011a. Umweltbelastungen des Konsums in der Schweiz und in der Stadt Zürich: Grundlagendaten und Reduktionspotentiale. Zürich: ESU-services GmbH im Auftrag der Stadt Zürich (unpublished).

Jungbluth N, Nathani C, Stucki M, Leuenberger M., 2011b. Environmental impacts of Swiss consumption and production: a combination of input-output analysis with life cycle assessment. Bern, CH: ESU-services Ltd. & Rütter+Partner, commissioned by the Swiss Federal Office for the Environment (FOEN), 171 pp.

Frischknecht R, Steiner R, Jungbluth N., 2009. The Ecological Scarcity Method - Eco-Factors 2006: A method for impact assessment in LCA. Zürich und Bern: Federal Office for the Environment FOEN.

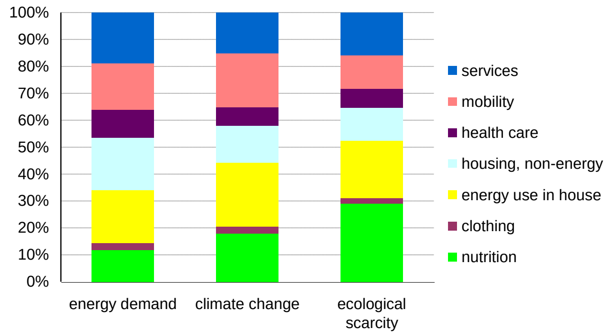

Figure. 1. Environmental impacts of different household activities (Jungbluth et al., 2011b).

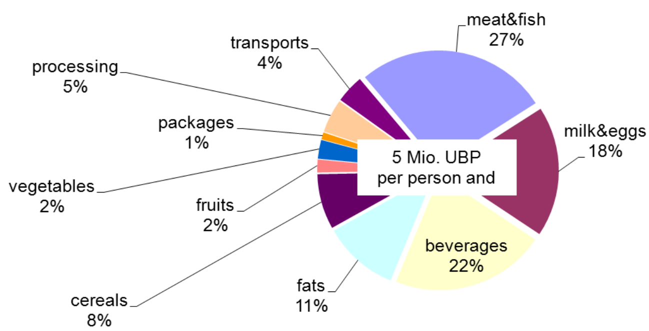

Figure 1. Importance of product groups in total impacts of nutrition

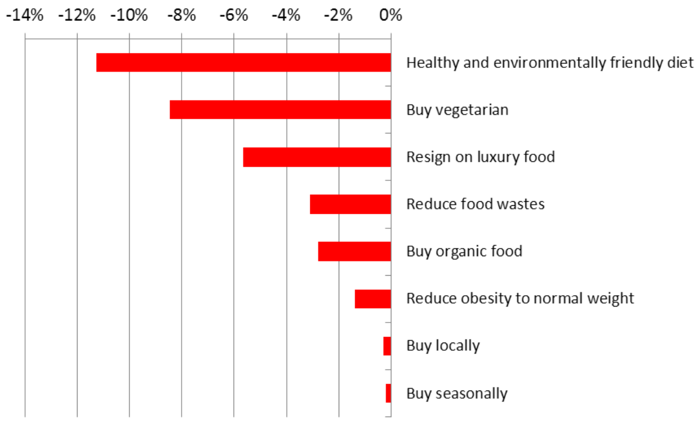

Figure 2. Reduction potentials for total environmental impacts due to behavioural changes in food consumption

Gender and dietary recommendations in an IO-LCA of food consumption in Germany

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Besides technical improvements and a reduction of food losses in the food chain, diet shifts offer practicable opportunities to reduce environmental impacts in the agri-food sector on a low-cost. Different foods of animal or plant origin play, due to their production intensity, a crucial role in the assessment of the environmental impacts of human nutrition and diets. Based on a representative nutrition survey in Germany from the year 2006, a life cycle assessment was conducted to quantify nutrition-related emissions of animal and plant-based foods, with a special focus on the socio-demographic factor gender in comparison with different dietary recommendations. Human nutrition has a strong effect on environmental impacts. Here, we consider the influence of different main-stream dietary patterns. The first part of the study builds mainly upon Meier and Christen (2012), where the influence of the factor gender in an LCA of food consumption was analysed. Here, we examine these gender-related differences in comparison to nutrition recommendations (D-A-CH & UGB), nutrition styles (ovo-lacto vegetarian, vegan) and the average diet profile 20 years ago (1985-89). For the study, representative data sets concerning German food production and consumption were used (BMELV 2009). Exact, subgroup specific intake data was provided by the both National Nutrition Surveys from the years 1985-89 and 2006 (Kübler et al. 1995, MRI 2008). The environmental impact assessment was based mainly on the input-output tables of SEEA (System of environmental and economic accounting, Schmidt and Osterburg 2011). To consider the impacts of food imports, emissions from direct land use change and land use (dLUC, LU), food processing, trade/transport and packaging, these were complemented by several LCA data sets - e.g. Leip et al. (2010), the Danish LCA Food database (Nielsen et al. 2003), Institute of applied ecology (2010). Thus, the system boundaries are set cradle-to-store. The functional unit considered on the product level refers to 1 kg consumed product. The reference year in the study is the year 2006. According to ISO 14040/14044 (2006) the four distinct steps of an LCA have been completed.

As regards environmental impact assessment, global warming potential (GWP) was assessed, which included emissions from direct land use change and land use (dLUC, LU), along with five inventory indicators (ammonia emissions, land use, blue water use, phosphorous use and cumulative primary energy demand (CED)). The following food groups were analysed: meat products (pork, beef/veal, poultry, goat/lamb), milk products (fresh milk, creamy milk products, cheese/curd, butter), egg products, fish products, grain products, vegetables, nuts/seeds, legumes, fruits, potato products, margarine/oils, sugar/sweets. For the comparison with dietary recommendations and dietary styles four quantifiable food related dietary profiles were distinguished: D-A-CH (official recommendations for Germany, Austria and Switzerland, DGE 2008), UGB (alternative recommendations by the Federation for independent health consultation with more legumes, vegetables and nuts instead of meat and milk products, UGB 2011). Data concerning the vegetarian (ovo-lacto) and the vegan diet profiles were taken from USDA, USDHHS (2010).

For all indicators the results show strong variation between the genders. Even if the physiologically different consumption amounts among men and women are levelled on a basis of 2,000 kcal person^{-1} day^{-1}, men show a higher impact in terms of GWP (CO_{2e} +8%), ammonia emissions (+14%), land use (+11%), P use (+10%) and CED (+2%). In contrast, women demonstrate a higher water demand (+18%) (Table 1, Fig. 1).

Both genders could reduce the impacts of their diets if they were to be more in line with the recommendations or diet styles. With the exception of blue water, the reduction potentials for men are twice as high as women's. In other words, the average female diet is already closer to the recommendations. Nevertheless, women's average diet corresponds to higher blue water use, mainly caused by higher consumption of fruits and nuts & seeds, which are often produced in water-scarce areas in foreign countries. Related to the average intake in 2006 the strongest reduction potentials were determined for the vegan and the ovo-lacto vegetarian diet, with the exception of blue water. Here we have to bear in mind that for the recommendations (D-A-CH, UGB) quantifiable intake amounts for nuts & seeds do not exist, although an increased intake in these scenarios would be probable. In comparison to the years 1985-89 all indicators (exception blue water) show lower impacts, mainly derived by changes in the diet. In comparison to that, impact changes due to food losses were lower and mainly contrarian, which could be explained by higher food losses in 2006 compared to 1985-89. The study shows that within one society distinct diet profiles with markedly different environmental impacts are already established. Taking cultural and physiological considerations among the genders into account, these differences could be seen as offering potential opportunities to strengthen sustainable diet profiles. Further research should also consider health impact assessments to ensure that alterations in diet profiles due to environmental constraints do not lead to disadvantageous public health effects. Particular attention should be paid here to potentially undernourished subgroups (such as toddlers, children, the elderly, sick people, pregnant women etc.).

Table 1. Environmental impacts of food consumption in the years 1985-89 and 2006 (incl. genders) in Germany as well as of several dietary recommendations & dietary styles, based on 2,000 kcal person^{-1} d^{-1}

		1985-89 mean	2006 mean	2006 men	2006 women	D-A-CH	UGB	ovo-lacto vegetarian	vegan
CO_{2e} emissions	t person^{-1} year^{-1}	2.3	**2.0**	2.1	1.9	1.8	1.8	1.5	0.9
NH_3 emissions	kg person^{-1} year^{-1}	7.7	**6.4**	6.8	6.0	5.1	4.6	3.9	0.7
Land use	m² person^{-1} year^{-1}	2,429	**2,059**	2,170	1,946	1,749	1,693	1,514	1,019
Water use (blue)	m³ person^{-1} year^{-1}	26.8	**27.1**	24.7	29.5	19.6	19.5	51.1	57.0
Phosphorous use	kg person^{-1} year^{-1}	7.4	**6.3**	6.7	6.0	5.6	5.4	4.5	2.3
Cumulative energy demand	MJ person^{-1} year^{-1}	13.0	**11.6**	11.7	11.4	10.7	11.1	10.1	8.4

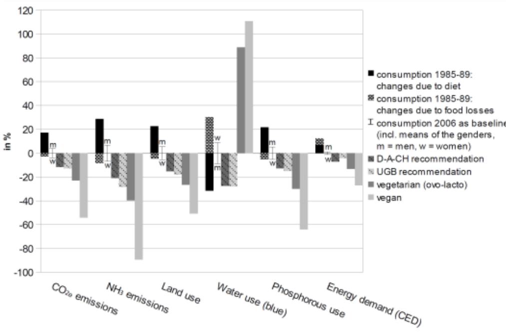

Figure 1. Environmental impacts of food consumption in 2006 in Germany as baseline scenario in comparison to 1985-89, genders and dietary scenarios, based on 2,000 kcal person^{-1} d^{-1}

Comparing environmental impacts of end-of-life treatment of food waste

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Every year huge quantities of edible food end up in landfills worldwide (e.g. 7 million tonnes in the United Kingdom and 33 million tonnes in the United States). Roughly one third originates from producers/supply chain, one third from retail and the final third from regular households. In addition to the costs for disposal, these landfills generate large amounts of greenhouse gases. Landfill gas emissions are one of the largest anthropogenic sources of methane especially because of food waste (Adhikari B. K.). In the United States food waste now represents the single largest component of municipal solid waste reaching landfills and incinerators, and generates more than 20 percent of all methane emissions in that country. Not only could the direct emissions from landfills be decreased by reducing the amount of landfilled food waste but the use of alternate methods for treatment of food waste could further reduce the environmental burden.

The goal of this study was to compare the environmental burden of landfilling with three alternative biowaste treatments "composting", "anaerobic digestion" and "municipal waste incineration" (Dinkel F., Zschokke M. and Schleiss K. (2011)). The functional unit used is 1kg of treated biowaste. Data for the investigated methods of treatment were based on ecoinvent version 2.2 and were extended with updated values. In particular, the emissions for composting and anaerobic digestion were updated by field measurements and generally show lower values than previously reported. The LCI includes new approaches to account for benefits in using biowaste as a fertiliser substitute. Studies comparing different technologies to utilise biowaste normally only take into account the benefits for energy and nutrients. These studies usually show that digestion or incineration is ecologically favourable to composting. In the this study we used an approach proposed by (Fuchs J and Schleiss K) making a substitution with peat and straw in order to include the value of soil structure on applying compost or digestate. To compare the different treatment processes, the systems were expanded using an avoided burden and basket of benefits approach (Dinkel F., Schleiss K., Zschokke M. (2009)). Different environmental impacts were calculated and to evaluate the impacts the methods Eco-Indicator 99 and ecological scarcity 2006 were used. In this abstract only results for global warming potential and Eco-Indicator 99 are presented. Several sensitivity analyses were made to determine the robustness of the impact methods.

Depending on the impact assessment method used, the ranking of the different treatment methods tend to vary. But taking into account the range of uncertainty the three examined treatment methods show comparable environmental impacts. The landfilling of food waste in contrast results in a much higher environmental impact compared to the other three treatment methods.

This study shows the enormous emission reduction potential if food waste is not landfilled but otherwise treated. Obviously it would be even better to reduce the amount of food going to waste as these methods are end of pipe solutions and the environmental impact of food production itself is normally much higher than the impact of landfill.

References

Adhikari B. K., October 2006, Waste Managment Research, vol. 24 no. 5 421-433

Dinkel F., Zschokke M. and Schleiss K., December 2011, Ökobilanzen zur Biomasseverwertung, Forschungs- und Entwicklungsprogramm Biomasse und Holzenergie, Schwerpunkt Biomasse ohne Holzenergie, Bundesamt für Energie BFE

Dinkel F., Schleiss K., Zschokke M., February 2009, Ökobilanz zur Grüngutverwertung in Basel, Amt für Umwelt und Energie, Basel-Stadt

Fuchs J, Schleiss K, 2008, Ökologische Bewertung der organischen Substanz, Zusatzmodul zu Forschungsprojekt Auswirkungen von Komposten und von Gärgut auf die Umwelt, Bodenfruchtbarkeit, sowie die Pflanzengesundheit, im Auftrag des BAFU, Bern

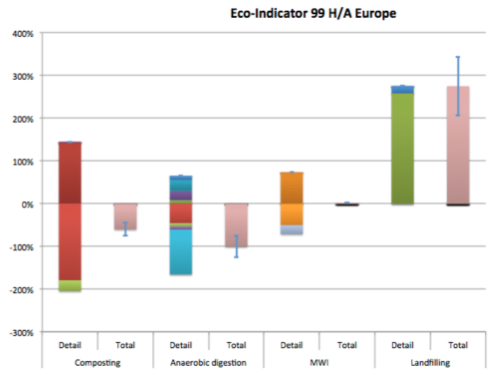

Figure 1. Eco-Indicator 99 H/A Europe

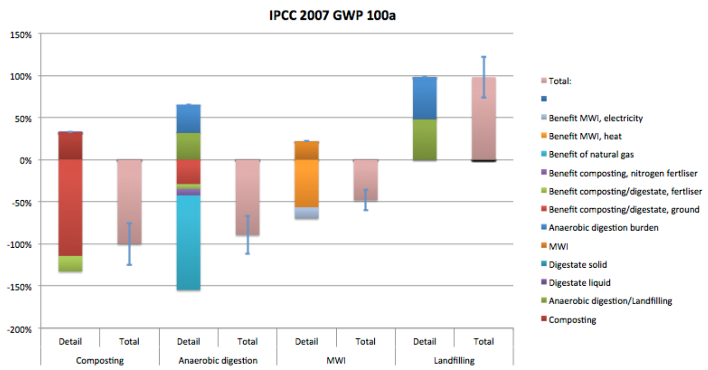

Figure 2. IPCC 2007 100a

High nutritional quality is not associated with low greenhouse gas emissions in self-selected diets of French adults

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Changing food consumption patterns is often considered as an important driver of climate change and a way of reducing the environmental impact of the food sector, which contributes approximately 15-30% of the total greenhouse gas emissions (GHGE) in the developed countries. Sustainable diets have been defined by the Food and Agriculture Organization (FAO) as "diets protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimising natural and human resources" (FAO, 2010). Accordingly, the FAO recommends to give due consideration to sustainability when developing food-based dietary guidelines and policies, and acknowledges the need for studies demonstrating the synergies between the different dimensions of sustainability (FAO, 2010). In the context of the INRA/CIRAD strategic study DuALIne (Esnouf et al., 2011), the aim of the present work was to analyse in detail the relationship between the nutritional quality of self-selected diets and their associated greenhouse-gas emissions (GHGE).

For each adult in the INCA2 national dietary survey (n=1918), the GHGE of his/her diet was estimated (in g CO_2e/d) based on the GHGE of highly-consumed foods (in g CO_2e/100g). The daily GHGE of each diet was correlated with the consumption of food-groups and with indicators of nutritional quality, such as the Mean Adequacy Ratio (MAR). Then, to avoid *a priori* assumptions about the food content of high and low nutritional quality diets, a way of classifying them that only relied on their energy density and their nutrient contents was specifically developed for this study, and the daily GHGE of diets of increasing nutritional quality according to this classification were compared. Thus, diets with the highest nutritional quality were defined as those having simultaneously, i) an Energy Density below the median, ii) a Mean Adequacy Ratio above the median and iii) a Mean Excess Ratio (percent of maximal recommended values for nutrients to limit) below the median.

Whatever the calculation basis (per 100g or per 100 kcal of food consumed) the highest GHGE was recorded for the group of meat, fish, poultry and eggs and the lowest for starchy foods. When expressed per 100 kcal, the GHGE of fruit and vegetables was similar to that of dairy products. After energy-adjustment, diet-related GHGE was positively correlated with MAR and negatively with dietary energy density. After adjustment for age, sex and energy intake, a higher consumption of sweets and salted snacks, and of mixed dishes and starchy foods was associated with a lower diet-related GHGE; in contrast, increasing the intake of the other food groups, including that of fruit and vegetables, increased diet-related GHGE (Fig. 1). High-quality diets contained more plant-based foods, notably fruit and vegetables, and less sweets and salted snacks than low-quality diets. After adjustment for energy intake, high-quality diets had significantly higher GHGE (4% and 14% in men and women respectively) than low-quality diets.

Healthy diets are supposed to be good for the environment because they mainly rely on plant-based foods which harm the environment less per unit weight than animal-based foods. In the present study, we observed that, despite containing large amounts of plant-based foods, high quality diets provide calories with a higher GHGE than low quality diets. The healthiness of diets, whether estimated by a high intake of fruit and vegetables, a low intake of sweets and salted snacks, a high nutrient density, a low energy density, or a more comprehensive definition of nutritional quality was associated with a slightly but significantly higher carbon impact. This suggests possible incompatibilities between environmental and nutritional objectives that should be further examined, using more comprehensive and detailed indicators of the environmental impact of food consumption.

References

Esnouf C, Russel M, Bricas N., 2011. Pour une alimentation durable-Réflexion stratégique duALIne.

FAO, 2010. Definition of sustainable diets. International scientific symposium "Biodiversity and sustainable diets united against hunger". FAO Headquarters, Rome.

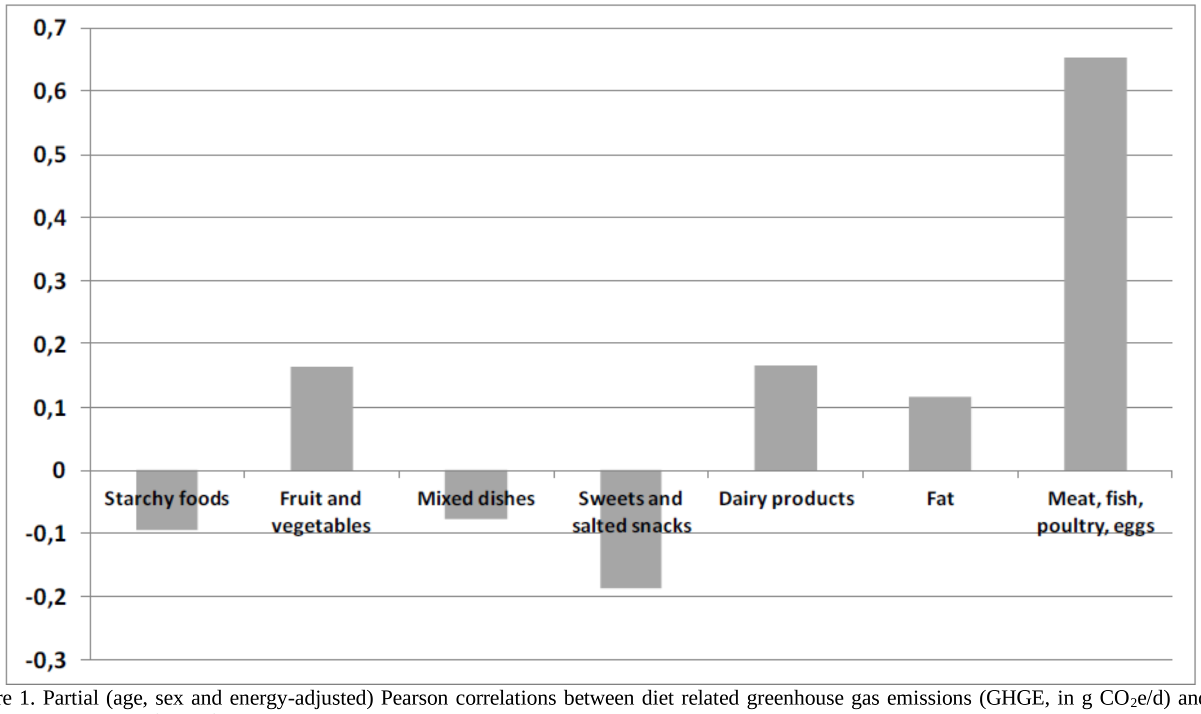

Figure 1. Partial (age, sex and energy-adjusted) Pearson correlations between diet related greenhouse gas emissions (GHGE, in g CO_2e/d) and the consumption (in g/d) of each food group by adults (n=1918) participating in the INCA2 survey.

Application of new UNEP/SETAC Life Cycle Initiative methods for land use impact assessment. Land use impacts of margarine

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New characterisation factors (CF) for land use and land use change (LUC) impacts relating to biodiversity and ecosystem services developed recently have been applied to a case study of margarine (Milà i Canals *et al*. 2012). The objectives of this study were to generate insights as to the ease of applying these new factors and to assess their value in describing a number of environmental impacts from land use and land use change relating to the margarine product system.

This case study is a partial descriptive LCA of 500g of packaged margarine used as a spread in the UK and Germany. The life cycle stages included were: agricultural production, oil processing, margarine manufacture and transportation to regional European distribution centres. In order to apply the new CF, the inventory flows for land occupation (land use) and land transformation (land use change) had to be identified and quantified. This process proved challenging particularly in terms of localising the sourcing regions, as well as tracking the land use flows in the underlying LCI databases (ecoinvent). These flows were then assessed using the new CF and land use-related environmental impact categories: Biodiversity Damage Potential (BDP, de Baan *et al*. 2012); Climate Regulation Potential (CRP, Müller-Wenk and Brandão 2010); Biotic Production Potential (BPP, Brandão and Milà i Canals 2012); and several other impacts on Ecosystem Services, other than CRP and BPP, described by Saad and Margni (2012): Freshwater Regulation Potential (FWRP); Erosion Regulation Potential (ERP); and Water Purification Potential related to Physico-Chemical Filtration (WPP-PCF) and Mechanical Filtration (WPP-MF). Figure 1 presents an overview of selected impact categories.

The new land use impact assessment methods applied help to identify hotspots in the life cycle of margarines, with different proportions and sources of vegetable oils. The specific impacts of each vegetable oil are determined mainly by the yield (and thus land occupation), but also by the type of agriculture (annual vs. permanent crops) and the sourcing location (and thus the sensitivity of biomes and occurrence of land use change).

The discussion will focus on some of the key challenges for the future application of land use impact assessment in LCA, such as the quantification of land transformation and its allocation to specific crops / products; determination of sourcing regions for globalised commodity supply chains; choice of reference situation to assess land use impacts; and the availability of data for commodity supply chains.

References

de Baan, L., Alkemade, R., Koellner, T. 2012. Land use impacts on biodiversity in LCA: a global approach. Int J Life Cycle Assess (in press).

Brandão, M., Milà i Canals, L. 2012. Global characterisation factors to assess land use impacts on biotic production. Int J Life Cycle Assess. DOI:10.1007/s11367-012-0381-3

Milà i Canals, L., Rigarlsford, G., Sim, S., 2012. Land use impact assessment of Margarine. Int. J. Life Cycle Assess. DOI:10.1007/s11367-012-0380-4

Müller-Wenk, R., Brandão, M. 2010. Climatic impact of land use in LCA—carbon transfers between vegetation/soil and air. Int J Life Cycle Assess. 15, 172-182.

Saad, R., Margni, M. 2012. Land use impacts on freshwater regulation, erosion regulation and water purification: a spatial approach for a global scale. Int J Life Cycle Assess (in press).

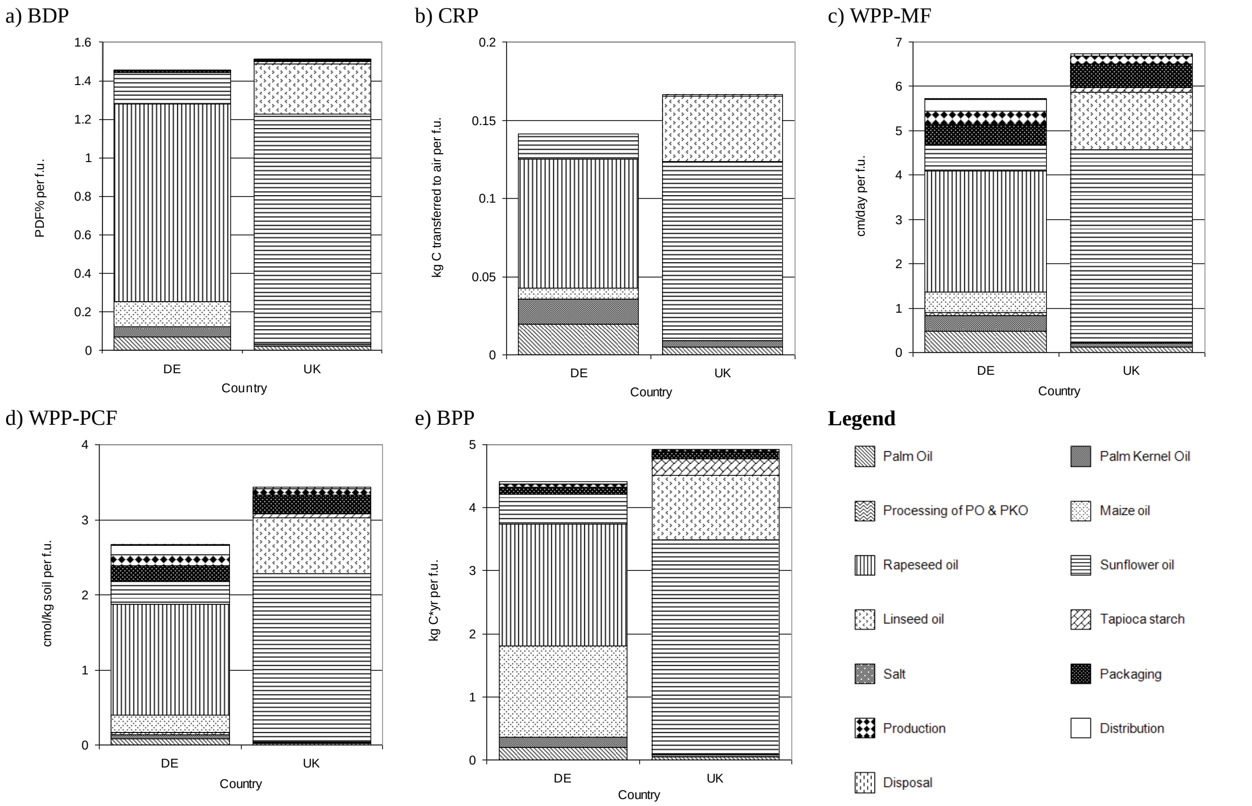

Figure 1. Contributions of the different ingredients and life cycle stages to the land use impact categories: a) BDP, Biodiversity Damage Potential; b) CRP, Climate Regulation Potential; c) WPP-MF, Water Purification Potential through Mechanical Filtration; d) WPP-PCF, Water Purification Potential through Physico-Chemical Filtration; e) BPP, Biotic Production Potential. All impacts expressed per functional unit (f.u.): 500g tub of margarine to be used as spread (Milà i Canals *et al*. 2012).

Development of an integrated indicator for land use based on the economic value of ecosystem services

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Soils are one of Earth's essential natural resources, supporting nearly all terrestrial life. In life cycle impact assessment (LCIA), potential impacts due to land use are calculated as the product of surface occupied (or transformed), occupation (or transformation) time and a parameter describing the land quality loss (ΔQ) (Mila iCanals *et al*., 2007). In current LCIA methodologies, the only operational endpoint level indicator for the land quality loss is solely related to terrestrial biodiversity (PDF.m^2.year, PDF being Potential Disappeared Fraction of species) and is not representative of all impacts that originate from land use as shown by a recent project named LULCIA (2008-2012), conducted under the aegis of the UNEP/SETAC Life Cycle Initiative (Koellner *et al*., 2012; de Baan *et al*., 2012; Saad *et al*., 2011; Brandão and Mila iCanals, 2012; Müller-Wenk and Brandão, 2010).
This project expanded the scope of land use assessment, going beyond the biodiversity assessment. This method relates land use to six additional indicators: biotic production potential (BPP), erosion regulation potential (ERP), fresh water regulation potential (FWRP), (mechanical and physico-chemical) water purification potential (WPP) and carbon sequestration potential (CSP), which represent provision and regulation services from ecosystems, as defined in the Millennium Ecosystem Assessment (MEA) (2005). Although the LCIA methodology becomes more comprehensive in regards to relevant pathways linked to land use, this development potentially reduces the capacity of LCA as a decision support system, providing seven midpoints for the land use impact category alone.
This project aims at developing a new method to value the reduction of ecosystem services provided to human society. The method consists in converting the above mentioned midpoint indicators in monetary terms, using economic valuation of the reduction of a given ecosystem service. BPP is estimated with productivity loss while CSP thanks to carbon social cost: less sequestration by soils is equivalent to emission. The other regulation services are estimated through current compensation costs, as they are considered essential (conservative approach).
This method is applied on a case study, the comparative LCA of bio-based polymers. Results show that impact scores are not only influenced by the bio-geographical variability of systems under study (e.g. crop yield in the inventory flow, the land location for the impact characterisation), but also by the socio-economical availability and typology of the compensation systems taken into account. Uncertainties and economic valuation assumptions are further discussed in the paper.
Overall this work shows the feasibility to translate all the midpoints indicators proposed by the LULCIA land use impact assessment framework into economic values, bringing a new level of interpretation for the decision maker. The converted indicators can be summed into an integrated indicator expressing potential impacts and they must be interpreted as the loss of natural (capital of) ecosystem services. It also potentially allows LCA to assess other impacts related to land use, such as aesthetics and recreational aspects (as they are conceptualised as cultural services in the MEA framework).

References

Brandão, M., Mila iCanals L., 2012. Global characterisation factors to assess land use impacts on biotic production. The International Journal of Life Cycle Assessment. 1-10.
de Baan, L., Alkemade, R., Koellner, T., 2012. Land use impacts on biodiversity in LCA: a global approach. The International Journal of Life Cycle Assessment. 1-15.
Koellner, T., de Baan L., Beck, T., Brandão, M., Civit, B., Goedkoop, M., et al., 2012. Principles for life cycle inventories of land use on a global scale. The International Journal of Life Cycle Assessment. 1-13. Accessed 30 April 2012.
LULCIA, 2008-2012. Operational Characterization Factors for Land use Impacts on Biodiversity and Ecosystem Services in the Life-Cycle Impact Assessment. http://www.pes.uni-bayreuth.de/en/research/projects/LULCIA/
Mila iCanals L.M., Bauer, C., Depestele, J., Dubreuil, A., Knuchel, R.F., Gaillard, G., et al., 2007. Key elements in a framework for land use impact assessment within LCA. The International Journal of Life Cycle Assessment. 12, 5-15.
Millennium Ecosystem Assessment, 2005. Our Human Planet, Island Press, Washington.
Müller-Wenk R., Brandão M., 2010. Climatic impact of land use in LCA—carbon transfers between vegetation/soil and air. The International Journal of Life Cycle Assessment. 15, 172-82.
Saad, R., Margni, M., Koellner, T., Wittstock, B., Deschênes, L., 2011. Assessment of land use impacts on soil ecological functions: development of spatially differentiated characterization factors within a Canadian context. The International Journal of Life Cycle Assessment. 16(3), 198-211.

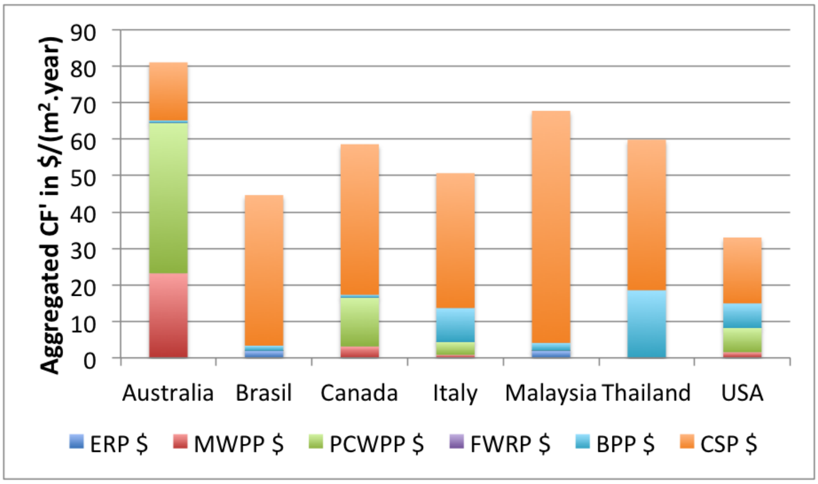

Figure 1. Graph of converted and aggregated land use CFs for different biopolymer production locations (monetarisation normalisation, equal weighting) for an agricultural land cover.

Land requirements for food in the Netherlands - an historical analysis over 200 years

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The production of food puts a large claim on land. On a global scale 30% of the land is used for the production of food. Earlier research showed that large differences in land claim existed between various food items and different menus required different land use (Gerbens-Leenes and Nonhebel, 2002). The land requirements for food are also determined by the crop yields. Both the yields and the menus change overtime and in this study we analyse the combined effect of changes in menu and agricultural yields on the land requirements for food in the Netherlands.
We constructed a historical database on food availability per person over 200 years using various sources. Next we collected yield data for most important food crops grown in the Netherlands. Finally we combined food availability data with the crop yields to determine the land required for food using the methodology developed in Kastner and Nonhebel, 2010.
Food consumption showed large changes: around 1800 over 40% of the food originated from livestock (with dairy contributing virtually the whole share), this drops to 20% in 1900 and increases again to 35% in 2000 (Fig. 1). In 1800, rye and barley were the cereals consumed most, while in 2000 wheat was the most important cereal. While the consumption of relevant quantities of sugar only started around 1880, in 2000 15% of the calories in the menu were obtained from sugar. Further from 1950 onwards animal fats in the diets were replaced by oils from the oilseeds.
The agricultural productivity showed large increases: in 1850 the rye yields were around 1500 kg per hectare, while in 2000 wheat yields of over 8000 kg/ha were recorded. Milk production per cow increased from 1000 kg in 1800 to 8000 kg/year. The combined effect of higher crop (feed!) production per hectare and higher milk production per cow led to a fast decline in land required for dairy.
In 1800 about 1.4 hectare per person was needed for the production of food, two thirds of this was for the production of dairy. In the following two centuries, the area needed declined fast to 0.15 ha per person in 2000 (Fig. 2). From 1800 to 1900 the decline was caused by the reduced consumption of animal products, from 1900 onwards the consumption of animal origin products increased again but due to use of mineral fertilisers the production per hectare increased, leading to overall decline of the land required for food per person.
The analysis above provides some interesting insights. In the first place it is striking that 200 years ago dairy played such a vital role in the Dutch consumption pattern. Next to that in the 200 years studied enormous efficiency increases (factor 8!) were observed both in crop production as in livestock production. The combined effect led to a decline in land required for food by a factor 10. However, in the same timespan the population increased from 2 to 17 million people, so the total amount of land needed to feed the Dutch population remained constant. The yield increases came together with (increased) use of fertilisers and pesticides. The environmental impacts of the use of these inputs will be included in a forthcoming study.

References

Gerbens-Leenes, P. W. and S. Nonhebel, 2002. Consumption patterns and their effects on land required for food, Ecological Economics 42, 185-199.
Kastner, T and Nonhebel, S. 2010. Changes in land requirements for food in the Philippines: a historical analysis. Land Use Policy 27, 853-863.

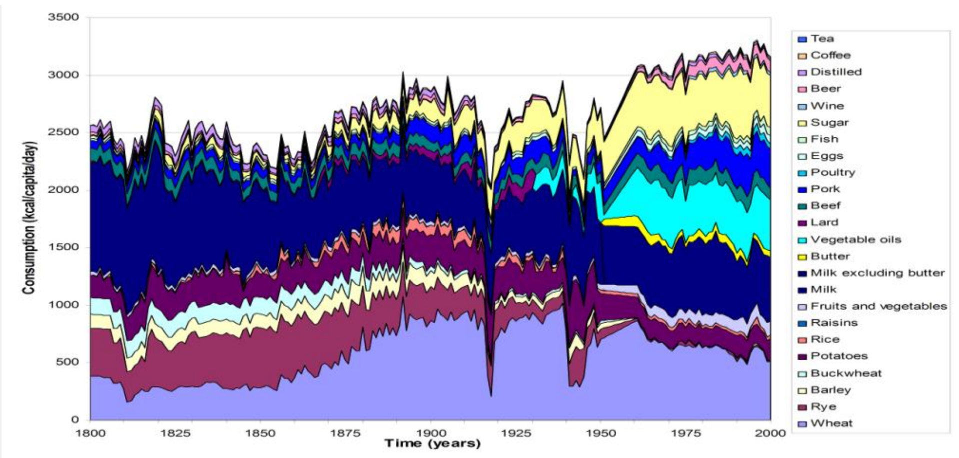

Figure 1. Food availability in the Netherlands (kcal per person per day) from 1800 onwards.

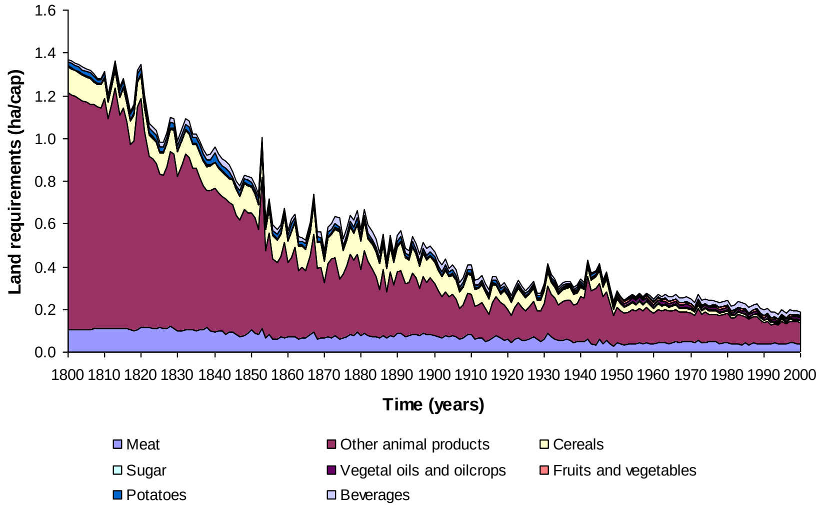

Figure 2. Development of the per capita land requirements in the Netherlands and the distribution over various consumption categories.

Organic farming without fossil fuels – LCA of energy self-sufficiency

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One principle of organic farming is the use of renewable resources, yet it is as dependent on fossil energy as conventional agriculture. However, with new technologies and the increased emphasis on reduction of greenhouse gas (GHG) emissions, this may change soon. Biomass offers opportunities for energy supply, but requires energy and land, and causes emissions. There are various biomass sources, as well as different technical options. Which of these are preferable? Are there enough biomass residues to supply energy to the production system, or is it necessary to take land from food production for fuel supply? This paper summarises results from a research project aiming at evaluating systems for supplying organic agriculture with heat, power and fuel generated from biomass produced on its own land, and the environmental consequences of such production. We investigated a crop-based production system with a seven-year crop rotation, as well as a system for milk production, where all feed was produced on the farm. The method used was consequential LCA. For each system (crop or milk) self-supply scenarios and a fossil reference system were defined. The biomass energy systems included straw for power, heating and ethanol; ley, manure and straw for biogas generating power, heat and fuel; and willow for heat and power. The selected technologies are available today, at least at the pilot or demonstration level. The investigation focused on biomass potential, energy balance and GHG emissions. Changes in soil carbon content were modelled with the ICBM model. For the arable farm, straw or ley from the crop rotation was sufficient for energy supply for farm activities. In the straw-based scenario, straw harvest from 25% of the farm area was needed. This scenario gave rather low GHG savings (9%) due to reduction in soil carbon content when removing straw from the fields. The scenario for anaerobic digestion of ley required 13% of the farm area and resulted in a 35% reduction of GHG emissions. For milk production, it was found that biogas from manure could supply about two thirds of the energy demand of the farm and that there was straw to supply the remainder. Changing from fossil to renewable energy reduced the total GHG emissions from 1 kg of milk at farm-gate by 29-44%. In conclusion, it was possible for the studied organic farms to become self-sufficient in energy and reducing GHG emissions by using residues produced within the farming system. The final results were sensitive to assumptions on soil carbon initial content and turnover, and handling of by-products.

References

Andrén and Kätterer, 1997 ICBM- the introductory carbon balance model for exploration of soil carbon balances. Ecological Applications. **7**(4): 1226-1236.

Kimming M., Sundberg C., Nordberg A., Baky A., Bernesson S., Norén O., Hansson P-A., 2011. Life cycle assessment of energy self-sufficiency systems based on agricultural residues for organic arable farms. Bioresource Technology. 102, 1425-32.

Kimming M., Sundberg C., Nordberg A., Baky A., Bernesson S., Hansson P-A., 2012. Renewable energy supply for organic milk production: self-sufficiency potential, energy balance and greenhouse gas emission. Submitted.

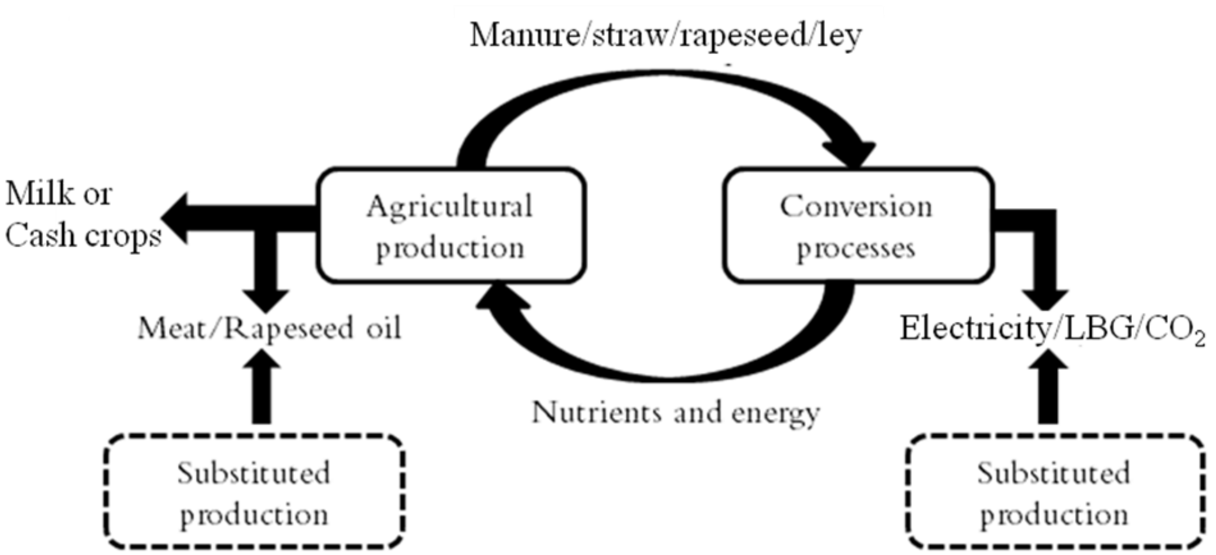

Figure 1. Energy and material flows on the arable and milk farms respectively. Substituted production refers to the impact on the external market of reduced or increased supply of goods from the farm to the respective market.

Peri-urban expansion: application of consequential LCA to assess land for food or housing

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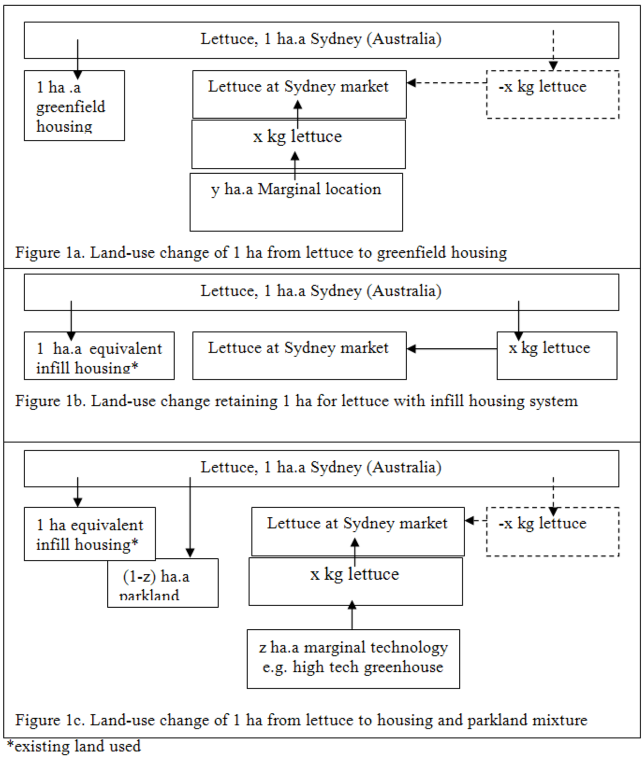
Competing land uses such as urban expansion are impacting fresh food production in peri-urban Sydney (Australia). Research is divided regarding the status of peri-urban horticultural land management in the Sydney basin. Although many qualitative papers on the benefits of peri-urban agricultural land retention exist both nationally and internationally, quantitative decision support data is predominantly absent. Government policies are trending in favour of development for urbanisation, with the number of horticultural farms in Sydney anticipated to halve under current planning policy. If this trend continues, horticulture may cease as a viable land use and economic function in the Sydney basin. Sydney's balance of horticultural produce will then be imported from marginal locations. It is not known, however, if the alternative food producing locations present a more or less sustainable environmental situation for vegetables on the Sydney market compared with local production. While there is a need to provide housing, opportunity exists for a data driven methodology to evaluate the environmental consequences of the decision to urbanise, for the purpose of informing policy. Consequential LCA (CLCA) provides a methodology that can assess environmental impacts relating to using land for housing versus land for food, and assist answering the question "What are the environmental consequences of urbanising Sydney's horticultural lands?" This project uses a case study approach, with lettuce supplied to the Sydney market as the commodity of choice.

Specifically, in this paper, the benefits and challenges of applying CLCA to generate decision making evidence to support peri-urban land use decisions are evaluated. In CLCA, the system boundaries can be defined to include the activities contributing to the environmental consequence of the change, meaning that impacts associated with both the urban and agricultural systems affected by this change can be included. As data collection in the agricultural system occurs at farm level, both for Sydney and marginal regions, CLCA has the benefit of allowing direct comparison of farming methods, productivity and technologies for lettuce growing both intra-region and inter-region. Avoiding the use of 'average' data obtains a more realistic analysis of environmental impacts. Preliminary results are indicating dramatic reductions in global warming potential when farm level data is used compared to Australian average estimates of lettuce growing, with on-farm practices contributing to significant inter-farm differences. Selection of multiple functional units (per ha and per kg) facilitates improved understanding of the environmental burdens. Additionally, the use of CLCA allows alternative means of increasing marginal production to be evaluated. Figures 1a and 1c illustrate two simplified scenarios where, due to displacement by housing, production increases occur via marginal regions or marginal technologies, both of which are valid. Figure 1b illustrates a scenario where the housing burden is fulfilled by adoption of a predominantly infill housing system with no displacement of Sydney horticulture. The benefit of CLCA at the urban-agricultural intersection is to provide a new perspective on peri-urban land use change. Scenarios for producing lettuce versus producing housing can be evaluated and consequential displacements associated with land use decisions assessed. Land use scenarios can be ranked according to their environmental impacts. The method implemented here permits for environmental impacts to be calculated for scenarios that include two distinct types of urban housing systems whilst accounting for agricultural diversity at the farm scale.

The challenges associated with using CLCA to address the above question include those typical to LCA: data integrity, uncertainty, method, functional unit, impact category, software and emission factor selection. Collecting data at farm and supply chain level assists improved data quality and ensures similar inputs between farms, although is time consuming. Building consensus on how urban systems should be incorporated into the CLCA is the greatest challenge. Input from contemporary studies on the Sydney basin identifying environmental impacts from alternative urban growth patterns, combined with LCA data for the built environment and an analysis of water scarcity using supplementary methods are factors for inclusion. Future work will apply the CLCA to analyse the consequences of urbanising Sydney's horticultural lands in a resource constrained and climatically uncertain future. Applying time limits to future scenarios, by which time marginal suppliers and technologies may have changed, is a further challenge for management.



Figures 1a, b, c. Simplified examples of scenarios to be analysed

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Greenhouse gas (GHG) emissions from soils are a major source of uncertainties within Agricultural LCA (Guinée et al., 2009). Among these, N_2O emissions strongly affect global warming. N_2O is estimated with IPCC guidelines (De Klein et al., 2006), agroecosystem models or by direct field measurements (Gabrielle and Gagnaire, 2008). IPCC guidelines have the disadvantage of ignoring soil characteristics, climate conditions and agricultural practices other than N input rate. Direct field measurements are very costly to be used at large scales. Here, we used the agro-ecosystem model CERES-EGC to estimate N_2O emissions from faba bean, winter and durum wheat, and barley crops grown in two experimental trials with different climates in France and Italy, considering also residues decomposition. Model outputs were compared with IPCC estimates (De Klein et al., 2006). CERES-EGC includes a crop growth model, soil water dynamics and soil organic matter decomposition modules. The model was tested with different datasets coming from European field sites and it showed good prediction of N_2O emissions. It runs on daily basis with climatic data, soil characteristics and agricultural management (Lehuger et al., 2009). Here, CERES-EGC was run with data of two trials: the ICC (Innovative Cropping systems with Constraints) trial located in the vicinity of Paris (France) with two cropping systems (PHEP aiming at guaranteeing High yield and Environmental Performances and 50%GHG aiming at halving GHG); CIMAS (Conventional versus Integrated Management Agricultural System) trial located in central Italy with the goal of comparing two rainfed cropping systems with two levels of external inputs (Nassi o Di Nasso et al., 2011). Patterns in simulated N_2O emissions (Figures 1 and 2) showed these emissions can be independent from fertiliser application dates. This was mainly due to the great influence of soil moisture, rainfall events and farming practices (Lehuger et al., 2009). Results showed the IPCC procedure estimated higher annual emissions for cereals of 740 g N_2O-N ha^{-1} y^{-1}(428 g N_2O-N ha^{-1} y^{-1} including post harvest periods) on average compared to simulation results and lower estimation of 304 g N_2O-N ha^{-1} y^{-1} (609 g N_2O-N ha^{-1} y^{-1} including post harvest periods) for faba bean (Table 1). Results revealed inclusion of climate, soil properties and management by means of CERES-EGC in a LCA would allow taking these emission factors of variation into account. Thus, estimates of N_2O emissions by simulation may increase accuracy of soil GHG emission in agricultural LCA.

References

Gabrielle, B., Gagnaire, N., 2008. Life-cycle assessment of straw use in bio-ethanol production: A case study based on biophysical modelling. Biomass Bioenerg. 32, 431-441.

Guinée, J.B., Heijungs, R., Voet, E., 2009. A greenhouse gas indicator for bioenergy: some theoretical issues with practical implications. Int. J. Life Cycle Assess. 14, 328-339.

De Klein, C., Novoa, R.S.A., Ogle, S., Smith, K.A., Rochette, P., Wirth, T.C., McConkey, B.G., Mosier, A., Rypdal, K., Walsh, M., Williams, S.A., 2006. Chapter 11: N_2O Emissions from Managed Soils, and CO_2 Emissions from Lime and Urea Application, in: Gytarsky, M., Hiraishi, T., Irving, W., Krug, T., Penman, J., (Eds.), IPCC Guidelines for National Greenhouse Gas Inventories. IPCC International Panel on Climate Change, Geneva, pp. 4:11.1-11.54.

Lehuger, S., Gabrielle, B., van Oijen, M., Makowski, D., Germon, J.-C., Morvan, T., Hénault, C., 2009. Bayesian calibration of the nitrous oxide emission module of an agro-ecosystem model. Agric. Ecosys. Environ. 133, 208-222.

Nassi o Di Nasso, N., Bosco, S., Di Bene, C., Coli, A., Mazzoncini, M., Bonari, E., 2011. Energy efficiency in long-term Mediterranean cropping systems with different management intensities. Energy 36, 1924-1930.

Table 1. Amounts of N applied as fertiliser and estimated N_2O-N emissions with the two methods: CERES-EGC and IPCC (cumulated values over the season were reported over a year period)

Crop	Trial	Cropping system	N applied with fertiliser (kg N ha^{-1})	CERES-EGC N_2O-N emissions (g ha^{-1} y^{-1})	CERES-EGC N_2O-N emissions (g ha^{-1} y^{-1}) including post harvest period	IPCC N_2O-N emissions (g ha^{-1} y^{-1})
Winter Wheat	ICC	PHEP	90[a]	1791	1976	2380
Barley	ICC	PHEP	60[a]	533	723	1542
Barley	ICC	50%GHG	80[a]	312	460	1755
Faba bean	ICC	PHEP	0	1163	1480	659
Faba bean	ICC	50%GHG	0	1246	1871	512
Durum Wheat	CIMAS	HI	92[b] +52[c]	1481	1987	2140
Durum Wheat	CIMAS	LI	46[b]+26[c]	1363	1894	1361
Faba bean	CIMAS	HI	0	727	876	776
Faba bean	CIMAS	LI	0	707	836	681

[a] NH_4NO_3 N content 33.5%; [b] Urea N content 46%; [c] NH_4NO_3 N content 26%

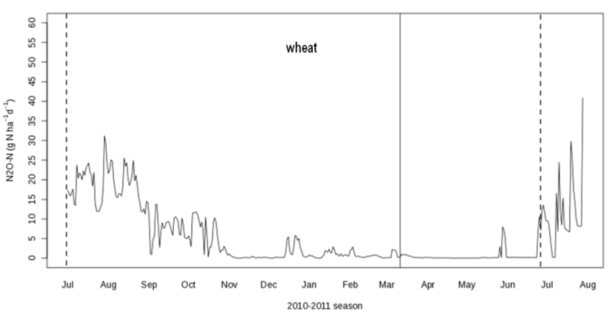

Figure 1. Model results of the analysed period for winter wheat in ICC PHEP system (from previous crop harvest to sowing of the following); vertical lines: full: date of fertiliser application, dashed: harvest dates

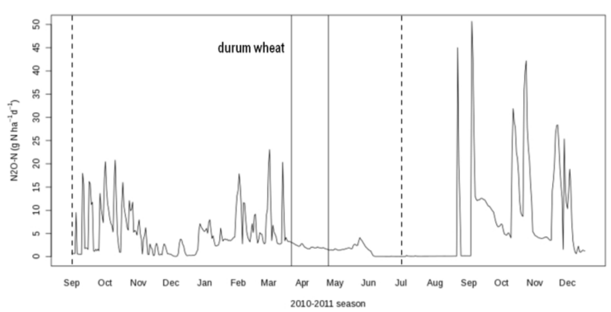

Figure 2. Model results of the analysed period for durum wheat in CIMAS high input system (from previous crop harvest to sowing of the following); vertical lines: full: date of fertiliser application, dashed: harvest dates

Using a model-based LCA to explore options for reducing national greenhouse gas emissions from crop and livestock production systems

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National governments have made commitments to reducing greenhouse gas emissions (global warming potential, GWP) and these have been devolved to equivalent commitments in each sector of the economy including agriculture. Using a model-based LCA (Williams et al. 2006, 2007, 2010) we explored the characteristics of GWP-reducing options in systems used to produce twelve crop and seven livestock commodities. With a functional unit of kg of product, differences between crops in GWP per kg product reflected differences in yield per hectare. Options to unify crops are to use metabolisable energy (ME) or crude protein (CP) as the functional unit, which provides an apparently more consistent GWP per unit, but crops that produce mainly ME (sugar and potatoes) have a very low GWP per unit ME, whereas crops which produce a high concentration of protein have a high GWP per unit ME. From the market price of crops (excluding potatoes), it can be estimated that the economic value of a unit of ME is £8.6/GJ and CP is £0.62/kg, leading to a relatively consistent 2.6 kg CO_2e/£ nutrient value with a small range, Table 1. Nitrogen fixing crops are slightly better and high nitrogen crops slightly worse.

Options to reduce GWP were considered as follows: crop husbandry: i) 20% decrease in applied N; ii) no-till (cereals and legumes only); iii) no straw incorporation and iv) irrigate all potatoes. Reductions in GWP per kg product ranged from 2% (sugar beet) to 15% (cereals). A crop research option, increasing crop yields by 20%, reduced GWP by 4 to 12%. Livestock options were: i) Increased lifetime output from breeding females; ii) increased annual milk yield (dairy cows); iii) improved feed conversion ratio (FCR) and iv) use best existing system. Using the system model identified a problem with the statements “increase annual milk yield” and “increase daily growth rate”. Both can be achieved by having a larger animal. Thus a cow which is 10% larger will be expected to require 10% more food for maintenance, give 10% more milk and require 10% more food because of that milk. There are three options: 1) larger animal 2) same size of animal giving more milk but eating more food for that milk 3) same size of animal giving more milk and eating no more food. The best alternative systems, Table 2, reduced GWP ranging between 7% (beef from the dairy herd) and 21% (extensive sheep meat).

Criteria other than GWP need to be taken into account in determining the best options. Half of the options reduce national production of the commodities, which conflicts with the requirement not to increase imports. Apart from the country’s food security, increased imports affect global agriculture and carry the risk of increased deforestation with consequent severe increases in GHG emissions. No-till increases pesticide use. Whilst decreasing nitrogen fertiliser reduces nitrate leaching, increased yields from crop breeding had negligible effect on nitrate leaching since the model requires that nitrogen input is increased pro-rata with yield. In this case, the main benefit is reduced energy per tonne of product. Overall the results indicate that improvements in productivity and efficiency of resource use are the best options for reducing GWP per unit of product.

References

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

Williams, A.G., Audsley, E., Sandars, D.L. (2007) Environmental burdens of livestock production systems derived from life cycle assessment (LCA). In: Garnsworthy, P. (Ed), 41st University of Nottingham Feed Conference, Sutton Bonington, Nottingham, Nottingham: Nottingham University, 171-200

Williams, A.G.; Audsley, E.; Sandars, D.L. (2010) Environmental burdens of producing bread wheat, oilseed rape and potatoes in England and Wales using simulation and system modelling Int. J. Life Cycle Ass., 15 (8), 855-868

Table 1. GWP of different crops and the effect of different functional units

Crop	Yield t/ha	DM g/kg	ME MJ/kg DM	CP g/kg DM	Global Warming potential, kg CO_2e per kg	GJ ME	kg CP	£ value
Winter bread wheat	7.7	860	13.6	130	0.51	0.044	4.56	3.00
Winter feed wheat	8.1	860	13.6	116	0.46	0.039	4.61	2.83
Winter barley	6.5	860	13.2	123	0.42	0.037	3.97	2.57
Spring barley	5.7	860	13.2	116	0.38	0.033	3.81	2.38
Winter oilseed rape	3.2	930	23.1	212	1.05	0.049	5.33	3.42
Sugar beet	63	220	13.2	68	0.04	0.015	2.87	1.25
Main-crop potatoes	52	200	13.3	93	0.14	0.053	7.53	2.57
Second-early potatoes	48	200	13.3	93	0.10	0.038	5.38	2.90
Field beans	3.4	860	13.3	298	0.51	0.045	1.99	1.98
Soya beans	2.4	860	14.5	415	0.70	0.056	1.96	2.13
Maize grain	7.2	860	13.8	102	0.38	0.032	4.33	2.43
Forage maize (DM)	11.2	280	11.0	101	0.30	0.027	2.97	1.91

DM=dry matter, ME=metabolisable energy, CP=crude protein

Table 2. Best alternative livestock systems and their estimated greenhouse gas emissions (GWP, kg CO_2e/kg product)

Sector	Best alternative system	GHGE from best alternative system (kg CO_2e/kg product[1])	Reduction in GHGE compared to average for sector (%)
Milk	Autumn-calving cows, housed 190 days/year. 8000 litres milk per year, 7 lactations per cow. 15% crude protein diet based on maize silage.	0.89	12
Dairy beef	Lower protein and lower forage diet, housed.	7.95	7
Suckler beef	Extended grazing. Spring calving, high genetic merit cow for fertility and calf growth. Grass finished calves.	14.1	12
Sheep meat	Extensive. Ewes of high genetic merit for fecundity and longevity. Late spring lambing outdoors. No housing. Winter grazing of saved pasture and forage crops. Low stocking rate.	11.5	21
Pig meat	High genetic merit for fertility and piglet growth. Sows and weaners outdoors. Finishing indoors on a slurry system, stored slurry immediately incorporated into land.	3.49	14
Poultry meat	Housed. Immediate incorporation of manure into land. FCR as for top 10% of sector.	2.54	7
Eggs	Housed, slurry, under-floor drying of manure, covering of manure store, Immediate incorporation of manure into land. FCR as for top 10% of sector.	2.57	13

FCR = Feed conversion ratio, [1]Whole milk and eggs, bone-in carcase weight

Improving estimates of life cycle nitrous oxide emissions from crop-based food products

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Most non-leguminous arable crops in Northern Europe respond positively to applications of N fertilisers. The Intergovernmental Panel on Climate Change (IPCC) provides a method for assessing emission of the greenhouse gas (GHG) nitrous oxide (N_2O) that occurs as a consequence of applying N fertiliser: at the national scale the default value for applied N lost directly as N_2O is 1% (range: 0.3–3%), for all crops regardless of management practices.

Within the UK, N_2O emissions contribute 6.1% (111,640 t N_2O) to the total of GHG emissions, with 78% of all N_2O emissions originating from agricultural practices (MacCarthy *et al.*, 2011). The contribution of primary food production to lifecycle GHG emissions of food products is typically 50% and may be larger for some foods (Wiltshire *et al.*, 2008). Thus, N_2O makes an important contribution to the lifecycle GHG emissions of food products.

A study in the UK is addressing the scientific and practical challenges of minimising nitrous oxide emissions from UK arable cropping. The project is called "Minimising nitrous oxide intensities of arable crop products (MIN-NO)" and objectives include the following:

1. To determine a more robust relationship between N_2O emission and the rate of mineral N fertilisers applied, both during crop growth and from crop residues;
2. Through expert estimation and debate, to identify practices which could lower the greenhouse gas emissions footprint of arable products such as bread, sugar, oils, peas, chicken, whisky and biofuels;
3. To assess how emissions might be estimated more accurately at farm and at national level.

A key hypothesis being tested in the MIN-NO project is that, because some N_2O emissions occur after crop N uptake, emissions relate to the balance between N supply and N uptake. Contrary to this, most current GHG accounting methods assume a direct proportionality between N fertiliser use and N_2O emissions from land, as agreed internationally by IPCC (2006). This assumption implies that large reductions in N fertiliser use and crop productivity are required to minimise the N_2O contribution to life cycle GHG emissions of crop products. However, if N_2O emissions were N-balance related, N amounts that minimise N_2O intensities would be similar to current use, and crop productivity would be maintained (Fig. 1).

Emissions of GHGs have been assessed for over 180 wheat crops, at an individual field scale, and work is in progress to gauge the variability in N_2O emissions as a result of variation in agricultural variables, and according to alternative life cycle assessment (LCA) approaches. Early results show that the GHG emissions from production of wheat varied from 190 to 923 t CO_2e per t (mean = 410; standard deviation = 101).

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References

MacCarthy J., Brown K., Webb N., Passant N., Thistlethwaite G., Murrells T., Watterson J., Cardenas L., Thomson A., and Pang Y., 2011. UK Greenhouse Gas Inventory, 1990 to 2009: Annual Report for Submission under the Framework Convention on Climate Change. Didcot UK, AEA Technology plc.

IPCC, 2006. IPCC Guidelines for National Greenhouse Gas Inventories. Eggleston H.S., Buendia L., Miwa K., Ngara T., Tanabe K., Japan, IGES.

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

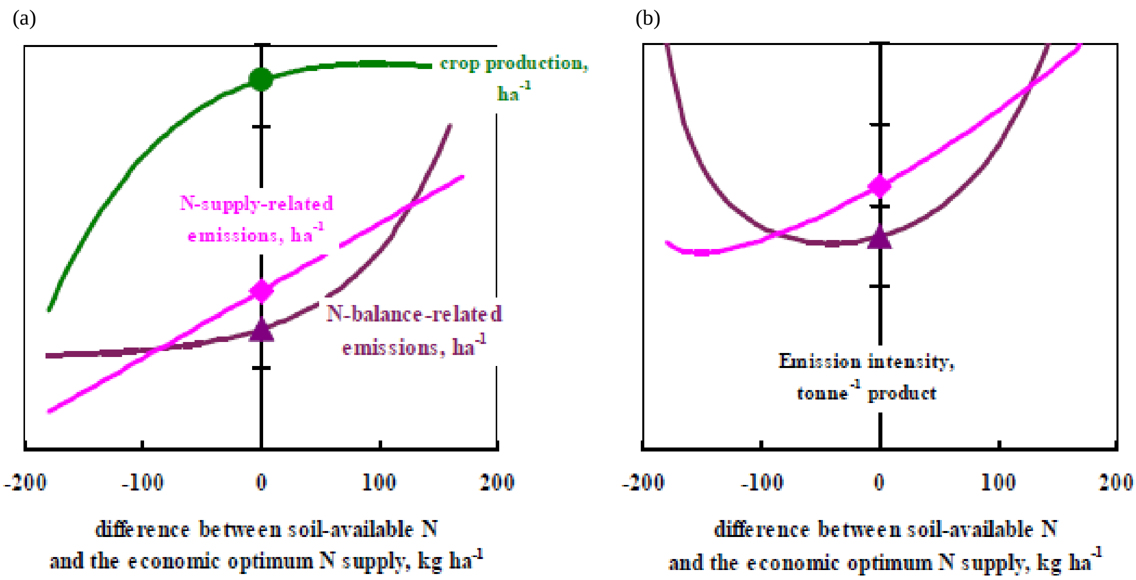

Figure 1. (a) Effects of N supply on crop production (green line & circle), and on N_2O emissions if related directly to N supply (pink line & diamond; as estimated by the IPCC Tier 1 approach) or to the balance between N supply and crop N uptake (purple line & triangle; as hypothesised here). (b) Consequent contrasting effects of N supply on N_2O emission-intensities of crop products for the IPCC (diamond) and our hypothesised (triangle) scenarios.

Introduction of a national method to estimate direct nitrous oxide emissions from mineral soils for Finnish product carbon footprinting

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Direct nitrous oxide emissions from managed soils play a very significant role in climate impacts of food products. However, an IPCC default emission factors (IPCC 1996) are applied almost without exception in carbon footprint studies of food products (Pulkkinen 2010). In the Finnish Foodprint-programme harmonised national guidelines were developed to assess climate impacts of food products. In addition to harmonising methodology, a more detailed method for estimating direct nitrous oxide emissions from mineral soils in Finland was developed to gain a more accurate understanding of climate impacts of food products.

The uncertainties of nitrous oxide emissions are very high due to large spatial and temporal variation (Snyder et al., 2009). To reduce the uncertainty of national estimates, Regina et al. (submitted) conducted research on nitrous oxide fluxes under Finnish conditions from 13 fields for periods of one to three years in 2000-2009. Their main finding was that the annual nitrous oxide emissions were lower from grass crops than from annual spring crops. The long period between harvesting and sowing under boreal conditions, when there is not vegetation during the long winter, increases the emissions from annual spring sown crops. It was possible to provide a method for estimating direct nitrous oxide fluxes from grass and annual spring crops from mineral soils in Finland that reflected national conditions better than the IPCC default method.

The crop type and the amount of mineral N applied best explained the variation in nitrous oxide emissions; the model is consequently based on these two effects. To estimate the burden of human activity (cultivation) only, a background emission was deducted from the derived emission estimates of both crops by deducting the emissions at zero fertiliser application rate.

These equations can be used to estimate the total emission from the field without dividing it between emissions from applied N, crop residues and N mineralisation. Indirect nitrous oxide emissions were not included in the field measurements and therefore need to be calculated separately.

The derived equations for estimating nitrous oxide (N_2O) flux from mineral soils for perennial crops (Eq. 1) and for annual spring crops (Eq. 2) are therefore:

$$N_2O \text{ flux } (kgN_2O\text{-}N\ ha^{-1}\ yr^{-1}) = 10 \wedge (-0.2762 + 0.002848 * minN)-0.529 \qquad \text{Eq. 1}$$

$$N_2O \text{ flux } (kgN_2O\text{-}N\ ha^{-1}\ yr^{-1}) = 10 \wedge (-0.2762 + 0.002848 * minN + 0.58) - 0.529 \qquad \text{Eq. 2}$$

The new national method gives markedly larger emissions to annual spring crops and smaller to perennial crops compared with the IPCC 2006 method. In a specific potato case study the new method increases the total climate impact by 25%. The national method highlights that under boreal conditions, such as Finland, direct nitrous oxide emissions on mineral soils might be twice as large as what IPCC 2006 method implies.

Acknowledging the substantial variation in nitrous oxide emissions, more accurate estimation methods need to be developed to understand the impacts of food produced in different climatic and geographic circumstances. Better knowledge of food production in different climates is needed. As interest in climate impacts of food grows, the need for more detailed assessment methods is urgent.

References

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

Pulkkinen, H., Katajajuuri, J.-M., Nousiainen, J., Silvenius F., 2010. Challenges in the comparability of carbon footprint studies of food products. In: Proceedings of LCA food 2010. vol 2, 65-70.

Regina, K., Kaseva, J. and Esala, M. 2012. Emissions of nitrous oxide from boreal agricultural mineral soils – statistical models based on measurements. Submitted to Agriculture, Ecosystems & Environment.

Snyder, C.S., Bruulsema, T.W., Jensen, T.L., Fixen, P.E., 2009. Review of greenhouse gas emissions from crop production systems and fertilizer management effects. Agriculture, Ecosyst. Env. 133, 247-266.

Modelling N_2O emissions from organic fertilisers for LCA inventories

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The IPCC model for determining N_2O emissions from soils (IPCC, 2006) is widely used within life cycle assessment (LCA) inventories to calculate soil N_2O emissions from agricultural products and processes. This emission factor based model considers the total N input by fertilisation and plant residues to estimate cumulative direct and indirect N_2O emissions. By doing so the model does not differentiate between different fertiliser types, i.e., mineral vs. organic. However, mineral and organic fertilisers differ in their mode of action in the way nutrients are transformed in the soil and utilised by plants (Gutser et al., 2005) potentially resulting in different N_2O emissions. This is of special relevance for products produced within agricultural systems mainly or exclusively using organic fertilisers, e.g. organic farming. Here, we propose a simple model taking into account the different mode of action of organic fertilisers.

Our model considers the C and N input through organic fertilisers and crop residues brought onto and into the soil (Fig. 1). In organic fertilisers only a fraction of the total N is readily available resulting in direct and indirect N_2O emissions (Loss 1 in Fig. 1). The rest of the N in organic fertilisers and also the N in plant residues act via the soil C-N pool where it is released by degradation of organic matter. The model considers two soil C-N pools differing in their stability of organic matter with fractions of short-term available C and N (short-term C-N pool) and stable fractions (long-term C-N pool) where C and N is captured for several 100 of up to a 1'000 years (Favoino and Hogg, 2008). In soils with a net gain in soil organic carbon (SOC) a net capture of N in stable organic matter takes place where it is immobilised ($N_{immobilised}$) and therefore no N_2O emissions will result from this N. The amount of $N_{immobilised}$ is subtracted in the model from the amount of N entering the C-N pool resulting in $N_{available\ C\text{-}N\ pool}$ from which also direct and indirect N_2O emissions arise (Loss 2 in Fig. 1). In soils with a degradation of SOC additional N from the C-N pool is mineralised. In this case $N_{available\ C\text{-}N\ pool}$ equals ($N_{C\text{-}N\ pool} + N_{mineralised}$). Due to the coupled biogeochemical cycles of C and N the amount of $N_{immobilised}$ can be determined by estimating the amount of C in the stable organic matter (Favoino and Hogg, 2008). The amount of C in the stable organic matter is then divided by the C:N-ratio of the soil. Accordingly the amount of N lost from the C-N pool is calculated via the amount of C mineralised.

When testing the model with field data from a 3 years study the calculated N_2O emissions showed a strong correlation to the measured values (R^2 = 0.84). Different fertiliser treatments including organic and mineral fertiliser were modelled with high reliability. When comparing calculations from our model with calculations from the IPCC model (IPCC, 2006) using data from an organic field trial (Berner et al., 2008) our model yielded 9% lower emissions on average over the entire crop rotation for conventional tilled plots. For reduced tilled plots our model calculations resulted in 23% lower emissions on average over the entire crop rotation than the emissions calculated with the IPCC model. The controversy regarding N_2O emissions from no- or reduced tillage systems is discussed. Our model has to be further validated with field measurements of N_2O. However, the model-simulations support earlier findings that the IPCC model overestimates N_2O emissions from organic fertilisers in certain cases. The N pathway via the C-N pool should be taken into account when modelling N_2O emissions from organic fertilisers and crop residues. For field situations are reflected with higher accuracy.

References

Berner, A., Hildermann, I., Fließbach, A., Pfiffner, L., Niggli, U., and Mäder, P., 2008. Crop yield and soil quality response to reduced tillage under organic management. Soil Till Res 101, 89-96.

Favoino, E., Hogg, D., 2008. The potential role of compost in reducing greenhouse gases. Waste Manage Res 26, 61-69.

Gutser, R., Ebertseder, T., Weber, A., Schraml, M., Schmidhalter, U., 2005. Short-term and residual availability of nitrogen after long-term application of organic fertilisers on arable land. J Plant Nutr Soil Sc 168, 439-446.

IPCC, 2006. 2006 IPCC Guidelines for national greenhouse gas inventories. Volume 4 Agriculture, forestry and other land use. Hayama, Japan.

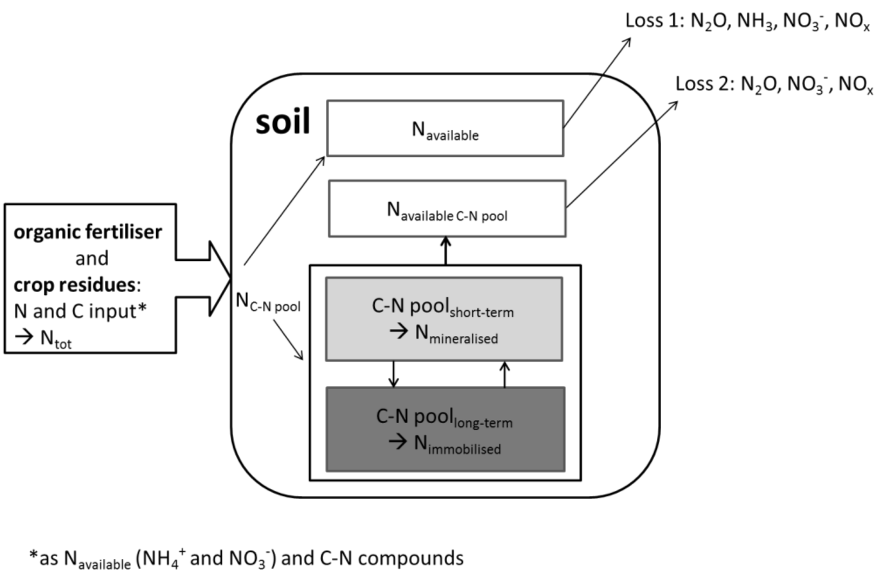

Figure 1. Soil N_2O emission model for organic fertilisers.

Sustainable meat consumption to meet climate and health goals - implications of variations in consumption statistics

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Food production has been identified as one of the most important drivers of environmental pressures. Results from life cycle assessments (LCA) normally show that animal based foods are more climate intensive compared to plant based foods. Reduced meat consumption has been suggested to be a necessary measure for mitigating food related GHG emissions and to have positive effects on public health in regions with affluent diet. However, how much meat consumption needs to be reduced to reach a sustainable level, e.g. including both environmental and health aspects, is still uncertain.

To develop recommendations for sustainable meat consumption, from a climate and health perspective, there is a need for a correct understanding of how much meat is produced and actually consumed. The purpose of this paper is to contribute to the understanding of critical issues regarding meat consumption statistics, its implication on LCA and recommendations of sustainable meat consumption levels.

Depending on the type of statistics and way of presenting data, the meat consumption level per capita may differ by a factor two, or more. This illustrate the importance of specifying the functional unit and clearly define if it refers to meat including or excluding bones, including losses along the food chain, or after weight reduction by cooking, for a correct utilisations and interpretation of meat consumption data and LCA's of meat. The need for reductions in current meat consumption to meet climate and health goals is estimated to 0-75% and 0-50%, respectively, depending on the region. The level of sustainable meat consumption needs to be studied more extensively in the future.

References

EIPRO, 2006. Analysis of the life cycle environmental impacts related to the total final consumption of the EU25. European Commission Technical Report. EUR 22284 EN.

Hallström, E., Börjesson, P., 2012 (unpublished results). Meat Consumption Statistics - Reliability and Discrepancy. Sustainability: Science, Practice, and Policy.

Garnett, T., 2011. Where are the best opportunities for reducing greenhouse gas emissions in the food system (including the food chain)? Food Policy 36, 23-32.

McMichael, A.J., Powles, J.W., Butler, C.D., Uauy, R., 2007. Energy and health 5 - Food, livestock production, energy, climate change and health. Lancet 370, 1253-1263.

World Cancer Research Fund/American Institute for Cancer Research, 2007. Food, Nutrition, Physical Activity, and the Prevention of Cancer: a Global Perspective. Washington DC, USA.

Table 1. Per capita meat consumption (kg/year) in different world regions

Region	**A[a]** Raw meat incl. bones	**B** Raw meat excl. bones	**C** B excl. losses in distribution and at consumer level	**D** C after weight reduction by cooking
North America	120	84	71	50
Oceania	115	81	68	48
Europe	77	54	46	32
South America	70	49	43	29
Asia	28	20	17	12
Africa	16	11	10	7

[a] Data in column A are based on FAO statistics which refer to the average quantity of meat including most bones at the slaughter exit. Available supply is quantified as the sum of nationally produced meat plus meat imports minus exports of meat, divided by the total population.

Table 2. Estimated need for reductions in meat consumption to meet climate and health goals[a]

Region	**Reduction needed in% to meet climate goals**	**Reduction needed in% to meet health goals**
North America	76	48
Oceania	75	46
Europe	62	19
South America	59	13
Asia	None	None
Africa	None	None

[a] To quantify the reductions in meat consumption needed to meet climate goals, data from column A in Table 1 has been compared with a consumption level of 29 kg per capita per year (FU: produced raw meat including bones). To quantify reductions needed to meet health goals data in Table 1, column D has been compared with a consumption level of 26 kg per capita per year (FU: consumed cooked meat).

Assessing the optimum level of detail for secondary GHG emissions databases

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The past years have seen LCA moving away from academic studies and into companies day-to-day operations (such as research and development). Product labelling, using LCA, is being implemented on a larger scale. Private initiatives by retailers like Tesco (Clare and Little, 2011) and the French government pilot (ADEME, 2011) are signs of that impulse, and created the demand for tools capable of providing results for a large volume of products. Tesco, who recently terminated the initiative, found that complex methods, or even traditional LCA, may be too time and resource consuming for companies. To overcome this barrier, a more practical, business-oriented side to LCA is required to simplify without compromising accuracy.

Some simplified tools use built-in databases with emissions for pre-recorded life cycles. Instead of giving users the possibility of rebuilding a life cycle for a product (e.g, butter), they have pre-established life cycle impact assessment (LCIA) results for the product. Users choose the most appropriate (e.g, CO_2 eq. emissions for conventionally produced simple butter in the Netherlands and for organic herb butter in Switzerland).

Common sense stipulates that the variability between specific agri-food products of the same type is high and cannot be grasped in a single number – the amount of fertilisers and yields change between farmers even in the same region and with the same general production method. However, studies that assess the validity of this approach are usually done for isolated case studies, and so no general conclusions can be drawn.

In this paper we use a statistical approach to test the hypothesis that simplified data can still provide accurate results to LCA studies. We used the Carbonostics database, which is the largest available built-in database of CO_2e for agri-food products. The database compiles more than 2,000 pre-recorded final LCIA results from providers such as ADEME, CleanMetrics, CLM, DEFRA, ecoinvent, ESU (Fig. 1). The database was peer-reviewed and validated by the Swiss NGO MyClimate.

We build a linear statistical model with CO_2e emissions as the dependent variable, and a collection of dummy variables as independent. These dummy variables include: (a) the type of product; (b) the production method (e.g., conventional, organic); and (c) the region of production (e.g, Europe, USA).

Our statistical test is at the type of product level. We use three levels of detail, namely:

1. General category (e.g, dairy, vegetables, oils, crops) – products grouped by broad categories;
2. Specific group within category (e.g, instead of dairy, separation in butter, buttermilk, cheese);
3. Specific variant within group (e.g., instead of butter, separation In simple butter and herb butter).

Level 3 is created using clustering analysis. So, if the model at level 1 is statistically significant (i.e, robust enough to explain most of the variance within product categories and to capture statistically significant different between categories), then studies can use “magic numbers” for carbon emissions attributed to each category, and no more detail is needed. If it’s the model at level 2, then information on groups is needed, and if it’s level 3 then some differentiation between products must be included.

Preliminary results (Fig. 2) show that models 1 and 2 are not sufficiently reliable. Modelling approach 3 provided interesting results, with enough statistical robustness. Production method was also an important variable while geographical region was not, even though this may be due to the fact that most of the records in the database are for Europe. The main output of this work is a table which, for each clustering group of agri-food products produced with each method in each region, provides the number obtained for CO_2e emissions and an estimate of the error.

References

Clare, H., Little, M., 2011. Breaking the link between consumption and emissions: improving corporate environmental performance through carbon footprinting. Proceedings of the 17th SETAC Europe LCA Case Studies Symposium, 28 February – 1 March, Budapest, Hungary.

ADEME, 2011. Affichage environnemental des produits de grande consummation (“Environmental labeling of large consumption products", in English). Available from: http://affichage-environnemental.afnor.org/ (accessed 16.04.11).

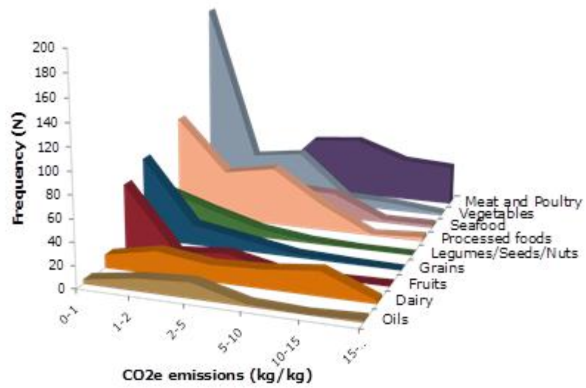

Figure 1. Number of records per type and GHG emissions dispersion.

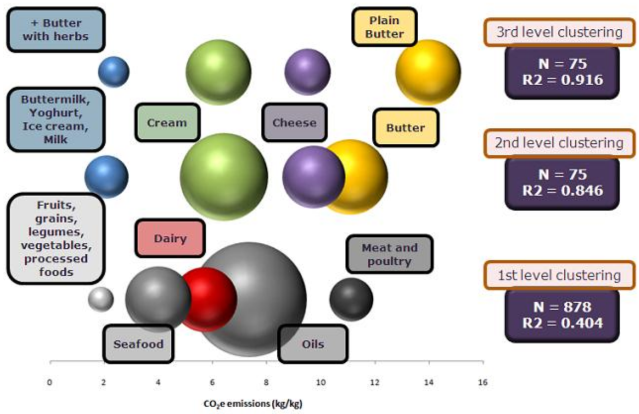

Figure 2. Statistical fit at each level of clustering (conventional, Europe). The location of each bubble in the axis indicates the average GHG emissions, and the size of the bubble is a scaled representation of the standard error.

A protocol for approaching uncertainties in life cycle inventories

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Results of life cycle assessments (LCAs) of equivalent food production systems often experience a great spread in outcomes between studies (da Silva *et al.* 2010). Part of this divergence relates to a lack of standardised methodological choices, including different views on data sourcing, system boundary setting, capital goods, allocation, carbon offsetting and storage, end-of-life treatment and land use change (Henriksson *et al.* 2011). Even ISO 14044 (2006) compliant studies can exhibit over two-fold differences compared to deterministic results due to sourcing of inventory data, and more than three-fold differences as a result of methodological choices for e.g. detergents (Koning *et al.* 2009). While a common set of product category rules could be agreed upon with regards to applied methods, underlying inventory data will chronically be subject to a dynamic reality and imperfect measurements (Huijbregts 1998; Huijbregts *et al.* 2001)

Uncertainty and variability in LCIs derive from primary data, literature sources, background databases and the decions made within these (e.g. allocation, cut-off). Given the inconsistent characteristics of these different sources, a practical approach to inventory data using aquaculture feeds as an example is here presented. The modelling includes foreground data collected from feed mills in Asia and literature sources, while background data derive from the ecoinvent v2.2 database. Each process within the foreground system boundary was assigned a mean, a standard deviation and a distribution to most economic and environmental flows using a standardised protocol (Fig. 1). Each flow, depending upon its characteristics, was assigned a standard deviation and distribution based either upon real data, weighted averages derived from meta-analyses or from a Numeral Unit Spread Assessment Pedigree (NUSAP). The outcomes were then used as inputs for Monte Carlo simulations of Asian aquaculture feeds.

The proposed approach identified a disperse range of data for identical flows and revealed common cross-referencing between studies, resulting in several publications relying on a single ”historical” value. Certain assumptions in the ecoinvent database with influence on LCAs of food production systems were also highlighted, e.g. the exclusion of variability in yields within their pre-defined standard deviations.

Knowing the uncertainty (including variability) of LCA data and related results is crucial to justify results and derived decision-making. Knowledge in this field is still fragmented although growing. We will illustrate a new critical approach to background data and quantify the uncertainty of LCI.

References

Henriksson, P.J.G., Guinée, J.B., Rene, K. & Snoo, G.D., 2011. Life cycle assessment of aquaculture systems – a review of methodologies. Int J LCA. 17(3), 304-313.

Huijbregts, M.A.J., 1998 Application of uncertainty and variability in LCA. Part I: a general framework for the analysis of uncertainty and variability in life cycle assessment. Int J LCA. 3, 273-280.

Huijbregts, M.A.J., Norris, G., Bretz, R., Ciroth, A., Maurice, B., von Bahr, B., Weidema, B. & de Beaufort, A.S.H., 2001. Framework for modelling data uncertainty in life cycle inventories. Int J LCA. 6, 127-132.

ISO 14044, 2006. Environmental management—Life Cycle Assessment— Requirements and Guidelines. Geneva, Switzerland.

Koning, A., Schowanek, D., Dewaele, J., Weisbrod, A. & Guinée, J., 2009. Uncertainties in a carbon footprint model for detergents; quantifying the confidence in a comparative result. Int J LCA. 15, 79-89.

Prudêncio da Silva, V., van der Werf, H.M.G., Spies, A. & Soares, S.R., 2010. Variability in environmental impacts of Brazilian soybean according to crop production and transport scenarios. J Environ Manage. 91, 1831-1839.

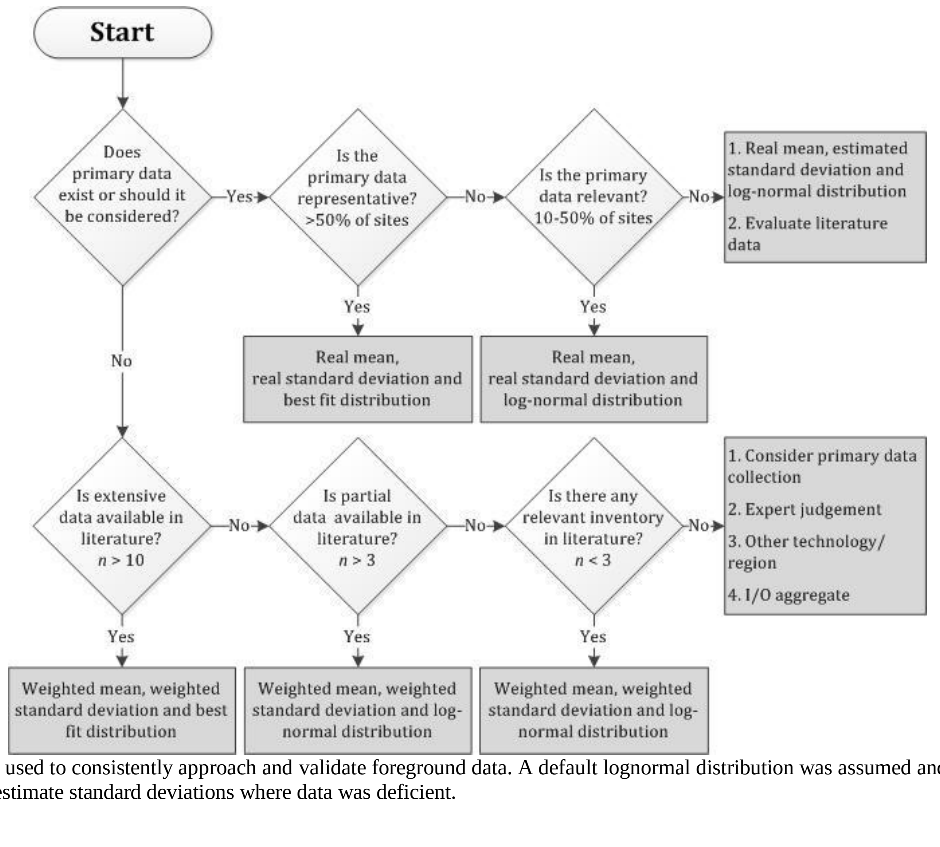

Figure 1. Decision tree used to consistently approach and validate foreground data. A default lognormal distribution was assumed and a NUSAP approach was used to estimate standard deviations where data was deficient.

Quantifying environmental impacts and their uncertainties for UK broiler and egg production systems

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A Life Cycle Assessment approach, "from cradle to farm gate" was applied to quantify the environmental burdens of the main poultry production systems in the UK. These included primary energy use, global warming potential, eutrophication potential and acidification potential of three broiler systems 1) standard indoor, 2) free range and 3) organic, and four hen egg production systems 1) cage, 2) barn, 3) free range and 4) organic (Leinonen et al. 2012a,b). The functional unit was either 1000 kg of expected edible carcass weight of broilers or 1000 kg of eggs. The analysis was based on an approach which applied a structural model for the industry and mechanistic sub-models for animal performance, crop production and major nutrient flows. Typical UK figures for performance, feed intake and composition, mortality, on-farm energy use and material use were provided by the poultry industry and applied in the analysis; these included variations for each system. Monte Carlo simulations were used to quantify the uncertainties in the outputs and to make statistical comparison between the systems.

Feed production, processing and transport resulted in greater overall environmental impacts than any other component of broiler production, i.e. 65 to 81% of the primary energy use and 71 to 72% of the global warming potential of the systems. Farm gas and oil use had the second highest impact in primary energy use (12 to 25%), followed by farm electricity use. Manure was a major source of acidification and eutrophication potentials. This resulted from relatively high excretion of unabsorbed N. The direct use of gas, oil and electricity was generally lower in the free range and organic broiler systems compared to the standard indoor system. The length of the production cycle was higher in the free range and organic broiler systems than in the standard indoor system, and as a result, the feed consumption and manure production per bird were also higher. This caused statistically significant differences in most of the environmental impact categories between the systems. The differences in the composition of the feed had also a major effect on the global warming potential in different broiler systems.

Similarly, in the egg production, feed production, processing and transport caused higher impacts than any other component, i.e. 54 to 75% of the primary energy use and 64 to72% of the global warming potential of the systems. Electricity (used mainly for ventilation, automatic feeding and lighting) had the second highest impact in primary energy use (16 to 38%). Gas and oil (mainly for heating in the pullet rearing and incineration of dead layer birds) caused 7 to 14% of the total primary energy use. The number of birds required to produce 1000 kg eggs was highest in the organic and lowest in the cage system. This was a combination of lower marketable output per bird and higher mortality rates in more extensive systems. The amount of feed consumed per layer bird was highest in the organic and lowest in the cage system. These general differences in productivity largely affected the differences in the environmental impacts between the systems, although in some impact categories (e.g. global warming potential) the differences were small and not always statistically significant.

Possibilities of reducing the environmental impacts of the UK poultry systems will be discussed. These include the use of alternative protein sources in the feed in order to reduce the high greenhouse gas emissions from the land use changes associated with the cultivation of soya, which is currently the main protein crop in UK poultry production.

References

Leinonen, I., Williams, A.G., Wiseman, J., Guy, J., Kyriazakis, I., 2012a. Predicting the environmental impacts of chicken systems in the UK through a Life Cycle Assessment: broiler production systems. Poult. Sci. 91, 8-25.

Leinonen, I., Williams, A.G., Wiseman, J., Guy, J., Kyriazakis, I., 2012b. Predicting the environmental impacts of chicken systems in the UK through a Life Cycle Assessment: egg production systems. Poult. Sci. 91, 26-40.

Table 1. Global Warming Potential (GWP), Eutrophication Potential (EP) and Acidification Potential (AP) per 1000 kg of expected edible carcass weight in the main broiler production systems in the UK.

	Standard	**Free range**	**Organic**
GWP (t CO_2e)	4.41[a]	5.13[ab]	5.66[b]
EP (kg PO_4e)	20.31[a]	24.26[a]	48.82[b]
AP (kg SO_2e)	46.75[a]	59.73[b]	91.55[c]

[a,b,c] Different superscript indicates statistically significant difference ($P < 0.05$) between the systems.

Table 2. Global Warming Potential (GWP), Eutrophication Potential (EP) and Acidification Potential (AP) per 1000 kg of eggs in the main egg production systems in the UK.

	Cage	**Barn**	**Free range**	**Organic**
GWP (t CO_2e)	2.92[a]	3.45[b]	3.38[ab]	3.42[b]
EP (kg PO_4e)	18.47[a]	20.32[b]	22.03[b]	37.61[c]
AP (kg SO_2e)	53.14[a]	59.43[b]	64.13[b]	91.63[c]

[a,b,c] Different superscript indicates statistically significant difference ($P < 0.05$) between the systems.

Influence of scenario uncertainty in agricultural inputs on LCA results for agricultural production systems

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Uncertainty analysis using the pedigree matrix for data quality along with Monte Carlo simulations is a common practice in life cycle assessment (LCA), and several LCA software products provide simulation functions. Because of certain special characteristics of agriculture, the uncertainties in parameters such as crop yield and direct field emissions are integrated into the LCA for agriculture (Basset-Mens et al., 2006); further, the uncertainty attributed to a wide variety of management practices has been estimated by statistical resampling (nonparametric bootstrapping) (Hayashi, 2011). However, in the case of the practical application of LCA to agricultural production systems, practitioners do not have sufficient knowledge of the details of background processes such as agricultural input production. Therefore, this study quantifies the scenario uncertainty in agricultural inputs, and assesses the influence of this uncertainty on a comparative LCA of agricultural production systems.

The quantification of uncertainty was conducted at the level of agricultural production systems. Conventional, environmentally friendly and organic rice cultivation in the central part of Japan were compared. The comparisons were made on the basis of generated scenarios (Fig. 1). First, the uncertainty due to unavailability of technological details was assessed by comparing the cases with and without adaptation in life cycle inventory (LCI) data for agricultural inputs. Second, the uncertainty due to the lack of knowledge of the production location of agricultural inputs was quantified by the explicit consideration of the transportation of domestic and imported agricultural inputs. Maximum uncertainty ranges were calculated by the comparison of different scenarios such as cases in which all chemical fertilisers were imported (import scenario) and those in which all made in Japan (domestic scenario). The national average scenario was also estimated using fertiliser statistics. Third, the uncertainty due to the lack of specification of agricultural inputs was analysed. Comparisons were made between the case in which only the total sum of chemical fertiliser costs was known and the case in which detailed information about the quantities of each chemical fertiliser was available. The NARO LCI database (Hayashi et al., 2010) and ecoinvent 2.2 were used for the assessment, and SimaPro 7.3 was used for the calculation.

The results can be summarised as follows. (1) There were no significant differences between the case with the adapted LCI data for chemical fertilisers and that with the original fertiliser data from ecoinvent. Similar results were obtained in the case of pesticides. (2) Lack of information on transportation scenarios caused uncertainty (Fig. 2). However, the relative superiority among conventional, environmentally friendly and organic rice cultivation remained unchanged. (3) Uncertainty due to the lack of the specification was larger than that due to the scenario indeterminacy described above (Fig. 3). The relative superiority between environmentally friendly and organic cultivation was indeterminable.

These results indicate that the quantification of scenario uncertainty is important for understanding the stability of the results in comparative LCA. The methodology used in this study can be developed as a technique to deal with scenario uncertainty in LCA of agricultural production systems.

References

Basset-Mens, C., van der Werf, H.M.G, Durand, P., Leterme, P., 2006. Implications of uncertainty and variability in the life cycle assessment of pig production systems. Int. J. LCA. 11, pp. 298-304.

Hayashi, K., 2011. Assessing management influence on environmental impacts under uncertainty: a case study of paddy rice production in Japan, in: Finkbeiner, M. (Ed.), Towards Life Cycle Sustainability Management. Springer, pp. 331-340.

Hayashi, K., Uchida, S., Hokazono, S., Sato, M., 2010. Modelling life cycle inventories for crop production in Japan: development of the NARO LCI database, in: Natarnicola, B., Settanni, E., Tassielli, G., Giungato, P. (Eds.), LCAFOOD 2010: VII International Conference on Life Cycle Assessment in the Agri-food Sector, Vol. 1. pp. 455-460.

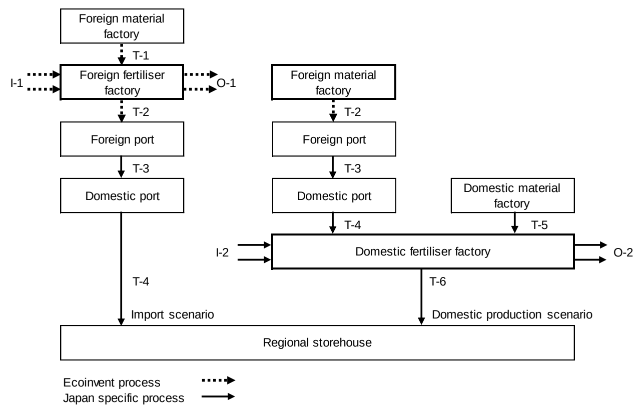

Figure 1. Generation of transportation scenarios in the case of chemical fertiliser production. T: transport stage, I: input and O: output.

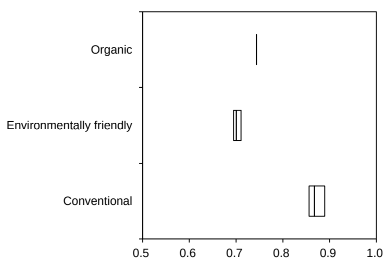

Figure 2. Greenhouse gas (GHG) emissions of the three production systems with uncertainty due to indeterminacy of transportation scenarios in the case of chemical fertiliser production (kg CO_2 eq./kg). From the left (in the boxes): the domestic production scenario, the national average scenario, and the import scenario.

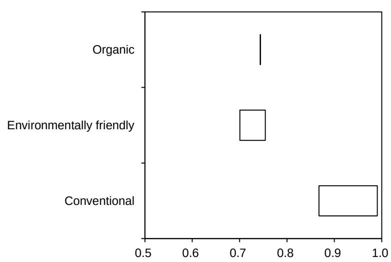

Figure 3. Greenhouse gas (GHG) emissions of the three production systems with uncertainty due to the lack of specifications in the case of chemical fertiliser production (kg CO_2 eq./kg). In the boxes, the upper bounds are GHG emissions based on input-output tables, and the lower bounds correspond to the national average scenario. It is assumed that values using emission factors based on input-output tables tend to be overestimated.

Using systems-based LCA to investigate the environmental and economic impacts and benefits of the livestock sector in the UK

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The livestock industry is a significant component of the agricultural and rural sectors in the UK. Grassland for livestock accounts for almost half of the terrestrial surface of the UK, and almost 2/3 of managed agricultural land It thus accounts for a major proportion of rural employment and income, and provides many landscape and biodiversity benefits. However, the livestock sector is also associated with large proportions of the environmental burdens from agriculture, for example, about 8% of UK greenhouse gas (GHG) emissions and 68% of the UK agricultural ammonia emissions. An integrated livestock LCA and ecosystems linear programming model was developed to assess the economic and environmental impacts of the UK livestock sector, using an ecosystem services framework. For this, the Cranfield Life Cycle Assessment Model (Williams et al., 2006, 2007) was combined with a grassland productivity model and a soil erosion model at a 5x5 km resolution across England and Wales. The systems-based LCA approach also enabled the implications of a range of alternative future scenarios to be explored, including a 25% reduction in livestock production balanced by plant commodities, a shift from red to white meat and arable substitution of the livestock sector. The model maximises the weighted net benefit of the ecosystems services generated from each of the livestock sectors (Table 2). The benefits included 'provisioning' products, such as meat, milk, and eggs as well as employment, both on livestock farms and 'multiplier' effects, e.g. arable feed growers, abattoirs. 'Cultural' benefits included landscape, biodiversity and recreation services and were considered jointly in terms of a value of willingness to pay that varied by land use. The main costs were the environmental burdens on 'regulating' services such as air quality (e.g. GHG and ammonia emissions) and water quality (e.g. emissions of nitrate and phosphate).

Results for the baseline scenario estimated the main benefit of UK livestock systems was from provisioning services (production of food), worth £8,270 million. This was £5,340 million when excluding labour. Cultural benefits, based on current willingness- to- pay values, were significant (£748 million) and were associated mostly with extensive grazing systems. The major ecosystem costs, associated with impacts on regulating services, were GHG (£2,060 million) and ammonia (£380 million) emissions. The analysis also considered the possible implications of reducing or entirely withdrawing livestock production in the UK and substituting it where possible, with arable production. From a spatial analysis of soil suitability for agriculture, an estimate was derived of the degree to which arable production might replace particular types of livestock production in the UK. The level of substitution from livestock land to arable land was limited: of the total modelled land area required for livestock production in the UK (estimated to be 6.89 Mha). About 21% of this was estimated to be well-suited to arable production, with 48% entirely unsuited, and therefore likely to be abandoned from agricultural use. This would result in the loss of current biodiversity, landscape features and probably have negative effects on the tourism and recreational opportunities associated with managed landscapes.

The model enabled trade-offs between provisioning, cultural and regulating services to be analysed, confirming, for example, the important role of livestock systems in providing cultural services, particularly the contribution of less intensive systems to landscape and biodiversity, and additionally the significant trade-offs between provisioning and regulating services, especially regarding impacts on air and water.

References

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

Williams, A.G., Audsley, E., Sandars, D.L. (2007) Environmental burdens of livestock production systems derived from life cycle assessment (LCA). In: Garnsworthy, P. (Ed), 41st University of Nottingham Feed Conference, Sutton Bonington, Nottingham: Nottingham University, 171-200.

Table 1. Illustrative description of the livestock ecosystem services linear programming model

	Sheep systems	Pig systems	Beef systems	Chicken systems	Egg systems	Dairy systems	Arable-well	Arable-moder-ate	Arable-marginal	Unsuita-ble	Emis-sions	Cultural	Rural labour		
Objective(services)														=	P+R+C
Provisioning	+	+	+	+	+	+	+	+	+				+	=	P
Regulating											+			=	R
Cultural	+	+	+	+	+	+	+	+	+	+		-ve		=	C
Constraint															
Production	1	1	1	1	1	1								=	Demand
Arable Land	+	+	+	+	+	+	1							=	L
Grassland	+	+	+	+	+	+	1	1	1	1				=	L
Hill Land	+		+							1				=	L
Emissions	+	+	+	+	+	+	+	+	+		-1			=	0
Labour	+	+	+	+	+	+	+	+	+				-1	=	0
Intra-system	+	+	+	+	+	+								=	0
Inter-system			1			-ve								=	0
Land types	+	+	+	+	+	+								<	L

Notes: + denotes positive coefficients, -ve denotes negative coefficients, +/-1 denotes unit coefficients, L denotes limits/constraints on land and soil types

Table 2. Selected optimising scenarios under hypothetical future conditions relative to current BAU (Business As Usual), with labour viewed as a benefit

	Current BAU £M	Optimised BAU £M	BAU + (up to 20% +) £M	GHG reduced by 25% £M	Red to white meat £M
Provisioning	9100	104%	106%	81%	92%
Arable[a]	0	21	0	557	533
Labour	3764	107%	104%	81%	84%
Dairy	2306	104%	118%	58%	107%
Eggs	267	94%	0%	94%	86%
Poultry	779	99%	113%	99%	129%
Beef	883	102%	105%	28%	49%
Pigs	436	102%	123%	102%	133%
Sheep	664	101%	101%	101%	0%
Regulation	-2700	100%	101%	81%	101%
Cultural	748	99%	100%	76%	30%
Net value	7148	105%	107%	80%	83%

[a] actual values give for arable as the arable BAU is 0 and relative values cannot be calculated; * Greenhouse Gas

Modelling GHG emissions of dairy cow production systems differing in milk yield and breed – the impact of uncertainty

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The inclusion, the discussion and the reporting of model changes due to uncertainties can be important to identify robustness and variation of model outcomes and sensitive or important variables (Pannell, 1997). In this study an existing deterministic model developed to calculate greenhouse gas (GHG) emissions of confinement dairy farm systems differing in milk yield (6000, 8000, 10000 kg milk/cow per year) and breed (dual purpose, milk breed) (Zehetmeier et al., 2012) was further developed. We incorporated uncertainty to account for epistemic uncertainty (e.g. emission factors for GHG modelling, GHG emissions from suckler cow production) and intrinsic variability (e.g. variability of production traits, such as calving interval, replacement rate and variability of costs and prices). The developed stochastic model accounts for two different methods for handling co-products of dairy farming (beef from culled cows and surplus calves): economic allocation and system expansion. In case of economic allocation GHG emissions are allocated between milk and co-products according to their economic value. Within system expansion it is assumed that beef derived from culled cows and fattening of surplus calves replaces beef from suckler cow production. The avoided GHG emissions from suckler cows are credited to the dairy farm.

In consistent with other studies (Flysjö et al., 2011) results showed that the choice of method for handling co-products of dairy cow production had the highest impact on mean values of model outcomes.

The inclusion of uncertainty gave insight into robustness of deterministic model outcomes and identified factors that had the highest impact on variation of model outcomes. In case of economic allocation variation of emission factor for soybean meal and nitrous oxide emissions from nitrogen input into the soil had the highest impact on variation of GHG emissions outcomes (up to 92%). In case of system expansion emission factor for beef derived from suckler cow production had the highest impact on variation of GHG emissions outcomes (up to 54%) resulting in even negative GHG emissions per kg milk. The method of system expansion is recommended if the consequences of changes or mitigation options in dairy cow production need to be evaluated. As stochastic models offer the advantage of predicting not just an outcome, but also the likelihood of this outcome, the robustness of GHG mitigation options can be evaluated.

Whereas the choice of method for co-product handling depends on the scope of GHG modeling in dairy farming the stochastic model approach gave an insight into robustness and variation of model outcomes within each method for co-product handling. This is of special importance identifying cost-effective GHG abatement options.

References

Flysjö, A., Cederberg, C., Henriksson, M., Ledgard, S., 2011. How does co-product handling affect the carbon footprint of milk? Case study of milk production in New Zealand and Sweden. Int J Life Cycle Assess 16, 420-430.

Pannell, D.J., 1997. Sensitivity analysis of normative economic models: theoretical framework and practical strategies. Agricultural Economics. 16, 139-152.

Zehetmeier, M., Baudracco, J., Hoffmann, H., and Heissenhuber, A., 2012. Does increasing milk yield per cow reduce greenhouse gas emissions? A system approach. Animal. 6, 154-166.

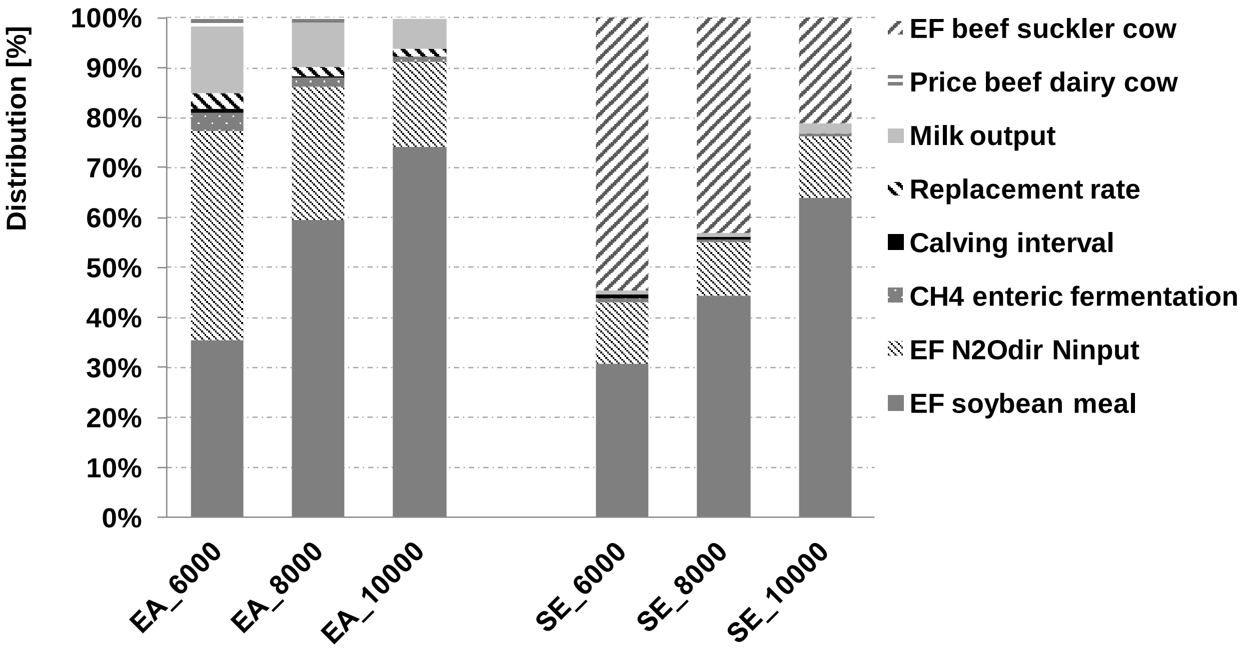

Figure 1. Parameters influencing variation of GHG emission outcomes. EA is economic allocation, SE is system expansion, EF is emission factor

Towards a sustainable animal production sector: potential and problems of LCA

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Animal production is surrounded by concerns around its environmental impact, the health and welfare of animals, the safety of animal products, and its impact on human health. Acknowledging these concerns, Dutch stakeholders along the animal production chain agreed to join forces in the transition towards a competitive sector that produces with respect for animals, humans, and the environment. A lot of research has been directed at feeding, breeding, technological or management innovations to improve sustainability performance of the animal production sector. Moreover, industry partners and other stakeholders start to invest in development of science-based tools to improve and monitor their sustainability performance (www.sustainabilityconsortium.org).

The aim of this paper is to review potentials and problems related to using life cycle assessment (LCA) in the transition to a sustainable animal production sector. We used GHG mitigation as a case study to illustrate the potential problems of using LCA in the field of animal production. Mitigation options discussed are: reducing enteric methane (CH_4) emission from ruminants, co-digestion of manure, and increasing annual milk yield per cow.

First, we address the importance of a life cycle perspective to evaluate innovations in the animal production sector, using the example of a feeding strategy with potential to reduce enteric CH_4 emission at animal level. We assessed the GHG reduction potential of increasing maize silage at the expense of grass silage in a dairy cow's diet at three interdependent hierarchical levels, i.e. animal, farm and chain level. Per ton of fat-protein-corrected milk (FPCM), increasing maize silage at the expense of grass silage with one kg DM per cow per day resulted in an annual emission reduction of 11 kg CO_2-e at animal level, 16 kg CO_2-e at farm level, and 17 kg CO_2-e at chain level. At farm and chain level, however, land use change (i.e. ploughing grassland for maize land) resulted in non-recurrent CO_2 and N_2O emissions of 720 kg CO_2-eq per ton FPCM. From an animal perspective, therefore, we would conclude that this feeding strategy offers potential to reduce GHG emissions, whereas from an LCA perspective it takes up to 42 years before annual emission reductions compensate for emissions related to land use change (Van Middelaar et al., 2012).

Second, we address the effect of methodological choices and handling multi-functionality of livestock systems on LCA results, using the example of increasing annual milk yield per cow? We answer questions such as: How to compare CO_2-e of smallholder systems in which cows produce 500 kg of milk annually with specialised systems in which cows produce 7000 to 8000 kg? How to compare CO_2-e of high-producing Friesian cows with moderate-producing Fleckvieh cows? Results demonstrate that complexity of livestock systems and related methodological choices have a major impact on evaluation of such an innovation.

Third, we address the importance of an integrated life cycle sustainability assessment of an innovation, using the example co-digestion of animal manure and increasing annual milk yield per cow. We concluded that most studies found in literature that addressed mitigation options for GHG emissions did not account for the impact on all other environmental impacts, or their relation with other aspects of sustainability, such as animal welfare (De Boer et al., 2011).

Fourth, we address the importance of stakeholder participation in the process of transition. Our experiences related to Feedprint (development of a carbon footprint tool for the Dutch feed industry) and TSC (The Sustainability Consortium) showed that to ensure application of life cycle thinking in the process toward sustainability, we need not only harmonisation of guidelines, high resolution global data and applicable tools, but also active involvement of stakeholders and acknowledgement of their interest.

References

de Boer I.J.M., Cederberg, C., Eady, S., Gollnow, S., Kristensen, T., Macleod, M., Meul, M., Nemecek, T., Phong, L.T., Thoma, G.,van der Werf, H.M.G., Williams, A.G., Zonderland-Thomassen, M.A., 2011. Greenhouse gas mitigation in animal production: towards an integrated life cycle sustainability assessment. Curr. Opin. Environ. Sustain., 3, 423-431.

Van Middelaar, C.E., Berentsen, P.B.M., Dijkstra, J., De Boer, I.J.M., 2012. Evaluation of a feeding strategy to reduce greenhouse emissions in dairy farming: the level of analysis matters. (Submitted).

Lessons learned from integrated environmental and socioeconomic life cycle assessments

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Over the years, numerous assessment methods have been developed to provide markets actors with the information needed to turn toward more sustainable practices. Because it is holistic, systemic and rigorous, the Life Cycle Assessment (LCA) approach has become one of the main tools in this regards. Initially developed to assess potential environmental impacts of a product, this approach has since evolved to also account for its cost implications (Life Cycle Costing – LCC), as well as for its social and socioeconomic consequences (Social Life Cycle Assessment – SLCA), thus allowing the assessment of all three dimensions of sustainability through a "life cycle" perspective.

However, despite their common conceptual foundations, these LCA tools still lack the integrated framework that would allow conducting a comprehensive assessment of the global sustainability level of a particular product. Although the UNEP/SETAC Life Cycle Initiative is currently developing a Life Cycle Sustainability Assessments (LCSA) methodology to carry out such projects, more development are admittedly needed, in particular from findings and lessons learned from applications combining ELCA, LCC and S-LCA (UNEP/SETAC 2012, 45).

By carrying out an integrated ELCA and SLCA applied to the Canadian dairy sector, this project de facto contributed to the development of the LCSA methodology. More specifically, this project, conducted for the Dairy Farmers of Canada (DFC), assessed both the environmental and socioeconomic impacts associated with milk production in Canada. By doing so, a number of methodological issues arose with respect to the definition of system parameters, the assumptions formulated, data collection and more importantly, with respect of the results interpretations and the formulation of recommendations.

Practically, the distinctiveness of the two methodological frameworks, especially in regards to the focus of the assessment (behaviours in SLCA vs. processes in ELCA), has restricted the possibility to discuss the direct trade-offs between the socioeconomic and environmental impacts assessed. While the discussion led to many relevant observations by comparing, for instance, the environmental performance of dairy farms to dairy farmers' agroenvironmental practices, large parts of the two assessments could not be compared against each other.

This presentation focuses on the key findings of the study dealing with two particular forms of integration, methodological and procedural. It takes stock of the issues encountered in each of these dimensions, highlights the lessons learned, and proposes recommendations for conducting integrated ELCA and SLCA in the future, thus contributing to the development of the LCSA methodology.

References

UNEP/SETAC (2012). Toward a Life Cycle Sustainability Assessment: Making Informed Choices on Products. Preliminary Version. United Nations Environment Programme. Paris.

An assessment of the sustainability profile of the U.S. dairy industry: environmental, economic and social considerations

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There is increasing interest among consumers, food manufacturers, retailers and other food system stakeholders in measures of product sustainability. This paper explores product sustainability in the dairy industry in three areas: the environment, the economy and society. A review of all three aspects, known as the three pillars of sustainable development (United Nations General Assembly, 2005) or the triple bottom line (Elkington, 1998), supports a more comprehensive view of sustainability. This approach recognises the potential trade-offs between environmental, economic and social impacts of production.

The impact of US dairy industry life cycle phases on environmental, economic and social sustainability were assessed using ISO 14040:2006 and ISO 14044:2006 Life Cycle Assessment (LCA) protocols. The Environmental LCA showed that: 1) farming stages contribute significantly (50+%) to each impact category, 2) feed production contributes significantly to carcinogens and water use, 3) crop production drives negative land use and ecosystem impacts, 4) pesticide application drives terrestrial ecotoxicity, 5) phosphorus (52%) and atrazine (18%) drive aquatic impacts and 6) approximately 50% of the human health impact occurs by the farm gate.

Economic contributions were measured in terms of: 1) employment - all wage and salary employees, as well as self-employed jobs in a given sector; 2) labor income - proprietary income (all income received by self-employed individuals) and wages (all worker salaries, payments, and fringe benefits paid by employers); and 3) value added - all payments to workers (labor income) plus indirect taxes and other property-type income, such as payments for rents, royalties, and dividends. The Input-Output analysis showed the contributions to employment were over 877,000 jobs in dairy production, processing and related activities; labor income was $35B, and value added impact was almost $71B.

The social scoping assessment utilises modeling of the supply chain via a global IO model derived from the Global Trade Analysis Project (GTAP). The global IO model maps the number of worker hours along the life cycle of a product category according to the sectors of the economy involved in production and their location (country). Results generated by the modeling of the dairy product supply chain are presented by country specific sector Social assessment identified the significance of dairy production along the life cycle in terms of worker hours with challenges of equitably integrating immigrant labor. The potential social impacts of domestic dairy production, both positive and negative, focuses on the social impacts of dairy production itself, rather than non-dairy processes that contribute to the supply chain. The social evaluation identifies potential issues that warrant more rigorous review.

References

United Nations General Assembly, 2005. 2005 World Summit outcome. Resolution A/60/1, adopted by the General Assembly on 15 September 2005.
Elkington, J., 1998. Cannibals with forks: The triple bottom line in 21st century businesses. Gabriola Island, BC: New Society Publishers.

Bioenergy production from perennial energy crops: a consequential LCA of 12 bioenergy chains including land use changes

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Biomass represents a keystone of future renewable energy systems due to its ability to store and provide carbon. This is essential for balancing the fluctuating energy production from intermittent sources like wind and solar power as well as for providing energy dense fuels, notably for aviation. Though renewable, biomass is however not unlimited in supply, and does involve considerable environmental costs, mainly through its incidence on land use changes. These, however, may be limited if perennial crops are used for bioenergy production.

In the idea of optimising the sustainability of bioenergy production, this study assessed, through consequential life cycle assessment (LCA), the environmental impacts associated with the production of bioenergy (heat and electricity) from 1 hectare of Danish arable land cultivated with three perennial crops, namely, ryegrass, willow and *Miscanthus*. For all these crops, four biomass-to-energy conversion pathways are considered: i) anaerobic co-digestion with manure, ii) gasification, iii) combustion in small-to-medium scale biomass combined heat and power (CHP) plants and iv) co-firing in large scale coal-fired CHP plants. These were assessed against a fossil fuels reference where the land is used for cultivation of spring barley, which has been identified as the marginal crop displaced by bioenergy cultivation in Denmark. For each of these 12 bioenergy systems, all relevant carbon and nitrogen flows were disaggregated and quantified for all the major processes involved, including soil carbon changes resulting from the cultivation stage, as well as direct and indirect land use changes (dLUC and iLUC, respectively). Uncertainties were addressed through sensitivity analysis (scenario uncertainties) and MonteCarlo analysis (parameter uncertainties). The life-cycle impact assessment was carried out according to the Danish EDIP 2003 method.

Results showed that global warming was the bottleneck impact, where only two scenarios, namely willow and *Miscanthus* co-firing, allowed for an improvement as compared to the reference (-45 and -82 t $CO_{2eq.}$ ha^{-1} over 20y, respectively). This differs from most published LCAs assessing similar bioenergy systems, typically showing tremendous global warming benefits when using perennial energy crops for bioenergy production. This divergence is essentially due to the fact that this study includes iLUC, whose impact was quantified as 309 t $CO_{2eq.}$ ha^{-1} of displaced spring barley (range: 141 – 477 t $CO_{2eq.}$ ha^{-1}), representing a paramount average of 58% of the induced greenhouse gas emissions. The greater performance of co-firing on global warming is essentially due to its higher electricity efficiency, highlighting the potential of electricity conversion optimisation for improving the environmental performance of bioenergy production. The other impacts assessed showed less pronounced results. Most energy conversion technologies allowed for a reduction of the N-eutrophication, except when ryegrass was the feedstock. This is mainly due to the dLUC, reflecting the higher requirements in nitrogen fertilisers for this crop (and consequently the higher nitrate leaching), as compared to the spring barley reference. All scenarios allowed for a reduction in P-eutrophication, except in the case of anaerobic digestion, due to the digestate application on land. The results of the uncertainty analysis (sensitivity and MonteCarlo analysis) showed that despite the significant uncertainties involved in the study, the ranking of the bioenergy scenarios found with the LCA results was robust, as it remained the same for both analyses. Only the iLUC uncertainty could change the conclusions: with minimum iLUC impacts, all bioenergy scenarios for willow and *Miscanthus* as well as co-firing of ryegrass achieved environmental savings on global warming.

Overall, co-firing of *Miscanthus* and willow were the options presenting the best environmental performances, and these may increase in the future with expected yield increases for these crops. It should however be highlighted that a main driver for future utilisation of biomass may be to balance electricity generation from fluctuating energy sources, for which gasification and anaerobic digestion may be more suited. On this basis, improving the environmental performance of these biomass-to-energy conversion technologies would be desirable.

A model of indirect land use change

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According to the Peters et al. (2012), around 9% of global carbon emissions in 2010 originated from deforestation. Often, these emissions are not addressed in life cycle assessment (LCA) because the causal link between the use of land and deforestation is not well described and because there is a missing consensus on how to establish this link. Further, several studies suggest that effects from intensification of cropland may be caused by changes in demand for land. In the following a new model and data for establishing the causal link between the use of land and the effects on land use changes and intensification are presented. Here, this link is referred to as indirect land use changes (iLUC).

iLUC is defined as the upstream consequences of the occupation of land, regardless of what you do to it. Whereas *indirect* land use changes are upstream life cycle impacts of an activity which induces the land use change, *direct* land use changes take place only in the land transforming activity. It should be noticed that the upstream effects, i.e. deforestation and intensification, of occupying land in one region of the world are likely to take place in other parts of the world.

The overall concept of the model is that it is assumed that the current use of land reflects the current demand for land, and that land use changes are caused by changes in demand for land. This concept is equivalent to all other modelling in life cycle inventory, i.e. the demand for a product determines the production volume. The market for land is defined as a service that supplies capacity for production of biomass. This market has inputs from different suppliers, e.g. land already in use, expansion of land (which may cause deforestation) and intensification. The presented model is applicable to all regions in the world and to all types of land use. The standard reference flow for the use of land, 'land tenure', is the land's potential production capacity, measured as the potential net primary production, NPP_0 (in unit kg carbon). This can easily be converted to occupation in units of hectare years (ha yr), e.g. by use of data in Haberl et al. (2007). The concept is illustrated in Fig. 1.

The starting point of the model is an inventory of the total global observed land use changes. The accounting framework for this is a land use change transition matrix, see Table 1. The land use change transition matrix is mainly based on FAO's Global Forest Resources Assessment (FAO 2010). Distinction is made between different markets for land; land suitable for arable cropping, land suitable for forestry, land suitable for rangeland, and other land (barren, desserts, ice caps etc.). The land tenure market activities have four types of inputs: land already in use, expansion, intensification and crop displacement. The emissions related to deforestation and intensification are based on IPCC (2006) and Schmidt (2008) respectively. The inventory framework allows for the application of consequential and attributional modelling assumptions. Time related effects are addressed by use of a fate function of CO_2 pulse emissions in the atmosphere opposed to the amortisation approach which is typically used in iLUC models.

References

FAO, 2010. Global Forest Resources Assessment 2010 – main report. FAO, Rome.

Haberl H. et al., 2007. Quantifying and mapping the human appropriation of net primary production in earths terrestrial ecosystems. PNAS, vol. 104, no. 31, pp 12942–12947.

IPCC, 2006. 2006 IPCC Guidelines for national greenhouse gas inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H S et al. (eds). IGES, Japan.

Peters G. P., Marland G., Le Quéré C., Boden T., Canadell J. G., Raupach M. R., 2011. Rapid growth in CO_2 emissions after the 2008-2009 global financial crisis. Nature Climate Change 2, 2–4.

Schmidt J H (2008), System delimitation in agricultural consequential LCA, outline of methodology and illustrative case study of wheat in Denmark. Int J Life Cycle Assess 13(4):350–364.

Schmidt J. H., Reinhard J., and Weidema B. P., 2012. Modelling of indirect land use changes in LCA, report v3. 2.-0 LCA consultants, Aalborg, http://www.lca-net.com/projects/iluc_model/

Table 1. Land use change matrix, unit: million ha. The global land use transition matrix is established for an average year in 2000-2010. The top column headings divide the total land into land not in use and land in use. For the land in use there are four land tenure markets. The growth of these markets, which involves deforestation and land degradation, can be seen as inputs in the rows. (Schmidt et al. 2012)

Transformation to:	**Non use**			**Markets**				
Transformation from:	Primary forest	Secondary forest	Other (grassland, wetland, scrubland)	Extensive forest land	Intensive forest land	Arable land	Rangeland	**Total land use ref. year**
Primary forest	1,102	0	0	1.09	0.084	3.02	0	**1,106**
Secondary forest	0.34	1,798	0	0	4.85	9.98	0	**1,813**
Other (grassland, wetland and scrubland)	0	1.30	3,769	0	0	0.60	1.88	**3,773**
Extensive forest	0	0	0	930	0	0	0	**930**
Intensive forest	0	0	0	0	196	0	0	**196**
Arable	0	0	0	0	0	1,624	0	**1,624**
Range	0	0	0	0	0	0	3,569	**3,569**
Total land use ref. year + 1	**1,102**	**1,799**	**3,769**	**931**	**201**	**1,638**	**3,571**	**13,012**

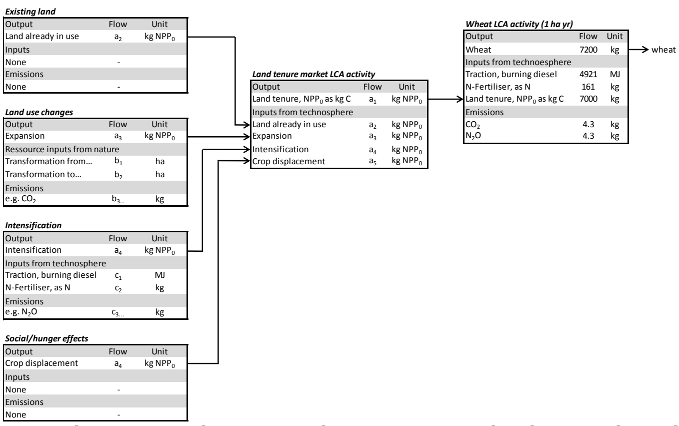

Figure 1. Illustration of the land tenure market activity and its inputs and outputs. An agricultural activity, here wheat, has inputs from the land tenure market activity. The land tenure market activity has inputs from four different supplies of biomass production capacity. Each of these suppliers is associated with emissions. The sum of these emissions is referred to as iLUC emissions.

Land use change - GHG emissions from food and feedstuffs

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Land use change (LUC) is assumed to be one of the major contributors to global CO_2 emissions (contributing 23% to the increase in atmospheric CO_2 concentration during the last 250 years; Hörtenhuber, 2011). Despite its great impact on global greenhouse gas (GHG) emissions and thus on global warming, LUC is hardly incorporated into estimations of the global warming potential (GWP) in LCAs and into current carbon footprints (CF) for food and feedstuffs for various reasons. Literature sources link methodological limitations to lacking information on aspects such as regions of origin for imported food and feedstuffs, the nature of land before conversion, the onset of LUC-related emissions and their temporal progression as well as debatable accounting periods for depreciation of LUC emissions. In contrast to these literature sources and to the use of average global emissions from LUC and land use (LU; see e.g. Vellinga et al., 2011) for overall feed, herein we present findings which should contribute to closing methodological gaps and to enable a more product-related inclusion of emissions from LUC. Generally, it is concluded that system boundaries should be defined rather extensively in the estimation of GHG emissions from agricultural production. This should include CO_2 from the degradation of above ground-biomass plus soil organic carbon from LUC and LU. CO_2-neutrality for emissions from LUC only exists theoretically as the storage of released carbon occurs over substantial time and not necessarily in spatial proximity. It is suggested that GHG emissions accounted for should be restricted to physically occurring fluxes of greenhouse gases which are related to a specific product. Accounting (depreciation) periods for LUC can be either derived from isolated areas with LUC emission or from a global carbon view. As a result, 10 or 20 years may be used as suitable default periods. The 10 year period includes the majority of LUC-related emissions released from soils as well as of emissions remaining in the atmosphere. Twenty years are more feasible for temperate conditions with their lower rates of CO_2-release (Hörtenhuber, 2011). For GHG estimates, information on characteristics of supply chains and on specified regions of origin is often available on a regional scale. Hence, a product related approach should be applicable for specific products, although emission factors which properly differentiate between regions or temporal dimensions remain to be a challenge. Indirect LUC (iLUC) can be assessed on a national scale, derived from expansion rates of crops (see Hörtenhuber, 2011; Hörtenhuber et al., 2011; Ponsioen and Blonk, 2012). However, iLUC is unfortunately much more difficult to be estimated on an international or even global scale and should be addressed in future studies. Due to its high relevance on the global scale, emissions from LUC need to be included in the estimation of GHG emissions where great quantities of LU/LUC-burdened inputs, such as extracted soybean meal as a feed component, are used. This can be illustrated by an estimated 50 percent less CO_2-eq per kg of broiler carcass if LUC-loaded feedstuffs (particularly extracted soybean meal) are substituted for (Hörtenhuber, 2011). Fig. 1 shows differences in feedstuff production between three possible approaches. The results call for a thorough and product-related analysis of LUC-related emissions in order to define strategies for reduction.

References

Hörtenhuber S., 2011. Greenhouse gas emissions from dairy production – assessment and effects of important drivers. Dissertation thesis. University of Natural Resources and Life Sciences, Vienna, Austria.

Hörtenhuber, S., Lindenthal, T., Zollitsch, W., 2011. Reduction of greenhouse gas emissions from feed supply chains by utilizing regionally produced protein sources - the case of Austrian dairy production. Journal of the Science of Food and Agriculture 91, 1118-1127.

Ponsioen, T.C., Blonk, T.J., 2012. Calculating land use change in carbon footprints of agricultural products as an impact of current land use. Journal of Cleaner Production 28, 120-126.

Vellinga, T., Blonk, H., 2011. Feed database for livestock systems - An improvement of CFP calculations for livestock systems. http://ebookbrowse.com/theun-vellinga-fao-pdf-d92065125, 2012-02-08

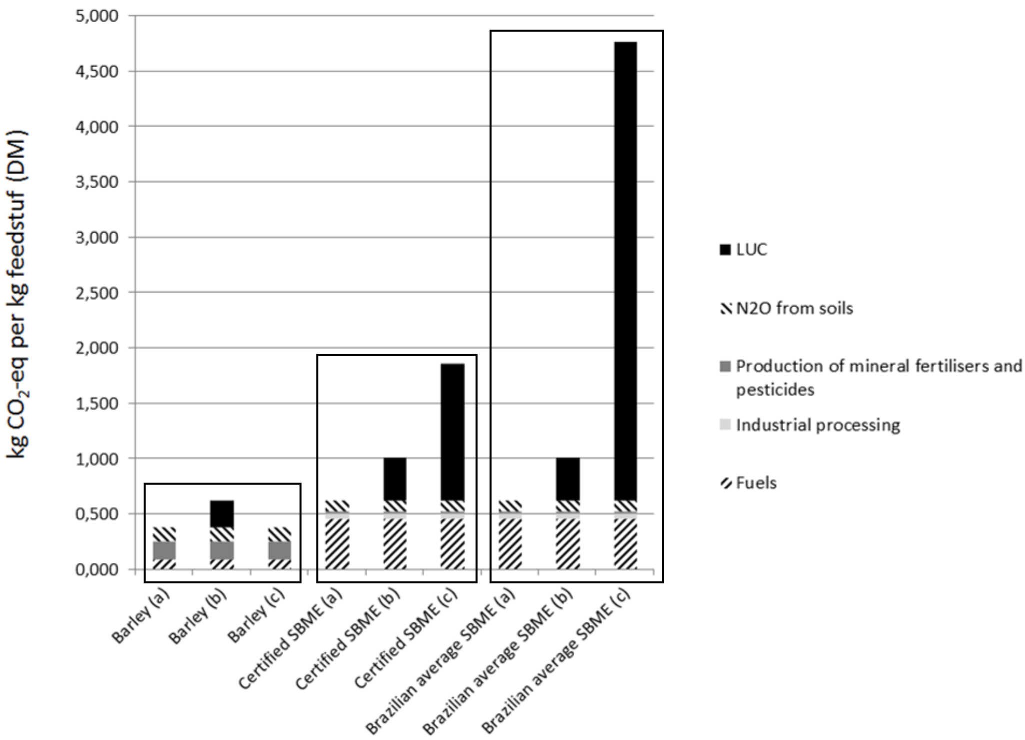

Figure 1. Total and source-related GHG emissions (kg CO_2-eq) for Austrian barley, certified extracted soybean meal (SBME; according to 'The Basel Criteria for Responsible Soy Production', http://awsassets.panda.org/downloads/05_02_16_basel_criteria_engl.pdf) and a national average of extracted soybean meal from Brazil. GHG emissions from land use change are partially included: (a) does not include any LUC-related GHG emissions, (b) accounts for LUC-emissions as derived from average global emissions (Vellinga et al., 2011) and (c) accounts for product-related LUC-emissions. Except for LUC-emissions in (b), all data and calculations used are based on Hörtenhuber (2011) and Hörtenhuber et al. (2011b).

LCA of sunflower oil addressing alternative land use change scenarios and cultivation practices

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The purpose of this study is to develop a Life-Cycle Assessment (LCA) to evaluate the environmental impacts of sunflower oil produced in Portugal, accounting for direct effects of land use change (LUC) and assessing the implications of adopting irrigated and non-irrigated cultivation. Previous studies calculated greenhouse gas (GHG) emissions for cultivation in Portugal (Gírio et al. 2010), but LUC was not assessed. In addition, no LCA of sunflower oil for Portugal has been published.

A LC model and inventory for sunflower oil produced in Portugal were developed and implemented. The LC model included LUC (alternative scenarios), sunflower cultivation (2 systems), oil extraction and transportation. Figure 1 presents the sunflower oil chain, including the alternative cultivation systems. A comprehensive evaluation of twenty-eight alternative LUC scenarios was also performed, considering 7 different previous land uses: severely degraded or improved grassland (medium and high input); perennial crop (no or reduced tillage, with or without manure). Table 1 shows the main inputs for the irrigated and non-irrigated cultivation systems. A detailed LC Inventory was implemented for sunflower cultivation and sunflower oil extraction, based on Portuguese process data. It should be highlighted that no fertiliser was applied in non-irrigated cultivation. In this type of cultivation, water is the limiting factor. Table 2 presents the inventory for sunflower oil extraction and treatment. Two co-products are produced during oil extraction: sunflower oil and meal. Three alternative allocation methods were applied (mass, energy and economic) to assess the influence of the allocation procedure in the results. Life Cycle Impact Assessment (LCIA) results were calculated based on the ReCiPe method (Goedkoop *et al*., 2008) for six impact categories: climate change, fossil depletion, freshwater eutrophication, marine eutrophication, terrestrial acidification and ozone depletion. GHG emissions for the various LUC scenarios were estimated based on IPCC (2006) and EC (2010).

The results show the importance of LUC and cultivation practices on the environmental performance of sunflower oil. We show that LUC is a critical issue for climate change results since large variations were calculated between the various LUC scenarios. Regarding the impact of using different types of cultivation practices, sunflower cultivated in non-irrigated land had higher environmental impacts in the categories of climate change, marine eutrophication, fossil fuel depletion and ozone depletion (OD). On the other hand, sunflower cultivated in irrigated land had higher impacts for terrestrial acidification and freshwater eutrophication (FWE). The FWE impacts were about 30 times higher for irrigated cultivation relatively to non-irrigated cultivation (in which there was no fertiliser input). Normalised environmental impacts are also presented, showing a similar magnitude for all categories (0.6×10^{-4}- 1.7×10^{-4}), except for FWE and OD. Detailed results concerning process contribution in the various stages of the sunflower oil chain are also assessed. Cultivation contributed 70%-99% to the life-cycle impacts in all categories, mainly due to fertilisers and diesel (agricultural processes in irrigated cultivation). Finally, we discuss optimal LUC scenarios and improvement opportunities in the sunflower oil chain.

References

EC, 2010. Directive 2009/28/EC of the European Parliament and of the council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. European Commission, Official Journal of the European Union, L140/16 of 5.6.2009.

Gírio, F.M., Matos, C.T., Oliveira, C.A., Silva, L., Bogel-Lukasik, R., Aguiar, R., 2010. Typical greenhouse gas emissions in the cultivation phase of raw materials for the production of biofuels. Report from Portugal. Agriculture. http://ec.europa.eu/energy/renewables/transparency_platform/emissions_en.htm

Goedkoop, M.J., Heijungs, R., Huijbregts, M., De Schryver, A., Struijs, J., Van Zelm R., 2008. A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level; First edition Report I

IPCC, 2006. Guidelines for national greenhouse gas inventories. In: Intergovernmental Panel on Climate Change, Agriculture, Forestry and other Land Use, vol. 4.

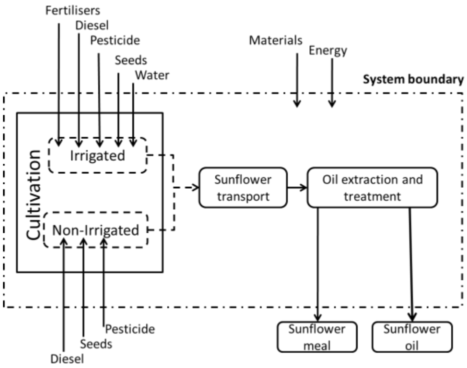

Figure 1. Sunflower oil chain.

Table 1. Inventory of sunflower cultivation (1 kg sunflower).

Main Inputs		Irrigated	Non-Irrigated	Unit
Fertilisers	N	0.007	-	kg
	K_2O	0.021	-	kg
	P_2O_5	0.021	-	kg
Pesticide (atrazine)		0.001	0.0023	kg
Seeds for planting		0.0023	0.0046	kg
Diesel		0.0523	0.1539	L
Water		1.5	_-	m^3

Table 2. Inventory of extraction and treatment of sunflower oil (1 kg).

Main Inputs	Value	Unit
Sunflower seeds	2.29	kg
Natural Gas	1.63	MJ
Bentonite	5.38×10^{-3}	kg
Hexane	2.53×10^{-3}	kg
Phosphoric acid	8.16×10^{-4}	kg
Electricity	9.66×10^{-2}	kWh
Co-products	**Value**	**Unit**
Sunflower oil	1	kg
Sunflower meal	1.29	kg

System expansion and allocation in the life-cycle GHG assessment of soybean oil

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This paper presents a life-cycle (LC) greenhouse gas (GHG) assessment of soybean oil addressing critical issues in the modelling and results. Different methods for handling co-production in the oil extraction process were compared. In particular, we performed a sensitivity analysis to illustrate the influence on the results of using different allocation approaches and scenarios for system expansion. The implications of alternative land use change (LUC) scenarios associated with the expansion of different soybean cultivation systems were also evaluated.
A LC model and inventory for the various stage of the soybean oil chain was developed and implemented. The model included LUC, soybean cultivation in Brazil and soybean transport to Portugal, where soybean oil extraction, together with soybean meal production, takes place. Several scenarios based on alternative allocation approaches and substitution systems (for soybean meal) were used for dealing with this co-production. A sensitivity analysis of allocation based in mass, energy (lower heating value, LHV) and market prices of oil and meal was performed. Table 1 shows the mass, energy and economic data used to calculate the allocation factors. Concerning the substitution scenarios, since soybean meal is mainly used as animal feed, two product systems that are currently displaced by soybean meal co-produced with soybean oil in Portugal were considered: "Imported Soybean Meal" (ISM) and "Imported Soybean" (IS).
Figure 2 presents the results of a sensitivity analysis conducted to illustrate the implications of different multifunctionality approaches on the GHG balance of soybean oil (excluding LUC). It can be observed that the results obtained for different approaches present significant variation: between -0,36 and 1,12 kg CO2eq/kg. The lowest value was obtained when the substitution scenario "Imported Soybean meal" (ISM) is adopted. On the opposite, soybean oil presents higher emissions for market price based allocation. This large variation of results demonstrates the critical influence on the results of the method selected for handling co-production. This also justifies the need to perform a sensitivity analysis, as recommended by ISO 14044:2006 (ISO, 2006). Concerning the LUC scenarios, the results show that LUC dominates soybean oil LC GHG emissions, but significant GHG variation was observed between the alternative scenarios. The original land choice is a critical issue to assure the sustainability of soybean oil production and degraded grassland should be preferably used for soybean cultivation.
The paper presents a discussion of the importance of assessing different approaches to deal with multifunctionality in agri-food chains, based on the soybean oil case. The sensitivity analysis conducted to illustrate the consequences of different multifunctionality approaches on the LC GHG assessment of soybean oil shows that results are very sensitive to the approach adopted.

Table 1. Soybean oil and meal mass ratios, LHV, market prices and corresponding allocation factors.

	Mass		**Energy**		**Market price**					
	Mass ratio (t/t oil)	**Allocation factor**	**LHV (MJ/kg)**	**Allocation factor**	**Prices[a] (US$/t)**			**Allocation factor**		
					Min	**Max**	**Av**	**Min**	**Max**	**Av**
Oil	4.1	20%	36.6	36%	837	1208	925	38%	43%	41%
Meal	1.0	80%	16.3	64%	335	388	331	62%	57%	59%

[a] International Monetary Fund (2011)

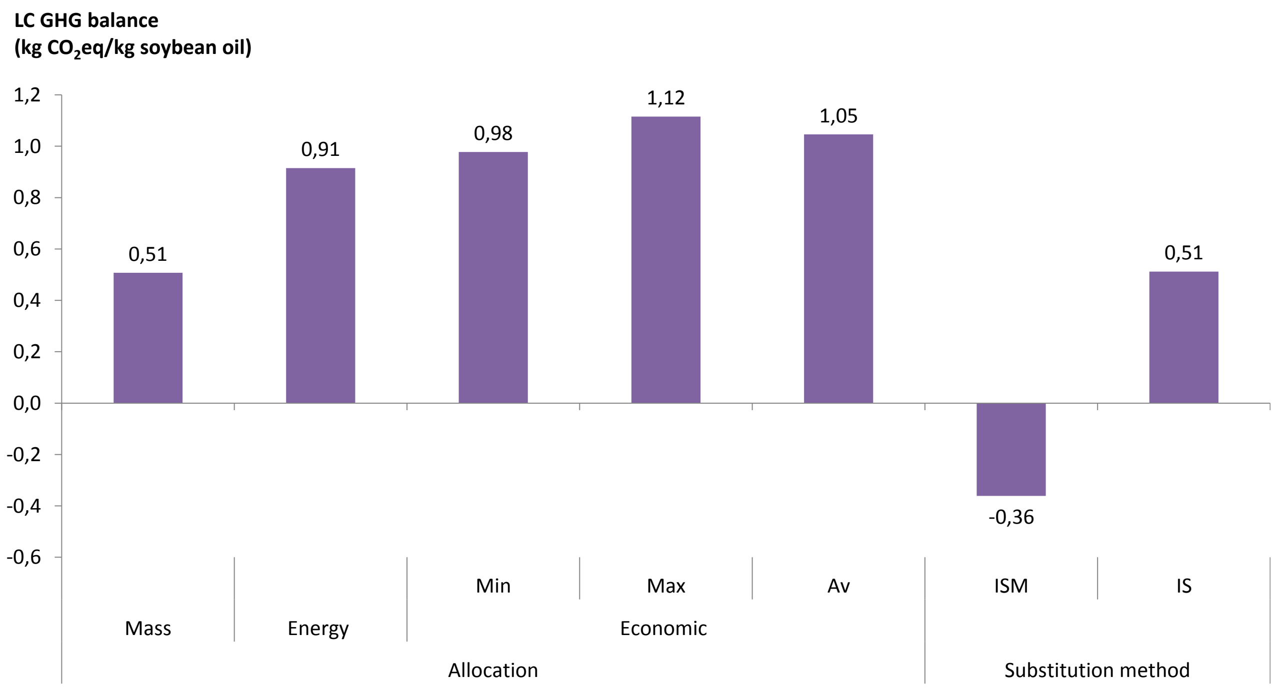

Figure 1. LC GHG emissions of soybean oil (no LUC, no-tillage): different methods for handling co-products.

Considering land use change and soil carbon dynamics in an LCA of French agricultural products

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In 2009 two French laws, Grenelle 1 and 2, were passed on the provision of reliable and complete environmental information on "product plus packaging" to consumers. The Life Cycle Assessment method was chosen to assess environmental impacts of goods. ADEME, the French Environment and Energy Management Agency, was mandated to set up an LCI database to support this policy. The Agri-BALYSE programme started in early 2010, involving: i) ADEME as commissioner; ii) ART (Switzerland) and INRA as project co-leaders; iii) CIRAD, ACTA and 10 technical agricultural institutes for data collection and implementation in practice. One of the aims of Agri-BALYSE is to provide LCIs of agricultural products at the farm gate.

The choice of appropriate methods for the estimation of resource use and emissions of pollutants is a major challenge for Agri-BALYSE. In this respect the impact of land-use change (LUC) on soil carbon dynamics is an important issue. Several studies propose methodologies to consider this issue, in particular for grassland and annual crops. Some of them (Gerber et al., 2010; IDF, 2010), are based on the IPCC (2006) recommendations, others, Leip et al. (2010), are not consistent with these recommendations.

In collaboration with CITEPA, the French institute in charge of reporting of greenhouse gas emissions, a method to estimate soil C dynamics from direct LUC in mainland France was developed. This method is based on IPCC (2006) recommendations. Thanks to the data from the French Soil Survey Network (Martin et al., 2011), the C soil stock was determined for both grasslands and annual crops. Then, the land use data from the Teruti-Lucas network (CITEPA, 2012) allowed us to determine areas involved in LUC for each year of the Agri-BALYSE reference period (2005-2009). The Teruti-Lucas network was used to estimate the rate of LUC over the last 20 years. The annual area concerned by LUC from grassland to annual crops and from annual crops to grassland was then calculated, as well as emission and sequestration of CO_2 (Table 1). These results then allowed the calculation of annual per ha emissions for biogenic CO_2 for grassland and annual crops, which are the main agricultural land use types in mainland France (Table 1).

References

CITEPA, 2012. CCNUCC – Rapport national d'inventaire pour la France au titre de la convention cadre des Nations Unies sur les changements climatiques et du protocol de Kyoto. CITEPA, Paris, France.

Gerber, P., Vellinga, T., Opio, C., Henderson, B., Steinfeld, H., 2010. Greenhouse gas emissions from the dairy sector. A life Cycle Assessment. FAO, Rome, Italy.

IDF, 2010. A common carbon footprint approach for dairy. The IDF guide to standard lifecycle assessment methodology for the dairy sector. Bulletin of the International Dairy Federation 445. International Dairy Federation, Brussels, Belgium.

IPCC, 2006. IPCC guidelines for notional greenhouse gas inventories, in: Eggleston, S., Buendia, L., Miwa, K., Ngara, T., Tanabe, K (Eds.), Volume 4: Agriculture forestry and other land use. IGES, Hayama, Chapter 5 and 6.

Leip, A., Weiss, F., Wassenaar, T., Perez, I., Fellmann, T., Loudjani, P., Tubiello, F., Grandgirard, D., Monni, S., 2010. Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions (GGELS). Final report. European Commission, Joint Research Centre, Ispra, Italie.

Martin, M.P., Wattenbach M., Smith P., Meersmans J., Jolivet C., Boulonne L., et Arrouays D.. 2011. Spatial distribution of soil organic carbon stocks in France. Biogeosciences 8(5): 1053-1065.

Table 1. Total estimated areas of land-use change from grassland to annual crops and from annual crops to grassland and CO_2 emissions per year per ha of annual crop and grassland in mainland France. Average total areas of annual crops and grassland for the Agri-BALYSE reference period and average CO_2 emissions from land use change expressed per ha of the total area of annual crop and grassland.

Land-Use Change	Area (ha)	Emission (t CO_2/ha)
Grassland to annual crops, 2005-2009	3 222 728	3.40
Annual crops to grassland, 2005-2009	2 764 221	-3.16
Total annual crops, 2005-2009	16 686 248	0.66
Total grassland, 2005-2009	11 139 626	-0.78

Using packaging to reduce food environmental impacts for commercial food service: an example

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The very first life cycle assessment was one comparing packaging options (Damar and Nuss, 1969), and studies of food packaging continue to be a common in the LCA field. Part of the reason for that is that approximately one-half of all packaging is used for food, and used packaging is a conspicuous fraction of the solid waste stream in developed countries (Staley and Barlaz, 2009).

With few exceptions, the environmental impact of packaging tends to be much smaller than the environmental impact of the contents of the packaging. The primary function of packaging is to protect and conserve the contents of the packaging, with secondary functions to inform and to track and to market the product. We can then ask the question: can the packaging, by reducing the losses of the contents lead to overall reduction of environmental impacts?

We evaluated the opportunity for food service losses to be mitigated by packaging, comparing frozen food packaging to a shelf-stable retort packaging to no packaging (made from scratch) scenarios, with and without food waste. The recipe for the contents (a beef chilli) was kept constant. In no case was the packaging more than 15% of the life cycle environmental impact, when using the TRACI model. The three packaging scenarios had essentially equivalent impacts per serving, with the exception that photochemical smog formation was higher in the packaged scenarios, due to transportation impacts.

Primary data was obtained for approximately 60% of the mass of the retort packaging and its contents. Secondary data was provided for the remainder and for the other scenarios. Wherever choices were made, they were selected to provide the most conservative impact of the frozen and made from scratch scenarios (i.e., the choice causing the least potential environmental impact of the product system).

We evaluated the scenario when 100 servings were prepared, and different fractions of the servings were not consumed (i.e. were wasted). We assumed that chilli that was heated to serve was discarded, the likely outcome when the menu cycle is more than approximately three days. The retorted package can be heated and returned to storage on the shelf when not opened.

The results showed that the retorted pouch could potentially reduce wastes prior to food service, and this could reduce the overall environmental impact of the food service by as much as 50%. Since the majority of food waste in developed countries occurs in the consumer portion of the life cycle (FAO 2011), this could show substantial improvements in the environmental impact of food service, especially in the case where the number of servings required is uncertain.

This study illustrates how packaging, although causing a small proportion of the life cycle impacts can provide significant environmental benefits when its use leads to less food waste. It highlights the importance of food waste and the need to educate food service organisations of their choices to reduce food waste.

References

Darnar, A. and G. Nuss. 1969. Environmental Impacts of Coca-Cola Beverage Containers.

Gustavsson, J, C. Cederberg and U. Sonneson, 2001. Global Food Losses and Food Waste. Extent, Causes and Prevention. Food and Agriculture Organization, Interpack2011, Dusseldorf, Germany.http://www.fao.org/fileadmin/user_upload/ags/publications/GFL_web.pdf

Staley, B. and M. Barlaz. 2009. Composition of Municipal Solid Waste in the United States and Implications for Carbon Sequestration and Methane Yield. J. Env. Engr. October 2009: 901.

Recycling of aseptic milk packaging and reverse logistic chain accounting

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Recycling is one of the best options to reduce the environmental impact of products and this objective has been pursued by Tetra Pak for the last two decades (Mourad et al., 2008). Actually, the reverse chain of milk aseptic packaging is well established and the composite material is almost totally recovered. Cellulose fibre content is recovered by efficient modern hydropulpers which are able to separate wood fibre from the residue of polyethylene / aluminium. The high quality fibre is used to produce new paper products. The residue of PE/Al is partially converted into roof tiles and sheets and partially processed by a plasma technology which breaks down the long polymer structure in the short chain of hydrocarbons obtaining paraffin and also recovers the metal content in high purity aluminium ingots. Although post-consumer packaging recycling is a goal pursued around the world, the methodological approach to calculate the environmental changes based on an LCA are not always clearly explained. For this reason, besides the normal goal to measure the environmental effects of these processes, the second objective of this paper is to present the LCA modelling and accounting of this reverse logistic chain. Using the principles of ISO 14041 and ISO/TR 14049, data from the reverse logistic chain including the recycling processes were collected and an open-loop with closed-loop recycling procedure with expanded system boundaries was used to model the system as described in Fig. 1. The credits of roof tiles co-production was done by the subtraction of the inventory of an equivalent mass of virgin aluminium roof tiles which are replaced by the recycled one. Aluminium recovery by plasma is considered as being at the boundary of this system as the recovered material has no changes in its inherent properties. The paraffin obtained is used to replace the petrochemical naphtha that is a precursor of polyethylene production. This reverse flow was called "recycled polyethylene" and was applied to discount the use of virgin polyethylene. Using this methodological approach for post-consumer packages which are recycled or landfilled, the following reductions in the environmental potential impacts were obtained for a 27% current recycling rate compared to no recycling: 23% in global warming, 8% in abiotic depletion, 14% in acidification, 15% in photochemical ozone creation, 12% in human toxicity and 6% in eutrophication measured by the functional unit of 1,000 litres of milk. In can be concluded from the results obtained in this project that even considering all the large transport distances in our country, and energy and materials used in the recovering processes, recycling bring environmental advantages.

References

Mourad, A.L., Garcia, E.E.C., Vilela, G.B., Zuben, F., 2008. Environmental effects from a recycling rate increase of cardboard of aseptic packaging system for milk using life cycle approach. Int. J. LCA 13, 140-146.

International Organization for Standardization, 2000. ISO 14049 – "Environmental management – Life cycle assessment – Examples of ISO 14041 to goal and scope definition and inventory analysis" Geneva, Switzerland, 44 p.

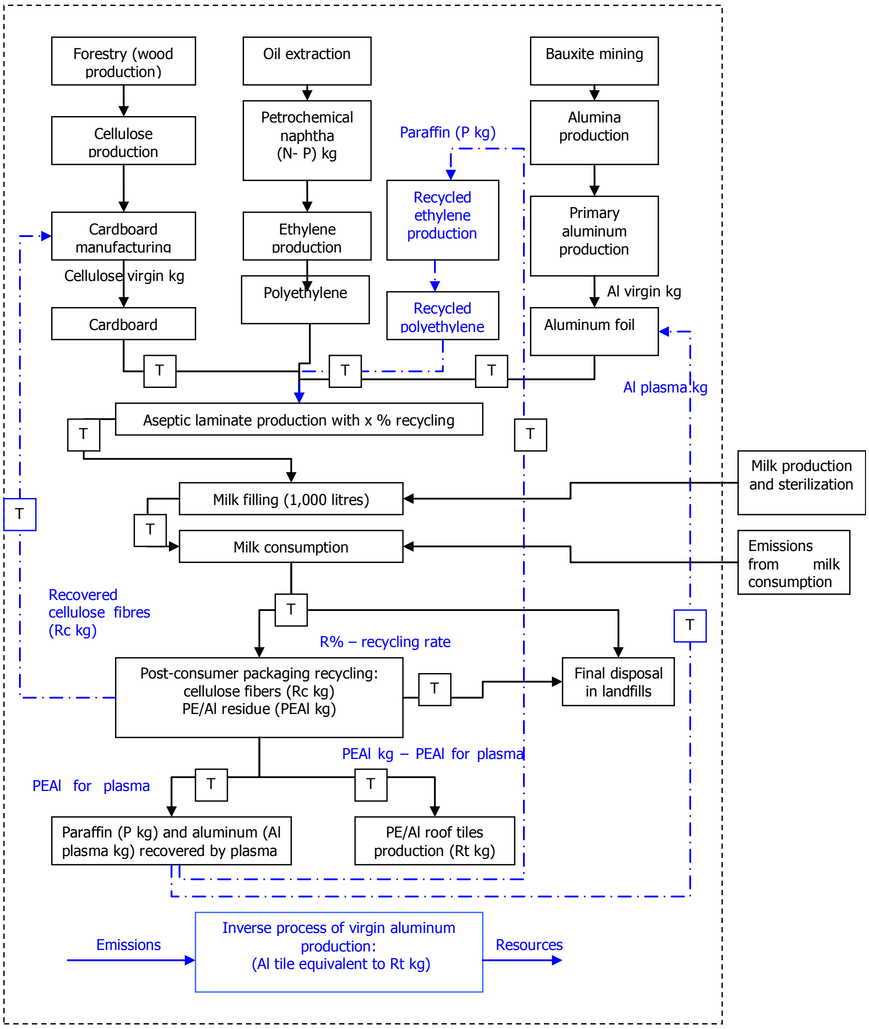

Figure 1. Model used to account the production and recovering of the aseptic milk packaging (open-loop with closed-loop recycling procedure and expanded system boundaries).

A multicriteria analysis for food packaging end-of-life optimisation based on a configurable life cycle assessment approach

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This study proposes the development of a mathematical model based on LCA results to assess the environmental efficiency of the end-of-life management of a common food packaging, *i.e.* Polyethylene terephalate (PET) bottles. For this purpose, multi-objective optimisation involving Genetic Algorithms and decision support tools were used to define optimal targets for efficient waste management.
This issue is of first importance for food packaging companies which have to deal with their products sustainability all along their life cycle; their products being in competition more and more with tap water.
This model can be easily adapted to any other food packaging, or any specific product like bio-based plastics or organic wastes to find the optimal allocation between valorisation paths, or between supply paths (for instance supply of a bio-refinery), in order to minimise the associated environmental impacts. After use, PET bottles can be landfilled, incinerated, or recycled by mechanical, chemical or thermal processes. Each recycling process leads to a different product e.g. fibers, films, bottles, chemicals, fuels, etc. (Al-Salem et al., 2009).
The model developed in this work computes the global environmental impacts associated with the treatment of PET bottles (expressed in kg) from cradle to ultimate graves, i.e. either incineration or landfill, in function of the flow of bottles in the different valorisation paths. They are based on the calculation of the impacts involved in each elementary process with Simapro LCA software tool, using the CML impact assessment method. The model also takes into account the fraction of PET regenerated into bottles that can be further recycled. Finally, the global impacts are the cumulative impacts corresponding to each "end-of-life". A non-linear model for the bottle waste collection stage is also considered; reflecting that the more diffuse the flow of bottles is, the more difficult it is to collect and consequently, the more environmentally impacting.
The resulting multi-objective problem is to find the allocation of bottles between valorisation paths that minimises the environmental impacts of bottle end-of-lives. It is solved using a genetic algorithm (Ouattara et al., 2012), and the trade-off between environmental impacts is illustrated through Pareto curves (Fig. 1). A decision support tool involving a variant of the so-called TOPSIS method (Technique for Order Preference by Similarity to Ideal Solution) then determines best compromises among the optimal solutions (Ren et al., 2007).
The model has been applied first to the case of France in 2010. When considering multiple recycling for PET bottles, the best solution is to collect 87% bottles and to regenerate all of them into bottles by mechanical recycling. In this case, abiotic depletion, acidification and GWP impacts respectively decrease by 141, 72 and 61%. We then applied the model to the Ile-de-France region with its current waste treatment industrial sites. The PREDMA regulation is aiming at a 60% waste collection rate in 2014 and 75% in 2019. Results in Figure 2 show that infinite recycling loops reduce abiotic depletion, acidification and GWP respectively by 64.5, 65 and 65%; meanwhile a 75% collection rate leads to a decrease of abiotic depletion, acidification and GWP respectively by 28.5, 25 and 115%.
It was also checked that the recycled bottle quality was not affected by successive bottle-to-bottle recycling, meaning that intrinsic viscosity and colour remain above the quality threshold standards.
The model of the PET packaging management system proposed here is particularly interesting to quantify the environmental impacts and determine optimal targets. The use of multi-recycling loops for PET bottles reduces significantly the environmental burdens. This could lead to new strategies for food packaging companies like developing new partnerships with local communities and waste treatment companies.
Further work is now devoted to the application of this methodology both to LCA of other food packaging (polylactic acid (PLA) bottles and bio-based PET bottles) and to the optimal material supply for bio-based ethanol synthesis used in different biomaterials by comparing different crops.

References

Al-Salem, S.M., P. Lettieri, P. and J. Baeyens, J., 2009. Recycling and recovery routes of plastic solid waste (PSW): A review. Waste Management, 29: 2625-2643

Ouattara, A., Pibouleau, L., Azzaro-Pantel, C., Domenech, S., Baudet, P., Yao, B., 2012. Economic and environmental strategies for process design, Computers & Chemical Engineering, 36: 174-188.

Ren, L., Zhang, Y., Wang, Y., and Z. Sun, Z., 2007. Comparative analysis of a novel m-topsis method and topsis. Applied Mathematics Research Express, 10.

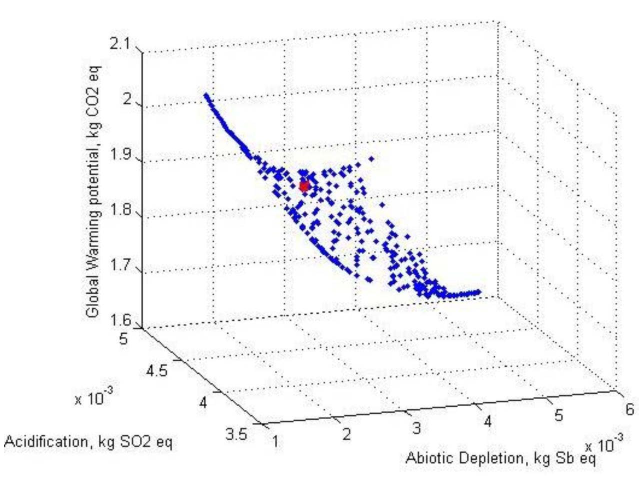

Figure 1. Triobjective optimisation results, in the case of multiple recycling loops (red point shows the best compromise found with TOPSIS method).

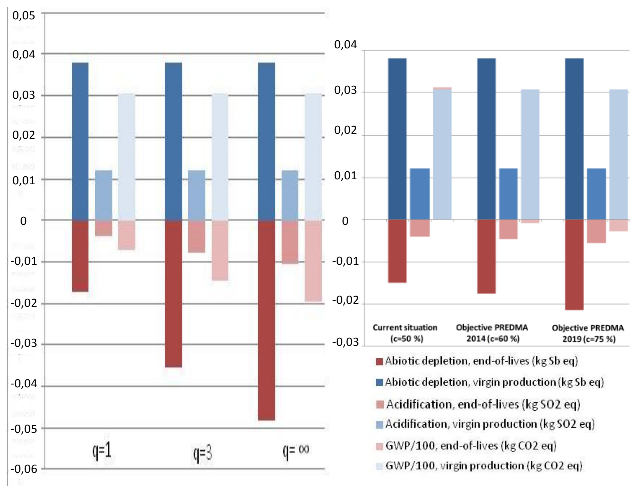

Figure 2. Effect of recycling loop number (q=[1..3]) and collection rate (c = 50% ; 60% ; 75%) on the environmental impacts assessment of PET bottle waste treatment in Ile-de-France region.

Environmental aspects used for food packaging design and product carbon footprint assessment

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In developing new designs for long shelf life food packaging, this study takes a product life cycle into account, with the product carbon footprint as an indicator. Technical and market variables are also included in the evaluation. For the assessment, the study uses four different containers for sausage products: tin container, rigid plastic, 100 percent flexible plastic and flexible aluminium pouch. Expected shelf life for the containers without refrigeration is two years. The methodologies used for the study are the ISO14040, ISO14044 and PAS2050:2008.

The goal of the life cycle assessment (LCA) is to compare the different alternatives to use for the design decisions. The functional unit for the LCA is "180g of packed, long life sausage". The data for the life cycle of each prototype, from raw material, manufactured packaging, transportation, food production processes, distribution, use and disposal were modelled with the Umberto software. (Carbon footprint for v1.2.; Fig. 1).

The results for the different containers are similar, because the materials used in the packaging have an important effect in the construction of the packaging. For example, aluminium has an important carbon footprint in the flexible aluminium pouch. See an example with the Sankey diagram for the product carbon footprint of the packaging in each life cycle stage in Fig. 1. Finally, the four different packagings are evaluated; the results noted the low impact of the rigid plastic and the 100 percent flexible plastic pouch, while the tin container has the biggest carbon footprint (Fig. 2).The rigid plastic container has an 80% less carbon footprint than the tin container, while the flexible aluminium pouch has a 60% less carbon footprint than the tin container.

For the technical aspect, different analyses were made, like global migration of containers, permeability of the packaging material. A Trained Sensorial Panel was used to identify taste and texture variations. In the marketing study, a consumer evaluation was made, use and sensorial variables for the product were analysed; there were no significant differences found regarding a product pattern.

The shelf life of the product in plastic containers was 50% lower compared to the shelf life of the tin container; this was associated with significant consumer doubt about the preservation of the product in plastic containers. Consumers indicated that they would store the product in the refrigerator before consumption. The above is a warning about a major change in habits by consumers as the main advantage of the long life sausages is the energy reduction in the use phase; because the product doesn´t need refrigeration, as the shelf-life of the tin container is two years. With refrigeration, fluorocarbons escaping from the system are another consideration. This could contribute to increased GHG emissions.

Price perception was also a factor. The consumers considered the price of the product, depending on the packaging material; in this case they thought the product in a plastic container has less advantage and therefore should be cheaper. They are not willing to pay more for the same product in a plastic container that in a tin container.

- The carbon footprint of product is a tool that includes eco-design criteria in food packaging, and could be used for marketing
- The material represents 80% of the entire carbon footprint impact of the different food packaging. The aluminium carbon footprint is four times higher than plastic on average, and increased the carbon footprint of the food packaging.
- The marketing study reached an important conclusion, as consumers prefer the tin container for the long life sausage; it will be a deciding factor for the packaging equipment design.
- All materials meet quality specifications, but the shelf life of the sausage the most important factor to consider, as plastic packaging leaves the product with less shelf life.

References

Carbon Trust, DEFRA, BSI, 2008. PAS2050:2008. Specification for the assessment of the life cycle greenhouse gas emissions of goods and services.BSI: London, 43 p.

ISO. ISO 14040:2006. Environmental management -- Life cycle assessment -- Principles and framework

ISO. ISO 14044:2006. Environmental management -- Life cycle assessment -- Requirements and guidelines

Valentina Siracusa et al., 2011. Life Cycle Assessment of multilayer polymer film used in food packaging field. Procedia Food Science 1, 235-239.

H. Williams et al., 2008. A life cycle perspective on environmental effects of customer focused packaging development Journal of Cleaner Production 16, 853-859.

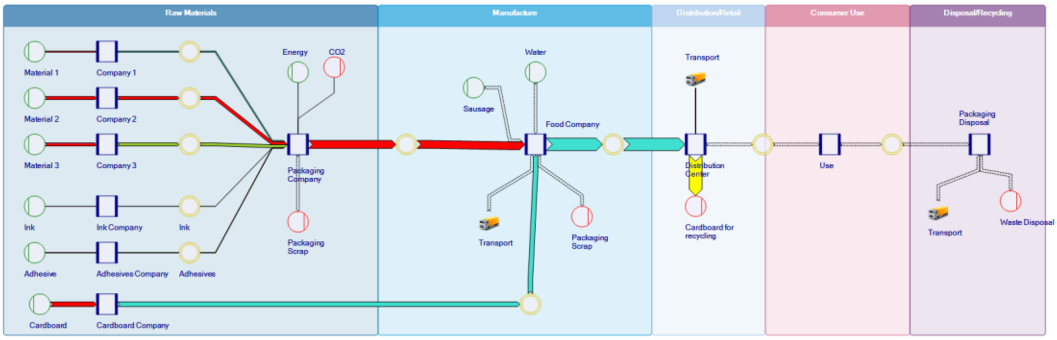

Figure 1. Life cycle carbon footprint flow

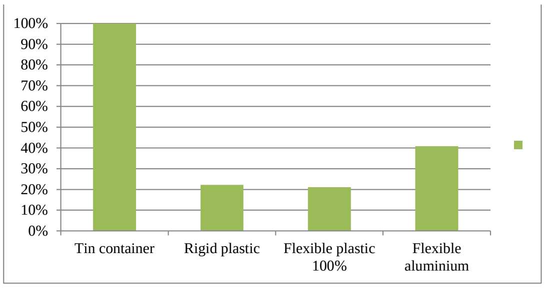

Figure 2. Carbon footprint related to functional unit.

The influence of packaging attributes on consumer behaviour in food-packaging LCA studies – a neglected topic

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The purpose of this paper is to highlight the importance of consumer behaviour in packaged food LCA studies. How consumers behave and interact with packaged food is important when undertaking an LCA of a packaged food. It is well known that consumers waste a significant amount of food product and that the functions of packaging can influence how much food is wasted. Examples include portion sizes, accessibility of the pack and ability to dispense the product. The role of packaging systems to reduce food waste is rarely modelled in LCA studies. This means that a packaging system format with a lower environmental impact, but that causes high food waste, appears to be a better alternative than a packaging system format with a higher environmental impact, but reduces food waste. This can be contradictory to the purpose of using LCA to reduce the overall environmental impact of the packaged food product, because food has generally much higher environmental impact than the packaging. Ensuring that LCA studies of packaged products consider both the environmental impacts of the food sourcing and production, packaging material sourcing and production and include associated food wastage across the supply chain can drastically change the outcome of an LCA study.

This paper will draw upon research conducted by Williams *et al*. (2008) that found fourteen packaging attributes that can affect food waste. Several case studies will be presented that illustrate the importance of considering food waste and packaging systems in conjunction with food product LCAs. We also argue that the functional unit in these kinds of studies should be set to “consumed food” rather than “delivered food” or “bought food”.

Comparative LCA of fruit and vegetable packaging trays

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Seven types of fruit and vegetable retail packaging trays currently used in Quebec are compared cradle-to-grave: polystyrene foam (XPS, virgin), oriented polystyrene (OPS, 90% virgin), polyethylene terephthalate (PET, 90% virgin, and RPET, 100% recycled), polylactide polymer (PLA, 90% virgin), polypropylene (PP, 90% virgin), and moulded pulp (MP, 100% recycled from newspaper). The functional unit is to "*Contain and permit the stacking and retailing of an amount of fruits or vegetables that can be contained in a tray volume of 52 cubic inches to consumers in Québec in 2010*". The cut-off approach is used to model the recycling and the use of recovered materials, and impacts are assessed with the IMPACT2002+ method (Jolliet *et al.*, 2003). Seven sensitivity analyses are performed on key parameters (tray weight, recycled plastics production, the presumed energy contexts of the various alternatives, recycling boundaries based on the system expansion approach, retailers transportation distance, and the LCIA method).

Results indicate that the main contributors to potential impacts throughout the entire life cycles of the trays are linked to production processes (raw materials and manufacturing energy production). Conversely, the contribution of the end-of-life is marginal (Fig. 1). From a comparative perspective, the results provide answers regarding the potential environmental gains associated with the use of different materials (virgin or recycled) for tray production, without affirming the advantage of one or another in every damage category. Specifically, PLA, PET and PP post the worst performances while XPS and MP have the best overall performances (Table 1). The main asset of the XPS tray lies in its significantly lower weight (up to 62% lower) despite its low recycled content and the impact from tray production. PLA is especially singling out for the ecosystem quality indicator because of the use of large areas of arable land for corn crop cultivation. The sensitivity analyses show that the plastic systems are very sensitive to the electricity grid mix used to form the tray, highlighting the environmental advantage of manufacturing the trays in Quebec Province where hydroelectricity is 95% of the grid mix. The sensitivity to the other parameters above-mentioned will be briefly presented, and some specific limitations of the study will also be highlighted, especially regarding data gaps and the use of proxy.

Besides reversing the popular belief over the negative attributes of polystyrene packaging (in the Quebec context where almost no recycling channel for PS exist), this critically reviewed LCA study has supported strategic decision processes within the company. Since this analysis was performed, Cascades has improved its manufacturing process by integrating upstream with an RPET extrusion and thermoforming line in its plants in Quebec province and is working continuously to enhance the recycled content of RPET material (currently 60%). Preliminary results indicate that the environmental impacts of RPET with a high degree of recycled content could be compared to those of XPS foam and moulded pulp.

References

Jolliet, O., Margni, M., Charles, R., Humbert, S., Payet, J., Rebitzer, G., Rosenbaum, R., 2003. IMPACT 2002+: A New Life Cycle Impact Assessment Methodology, Int. J. LCA, 8(6), 324-330.

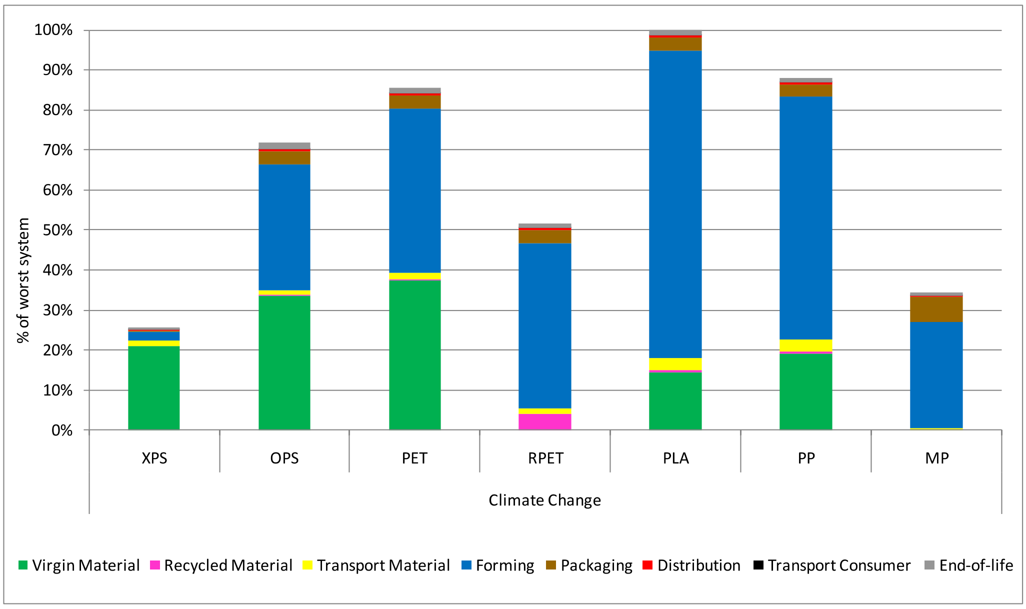

Figure 1. Contribution of life cycle stages on the climate change impact indicator for the analysed products. (Note: for MP tray, impact of Recycled Material (i.e. recycled pulp production) is aggregated within the Forming (i.e. moulding) stage)

Table 1. Relative impacts of the analysed products in the six damage categories.

	XPS	OPS	PET	RPET	PLA	PP	MP
Human Health	13%	32%	85%	23%	100%	62%	7%
Ecosystem Quality	5%	15%	26%	17%	100%	29%	10%
Climate Change	26%	72%	85%	51%	100%	88%	34%
Resources	33%	82%	100%	53%	87%	84%	27%
Aquatic Acidification	19%	44%	52%	30%	100%	90%	10%
Aquatic Eutrophication	18%	23%	59%	20%	100%	71%	26%

Systems with the most potential impact
Systems with the least potential impact
Intermediary systems

A systems-LCA model of the stratified UK sheep industry

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The UK sheep industry can be divided into hill, upland and lowland farms. There are a many breeds ranging from the smaller breeds most suited to the severe conditions of hill farming to the larger breeds associated with lowland farming. The system that has developed combines the qualities of these different breeds to develop hybrid vigour and make best use of the available land at different altitudes (Fig. 1). Thus, hill farms produce ewes that are sold to upland farms where they are crossed with high genetic merit rams to produce ewes that are, in turn, sold for breeding to lowland farms. In addition, there are purebred flocks with intermediate characteristics. Whilst most male lambs on lowland farms can be finished (i.e. reach the weight and condition for slaughter) before the end of the summer, a decreasing proportion on upland and hill farms can achieve this and many must be sold to lower land farms, where they are grown and finished over winter or kept as "stores" until the next spring. A small proportion of lowland flocks lamb very early, being brought up with a relatively high concentrate supply to meet the Easter spring market (high economic value). Lambing then proceeds with the rest of the lowlands, upland and hills in sequence. The LCA analysis of the production of lamb meat thus has to take into account the different sizes of the breeds and consequent feed requirements, different types of land and consequent inputs and yields of grass, and different rates of lamb growth and ewe productivity. The Cranfield sheep LCA model addresses this using systems modelling to link the various sub-systems. The complex equations linking the systems ensure that the numbers are coherent and enable various options to be analysed. Options may be long term breeding goals, such as greater fecundity or policy oriented, such as concentrating sheep production in the hills or lowlands, in response to changing land demands.

Core parts of the systems model include main features of animal production, such as longevity, mortality, fecundity of ewes (hence replacement rates) and potential daily liveweight gains of lambs (Williams et al., 2006). Weight gain by lambs, ewes supporting lambs before weaning or maintenance requirements all demand metabolisable energy. The satisfaction of energy needs is met mainly by grazing grass, but on land of widely varying quality between the lowlands and hills. A grass production sub-model calculates productivity for these and hence determines the main land requirements as well as energy use for pasture management. Overall, relatively small amounts of concentrates are also supplied.

The model also uses the concept that the same feed produces a distribution of weights of lambs after the summer from any production system. Thus, lambs of different weights move forward into particular, appropriate continuing systems, either being finished that year or being kept until the spring.

The main marketable output of the sheep industry is lamb meat. Mutton, from ewes and rams, is also produced, which also enters the human food chain, but with a lower economic value and tends to reach different markets. A higher proportion of mature sheep carcasses do not meet human market needs and have a much poorer conformation than lambs, so it was assumed that the relative utility of a mature carcass was 90% of that from lamb. The output of wool is relatively small and 3.5% of overall burdens were allocated to wool. The functional unit is thus 1000 kg expected edible carcass weight of sheep meat, i.e. the expected mixture of lamb and mutton carcass from any configuration of the national flock. The relatively small burdens of slaughter and any downstream processing are not included.

Some examples of the baseline case (Table 1) and alternatives are presented (Table 2).The effects of radical change in the proportions of lowland ewes change energy use and emissions by 2 to 12%, but land occupation changes are much larger. Higher potential gains in environmental performance can be expected if lambing rates are increased, which is a mixture of a breeding goal and managerial quality. Other alternatives will be explored.

References

Williams, A.G., Audsley, E., Sandars, D.L., 2006. Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities. Final report to Defra on project IS0205. http://preview.tinyurl.com/Cranfield-IS0205

Table 1. Baseline burdens of producing 1 t expected edible carcass weight of lamb at the national level.

Baseline burden	Value
CED, GJ	22.2
GWP, t CO_2e	22.3
Eutrophication potential, kg PO_4 eq.	100
Acidification potential, kg SO_2 eq.	87
Abiotic resource use, kg Sb	13
Good quality land, ha	0.5
Poor quality land, ha	10.0
All land, ha	10.5

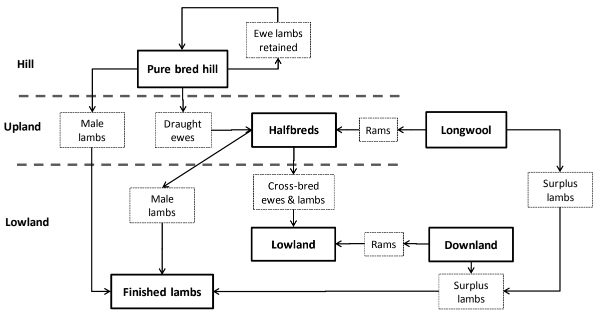

Figure 1 Simplified structural model of sheep production in the UK.

The effects on land occupancy are complex, because the quality of grassland is so varied and some arable land is needed for concentrates.

Table 2. Results of changing scenarios on main burdens of producing lamb. Values are the ratio of scenario results over baseline results.

Scenario description	Baseline value	Effect of scenario	Effect of results: CED	GWP	Land occupation: Good quality	Poor Quality	Total
Proportion of ewes on lowland	37%	Halve	93%	102%	107%	125%	125%
		Double	112	97%	88%	58%	60%
Proportion lowland lambs finished in early spring	10%	Halve	99%	100%	99%	100%	100%
		Double	103%	101%	103%	100%	100%
Increase sheep weight	66 kg#	+5%	113%	113%	113%	109%	109%
		+10%	124%	126%	123%	119%	119%
Increase in fecundity	1.2 lambs per ewe#	-10%	111%	108%	111%	107%	107%
		+10%	96%	95%	96%	95%	95%
Increase in killing out percentage	47%	+2.35%	99%	97%	99%	96%	96%
		+4.7%	95%	93%	95%	92%	92%
Increase in ewe longevity, years	3.7#	+0.5 year	100%	98%	100%	98%	98%
		+1 year	98%	96%	98%	96%	96%

Note: # Weighted average across sheep types

Carbon footprint of sheep farms in France and New Zealand and methodology analysis

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The environment is becoming increasingly important to consumers and there are economic implications in the comparison between products based on their environmental performance. In the perspective of eco-labelling of products in several countries, this issue is particularly important for meat products, identified for their significant impact on climate change (Hamershlag, 2011). In this context, environmental assessments of farm systems and agricultural products are becoming essential at an international scale. This should include identification of methodology issues to ensure reliable and equitable comparisons. These environmental assessments will also increase understanding of the different emissions sources in order to identify options to reduce them.

This study deals with the carbon footprint of French and New Zealand lamb production at the cradle-to-farm gate. It has been led by two applied research teams, who have already worked on this topic (e.g. Ledgard et al., 2010). The objectives of the study were to analyse the differences between systems and countries and to share knowledge about methodological issues. In France, sheep meat comes from a large diversity of farming systems. This analysis has been performed on a sample of farms representing two contrasting systems: "in-shed lamb" *vs* "grass lamb" (Table 1). In New Zealand, the main "grass" system (mixed sheep and beef on hill country; perennial grasslands) has been studied (Table 1). Each system was analysed using a methodology developed to fit its own country. A sensitivity analysis was performed, by crossing the methodologies; the New Zealand data set was analysed with the French methodology and vice versa.

The average carbon footprint of French lamb was 12.9 kg CO_2 eq./kg live weight (LW) sold (Table 2). There was no significant difference between the two French systems (Grass 12.74; In-shed 12.94), but there was high variability between farms within each system (standard deviations of 2.9 and 2.8, respectively). The carbon footprint of the main New Zealand system was 8.52 kg CO_2 eq./kg LW. The results varied between countries due to the different farm systems used. The higher carbon footprint of French lamb was due to the use of external feed inputs and the fact that sheep are housed in-shed for part of the year, with emissions from manure management. Conversely, in New Zealand, where productivity is often higher due to warmer climatic conditions, the animals stay outside all year round eating perennial pastures and therefore there are no gaseous emissions linked to external food production and manure management.

The sensitivity analysis showed that results are highly dependent on methodological choices. The cross-test performed resulted in variation of results between -2.5% to +47%. In particular, two points can be mentioned. Methane from enteric fermentation, which is the main source of emissions in France (53%) and in New Zealand (73%) was calculated using tier 1 and 2 methods respectively. The choice of allocation between meat and wool is also crucial; there was a small difference between countries when mass allocation was used and a much larger difference using economic allocation (Table 2). In New Zealand, wool has an economic value because of its use in carpet making, whereas in France it has little economic value (less than 1% of total economic returns). This led to variation of results from -5.9% to 11.7%.

Methodological issues are important and there is a need to build a common framework to allow comparison of results. Currently, a range of international groups are working on a standard for carbon footprinting of lamb, through the initiative of the Beef and Lamb New Zealand organisation. The aim will be to define a common framework with respect to some methodological rules but with the possibility for countries to take into account their specificities.

References

Hamershlag, K., 2011. Meat eater's guide to climate change and health. Environmental Working Group, USA.

Ledgard, S.F., Lieffering, M., McDevitt, J., Boyes, M. and Kemp, R., 2010. A greenhouse gas footprint study for exported New Zealand lamb. AgResearch, New Zealand.

Table 1. Technical description of the lamb production systems studied.

	France "In-shed"	France "Grass"	New Zealand "Grass"
Number of farms	85	19	151
Number of case study farms	1	1	1
Main characteristics	Significant use of housing	Significant use of perennial grasslands	Significant use of perennial grasslands
Mixed (M) or specialised (S)	S	S	M
Average effective area (ha)	102	114	430
Number of ewes (head)	555	670	2000
Ewe productivity (lambs weaned / ewe)	1.35	1.19	1.21
Kg concentrate / ewe / year	210	145	0
Time of grazing (days / year)	205	280	365

Table 2. Carbon footprint of French and New Zealand lamb at the farm gate and the relative contribution from different sources of emissions (using mass allocation).

	France Average	France "In-shed"	France "Grass"	New Zealand "Grass"
Carbon footprint (kg CO_2 eq/ kg LW)	12.9	12.94	12.74	8.52
Enteric fermentation (%)	53.3	53.1	54.1	72.5
Manure in buildings (%)	5.7	5.9	4.5	-
Manure storage (%)	3.7	3.8	3.2	-
Fertiliser use (%)	6.3	6.5	5.5	3.5
Grazing (%)	10.6	9.9	13.3	20.1
Energy use on farm (%)	3.3	3.2	3.9	1.4
Inputs[1] (%)	17.0	17.5	15.0	2.5

[1]Inputs: feed, fertilisers, energy purchased

Table 3. Percentage of the carbon footprint allocated to meat depending on the allocation methodology.

Country	Economic allocation	Mass allocation
France	99.7%	89.6%
New Zealand	78.0%	85.4%

Regionalised land use impact modelling of milk production in the US

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Land is a natural resource that is often taken for granted, yet essential in the food and agriculture sector. Thus, a sustainable use of land requires informed decisions based on a meaningful impact assessment in LCA, a decision-support tool used to address potential environmental impacts of a product over its entire life cycle. So far, most studies addressing milk and dairy-based products account impacts based on an inventory data related, simply by reporting the amount in hectare or square meters of land occupied or transformed within a time span.

The main goal of this study is to provide insights on a regionalised assessment of land use-related impacts to milk production in the US with a particular focus on the feed production life cycle stage. The functional unit is one kg of fat protein corrected milk. Build upon recommendations of previously published works as well as the framework and the principles established by the UNEP/SETAC Life Cycle Initiative working group on Land Use LCIA (LULCIA, 2008-2012), the proposed land use impact assessment method addresses potential impacts on biodiversity and a range of ecosystem services. The latter are reported by the the Millennium Ecosystem Assessment as being degraded.

This study highlights the need to collect detailed inventory-level information. Being highly influenced by the condition of the location, the impact magnitude depends not only on the intensity of use but on several bio-geographic factors, such as climate conditions, vegetation patterns and soil type properties. A spatial differentiated approach was considered, using regionalised characterisation factors that consider bio-geographic unit boundaries and US states resolution. This enabled a relevant assessment of a national average impact profile. Different supply mix scenarios were also assumed for all feed crop production in the ration (eg. on farm produced and purchased crops).

A comparison between results indicated different share of contribution to the total impacts and for which the crop provenance could be traced back to its production location. States, such as Wisconsin and California, which are major contributors to the national milk production (13% and 22% respectively) require significant amount of crop in the feed. However, not being a sizeable in-state corn grain production, they require a large supply of feed produced in other states. The latter are located in the Corn Belt region and constitute the main suppliers' to many other states dairy producers. Typical land use impacts on biodiversity are expressed in units of potentially disappeared fraction (PDF) of species on a unit surface. Results from corn grain production were of 0.17 PDF.m^2.yr per kg of milk (Wisconsin) and 0.14 PDF.m^2.yr per kg of milk (California). This corresponds to a contribution of 17% and 14% respectively for both states. Driven by the yield of production, land use area requirements in square meters per kg of dried matter of crop produced varied up to 6 times from one crop to another. Moreover, the variation of land use impacts per kg of milk produced from state to state varied up to 15 times for nationally produced crops (e.g., corn grain).

These findings indicate that it is relevant to address spatial variation at both the inventory and impact assessment levels. Spatial differentiation increases the discriminating power when assessing impacts which is crucial to guide decision makers, especially for large territories, such as the U.S., having a large number of ecosystems types. A finer scale assessment based on US ecoregions could bring additional discrimination to the results considering more specific and site-dependent characterisation factors.

References

LULCIA (2008-2012). Operational Characterization Factors for Land use Impacts on Biodiversity and Ecosystem Services in the Life-Cycle Impact Assessment Compatible with the Framework of the UNEP- SETAC Life Cycle Initiative (LULCIA). http://www.pes.uni-bayreuth.de/en/research/projects/LULCIA/

LULCIA (2008-2012) (submitted): Handbook on LCIA of Global Land Use, Biodiversity and Ecosystem Services within the framework of the UNEP/SETAC Life Cycle Initiative. Special issue in the Int J LCA.

Greenhouse gas emissions from production of imported and local cattle feed

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Studies of carbon footprint (CF) of milk have shown that 80-90% of the total greenhouse gas (GHG) emissions are related to processes before the milk leaves the farm. On the farm, methane emission from enteric fermentation gives the highest single contribution to CF of milk followed by the emissions related to feed production. The hypothesis of the present study was that by choice of feed, farmers can reduce CF of milk. The aim of this paper is to 1) estimate CF of different feedstuffs for dairy cattle and 2) compare two feeding strategies for dairy cows regarding GHG emissions from the feed production. The functional unit (FU) is '1 kg dry matter (DM) of feed ready to eat' (1) and for the comparison of the two feeding strategies, the FU is 'amount of feed for production of 1 kg milk (ECM)' (2). The main system studied was production of conventional grown fodder crops at dairy farms in Denmark. Besides that, a system with production of soybean in Brazil was included for production of soybean meal.

An attributional life cycle assessment (ALCA) approach has been used, handling co-products by economic allocation and taking into account LUC which was quantified based on PAS2050 (BSI, 2008). For comparison, a consequential approach (CLCA) was applied, where co-products were handled by system expansion and contribution from indirect LUC was estimated according to Audsley et al. (2009). Two feeding strategies, a 'local' and an 'import' strategy were compared. In both strategies, the cows have the same level of feed intake and milk production. In the 'local' strategy all feeds are grown in Denmark and the concentrated protein feed is based on rapeseed meal. In the 'import' strategy, 70% of the feeds are grown in Denmark and the concentrated protein feed is based on imported soybean meal. In both strategies, maize silage is the main roughage supplied with a relatively small amount of grass silage.

CF of animal feeds is shown in Table 1 (ALCA). Roughage is grown on the farm and has relative high dry matter (DM) yields per ha, especially maize silage. Therefore CF of roughage (g CO_2 eq./kg DM) is lower than CF of concentrated feeds. Rapeseed cake and soybean meal are both co-products from oilseed production and supply protein to the ration. GHG emissions from growing and processing rapeseed cake and soybean meal are quite similar, but due to transport of soybean meal from South America, CF of soybean meal is nearly double of CF of rapeseed cake, and much higher if contribution from direct land use change (LUC) is also included. In Table 2, CF of animal feeds is calculated by ALCA. As can be seen in Table 3, in the attributional calculation (ALCA), there is little difference in GHG emissions related to growing and processing the mixture of feedstuffs between the two strategies. However, the inclusion of GHG contribution from transport increases the difference making the 'local' strategy a moderately better choice than 'import' strategy. The inclusion of GHG emissions from dLUC increases significantly the CF of feed in the 'import' strategy to a range that is double that in the 'local' strategy. As also seen in Table 3, if calculated based on CLCA there were no differences in the CF of the feed between the 'local' and 'import' strategy as GHG contribution from iLUC was similar for the two strategies.

In conclusion, there were variations in CF of different feedstuffs. However, when calculating CF of a complete feed ration for cows by ALCA, the main reason for differences was related to contribution from transport, and especially from LUC calculated as direct LUC. However, if calculated by CLCA there was only minor differences in total GHG emissions from a 'local' and an 'import' feeding strategy, as LUC was calculated as indirect LUC, which only cause minor differences between the two strategies

References

Audsley et al. (2009). How low can we go? WWF- UK.

BSI, 2008. PAS2050. Specification for the assessment of life cycle greenhouse gas emissions of goods and services.

Table 1. Carbon footprint (CF) of conventionally grown animal feed per kg dry matter (DM)(ALCA)

		Contribution to CF, CO_2 eq. gram per kg DM				Land use	
Feedstuff	**Place of origin**	**Growing**	**Processing**	**Transport**	**Total**	**m^2/kg DM**	**dLUC g CO_2/kg DM**
Grass silage	The farm	318	71 [1)]	0	389	1.15	0
Maize silage	The farm	147	63[1)]	0	210	0.89	0
Barley	Denmark	487	11	17	515	2.43	0
Rapeseed cake	Denmark/Germany	310	28	118	456	1.24	0
Soybean meal	Argentina/Brazil	367	39	422	828	1.83	2288

[1] Including diesel used for traction and transport at the farm

Table 2. Carbon footprint (CF) of conventionally grown animal feed per kg dry matter (DM)(CLCA)

		Contribution to CF, CO_2 eq. gram per kg DM				Land use	
Feedstuff	**Place of origin**	**Growing**	**Processing**	**Transport**	**Total**	**m^2/kg DM**	**iLUC g CO_2/kg DM**
Barley	Denmark	528	11	18	557	2.42	346
Rapeseed cake	Denmark/Germany	368	0	118	486	2.24	320
Soybean meal	Argentina	150	59	463	672	2.41	345

Table 3. Effect of feeding strategy and LCA method on GHG emission from feed production (ALCA)

	ALCA		CLCA	
Strategy	**Local**	**Import**	**Local**	**Import**
GHG from feed[1)], g CO_2/kg ECM				
From growing the feed	0.20	0.21	0.23	0.19
From processing the feed	0.01	0.01	0.00	0.01
From transport	0.02	0.05	0.02	0.05
From LUC (direct or indirect)	0	0.23	0.15	0.15
From LU	0.21	0.19	0.26	0.26
Total	0.22	0.26	0.26	0.25
Total, including LUC	0.22	0.48	0.41	0.40
Total, including LUC + LU	0.44	0.67	0.67	0.66
Land use, m^2/kg ECM	0.90	1.01	1.07	1.06

[1] GHG emissions related to feed production (only for cows) calculated per kg milk produced

Environmental life cycle assessment of milk in Canada

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As part of a variety of initiatives to help improve the environmental performance of dairy production in Canada, the Canadian Dairy Farmers have commissioned a full environmental and socio-economic life cycle assessment (LCA) for the cross-Canadian production of milk. Because of the broad range of impact categories evaluated, the environmental and social LCAs are hereby proposed separately, with a combined interpretation presented as well.

The Canadian Milk LCA study is innovative in many ways. Firstly in terms of inventory (data), as it uses a large representative data set from over 250 farms across the country, combined with the results of a survey on farm practices of over 500 farms. This allows for interpretation on variability, as well as outlining different sub-categories of farms, based on size and practices. Moreover, using the geographical coordinates of the 13,331 farms in Canada allows for impact regionalisation considering geographical precision (ecoregions, watershed, etc) to facilitate a precise geographical interpretation of impact in different Canadian areas. In terms of characterisation of impact, the study uses spatially explicit factors for potential acidification, eutrophication, ecotoxicity, human toxicity, land use and water use impacts.

In line with similar studies, the environmental LCA found that the main sources of impact came from feed production, enteric fermentation and manure management. However, in order to understand the impact of the choices in practices, an analysis of typical scenarios based on size, geography, tie-stall vs free range, and replacement cow ratio is presented.

Regionalisation of impact for the assessment over such a geographically diverse area is important to understand where specific risks exist. With regards to Canada, water scarcity is generally inexistent, yet at a watershed level, scarcity is a definite problem in an agriculturally intense area, targeting a concern of great importance.

Quantification of the reduction potential of GHG mitigation measures on Swiss organic farms using a life cycle assessment approach

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The environmental benefits of organic farming compared to conventional farming include a reduced toxicity potential and mitigation of greenhouse gases (GHG). However, from a LCA perspective, i.e. when relating emissions to food production, organic farming frequently performs worse than conventional or integrated management due to reduced productivity (e.g. Williams *et al.*, 2006). Furthermore, recent studies found a high variability between farms, even if they are of the same farm type or region (Hersener *et al.*, 2011). This implies a high potential for optimising farm management with respect to environmental performance on organic farms. Currently, different mitigation measures for reducing GHG emissions from agriculture are discussed by farmers, policy makers and researchers. However, quantitative assessments of these measures at farm level lack. Hence, the aim of this study was to quantify the GHG mitigation potential of selected measures for organic farms in Switzerland.

We selected two typical Swiss organic farms (mountain region/dairy farm, and lowlands/mixed farm) and calculated the effect of 13 potential GHG mitigation measures taken on these farms (Table 1). The measures were chosen according to a) their mitigation potential, b) the absence of trade-offs with other environmental impact categories, c) the applicability on Swiss organic farms and d) the ease to model their impacts at farm level. The exact specification of the measures was defined according to the local conditions of the selected farms, in consent with the farmers. We built a single-farm model which enabled us to calculate the GHG emissions of a farm in different conditions, using ecoinvent and other data sources as well as data from own assessments. The model is able to take into account interactions between plant and livestock production including emissions of purchased inputs and to calculate emissions based on different functional units. Each farm was assessed a) without implementation of the measures and b) with each of the measures implemented individually. As there are several products involved, we present results for the entire farm.

Seven of the selected measures show a very limited mitigation potential of below 1% of total GHG emissions (Table 1). This is due to the fact that the GHG emission profile of both farms is dominated by CH_4 emissions from enteric fermentation of the dairy cows and its offspring. More effective measures are conversion to full-grazing systems, use of dual-purpose cattle breeds, increased number of lactations of dairy cows, composting livestock manure, use of photovoltaics, use of solar heat, and optimisation of machine life. At the dairy and mixed farm, respectively, 6% and 10% of mitigation can be realised by technical means and 10% and 8% with agronomic measures where losses in productivity (estimated based on scientific literature) may occur. Total mitigation potential of the measures analysed is 17% (dairy farm) and 18% less emissions (mixed farm), respectively.

However, the effectiveness of the optimisation measures depends on farm specific characteristics. Furthermore, if the mitigation potential is calculated production-related, implementing measures that reduce productivity could lead to negative impacts on global warming potential.

References

Hersener, J.-L., Baumgartner, D., Dux, D. 2011. Zentrale Auswertung von Ökobilanzen landwirtschaftlicher Betriebe (ZA-ÖB). Schlussbericht, Agroscope Reckenholz-Tänikon (ART), Zürich, Switzerland.

Williams, A.G., Audsley, E., Sandars, D.L. 2006. Energy and environmental burdens of organic and non-organic agriculture and horticulture. Aspects of Applied Biology. What will organic farming deliver? 79: COR 2006, pp. 19-23.

Table 1. Optimisation potential of selected GHG-reduction measures on two typical Swiss organic farms

Parameter	Unit	Specialised dairy farm		Mixed farm (dairy/arable)		
Location		Mountain region		Lowlands		
Farm size	ha	25.1		51		
Stocking density	livestock units/ha	1		1		
Total GHG emissions	kg CO2-eq / per farm and year	139,066	*100.00%*	277,911	*100.00%*	
Potential reduction of GHG emissions	**Unit**	**Absolute**	***Relative***	**Absolute**	***Relative***	**Potential impact on productivity**
Composting livestock manure	kg CO2-eq / per farm and year	-4,429	*-3.18%*	-12,128	*-4.36%*	
Increased number of lactations of dairy cows	kg CO2-eq / per farm and year	-7,788	*-5.60%*	-8,677	*-3.12%*	slightly reduced productivity
Use of dual-purpose cattle breeds	kg CO2-eq / per farm and year	-3,977	*-2.86%*	-7,357	*-2.65%*	reduced milk/increased meat production
Use of photovoltaics (on total roof area)	kg CO2-eq / per farm and year	-4,073	*-2.93%*	-6,153	*-2.21%*	
Conversion to full-grazing system	kg CO2-eq / per farm and year	-4,672	*-3.36%*	-6,128	*-2.21%*	Estimated reduction in milk production 11-19%
Optimisation of machine life	kg CO2-eq / per farm and year	-2,206	*-1.59%*	-4,237	*-1.52%*	
Shade trees on pastures	kg CO2-eq / per farm and year	-226	*-0.16%*	-753	*-0.27%*	< 1% reduced pasture productivity
Energy-efficient milk cooling devices	kg CO2-eq / per farm and year	-235	*-0.17%*	-518	*-0.19%*	
Concentrate-free feeding rations	kg CO2-eq / per farm and year	-371	*-0.27%*	-343	*-0.12%*	0-10% reduced productivity
Application of Eco drive mode	kg CO2-eq / per farm and year	-728	*-0.52%*	-2,206	*-0.79%*	
Optimization of machines and tractors	kg CO2-eq / per farm and year	-111	*-0.08%*	-1,935	*-0.70%*	
Use of solar heat (for process water on farm)	kg CO2-eq / per farm and year	-139	*-0.10%*	-262	*-0.09%*	
Reduced tillage*	kg CO2-eq / per farm and year	-		-564	*-0.20%*	+/- 10% productivity changes
Potential GHG savings if all measures are implemented	**kg CO2-eq / per farm and year**	**-28,955**	***-20.82%***	**-51,261**	***-18.45%***	

*calculations do not take into account potential gains in carbon stocks

Produce beef or biodiversity? The trade-offs between intensive and extensive beef fattening

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According to the concept of multi-functionality, agriculture has to fulfil several functions. In addition to the production of food, feed, fibre and fuels, it aims at maintaining a high level of biodiversity, maintaining agricultural production in marginal areas, and ensuring living for a rural population. The productive function requires highly productive systems, whereas to increase biodiversity, extensive management is needed. This trade-off between high productivity and high biodiversity potential is highlighted in this paper, using a case study with different beef production systems in Switzerland.
The SALCA-biodiversity method (Jeanneret et al., 2008) is used to assess potential impacts of agricultural management on the overall species diversity. The method uses 11 indicator organisms groups to describe the potential impacts on biodiversity. Three different beef production systems were evaluated using model farms: an integrated beef fattening (IBF), an integrated suckler cow system (ISC), and an organic suckler cow system (OSC), all located in the lowlands. First an inventory of all used agricultural areas (for feedstuff production, grazing, rearing animals, etc.) was established. Then, an inventory of all management activities influencing biodiversity was established and the potential impacts on the indicator organism groups were assessed. The average biodiversity scores were calculated as area and time weighted averages of all used agricultural areas. Within a given crop the differences were relatively small, whereas the differences due to different management intensities of grassland were very large. The final result is thus determined by the composition of the feed ration, the yields of the different feed raw materials, which determine the area required for their production, and the management intensity and type of use (grazing, cutting) for grassland.
The integrated beef fattening system uses two to three times less area to produce 1 kg of beef compared to the suckler cow systems. This is due to the fact that the suckler cow has to be fully allocated to the beef production, whereas in an intensive beef fattening system, the calf can be considered as a by-product of dairy production and the mother cow is allocated mainly to the milk. Furthermore, the suckler cow systems use partly extensively managed grassland with lower yields. The OSC needs slightly more area to produce the same amount of beef than ISC, due to lower yields of organic crops and grasslands.
The overall species diversity was estimated to be lowest for the IBF and higher for the suckler cow systems (Fig. 1). This difference is explained by the fact that overall species diversity is generally higher in grassland than in crops. In particular less intensively and extensively managed grassland had higher scores for overall species diversity. Due to the ban of pesticides, the OSC had a slightly higher biodiversity score than ISC.
Now we have to consider that the areas used are very different: the integrated beef system uses less area; this leaves area for other uses. If we assume that the excess area is used for ecological compensation areas, the integrated system would have the highest overall biodiversity score. If however, the excess area is managed in the same way as the rest of the system, the extensive systems would have the highest scores, but the overall production would not be the same.
Two scenarios have been calculated to estimate the theoretical potentials for biodiversity and productivity of beef fattening: one scenario assesses the maximal biodiversity potentials, which could be achieved by extensive management (Fig. 1). The difference to the studied systems is considerable. This shows that the current beef production systems have a high potential for development both in terms of higher productivity or higher biodiversity. These two goals are in conflict. Research is needed to develop beef fattening systems which better reconcile a good productivity with a high level of biodiversity (the green arrow “sustainable development”).

Reference

Jeanneret, P., Baumgartner, D.U., Knuchel, R.F. & Gaillard, G., 2008. A new LCIA method for assessing impacts of agricultural activities on biodiversity (SALCA-Biodiversity). In: Proceedings of the 6th International Conference on LCA in the Agri-Food Sector – Towards a sustainable management of the Food chain, Nemecek, T. & Gaillard, G. (eds.). November 12–14, 2008, Zurich. Agroscope ART, 34-39.

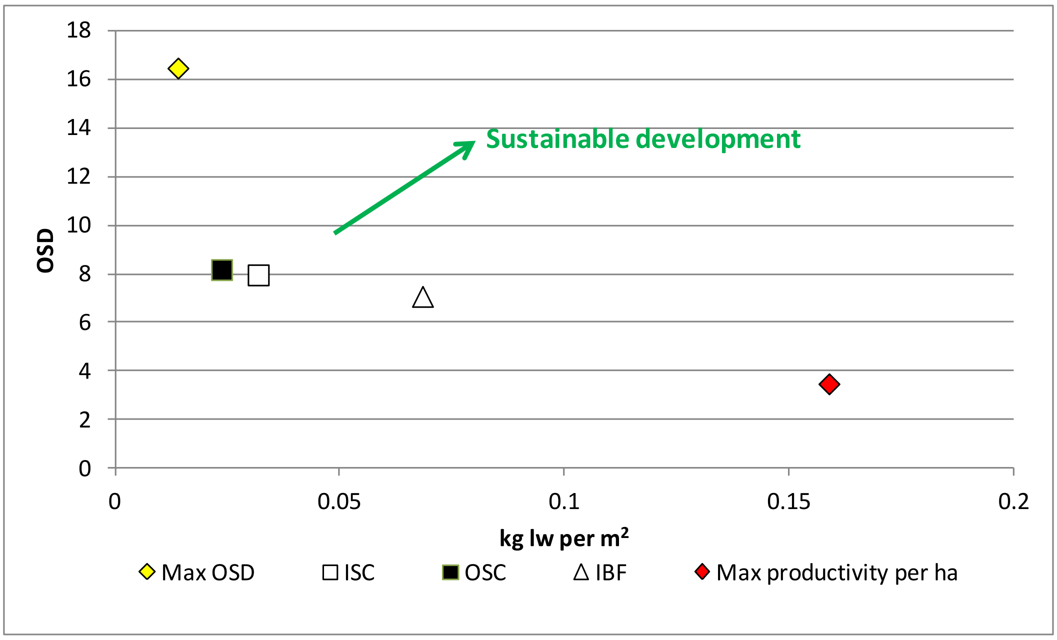

Figure 1. Comparison of overall species diversity (OSD) of three beef fattening systems: integrated beef fattening (IBF), integrated suckler cow system (ISC), organic suckler cow system (OSC). “Max OSD” shows the theoretical potential for highest biodiversity in a beef production system, “Max productivity per ha” shows the theoretical potential for high productivity.

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Assessing land use impacts on biodiversity on a regional scale: the case of crop production in Kenya

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Agricultural production occupies about one third of the global terrestrial surface. This causes major impacts on ecosystems and biodiversity at multiple spatial scales (e.g. local, regional and global). To evaluate options for reducing these impacts, decision-support tools such as life cycle assessment (LCA) should assist decision-makers in obtaining the relevant environmental information related to their product system. In many land use life cycle impact assessment (LCIA) methods, *local* impacts on biodiversity are quantified, which reflect the local extirpation of species from the used piece of land, but do not address landscape-level changes in the amount, quality and configuration of habitat. Therefore, although they may be high, such local impacts may not be very environmentally relevant, as the species can still survive in adjacent areas and recolonise the field after it is abandoned, making local extinctions potentially reversible. As local conversion of habitat continues, extinction risk increases to an extent that there is not enough habitat remaining at a regional or global level, leading to regional or global extinction, respectively. Global extinction is fully *irreversible* and thus of highest environmental concern. In this case, the accumulated land use activities in a region are decisive in determining the overall impact of land occupation and transformation. This requires additional information on the landscape surrounding the agricultural field of interest and is more data demanding, but provides more environmentally relevant information to the user of an LCA. In the case of global extinction risk, information on the threat levels in all global habitats of a species need to be considered, requiring information from outside the area of agricultural production considered in a typical LCA study.

In this paper, we present a method to quantify regional land use impacts in LCIA. As earlier land use LCIA studies, we base our assessment on the species-area relationship (SAR), a model often used to predict extinction rates due to habitat loss. The SAR is derived from island biogeography theory, which describes a non-linear (often power) function between species richness and area of natural island ecosystems. As SAR models tend to overestimate extinction rates, we base our method on an adapted SAR model, the matrix-SAR developed by Koh and Ghazoul (2010). This model considers the habitat quality of the matrix, i.e. the human-modified land in between the natural ecosystems.

We applied the model to agricultural land use in Kenya, a country that hosts two global biodiversity hotspots that have already lost more than 70% of their natural habitats due to human activity. This largely results from an overlap in areas with high agricultural suitability and high biological value, that have attracted a dense and growing population causing continued land use change or intensification and encroachment of protected areas. Large shares of species rich ecosystems have been converted to small-holder and large-scale agricultural land to produce subsistence or export-orientated cash crops such as tea, coffee, cashews and flowers. We use the matrix-SAR model to assess the overall regional damage of land use to biodiversity. This damage is then allocated to the different land use types within this region.

In contrast to local impacts, the presented regional characterisation factors reflect differences of land use impacts occurring in species rich or species poor ecosystems with high or low levels of endemism, or of land use impacts occurring in highly disturbed or pristine ecosystems. In addition, they directly reflect conservation targets that aim to prevent regional or global extinction. This regional assessment method should thus provide more environmentally relevant assessments of land use impacts of agricultural products. As we use globally available data as a starting point, this method could also be applied to other world regions.

References

Koh, L.P., Ghazoul, J., 2010. A matrix-calibrated species-area model for predicting biodiversity losses due to land-use change. Conserv. Biol. 24, 994-1001.

Modelling effects of river water withdrawals on aquatic biodiversity in LCIA

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Water abstraction for crop production is expected to increase during the next century in Switzerland (Fuhrer et al. 2009) and certain regions of Europe (EEA 2009) due to climate change. Rivers are a significant source of water for irrigation, and therefore impacts of river water withdrawals should be included in LCIA of crop production. The impact of river water withdrawals on freshwater biodiversity has been modelled in LCA (Hanafiah et al. 2011) by using a relationship between fish species richness aggregated within river basins to average discharge at the mouth of the basins, based on statistical regression. However the parameterisation used, developed for latitudes below 42° and near-natural rivers, is not applicable to Switzerland and much of Europe. Furthermore, local effects are not addressed.

We therefore developed species-discharge parameterisations for Switzerland and Europe, including macro-invertebrate taxa in addition to fish for Switzerland, so as to reflect more ecosystem functionality. We show that the goodness of fit can be highly improved for certain regions if a higher spatial resolution is used (for example subsets based on eco-region): such spatial subsets for Europe revealed Pearson's R^2 of up to 0.59 compared to 0.35 for the whole dataset (Fig. 1), and for Switzerland R^2 was improved from 0.69 to 0.9. We assessed the sensitivity of results between such "improved-fits" and the initial generic model: predictions of PDF are similar, although the parameterisations with higher spatial resolution predict species richness more accurately (the slopes of the parameterisations show similar trends, whereas absolute values such as maxima differ). The parameterisations for Switzerland show that the potential fraction of species lost (PDF) due to marginal withdrawals of river water is higher for smaller rivers and suggest threshold behaviour between small and large rivers. Uncertainty in the species-discharge relationship was observed to be high for discharges below $20 m^3/s$ for Switzerland, in which range other sources of variability should be explored.

Generalised relationships between discharge and aquatic species richness are not confirmed by experimental studies, as effects are highly site-specific (Poff and Zimmerman 2010). Additionally, the major hypothesis of the reference model is debated, namely: inferring causality between changes in discharge and aggregate species richness in the watershed ("aggregated-level"). Using site species richness ("site-level") rather than aggregated-level richness in the regression may be an improvement, as we briefly show with the example of a small watershed. In keeping with the site-specific nature of such relationships (as mentioned above), correlations tested for larger spatial scales were found to be weak, illustrating their limited use for larger spatial scales and generic application.

We conclude that our aggregated-level parameterisations can be used to calculate characterisation factors specifically for Switzerland and for eco-regions of Europe, however with high uncertainties for small rivers. For adequate species richness prediction, the use of such spatially-differentiated parameterisations is recommended, whereas the generic parameterisation is sufficient for estimates of PDF. Site-level models may improve ecological meaningfulness in localised assessments, but additional drivers should be included to improve model strength and reduce uncertainties.

References

European Environment Agency (EEA), 2009. Water resources across Europe - confronting water scarcity and drought. Copenhagen, 55 p.

Fuhrer, J., Jasper, K., 2009. Bewässerungsbedürftigkeit in der Schweiz. Agroscope Reckenholz-Tänikon, Swiss Federal Office for Agriculture, 74 p.

Hanafiah, M.M., Xenopoulos, M.A., Pfister, S., Leuven, R.S.E.W., Huijbregts, M.A.J., 2011. Characterization factors for water consumption and greenhouse gas emissions based on freshwater fish species extinction. Environ. Sci. Technol. 45(12), 5272-5278.

Poff, N.L., Zimmerman, J.K.H., 2010. Ecological responses to altered flow regimes: a literature review to inform the science and management of environmental flows. Freshwater Biology 55, 194-205.

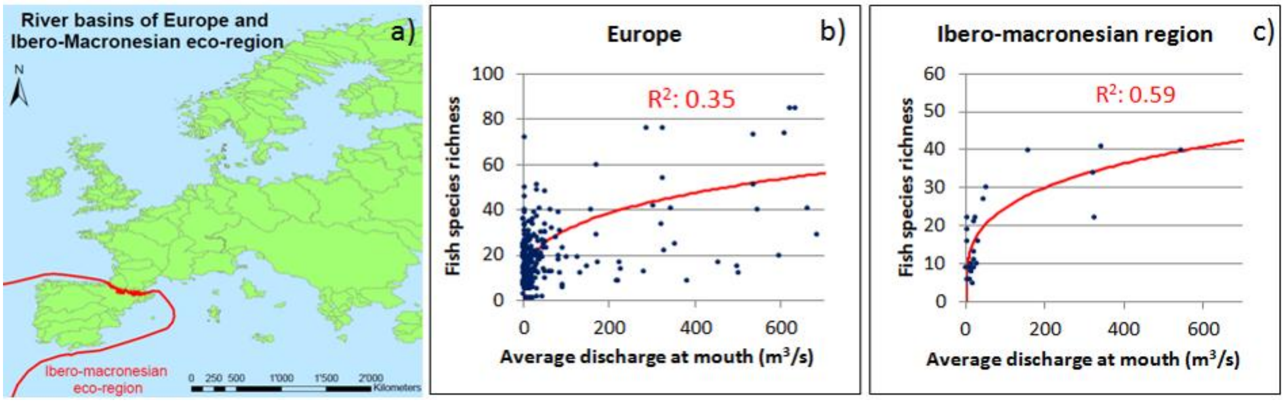

Figure 1. Improvement of correlation strength using regionalised species-discharge relationships: an example for Europe: a) map of river basins of Europe, with ibero-macronesian eco-region highlighted in red, b) species-discharge relationship for Europe, c) species-discharge relationship for ibero-macronesian region.

Soil-quality indicators in LCA: method presentation with a case study

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Soils are an essential resource in both managed and natural systems, and maintaining soil quality is critical to the sustainable development of human activities, in particular agriculture. The difficulty in representing impacts on soil quality remains an unresolved problem in LCA because of soil's spatial and temporal variability and the complex interactions among soil properties. It is crucial to consider soil quality in the environmental assessment of products, especially those with a majority of their life cycle in biological processes (such as agriculture and forestry). The objective of this study was to establish a framework for quantifying indicator(s) of impact on soil quality in a life cycle perspective, valid for all pedo-climatic conditions and considering both on-site and off-site agricultural soils. The method developed answers needs identified by Garrigues et al. (2012) for LCA indicators of impacts on soil quality. The case study focused on the soil-quality impacts of producing pig feed in Bretagne, France. The indicator categories considered were erosion, soil organic matter (SOM) and compaction. Erosion and SOM impacts already exist in LCA approaches, but compaction impacts have yet to be estimated in detail in LCA.

The LCI and LCIA are based on simulation modelling, using models simple enough for use by non-experts, general enough to parameterise with available data at a global scale and already validated: RUSLE2 for erosion (Renard et al., 1993); RothC for SOM (Coleman et al., 2008) and COMPSOIL for compaction (O'Sullivan et al., 1999). Most of the input data necessary for establishing the LCI are common to the three midpoint indicators. Rules and recommendations for estimating or finding data are given to standardise the method. Guidelines are also specified to account for crop-based ingredients from multiple sites in products such as animal feeds (Fig. 1). One difficulty lies in allocating soil-quality impacts of crop rotations to individual crops. Overall impact values result from the combination of soil, climate, and management characteristics for each crop in the feed (Table 1). The erosion indicator represents a loss of soil, while the SOM indicator represents an increase or decrease in the stock of soil carbon stock. The compaction indicator represents a loss of soil porosity and distinguishes topsoil from subsoil compaction because the former is more easily reversible.

The framework allows for incremental improvement of the method through the inclusion of new soil-quality impacts. Improvement efforts will focus first on developing robust impact indicators for individual soil processes before considering whether to aggregate them into a single indicator. Nonetheless, a variety of aggregation approaches can be explored (Garrigues et al., 2012).

References

Coleman, K., Jenkinson, D.S., 2008. RothC-26.3: a model for the turnover of carbon in soil. Model description and Windows users guide. Harpenden, Herts, UK, p. 47.

Garrigues, E., Corson, M.S., Angers, D.A., van der Werf, H.M.G., Walter, C., 2012. Soil quality in Life Cycle Assessment: Towards development of an indicator. Ecol. Indicat. 18, 434-442.

O'Sullivan, M.F., Henshall, J.K., Dickson, J.W., 1999. A simplified method for estimating soil compaction. Soil Till. Res. 49, 325-335.

Renard, K.G., Ferreira, V.A., 1993. RUSLE model description and database sensitivity. J. Env. Qual. 22, 458-466.

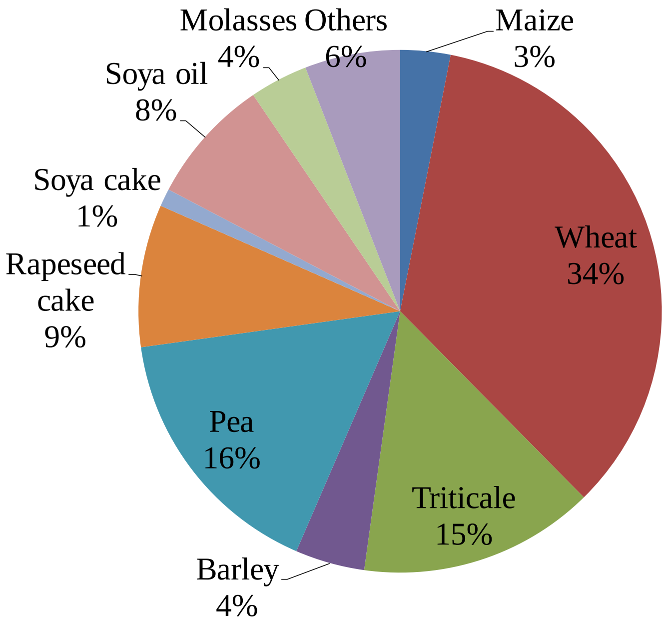

Figure 1. Ingredient composition (by mass) and source in representative pig feed produced in France.

Table 1. Erosion, change in soil organic matter (SOM), and compaction impacts on soil quality for 1 tonne of pig feed produced in Brittany, France

EROSION	SOM CHANGE	COMPACTION
0.177 t soil/t feed	-0.026 t C/t feed	Topsoil: 17.6 m^3/t feed Subsoil: 5.9 m^3/t feed Total: 23.5 m^3/t feed

Finnish consumer understanding of carbon footprinting and food product labelling

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In Finland around 25% of greenhouse gas emissions (GHG-emissions) of private consumption originate from the production and consumption of food products; including household food preparation, food preservation, journeys to shops and meal services. One way to inform consumers of food products' GHG-emissions is carbon labelling. In fact, carbon labelling of food products has grown steadily during the past years. For instance, in Finland the first carbon label came to food packages in 2008, and to date six Finnish food companies have carbon labels in their product packages. Overall over 40 Finnish food products are carbon labelled and more products are going to be labelled in future. Some food companies are also communicating their products' carbon footprints only on their websites. Additionally, some food companies are stating that they are compensating their products' carbon footprints. The challenge is, however, that there is not a comprehensive understanding on consumers' information desires. Surely, in the past years the issue has been studied in few international studies, but a more profound and up-to-date study is clearly needed.

In a Finnish project, Climate Communication 2 (2011-2013), Finnish consumers' understandings on carbon footprinting and information desires are studied. Understanding the complexity and broad scope of the topic, our aim was to find out at least: whether most of the consumers understand the meaning of such labels, whether consumers need and/or use this kind of information when choosing between products, and in which form and where the information should be given to them. In the project we arranged focus group discussions for some consumers: there were 33 participants and altogether 5 focus groups. The key criteria which allowed a consumer to be selected into the group discussions was that the consumer stated that environmental friendliness is at least a rather important factor when grocery shopping. In the discussions all the participants regarded many other buying criteria, such as, taste, price and healthiness, as stronger factors than environmental friendliness when grocery shopping. Moreover, only a couple participants regarded food as one of the main environmental stressors, meanwhile, especially housing and transportation were often mentioned. However, when asked directly, the participants thought that food has some sort of impact on the environment: all groups mentioned food packaging waste, food waste, food trafficking, and meat production to have impact on the environment. Climate impact of food was mentioned twice, but as an aside.

Another a bit surprising finding was that while the participants had heard the term "product carbon footprint" only a couple of them described the term at least somewhat correctly. A majority thought that the term is referring to environmental impacts in general, and many thought that product carbon footprint would be calculated taking only into account the energy needed to produce the product. What is more, nobody mentioned "climate impact". After giving the exact definition of carbon footprint the participants were single-minded that communicating product carbon footprints is a positive thing. However, a majority agreed on that the focus is quite narrow and other environmental impacts should be taken into account as well. Many participants also questioned whether the communication of product carbon footprints would really have any impact on their buying behaviour. Some of them stated that carbon label could have an impact on their final decisions only when the choice is to be made between two otherwise equal products.

The most definite outcome from the discussions was that there is a clear need to educate consumers to understand better the concept of product carbon footprint. This would allow better understanding of the importance of the product carbon footprint information to consumers. Whether accurate understanding of carbon footprinting would increase demand for carbon labelled food products is still uncertain. Altogether, the group discussions deepened understanding of how some consumers view carbon footprinting/labelling at the moment and how clear and interesting the issue is (and could be) to them. However, the group discussions gave only a narrow view on the consumers' thoughts on the issue, and so, to get a broader view a well-needed next step was an extensive quantitative survey on the issue. The aim of the quantitative survey was to obtain around 1000 responses from a miscellaneous consumer group (e.g. different age groups, different levels of environmental consciousness etc.).

Application trial of the new PAS 2050-1 supplementary requirements for horticultural products: carbon footprint of pumpkin

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This lecture provides information and details on the new PAS 2050-1 supplementary requirements (formerly ‘Product category rules – PCRs) for horticultural products to be released in March 2012. This is one of the first supplementary requirements in the agricultural and food industry and may be used as a guideline for industries other than horticulture; it may assist the food industry in gaining information on GHG emissions for the supply of their raw materials such as agricultural crops. The data presented originate from one of the four international pilot projects. In the German application trial, asparagus, strawberry, rhubarb and pumpkin were employed; the talk will concentrate on the latter commodity. The new PAS 2050-1 includes recommendations for a "cradle to gate" or "business to business" approach. It provides an Excel tool for both land use change (LUC) and the nitrogen balance within a crop rotation. Examples will be given for issues to be excluded such as Capital goods or included such as biogenic carbon of the horticultural product.

The objective of this contribution was to determine experiences (pro and cons) of the implementation of these new supplementary requirements (‘SRs’) for horticultural products to the PAS 2050: 2011 as part of this pilot study. The new horticulture specific requirements to the Standard PAS 2050:2011 were evaluated while calculating the carbon footprint for the four crops, including autumn pumpkin for sale in Germany.

Three farms with different pumpkin cultivation were chosen: a) a small scale organic (50 kg N/ha) , b) a small scale integrated production (IP) (120 kg N/ha), and c) a large scale business enterprise (70 kg N/ha). Area viz hectare was chosen as the first and mass i.e. kg saleable product as the second functional unit. System boundaries ranged from plantlet or seed acquisition to sale.

The Carbon Footprint at the cultivation level ranged between 157 kg CO_2eq/ha (organic) and 251 kg CO_2eq/ha (small scale (IP)). Taking the yield into account the mass specific Carbon Footprint was from 8 g CO_2eq/kg saleable pumpkin to 20 g CO_2eq/kg saleable pumpkin. The nitrous oxide emissions, which originated from the nitrogen fertilisation, were calculated based on 0.7% N_2O per kg applied N. They were the most relevant source of GHG emissions in the cultivation phase. Neither the form (organic or inorganic) nor the amount of applied nitrogen (2.5-fold difference) influenced the carbon footprint. However, carbon reduction potentials include use of nitrification inhibitors such as DMPP and DCD, which reduce the nitrous oxide emissions by ca. 40 or 30%, respectively. Plant protection (methiocarb in the IP) contributed less 1% to the carbon footprint.

The large specialised farm showed the best carbon footprint 8 g CO_2eq/kg pumpkin due to the use of potassium fertiliser and 3-fold larger yields (18t t/ha versus 5.8 t/ha in the organic) and, to a lesser extent, its sheer scale. On the other two farms, cultivation is more extensive with the main income not from pumpkin; any increase in farm size or their pumpkin acreage would not improve their efficacy and cradle-to-gate carbon footprint.

References

Schaefer, F., Blanke, M., 2012. Farming and marketing system affects carbon and water footprint – a case study using Hokaido Pumpkin. Journal of Cleaner Production 80, in press.

Kuikmann, P.J., van der Hoek K.W., Smit, A., Zwart, K., 2006. Update of emission factors for nitrous oxide from agricultural soils on the basis of measurements in the Netherlands. Alterra report 1217. 40 pp.

Table 1: Contribution to the carbon footprint of N_2O emissions* from application of nitrogen fertiliser during cultivation phase.

Farm business type	kg N fertiliser/ha/yr	kg N_2O emissions/ ha*	kg CO_2eq/ ha	yield (t/ha)	g CO_2eq/ kg pumpkin
Organic	50	0.35	104	5.8	18
IP small farm	120	0.84	250	12.5	20
IP large farm	70	0.49	146	18.1	8

*Kuikmann et al. (2006)

Environmental assessment of Breton pate production: the Hénaff case study

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Product environmental footprint, and particularly product carbon footprint (PCF), is now driving sustainable business strategy. PCF is particularly important for food and agriculture companies, since food products have high impacts throughout their lifecycle, and particularly during the agricultural stage. As the true impact of these products is increasingly disclosed, consumers are empowered to make informed choices. Ensuring sustainability is, today, as important as ensuring nutritional balances. This is a new reality to which companies must adapt.

French company Hénaff (http://www.henaff.com/) based in the Bretagne region took a first step three years ago to assess the impacts of its activity by calculating the overall organisation greenhouse gas (GHG) emissions ("Bilan Carbone" in France). The main conclusion was that around 90% of the company's impact was due to sourcing materials such as food ingredients. In 2011, Hénaff partnered with Bluehorse Associates, a sustainability metrics company based in Paris, and the École Centrale Paris, to conduct its first PCF study and inquire further into the life cycle impacts of its activity. The study targeted nine different pork patés, produced with pork from different meat production systems (conventional, organic and other quality certifications), and the life cycle considered is shown in Figure 1. The PCF study also included a detailed analysis of product nutrition. We used software Carbonostics, a smart lifecycle management tool designed to pinpoint the hotspots of any food product or menu along three key criteria: cost + carbon + nutrition.

Results show that the GHG emissions of Hénaff patés range from 200-330 g CO_2e per 100g of product. This number is significantly lower than available international benchmarks. This is related to the fact that studies available for pork production in Bretagne (Basset-Mens and van der Werf, 2005) reveal lower emissions than pork produced elsewhere. The whole life cycle of pork production was, confirming the Bilan Carbone report, the main hotspot in the carbon footprint, accounting for more than 80% of the total GHG emissions. Energy spent for processing and packaging, the only life cycle step that Hénaff controls directly, accounts for less than 10% of the impact.

We also found that organic products have higher GHG emissions, which is an indirect consequence of the lower productivity of swine feed ingredients. Conventional pork paté has the lower emissions.

On the other hand, nutritional indicators are better for organic and certified pork patés and worse for conventional patés. So, if the reference flow is unit of nutritional indicator (e.g. calories, protein, etc.) instead of mass of product, results can be inverted. This fact highlights the difficulty of choosing a functional unit for studies on food products. The function of a food product is to provide quality nutrition, but since there are many different indicators life cycle assessment practitioners normally use simple comparisons between amounts. This may lead to biased results.

Pork meat was particularly challenging as a case study also because the choice of allocation method for pork parts has a dramatic effect on results. Patés use parts such as pork neck and fat, which share the majority of the pork production impacts. We used economic and mass allocation, and results changed significantly (more than 10%). Some international standards recommend economic allocation (e.g. PAS2050 in the UK), while others recommend mass allocation (e.g. BPX 30323, GHG Protocol). This discrepancy is a strong limitation to inter-study comparability.

References

Basset-Mens, C., van der Werf, H.M.G., 2005. Scenario-based environmental assessment of farming systems: the case of pig production in France. Agr. Ecos. & Env., 105, 127–144.

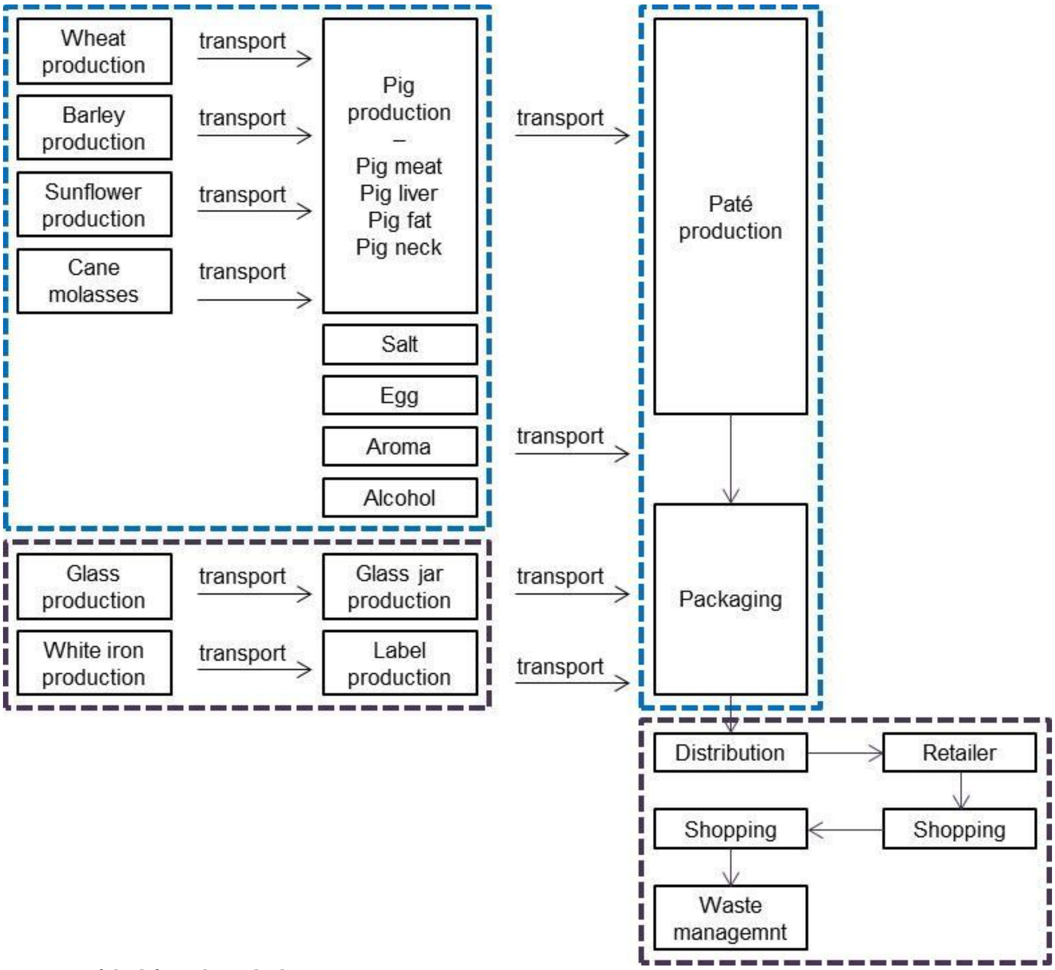

Figure 1. Representation of the life cycle studied.

Estimating carbon footprints of individual crops in organic arable crop rotations

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Organic agriculture relies to a high degree on recycling of nutrients and using crop residues as a mean to fertilise the crops and maintain soil fertility. Thus, the basket of products that originates from an organic production is diverse and to a high degree interlinked. This constitutes a challenge when using LCA for analysing organic agricultural products derived from the more complex systems. For example with regard to allocation aspects when green manure crops or catch crops are included in the crop rotation. Furthermore, the need to include soil carbon changes in the LCA of organic products is more urgent since organic crop rotations often increase soil carbon sequestration (FAO, 2011).
The challenge of estimating carbon footprints of organic crops was studied in an organic arable crop rotation experiment grown at three different locations in Denmark for three years (2006-8). The organic crop rotations were designed to explore ways to avoid the use of conventional manure in organic crop rotations. The carbon footprints of the crops from four different scenarios (crop rotations) were compared. The four different scenarios are illustrated in Fig. 1; three organic (‘Slurry’, ‘No input’ and ‘Mulching’) and one conventional crop rotation. The aim of the present paper is to explore and suggest a method to estimate the carbon footprints of individual crops in organic arable crop rotations.
The carbon footprint of the crops were estimated using two different approaches based on either a) the full crop rotation, giving greenhouse gas (GHG) emissions of the average of all crops in the crop rotation per kg DM sales crop or b) the individual crops, giving GHG emissions per kg DM for the specific sales crops, e.g. barley in the crop rotation. The last approach was done by splitting the environmental burden and benefits from e.g. the green manure equally on the crops on a per hectare basis.
The analysis of the full crop rotation showed no significant differences in carbon footprint of sales crops between the different crop rotations, giving carbon footprint values between 400 and 500 g CO_2 eq. kg^{-1} DM of the sales crops. The higher N_2O emissions from grass-clover in the ‘Mulching’ rotation were counteracted by a higher soil carbon sequestration. The ‘No input’ rotation had lower yields and a negative soil carbon sequestration, which increased the carbon footprint of the sales crop from this rotation
The analysis of the individual crops was able to give a specific carbon footprint value of e.g. spring barley grown in the different crop rotations (Fig. 2). Fig. 2 shows that the carbon footprint values for e.g. spring barley grown in the ‘Mulching’ rotation was affected by the soil carbon sequestration and the N_2O emissions caused by the green manure crop compared to the ‘Slurry’ or ‘Conventional’ rotations. These findings show that the contributions caused by the green manure crop to the carbon footprint of the organic crops are considerable.
In conclusion, the study highlights the importance of analysing the whole crop rotation and including soil carbon changes when estimating carbon footprints of organic crops where especially green manure crops are included.

References

FAO, 2011. Organic agriculture and climate change mitigation. A report of the Round Table on Organic Agriculture and Climate Change. December 2011, Rome, Italy.

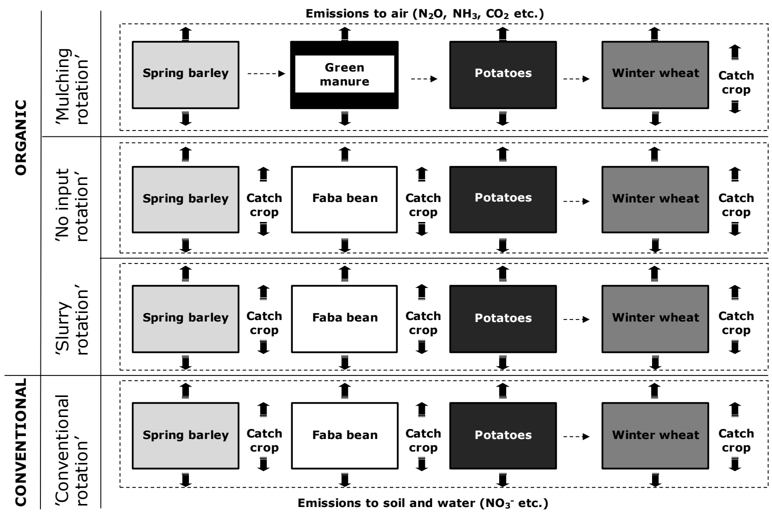

Figure 1. Illustration of the crop rotations analysed in the study. The studied crop rotations were grown at three locations in a randomised and replicate long-term experiment in Denmark (Jyndevad, Foulum and Flakkebjerg) during three years (2006-8).

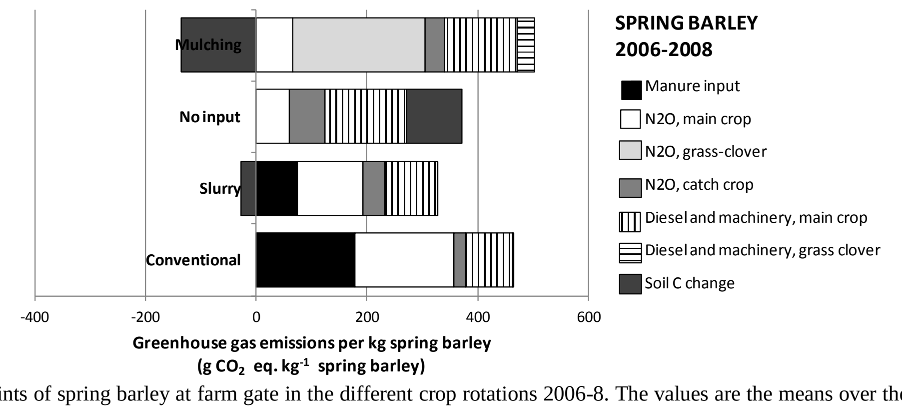

Figure 2. Carbon footprints of spring barley at farm gate in the different crop rotations 2006-8. The values are the means over the three locations and three years (2006-8).

The carbon footprint of Brazilian canary melon

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Emission of greenhouse gases is an environmental concern that has been the focus of food producers and consumers worldwide. Consumers and retail companies are increasingly aware of the possibility to base purchase decisions on carbon labels. Brazil is the second world melon exporter country in the world (FAO, 2011). The main exporting melon producers in Brazil are clustered in the semi-arid Low Jaguaribe and Açu region, in the neighbouring states of Ceará and Rio Grande do Norte. In 2009, 98% of the melon produced in this region was exported (IBGE, 2009), belonging to the Cucumis melo inodorous Naud group, commonly known as canary yellow melon. To our knowledge, the carbon footprint (CF) of Brazilian melon production is not assessed and explored. The objective of this study, therefore, is to quantify GHG emissions along the production chain of Brazilian melon, and, to identify improvement options.
The product system encompasses (i) upstream processes, i.e. the production and transport of inputs, such as seeds, pesticides, diesel and plastics, (ii) melon processes at the Low Jaguaribe and Açu region, i.e. the production of seedlings, melons and packing, and (iii) downstream processes, i.e. transport of melons to Europe and solid waste disposal. The functional unit is one ton of exported canary melon. Primary data related to materials and energy use was obtained from farmers and researchers at the Brazilian Agriculture Research Corporation (Embrapa) - Tropical Agroindustry branch, through a structured questionnaire, during the first semester of 2011. The emissions of carbon dioxide, nitrous oxide and methane are estimated from the amount of input used in different activities, applying emission factors proposed by IPCC (2006) and the Brazilian GHG Inventories (MCT, 2010). GHG emissions from melon processes at the Low Jaguaribe and Açu region are considered, regarding the following activities: land use change (biomass loss, with cutting and burning, and soil organic matter mineralisation); nitrogen fertilisation (including incorporation of field residues on soil); and fossil fuel combustion by tractors. The CF is accounted in terms of CO_2-equivalentes, considering the global warming potential of GHG in a time period of 100 years (IPCC, 2006). The CF of canary melon is calculated considering a reference situation and two production scenarios.
Considering all processes and the uncertainty in measurements, the average CF of canary melon in the reference situation, up to their distribution in the European market, is 710 kg CO_2-eq/t melon (Figure 1). Indirect emissions, from the production of inputs and transports, exceeded direct emissions from melon processes at the Low Jaguaribe and Açu region. The major melon process in this region contributing to GHG emission is crop production, i.e. land conversion from Caatinga vegetation to melon fields and nitrogen fertilisation application (Table 1), whereas the major up- and downstream processes are fertiliser and plastic production. Moreover, scenario analyses shows that the CF of canary melon can be reduced by 6% (scenario 1) lowering N fertilisation from 6 to 4 kg N/t melon and by 24% (scenario 2) sitting of new melon fields in existent agriculture areas. The results of this study may support Brazilian melon producers when calculating melon carbon footprint and deciding which management practices to use to reduce it.

References
Brazilian Institute for Geography and Statistics (IBGE), 2009. National Agriculture Production. Available at: www.ibge.gov.br.
Brazilian Science and Technology Ministry (MCT), 2010. Brazilian inventory of emissions and removal of GHG not controlled by the Montreal Protocol. Available at: http://www.mct.gov.br.
Food and Agriculture Organization (FAO), 2011. FAOSTAT: melon production. Available at: http://faostat.fao.org/site/567/default.aspx#ancor.
International Panel on Climate Change (IPCC), 2006. Guidelines for National Greenhouse Gas Inventories. Available at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/0_Overview/V0_1_Overview.pdf.

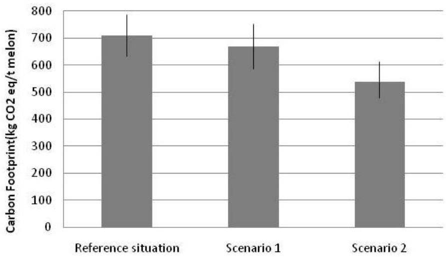

Figure 1 – Carbon footprint of canary melon in different scenarios

Table 1. Estimated GHG greenhouse of one ton of exported canary melon in the reference situation

Inputs and outputs	Unit per production unit	Seed production	Seedling production	Crop production	Melon packing
Area	m^2	0.30	0.01	441.92	0.52
Seed	g	0.08	33.66	0.00	0.00
Seedling	g	9.03	0.00	2.471.75	0.00
Coconut substrate	g	1,011.11	3,564.00	0.00	0.00
Water	L	0.09	0.06	186.05	0.15
Electricity	kWh	11.49	0.46	72.60	18.15
Diesel	g	0.00	0.00	7,207.20	0.00
Cleaning products	g	0.00	0.00	0.00	648.10
Plastics	g	73.27	519.31	38,008.36	659.01
Papers	g	0.00	0.00	0.00	58,495.80
Wood (pallets)	g	0.00	0.00	0.00	11,965.80
Fertilisers					
Organic compost	g	0.00	0.00	123,684.66	0.00
N	g	4.05	1.65	5,548.72	0.00
P_2O_5	g	0.59	1.65	6,660.24	0.00
K_2O	g	7.47	0.00	9,613.66	0.00
Others	g	3.98	0.00	2,347.80	0.00
Pesticides					
Insecticide	g	1.28	0.01	765.72	0.00
Fungicide	g	0.55	0.02	480.19	2.66
Herbicide	g	0.46	0.00	0.00	0.00
Solid waste					
plastic	g	66.01	523.47	38,008.36	0.00
empty pesticide packages	g	0.16	0.00	643.50	0.31

Nutrient based functional unit for meals

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In the European Union more than a quarter of the environmental impact is estimated to come from the food chain. There is an on-going discussion on how to reduce the environmental impact along the food production and supply chain. One of the most widely spread proposition is to alter food consumption patterns by replacing animal foods with plant-based foods. And of course there is a big difference between the environmental impacts of the production of 1kg vegetables and 1 kg meat. However, nutritional values or nutritional health of food are seldom considered in such comparisons. It is important to use a functional unit that is relevant from a nutritional perspective.

The goal of this study was to compare the environmental impact of real restaurant meals and their ingredients and to show the influence of the different functional units (1 meal; 1 meal adjusted by the nutrient density score (NDS); 1 meal adjusted by the nutrient rich food index NRF)) on the results. The following meal combinations were compared (among others): proteins (beef vs. poultry vs. mushrooms) with potatoes and green beans (fresh beans Switzerland vs. fresh beans Egypt vs. fresh beans greenhouse grown).

In this study, the NDS was calculated according to Drewnowski (2005). The sum of proteins, carbohydrates, fats, 10 vitamins and 8 trace elements were considered and each weighted according to the recommended daily intake meaning the higher the nutrient density the more valuable the food was. The NRF was calculated according to Drewnowski (2009). The NRF9.3 was chosen because it best correlates to a healthy diet (Drewnowski 2009). The NRF9.3 contains nine nutrients to encourage (protein, fibre, Vitamins A, C and E, Minerals Ca, Fe, Mg, K) and 3 nutrients to limit (saturated fat, added sugar, Na). Nutrient contents were taken from the USDA National Nutrient Database for Standard Reference (2011).

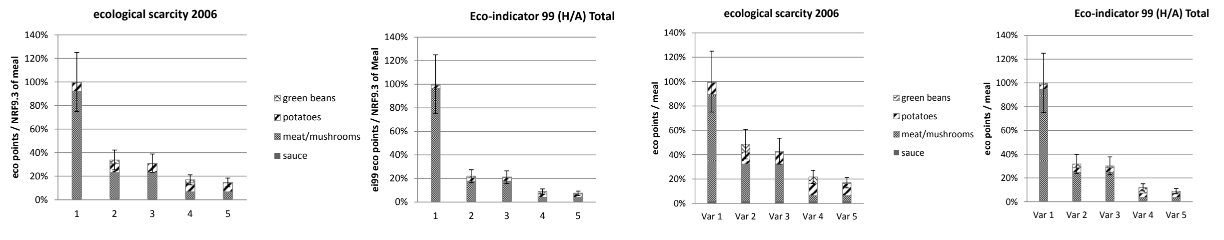
Production data for beef and poultry (Integrated production, Switzerland) were based on Jungbluth (2000) updated by the Wirz handbook (LBL 2005) and own data inventories. Potato production (integrated production, Switzerland) was taken from the ecoinvent report No. 15 (Nemecek & Kägi 2007). Data for bean production (good agricultural practice, Germany) was based on Lattauschke (2002) and data for mushroom production (conventional, Poland) was taken from Hessische Landesfachgruppe (2002). Data for the further processing of the ingredients and preparing of meals was based on Dinkel et al. (2006). Data for meals was based on real canteen menu. The ecoinvent inventory V2.2 database (ecoinvent 2010) was used for other secondary data (fertiliser production, transportation and other) and emission factors.

The comparison of the environmental impacts of the meals depends on the functional unit we choose. A comparison of the environmental impact in reference to one meal shows as expected that the most relevant impact comes from meat (Fig. 1). Meals with beef have a significantly higher environmental impact than meals with poultry whilst vegetarian meals show a significantly lower environmental impact. All other inputs are of secondary relevance. If the results are weighted by the NDS in order to compare the environmental impact of the meals in reference to their nutritional value, meat (especially beef) still shows a high impact but is not as dominant due to its high nutrient density (Fig. 2). Other ingredients such as potatoes and beans also contribute significantly especially if the ecological scarcity method is considered, Taking the uncertainty into account a meal with vegetables out of season can but must not have a significant lower environmental impact than a meat meal. If the results are weighted by the NRF9.3 in order to compare the environmental impact of the meals in reference to their nutritional health, meat (especially beef) shows an even higher impact than in the comparison per meal. All other inputs are of secondary relevance compared to meat.

This study compared three different functional units for meals of which two considered nutritional aspects of food. Different conclusions may be derived based on the chosen functional unit leading to different food recommendations. The functional unit to be chosen depends not only on the goal of the study but also on the circumstances such as cultural background or the measure of value of the stakeholder. We are convinced that the consideration of nutrient density is important in the context of the environmental debate. Furthermore, environmental impacts of meals can be directly linked to nutritional considerations of meals.

References

Dinkel et al. (2006). Calculations for "Der kluge Einkaufswagen" Unterrichtseinheit zu den Themen Umwelt, Konsum, Ökobilanzen. BAFU.
Drewnowski A. (2005). Concept of a nutrious food: toward a nutrient density score. Am J Clinical Nutr 2005; 82: 721-32
Drewnowski A. (2009). Defining Nutrient Density: Development and Validation of the Nutrient Rich Food Index. Journal of the American College of Nutrition, Vol.28, No. 4, 421S–426S
Ecoinvent (2010). Ecoinvent 2010: Version 2.2, Swiss Center for Life Cycle Inventories. May 2010.
Hessische Landesfachgruppe, 2002. Fachexkursion nach Polen – Austern- und Champignonanbau, Handel und Substratherstellung. Der Champignon.
Frischknecht et al. (2009) Methode der ökologischen Knappheit - Ökofaktoren 2006. Bundesamt für Umwelt (BAFU)/ÖBU.
Jungbluth N. (2000). "Umweltfolgen des Nahrungsmittelkonsums: Beurteilung von Produktmerkmalen auf Grundlage einer modularen Ökobilanz" Dissertation ETH Nr. 13499, Umweltnatur- und Umweltsozialwissenschaften, Eidgenössische Technische Hochschule Zürich, 316 Seiten.
Landwirtschaftliche Beratungszentrale Lindau (LBL), 2005. Wirz Handbuch – Pflanzen und Tiere. Wirz Verlag
Lattauschke, G, 2002. Hinweise zum umweltgerechten Anbau von Freilandgemüse im Freistaat Sachsen – Buschbohnen. Sächsische Landesanstalt für Landwirtschaft. http://www.landwirtschaft.sachsen.de/LFL
Nemecek T. & Kägi T. (2007). Life Cycle Inventories of Swiss and European Agricultural Production Systems. Final report ecoinvent V2.0 No. 15a. Agroscope Reckenholz-Taenikon Research Station ART, Swiss Centre for Life Cycle Inventories, Zurich and Dubendorf, Switzerland.



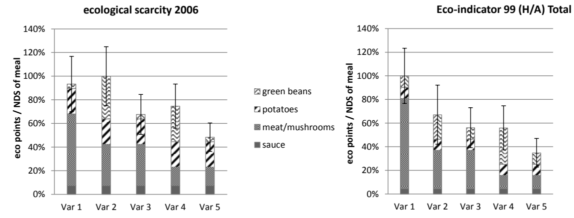


Figure 1. Environmental impact per meal, per NDS of meal and per NRF9.3 of meal, normalised to the maximum. Var 1: beef+potatoes+green beans CH, Var 2: poultry+potatoes+green beans ES, Var 3: poultry+potatoes+green beans CH, Var 4: mushrooms+potatoes+green beans greenhouse, Var 5: mushrooms+potatoes+green beans CH.

Carbon footprint of organic vs. conventional food consumption in France

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European food consumption accounts for 20-30% of the environmental impacts generated by consumer products. Our diet is thus directly concerned by the struggle against environmental damages. Simultaneously, organic agriculture, scheme with strict specification, emerges as a way to mitigate our impact on the environment, and organic market has been booming for the past 10 years. It appears relevant to assess the extent to which the rapid development of this rising form of agriculture can have a positive effect on the environment. Indeed, if the environmental benefit of organic farming methods is fairly accepted when results relate to the hectare of land use, impact calculation per unit of production lead to more heterogeneous conclusions. Given foods aim at being eaten, as part of a whole diet, is it relevant to compare environmental impacts of non-organic product and its organic equivalent to estimate the impacts and benefit of the organic farming, as the studies carried out so far seem to suggest? Thus, the main scientific goal of this project is to evaluate the environmental impact of "organic vs. conventional consumption" on a wider scale than individual products.

Two steps were followed: characterisation of organic and conventional patterns and application of the LCA methodology to quantify their environmental burden. The consumption patterns were established considering the global amount of food annually purchased and counting the whole life cycle of food products. The functional unit was defined as "to produce, supply and consume an average food basket in 2009", and applied to the various types of French consumers. The Kantar Worldpanel provided detailed data on the food items purchased by French consumers. For representativeness concerns, the organic and consumers were defined as purchasing more than 50 and less than 3 organic products per year. Literature review was performed as well as simplified LCAs to build the emission factors database, covering all stages of food items life cycles. Only global warming potentials were listed, as other impacts did not covered enough products to calculate satisfying consumption pattern footprints.

Conventional and organic consumers' purchases amount to 524 and 496 kg per year, with respective mass shares of organic products of 0.3 and 11.6%, beverages excluded. Fruits and vegetables consumption rises with organic product purchases, while Dairies, Meat fish and eggs and Ready-made meals decline. Organic consumer carbon footprint is slightly inferior to conventional consumer's one, reaching 1 149 against 1 173 kg CO_2 eq. Cultivation and farming stage carries the great majority of the impact (about 75%). Considering food categories, Meat, fish and eggs and Dairies are the main contributors together accounting for about 66% of the emissions.

The organic pattern would gain to be improved, since committed consumers often consume more than 50 organic products per year. Further research regarding meat, fish and eggs, Dairies and F&V carbon footprints could be a priority to enhance the quality of these results, considering both their level of consumption and environmental burdens.

Outcomes are coherent with the literature, which provides same orders of magnitudes for food consumption carbon footprints. Given the uncertainty of the results, coming both from data and emissions factors, we cannot state that one pattern performs better than the other. However, organic basket composition counterbalances the higher purchases. Improving the organic consumption pattern and environmental knowledge regarding Meat, fish and eggs, Dairies and F&V should lead to more accurate results.

References

Muñoz, I., Milà i Canals, L., Fernandez-Alba, A., 2010. Life cycle assessment of the average Spanish diet 2010 including human excretion. Int J of Life Cycle Assess. 15:794-805

Cederberg, C., Mattsson, B. 2000. Life cycle assessment of milk production — a comparison of conventional and organic farming. J Clean. Prod. Volume 8, Issue 1, February 2000, Pages 49–60.

Thomassen, M.A., Dalgaard, R., Heijungs, R., de Boer, I., 2008. Attributional and consequential LCA of milk production. Int J of Life Cycle Assess. 13:339-349.

Table 1. Annual purchases and GHG emissions per capita

Consumer groups (nb of organic products purchased)	Food basket weight (kg/capita/year)	Global Warming Potential (kg. CO_2 eq.)
Group 1 - French consumer average	505	1179
Group 2 - < 3 products	496	1173
Group 5 - > 50 products	524	1149

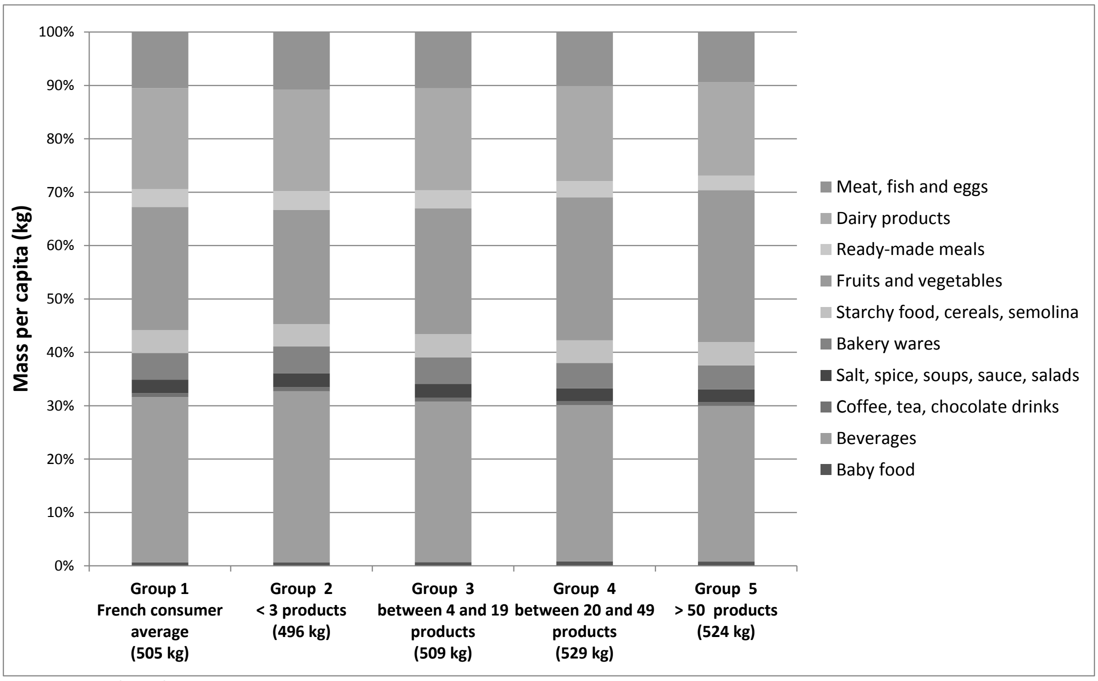

Figure 1. Composition of the food baskets

Nutrition in LCA: Are nutrition indexes worth using?

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The ISO 14040 standard requires that functions of the system being studied shall be clearly specified, and comparisons between systems shall be made on the basis of the same function(s), quantified by the same functional unit(s) in the form of their reference flows. Selected FU(s) should go together with a goal and a scope for the study. Environmental impact of food is currently mostly considered on mass basis in public debate and scientific discussion, although nutrition undoubtedly is one of the main functions of food. Furthermore, the nutritional dimension is not uniform, but rather multiple. There is a growing interest in considering nutrition and environment simultaneously.

The paper develops a methodology to combine nutritional and environmental aspects for food LCA. Climate impact and eutrophication potential were used as examples of the environmental category. The usability of nutritional indexes is tested and discussed. Nutritional indexes tested were Nutrient Rich Food, NRF9, Naturally Nutrient Rich, NNR, and Nutrient Adequacy Ratio, NAR16 (Drewnowski and Fulgoni, 2007). These indexes combine data for recommend nutrients. NRF9 includes nine nutrients (protein, fibre, Ca, Fe, Mg, K and Vit A, C and E). NNR includes 15 nutrients (Protein, fibre, MUFA, Ca, Fe, Zn, K, Vit A, C, D, E, thiamin (B1), riboflavin (B2), B12 and folate). NAR16 includes 16 nutrients (protein, fibre, Ca, Fe, Mg and Vit A, C, D, E, B1, B2, B5, B6, B12, niacin and folate). The Finnish nutrient database does not provide information on B5, so in this study NAR16 included 15 nutrients. Other indexes consisting of recommended nutrients were also considered, but the lack of nutritional data restricted their use. From the point of view of the science of nutrition, recommendation for and against nutrients should be considered. In this study, indexes for nutrients to be recommended and limited were applied to a nutrient calculation, but not to environmental assessment, because they confer negative values to some foods. Negative values are not directly applicable in LCA as they produce a negative environmental impact. Indexes consisting of only nutrients to limit were not regarded as suitable for linking to LCA by means of FU as they do not present benefit from food but rather disadvantage.

The test calculation included several foods from several product groups. Nutritional data were based on national nutrition recommendation (Anon, 2005) and the national food composition database (Fineli® - Finnish Food Composition Database). LCA results used in the study were from the previous studies of the research team (Saarinen et al., 2012a; Usva et al., 2012; see also Virtanen et al., 2011 and Saarinen et al., 2012b), Ecoinvent database and Wanhalinna (2010).

The nutrient indexes, such as NRF9 and NAR16, attempt to represent a general nutritional value for individual foods by reflecting dietetic nutritional values (see from validation of nutrient indexes e.g. Fulgoni et al., 2009). They are intended for application to all types of food. They quantify an average share of nutrients in 100 g of a product (or any other amount of food) for their daily nutrient recommendation. The nutrient indexes were combined for the LCA using a formula: E/N index = LCA measure of a impact category at issue in relation to 100 g of a product / a nutrient index measure (related to 100 g of a product).

Preliminary results show that environmental impact seems to dominate the results when the indexes are applied to several kinds of foods. A recommendation to consumers from an environmental point of view has been to restrict animal-based foods and to favour plant-based foods. This new insight seems to strengthen the recommendation. However, some exceptions established, in addition to differences between the climate impact and the eutrophication potential, and among different nutrient indexes.

The paper represents a novel approach to include a nutritional aspect to food LCA (see other approaches used or suggested e.g. Schau and Fet (2008) and Smedman et al. (2011). This approach provides an interesting insight into sustainable food choices. However, from the point of view of nutrition science and national nutrition, inclusion of nutrients to be limited alongside nutrients to be recommended is a necessity. This challenge has to be met before the approach can be applied to practical situations. Also a reformulation of the nutrient composition of the index has to be considered, so that the index better fits with current science of nutrition knowledge and national nutrition requirements.

References

Anon., 2005. Suomalaiset ravitsemussuositukset - ravinto ja liikunta tasapainoon 2005. (in Finnish) (Finnish Nutrition Recommendations – nutrition and exercise to the balance 2005.) Valtion ravitsemusneuvottelukunta (National Nutrition Council). 56 p. Edita, Helsinki. ISBN 951-37-4501-5.

Drewnowsi, A. and V. Fulgoni III, 2007. Nutrient profiling of foods: creating a nutrient-rich food index. Nutrition Reviews, 66: 23-39.

Fineli® - Finnish Food Composition Database. National Institute for Health and Welfare. Available at: www.fineli.fi.

Fulgoni, V.L., Keast, D.R. and A. Drewnowski, 2009. Development and validation of the nutrient-rich foods index: a tool to measure nutritional quality of foods. J Nutrition 139, 1549-1554.

Saarinen, M., Kurppa, S., Virtanen, Y., Usva, K., Mäkelä, J. and A. Nissinen, 2012b. LCA approach to the impact of homemade, ready-to-eat and school lunches on climate and eutrophication. J Cleaner Production 28, 177-186. http://dx.doi.org/10.1016/j.jclepro.2011.11.038

Saarinen, M., Virtanen, Y. and H. Hyvärinen, 2012a. LCAs of large repertoire of Finnish outdoor plant products. Abstract for LCA food 2012 conference.

Schau EM and AM Fet, 2008. LCA Studies of Food Products as Background for Environmental Product Declarations. Int J LCA 13: 255–264

Smedman, A., Lindmarka-Månsson, H., Drewnowski, A. and A-K.M Edman, 2011. Nutrient density of beverages in relation to climate impact. Food & Nutrition Research, 54, 5170 – DOI: 10,340/fnr,v54i0,5170

Usva, K., Nousiainen, J., Hyvärinen, H. and Y. Virtanen 2012. LCAs of average animal products pork, beef, milk and eggs in Finland. Abstract for LCA Food 2012 Conference.

Wanhalinna, V., 2010. Leivän hiilijalanjälki (in Finnish) (Carbon footprint of bread). Master thesis. University of Helsinki. ISSN 0355-1180

Virtanen Y, Kurppa, S., Saarinen, M., Katajajuuri, J-M., Usva, K., Mäenpää, I., Mäkelä, J., Grönroos, J. and A. Nissinen, 2011. Carbon footprint of food – approaches from national input-output statistics and a LCA of food portion. J Cleaner Production, 19, 1841-1856.

Comparing the environmental impact of human diets varying in amount of animal-source food – the impact of accounting for nutritional quality

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Studies comparing the environmental impact of human diets that vary in amount of animal-source food generally not account for the nutritional quality of these diets. Because diets may differ in amount of energy and nutrients, the impacts of these diets are not comparable. To make impacts comparable, we quantified the amount of 12 nutrients in diets described in 13 peer reviewed studies. We also computed their composite nutritional quality, expressed as the Nutrient Rich Diet9.3 score (NRD9.3). We expressed the GWP per unit protein and per unit NRD9.3. Diets that had higher levels of animal protein had higher (excessive) levels of total protein and were generally lower in composite nutritional quality. Diets that had lower levels of animal protein had lower GWPs per gram protein and per unit NRD9.3. Accounting for composite nutritional quality gave stronger contrasts in GWP between human diets than original comparisons.

A novel nutrition-based functional equivalency metric for comparative Life Cycle Assessment of food

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Establishing functional equivalency has always been a methodological challenge in life cycle assessment studies of foods. While most food LCAs have been conducted on a mass or volume functional unit basis, this does not fully capture the primary function of foods – delivering nutrition – making comparisons between different food types in consumer-oriented analyses difficult. Quality-based correction factors such as "energy corrected milk" (Cederberg & Mattsson 2000) or "protein corrected wheat" (Audsley 2003) assist in normalising natural variations in qualities that influence value and processing. Martinez-Blanco et al (2011) use antioxidant compound content as a functional unit in comparing cultivation and fertiliser options in cauliflower production. In a recent literature review, de Vries and de Boer (2010) compare impacts of livestock products on the functional unit basis of "protein delivered" and "average daily intake," allowing comparison across disparate food types. Such single nutrient based functional units have merit for particular study goals, but the fact remains that healthy nutrition is complex and multi-dimensional. Schau and Fet (2008) propose the need for a quality corrected functional unit that incorporates fat, protein and carbohydrate content, as well as potentially other quality functions, as deemed necessary.

The Overall Nutritional Quality Index (ONQI) is a tool designed to aid consumers in making well-informed dietary choices (Katz et al, 2010). Developed by nutrition and public health experts, the ONQI algorithm combines into a single score over 30 entries representing both micro- and macro-nutrient properties of foods, weighted on the basis of the effects (both promotional and detrimental) that nutrients have on health. The index has been validated through expert panel rankings and statistical diet comparisons, and has been implemented in over 500 supermarkets across the US as NuVal. In this paper, we explore the utility of ONQI as a nutrition-based functional equivalency metric in environmental impact assessments of food. Using the NuVal score (ONQI adjusted to values from 1-100) as a nutritional quality correction factor allows comparisons of environmental impacts of foods on the basis of their relative contribution to a healthy diet. Figure 1 demonstrates the influence of the NuVal "nutritional weighting" on life cycle energy and GHG emissions per kcal of food energy. Limitations and potential merits will be discussed in comparison to other normalisation and functional equivalency approaches mentioned above.

References

Schau, E. M., Fet, A. M., 2008. LCA Studies of Food Products as Background for Environmental Product Declarations. Int. J. LCA. 13, 255-264.

Martinez-Blanco, J., Anton, A., Rieradevall, J., Castellari, M., Munoz, P., 2011. Comparing nutritional value and yield as functional units in the environmental assessment of horticultural production with organic or mineral fertilization. Int. J. LCA. 16, 12-26.

Cederberg, C., Stadig, M., 2003. System Expansion and Allocation in Life Cycle Assessment of Milk and Beef Production. Int J LCA 8, 350–356.

Audsley, E., 2003. Harmonisation of environmental life cycle assessment for agriculture: final report. Concerted Action AIR3-CT94-2028, European Commission DG VI Agriculture, Brussels.

De Vries, M., de Boer, I.J.M., 2010. Comparing environmental impacts for livestock products: A review of life cycle assessments. Livestock Science. 128, 1-11.

Katz, D.L., Njike, V.Y., Rhee, L.Q., Reingold, A., Ayoob, K.T., 2010. Performance characteristics of NuVal and the Overall Nutritional Quality Index (ONQI). Am. J. Clin. Nutr. 91, 1102S-1108S.

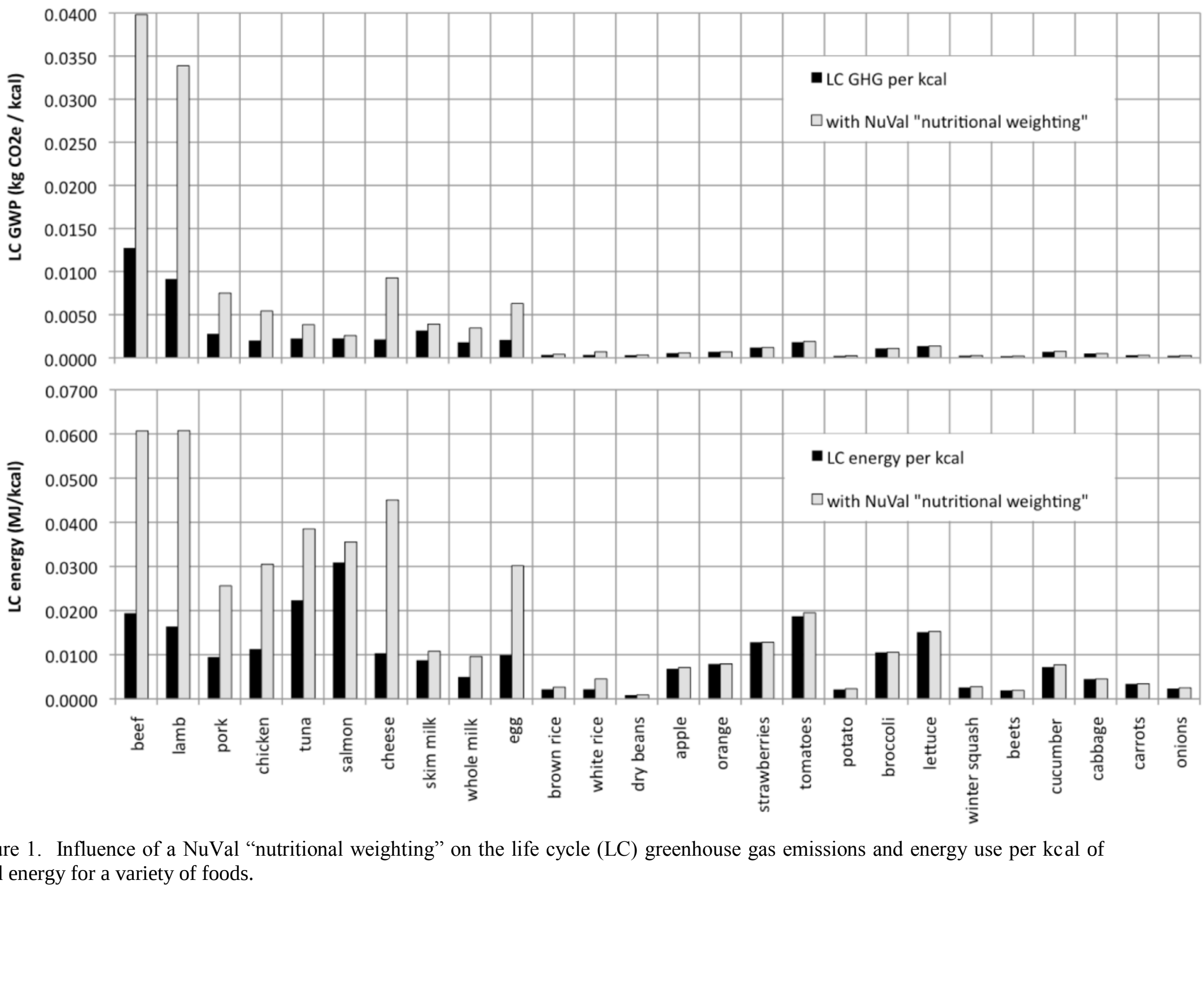

Figure 1. Influence of a NuVal "nutritional weighting" on the life cycle (LC) greenhouse gas emissions and energy use per kcal of food energy for a variety of foods.

State of the art of LCA application in the fruit sector

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This paper critically reviews LCA studies in fruit production and distribution systems as a part of the results of the work carried out by the Agri-Food working group of the “Rete Italiana LCA” (Italian LCA Network) – fruit products subgroup.

To assess papers that reflect mainstream ideas about application of LCA in fruit systems, only peer-reviewed papers from international journal and conference proceedings were considered. We preferentially included studies that considered the life cycle until the fruit was produced. Studies that considered the whole production of derivates (e.g., fruit juice production) were only included if they added to the analysis in the plantation stage.

A total of 19 works were identified divided in 11 articles form ISI journals and 8 papers in proceedings from the LCA congress series. The review covers all main aspects for conducting an LCA in fruit production system, in particular the following characteristics have been considered:

- *General aspects of the study cases* (e.g. year of the study, geographic area of reference) to locate temporally and geographically such studies; the review highlight that, with exception for a few pioneering papers, most of the works have been published in the second half of the decade. The location of the studies reflects places with the most importance for fruit production: Brazil, New Zealand, Italy and Spain.
- *Product considered and functional unit:* this is a key-aspect for such application because fruits and fruit products may have different quality, nutrient and economic values, thus it may be difficult to find a significant functional unit.
- *Life-cycle-based methodology adopted*: although all paper describe an LCA-based methodology, some of them consider specific tools or approaches which may be consider as a derivation of the LCA described in the ISO standards, such as Carbon Footprint methods.
- *Objectives*: the objectives of the various studies are quite heterogeneous and include: 1) profile the environmental burden of a fruit product; 2) identify the environmental hot spots in production systems performance; 3) describe management strategies to increase environmental performance; 4) compare different fruit products (e.g. cultivars); 5) compare different agrotechniques (e.g. organic vs. conventional), 6) compare different environmental assessment methods; 7) profile the environmental burden of a production in a given area; 8) evaluate the environmental properties of a fruit supply chain; 9) assess a preliminary study for PCR.
- *System boundaries*: mainly set up with cradle-to-gate or cradle-to-market approaches, and some rare cases of cradle-to-shelf or cradle-to-use approaches.
- *Data origin*: studies are well divided between works that use field data and work with literature or statistical references. Strengths and weakness may came from both methods.
- *Environmental impact assessment method*: the characteristic with the highest heterogeneity; it is impossible to define a best suitable method.

Furthermore the review highlights peculiarities and strengths, limits and problems in the application of LCA to fruit production systems, such as the modeling of the orchard system and the definition of allocation strategies. Due to the relatively high variability in study cases and approaches, it was not possible to identify any one method as being better than the others. However, remarks on methodologies and suggestions for standardisation are given and the environmental burdens of fruit systems are highlighted.

Table 1. List of all papers presenting applications of LCA in fruit production systems since January 2012 from ISI Journal and conferences, listed by date of publication. Country category considers the area of the study and not necessarily the location of the research group. For description of objectives, see reference numbers in the text.

REFERENCE	COUNTRY	PRODUCT	MAIN OBJECTIVES	FUNCTIONAL UNIT	BOUNDARIES	DATASET	ASSESSMENT METHOD
Blanke and Burdick, 2005	Germany, New Zealand	Apple	8	Mass based (kg)	Cradle-to-market	Literature and other databases	Characterisation factors from literature
Sanjuán et al., 2005	Spain	Orange	1, 2, 7	Mass based (kg)	Cradle-to-gate	Literature and other databases	CML , WMO, POPC and USES
Milà i Canals et al., 2006	New Zealand	Apple	1, 2, 3	Mass based (t)	Cradle-to-market	Commercial orchards + validation	EDIP1997
Mouron et al., 2006	Swiss	Apple	1, 2, 3, 7	Land based (ha); Receipt based ($)	Cradle-to-gate	Commercial orchards	SALCA (2003)
Williams et al., 2006	UK, Spain	Strawberry	8	Mass based (1t at distribution)	Cradle-to-market	Literature and specific databases	Characterisation factors from literature
Milà i Canals et al., 2007	UK, New Zealand	Apple	8	Mass based (kg)	Cradle-to-market	Literature and specific databases	Characterisation factors from literature
Sim et al., 2007	Brazil, Chile, Italy, UK	Apple	8	Mass based (1t, just grade 1)	Cradle-to-retailer	Literature and specific databases	CML 2 Baseline 2000
Beccali et al., 2009	Italy	Citrus based products	1	Mass based (1kg of juices and oil)	Cradle-to-market	Primary data from field and secondary from lit.	IPCC 2001 GWP100; CML 2 Baseline 2000
Coltro et al., 2009	Brazil	Orange	1, 7	Mass based (FU=t)	Cradle-to-gate	Commercial orchards	Characterisation factors from literature
Beccali et al., 2010	Italy	Citrus based products	3	Mass based (1kg of juices and oil)	Cradle-to-market	Primary data from field and secondary from literature	IPCC 2001 GWP100; CML 2 Baseline 2000
Cerutti et al., 2010	Italy	Peach	1, 2, 6	Mass based (kg)	Cradle-to-gate	Commercial orchards + validation	Eco-Indicator 99
Cudjoe et al., 2010	Ghana	Pineapple	2, 3	Mass based (kg)	Cradle-to-gate	Commercial orchards	Characterisation factors from literature
Ingwersen, 2010	Costa Rica	Pineapple	1, 9	Mass based (serving portion)	Cradle-to-retailer	Commercial orchards	Ecoinvent 2.0
Liu et al. 2010	China	Pear	2, 8	Mass based (t)	Cradle-to-market	Commercial orchards	IPCC 2007
Clasadonte et al., 2010a	Italy	Peach	4	Mass based (kg)	Cradle-to-gate	Commercial orchards	Impact 2002+
Clasadonte et al., 2010b	Italy	Orange	1, 3	Mass based (kg)	Cradle-to-gate	Commercial orchard	Impact 2002+
McLaren et al., 2010	New Zealand	Apple, Kiwifruit	1, 3	Mass based (kg)	Cradle-to-use	Commercial orchards	PAS 2050
Cerutti et al., 2011	Italy	Apple	8	Mass based (kg)	Cradle-to-market	Retailer and associated orchards	EDIP 1997
Knudsen et al., 2011	Brazil	Orange	5, 8	Mass based (1l of juice); Mass based (FU=1t of fruit)	Cradle-to-market Cradle-to-gate	Commercial orchards and statistics	EDIP 1997 + IPCC 2007 (GHG); IMPACT2002+ (energy)

An LCIA-based typology for more representative results and refined data collection of a horticultural cropping system in the Tropics. The case of tomato production in Benin, West Africa

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The growing awareness regarding the environmental issues associated with global food supply chains has now reached the fruits and vegetables sector, stressing the need for evaluating the different product origins and associated technologies (Milà i Canals et al., 2008 ; Martínez-Blanco et al., 2011). Although the relevance of Life-Cycle Assessment (LCA) to assess agricultural systems has been validated for a large number of products (Brentrup et al., 2004), its application to horticultural production systems especially in tropical contexts is more recent and comes with renewed and specific issues. Considering the data and expert knowledge scarcity in tropical areas, the first challenge lies in obtaining representative Life-Cycle Inventory (LCI) data valid for a given function at a given scale as defined in a specific LCA goal and scope.

This study examines the environmental impacts of cropping systems representative of against-the-season tomato production in Benin dedicated to local consumption. The authors proposed 1) to classify cropping systems with a typology based on their potential impacts, given a particular agricultural context, and 2) to analyse the contribution of cropping system components to the overall environmental impacts of the systems. By analyzing the factors governing the variability of the environmental impacts across the diverse systems, this study aimed to identify the cropping systems' components that were likely to influence the environmental impacts of the production of against-the-season tomatoes in Benin.

To explore the diversity of cropping systems at the regional scale, the 2011 dry season tomato production in the coastal area of Benin was chosen. Among the 50 producers identified, 12 fields were selected based on local experts' advice. Each agricultural operation occurring in the field was recorded and quantified during the full crop-cycle, from nursery to harvest. An ISO-compliant LCA was performed for the 12 cropping systems selected. To explore the variability of Life-Cycle Impact Assessment (LCIA) results for the studied function at the regional scale, a 2-step statistical treatment of cropping systems was then performed based on their LCIA results.

The proposed typology allows the identification of representative individual fields to assess the environmental impact of tomato cropping systems in Benin. The resulting cropping system types were analysed to identify the contribution of cropping systems components and using additional agronomical variables, to highlight the influence of cropping systems' characteristics. It led to recommendations on data collection and methodological improvement to reach representative LCI for horticultural cropping systems in the Tropics.

References

Brentrup F, Küsters J, Kuhlmann H, Lammel J., 2004. Environmental impact assessment of agricultural production systems using the life cycle assessment methodology: I. Theoretical concept of a LCA method tailored to crop production. European Journal of Agronomy 20:247-264.

Martínez-Blanco J, Muñoz P, Antón A, Rieradevall J., 2011. Assessment of tomato Mediterranean production in open-field and standard multi-tunnel greenhouse, with compost or mineral fertilisers, from an agricultural and environmental standpoint. Journal of Cleaner Production 19:985-997.

Milà i Canals L, Muñoz I, Hospido A, Plassmann K, McLaren SJ, Edwards-Jones G, et al., 2008. Life Cycle Assessment of domesctic vs. imported vegetables. Case studies on broccoli, salad crops and grean beans. Guilford: Center for environmental strategy University of Surrey.

French agricultural practices traceability system employed for environmental assessment

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InVivo, a French agricultural cooperatives union, has developed and implemented decision-making tools to help farmers manage fertilisation and plant protection. These tools enable pedologic, climatologic and agronomic data collection for each agricultural field on a farm, creating a traceability system allowing for plot-scale LCA indicators calculation.
An LCA was conducted on winter wheat based on a 2009 harvest real agricultural practices, involving six cooperatives, 13,941 plots, and covering 95,432 ha in production basins across France. Several indicators were calculated: water consumption, greenhouse gases emissions, marine and freshwater eutrophication, primary energy consumption, acidification, freshwater ecotoxicity. Every practice necessary for grain production and harvest was considered: cultivation, sowing, fertiliser and pesticide production and application, fuel consumption. Transportation to the grain silo and storage were subsequently considered.
The main conclusions are: (1) regarding impacts on freshwater ecotoxicity, pesticide use and fertiliser use are predominant; (2) regarding the other LCA indicators, fertiliser production and fertiliser use are predominant; (3) results are highly scattered when observed among fields and much less among production basins; and (4) results depend on the product's technological quality.
The next step will be to identify ways to improve LCA results indicator by indicator by improving agricultural practices. InVivo's advice and decision-making tools prove suitable for mass traceability and mass environmental impact minimisation.
Same types of study have been conducted by InVivo, with real data for agricultural practices, on other crops, such as barley, maize, etc., creating an environmental information system.

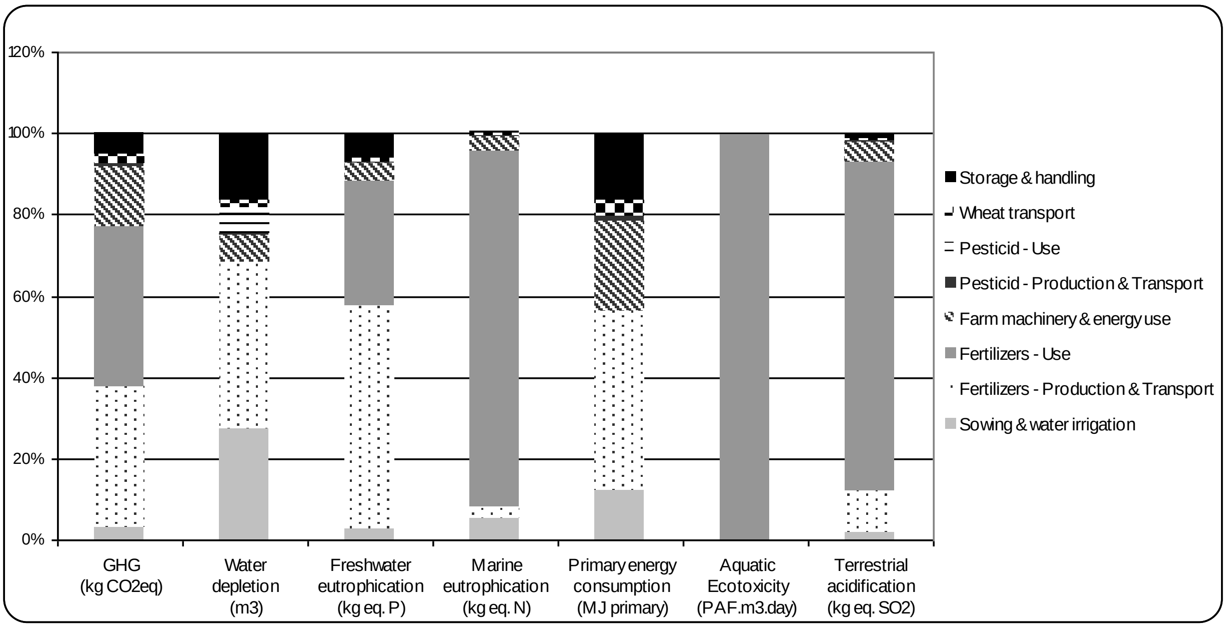

Figure 1. Contribution of stages of the wheat life cycle to LCA indicator results

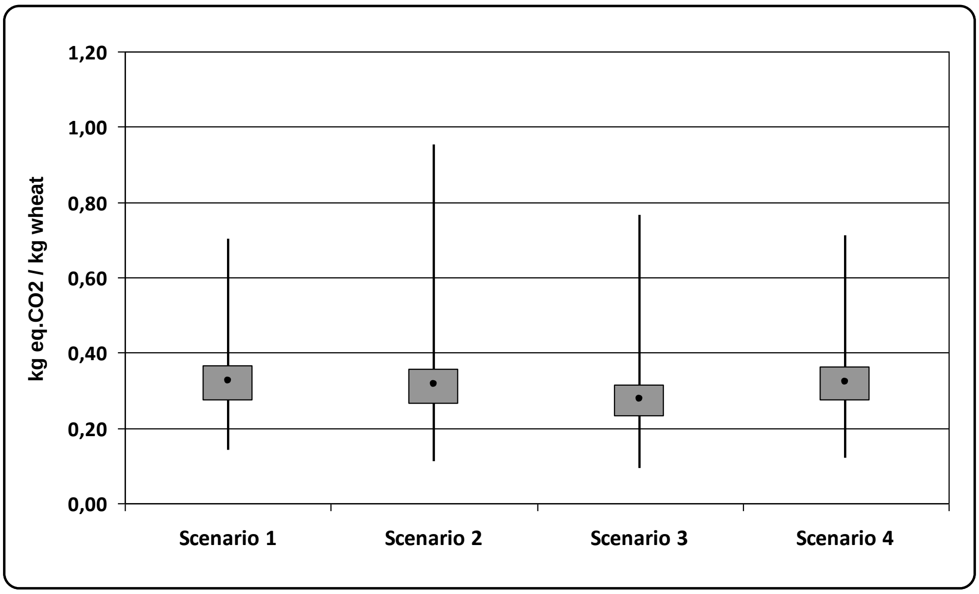

Figure 2. Inter-plot variability of the Climate Change indicator

LCA of starch potato from field to starch production plant gate

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Starch, mainly produced from potato in Northern France, currently provides basic molecules for many industrial and non-food applications. To integrate accurate and consistent data in LCAs of starch derived products, a specific LCA study was carried out focusing on the upstream processes from potato field production to the starch processing plant gate. Very few literature references actually exist on potato crop LCA, most of them being food potato (D'Arcy et al., 2010; Williams et al., 2010) with crop management techniques different from those of starch potato. Hence, in the present study, we used technical data from starch potato producers and specific supply chain data. To provide adapted and accurate impact assessment, a focus was made on in-field fluxes assessment methods in the inventory step. These fluxes were estimated using two models, AMG, (Saffih-Hdadi and Mary, 2008) and Pest-LCI (Birkved and Hauschild, 2006) respectively simulating soil carbon sequestration potential and pesticide emissions into the main environmental compartments. These models were adapted to local characteristics with consideration of soil and weather data and crop rotation (namely: sugar beet/winter wheat/potato/winter wheat).

Results for 1 ton of potato at the plant gate showed a wide influence of soil carbon dynamics in the climate change impact. Potato cultivation led to a soil carbon release that contributed 15% of this impact, corresponding to a release of 0.02 t C/t DM/year, which is far different from the value given by Arrouays et al., 2002, for French food potato (a sequestration of 0.008 t C/t DM/year). Transportation and storage had a significant share in several impacts, particularly for energy consumption (39%), underlining the necessity to account for specific supply chain description in the LCA. Pesticides spraying and emissions made up 68% of the ecotoxicity impact.

These results were obtained with promising inventory methods, relying on modeling approaches already proven to be able to integrate various biophysical and technical crop production conditions in agricultural LCA, as in the studies from Adler et al., 2007; Gabrielle and Gagnaire, 2008. Moreover, in the current context of pesticide application reduction, the proposed approaches are relevant to assess new production scenarios with lower pesticide usage. Indeed, the original methods applied in this study are analytical and capable of integrating, exploring and discriminating a wide range of production scenarios. Finally, they are generic enough to be applicable to various crop production contexts as well as to food and non-food products and chains, such as bioenergy chains (Godard et al., 2012).

References

Adler, P. R., Del Grosso, S. J., Parton, W. J., 2007. Life-cycle assessment of net greenhouse-gas flux for bioenergy cropping systems. Ecological Applications. 17 (3), 675-691.

Arrouays, D., Balesdent, J., Germon, J.-C., Jayet, P.-A., Soussana, J.-F., Stengel, P., 2002. Mitigation of the greenhouse effect Increasing carbon stocks in French agricultural soils? Scientific Assessment Unit for Expertise, Assessment Report by the French Institute for Agriculture Research (INRA) on request of the French Ministry for Ecology and Sustainable Development. Paris.

Birkved, M., Hauschild, M. Z., 2006. PestLCI--A model for estimating field emissions of pesticides in agricultural LCA. Ecological Modelling. 198 (3-4), 433-451.

D'Arcy, A., O'Halloran, J., Sage, C., 2010. An LCA of potato production in Ireland: impacts on ecology and environment. In: Università degli studi di Bari Aldo Moro, editor. VII international conference on Life Cycle Assessment in the agri-food sector. Bari, Italy.

Gabrielle, B., Gagnaire, N., 2008. Life-cycle assessment of straw use in bio-ethanol production: A case study on biophysical modelling. Biomass and Bioenergy. 32 (5), 431-441.

Godard, C., Boissy, J., Gabrielle, B., 2012. Life-cycle assessment of local feedstock supply scenarios to compare candidate biomass sources. accepted to Global Change Biology Bioenergy.

Saffih-Hdadi, K., Mary, B., 2008. Modeling consequences of straw residues export on soil organic carbon. Soil Biology and Biochemistry. 40 (3), 594-607.

Williams, A., Audsley, E., Sandars, D., 2010. Environmental burdens of producing bread wheat, oilseed rape and potatoes in England and Wales using simulation and system modelling. The International Journal of Life Cycle Assessment. 15 (8), 855-868.

Barilla EPD Process System to increase reliability, comparability and communicability of LCA studies

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The aim of this work is to show how a large company integrates the life cycle approach into its policies and views to reduce the footprint using reliable data suitable also for communication purposes. BARILLA is currently one of the top Italian food groups. It produces more than 100 products in about 50 plants around the world. The company has been using the LCA for more than a decade. Since 2008, life cycle thinking made its way into company strategy, as an instrument to thoroughly study the production chain and localise the most substantial environmental impacts.

During 2010 an internal LCA process was implemented and certified in compliance with the International EPD® regulations to perform environmental impact calculation in an easy, quick and reliable way and to provide certified and published results. Thanks to that Barilla has become the first private food company with an internal EPD process system. Barilla's EPD internal process is based on three principle elements:

- the LCA databases, in which all the most important raw materials, energy, production plants, packaging materials and other useful information are studied;
- the Product system that represents the product group model calculation tool, based on the Product Category Rule (PCR);
- the Product specific data, essentially the recipe (raw material and packaging) of a specific product

The system works as a "funnel process" (Fig. 1): data from the database and from product specific information are processed by the product system tool to have the specific LCA data sheet results. This document is then used for the preparation of the EPD. The overall system is verified twice a year by an accredited Certification Body.

It is foremost that all adopted rules and hypotheses be established it utmost clarity in order to continuously increase the suitability and reliability of the LCA implemented by companies. Since databases are a key element, their availability and updating shall undergo constant improvement through a specific updating procedure. During 2011 several EPDs were developed and published following the EPD internal process.

At 30th April 2012, fifteen EPDs are published on the website: all Barilla pasta blue-box produced in Italy, U.S.A., Turkey, Greece; four top selling products with brand Wasa (Original, Havrecknacke, Solruta, Husman); eight most famous Italian products with brand Mulino Bianco (Tarallucci, Galetti, Rusks, Crackers, Soft Bread, mini cakes); two products with brand Pavesi (Gocciole classiche and Pavesini).

In this way 40% of the volume of the whole Barilla production has been evaluated by using the Environmental Product Declaration (EPD).

Figure 2 and 3 report results respectively from the EPD on Pasta Barilla (dry durum wheat pasta produced in seven Barilla's plants located in Italy, Greece, Turkey and USA) and the EPD on Wasa Husman (a typical Swedish bakery product, produced in Filipstad, a Barilla's plant located in Sweden).

References

ISO 14040 - Environmental management, Life cycle assessment, Principles and framework
ISO 14044 - Environmental management, Life cycle assessment, Requirements and guidelines
ISO 14025 - Environmental labels and declarations - Type III environmental declarations - Principles and procedures
International EPD Cooperation; introduction, intended uses and key programme elements; v. 1 of 29/02/2008
International EPD Cooperation; General Programme Instructions for Environmental Product Declaration; version 1 of 29/02/2008
International EPD Cooperation; Supporting annexes for Environmental Product Declaration; version 1 of 29/02/2008
International EPD Cooperation; Process Certification Clarification (PCC) for the International EPD System; Guidelines; ver. 1.0 of 23/04/2010
International EPD Cooperation; Process certification clarification for the International EPD® system. Version 1.0 of 23/04/2010
International EPD Cooperation ; PCR 2010:01; CPC 2371: Uncooked pasta, not stuffed or otherwise prepared; version 1.1 of 18/06/2010
International EPD Cooperation; PCR 2012:06; CPC 234: Bakery Products; version 1.0 of 17/04/2012
International EPD Cooperation ; PCR 2010:09; CPC 23995: Sauces; mixed condiments; mustard flour and meal; prepared mustard; version 1.1 of 9/11/2010

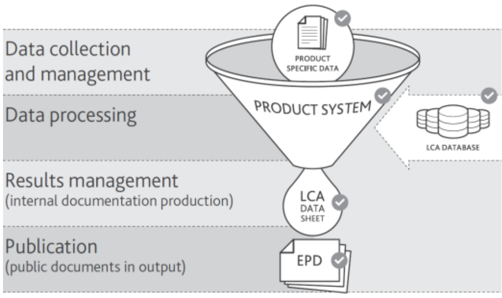

Figure 1. The "funnel process"

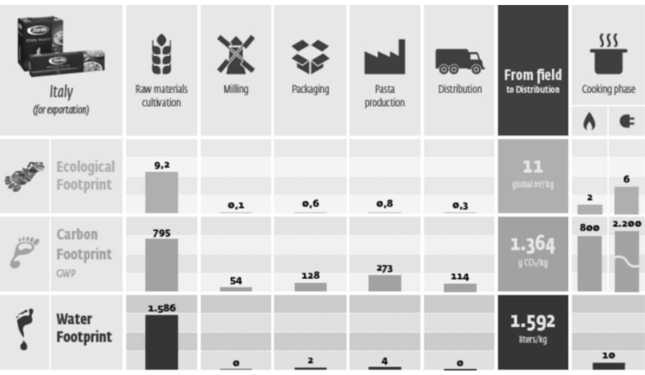

Figure 2. Example of results from the EPD on Pasta Barilla, produced in Italy for export (http://www.environdec.com/en/Detail/?Epd=7699)

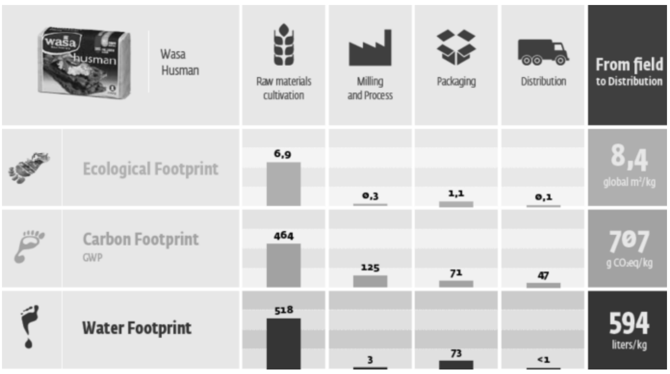

Figure 3. Example of results from the EPD on Wasa Husman (http://www.environdec.com/en/Detail/?Epd=8236)

LCA-based hotspot analysis of food products to inform a major Chilean retailer's sustainability strategy

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This paper reports on a project commissioned to Fundación Chile and Edge Environment by a major Chilean retailer to:

- Engage the retailer's merchants and suppliers to focus efforts on science-based hotspots;
- Provide a starting point for industry engagement to begin implementation of management practices based on life cycle information;
- Develop a product category specific measurement and reporting system.

Product category LCAs have been carried forward for nine food products: milk, chicken meat, blueberries, apples, grapes, avocados, wine, beer and pasta.

The common objective of the nine studies was to develop LCA models of the food product categories to identify overall environmental hotspots of impacts and improvement opportunities, modelled using:

- A common LCA methodology (ISO 14040 and 14044 compliant) aligned with the concurrent developments of the Sustainability Consortium;
- Best available Chilean or adapted international cradle to grave life cycle data for a set of deemed typical product category scenarios (e.g. conventional and organic production). Cradle-to-grave models have been built based on published studies, typical agricultural practices and background information derived from international databases, adapted to Chilean conditions (electricity mix, recycling rates, transport distances);
- ecoinvent v2.2 background data adapted to consistent economic allocation, using Chilean recycling rates and electricity grid mix;
- The impact assessment method ReCiPe World Midpoint H (Goedkoop et al., 2009) with USEtox Recommended characterisation factors for human and eco-toxicity. Normalisation and weighting factors were specifically derived from Chilean data and a sample of public opinion. The weighted environmental impact score, which has been called the Daily Eco-Impact Indicator, is calculated so that a score of 100 corresponds to the average Chilean citizen's overall daily impact on the environment.

Daily Eco-Impact Indicator results per impact category are shown for the nine product categories in Figure 1 (two scenarios are shown for each category), based on a typical serving size (USDA). In Figure 2, the Daily Eco-Impact Indicator results are shown divided by life cycle stage. These results are not intended to be used for product differentiation in terms of environmental preferability.

The studies and results reported in this paper are intended to be submitted for public comment, and the internationally sourced life cycle data to be improved with Chilean specific production data.

References

Goedkoop, M., et al., ReCiPe 2008 - A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. First edition. Report I: Characterisation, 2009: NL.

USDA, Choose My Plate; http://www.choosemyplate.gov/food-groups/ (Accessed February 9, 2012).

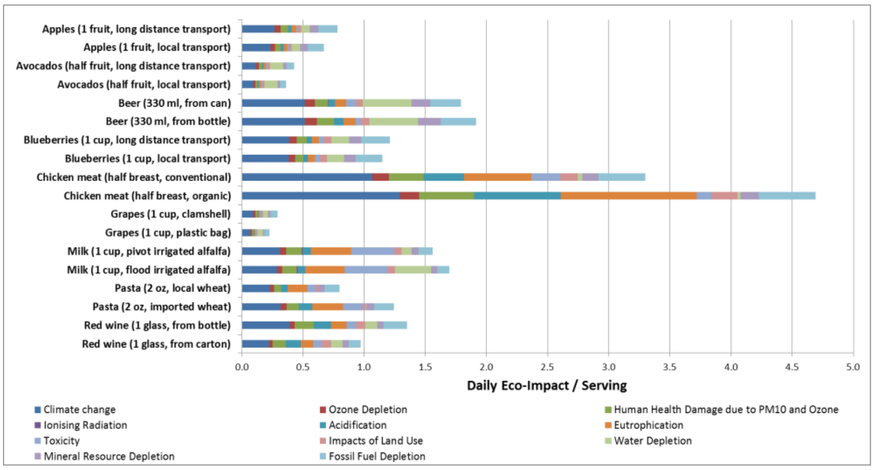

Figure 1. Daily Eco-Impact per typical serving, divided by environmental impact category.

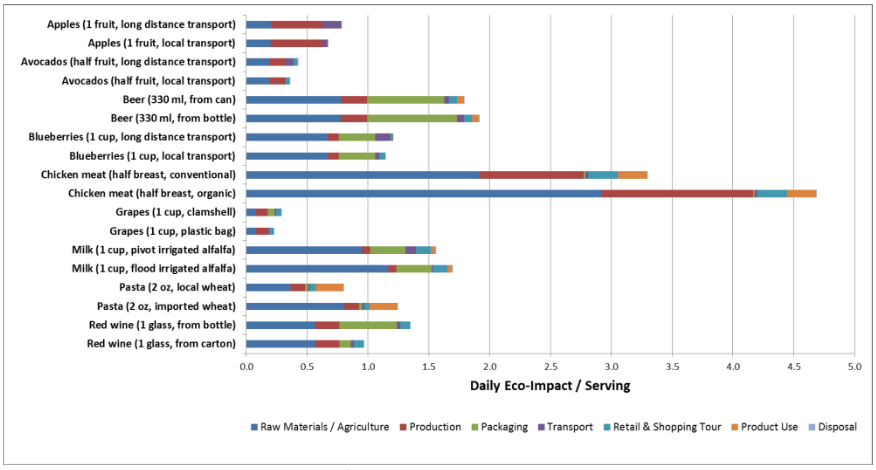

Figure 2. Daily Eco-Impact per typical serving, divided by life cycle stage.

Implementation by a large-scale retailer of a multi-criteria environmental labelling for food products: the Casino Environmental Index

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Since 2006, BIO Intelligence Service supports Casino, a major retailer, in its efforts to evaluate the environmental impact of its own-brand products in France. The Carbon Index presents greenhouse gas emissions involved in producing 100 g of the finished product. It has been placed on-pack on more than 600 products. In 2011, thanks to eco-labelling works and experimentation in France, BIO IS and Casino, along with seven partners (suppliers and NGO), have developed a multi-criteria environmental labelling methodology, resulting in communicating a single-score to consumers: the Environmental Index.

The Environmental Index is based on LCA methodology, the latter being adapted to better fit environmental labelling cost and efficiency constraints. The methodology has been established with suppliers, who, as data collectors for LCA calculations, know the kind of data they can provide at an acceptable cost. It has also been designed to be relevant to consumers as multi-criteria information is proven difficult to understand, contrary to single-score information.

The quantification of the environmental impacts of food products, from cradle-to-grave, relies on the LCA methodology, recommendations of ADEME-AFNOR platform and the draft Food PCR. Three environmental indicators are evaluated: GHG emissions (g eq.CO_2), untreated water consumption (L) and eutrophication (g eq.PO_4^{3-}).In order to facilitate interpretation of the results and help customers in their decision-making, LCA results are weighted and then aggregated through PRIOR® method. The score obtained represents the environmental impact of 100g of product compared to the environmental impact of the total daily consumption of food of a French person. The score is available on-pack and on a dedicated web site (www.indice-environnemental.fr), where all LCA information is made available (results for each indicator and per life-cycle stage) as well as advice on recycling best practices.

The results of this project are (1) the Environmental Index of more than 160 product references are already available on the web site and on-pack. The single-score expressed in percentage provides a benchmark, like the nutritional information, and makes it easier for consumers interested in responsible consumption to compare products. (2) The approach is perceived very positively by consumers: they ask questions and show interest in understanding the concept of environmental impacts. (3) For manufacturers, the data collection is easily treated, especially for suppliers who have already participated to the Carbon Index. Nonetheless, time spent for data collection can be important as several departments within a company can be involved in data collection (evaluation in progress).

The aggregation method may be subsequently updated: the weighting of each indicator in the light of social, cultural and scientific priorities of 2012, water consumption weighting. The method could also be extended to European context, and enriched with biodiversity information as soon as a consensual calculation methodology is available. Moreover, support information around environmental labelling, indicators and the Environmental Index should be prepared to improve the level of understanding of the approach.

The Environmental Index project allows testing a methodology of environmental labelling expressed with a single and simple score with the participation of various actors of the agro-industry sector. The methodology chosen is flexible for integration of future upgrades (addition of further environmental criteria, adaptation to non-food products, etc), without having to change the format of the Environmental Index, to which consumers are getting used to.

References

ADEME-AFNOR, 2011, BPX30-323: référentiel de bonnes pratiques sur l'affichage environnemental des produits de grande consommation

Labouze E., 2006. PRIOR®, un outil de priorisation des enjeux environnementaux - Guide pratique destiné aux acteurs de l'éco-conception

Figure 1. Illustration of Environmental Index for grape juice

	Emission de gaz à effet de serre (gramme équivalent CO_2)	Consommation d'eau brute (litre)	Pollution aquatique (gramme équivalent PO_4^{3-})
Matières premières	67.7	67.7	0.47
Transformation	3.97	0.09	0.00
Transport	36.50	0.14	0.04
Emballage	8.81	0.17	0.02
Distribution	9.31	0.67	0.02
Utilisation	4.27	0.25	0.01
Fin de vie produit fini	6.53	0.09	0.03
Total	**137.09**	**69.11**	**0.59**

Figure 2. Detailed results for grape juice

Fateful and faithful: the success factors of eco-labelling

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Eco-labelling schemes are on the rise – customers and environmental experts alike are confused with the booming "industry". The difference between the two groups is that the customers' decision for or against a label is the *fateful* one: it decides the ultimate success or failure of the label. At the same time the judgment of an environmental expert – the one *faithful* to *some* aspect of sustainability – carries the responsibility of steering private and public opinion in the right direction. The titular word game is meant to illustrate the core of the challenge: different stakeholder groups have very different needs and influence regarding value and success of eco-labelling initiatives. But why label food at all? And more importantly, how? Is it sufficient to declare the quality in terms of taste and nutritional value or do we need to know about the sourcing of ingredients and use of pesticides, fertilisers? Does a full Life cycle Assessment (LCA) have added value compared to type I declarations? Or to put it in a single, practical question: what makes the TüV or CarbonTrust labels successful, the EU-Bio-label popular over many other labels that spring up then die off within years of the launch? These are the questions for which this semi-theoretical paper seeks answers to.

The authors set out to explore the success factors and discovered that stakeholder engagement is in fact the make-or-break factor. The diverging interests must be harmonised and the key to that lies in asking the right questions (Table 1). In addition to evaluating some good examples from the multitude of existing labels and active stakeholder groups, the present paper discusses a stepwise protocol on "how to create a successful label" using the case study of the EU-funded Life+ project "HAproWine" (EU - LIFE08 ENV/E/000143) aimed at developing an eco-label for wine produced in the Spanish region Castilla y León.

The steps can be summarised as follows:

(1) Prepare a small-scale pilot project
(2) Engage the stakeholder groups: survey the interests of representatives of consumers, retailers, producers, and governmental or other authorities who are interested in managing, verifying or promoting the aspect of sustainability targeted by the label
(3) Define the objective of the label: which information should it carry in order to satisfy the interests and needs of the stakeholder groups?
(4) Define the requirements of awarding the label (quality criteria, award system, review/verification system, validity and organisational structure)
(5) Involve stakeholders in milestone decisions as checkpoint: is the label in fact addressing their interests?
(6) Evaluate outcomes of the pilot project based on the percentage of labels awarded, the satisfaction level of the stakeholder groups involved, the practicability of the awarding scheme, the meaningfulness of the label
(7) Roll out label with help of stakeholders involved in pilot

Through the evaluation of some key existing examples and the case study of developing a new label in the food industry based on LCA, the paper identifies underlying factors of success and failure.

References

Díez Vázquez, J. À. et al., 2010-2012. HAproWINE (EU - LIFE08 ENV/E/000143) Integrated waste management and life cycle assessment in the wine industry. http://www.haprowine.eu/
Kwasniewski, N. 2012. "Öko-Test" und Co. Welche Lebensmittelsiegel wirklich taugen. Spiegel Online available online at http://www.spiegel.de/wirtschaft/service/0,1518,813556,00.html
J Sainsbury. 2011. Corporate Social Responsibility Report. http://www.j-sainsbury.co.uk/
Tesco. 2010. Corporate Responsibility Report. http://www.tilles.co.uk/companies/tesco/reports.html
Marks & Spencer. 2006. Corporate Social Responsibility Report. http://corporate.marksandspencer.com/

Table 1. Eco-label success factors from the perspective of different stakeholder groups.

Stakeholder group	Highest priority questions	Solutions
Producer	Does the label help me sell my product?	Label may be required to sell in certain retailers, or it could enable cost reduction or higher pricing
Retailer	Does the label ensure that I can meet my sustainability targets? Can I document achievements?	Label may enable reducing the retailer's Scope III emissions and can be documented quantitatively as well qualitatively in different reporting schemes (CSR, CDP, GRI...)
Consumer	What does the label tell me and how can I find the one most attractive food product for me?	Labels must convey simple information, be it qualitative (<5% mineral fertiliser allowed) or quantitative (50g CO2e) and provide a benchmark; eco-labels should not *significantly*[a] decrease product quality or increase product cost; Labels shall be issued by some *authority*[a]
(Non-) Governmental Authority	Are the criteria for the label easy to verify and practicable for national/global targets?	Label schemes must require straightforward calculation rules and evaluation schemes; data collection rules must also be specified and verifiable; Labelled products should facilitate meeting national or regional targets (fair trade agreements, CO_2 cap agreements etc.)

[a] Words in *italics* are subjective reference points and shall be further specified

Carbon footprinting and labelling of agri-food products: practical issues for the development of Product Category Rules

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Carbon Footprint has emerged as an approach to estimate Greenhouse Gas (GHG) emissions throughout the product's life cycle. The carbon footprint information is also encouraged to be provided to consumers via Carbon Label as an indicator of the climate-friendliness to take into account in their purchasing decisions. The carbon footprint and label strategy is expected to stimulate a market demand for lower carbon products to move towards the reduction of GHG emissions at both production and consumption. Agri-food is identified as one of the main industrial sectors contributing significantly to GHG emissions. Thus, they are targeted and given priority in several countries implementing carbon footprinting to put carbon labels so as to raise awareness of consumers on the carbon footprint attached to their purchasing choices for climate change mitigation. However, it is most critical that the carbon footprinting methodology is standardised internationally to be able to compare the carbon footprint values between products. It must be emphasised that though carbon footprints are not intended in principle for comparison between "apples and oranges"; however, in practice such comparison by the consumers is unavoidable. Based on a number of carbon footprinting case studies conducted in Thailand in 2008-2011 (e.g. rice, tapioca, sweet corn, baby corn, asparagus, pineapple, chicken, shrimp, tilapia, etc.), some major practical issues were raised to consider when developing the Product Category Rules (PCR). First, the system boundary in principle should cover all life cycle stages including at the sale's point (e.g. chilled storage), pre-consumption (e.g. household storage), consumption (e.g. cooking), and post-consumption (e.g. food and packaging waste disposal) except in the case of food ingredients as they are only a composition of other food products in the forms of dish or meal (Mungkung et al., 2010a). It is also important that the assumptions of sale's point, pre-consumption, consumption and post-consumption are on the same basis for the same food products. Second, the product unit should not be the sold unit but reflecting the functional unit of product which could be kcal or g of protein or g of nutrients based on daily requirement or per serving or per meal depending on the grouping of products with similar characteristics and through the stakeholder consultation process. Third, the allocation methods are a potential source of variation in results that could significantly affect the carbon footprint values of another product system that use the co-products or wastes from previous product systems; mass allocation seems more practical from the industry's point of view. Economic allocation is attached to the prices which can vary hugely in some products and the factory-gate prices can also be different from one place to another within the same country as well as different in different countries depending on the consumers' preferences (which may be attached to culture or religion or special diet patterns) (Mungkung et al., 2010b; Schäfer and Blanke, 2011). In addition, the industry is concerned about the data recording systems among different companies which can be a constraint for Small and Medium Enterprises to adopt carbon footprinting; moreover, the companies with better data recording system can achieve the quality level of data required while some see it as a technical barrier to allocate the use of resources especially steam, heat and electricity among different processing lines and hundreds of similar products. It is evident that carbon footprinting can help identifying the hot spots for improvement and reflect on the efficiency of resource use and waste management including the potential for cost reduction. Nevertheless, the industry feels that the carbon footprint methodology should be clearly stated without ambivalence, easy to practise, and fast to achieve the carbon footprint value. For comparing the products produced from different countries, it is foreseen as a threat as there are many factors that can influence the carbon footprint values which are not easy to convey to consumers via carbon labelling (Mungkung et al., 2010b). It is suggested that the carbon footprint labelling should be easy to understand by using the logo to indicate that producers have reduced GHG emissions, while this claim is verified from the registered third-party with the responsible organisation who owns the carbon labelling schemes.

References

Mungkung, R., Gheewala, S., Poovarodom, N., Towprayoon, S. 2010a. Carbon Footprint and Label for Rice Products [in Thai]. S.P.M. Printing Co., Ltd., Bangkok, Thailand. 83 p.

Mungkung R., Gheewala, S., Bonnet, S., Hospido, A., Kanyarushoki, C., van der Werf, H. and Poovarodom, N. 2010b. Carbon Footprinting and Labelling: Experiences from the Thai food industry Available online: http://www.thaicarbonlabel.sci.ku.ac.th/

Schäfer, F. and Blanke, M. 2011. Farming and marketing system affects carbon and water footprint – a case study using Hokaido pumpkin. Journal of Cleaner Production (in press) doi:10.1016/j.jclepro.2011.08.019

Characterising pesticide residues and related health impacts in LCIA

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Multiple pathways contribute to the exposure of the general population to pesticides, such as inhalation and ingestion intake of applied fractions undergoing wind-drift, runoff, and leaching, but the most important pathway being consumption of fractions directly reaching the treated food crops. However, health impacts of pesticides from food consumption are still poorly represented in existing Life Cycle Impact Assessment (LCIA) approaches. In addition, pesticide uptake and translocation mechanisms vary considerably between crop species and may demonstrate significant differences in related health impacts as discussed in Fantke et al. (2011a). Therefore, assessing pesticide residues in multiple crops plays an important role in the evaluation of current agricultural practice. In light of this, a new dynamic plant uptake model – dynamiCROP – was designed to assess the dynamics of pesticide residues in different crops and to characterise the related human intake of these residues via consumption of harvested crop components.

The model, which is fully described in Fantke et al. (2011b), is based on a flexible set of interconnected compartments (Fig. 1) and is customised to wheat, paddy rice, tomato, apple, lettuce, and potato, thereby accounting for the major mass fraction of worldwide human plant-based diet. Modelled residues are evaluated against residues measured in experimental studies, such as Itoiz et al., 2012 for lettuce. Furthermore, the functioning of the underlying dynamical system was analysed to estimate the model input uncertainty and to parameterise the complex system for use in spatial or nested multimedia assessment models currently applied in LCIA (Fantke et al., 2012). The parameterised crop-specific models are adequate to assess pesticide residues in crops and enable the user to calculate these residues by providing only a very small set of input data.

Finally, human intake fractions (Fig. 2) are connected to effect information for characterising human health impacts. When combined with substance-specific pesticide application statistics, absolute impacts per considered land use area can be estimated and compared to other LCA endpoints. Human intake fractions, effect and characterisation factors (CFs) are provided for use in LCIA for 726 substance-crop combinations. CFs were calculated for 121 pesticides applied to the six crops and were 1 to 5 orders of magnitude higher than factors estimated from fractions lost via wind-drift, runoff and leaching. Human health impacts vary up to 9 orders of magnitude between crops and 10 orders between pesticides. Main aspects influencing the fate behaviour of pesticides were identified as half-life in plants and on plant surfaces, residence time in soil as well as time between pesticide application and harvest.

References

Fantke P, Charles R, de Alencastro LF, Friedrich R, Jolliet O. 2011b. Plant uptake of pesticides and human health: Dynamic modeling of residues in wheat and ingestion intake. Chemosphere 85: 1639-1647.

Fantke P, Juraske R, Antón A, Friedrich R, Jolliet O. 2011a. Dynamic multicrop model to characterise impacts of pesticides in food. Environ. Sci. Technol. 45: 8842-8849.

Fantke, P., Wieland, P., Wannaz, C., Friedrich, R., Jolliet, O., 2012. Dynamics of pesticide uptake into plants: From system functioning to parsimonious modeling. Environ. Modell. Softw. (submitted)

Itoiz, E.S., Fantke, P., Juraske, R., Kounina, A., Vallejo, A.A., 2012. Deposition and residues of azoxystrobin and imidacloprid on greenhouse lettuce with implications for human consumption. Chemosphere. (submitted)

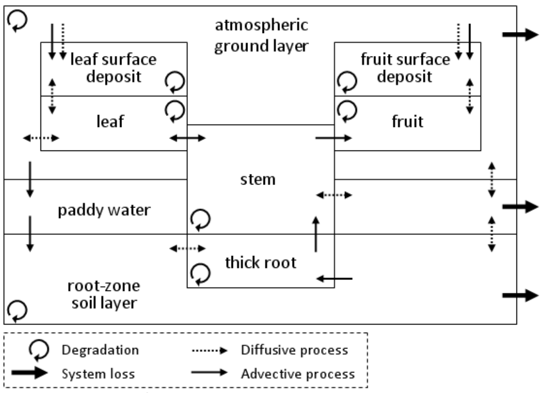

Figure 1. Graphical representation of model setup consisting of environmental compartments and processes within/between compartments.

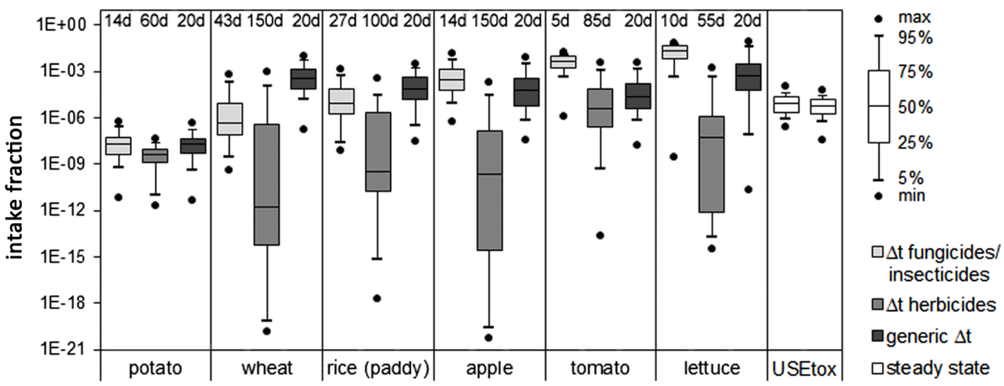

Figure 2. Intake fractions from consumption of pesticide residues for 121 substances applied to 6 food crops at different times to harvest Δt and from fractions undergoing wind-drift, runoff and leaching under steady state conditions as calculated with USEtox (www.usetox.org).

Bridging the gap between LCI and LCIA for toxicological assessments of pesticides used in crop production: application to banana growing

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In Life Cycle Assessment (LCA), the Life Cycle Inventory (LCI) provides emission data for the various environmental compartments and subsequently Life Cycle Impact Assessment (LCIA) determines the final distribution, fate and effects of substances such as pesticides. Given the overlap between the Technosphere (the studied anthropogenic system) and the Ecosphere (the natural environment) in agricultural case studies, it is, difficult to establish what LCI needs to capture with respect to degradation and partitioning of the pesticides in air, water and soil at the local scale. While evaluating the partitioning of the emitted substances, LCA practitioners must keep in mind that human toxicity and ecotoxicity models used in LCIA also include inter compartment transfers, fate, and degradation mechanisms at larger temporal and spatial scales such as long-range transmission of air pollutants at regional, continental, and global scale (Fig. 1).

Up to now, LCA practitioners have been using several hypotheses to build agricultural inventories. For example, the application of a regional or global scale model of substance transfers in the LCI phase (inducing an overlapping with LCIA models), or the application of a simplified approach assuming that pesticide emissions are entirely emitted to the soil compartment, or 85% is emitted to soil, 5% to crops and 10% to air (Audsley et al. 1997; Margni et al. 2002) are commonly used. To date, no clear distinction nor guidance are provided on how to combine LCI and LCIA models with respect to toxicological assessments of pesticides applied in agriculture.

This paper aims to provide guidance to better define the boundaries in space and time between what should be included in LCI and where LCIA takes over. A literature review was undertaken on available methods and models for both LCI (e.g. Birkved and Hauschild, 2006) and LCIA (e.g. Rosenbaum et al. 2008) with a special focus on toxicological assessments of pesticides used in crop production. The relevant biophysical phenomena are identified (Fig. 2) and guidelines are proposed to overcome the gaps between LCI and LCIA as well as to harmonise further comparisons of agricultural LCA results.

To complement these recommendations a case study on bananas is presented to i) characterise the current gap between LCI and LCIA, and ii) demonstrate the application of the proposed solution to the current LCA approach. From this case study, it is clear that impact assessment results for both human health and ecosystems are strongly influenced by the LCI hypotheses. The LCI hypotheses involving either inadequate model scales, or a too simplistic LCI, or non-equilibrated balances lead to an underestimation of up to a factor of 5.

References

Audsley, E., Alber, S., Clift, R., Cowell, S., Crettaz, P., Gaillard, G., Hausheer, J., Jolliet, O., Kleijn, R., Mortensen, B., Pearce, D., Roger, E., Teulon, H., Weidema, B., Van Zeijts, H., 1997. Harmonisation of environmental life cycle assessment for agriculture. Final Report Concerted Action AIR3-CT94-2028, European Commission DG VI Agriculture

Birkved, M., Hauschild, M.Z., 2006. PestLCI - A model for estimating field emissions of pesticides in agricultural LCA. Ecol. Model. 198, 433-451.

Margni, M., Rossier, D., Crettaz, P., Jolliet, O., 2002. Life cycle impact assessment of pesticides on human health and ecosystems. Agr. Ecosyst. Environ. 93, 379-392.

Rosenbaum, R.K., Bachmann, T.M., Swirsky Gold, L., Huijbregts M.A.J., Jolliet, O., Juraske, R., Koehler, A., Larsen, H.F., Macleod, M., Margni, M., McKone, T.E., Payet, J., Schuhmacher, M., Van de Meent, D., Hauschild, M.Z., 2008. USEtox—The UNEP-SETAC toxicity model: recommended characterisation factors for human toxicity and freshwater ecotoxicity in Life Cycle Impact Assessment. Int. J. LCA 13, 532-546.

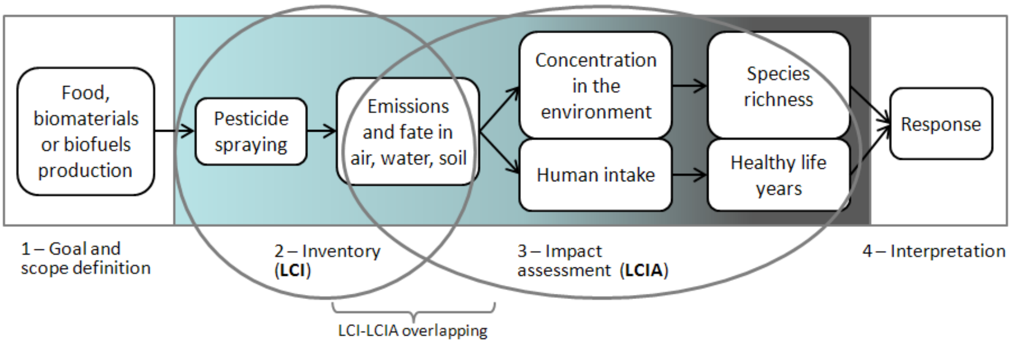

Figure 1. Overview of the 4 LCA phases of pesticides used in agricultural crop production highlighting an overlapping between LCI & LCIA.

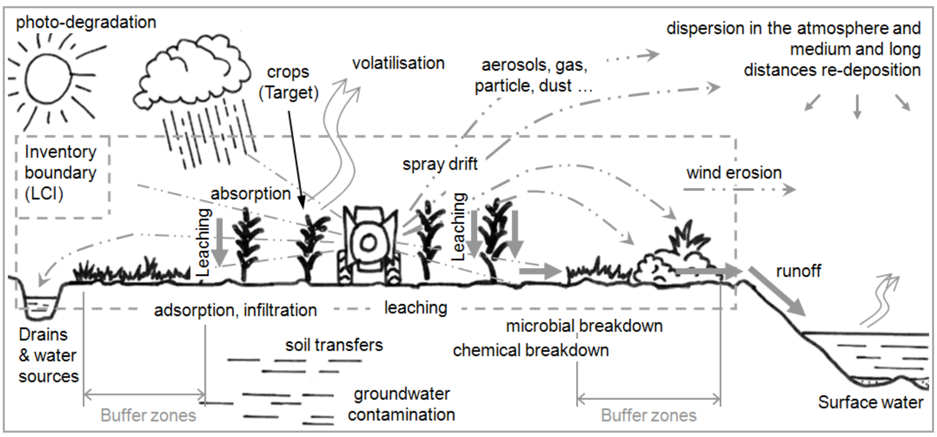

Figure 2. Proposed system boundary for LCI and associated mechanisms from pesticide spraying to emissions in air, soil and water.

Allocation challenges in agricultural life cycle assessments and the Cereal Unit allocation procedure as a potential solution

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For agricultural life cycle assessments (LCA) several different allocation approaches are currently used. This leads to a broad range of uncertainty in LCA results (Curran, 2008; Kim and Dale, 2002; Gnansounou et al., 2009; Singh et al., 2010). The ISO standards ISO 14040 and 14044 give guidance on how to deal with allocation situations, but they offer a hierarchy of choices rather than a particular method (Finkbeiner et al., 2006). In addition, parts of the environmental burden might not be accounted for, if individual products are co-produced in the same agricultural system but used in different sectors, e.g. flour from wheat grain used in bakeries and wheat straw used in biofuel production. The users of the individual co-products (baker and biofuel producer) may use different allocation methods and as a consequence their separate LCAs are not aligned to each other. This can lead to situation that the total environmental burden is allocated inadequately. Two examples for this phenomenon of unintended ignorance or unintended double-counting of environmental burden are shown in Figs. 1 and 2.

Specific requirements for an allocation method suitable for the agricultural sector are defined, which were used to test the allocation different approaches. The Cereal Unit was identified as a promising denominator for an agricultural allocation procedure. Its calculation is mainly based on the nutritive properties for animal feeding and on the share of feed material use per animal species in a certain region. Advantage of the Cereal unit is, that it is not limited to animal feed. Auxiliary calculations allow the inclusion of animal products (e.g. milk, wool or meat) and of products not intended for animal feeding (e.g. fruits or herbs). The Cereal Unit has been developed since decades for purposes of agricultural statistics and is optimised continuously. (Becker, 1988; BMELV, 2012; Klapp, 2011; Mönking et al., 2010). Using Cereal Unit conversion factors, almost all agricultural products can be converted into one common parameter. Hereby all agricultural products become comparable.

A new allocation approach for agricultural LCAs, based on the Cereal Unit, is suggested. Exemplary results are shown in Fig. 3 for barley, soybeans, sugar beet, wheat, sunflower and rapeseed. The Cereal Unit allows using one common allocation procedure within agricultural LCAs by meeting the requirements of this sector. This approach could help to solve agricultural allocation problems and might lead to more robust LCA results for services and products originated from agricultural raw materials. We recommend investigating the applicability of the Cereal Unit allocation approach for agricultural LCAs.

References

Becker, J.W., 1988. Aggregation in landwirtschaftlichen Gesamtrechnungen über physische Maßstäbe – Futtergersteneinheiten als Generalnenner, Justus-Liebig-Universität Gießen, Gießen, p. 366.

BMELV, 2012: Statistisches Jahrbuch über Ernährung, Landwirtschaft und Forsten der Bundesrepublik Deutschland 2011. Landwirtschaftsverlag Münster Hiltrup, p. 700.

Curran, M.A., 2008. Development of life cycle assessment methodology: a focus on co-product allocation. Erasmus University Rotterdam, p. 204.

Finkbeiner, M., et al., 2006. The new international standards for life cycle assessment: ISO 14040 and ISO 14044, Int. J LCA, 11, 80-85.

Gnansounou, E., et al., 2009. Life cycle assessment of biofuels: Energy and greenhouse gas balances, Bioresource Technology, 100: 4919-4930.

Kim, S., & Dale, B.E., 2002. Allocation procedure in ethanol production system from corn grain - I. System expansion, Int. J LCA, 7: 237-243.

Klapp, C., 2011. Getreide- und Vieheinheitenschlüssel als Bewertungsmaßstäbe in der Landwirtschaft internationaler Vergleich und Konsequenzen alternativer Viehbewertungen. Cuvillier, Göttingen, p. 366.

Mönking, S.S., et al., 2010. Überarbeitung des Getreide- und Vieheinheitenschlüssels Endbericht zum BMELV-Forschungsprojekt 06HS030, Georg-August-Universität Göttingen, Göttingen, p. 537.

Singh, A., et al., 2010. Key issues in life cycle assessment of ethanol production from lignocellulosic biomass: Challenges and perspectives. Bioresource Technology, 101: 5003-5012.

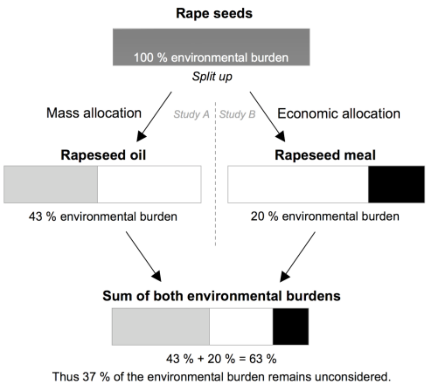

Figure 1. Unintended ignorance of environmental burden due to different allocation approaches for by-products from the same agricultural system

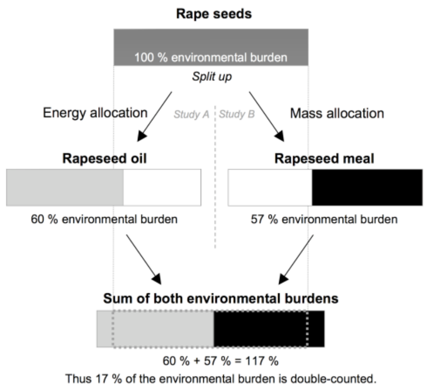

Figure 2. Unintended double-counting of environmental burden due to different allocation approaches for by-products from the same agricultural system. Grey and black areas represent environmental burden. Dotted lines indicate initial environmental burden (100%) and overhanging bars represent double-counted environmental burden.

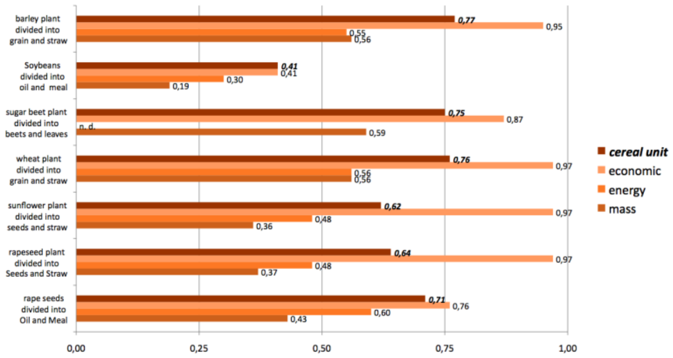

Figure 3. Comparison of mass-, energy-, economic- and Cereal Unit-allocation for selected agricultural products; sizes of bars indicate allocation ration between the environmental burden of first product and total environmental burden

LCA applied to pea-wheat intercrops: the significance of allocation

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Cereal-legume intercrops (ICs) are a promising way to combine high productivity and several ecological benefits in temperate agro-ecosystems. These advantages are mainly linked to the complementary use, in time and space, of Nitrogen (N) sources by the components of the IC (Trenbath, 1976). ICs allow the production of biomass with a low fertiliser N-input according to various targets (high-protein cereal grains, forage or energy crops) (Naudin et al., 2010). Life cycle assessment (LCA) is a method to assess impacts of a product considering all stages of its life cycle. This methodology, so called "from cradle to grave", assesses resource use and emissions to the environment, from the extraction of resources, through each step of the production process, including product parts and recycling or final disposal (Guinée et al., 2002). In the case of product systems yielding several co-products, impacts have to be allocated among the co-products. This is the case for cereal-legume IC, and the estimated impacts of the co-products may well be dependent on the choice of the impact allocation method. The aim of this study was to apply LCA to ICs by (i) testing several methods of impact allocation (mass, economic, based on N yield in grains, or system expansion) (ii) in order to assess the environmental impacts of the co-products.

Agronomic performances of winter pea-wheat IC, sole cropped (SC) pea and wheat were assessed in field experiments carried out in 2008 in western France (see experiment B in Naudin et al., 2010). Potential impacts on climate change (CC), eutrophication (EU) and total cumulative energy demand (CED) were estimated according to LCA methodology, from soil tillage for sowing to harvest (including the grain sorting process). The functional unit is 1 kg of wheat grain (of bread making quality). Direct emissions were estimated based on the field experiment and IPCC 2006 (International Panel on Climate Change) recommendations. Indirect emissions were estimated with the help of the Ecoinvent 2007 database.

ICs allowed producing wheat with lower impacts than sole cropped wheat, whatever the allocation method (reduction was at least -20%; Fig. 1). Allocation method strongly affected results. It did produce surprising results, as shown by negative impacts for wheat from no-fertilised ICs in case of allocation by system expansion. Actually, this allocation method estimated impacts for IC pea from the impacts associated with the production of the same quantity of SC pea grains. In this case, interspecific complementarity which allows a better efficiency in resource use was not taken into account. Our proposition is to avoid allocations by assessing impacts of ICs from those of SCs. Indeed, wheat and pea grains from ICs are of the same quality as those from sole cropping (Naudin et al., 2010), and introduction of ICs in cropping systems is to be considered as a substitution for a combination of both SC wheat and SC pea. Two comparisons are proposed: i) equivalence of area: impacts of IC cropped on 1 ha, compared to 1 ha of a combination of SCs according to relative sown densities in IC; ii) equivalence of production: impacts of IC cropped on 1 ha, compared to a combination of SCs producing the same quantity of wheat and pea grains as in IC (Fig. 2). Results show that ICs always decreased impacts compared to SCs (from -13% to -54%). At last, our proposition involves redefining our functional unit and estimating impacts for a mix of wheat and pea grains (including grain sorting).

References

Guinée, J.B., Gorrée, M., Heijungs, R., Huppes, G., Kleijn, R., de Koning, A., et al., 2002. Life cycle assessment. An operational guide to the ISO standards. Leiden, The Netherlands: Centre of Environmental Science, Leiden University.

Naudin, C., Corre-Hellou, G., Pineau, S., Crozat, Y., Jeuffroy, M.-H., 2010. The effect of various dynamics of N availability on winter pea-wheat intercrops: crop growth, N partitioning and symbiotic N_2 fixation. Field Crops Research. 119, 2-11.

Trenbath, B.R., 1976. Plant interactions in mixed crop communities. Multiple cropping. Pappendick et al., American Society of Agronomy (ed.), Madison, Wisconsin, pp. 129-169.

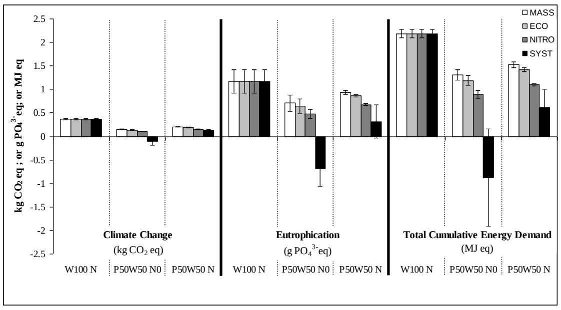

Figure 1. Potential impacts per kg of wheat grains (bread making quality) according to different propositions for allocation of impacts among grains of wheat and pea in intercrop yield. W100: wheat sole crop. P50W50: substitutive intercrops of pea and wheat ("50" indicates half of the recommended plant density when sole cropped). Crops are N-fertilised ("N": 190 kg N ha^{-1} on sole cropped wheat, and 45 kg N ha^{-1} at the beginning of stem elongation on N-fertilised intercrops), or not ("N0"). MASS: mass allocation. ECO: economic allocation. NITRO: allocation according to the quantity of Nitrogen in wheat and pea grains. SYST: allocation by system expansion. Values are means (n=3)±SE (Standard Errors).

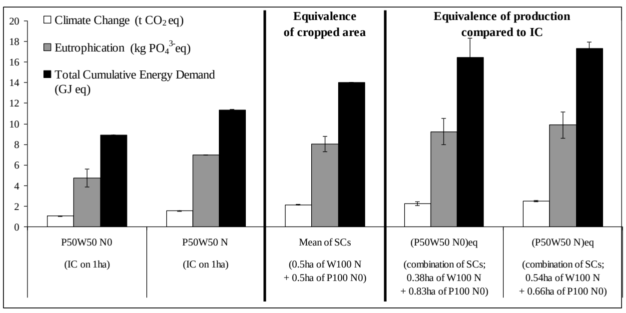

Figure 2. Potential impacts of 1 ha of pea-wheat intercrops compared with combinations of respective sole crops on a basis of equivalence of cropped area or of equivalence of production (including impacts from grain sorting process). W100: wheat sole crop. P100: pea sole crop. P50W50: substitutive intercrops of pea and wheat ("50" indicates half of the recommended plant density when sole cropped). IC: intercrop. SC: sole crop. Crops are N-fertilised ("N": 190 kg N ha^{-1} on sole cropped wheat, and 45 kg N ha^{-1} at the beginning of stem elongation on N-fertilised intercrops), or not ("N0"). Values are means (n=3)±SE (Standard Errors).

Life cycle assessment at the regional scale: innovative insights based on the systems approach used for uncertainty characterisation

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Agricultural LCA at territory scale opens up great interest for public decision makers and especially when it comes to manage a common resource like groundwater (often overexploited at high energy cost) that sustain agriculture in semi-arid locations. Territory scale LCA could not be done by transferring the "standard" product scale methodology to this meso-scale and a simple aggregation of product scale LCA is not realistic for several reasons. First, an agricultural territory is a multi-product system that supports a large range of farming practices combining crop and livestock often produced in synergy. Second, aggregation would be extremely data and time consuming, in the data collection phase, and would lead to uncertainty propagation (Fig. 1).

Another method is therefore needed to address these two main pitfalls of agricultural LCA at territory scale. The methodological challenges are mainly related to the LCI critical stage. The methodological issues are namely: "How to model the territory system and its LCI flowchart without any oversights or double counting, whereas it is a huge and complex system? How to design data collection strategy and approach if we consider the high diversity and variability of farming practices and their potential huge combination?"

Few studies have performed LCA of an agricultural territory, and they only partially accounted for interconnection flows between farms (Haas et al. 2005, Payraudeau et al. 2006). Developing farm typologies is a way to deal with the great variability of flows related to agricultural practices (Dalgaard et al. 2006). The strategy chosen for collecting data depends on the objective of the LCA. Data can either be collected at farm scale, this latter being considered as a black box, or at a lower scale, i.e., on farm sub-systems. Collecting data related to farm sub-systems provides information about which crop or livestock production is most impacting and should be improved and reveals potential recycling flows but is time consuming. But aggregating elementary flows at farm scale could increase data uncertainty due to the error margin when assessing each farm sub-system flow.

We propose a hybrid method to build up a LCI at a territory scale, with the objective of assessing alternative agricultural scenarios. Firstly the territory is modeled with the System Approach, ie as a combination of farm types and their interconnections; each farm type being modeled as a combination of production factors to generate several crop and livestock outputs. Even when farm accounts are available, flows related to agriculture are very difficult to assess and mainly rely on interviews, being prone to uncertainty. To cope with this problem, we lastly propose to combine data collection at several scales of the farming systems in order to decrease the data uncertainty. Data are collected at the scale where they have not been disaggregated and their consistency is checked against aggregated data collected at a lower scale and farmer's rules for inputs allocation among its crop and livestock systems. This approach, combining inventory at different scales as presented in Fig. 2, is applied to a first simplified example of farming system in Tunisia and compared to partial classic LCI aggregations in order to show its benefits (Fig. 1).

References

Dalgaard R, Halberg N, Kristensen IS, Larsen I, 2006. Modelling representative and coherent Danish farm types based on farm accountancy data for use in environmental assessments. Agriculture, Ecosystems & Environment, 117: 223-237.

Haas G, Geier U, Frieben B, Köpke U., 2005. Estimation of environmental impact of conversion to organic agriculture in Hamburg using the Life-Cycle-Assessment method. 1-16.

Payraudeau, S., Van der Werf, H.M.G., and Vertès, F., 2006. Evaluation of an operational method for the estimation of emissions of nitrogen compounds for a group of farms, Int J. Agricultural Resources, Governance and Ecology, 5: 224-246.

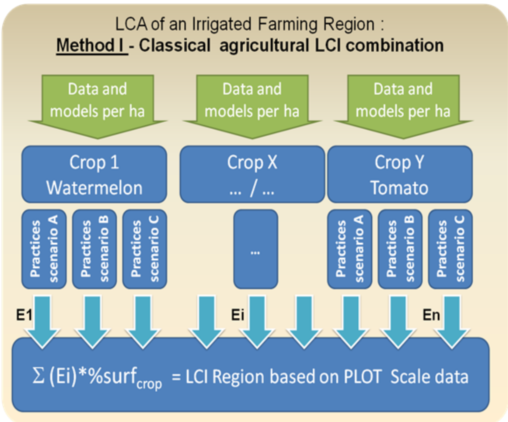

Figure 1. LCI by bottom up approach: aggregating field scale data.

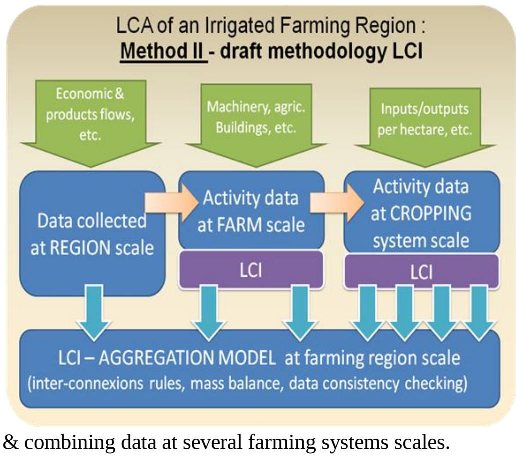

Figure 2. Proposed Methodology: collecting & combining data at several farming systems scales.

Generic model for calculating carbon footprint of milk applied to Denmark and Sweden

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Dairy production – from farm to retail – represents 2.7% (±26%) of global anthropogenic greenhouse gas (GHG) emissions, where about 80-90% occur before farm gate (Gerber et al., 2010). The dairy company Arla Foods is one of many companies committed to reduce GHG emissions in the whole value chain. One action is to develop a tool to assess the carbon footprint at farm level.

The aim of the study is to establish a generic model, which can be used for calculation of carbon footprint/LCA of milk. The model has certain facilities, which make it useful for carbon footprint calculations both at farm level and country level. The functional unit is '1 kg energy corrected milk (ECM) from farm gate'. The applied methodology follows the international standards on life cycle assessment: ISO 14040 and 14044 and the international standard on carbon footprints on products: ISO 14067-1. The model also includes switches that enables for, within the same scope, transforming the results to comply with allocation/average modelling, PAS2050 (Carbon Trust et al. 2010) and IDF (2010) guide to standard LCA methodology for the dairy industry. The system boundaries applied for the different standards are presented in Figure 1.

The model is established as a parameterised agricultural model, and the user face is made for farmers and their advisers. The input parameters are predefined and include: stock-size, feed intake, milk- and crop yields, stable systems, weight and age of animals etc. When the user has entered these parameters, results can easily be presented according to the desired standards mentioned above. The effects of indirect land use changes (ILUC) according to Schmidt et al. (2012) is captured in the model and can be included or excluded in the results by use of a switch.

Currently, the model includes two 2005-baseline milk systems for Sweden and Denmark, and three 2005-baseline beef systems for Denmark, Sweden and Brazil. The latter because it is identified as global marginal beef producer, and therefore used for system expansion, when performing consequential LCA (according to ISO 14040 and 14044) of the milk. Furthermore, 34 different crop activities (barley, wheat, corn, permanent grass etc. in different countries) are included in the model. Application of the model to other countries is straight forward, and baseline data for Germany and Great Britain might be included later this year.

Each of the cattle and crop activities are balanced according to nitrogen contents in inputs and outputs and thereby all nitrogen is accounted for. Completeness in data is further ensured by using a hybrid approach (process-based inventory data are supplemented by input-output based data). The greenhouse emissions are calculated according to IPCC (2006). The carbon footprint of Danish milk is 1.06 kg CO_2-eq. per kg Danish milk and slightly higher for Swedish milk.

References

Carbon Trust, Dairy UK and DairyCo, 2010. Guidelines for the Carbon Footprinting of Dairy Products in the UK. Carbon Trust, Dairy UK and DairyCo

Gerber, P., Vellinga, T., Opio, C., Henderson, B., Steinfeld, H., 2010. Greenhouse Gas Emissions from the Dairy Sector, A Life Cycle Assessment. FAO, Food and Agriculture Organization of the United Nations, Animal Production and Health Division, Rome, Italy.

IDF, 2010. A common carbon footprint approach for dairy – The IDF guide to standard life cycle assessment methodology for the dairy sector. Bulletin of the International Dairy Federation 445/2010

IPCC, 2006. 2006 IPCC Guidelines for national greenhouse gas inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H S et al. (eds). IGES, Japan.

Schmidt J. H., Reinhard J., and Weidema B. P., 2012. Modelling of indirect land use changes in LCA, report v3. 2.-0 LCA consultants, Aalborg, http://www.lca-net.com/projects/iluc_model/

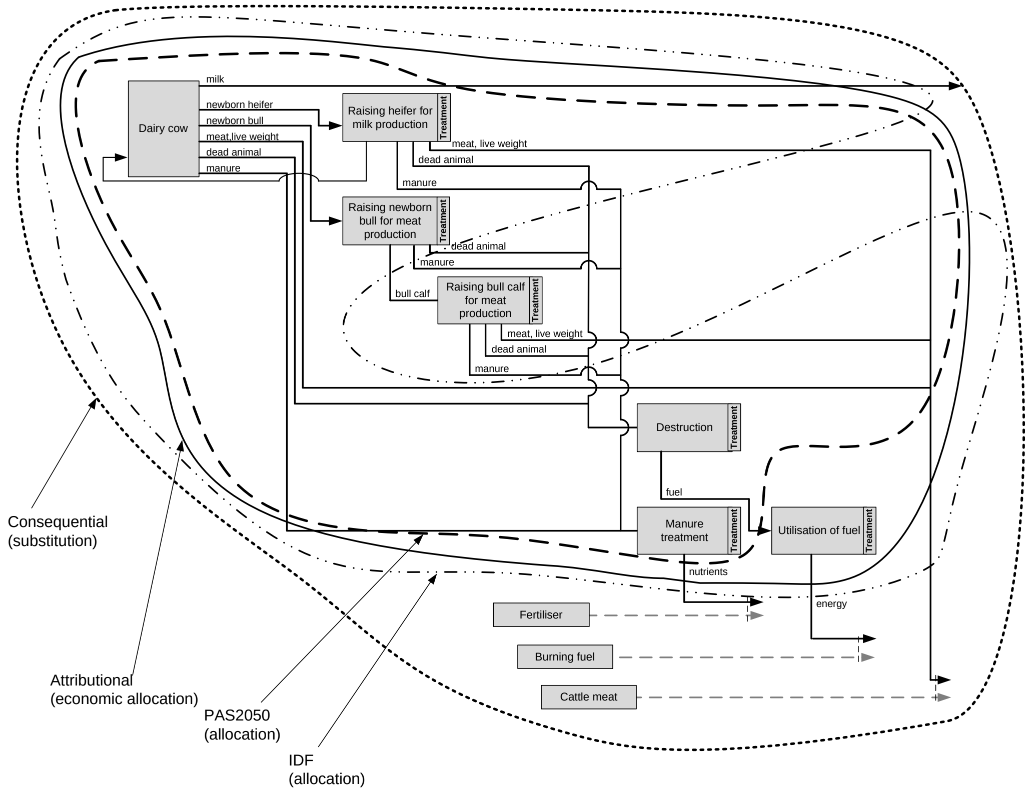

Figure 1. Dairy system. Different system boundaries for substitution/allocation

LCI-dataset gap bridging strategies in the program Agri-BALYSE

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The situation is well known and each LCA-practitioner has to deal with it: Once the system model is designed and the unit processes as well as their in- and outputs are identified, they should be assigned to the appropriate life cycle inventory (LCI) in an existing database (e.g. ecoinvent). The question is only: what is appropriate? Is it appropriate to assign a "6-row self propelled tanker harvester with a 20 tons tank" used to harvest sugar beets in France e.g. to the existing ecoinvent LCI-dataset "harvesting, by complete harvester, beets, CH" knowing that this process uses a 1-row harvesting machine? The number of agricultural activities and inputs used in "real world" agricultural practice applied in France exceeds the number of available and accurate LCI-datasets by far (see table 1). While this issue may be of minor concern for a one-product LCA study, it will become a very important question when creating a multi-product LCI-database with the aim of comparison: How to deal with these "upstream-dataset gaps"? How to ensure comparable quality of the resulting LCA's? Recently, Milà i Canals et al. (2011) suggested four different strategies to bridge data gaps (scaled, direct and averaged proxies as well as extrapolated data). In the framework of its program, Agri-BALYSE adopted this approach to state a clear strategy to face upstream-dataset gaps.

The program Agri-BALYSE is an initiative launched by the French authorities in order to develop a public LCI-database of agricultural products in France (including a small panel of imported tropical products) by the end of 2012. The program is managed by a consortium consisting of fourteen partners (ADEME, INRA, ART, CIRAD and ARVALIS, CETIOM, UNIP, IFV, ITB, CTIFL, ASTREDHOR, IFIP, ITAVI, Institut d'Elevage). As data collection is not performed centrally, the fourteen partners have developed several tools that ensure the comparability and consistency of the data: A data collection tool, an accompanying data collection guide as well as a framework of data processing tools in order to calculate the LCI data (see figure 1). An important step in this phase is the assignment of the raw data to the existing LCI-datasets.

According to the ILCD Handbook (2010), methodological consistency is a "shall-criterion" when selecting secondary data sets. Hence, the program Agri-BALYSE abstained from using datasets from several LCI-databases. Focussing on a single LCI-database, the gap-bridging-strategies proposed by Milà i Canals et al. (2011) are a suitable resort. Agri-BALYSE defined for each category of agricultural input category a specific strategy to treat inputs with missing LCI-datasets (see table 1). For fertilisers, Agri-BALYSE uses the average proxy approach by creating a proxy-LCI dataset reflecting an "average French fertiliser" based on the fertiliser consumption 2005-2009 (differentiated by N-, P- and K-fertilisers), whereas for active ingredients direct proxies are applied on the basis of their chemical structure. Agricultural machines as well as processes are extrapolated by adopting the available data sets with their main activity parameters (life time and weight for machines; energy consumption and working time for processes).

References

Milà i Canals L, Azapagic A, Doka G, Jefferies D, King H, Mutel C, Nemecek T, Roches A, Sim S, Stichnothe H, Thoma G, Williams A, 2011. Approaches for addressing Life Cycle Assessment data gaps for bio-based products. J Ind Ecol 15(5) 707-725.

European Commission Joint Research Centre, 2010. ILCD Handbook: General Guide for Life Cycle Assessment - Detailed guidance, 1st edition, European Union, p. 247.

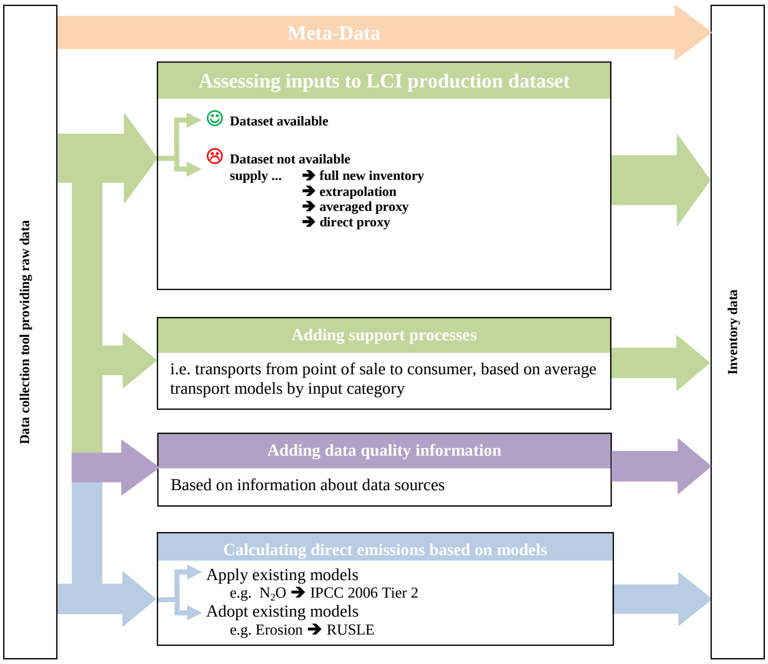

Figure 1. Assessing inputs to existing LCI-datasets is an important step when converting raw data to LCI-data. The figure shows all parts of the data processing phase in the framework of the program Agri-BALYSE: LCI-dataset assessing as well as adding of support process, quality information, meta-data and direct emissions.

Table 1. Number of available inputs per input category in the data collection tool of Agri-BALYSE

Input category	No. of inputs (real word)	No. of LCI datasets in ecoinvent V2.2	Gap bridging strategy and number of additional inventories (LCI)
Active ingredients	236	94	Direct proxies (no new LCI)
Agricultural processes	276	39	New inventories (by extrapolation) and standardisation (➔ ca. 70 LCI),
Buildings and facilities	58	18	New inventories (+58 LCI)
Feedstuffs	164	19	New inventories (+ 63 LCI), direct proxies
Fertilisers	119	25	Averaged proxies (+ 3 LCI)
Machines	200	6	New inventories (by extrapolation) and standardisation (➔ 14 LCI),
Seeds	48	28	New inventories (by extrapolation ➔ ca. 10) , direct proxies

Cradle to gate life cycle inventory and impact assessment of glyphosate

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Agricultural production requires application of large number of herbicides and pesticides. Life cycle inventory databases have long relied on estimates of energy use from Green (1987) for production of these chemicals, which lack transparency and information on chemical process emissions. As part of a recent effort, we used the design-based method to model production of cyhalofop-butyl, dazomet, glyphosate, and chloropicrin. Industrial literature, patents, and input from agricultural chemists were used to select a representative chemistry and develop more detailed descriptions of the production processes (Jimenez, et. al., 2000). To provide complete transparency, production of each chemical was divided into gate-to-gate processes that include one or two primary chemical reactions. Reports were generated on a gate-to-gate level and include (1) all included chemistries, with reaction and overall process yields, (2) process descriptions and literature reviews, (3) detailed process flow diagrams include all material flows into and out of the process and process temperatures and pressures, (4) mass flow tables (5) energy flows at the unit process level. Environmental Clarity tools were used to facilitate consistent calculations and documentation.

Glyphosate is the active ingredient in a broad-spectrum herbicide originally marketed by Monsanto as Roundup. Commercial formulations are typically salts, which are more soluble in water. Glyphosate is the active ingredient, and a 100% pure solid product is discussed in this presentation. Commercial glyphosate production routes were summarised by Bryant (2003). The Monsanto routes and Chinese chloracetic acid route goes through iminodiacetic acid (IDA) and phosphonomethyl iminodiacetic acid (PMIDA). The primary production route for IDA in world production, that used in the new Monsanto route, and this life cycle dataset is diethylamine. The ecoinvent 2.2 model (Sutter, 2010) is based on the route given by Unger (1996), which according to Bryant (2003) has never been used commercially.

The abbreviated chemical supply chain in Fig. 1 shows production steps from commodity chemicals through glyphosate. There is an apparent low yield of PMIDA from reaction inputs. This is mostly due to a large production of sodium chloride as the disodium salt of IDA reacts with hydrochloric acid produced from phosphorus trichloride. Significant fossil fuel inputs are used in non-energy molecular building steps to create the ammonia, ethylene oxide, formaldehyde, and metallurgical coke intermediates.

The energy use for heat and electricity is shown in Figure 2. The largest energy use is in the glyphosate gtg, which requires a large heat input to evaporate water for crystallisation and drying steps. The next three largest energy inputs are for phosphorus trichloride, sodium hydroxide, and ethylene oxide. The net natural resource energy value for heating and electricity needs was 149 MJ HHV/kg glyphosate. An additional 35 MJ HHV of raw materials are used for molecular building per kg glyphosate. Thus, the cradle-to-gate consumption of energy was 184 MJ HHV/kg glyphosate. For comparison, the ecoinvent 2.01 and 2.2 models had 405 and 224 MJ LHV fossil energy for glyphosate production. For glyphosate, it appears that ecoinvent has a non-commercial route and possibly some stoichiometric errors. However, the relative lack of transparency in ecoinvent documentation prevents a more meaningful comparison.

The detailed analysis and documentation produced on this project represents an important change in our understanding of the life cycle of glyphosate, cyhalofop-butyl, dazomet, and chloropicrin. In the case of glyphosate, this new dataset models the commercial production route, includes the chemical emissions from reaction by-products, and achieves a level of transparency that other lci data suppliers should strive for.

References

Bryant, R.B., 2003. Specialty Chemicals Magazine,http://www.agranova.co.uk/pdf/RJB_ChemSpec2003.pdf
Green, M., A. McCulloch, 2007, Energy considerations in the use of herbicides, J.Sci. Fd Agric, 27:95-100
Jimenez-Gonzalez, C. ,Overcash, M., 2000. Energy sub-modules applied in life cycle inventory of processes, J. Clean Products Process., 2, 57-66.
Sutter, J., 2010. Life cycle inventories of pesticides, Swiss Centre for Life Cycle Inventories, St. Gallen
Unger, T.A., 1996. Pesticide synthesis handbook, Noyes, New Jersey.

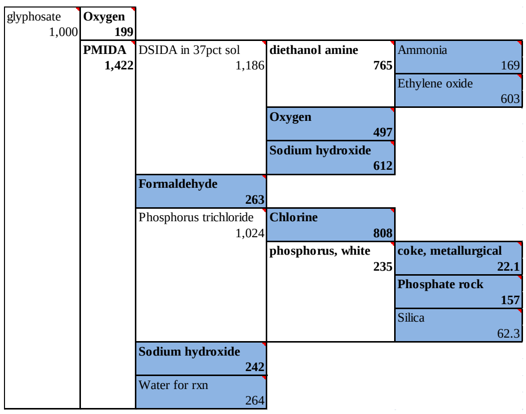

Figure 1. Chemical supply chain of glyphosate

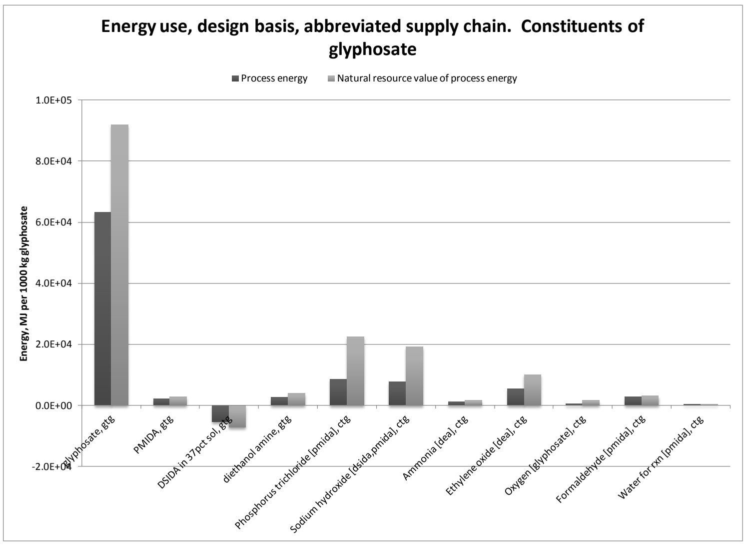

Figure 2. Energy use of glyphosate production

Review of GHG calculators at farm and landscape scales

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Climate change has probably been the most studied impact category amongst LCA. It is also the criterion that is most likely to be adopted on short term for food labelling and implementation of green taxes. In parallel to IPCC work and progress on methodological issues, many GHG calculators have been developed recently to assess agriculture and forestry practices. All these tools provide results in eqCO_2/ha or eqCO_2/product but they have some important differences concerning methodologies and perimeters accounted. A review of the available tools has been carried out to highlight these differences and propose a typology. The review considers tools working at landscape scale, including several productions: crop, livestock and forest. About 15 major tools were identified, amongst them EX-ACT (Bernoux et al., 2010), ClimAgri, Cool Farm Tool (Hillier et al., 2011), Holos, USAID FCC and ALU.

Environmental assessment at landscape scale implies several challenges (UNEP, 2012). Up scaling implies a change in data availability. At plot scale and farm scale, technical data are easily available and can be provided directly by farmers. At regional scale, data inventory often needs to be obtained from statistical data base or expert knowledge, increasing uncertainties. Another challenge with landscape assessment is how to consider heterogeneity. Indeed GHG emission and carbon stocking processes can be quite site specific (ex: N2O emissions from fertilisers). Calculators either use bio-physical models, such as the soil organic matter dynamic models Roth-C or Century, possibly linked with spatial databases (Cerri et al., 2004), or average emission factors provided by IPCC or national studies (IPCC 2006). The use of bio-physical models allows more accurate estimations than IPCC average factors (once the model has been properly calibrated). However, these models work at field scale and need to be linked with spatially explicit dataset ("soil maps") to work at landscape scale, these dataset not being available in most situations. In the future, proxy (NIRS) or remote sensing (satellites image analyses) technologies might enable for cheap direct measurement of the carbon stock changes or GHG emissions at large scale. Accounting for time dynamic is also important, especially considering land use change and carbon storage with the GWP_{100} used as a reference. At landscape scale, management choices can induce some leakage. So far there is no consensus on the best way to take it into account, especially concerning indirect land use changes. Depending on the final aim of the user, each calculator tries to find the best compromise between user-friendliness, time consumption and result accuracy. So the review discuss about how all these aspects are considered in GHG calculators. In the end, the aim is to promote transparency and help policy makers, farmers and carbon experts to choose most adapted tool for their goal and better interpret the results.

References

Bernoux, M., Branca, G., Carro, A., Lipper, L., Smith, G., Bockel, L., 2010. Ex-ante greenhouse gas balance of agriculture and forestry development programs. Scientia Agricola. 67, 1, 31-40.

Cerri, C.E.P., Paustian, K., Bernoux, M., Cerri, C.C., Mellilo, J.M., 2004. Combining soil C and N spatial variability and modelling approaches for measuring and monitoring soil carbon sequestration. Environmental Management 33 (S1), 274-288.

Hillier, J., Walter, C., Malin, D., Garcia-Suarez, T., Mila-i-Canals, L. and Smith, P., 2011. A farm-focused calculator for emissions from crop and livestock production. Environmental Modelling and Software, 26, 1070-1078.

IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). IGES, Japan.

UNEP, 2012. UNEP Year Book: Emerging issues in our global environement. 80 pp. Available on line at http://www.unep.org/yearbook/2012.

Management and reduction of on-farm GHG emissions using the 'Cool Farm Tool': a case study on field tomato production

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Globally, agriculture and land use change accounts for approximately 10-12% of GHG emissions (Smith et al., 2007) but also presents significant potential for mitigation (Smith et al., 2008). It has thus become a political focal point for emissions reduction. If this is to be realised, attention must be paid to the basic unit of agriculture, the farm. Effectively managing GHG emissions at the farm level can be achieved through the deployment of well documented good agricultural practices (GAPs) and resource optimisation. Quantifying and measuring farm level GHG impacts however, can provide additional insights and opportunities for reduction which farmers typically lack.

The Cool Farm Tool, developed by Hillier et al. (2011), is a multi-crop, globally applicable, farm-scale GHG calculator with high management sensitivity relevant for the farmer's specific system. It integrates a number of globally determined empirical models (Hillier et al., 2011) and requires information inputs easily accessible to farmers (e.g. fertiliser application, tillage practices), enabling them to measure their own farm GHG impact and explore different emission reduction scenarios. It therefore provides decision support to encourage low carbon farming and offers a low-cost (it's open source) and robust means of measuring on-farm GHG emissions quickly and with instant results. The tool has recently been deployed at scale through the 'Cool Farming Options' project hosted by the Sustainable Food Lab (2011). In this project a number of companies from around the world have been using the tool within a diverse range of food supply chains and in doing so, have begun to build up a multi-crop and multi-regional data repository.

This paper presents a case study of the application of the Cool Farm Tool in its first year with field tomato growers from several farms supplying into a global supply chain. It describes the emissions profiles of these farms and illustrates the variability inherent among farming systems globally as a function of variability in management practices, climate, geography, soil properties and technology used. In addition these GHG figures are compared to current published literature sources and modelled data (Nemecek et al., 2012) to demonstrate the potential of the Cool Farm Tool as a data provider at a territorial or regional level. Finally some conclusions and potential future developments for the tool methodology and use are presented.

References

Hillier, J., Walter, C., Malin, D., Garcia-Suarez, T., Milà i Canals, L. & Smith, P., 2011. A farm-focused calculator for emissions from crop and livestock production. Environmental Modelling & Software, 26, 1070-1078.

Nemecek, T, J., Weiler, K., Plassmann, K., Schnetzer, J., Gaillard, G., Jefferies, D., Garcia-Suarez, T., King, H., Milà i Canals, L., 2012. Estimation of the variability in global warming potential of a worldwide crop production using a modular extrapolation approach. Journal of Cleaner Production. (Submitted).

Smith, P., D. Martino, Z. Cai, D. Gwary, H. Janzen, P. Kumar, B. McCarl, S. Ogle, F. O'Mara, C. Rice, B. Scholes, O. Sirotenko., 2007. Agriculture, in: [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (Eds.)], Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change., Cambridge University Press, Cambridge, United Kingdom and New York, NY, US.

Smith, P., D. Martino, Z. Cai, D. Gwary, H. Janzen, P. Kumar, B. McCarl, S. Ogle, F. O'Mara, C. Rice, B. Scholes, O. Sirotenko, Howden, M., McAllister, T., Pan, G., Romanenkov, V., Schneider, U., Towprayoon, S., Wattenbach, M. & Smith, J. U., 2008. Greenhouse gas mitigation in agriculture, Philosophical Transactions of the Royal Society, 363, 789-813.

Sustainable Food Lab, 2011. Cool farming options. [Online] Available from: http://www.sustainablefoodlab.org/projects/climate (Accessed: 10/02/12).

PalmGHG, the RSPO greenhouse gas calculator for oil palm products

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Nowadays, palm oil is the most used vegetable oil worldwide, representing more than 30% of total produced vegetable oils by volume (Omont, 2010). About 10-15% of global production is certified by the Roundtable on Sustainable Palm Oil (RSPO) (USDA, 2011 and RSPO, 2011). RSPO is a non-profit association promoting the production and consumption of sustainable palm oil through a voluntary certification scheme. Two successive science-based working groups on greenhouse gas (GHG WG) have been active in RSPO between 2009-2011, with the aim of identifying ways leading to meaningful and verifiable reduction of GHG emissions.
The GHG WG recommended the use of a greenhouse gas (GHG) calculator to allow producers calculate the GHG balances of oil palm products. To this end, PalmGHG was developed by the GHG WG as an excel spreadsheet using the life cycle assessment approach and based on a previous tool by Chase & Henson (2010). PalmGHG quantifies the major sources of emissions and sequestration for a palm oil mill and its supply base, as for the certification scheme, and is compatible with standard international GHG accounting methodologies. The calculator is flexible, allowing for different crop rotation lengths and alternatives to the default values. It calculates the total net emissions per ha, allocates these to co-products, and expresses them as t CO_2e/t palm product, e.g. crude palm oil (CPO) or palm biodiesel (according to 2009/28/EC). The calculations can be done on an annual basis: this allows for identification of principal emission sources for management purposes; regular reporting, internally to the company and externally to the supply chain; and monitoring.
A pilot study was carried out in 2011 on nine RSPO companies, to determine its ease of use, and suitability of PalmGHG as a management tool. Results from eight mills gave an average of 1.03t CO_2e/t CPO, with a wide range of -0.07 to +2.46t CO_2e/t CPO (Fig. 1). Previous land use and the percentage of the area under peat were the main causes of the variation. PalmGHG readily allows manipulation of input data to test management interventions. Results of scenario testing showed that high emissions result from clearing logged forest or peat, and conversely that very low (negative) emissions result from clearing low biomass land such as grassland. Net emissions below 0.5t CO_2e/t CPO can be obtained from a mature industry that is replanting palms and capturing methane and generating electricity from the biogas.
Further modifications to PalmGHG are still being made, notably to amend default values. Moreover, it should be still upgraded to a user-friendly software, completed by simplifying procedures for data entry, and providing documentation. Further recommendations of the GHG WG to Executive Board refer e.g. to the characteristics that should be met by new plantations in order to ensure low GHG emissions.

References

Chase, L.D.C. Henson, I.E., 2010. A detailed greenhouse gas budget for palm oil production. Int. J. Agric. Sustain 8(3), 199-214.
Omont H., 2010. Contributions de la production d'huile de palme au développement durable. Problématique générale, controverses. Ol. Corps Gras Li. 17 (6), 362-367.
RSPO, 2011. updated data on the webpage, visited on 10/02/2012: www.rspo.org
USDA, 2011. USDA report of Feb. 2011

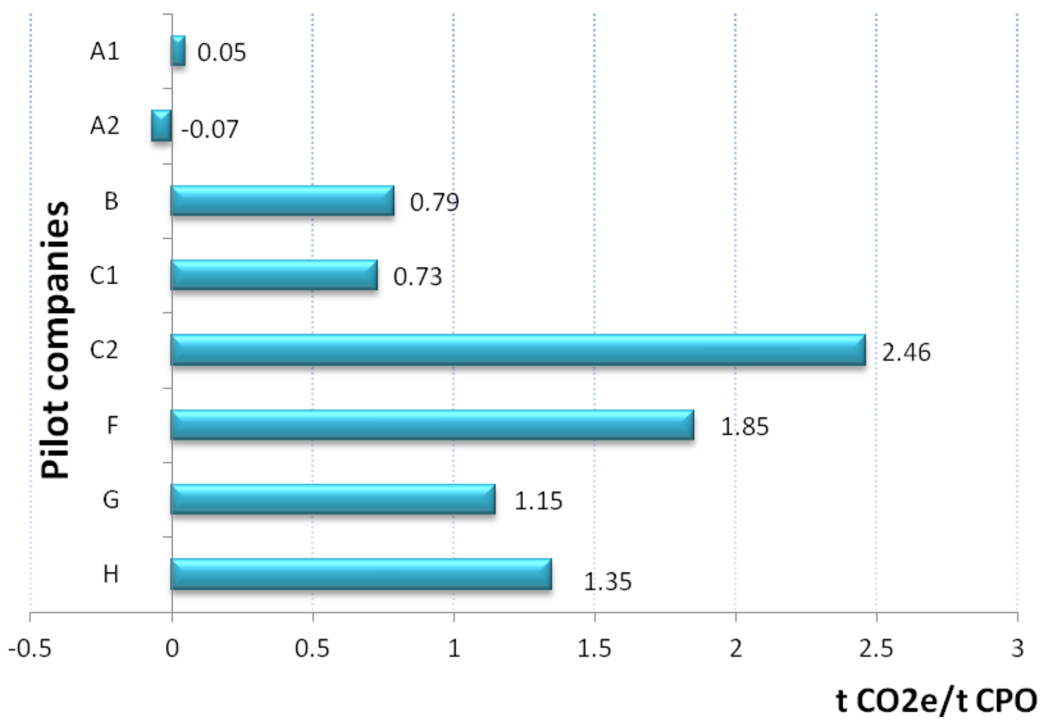

Figure 1. GHG net emissions per tonne of Crude Palm Oil (CPO) of companies involved in the pilot.

Review and future perspectives in the environmental assessment of seafood production systems

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A total of 33 Life Cycle Assessment (LCA) related publications relating to seafood production systems were identified and critically reviewed with the aim of understanding the current trends in environmental assessment of the fishing sector and its supply chain (Vázquez-Rowe et al., 2011). These were limited to those analysing wild caught fish systems (fisheries), while excluding aquaculture products. The studies were divided into four different subgroups: fisheries assessment, processing and/or supply chain of seafood products, food meal and diet studies and carbon footprint evaluation of fishing systems. Common elements and differences within and across them were searched and discussed.

The revision revealed a gradual increase in the number of publications within the last few years, despite the fact that this proliferation was concentrated mainly in the fishery stage of the production system. Furthermore, a set of methodological innovations that had previously been pointed out as needed for the adaptation of LCA to fishing systems (Pelletier et al., 2007) have been attained, while others are yet to be developed. Hence, a critical and updated review of the main methodological assumptions in LCA studies (allocation, functional unit, etc) is provided, as well as a set of methodological advances, which include novel impact categories (i.e. seafloor impact potential, biotic resource use or global discard index) or the combination of LCA with other methodologies, such as Data Envelopment Analysis (DEA).

Finally, based on the observed state-of-the-art, a common ground protocol is proposed for fisheries LCA studies, in which recommendations on how to elaborate the four stages of LCA as applied to fisheries is indicated (Fig. 1). The main objective of this framework is to set a best practices guideline for future studies, in order to guarantee result transparency and reproducibility.

References

Pelletier, N., Ayer, N., Tyedmers, P., Kruse, S.A., Flysjö, A., Robillard, G., Ziegler, F., Scholz, A.J., Sonesson, U., 2007. Impact categories for Life Cycle Assessment research of seafood production systems: Review and Prospectus. Int. J. Life Cycle Ass. 12, 414-21.

Vázquez-Rowe, I., Hospido, A., Moreira, M.T., Feijoo, G., 2011. Review: Best practices in Life Cycle Assessment implementation in fisheries. Improving and broadening environmental assessment for seafood production systems. Trends Food Sci. Tech. (in review).

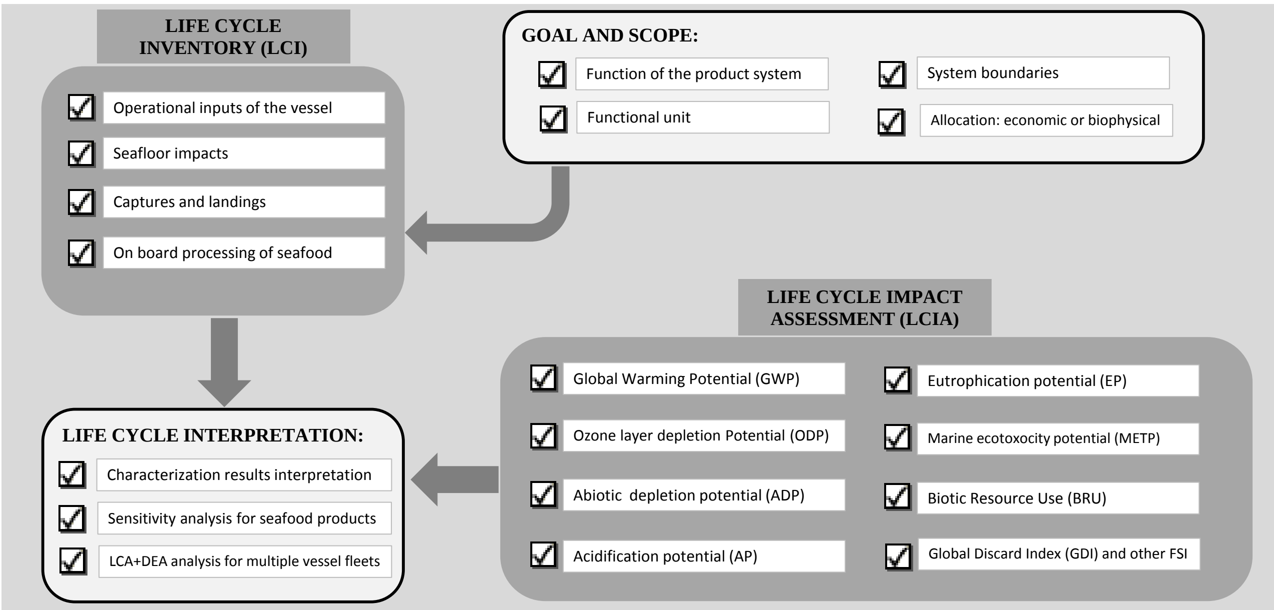

Figure 1. Recommended best practices in LCA implementation for fishing systems.

Overfishing, overfishedness and wasted potential yield: new impact categories for biotic resources in LCA

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Overfishing is one of the largest environmental challenges that mankind face and it affects both natural ecosystems as well as natural recourses, but yet it has not been directly incorporated in LCA methodology which limits a holistic scope of any Seafood LCA. We propose Wasted Potential Yield as a midpoint impact category to fill this gap, complemented with two sub-impact categories explaining the main contributing mechanisms: F-Overfishing and B-Overfishedness. Characterisation methods relate to the Maximum Sustainable Yield (MSY) concept that has been reinstated as a management goal for the European Union with full implementation deadline to 2015 demanded by the Johannesburg Plan of Implementation.

The Wasted Potential Yield (WPY) concept for biotic resource depletion combines nonlinearly the effect of F-overfishing (Fishing mortality > Fishing mortality that lead to MSY) and B-overfishedness (five year average spawning stock biomass < theoretical spawning stock biomass at MSY). It directly measures potential damage to the Area of Protection (AoP) Natural Resources, by worsening future possibilities to cover society needs, and indirectly measures damage to the AoP Natural Environment by degrading top predator stocks that hold key functioning roles of the ecosystem. The characterisation function is based on a surplus yield model that compares a projection of current fishing practise with the results of an optimal MSY practise. Input data are metadata from currently used annual stock assessments complemented with a limit values obtained from literature.

Characterisation factors were obtained for 43 European commercial stocks regarding 13 species between 2000-2010, which covered approximately half of European catches and 7% of the global catches, i.e. most of the commercially important stocks in the North East Atlantic. Grouped into species groups, the European cod stocks were found in worst shape in terms of wasted potential yield for the 2010 assessment, followed by plaice and whiting stocks, see figure 1. They are all demersal (ground dwelling) species relatively far up in the trophic chain. The five best placed species groups in relation to biotic resource use were all pelagic species of typically smaller body size and lower mean trophic level. However, the category characterisation factors showed large variability between years and stocks due to the high variation in wild caught fishery production system. Therefore we stress the need for both general aggregated database characterisation factors and routines for continuous data collection by the LCA practitioner to minimise spatial and temporal error of representativeness.

Furthermore, all characterisation factors are normalisable and additional conversion of WPY into monetary endpoints, or damage to natural ecosystems is possible within the same framework, but subject to high model uncertainty. Excising pricing indexes could be used for Natural Resource characterisation but Natural Ecosystem damage requires additional ecological importance indices for each stock in each ecosystem. However, Wasted Potential Yield methodology (including sub impact categories) could still be used as midpoint categories to complement existing fishery specific impact categories and fill the methodological gap of single stock overfishing, which are the minimum inclusion criteria for all major seafood labels and sustainable seafood guides know to us. Without directly addressing and quantifying the resource and biological effects implied by overexploitation of target stocks, any future seafood LCA could be misinterpreted, or even deliberately misused as a biased proxy for total "environmental" damage.

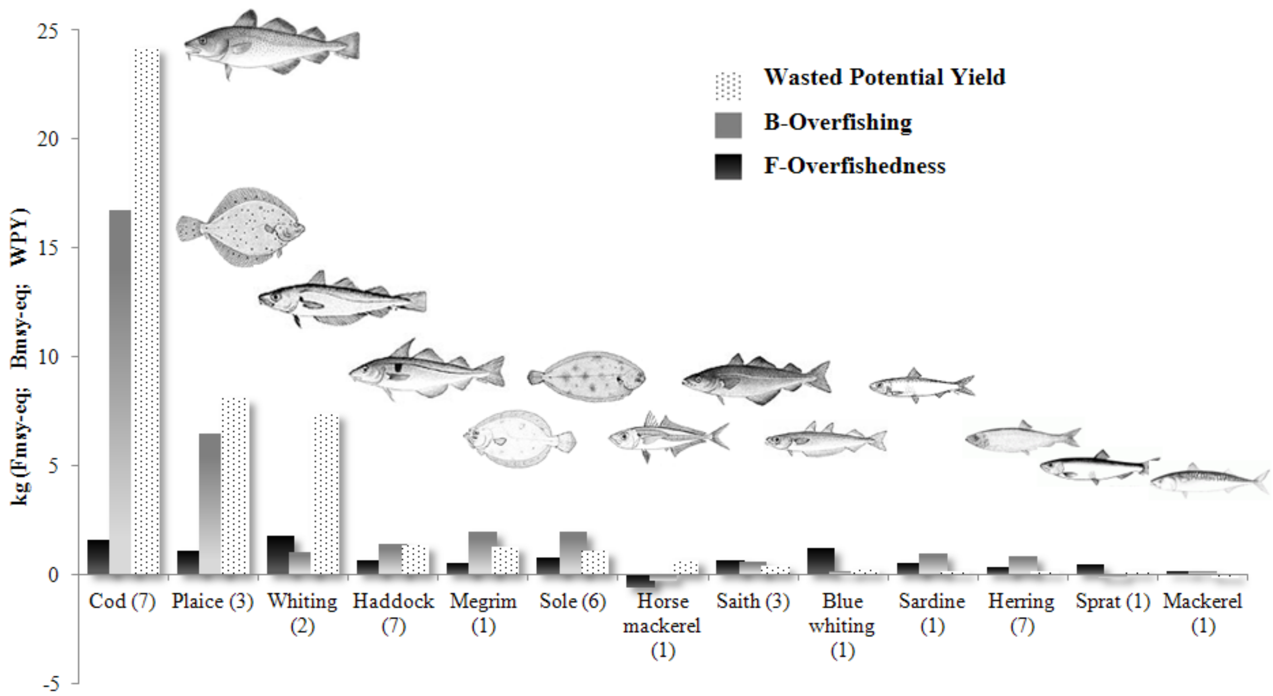

Figure 1. Characterisation of 2010 values of F-Overfishing (black) calculated as F/Fmsy-1, B-Overfishedness (grey) calculated as Bmsy/B-1 and Wasted Potential Yield (WPY) plotted according to their common mass based unit. Brackets indicate number of stocks included. Illustrations: FAO

A new approach for fisheries impact assessment in LCA

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Life Cycle Assessment (LCA) tends to be exhaustive for the impacts it assesses in most cases, but as identified by Pelletier et al. (2007), there is a need of improvement within this method for assessing impacts of seafood products. Because direct environmental impacts of fisheries can hardly be assessed using conventional methods of Life Cycle Assessment (LCA), we suggest building a new methodological framework to account for most of them. We propose a regionalised method of calculation for characterisation factors dedicated to an uptake of biomass through fishing activities. In this first stage only impacts of species removal are considered, excluding alterations of habitat in terms of biodiversity. The characterisation factors are proposed for the assessment of both impacts (1) on biotic natural resources (BNR) depletion and (2) on life support functions (LSF) of marine ecosystems, as suggested by Udo de Haes et al. (2002). The two assessments are based respectively (1) on Maximum Sustainable Yield (MSY)-related points, in order to take into account the state of the stocks for the particular species we assess, (2) on the quantity of carbon the ecosystem is deprived of through Net Primary Production used (NPP_{use}) and on the scarcity of the biomass within the ecozone. Data related to MSY that can be harvested are available for many aquatic species (Ricard et al. 2011). NPP_{use} can be calculated considering trophic levels of the uptake (Pauly and Christensen 1995) and the biomass scarcity is characterised using the total amount of NPP produced in a given ecozone (using Geographical Information System software). The method is applied on two examples of fisheries (Atlantic cod and Atlantic herring in the gulf of Maine, USA) to demonstrate its relevance for comparisons between different fisheries, exploiting different fish species. A discussion on the compatibility of this method with other frameworks is then performed. For BNR depletion assessment, there is no consensus at the moment. For LSF capability, the developed method followed the consensual framework of Milà i Canals et al. (2007), also using the recommendations of regionalisation provided by Koellner et al. (2012). Both results were expressed in potential time of regeneration within the ecosystem, which appear to be a useful and relevant unit.

References

Koellner, T., de Baan, L., Beck, T., Brandão, M., Civit, B., Goedkoop, M., Margni, M., i Canals, L., Müller-Wenk, R., Weidema, B. and Wittstock, B., 2012. Principles for Life Cycle Inventories of Land Use on a Global Scale. Int J Life Cycle Assess 1-13.

Milà i Canals, L., Bauer, C., Depestele, J., Dubreuil, A., Knuchel, R., Gaillard, G., Michelsen, O., Müller-Wenk, R., Rydgren, B., 2007. Key Elements in a Framework for Land Use Impact Assessment Within LCA. Int J Life Cycle Assessment. 12 (1), 5-15.

Pauly, D., Christensen, V., 1995. Primary Production Required to Sustain Global Fisheries. Nature. 374 (6519), 255-257.

Pelletier, N., Ayer, N., Tyedmers, P., Kruse, S., Flysjo, A., Robillard, G., Ziegler, F., Scholz, A., Sonesson, U., 2007. Impact Categories for Life Cycle Assessment Research of Seafood Production Systems: Review and Prospectus. Int J Life Cycle Assessment. 12, 414-421.

Ricard, D., Minto, C., Jensen, O.P., Baum, J.K., 2011. Examining the Knowledge Base and Status of Commercially Exploited Marine Species with the RAM Legacy Stock Assessment Database. In press in Fish and Fisheries. doi:10.1111/j.1467-2979.2011.00435.x.

Udo de Haes, H. A., Finnveden, G., Goedkoop, M., Hauschild, M., Hertwich, E., Hofstetter, P., Jolliet, O., et al., 2002. Life cycle impact assessment: Striving towards best practice, SETAC Press, Pensacola.

Regionalised method to assess soil erosion in LCA

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Ecosystem services (ES) are resources and processes that are supplied by natural ecosystems. Despite their fundamental role in sustaining ecosystem functioning and human activities, they have been traditionally overlooked in life cycle oriented methods such as life cycle assessment (LCA), a method that is meant to encourage environmental sustainability. This oversight can lead to improper decisions. Currently, LCA is rapidly progressing in order to account for impacts on ES triggered by land use human activities. The inclusion of ES in LCA will result in more consistent decision-making processes.

The objective of the present research was to develop a globally applicable method to integrate the erosion regulation potential ES in LCA. Erosion is highly relevant worldwide and, at the same time, data and estimation models for the assessment may be available. Soil erosion depends very much on local conditions (climate, soil, topography); hence, a conventional site-independent linear impact assessment model (LCIA) might not be very accurate. Unlike conventional LCIA, the developed model is spatially explicit and characterisation factors (CFs) were regionalised on a 5 arc-minutes (approximately 10*10 km^2) resolution grid, without aggregating values on broader administrative or ecological scales. Two endpoint indicators covering the areas of protection damage to resources and damage to ecosystem quality were defined. The indicator for damage to resources informs of the decrease in local soil stock as response to soil loss mass due to land occupation. We proposed to calculate soil losses in the inventory with the universal soil loss equation (USLE, Wischmeier and Smith, 1978), although other estimation models may also be applied. Final damage is expressed as surplus (solar) energy needed to rebuild the stock of soil loss. The indicator for damage to ecosystem quality can be divided in a fate step, linking soil organic carbon (SOC) loss to soil loss, and an effect step, linking ecosystem biomass productivity drop to SOC loss. Final damage expresses the net primary production depletion as response to soil loss mass due to land occupation. We assessed ecosystem biomass production as a function of the net primary production of potential natural vegetation (NPP_0).

Fig. 1 shows the regionalised CFs for (a) the resource-depletion impact pathway and (b) the ecosystem-quality impact pathway.

The method was applied to the agricultural stage of five crop rotation systems with food and energy crops in more than one hundred plots located throughout Spain. This is a highly diverse country in climate, soil and topography, where water erosion is one of the main causes of land degradation. Results (Table 1) show that there are significant differences in the environmental damage from soil erosion between watersheds due to the variability in soil and SOC losses registered in the LCI and the CFs. It is therefore crucial to accurately specify the geospatial location of the system under analysis to avoid losing quality in both the LCI and LCIA results.

The developed method aims to contribute to a better land use impact assessment of agricultural and forestry production systems. Further research should focus on testing the applicability of the method across the overall life cycle of a product and to determine the most relevant and feasible scale at which to aggregate CFs (e.g., country) to deal with data gaps on location of processes, especially in the background system.

References

Wischmeier, W.H., Smith, D.D., 1978. Predicting rainfall erosion losses – A guide to conservation planning, Agricultural Handbook no. 537, Department of Agriculture, United States.

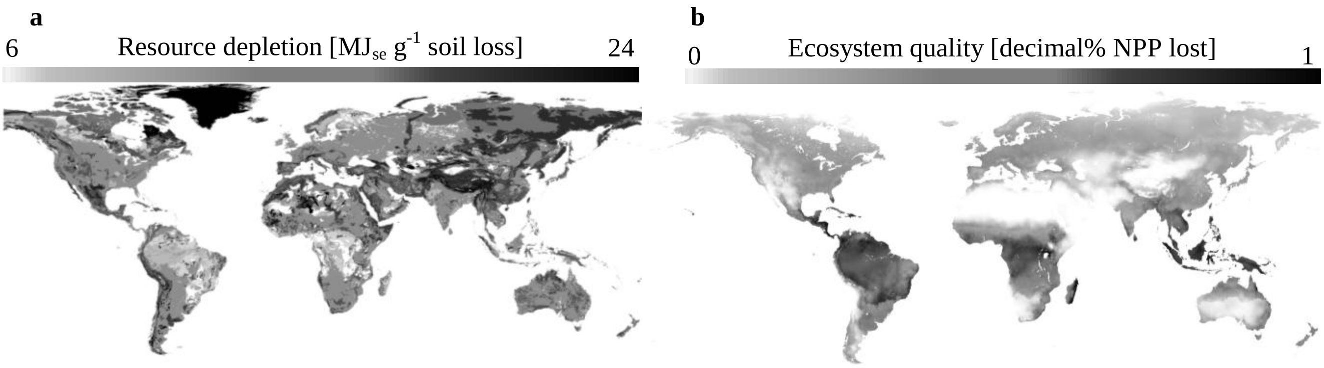

Table 1. Damage to resources and to ecosystem quality (LCIA) of the five crop rotation systems studied on five important watersheds in Spain and arithmetic country average. Results are per m^2 and year of land occupation.

	Ebro	Duero	Tajo	Segura	Guadalquivir	Country average ± SD
Resources [MJ_{se}]						
B-W-R[a]	6366	4125	9028	5778	9943	10410 ± 6290
B-W-P[b]	6612	4394	9293	5777	9841	10585 ± 6444
B-W-F[c]	10285	6978	14450	8948	15608	16198 ± 9652
B-W-OR[(*)d]	6000	3606	8691	5576	9156	9729 ± 5941
PP[(*)]-PP[(*)]-PP[(*)e]	1334	746	1602	975	1585	1776 ± 1142
Ecosystem quality [NPPD, decimal% of NPP lost]						
B-W-R[a]	0.03	0.02	0.04	0.02	0.05	0.047 ± 0.028
B-W-P[b]	0.04	0.02	0.04	0.02	0.05	0.048 ± 0.028
B-W-F[c]	0.05	0.03	0.06	0.03	0.07	0.070 ± 0.043
B-W-OR[(*)d]	0.03	0.02	0.04	0.02	0.05	0.045 ± 0.027
PP[(*)]-PP[(*)]-PP[(*)e]	0.02	0.01	0.01	0.01	0.02	0.017 ± 0.006

[a] winter barley – winter wheat – rye
[b] winter barley – winter wheat – pea
[c] winter barley – winter wheat – unseeded fallow
[d] winter barley – winter wheat – oilseed rape
[e] poplar – poplar – poplar
Asterisks indicate crops for energy use.

The effect of crop management on soil organic matter in LCA of agricultural products

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The agricultural sector has an important role in greenhouse gas (GHG) mitigation, since cropland soils can also act as sinks. Attention has already been drawn to the value of soil quality and soil organic matter (SOM) in the life-cycle of agricultural products (Cowell et al. 2000), and Milà i Canals et. al. (2007) proposed SOM as the sole indicator of soil quality. Nevertheless, many life-cycle assessment studies of food and non-food products do not take into account changes in SOM in arable land. Indeed, few studies have incorporated soil into an LCA study (Milà i Canals et al. 2007; Brandão et al., 2011) and no common methodology for its estimation and LCA inclusion currently exists. SOM changes are strongly influenced by management practices and soil and climate conditions, and are therefore entirely site-specific. Many process-oriented SOM models are available to estimate emissions on a daily, monthly or annual basis, with the most frequently-adopted being Century, RothC and DNDC. Some of these models have already been incorporated into LCA analysis (Milà i Canals et al. 2007; Hillier et al. 2009). However, the huge amount of data required (meteorological data, crop phenological data, and chemical and physical soil characteristics) to run these models and to establish the life cycle inventory (LCI) could limit widespread use of this approach. A simpler one-compartment SOM model would be more easily integrated into the LCA study. Recently, many authors have adopted the Hénin-Dupuis SOM model (1945) for cropping system and orchard studies under different climate conditions, and it has proved useful for less-detailed modelling at sites where input requirements for running the more complex models are not readily available (Di Bene et al. 2011). The Hénin and Dupuis model evaluates the effect of agricultural practices on the evolution of the SOM pool and is described by the following equation:

$$SOM_t = SOM_0 e^{-k_2 t} + k_1 OM_I / k_2 (1 - e^{-k_2 t})$$

where SOM_t is the SOM pool (Mg ha^{-1}) at time t; SOM_0 is the initial SOM pool (Mg ha^{-1}) at time t = 0; k_2 is the mineralisation coefficient corresponding to the annual rate of SOM loss by mineralisation; k_1 is the humification coefficient and refers to the annual rate of OM inputs incorporated in SOM; and OM_I is the annual OM inputs (Mg ha^{-1}).

Moreover, we identified a Minimum Data Set (MDS) for agricultural product LCAs that accounts for soil carbon, thus establishing standard for inventory. This MDS includes the following: physical and chemical soil characteristics, climate parameters, OM inputs and management practices. The model was applied to wine chain considering four scenarios with decreasing levels of organic matter inputs, taking into account: manure distribution at vineyard planting; inter-row grassing with cover crops; incorporation of pruning residues into the soil. This SOM balance method was sensitive to changes in management practices.

References

Brandão, M., Milà i Canals, L., Clift, R., 2011. Soil organic carbon changes in the cultivation of energy crops: Implications for GHG balances and soil quality for use in LCA. Biomass Bioenerg. 35, 2323-2336.

Cowell, S.J., Clift, R., 2000. A methodology for assessing soil quantity and quality in life cycle assessment. J. Clean. Prod. 8, 321-331.

Di Bene, C., Tavarini, S., Mazzoncini, M., Angelini, L.G., 2011. Changes in soil chemical parameters and organic matter balance after 13 years of ramie [Boehmeria nivea (L.) Gaud.] cultivation in the Mediterranean region. Eur. J. Agron. 35, 154-163.

Hénin, S., Dupuis, M., 1945. Essai de bilan de la matière organique du sol. Ann. Agron. 15, 17–19.

Hillier, J., Whittaker, C., Dailey, G., Aylott, M., Casella, E., Richter, G., Riche, A., Murphy, R., Taylor, G., Smith, P. 2009. Greenhouse gas emissions from four bioenergy crops in England and Wales: Integrating spatial estimates of yield and soil carbon balance in life cycle analyses. GCB Bioenergy 1:267-281.

Milà i Canals, L., Romanya, J., Cowell, S., 2007. Method for assessing impacts on life support functions (LSF) related to the use of "fertile land" in Life Cycle Assessment (LCA). J. Clean. Prod. 15, 1426-1440.

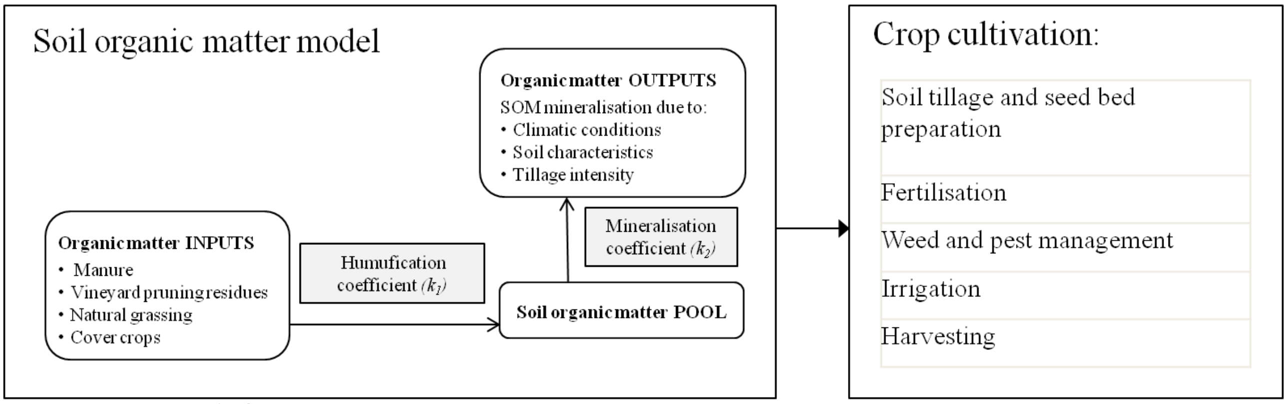

Figure 1. The inclusion of Hénin-Dupuis soil organic matter model in a crop cultivation system boundaries.

Life cycle-based eMergy analysis to compare organic and conventional production systems

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The aim of this work is to evaluate the environmental sustainability of two different agri-food systems conductions, organic and conventional, through the parallel use of Life Cycle Assessment (LCA) and eMergy. In this paper we have selected and analysed two typical Tuscan (Italy) products, wine and olive oil. Concerning wine productions, the organic farm (OW), (10 ha of vineyards), has a medium production of 3500 -5000 L/ha per year, while the conventional farm (CW) (120 ha of vineyards) produces a yield of 2000-3500 L/ha per year. The discrepancy between the wines production data of the two farms is due to the strong selection forced by the conventional farm to obtain a highest quality of wine. Concerning olive oil production, the organic farm (OO) is extended for 4 ha, the annual mean production is 250 kg/ha per year. The conventional farm (OC) has 20 ha destined to olive cultivation, the production of oil has an annual mean of 483 kg/ha. For LCA analysis, characterisation was determined through the use of CML 2 Baseline Method 2000 (Guinée et al., 2001), choosing Acidification Potential (AP), Eutrophication (EU), Global warming (GWP100) and Photochemical Oxidation (PO) as impact categories. Concerning wine productions, CW has the highest values of impacts for LCA (Fig.1) and for specific eMergy results (4.22E+09 sej/g), due to a large use of chemical products and the lower yield in wine, while OW shows lower impact both in LCA (Fig. 1) and eMergy (2.75E+09 sej/g). Packaging phase records maximum values for both methodologies essentially due to the use of glass. Emergy evaluation highlights 99% use of non-renewable resources for CW and OW. By grouping eMergy flows in macro-categories, the highest contribution is due to materials for packaging (61% in CW and 63% in OW), followed by chemicals-fertiliser in CW (23%) and energy (diesel and electricity consumption) in OW (13%), finally human labour has 6% in CW and 13% in OW. The direct contribution of the natural resources (e.g., sun; rain) represents negligible percent. Results of oil production highlight highest values for CO concerning LCA impacts (Fig.2) as well as for specific eMergy values (5.18E+10 sej/g), while OO registers lower results both for LCA impact categories and for specific eMergy (3.74E+10 sej/g). The agricultural phase has the main weight for CO and OO and for both methodologies. Emergy evaluation shows 96% use of non-renewable resources for CO, and 88% for OO. Considering the main contributions of eMergy flows (as done for wine production), the conventional system has 78% for chemical and fertiliser, followed by 8% due to packaging materials; while organic system has 35% derived from energy consumption, a big contribution of 25% from human labour and 11% from packaging materials. A compared LCA-eMergy evaluation is fundamental to outline the environmental value of issues involving social factors, ecosystem properties and product's quality. The application of the two LCA and eMergy methodologies provided variegated and differentiated information about the agri-food systems examined.

References

Guinée, J.B., Gorrée, M., Heijungs, R., Huppes, G., Kleijn, R., Koning, A. de, Oers, L. van, Wegener Sleeswijk, A., Suh, S., Udo de Haes, H.A., Bruijn, H. de, Duin, R. van, Huijbregts, M.A.J., 2002. Handbook on life cycle assessment. Operational guide to the ISO standards. I: LCA in perspective. IIa: Guide. IIb: Operational annex. III: Scientific background. Kluwer Academic Publishers, Dordrecht.

Odum, H.T., 1996. Environmental Accounting: Emergy and Environmental Decision Making. Wiley & Sons, New York, USA.Tukker, A. and Jansen, B., 2006. Environmental impacts of products. A detailed review of studies. J. Ind. Ecol. 10 (3), 159-182.

Rugani, B., Huijbregts, M.A.J., Mutel, C., Bastianoni, S., Hellweg S., 2011. Solar Energy Demand (SED) of Commodity Life Cycles. Environ. Sci. Technol. 45 (12), 5426-5433.

Zhang Y., Singh S., Baral A., Bakshi B.R., 2010b. Accounting for Ecosystem Services in Life Cycle Assessment, Part I: A Critical Review. Environ. Sci. Technol. 44, 2232-2242.

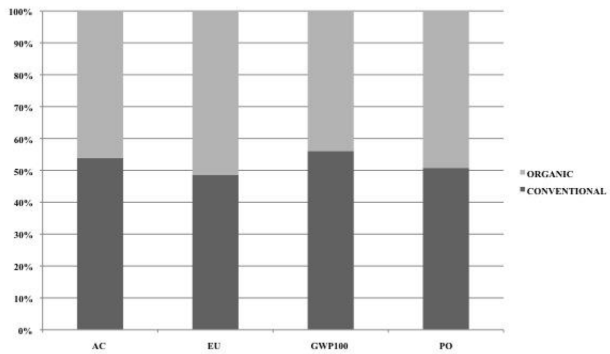

Figure 1. Comparison between organic and conventional wine production. Characterisation results, CML 2 Baseline method 2000.

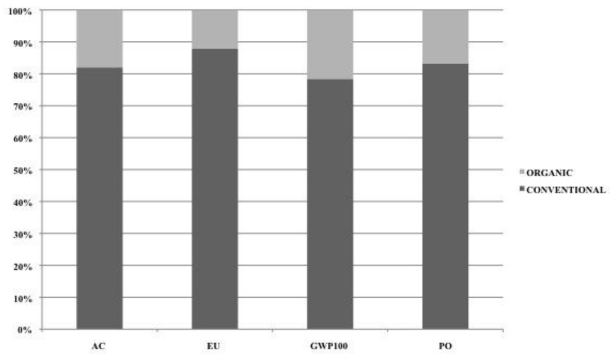

Figure 2. Comparison between organic and conventional olive oil production. Characterisation results, CML 2 Baseline method 2000.

Assessment of a digestibility-improving enzyme's potential to reduce greenhouse gas emissions in broiler production

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Food products represent around 1/3 of all human induced greenhouse gas (GHG) emissions and especially meat products represent significant GHG emissions, to a large extend related to the production of animal feed (Foley et al. 2011). Enzyme solutions are particularly interesting because they can improve the availability of nutrients in animal feed and thereby reduce the amount of feed required to produce a certain quantity of meat or a possibility to include a higher ratio of cheaper feed ingredients with a lower nutritional value achieving the same growth performance (Barletta, 2011).

The objective of this study was, therefore, to examine a digestibility-improving enzyme's potential to reduce GHG emissions. The digestibility improving enzyme examined was Axtra XAP developed by Dupont, Danisco Animal Nutrition for broiler production. It was examined through a comparative life cycle assessment (LCA), comparing two scenarios: scenario one, where Axtra XAP was not included in the diet and scenario two where Axtra XAP was included in the diet allowing for a higher ratio of cheaper feed ingredients with a lower nutritional value to be included in the diet.

The applied modelling approach was a consequential life cycle assessment (CLCA) and it was modelled using SimaPro. The study basically follows the ISO 14040 and 14044 standards. Furthermore, indirect land use changes (ILUC) were included. All feed formulations were economically optimised. Reduction in GHG emissions, resulting from reduced manure generation and changes in the manure composition, were calculated according to the guidelines from the Intergovernmental Panel on Climate Change (IPCC, 2006a; IPCC 2006b).

The findings of the study revealed that the use of Axtra XAP leaded to significant savings in GHG emissions from the broiler production. The main driver for the savings in GHG emissions was changes in the feed, a detailed overview of the results are illustrated in figure 1. The findings showed that Axtra XAP might reduce GHG emissions from broiler production by 4.9%. A sensitivity analysis was conducted in order to assess how uncertainties in data and other preconditions affected the results. The analysis showed that the results varied substantially. The most important parameters were the inclusion or exclusion of ILUC and changes in the feed formulation.

References

Barletta, A., 2011. Introduction: Current market and expected developments. In Enzymes in Farm Animal Nutrition, 2nd Edition, edited by M.R Bedford and G.G. Partridge.

Jonathan, A.F., Ramankutty, N. Brauman, K.A., Cassidy, E.S., Gerber, S., Johnston, M., Mueller, N.D., O'Connell, C., Ray, D.K.., West P.C., Balzer, C., Bennet, E.M., Carpenter, S.R., Hill, J. Monfreda, C., Polasky, S., Rockstrôm, J., Sheehan, J., Siebert, S., Tilman, D., Zaks, P.M.,. Solutions for a Cultivated Planet. Nature. 478, 337-342

IPCC, 2006a. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4. Agriculture, Forestry and other Land Use, Chapter 10. N_2O Emissions from Livestock and Manure Management.

IPCC, 2006b. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4. Agriculture, Forestry and other Land Use, Chapter 11. N_2O Emissions from Managed Soils and CO_2 Emissions from Lime and Urea Application.

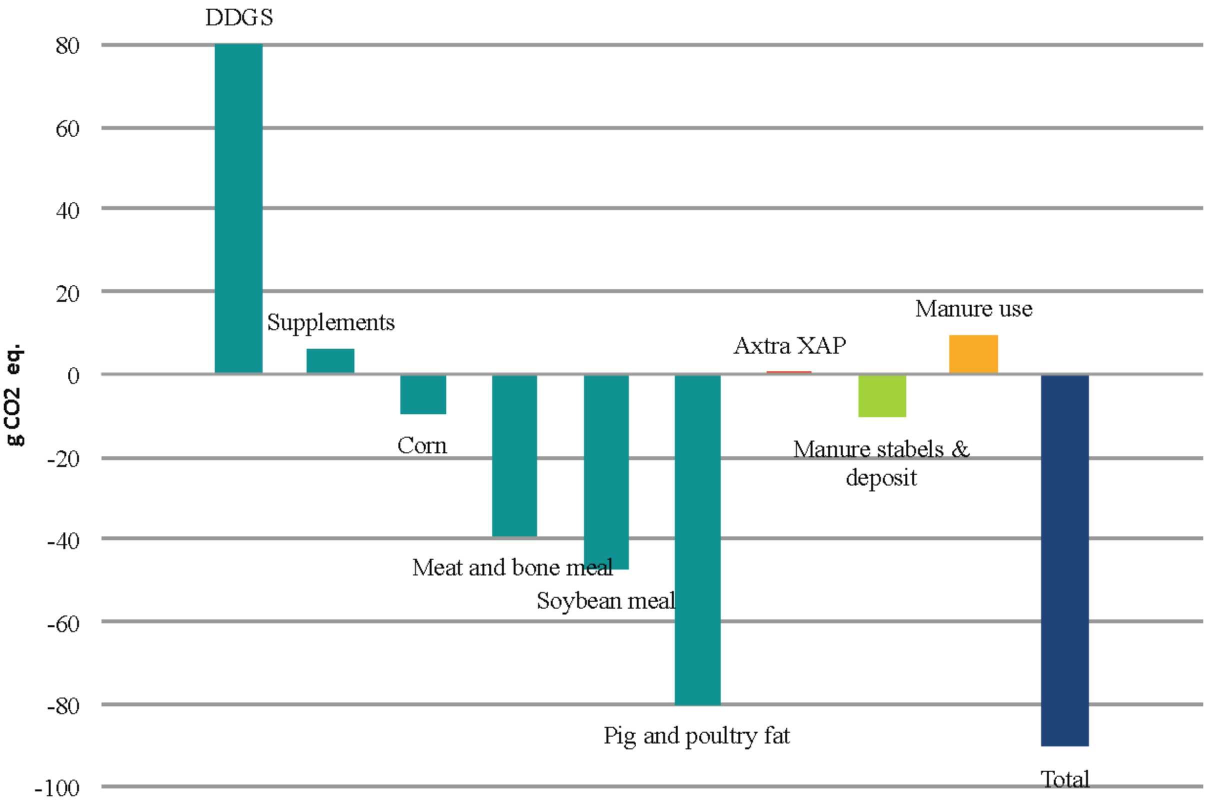

Figure 1. Changes in GHG emissions caused by the use of Axtra XAP in scenario two compared to scenario one. Negative values indicate a decrease in GHG emissions and positive values indicate an increase in GHG emissions.

Comparison of two production scenarios of chickens consumed in France

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The use of the Life Cycle Assessment - LCA - provides interesting comparisons between different scenarios of producing a same product. In this study we investigate if imported chickens from Brazil, fed with locally produced grains cause less or more impact than chickens produced in France, using a feed part of which comes from Brazil. We assume that the chicken produced in France was a standard intensive system (ST) with a feed made with French ingredients (maize, wheat, and rapeseed) and with soybean from Brazil. For the Brazilian case, we assumed standard intensive systems, that chickens were fed mainly with maize and soybeans produced in the region in which the chickens were raised. As we have two scenarios that represent the Brazilian situation, we propose a scenario consisting of 75% of South chicken (SO - considered representative for the three southern states) and 25% of Centre West chicken (CW), adding to this scenario the transport distances. The LCA for the four systems studied begins with the production of inputs and goods used to produce crops, passing through the phases of crop production, grain drying and processing, feed manufacturing, production of chicks, chicken rearing, slaughter, cooling and packaging of whole chicken, including all transport phases, up to the slaughterhouse gate, adding the transport to France, for the Brazilian scenario. The production and maintenance of chicken houses and of slaughterhouse buildings and machines were not included. Functional unit was 1 ton of chicken cooled and packed delivered in France. The method used for life cycle impact assessment was the CML 2 baseline 2000 with modifications. The results are showed in Table 1. From an environmental point of view, importing chicken from Brazil rather than producing it in France with Brazilian soybeans, was better with respect to climate change and land occupation, which are both global impacts. With respect to acidification, terrestrial ecotoxicity and energy demand chicken imported from Brazil had larger impacts than the chicken produced in France.

References

Guemene D, Lescoat P. 2007. Le programme “AviTer”. Etude des impacts des filières avicoles sur le développement durable des bassins de production et des territoires en France et au Brésil. ITAVI: Paris, France.
Katajajuuri J-M, Grönroos J, Usva K. 2008. Environmental impacts and related improvement options of supply chain of chicken meat. Presented at the 6th International Conference on LCA in the Agri-Food Sector. Zürich. 125-126 pp.

Table 1. Contributions of the main life cycle stages for six impacts for 1 ton of chicken cooled and packaged produced in France (ST) and 1 ton of chicken cooled and packaged produced in Brazil and delivered in France.

Origin of chicken	Life cycle stage	Acidification kg SO_2eq	Eutrophication kg PO_4eq	Climate change t CO_2eq	Terrestrial ecotoxicity kg 1,4DB eq	Land occupation m^2a * 1000	Cumulative energy demand TJ
France (ST)	Slaughter	0.3	1.6	0.07	0.3	0.07	3.2
	Chicken production	27.8	6.6	0.80	1.3	0.23	6.0
	Feed production	12.4	12.8	2.30	7.0	3.52	20.8
	Total	**40.5**	**21.0**	**3.17**	**8.6**	**3.82**	**30.0**
Brazil (75% SO + 25% CW)	Slaughter	0.5	1.5	0.05	0.6	0.31	6.5
	Chicken production	20.1	4.7	0.59	1.7	0.11	7.3
	Feed production	24.3	14.1	1.51	7.0	3.14	17.5
	Transport Brazil-France[a]	3.0	0.4	0.25	0.6	0.00	4.5
	Total	**47.9**	**20.7**	**2.40**	**9.9**	**3.56**	**35.8**
Difference of total Brazil relative to ST – absolute and (%)		**7.4 (18)**	**-0.3 (-1)**	**-0.77 (-24)**	**1.3 (15)**	**0.26 (-7)**	**5.8 (19)**
Transport Brazil-France relative to ST (%)		**7**	**2**	**8**	**7**	**0**	**15**

[a] Transport by refrigerated truck, ship and train, from Brazil slaughter gate to France. Other transport stages, like feed transport, chicken transport, inputs transport, etc. are included in earlier stages.

Effect of ethics on integral ecological impact of organic eggs

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Organic agriculture has a specific perspective on sustainability, captured in their goal, definition and four principles of organic agriculture and resulting certification (IFOAM, 2012). We refer to this perspective as the organic-ethical framework. For organic egg production, this framework implies three main requirements: (1) loose hen housing, (2) outdoor access, and (3) limited use of external resources, i.e. artificial fertilisers, pesticides, herbicides, genetically modified organisms, and medication. Our research objective was to assess the effect of these three requirements on the integral ecological impact of Dutch organic egg production. We approached this objective in three steps. In step 1 we compared life cycle assessment (LCA) results of egg production with and without an organic ethical framework. In step 2 we identified main ecological issues of current Dutch organic egg production by means of LCA. In step 3 we explored options to reduce integral ecological impact of Dutch organic egg production within the boundaries of the organic ethical framework, i.e. replace single-tiered with multi-tiered loose hen housing and replace imported with regional diet ingredients.

Comparison of battery cage with barn egg production shows that the requirement of loose hen housing results in a 12% to 176% higher impact for the ecological issues studied, except for phosphorus (P) deficit which was equal (Table 1). This higher impact is mainly explained by a higher conversion of feed to eggs of loose housed hens (2.33 kg feed kg^{-1} egg) compared with hens in battery cages (1.99 kg feed kg^{-1} egg) (Dekker et al, 2011b). A second reason for the higher acidification potential of loose hen housing was that reduction of ammonia emission by drying and removal of manure in loose laying hen houses is problematic. Comparison of barn with free range egg production shows that the requirement of access to an outdoor run results in a relative small, i.e. 0% to 10%, increase of the ecological impact (Table 1). Comparison of free range and organic egg production shows that the requirement of limited use of external resources results in a 10% lower global warming potential, a 15% lower energy use, a 93% lower fossil P use, a 108% lower nitrogen (N) surplus and a 114% lower P surplus, but a 82% higher land occupation, a 68% higher acidification potential, a 1767% higher N surplus and a 900% higher P deficit (Table 1). We found that differences in the ecological impact of egg production systems with and without limited use of external resources resulted mainly from differences in type and amount of fertilisation and conversion of feed to eggs. Multi-tiered housing to dry and remove manure (mitigation housing in Table 1; Dekker et al., 2011a) and production of diet ingredients and eggs in the same region to assure availability of manure and increase yields (mitigation diet in Table 1; Dekker et al. 2012b), have potential to reduce the ecological impact of organic egg production within the ethical boundaries of organic egg production. If these mitigation options are applied we predict a lower energy use, fossil P use, N surplus and P surplus, but a higher global warming potential, land occupation, acidification potential, N deficit and P deficit for organic compared with battery cage egg production.

We conclude that increases of the ecological impact caused by the organic ethical framework mainly result from inefficient N and P management and inefficient conversion of feed to eggs. Issues in the current egg production chain regarding manure management are: (1) a lack of regionally available manure (Dekker et al., 2011b), (2) unbalanced application and N-P ratios of manure fertiliser, (3) high N-emissions from faeces in loose housing systems, and (4) loss of N and P from manure in the outdoor run (Dekker et al., 2011b; Dekker et al., 2012a). The higher conversion of feed to eggs may be caused by: (1) a higher body mass of loose housed hens, (2) increased freedom of movement, (3) prohibited use of external resources, caused by a worse amino acid profile of the diet, (4) limited use of medication, and (5) a smaller number of hens per m^2 in the hen house, which generally results in a lower indoor temperature (Van Knegsel and van Krimpen, 2008; Dekker et al., 2012b; Dekker et al., 2011a). Research is required to determine whether inefficient N and P management and inefficient conversion of feed to eggs in organic egg production must be accepted as an implication of the organic ethical framework or can be further reduced within the boundaries of the organic ethical framework.

References

Dekker, S.E.M., de Boer, I.J.M., Aarnink, A.J.A., Groot Koerkamp, P.W.G., 2011a. Emissions of ammonia, nitrous oxide, and methane from aviaries with organic laying hen husbandry. Biosystems Engineering, 110: 123-133.

Dekker, S.E.M., de Boer, I.J.M., Vermeij, I., Aarnink, A.J.A., Groot Koerkamp, P.W.G., 2011b. Ecological and economic evaluation of Dutch egg production systems. Livestock Science, 139 (1-2): 109-121.

Dekker, S.E.M., Aarnink A.J.A., de Boer, I.J.M., Groot Koerkamp, P.W.G., 2012a. Total loss and distribution of nitrogen and phosphorus in the outdoor run of laying hens. British Poultry Science, (*in press*).

Dekker, S.E.M., de Boer, I.J.M., van Krimpen, M.M., Aarnink, A.J.A., Groot Koerkamp, P.W.G., 2012b. Effect of composition of concentrates on ecological impact of organic egg production. Livestock Science, (*in press*).

IFOAM, 2012. http://www.ifoam.org.IFOAM: International Federation of Organic Agricultural Movements.

Van Knegsel, A.T.M., van Krimpen, M.M., 2008. Energy and protein requirements of organic housed poultry (Energie- en eiwitbehoefte van biologisch gehouden pluimvee). Report 122. Wageningen UR Animal Sciences Group, Lelystad, Netherlands, 22 pp.

Table 1. Production characteristics and ecological impacts of existing egg production systems with and without three ethical requirements (i.e. loose hen housing, outdoor access, and limited use of external resources), mitigation housing (i.e. replace single-tiered with multi-tiered housing), and diet (i.e. replace imported with regional diet ingredients in percent relative to battery cage egg production).

	Battery cage eggs [a]	**Barn eggs [a]**	**Free range eggs [a]**	**Organic eggs [a]**	**Mitigation housing [a]**	**Mitigation diet [b]**
Loose hen housing	No	Yes	Yes	Yes	Yes	Yes
Outdoor access	No	No	Yes	Yes	Yes	Yes
Limited use of external resources	No	No	No	Yes	Yes	Yes
Single-tiered housing	No	Yes	Yes	Yes	No	No
Multi-tiered housing	No	No	No	No	Yes	Yes
Regional diet ingredients	No	No	No	No	No	Yes
Global warming potential	100%	120%	123%	113%	114%	104%
Energy use	100%	112%	115%	100%	98%	77%
Land occupation	100%	115%	125%	207%	207%	141%
Fossil P use	100%	115%	118%	25%	25%	-
Acidification potential	100%	276%	283%	351%	209%	207%
N deficit	100%	133%	133%	1900%	1900%	1615%
P deficit	100%	100%	100%	1000%	1000%	410%
N surplus	100%	115%	122%	14%	14%	14%
P surplus	100%	115%	124%	10%	10%	8%

[a] Dekker et al, 2011b; [b] Dekker et al, 2012b

Environmental impacts of different pork and chicken meat production systems in Switzerland and selected import sources

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Animal production faces many challenges today and consumer awareness of animal welfare and of the environmental impacts of animal production rises. However, there is a risk of a conflict of goals when only improving one of these aspects. In this study, we compared three different production systems (conventional, label production with improved animal welfare and organic) in Switzerland and selected import products both for pork and chicken meat. The life cycle was analysed up to the delivery to the retail store.

Data and design of model farms for Swiss production systems were derived from the project Life Cycle Assessment – Farm Accountancy Data Network (LCA-FADN), where data from more than 100 farms have been collected (Hersener et al., 2011). Data for slaughter and meat processing as well as storage and transport were obtained from a Swiss meat processor and from literature. LCAs were calculated with the method SALCA (Swiss Agricultural Life Cycle Assessment, Nemecek et al., 2010). The analysis is carried out at two levels: at farm gate with the functional unit of 1 kg live weight (LW) and at the retail store gate, with the functional unit of 1 kg meat, packed and cooled.

When considering the whole supply chain up to the retail store, agricultural production was found to be responsible for at least 75% of the environmental impacts in each analysed environmental impact category (Fig. 1). Both in pork and in chicken production, feedstuffs are the dominant inputs. Feedstuffs account for about 40% of the non-renewable energy consumption and global warming potential and for around two thirds of the human toxicity and ecotoxicity impacts of pork at the farm gate (Fig. 2). In chicken production, where environmental impacts per kg LW are generally lower compared to pork, feedstuffs are even more important. Here, feedstuffs account for more than 50% of the non-renewable energy consumption and more than 70% of the global warming potential of 1 kg chicken (LW).

In pig production, the differences between conventional production and production under improved animal welfare conditions are minor, as the level of productivity (daily gains, feed conversion, etc.) remains more or less the same and hardly any further inputs are needed. There is only a slight increase in eutrophication and acidification potential which results from higher ammonia emissions due to the straw bedding and the outdoor run.

On the contrary, in chicken production the differences between conventional and label production are considerable. Production intensity in label production is much lower as slower growing strains are used and animals are slaughtered at a higher age. Environmental impacts of label chicken meat are between 25 and 40% higher compared to conventional production (Fig. 1).

Organic pork and chicken meat production has advantages in some categories (e.g. lower toxicity, less potassium and phosphorus use) and disadvantages in others (e.g. higher energy consumption, more agricultural area needed), mainly because of the differences in feedstuff production under conventional and organic conditions. The difference in fattening performance is comparatively small in pig production and higher in broiler production where again slower growing strains and moderate deficiencies in feed rations led to slower growth rates and less feed efficiency.

For monogastric animals, a reduction of environmental impacts by improved feedstuff production and feeding strategies seems to be most promising, albeit other measures (e.g. improved manure management) have also a potential to reduce environmental impacts of meat production. More intensive production systems tend to have less environmental impacts per kg of produced meat because of a more efficient use of inputs, particularly feed. However, systems with improved animal welfare can produce with similar environmental impacts as long as animal performance reaches the same level of productivity.

References

Nemecek, T., Freiermuth Knuchel, R., Alig, M. & Gaillard, G., 2010. The advantages of generic LCA tools for agriculture: examples SALCAcrop and SALCAfarm. In: 7th Int. Conf. on LCA in the Agri-Food Sector, Notarnicola, B. (eds.). Bari, Italy. 433-438.

Hersener, J.-L., Baumgartner, D.U., Dux, D. (Eds.), 2011. Zentrale Auswertung von Ökobilanzen landwirtschaftlicher Betriebe (ZA-ÖB). Forschungsanstalt Agroscope Reckenholz-Tänikon ART, Zürich/Ettenhausen.

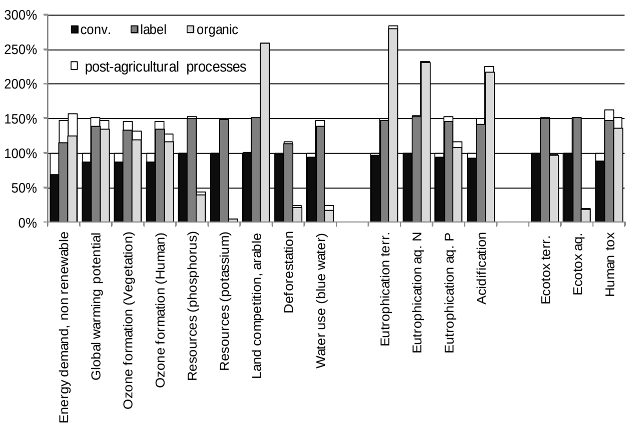

Figure 1. Differences in environmental impacts for 1 kg of chicken meat at farm gate and at the retail store for three production systems in Switzerland. Environmental impacts as described in Nemecek et al. (2010).

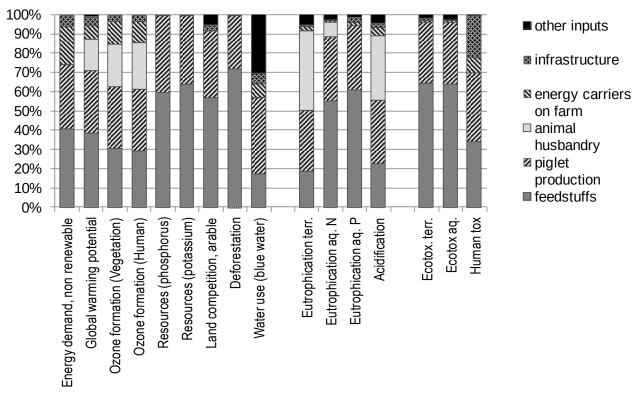

Figure 2. Contribution of inputs to environmental impacts of 1 kg of pork (live weight, at farm gate) for Swiss conventional production. Environmental impacts as described in Nemecek et al. (2010).

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Evaluation of the environmental sustainability of different European pig production systems using life cycle assessment

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The environmental sustainability of 15 European pig production systems has been evaluated within the EU Q-PorkChains project, using life cycle assessment (LCA). One conventional and two differentiated systems were evaluated from each of five countries: Denmark, Netherlands, Spain, France and Germany. The information needed for the calculations was obtained from an enquiry conducted on 5 to 10 farms from each system. The different systems were categorised among conventional (C), adapted conventional (AC), traditional (T) and organic (O).
Compared to conventional, the differentiation was rather limited for AC systems with only some changes in order to improve either meat quality, animal welfare or environmental impact, depending on countries. The difference was much more marked for the traditional systems with the use of fat slow-growing traditional breeds and generally the outdoor raising of the fattening pigs.
The environmental impacts were calculated at farm gate, including the inputs, and expressed per kg live pig and per ha land use. For the conventional systems, the impact per kg live pig on climate change, acidification, eutrophication, energy use, and land occupation were 2.251 kg CO_2-eq, 44 g SO_2-eq, 18,5 g PO_4-eq, 16.2 MJ and 4.13 m2, respectively. Compared to C, the corresponding values were on average 13, 5, 0, 2 and 16% higher for AC; 54, 79, 23, 50 and 156% higher for T, and 4, -16, 29, 11 and 121% higher for O. Conversely, when expressed per ha of land use, the impacts were lower for T and O differentiated systems, by 10 to 60% on average, depending on the impact category. This was mainly due to larger land occupation per kg pig produced as well for feed production and for the outdoor raising of sows and/or fattening pigs. The use of litter bedding tended to increase climate change impact per kg pig. The use of traditional local breeds, with decreased productivity and feed efficiency, resulted in higher impacts per kg pig produced, for all categories. Differentiated T systems with extensive outdoor raising of pigs resulted in markedly reduced impact per ha land use. Eutrophication potential per ha was substantially lower for O systems. Conventional systems were generally better for global impacts, expressed per kg pig, whereas differentiated systems were better for local impacts, expressed per ha land use.
The diversity in production systems considered in the present study resulted in large variations in all environmental impacts. However, the results depend on the functional unit. The degree of intensification inversely correlates with the environmental impact per kg pig, whereas the opposite is found when the impact is expressed per ha. According to the results from this study, LCA appears a suitable methodology for the evaluation of the environmental sustainability of pig production systems and can contribute to the overall assessment of sustainability.

Life cycle assessment of pig slurry treatment technologies

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Large amounts of animal manure are produced in Europe and its management is associated with a number of environmental impacts. Impact categories that are mainly affected by animal manure management are *(a)* global warming potential, caused by methane and nitrous oxide emissions, *(b)* acidification potential, induced by ammonia emissions, and *(c)* eutrophication potential caused by nitrogen and phosphorus emissions.
These impacts are accentuated because an increasing share of agricultural land in Europe receives excessive amounts of animal manure. These so-called hotspot areas are characterised by high livestock densities and insufficient land for manure application. This has resulted in phosphorus surplus in these areas and associated risks for losses to the environment. In other areas, agricultural fields do not receive sufficient amounts of nutrients from manure and farmers need to apply mineral fertilisers to their fields. Non-renewable natural resources like phosphate rock, oil and natural gas, are used for the production of mineral fertiliser and there are considerable environmental emissions, such as CO_2 and phosphate leaching, related to the extraction, manufacturing and use of these fertilisers. In order to decrease the consumption of mineral fertiliser and avoid losses from areas with excessive availability of animal manure, geographical redistribution of animal manure needs to improve.
To enhance nutrient re-distribution, slurry treatment technologies have been developed that focus on the separation of slurry into a solid and a liquid fraction. The liquid fraction contains most of the easily available nitrogen but less than half of the phosphorus, so is mainly valued as a nitrogen fertiliser. However, the high water content in the liquid fraction makes the fraction relatively heavy and less suitable for long distance transportation. Agricultural land nearby the farm often has been treated with slurry for multiple years, which implies that phosphorus concentrations in the soil are already sufficiently high to supply the crop demand. The solid fraction is more transportable, due to its relatively low water content. It has a high concentration of slowly-available nitrogen and phosphorus, so is mainly valuable as a phosphorus fertiliser. Additional technologies that are developed to avoid environmental impacts include ammonia stripping from the liquid fraction, which reduces emissions of ammonia, various technologies for energy extraction and upgrading of the solid fraction such as composting which may improve the solid fraction as a soil amendment.
The objectives of this study are to determine environmental impact potentials of slurry treatment technologies in a Life Cycle Assessment (LCA) and to compare impact potentials of treatment technologies with a reference.
The assessment was performed using consequential LCA and system expansion was used whenever additional processes were included compared to the reference scenario. It assesses the handling of 1000 kg of slurry ex animal and provides an overview of potential impacts on the environment of six different scenarios. These scenarios are *(a)* direct land application (reference scenario), *(b)* solid liquid separation by decanter centrifuge, *(c)* solid liquid separation by mechanical screw press, *(d)* decanter centrifuge separation with ammonia stripping of the liquid fraction and *(e)* screw press separation and composting of the solid fraction. In scenario *(a)*, all manure is applied to agricultural land nearby the farm. In the other scenarios, the solid fraction is transported to agricultural land with low phosphorus status, 100 km away from the farm. The modelling used the GaBi Software and the impact assessment method used was ReCiPe2008.
In general, the treatment technologies analysed in this LCA show environmental impact potential reduction in comparison to a reference scenario. The only scenario that seems to have a higher impact potential, with respect to the global warming potential and acidification, is the scenario with screw press separation and composting of the solid fraction. The decanter centrifuge scenarios show higher impact potential reductions than the screw press scenarios. The sensitivity analysis shows that results are particularly sensitive to phosphorus loss rates. For all variables included in the sensitivity analysis, relative scenario ranking does not change.

Communication of LCA results in the French environmental experimentation context: user-friendly web-based tool for the case of coffee

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Since the 1st of July 2011 a French experimentation on environmental labelling of consumer products is on-going. This experimentation results from the "Grenelle de l'Environnement" initiative, promoted by the French Parliament (Cros et al. 2010). The objective of the Grenelle initiative is to inform consumers about the environmental performance of consumer products throughout their life cycle, as a choice criterion when making a purchase.

One of the main challenges of this initiative is the communication of life cycle assessment (LCA) results to the general public, that is, moving from scientific report based results to simple and user-friendly means of communication. In this context, Quantis has developed with the Nestlé brand *Nescafé®* a web-based tool, called the *Nescafé® LCA Communication Tool*, to present the results of an LCA made on a cup of coffee, one of the products evaluated in the context of the French Experiment. The tool is intended to help in the communication to the general public; therefore, it has been chosen to develop an interactive web-based tool that displays results in an attractive and user-friendly way (http://nescafe.outil-acv.com/).

The full life cycle impacts of a cup of spray dried soluble coffee are based on Humbert et al. (2009) and are assessed for the climate change, water consumption and land occupation impact categories, using IMPACT 2002+ (Jolliet et al. 2003). The results are compliant with the standard developed for the French experimentation (BPX 30-323 2011) and follow the recommendations provided by the specific working group concerning food products leaded by ADEME-AFNOR.

The *Nescafé® LCA Communication Tool* allows consumers to analyse the results per life cycle stage and per indicator. Consumers can "navigate" through the results and discover for themselves the environmental impacts of the different life cycle stages on the selected environmental indicator. This allows displaying complex results of an LCA in a simple and engaging way by having only a limited amount of information on display at a time. Monitoring of consumer perception is on-going through July 2012; results and key learnings will be presented at the conference.

References

BP X 30-323, 2011. Principes généraux pour l'affichage environnemental des produits de grande consommation. Référentiel de bonnes pratiques. AFNOR. France.

Cros, C., Fourdrin, E., Réthoré, O., 2010. The French initiative on environmental information of mass market products. International Journal of Lice Cycle Assessment 15, 537-539.

Humbert, S., Loerincik, Y., Rossi, V., Margni, M., Jolliet, O., 2009. Life cycle assessment of spray dried soluble coffee and comparison with alternatives (drip filter and capsule espresso). Journal of Cleaner Production 17, 1351-1358.

Jolliet, O., Margni, M., Charles, R., Humbert, S., Payet, J., Rebitzer, G., 2003. IMPACT 2002+: a new life cycle impact assessment method. International Journal of Life Cycle Assessment 8(6), 324–30. Version adapted by Quantis (http://www.quantis-intl.com).

Nescafé website, 2011, http://nescafe.outil-acv.com/

Figure 1. Nescafé® LCA Communication Tool interface, "From field to cup"

Figure 2. Nescafé® LCA Communication Tool, LCA results for the global warming potential indicator

Food labelling from a consumers' perspective

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In particular in the food sector the variety of products is enormous. Large stores in Germany sell more than 30.000 different articles, the market as a whole offers more than 100,000 articles. Thus, consumers have to choose between huge varieties of products, some of them quite similar. For decision making they can use the information given on the product.

Against this background the recent practice regarding labelling of food attributes that consumers have to trust in like environmental impacts or social issues is analysed with a focus on Germany. The analysis focusses mainly on environmental issues and identifies problems in recent practice. For this purpose the findings from different studies and strategy papers of commissions and Advisory boards on food labelling have been analysed and brought together. The analysis has been carried out from a 'consumers' perspective' – a research methodology developed in the German research project 'Ernährungswende' founded by the German Ministry for Education and Research (Hayn et al. 2005).

The following insights could be gained (Eberle et al. 2011):

- In general, a "label means any tag, brand, mark, pictorial or other descriptive matter, written, printed, stencilled, marked, embossed or impressed on, or attached to, a container of food" (WHO/FAO 2007, p. 2). Furthermore, consumers also understand results of product tests as labels, i.e. the test results of the German 'Stiftung Warentest' which gives the opportunity to print the results on the product. Also brands can be seen as labels from a consumers' perspective in particular if concrete product qualities are promised with the brands name or logo.
- Up to date there are no food labels in place that consider the whole product's life cycle based on a LCA approach and at the same time cover all important environmental impact categories.
- LCA would certainly be the most appropriate approach to get insights on a product's environmental performance. However, to get an almost complete picture of the quantified environmental impacts of food it is urgently necessary to enforce investigation on suitable methods and on impact categories not yet included in LCA by default like impacts on ecosystems and biodiversity.
- Furthermore, a lot of methodological and 'translation' work - the translation of LCA results in a simple and understandable message that really supports purchasing decisions - is still to be done.
- Empirical research is missing with respect to how consumers understand and use the information given by labels.
- Labels which intend to stimulate development processes towards more sustainability or environmental friendliness - so-called 'process labels' - are still rare, but the need for such labels is seen.

The analysed studies give recommendations how to face the identified problems. Aim has to be to avoid misguidance of consumers, to avoid misuse of labels only for marketing purposes and to support more sustainable or more environmental friendly purchasing decisions through credible and meaningful labels.

References

Eberle, U., Spiller, A., Becker, T., Heißenhuber, A., Leonhäuser, I.U., Sundrum, A., 2011. Political strategy for food-labelling; Joint Statement of the Scientific Advisory Boards on 'Consumer and Food Policy' and 'Agricultural Policy' at the Federal German Ministry of Food, Agriculture and Consumer Protection (BMELV), Berlin

Hayn, D., Eberle, U., Rehaag, R., Simshäuser, U., Scholl, G., 2005. Konsument/innenperspektive. Ein integrativer Forschungsansatz für sozial-ökologische Ernährungsforschung. Discussion paper No. 8, www.ernaehrungswende.de

WHO/FAO (eds.), 2007. Codex Alimentarius, 5th edition, Rome

Communicating LCA results to the interested consumer - development of a criteria-based meat guide

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The carbon footprint (CF) of meat has received increasing attention in the quest for more sustainable eating habits. While a low CF of meat is generally associated with low impacts across animal species in many environmental impact categories, such as eutrophication, acidification and land use, there is a risk of conflicts with categories such as biodiversity loss and pesticide use (Röös et al., 2012). In addition, focusing on reducing emissions of greenhouse gases risks decreasing animal welfare and increasing the use of antibiotics. This project sought to develop a consumer guide that could assist Swedish consumers towards less environmentally harmful meat choices and that could also function as a communication tool, raising awareness of the different environmental aspects of meat production and potential conflicts with animal welfare. The target groups for the consumer guide were 'the interested consumer', i.e. those interested in accurately comparing the environmental impacts of different meat production systems, and employees working with food as their profession, e.g. buyers and personnel in the retail, restaurant and public procurement sectors.

One of the main challenges was to find suitable indicators that accurately communicated the environmental impacts of meat production, while still being easy to understand. One option would have been to use an end-point indicator that aggregated the results from many impact categories. This was done in a meat guide for Swiss consumers, which used the 'potential species loss per year' indicator from the ReCiPe-method (Blonk et al., 2012). However, such aggregation did not satisfy our requirement for a guide that also functioned as a communication tool, raising awareness of the origins and causes of environmental impacts of meat production, the potential conflicts between different environmental goals and the implications for animal welfare. Therefore, CF was chosen as one of four indicators, due to its familiarity and its ability to act as a proxy for eutrophication, acidification and land and energy use in most cases of meat production relevant for the guide. The other three indicators, chosen due to their risk of conflicting with CF, were biodiversity, use of pesticides and antibiotics, and animal welfare. For each indicator, criteria for three levels of environmental or animal welfare 'harm' were developed (Table 1). The well-known metaphor of a traffic light was chosen to illustrate these three levels. The products included in the guide were mainly based on certification schemes or other control programmes with a high level of participation, in order to ensure that the criteria could be verified as thoroughly as possible (Fig. 1). Displaying the impact categories explicitly allowed conflicting environmental goals to be demonstrated in an illuminating way. For example, it can be seen that animal welfare-friendly, pasture-based beef production, which keeps pastures open and helps conserve their rich biodiversity and minimises the use of pesticides and antibiotics, is also associated with high emissions of greenhouse gases.

All simplifications involve difficulties in conveying a complete and fair picture. The meat guide presented here has several disadvantages as regards guiding consumers towards less environmentally harmful food choices. For example, all indicators are given equal weight although the CF indicator acts as a proxy for several impact categories, and the design of the criteria includes subjective judgements. However, the guide represents an attempt to make LCA results on the food product category with the greatest environmental impact accessible to the wider public.

References

Blonk, H., Marinussen, M., Goedkoop, M., 2010. Developing an LCA based consumer guide for environmental and animal welfare performance of meat/animal products. Proceedings of LCA Food 2010 (Vol 1), pp. 381-386

Röös, E., Sundberg, C., Tidåker, P., Strid, I., Hansson, P-A., 2012. Can carbon footprint serve as an indicator of the environmental impact of meat production? Ecological Indicators, in review.

Table 1. Criteria for different traffic light symbols.

Global warming	Carbon footprint less than 1.5 kg CO_2e/kg	Carbon footprint between 1.5 and 12 kg CO_2e/kg	Carbon footprint greater than 12 kg CO_2e/kg
Biodiversity	Contributes positively to the preservation of sensitive flora and fauna (through grazing of pastures) **or** require less than 5 m^2 per kg of product (reducing the pressure on new cropland globally)	Does not use imported soy **and / or** the cultivation contributes to more plants and animals in the cultivated landscape	Other
Use of pesticides and antibiotics	The use of chemical pesticides is not permitted **or** requires less than 5 m^2 per kg product **and** very restrictive antibiotic use	Low pesticide use (up to 0.25 g active ingredient per kg of grain) **and** very restrictive antibiotic use	Other
Animal welfare and outdoor grazing	Covered by the Swedish animal welfare legislation or equivalent **and** allowed to graze outdoors	Covered by the Swedish animal welfare legislation or equivalent **or** are allowed to graze outdoors	Other

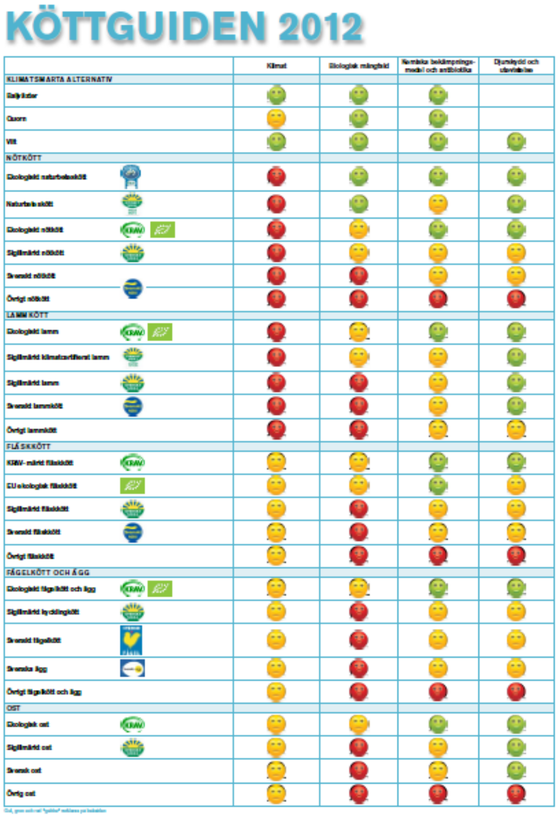

Figure 1. The Swedish meat guide

Life cycle impacts of protein-rich foods for consumer information. How LCA results can be used to inform consumers to make environmentally sustainable supermarket choices

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CE Delft has calculated the environmental impacts of 98 different animal products and animal product alternative life cycles from the farm to the supermarket. The goal of this study was to provide the consumer with scientifically sound environmental data for several protein-rich products. As there are currently several different variants of products available in the supermarkets, such as conventional, organic and free-range options, it is often difficult for the consumer to assess the relative sustainability of products. The results of this expansive life cycle assessment have been used in a mobile application. This consumer support tool will allow Dutch consumers to scan product barcodes and obtain relevant environmental impact information on their mobile phones. This tool is envisioned to be also made applicable for other European countries in the near future. The life cycle assessments were focussed upon accurately modelling the current impacts of the studied products. In that way comparisons could be made not only *between* product groups but also *within* product groups.

The impact assessment for the products was carried out using a customised version of the ReCiPe (hierarchic) method on both mid and endpoint levels. This was done in order to relate to the consumers perception and understanding of sustainability issues regarding protein-rich products. All of the impact categories have, for this reason, been clustered into four main categories: Nature and Environment (measured in species.year), Human Health (measured in DALY), Climate Change (measured in kg CO_2 eq, Land Use (measured in m^2) The results of the environmental assessment of the categorised 98 products are shown in Fig. 1 and Fig. 2 for nature & environment and climate change, respectively.

The results from the analysis show substantial differences between the lowest and the highest scoring products, particularly in terms of the effects on nature & environment. As shown in Figs. 1 and 2, there are clear outliers in the results, both in terms of low environmental impact and high environmental impacts. However, the most pronounced trend is that the difference in environmental impact within product groups can be just as great as the environmental impacts between product groups. Large variations in environmental impacts within product groups can have an effect on the ranking of a particular product group, such that general statements regarding the scores of specific groups are more difficult to be made.

In the presentation we will not only go into detail regarding the results, but will also discuss the choice of impact assessment categories and presentation of the results into the consumer support tool.

References

Blonk, H., Kool, A. and Luske, B. (2008). Milieueffecten van Nederlandse consumptie van eiwitrijke producten: Gevolgen van vervanging van dierlijke eiwitten anno 2008, Blonk Milieuadvies, 2008

Broekema, R., Blonk H., with Alverado, C. and Hegger, S. (2009). Milieukundige vergelijkingen van vleesvervangers, Blonk Milieuadvies, 2009

Cederbeg, C., Persson, U.M., Neovius, K., Molander, S. and Clift, R. (2011). Including Carbon Emissions from Deforestation in the Carbon Footprint of Brazilian Beef. Environmental Science and Technology, vol. 45, no.5 (2011); p. 1773-1779.

Head, M., Sevenster, M. and Croezen, H. (2011). Life Cycle Impacts of Protein- rich Foods for Superwijzer. Report 11.2329.57, CE Delft.

IDF (2010), A common carbon footprint approach for dairy: the IDF guide to standard lifecycle assessment methodology for the dairy sector, In: Bulletin of the International Dairy Federation no.445, 2010

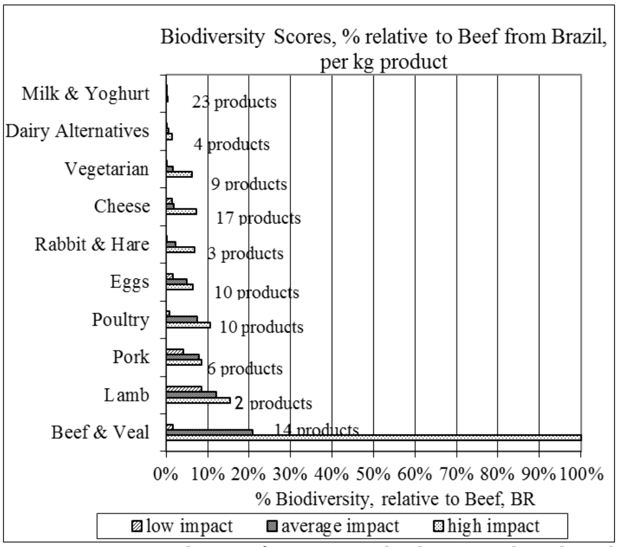

Figure 1. Categorised scores for impact on biodiversity. The coloured bars indicate the lowest impact (green), average (yellow) and highest (red) scores per category. The number of products represented in each category is given beside the scores

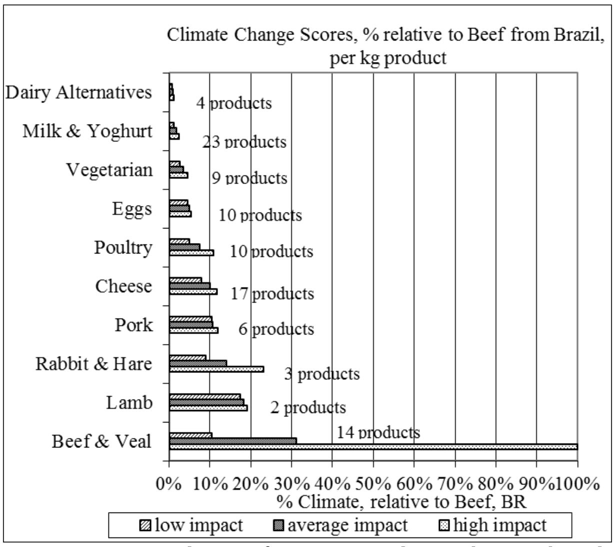

Figure 2. Categorised scores for impact on climate change. The coloured bars indicate the lowest (green), average (yellow) and highest (red) scores per category. The number of products represented in each category is given beside the scores

Environmental impact of different broiler production systems in Malaysia and consumer willingness to pay for reduced impact

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In Malaysia, the steady increase in poultry meat production might be taxing to the environment because much of the increased production comes from intensive systems. As yet, there have not been any studies which quantify the environmental impacts of broiler chicken production in different systems in Malaysia, nor the potential for consumers to pay any additional costs arising from changes in production systems to minimise environmental problems. The objectives of this study were to i) estimate the environmental impact of different broiler production systems in Malaysia; and ii) estimate consumers' willingness to pay (WTP) for chicken meat produced with a higher regard for the environment, with consideration of socio-demographic and economic characteristics.

Evaluation of the environmental impact of broiler production systems was carried out using the Life Cycle Assessment (LCA) method, with a functional unit of 1 tonne live weight of broiler chicken and by taking a cradle to farm-gate approach through the use of specialist software (SimaPro 7.3, PRé Consultants, Amersfoort, Netherlands). The environmental impact analysis used data from the two major broiler chicken production systems, namely intensive closed-house and open-house systems, and a semi-intensive system. Standard data including feed intake, physical performance, energy and materials used were supplied by the broiler industry. The analysis also considered feed production, transportation, and the fate of the manure. Results showed that feed production and transportation contributed the greatest impact for all systems. Four midpoint impact categories from both production systems (Table 1) show clear differences between the three housing systems, with the closed house system being the least environmentally impacting.

For consumer behaviour, a Contingent Valuation Method (CVM) was used to ascertain the maximum WTP of consumers for broiler-HRE using a structured survey across Peninsular Malaysia, representing different socio-demographic divisions of society. Data were also collected to estimate consumer awareness about the impact of broiler production on the environment and attitudes when purchasing chicken meat. Selected consumer attributes were then used to examine relationships which relate consumers' choices and their WTP. Over half of respondents believed environmental problems were generated from the production stage (including housing system), whereas 44% stated that manure handling had negative impacts to environmental quality. Only 5% considered that production of feed (including transportation) contributed to environmental problems. The environmental awareness of respondents resulted in a stated WTP value which was significantly more than average current price at both national and regional levels. Thus, over 50% of respondents were willing to pay an increment of 10% above the existing market price. Relationship tests showed that education, occupation class and gender were parameters that influenced respondents' WTP for broiler-HRE.

The findings of this study will be a catalyst to investigate the potential policy changes which could be brought in to animal production in Malaysia and to assess their impact on the poultry industry from producers' and Government perspectives in order to achieve sustainable meat production by the convergence of the three recognised sustainability pillars of economic development, social equity and environmental protection.

Table 1. Life cycle impact assessment of energy use, global warming potential, acidification potential and eutrophication potential associated with the production of one tonne live weight of broiler chickens from three different Malaysian housing systems.

Production System	**Energy Use (MJ)**	**Global Warming Potential (kg CO_2 eq.)**	**Acidification Potential (kg SO_2 eq.)**	**Eutrophication Potential (kg PO_4 eq.)**
Intensive system				
Closed House	8,375	1,257	16.8	10.0
Open House	8,484	1,367	19.4	11.7
Semi-Intensive	10,386	1,747	23.6	14.1

Table 2. The environmental impacts from different broiler production systems in Malaysia (FU of 1 tonne live weight of broiler chicken).

Production System	**Global Warming Potential* (kg CO_2 eq)**	**Acidification Potential (kg SO_2 eq.)**	**Eutrophication Potential (kg PO_4 eq.)**
Intensive system			
Closed House	1,881	13.8	8.19
Open House	2,102	15.9	3.52
Semi-Intensive	2,355	17.6	10.64

Table 3.

Impact by system	**Broiler feed-related**		**Breeder feed-related**		**On-farm inputs/ emission**		**Fertiliser credit**	**Total**
Energy use (MJ)								
Closed house	8,946	*74.2%*	828	*6.9%*	2,280	*18.9%*	-3,679	**8,375**
Open house	10,417	*83.4%*	1,104	*8.9%*	908	*7.3%*	-3,945	**8,484**
Semi-intensive	12,892	*84.9%*	1,065	*7.0%*	1,236	*8.1%*	-4,807	**10,386**
Global Warming Potential (kg CO_2 eq.)								
Closed house	1,603	*82.7%*	142	*7.3%*	192	*9.9%*	-680	**1,257**
Open house	1,866	*86.7%*	190	*8.8%*	95	*4.4%*	-784	**1,367**
Semi-intensive	2,309	*87.6%*	179	*6.8%*	148	*5.6%*	-889	**1,747**
Acidification Potential (kg SO_2 eq.)								
Closed house	12.8	*67.8%*	1.2	*6.5%*	4.9	*25.7%*	-2.0	**16.8**
Open house	14.9	*68.5%*	1.6	*7.5%*	5.2	*24.0%*	-2.3	**19.4**
Semi-intensive	18.4	*70.1%*	1.4	*5.2%*	6.5	*24.6%*	-2.7	**23.6**
Eutrophication Potential (kg PO_4 eq.)								
Closed house	7.9	*76.0%*	0.7	*7.0%*	1.8	*17.0%*	-0.3	**10.0**
Open house	9.2	*76.1%*	1.0	*8.0%*	1.9	*15.9%*	-0.4	**11.7**
Semi-intensive	11.4	*78.6%*	0.7	*5.0%*	2.4	*16.4%*	-0.4	**14.1**

Environmental impacts accompanying the production of milk, bovine meat and grain under heterogeneous conditions in Norway

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We will present key results from a large, ongoing, three-year project on environmental impact and resource use efficiency of selected food production chains in Norway (from cradle to store). The assessment presented here covers processes from cradle to farm gate, including all activities on the farm, along with the production of machinery, equipment, buildings, diesels, oil, fertiliser, lime, seeds, pesticides and medicines. Net mineralisation of humus, which may play a major role for greenhouse gas emissions under certain conditions, is also considered.

In the ongoing project, the ambition is to account for the outspoken heterogeneity, which characterises Norwegian agricultural systems, as soil type, management, climatic- and topographic conditions may vary largely between regions and between farms within the same region. To do so, we use high resolution inventory data, based partly on interviews with farmers, farm advisors, and agricultural experts, partly on data available in databases (e.g. soil properties, yields), and partly on models used for interpolations where robust data is lacking.

LCA studies of Norwegian agri-food chains are scarce in the peer reviewed literature. A better understanding of the environmental impacts associated with agricultural production in Norway is important for three main reasons: Firstly, such data is required for environmental benchmarking of various food pathways in order to assess the environmental profile of Norwegian food production versus imported products. Secondly, establishing and consolidating knowledge on the environmental profile of current production practices is essential to develop future agriculture policies in an increasing carbon constrained world. Thirdly, a recent political goal set for the agricultural sector in Norway push for an increase in production of 1% annually for the next 20 years, and this increase should be as environmental friendly as possible.

The objective of this study is to perform a life cycle assessment from cradle to farm gate for Norwegian cereal- and dairy production, covering the three most important regions for each production chain, respectively. Functional units are 1 kg of barley, oats, wheat, bovine carcass and energy corrected milk. There will be focused on identifying regional hotspots, and scenarios will be run in order to find possible, region wise improvements to reduce the overall environmental impact.

Assessing carbon, water and land use footprints for beef cattle production in southern Australia

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For agri-food products, environmental impacts from GHG emissions, water and land use are often most important. There are also many tradeoffs between these, meaning that any single stand-alone indicator is of limited value in motivating wise decision making which leads to reduced overall environmental burden. For example, land can be used for food production or for carbon sequestration and some forms of agriculture conserve more carbon than others. Actions to reduce agricultural GHG emissions may involve greater water use, and actions to achieve water efficiency and water quality objectives may involve greater energy use. Furthermore, a small area of irrigated land may produce as much food as a larger area of non-irrigated land. The evaluation of alternative agri-food production systems and products is therefore not straightforward.

In previous research, the carbon footprints (cradle to farm gate) for six diverse beef cattle production systems in southern Australia were calculated and found to range from 10.1 to 12.7 kg CO_2e kg^{-1} live weight (Ridoutt et al., 2011). This compared to LCA-based water footprints of 3.3 to 221 L H_2Oe kg^{-1} live weight for these same systems (Ridoutt et al., 2012), calculated using the Water Stress Index (WSI) of Pfister et al. (2009). Following Ridoutt and Pfister (2010), 1 L H_2Oe represents 1 L of consumptive freshwater use at the global average WSI. In this study, land use footprints were calculated and expressed in the reference unit m^2.yr-e, where 1 m^2.yr-e represents 1 m^2 of land occupation for 1 year at the global average potential net primary productivity (NPP_0). To assist in interpretation, the carbon, water and land use footprint results were also normalised using the global economic system in the years 1995-2000 as a reference.

For beef cattle production in southern Australia, the land use footprint results ranged from 86 to 172 m^2.yr-e kg^{-1} live weight, which represents between 1.3 and 2.7% of an average global citizen's annual land use footprint. These results were approximately 10 and 1000 times the normalised carbon and water footprint results, thereby highlighting the importance of land use in cattle production.

An LCA-based land use footprint indicator could help in understanding the incremental pressure on land resources of agri-food production systems and consumption patterns, and enable the assessment of tradeoffs with GHG emissions and water use impacts. A simplified resource-based assessment of land use in LCA could also offer advantages in terms of reliability, transparency and communicability over a profile of indicators relating to individual ecosystem services. While NPP_0 is an objective measure of the intrinsic productive capability of land and can be used to improve land use assessment beyond a simple measure of land area alone, further development of the land use footprint indicator is recommended as factors other than NPP_0 determine the desirability of land in terms of human development.

References

Pfister, S., Koehler, A., Hellweg, S., 2009. Assessing the environmental impacts of freshwater consumption in LCA. Environ. Sci. Technol. 43, 4098-4104.

Ridoutt, B.G., Pfister, S., 2010. A revised approach to water footprinting to make transparent the impacts of consumption and production on global freshwater scarcity. Glob. Environ. Change 20, 113-120.

Ridoutt, B.G., Sanguansri, P., Freer, M., Harper, G., 2012. Water footprint of livestock: Comparison of six geographically-defined beef production systems. Int. J. Life Cycle Assess. 17, 165-175.

Ridoutt, B.G., Sanguansri, P., Harper, G.S., 2011. Comparing carbon and water footprints for beef cattle production in southern Australia. Sustain. 3, 2443-2455.

Effect of farming practices on environmental impacts of beef cattle production systems

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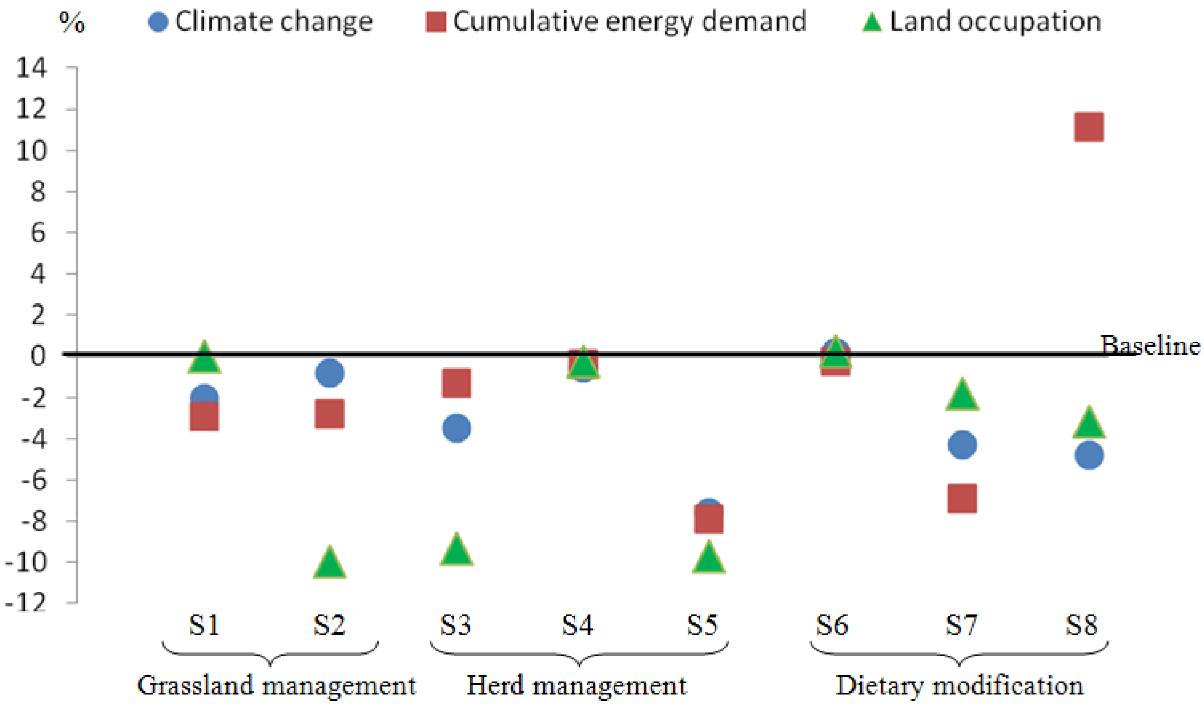
This study examines farming-practice scenarios aiming to reduce environmental impacts of beef-cattle production systems using the life cycle assessment approach. Our baseline scenario includes a standard cow-calf herd with finishing heifers based on grazing, and a standard bull-fattening herd using a diet mainly based on maize silage, corresponding to current farm characteristics and management by beef farmers in France. Description and results are in Nguyen et al. (2012). Eight farming-practice scenarios aiming to reduce green-house gas emissions relative to the baseline scenario were developed. These scenarios are based on practices that are currently applied by some farmers or that can be applied without adverse effects on animal performances, based on experimental results. These scenarios modified grassland management (S1: decreasing mineral N fertiliser on grassland; S2: decreasing grass losses during grazing) or herd management (S3: intensified fattening of female calves from 9 to 19 months; S4: increasing longevity of cows from 7 to 8 years; S5: advancing first calving age from 3 to 2 years). Other scenarios modified the diet, such as replacing protein sources (S6: partially replacing a protein supplement by lucerne hay for the cow-calf herd, S7: replacing soybean meal with rapeseed meal for the fattening herd) or increasing omega-3 fatty-acid content using extruded linseed (S8). Compared to the baseline, the most promising practice to reduce environmental impacts was decreasing calving age (S5), which decreased climate change and cumulative energy demand per kg carcass by 8% (Fig. 1). Feeding extruded linseed (S8) decreased climate change by 5% by reducing enteric methane but increased cumulative energy demand by 11% due to the energy needed to produce the extruded linseed and concentrate feed. For some scenarios (S2, S3 and S5), land occupation per kg of carcass decreased by 9-10%. If this area no longer needed for cattle production were converted to forest (with an average 55-year rotation) to sequester carbon in tree and soil biomass, climate change per kg of carcass could be reduced by 7, 10 and 14% for scenarios S2, S3 and S5, respectively. Effects of farming-practice scenarios on environmental impacts depended on impact categories. Each of these scenarios affected only part of the whole system; therefore, reductions in impacts did not exceed 10%. We have yet to explore scenarios combining several of the most promising options; doing so may further decrease environmental impacts of the beef-production system. The feasibility of applying these practices depends on local climate and soil conditions and the willingness of farmers to adopt innovations in their management. Planting forest on land no longer needed to produce beef can considerably reduce a farm's environmental impacts.

References

Nguyen, T.T.H., van der Werf, H.M.G., Eugène, M., Veysset, P., Devun, J., Chesneau, G., Doreau, M., 2012. Effects of type of ration and allocation methods on the environmental impacts of beef-production systems. Livest. Sci., accepted.



S1: Mineral N-fertiliser decreased from 28 to 18.5 kg/ha of permanent grassland
S2: Grass losses on pasture decreased from 31.5 to 16.5%
S3: Female calves fattened intensively instead being reared at a moderate growth rate
S4: Cow longevity increased from 7 to 8 years
S5: Age at calving decreased from 3 to 2 years
S6: Protein supplement partially replaced with lucerne hay
S7: Soybean meal replaced with rapeseed meal
S8: Lipid content in winter diets increased by using extruded linseed instead of concentrate

Figure 1. Change in climate change, cumulative energy demand and land occupation impacts (per kg carcass) of farming-practice scenarios applied to beef-production systems (S1 to S8) relative to the baseline scenario.

An assessment of greenhouse gas emissions and economics of grass based suckler beef production systems

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In Ireland, agriculture is the largest contributor of greenhouse gas (GHG) emission accounting for 30.4% of total emissions in 2010 (EPA, 2011). Agriculture will be required to share the burden of the EU target to reduce emissions by 20% by 2020. The objective of this paper was to evaluate the impact of stocking rate for steer beef production systems on technical and economic performance and greenhouse gas emissions taking account of both farm emissions (direct and indirect) and emissions up stream of the farm gate (those associated with the production of farm inputs). A bioeconomic model of suckler beef production systems, the Grange Beef Systems Model GBSM (Crosson, 2008) was used to generate steer beef system production scenarios and to evaluate their technical and economic performance. The scenarios were based on spring calving suckler calf to beef research farm systems in Ireland finishing heifers and steers at 20 and 24 months of age, respectively. Stocking rate was increased by increasing fertiliser nitrogen (N) application rates. Eight scenarios representing production systems stocked at between 150 and 220 kg organic N/ha were evaluated. To model the impact of each scenario on GHG emissions, the technical output of the GBSM was used as inventory analysis in the LCA model and various GHG emission factors were integrated with the production profile. All the estimated GHG emissions are converted to their 100-year global warming potential carbon dioxide equivalent (CO_2e) which on a weight basis, relative to CO_2 was set to a factor of 25 for methane (CH_4) and 298 for N_2O. Carcass output and profitability increased with increasing stocking rate. At a stocking rate of 150 kg organic N/ha, total emissions were lowest when expressed per kg of beef carcass (22.2 kg CO_2e /kg beef) and per hectare (9.2 t/CO_2e/ha). As stocking rate increased, output and economic returns also increased with modest increases in GHG emissions per kg beef. However, emissions per hectare increased substantially with stocking rate increases. Enteric fermentation was the greatest source of GHG emissions and ranged from 48% to 47% of total emissions with increasing stocking rate. As stocking rate increased, the relative contribution to total GHG emissions was also lower for manure management and diesel use, whereas the contribution was higher for emissions associated with soils, indirect N_2O and purchased inputs. The higher emissions from soils, indirect N_2O and purchased inputs rate are a reflection of the greater amount of N fertiliser applied, greater amount of N leaching and ammonia volatilisation, and greater amount of fertiliser production, respectively, as stocking rates increased. Net margin per tonne of CO_2e was lower at a stocking rate of 150 kg organic N/ha (€39.5/t CO_2e) compared to the stocking rate of 220 kg organic N/ha (€49.5/t CO_2e). The analysis showed that production systems which minimise emissions on an area and product based basis also result in lower profitability. Furthermore, the analysis showed that profitability can be increased substantially by operating at higher stocking rates with only modest increases in GHG emissions per kg beef carcass.

References

Crosson, P. 2008 Proc. of the 22nd Annual Meeting of the European Grassland Federation, Uppsala, Sweden, 9-12 June p. 771

EPA, 2011. Ireland's Greenhouse Gas Emissions Projections 2010-2020. Environmental Protection Agency, Johnstown Castle Estate, Co. Wexford, Ireland.

Could cultured meat reduce environmental impacts of agriculture in Europe?

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Livestock production is one of the major contributors to global environmental degradation. The contribution of livestock production to greenhouse gas (GHG) emissions in the European Union (EU) has been estimated to account for 9.1% of total EU emissions or 12.8% when land use and land use change emissions are taken into account. Furthermore, livestock production accounts for a large share of land and water use, and is the main contributor to the eutrophication of water ways and losses of biodiversity. The main strategies to reduce the negative environmental impact of livestock production include changes in feeds, improvements of manure management and breeding animals with higher feed-to-food conversion ratios. To achieve more substantial improvements, new approaches to meat production will be required, unless vast majority of people adopt purely plant based diets.

A novel alternative to conventionally produced meat is to cultivate animal muscle cells *in vitro* without growing the whole animals. Currently, cultured meat, also known as *in vitro* meat, production is in the research stage, but it has been estimated that the commercial production could start within a decade. It has been shown that the potential environmental impacts of cultured meat are substantially lower compared to meat produced in Europe. When cyanobacteria hydrolysate is used as the main nutrient and energy source for the muscle cell growth the life cycle assessment based GHG emissions were 78-96% lower, land use 99% lower and water use 82-96% lower compared to conventionally produced European meat. Energy use was higher compared to poultry, but lower compared to beef, sheep and pork.

This paper extends previous research by demonstrating the total potential GHG emission reductions, and changes in land, water and energy use requirements in the EU-27 with differing replacement levels of conventional versus cultured meat. The environmental benefits resulting from alternative use of land released from agriculture are also considered. Furthermore, the impacts of cultured meat are compared with plant based protein sources. Finally, the uncertainties related to the potential of cultured meat mediated reductions in environmental impacts of livestock production in the EU are discussed.

The results showed that if all meat produced in the EU-27 was replaced by cultured meat, the GHG emissions would be reduced by two orders of magnitude compared to current meat production practices (Table 1). When the opportunity costs of land use were included, the environmental benefits were even higher. When the environmental impacts of cultured meat were compared with meat products, crops, tofu and quorn per unit of product, protein and energy (Table 2), it was found that cultured meat had lower land use requirements than any other product, regardless of functional unit, except spirulina. The energy use and GHG emissions of cultured meat were higher than those of crops. More research and development is required before the product can be commercialised. Efforts are also needed for gaining the public acceptance of the technology.

References

Leip, A., Weiss, F., Wassenaar, T., Perez, I., Fellmann, T., Loudjani, P., Tubiello, F., Grandgirard, D., Monni, S., Biala, K. 2010. Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions (GGELS) – final report. European Commission, Joint Research Centre.

Tuomisto, H.L., 2010. Food Security and Protein Supply –Cultured meat a solution? Aspects of Applied Biology. 102, 99-104.

Tuomisto, H.L., Hodge, I.D., Riordan, P., Macdonalds, D.W. 2012. Comparing energy balances, greenhouse gas balances and biodiversity impacts of contrasting farming systems with alternative land uses. Agricultural Systems. 108, 42-49.

Tuomisto, H.L., Teixeira de Mattos, M.J., 2011. Environmental Impacts of Cultured Meat Production. Environ. Sci. Technol. 45, 6117-6123.

Table 1. Estimated impacts for the entire EU-27 of current meat production practices and reduction achieved by using cultured meat technology with and without taking into account land use and land use change (LULUC) emissions (the former includes opportunity costs of land use).

Impact	Unit	Current meat	Cultured meat	Reduction quantity	%
GHG without LULUC	1000 t CO_2-eq	301570	3669	297900	99
GHG with LULUC	1000 t CO_2-eq	434565	-2183663	2618200	603
Water use	1000 m^3	164250	10060	154200	94
Land use	km^2	1650000	4474	1645500	100

Table 2. Land use, energy use, greenhouse gas emissions (GHG), and water use of plant, livestock and meat substitute products per functional unit of mass, protein, or energy in the product.

	per edible (t)				per protein (t)				per energy unit (TJ)			
Product	Land ha	Energy TJ	GHG t CO_2-eq	Water 1000m^3	Land ha	Energy TJ	GHG t CO_2-eq	Water 1000m^3	Land ha	Energy TJ	GHG t CO_2-eq	Water 1000m^3
wheat	0.14	2.5	0.8	3.6	1.1	19	6	28.2	11	0.2	62	27.6
soybean	0.42	3.0	1.3	2.2	1.2	8	4	6.1	27	0.2	84	140.9
maize	0.14	2.4	0.7	1.4	1.1	19	5	10.8	10	0.2	44	92.8
field bean	0.30	2.0	1.0	3.0	1.4	9	5	13.6	22	0.1	74	219.5
spirulina	0.02	10.1	0.8	0.5	0.0	16	1	0.7	2	0.7	54	29.3
beef	4.34	52.5	29.8	11.8	19.3	233	132	99.2	679	8.2	4665	3491.6
pork	0.99	22.3	8.5	4.9	4.5	102	39	29.8	108	2.4	928	711.1
sheep	2.91	48.7	36.9	8.3	14.5	243	184	87.9	297	5.0	3766	1796.3
poultry	0.94	17.6	6.7	3.8	4.2	79	30	25.2	103	1.9	733	612.5
salmon	-	25.4	1.8	-	-	151	11	-	-	3.7	260	-
eggs	0.55	11.8	4.6	3.4	4.4	94	37	30.1	105	2.2	878	716.4
milk	0.12	2.5	1.1	1.1	3.7	79	33	33.6	45	1.0	400	406.0
cheese	0.72	20.0	8.8	5.2	2.8	78	34	20.2	42	1.2	510	299.0
quorn	0.17	38.0	2.3	-	1.0	233	14	-	38	8.5	514	-
tofu	0.30	15.6	2.0	-	3.8	200	26	-	86	4.5	575	-
cultured meat	0.02	31.7	1.9	0.5	0.1	166	10	2.7	5	7.1	423	116.5

The environmental effects of seasonal food purchasing: a case study

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As urbanisation progressed in the second half of the 20th Century and the agricultural workforce shrank, so Western European citizens disengaged from food production, losing their connection with its seasonal patterns. Recently, interest in seasonal foods has been resurgent; Dibb et al. (2006) state that 2/3 of people in the UK are now "taking steps to buy seasonally".This trend has various drivers but - as Dibb et al.'s title suggests - some see implications for the environment in it.

We discuss elsewhere the difficulty of clearly separating seasonal food from "unseasonal" (Brooks et al. 2011). Here, drawing on a study of several foods funded by Defra, we consider the question of how environmental impacts vary across the year for a food consumed in the UK by applying life cycle assessment (LCA) to one fruit, the raspberry. Fig. 1 shows how UK consumption of raspberries changes through the year. There is hardly competition between local production - which many would term "seasonal" - and imports; rather the latter complement the former in an overall supply pattern. To gain some insight into the environmental implications of this supply pattern an LCA of raspberries was conducted. This covered 3 functional units:

A. 1kg raspberries delivered fresh to a supermarket distribution centre (RDC) in May
B. 1kg raspberries delivered fresh to a supermarket RDC in July
C. 1kg raspberries delivered frozen to a supermarket RDC in November

For A, the product system involved production in Southern Spain in fields that are covered for the whole season with polytunnels; raspberry canes are imported and ground prepared each year. For B and C production was in the east of England, on canes grown for seven years in fields covered with polytunnels during fruiting. These are commonly-encountered systems and sites producing for the UK supply pattern. Product systems incorporated production of canes and polytunnels as well as all other inputs.

Primary data from individual operating locations were used to characterise agricultural operations, with expert consultation used to fill data gaps. Background data for inputs such as fertilisers, fuel and polyethylene film were taken from the ecoinvent database v2. A single set of data, from one of the operating locations, was used to characterise all packhouse operations and packaging. Datasets representing refrigerated transport and cold storage were developed using survey data for the UK (Brunel University 2009; Evans, n.d) and ecoinvent vehicle operation/electricity data.

Impact assessment used CML midpoint methods for the categories global warming, eutrophicaiton, acidification and photochemical oxidation. In addition agricultural land occupancy, weighted and unweighted water footprint and the environmental impact quotient (EIQ) of pesticides used were reported.

The impact assessment results are shown in Table 1. The differences between the three situations are not large, except in the case of the water footprint measures. The fact that both canes and fruit are subject to long-distance refrigerated transport is a significant factor behind the higher acidification and abiotic depletion values obtained for A. Sensitivity analysis shows that the results in each particular case are very sensitive to fruit yield, and for A also to the yield of canes in cane production. For impact categories other than water, likely (e.g. year-to-year) variations in these factors could cause changes in the results greater than the differences between columns A, B and C of Table 1.

References

Brooks, M., Foster, C., Holmes M., Wiltshire J., 2011. Does consuming seasonal foods benefit the environment? British Nutrition Bulletin, 36, 449-453.

Brunel University, 2009 GHG Impacts of Food Retailing; report of project FO 0405. Defra, London.

Dibb, S., Collins, J. and Mayo, E., 2006. Season's Promise: an enjoyable way to tackle climate change. National Consumer Council.

Evans, J., n.d. Cold storage of food. Review of available information on energy consumption and energy savings options. FRPERC, University of Bristol.

Table 1. LCIA results, raspberries in the UK at different times of year.

Impact Category	Product System: A. Raspberries, fresh at UK RDC in May	B. Raspberries fresh at UK RDC in July	C. Raspberries frozen at UK RDC in November
GWP100 (kg CO_2 eq)	7.3	7.4	7.7
Water footprint (WF) (m^3 Virtual water)	2.7	1.3	1.3
Weighted WF (m^3 Virtual water)	2.7	0.09	0.09
Agricultural land occupation (m^2.yr)	1.5	1.6	1.6
Pesticide hazard indicator E.I.Q., direct	0.3	0.3	0.3
Abiotic depletion (kg antimony eq.)	0.01	0.004	0.006
Photochemical oxidation -high NO_x (kg ethylene eq.)	0.0004	0.0001	0.0002
Acidification - (kg SO_2 eq.)	0.01	0.003	0.004
Eutrophication (kg PO_4--- eq.)	0.005	0.004	0.004

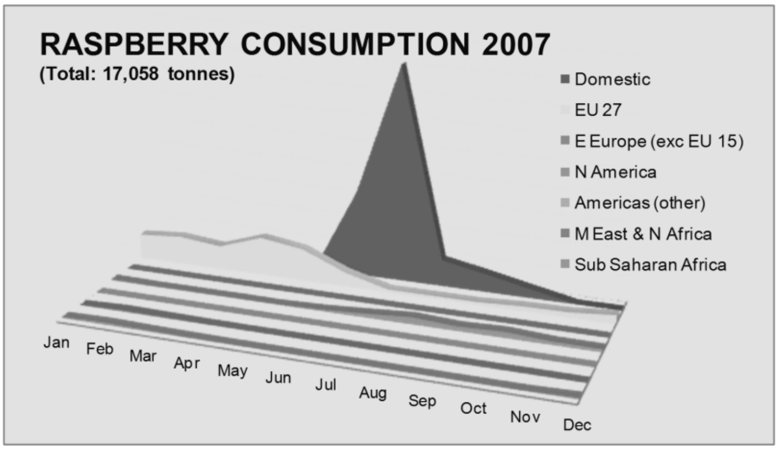

Figure 1. UK Raspberry Consumption, 2007, Source: UK Trade Statistics

Food waste from cheese and yoghurt in a life cycle perspective

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Food loss gives a major contribution to climate changes. I many LCA studies this is an element, which have not been included at all or with data only based on assumptions. In this case study of cheese, specific data of food loss have been included for retailer and consumer. In a similar study on yoghurt, specific data of food loss have been included for retailer.

In the LCA of cheese and its packaging system, sliced cheese is compared to cheese in whole pieces (Curran, 2012). The results show that consumer waste is much higher for cheese in whole pieces than sliced cheese. The difference outweighs the increased use of packaging for sliced cheese. GHG emissions of food loss are calculated as both emissions from production of the cheese that becomes waste and emissions from waste management. The packaging system in itself represents approximately 3% of total GHG emissions for sliced cheese, but as shown above it affects the whole system much more than production of packaging and packaging waste. By comparison the packaging for cheese in whole pieces represents less than 1% for the total GHG emissions.

In the LCA of yoghurt, four different sizes of product and belonging packaging systems are compared. The results show that the packaging for the largest product unit had the lowest total GHG emissions. The packaging system represents between 6% and 14% of total GHG emissions for the four yoghurt systems.

The results of the study support the literature (Williams et al., 2008 and Johansson, 2002) but also provide increased robustness by using specific data for product waste. A packaging system with a larger packaging consumption can be justified with reduced environmental impact if it avoids products waste.

References

Curran, M. A. 2012. Life Cycle Assessment Book. In press.

Johansson, 3. 2002. Förpackningens betydelse för produktförluster i hemmet. Packforsk report nr. 204.

Ventour, L 2008. "The Food We Waste" Report from WRAP, England. http://wrap.s3.amazonaws.com/the-food-we-waste.pdf

Williams, H., Wikström F., Löfgren M., 2008. A life cycle perspective on environmental effects of customer focused packaging development. Karlstad University, SE-651 88 Karlstad, Sweden. Journal of Cleaner Production 16, 853-859.

Büsser S. and Jungbluth N. (2009) LCA of Yoghurt Packed in Polystyrene Cup and Aluminium-Based Lidding. ESU-services Ltd. Uster, Switzerland. Commissioned by German Aluminium Association (GDA) in cooperation with European Aluminium Foil Association (EAFA), Düsseldorf, Germany.

Bulletin of the IDF No. 436/2009 - Environmental/Ecological Impact of the Dairy Sector: Literature review on dairy products for an inventory of key issues List of environmental initiatives and influences on the dairy sector http://ns6924.ovh.net/Residents/filidf/Public/Publication.php?ID=28664.

Food waste in the food chain and related climate impacts

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Finnish Foodspill study focusing on mapping the volume and composition of avoidable food waste in Finnish food production-consumption chain (food industry, retail, food services, and households) was carried out in Finland in 2010. Household food waste was studied through a follow up – study in which 380 households, in total, weighed their avoidable food waste daily during a two-week period. Food services and restaurants weighed their organic and food waste, and retail sector were interviewed to gather information on the amounts and reasons for food waste in stores and the attitudes to find out how much and why food is being discarded in stores and what their attitudes are regarding food waste. Several companies from Finnish food industry participated in the project by delivering data and estimates on the amounts of food waste generated in their production plants.

According to the results of the household food waste study, if generalised to the entire Finnish population, on average 23 kg per person and year of avoidable food is wasted in households. Altogether this corresponds 120-160 million kg of food waste per year from the household sector. The amount of food waste in households varied drastically from 0-160 kg per person per year. Majority of the discarded food was fresh and perishable, or leftovers from cooking and dining. The main discarded foodstuff were vegetables 19%; home cooked food 18%; milk products 17%; bakery products 13%; and fruits and berries 13%. For meat, fish and eggs the number was 7%; and for convenience food 6%.

Also the influences of several socio-demographical, behavioural, and attitudinal factors on the generation of household food waste were analysed systematically. Statistically significant factors were: the size of the household, the gender of the person mainly responsible of grocery shopping, the frequency of buying discounted food products, householders' own views of their potential to reduce food waste, and the householders' own views of the influence of purchasing particular food packet sizes.

In food service sector the amount of food waste varied from 7-28% of cooked food, depending on restaurant type. In the whole sector it was estimated to be 75-85 million kg per year. In retail sector food waste was estimated to be 65-75 million kg per year. The food industry was estimated to produce around 75-140 million kg of food waste per year and, thus, it was estimated that every year consumers, food services, food industry and retailers together waste about 320-460 million kg of food in Finland.

In the study rough estimations of the climate impacts of household food waste were made by using literature data on climate impact of different food products. Even if pork and beef products amounted to only 4% of all discarded food, their carbon footprints were one of the highest compared to other food categories. For example, the amount discarded cheese amounted to less than 2% of total food waste in households, but it's carbon footprint was almost equal to discarded vegetables. Converted into greenhouse gases, in Finland the annually discarded food from households equals to the annual carbon dioxide emissions of 100 000 cars. The overall carbon footprint and its uncertainties of the entire Finnish food waste are presented in the final paper.

Overall, the production of food that is wasted causes remarkable, unnecessary environmental impacts. A huge amount of resources are used to cultivate, produce, store and distribute food that is not consumed. All these resources e.g. land, fertilisers, fuel, materials, transportation, water, and electricity result in significant amount of greenhouse gas emissions and also cause other environmental impacts such as water eutrophication.

Product energy use within the agri-food supply chain

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The global food system consumes very large amounts of energy, a position which is made more challenging as an increasing global population is demanding more food. In order that food production can be made more sustainable, it is important to produce food in a more energy efficient way or to identify food types that require less energy in production. This paper presents the results of a UK study that undertook a supply chain analysis of the embedded energy of selected food products.

A review of the academic literature identified over 50 products for which energy analysis had been undertaken for at least one stage of the food supply chain; the majority of papers related to primary production. Embedded energy values for individual food products across the whole supply chain (primary production to retailer) ranged from 2.4 MJ/kg for potato to 83 MJ/kg for coffee. For most food products, the indirect and direct energy used in primary production remained the dominant use; 45, 45 and 72% respectively for potato, milk and pork. Processing was the second biggest influence for selected products, e.g. the frying stage for oven chips consumed 50% of total energy requirement. Embedded energy values for total product market share was dominated by 'every day' items, e.g. meat, bread, milk and cheese.

The review was supported by new analysis of four multi-ingredient products. Data were collected from multiple sources (farmers, trade associations, food processors, food manufacturers and retailers). The embedded energy of tinned soup, pasta sauce in a glass jar, restaurant pizza and chocolate biscuits was 9, 24, 28 and 20 MJ/kg, respectively. The results show that different products have very different demands for energy and that the 'hotspot' of energy use varied greatly with product; however, in many situations it was possible to identify approaches to reduce energy use or to substitute one product with another. The choice of packaging was very influential for some products; e.g. the glass jar for pasta sauce was responsible for 50% of the total product embedded energy whilst the cardboard for frozen pizza was responsible for only 18% of the total product embedded energy.

Despite the high cost of energy, its contribution to product price remains relatively minor for most products and most food companies do not identify energy as a priority; hygiene and food safety being the dominant focus.

Comparison of the life cycle impacts of ready-made and home-made meals

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Convenience food now constitutes more than a third of the British food market with approximately 8.8 kg of chilled and frozen ready-made meals consumed per capita per year (Millstone and Lang, 2008) and with a market valued at £2.7 billion in 2010 (MINTEL, 2011). Yet, there is currently little information on the life cycle environmental impacts of convenience food, and particularly ready-made meals. Whilst numerous LCA studies exist of single food items, there are few studies of complete meals, with most focusing on global warming potential (e.g. Carlsson-Kanyama, 1998; Stichnothe et al., 2008) or on a limited number of environmental impacts (e.g. Davis and Sonesson, 2008; Davis et al., 2009; Berlin and Sund 2010). To date, only two studies have considered the full LCA impacts of ready-made meals, both based in Spain (Calderon et al., 2010; Zufia and Arana 2008).

This paper compares the environmental impacts of ready-made meals prepared industrially and meals made at home. As an example, a meal consisting of chicken meat, vegetables and tomato sauce is considered. The functional unit is defined as 'preparation and consumption of a meal for one person' and the scope of the study is from 'cradle to grave'. Several scenarios are considered to compare the influence of ingredient sourcing, refrigeration and cooking options. The study is based in the UK.

The results indicate that, overall, the home-made meal has lower environmental impacts than the ready-made meal. However, if the home-made meal is prepared with organic ingredients, the ready-made meal (with conventional ingredients) becomes a better option for some impacts, including global warming potential. For the ready-made meal options considered, the lowest impacts are found for the meal prepared from fresh ingredients and heated in a microwave; the worst option is the frozen ready-made meal made from frozen ingredients and heated in an oven. The home-made meal with the ingredients from conventional farming systems has lower impacts than the same meal made using organic components. The main hotspots for both types of meal are the ingredients and refrigeration. The contribution of packaging and meal cooking at home is relatively small, although the latter is more significant for home rather than ready-made meals. With respect to the ingredients, chicken and tomato are two key hotspots; their impacts are higher if sourced in the UK than imported, despite longer transport distances.

References

Berlin, J. and Sund, V., 2010. Environmental Life Cycle Assessment (LCA) of Ready Meals. SIK Report No. 804 2010. http://www.sik.se/archive/pdf-filer-katalog/SR804.pdf.

Carlsson-Kanyama, A., 1998. Climate change and dietary choices – how can emissions of greenhouse gases from food consumption be reduced? Food Policy, 23(3/4): 277-293.

Calderón, L. A., Iglesias, L., Laca, A., Herrero M., and Diaz, M. 2010. The utility of life cycle assessment in the ready meal food industry. Resources Conservation and Recycling 54(12): 1196-1207.

Davis, J. and Sonesson, U., 2008. Life cycle assessment of integrated food chains - a Swedish case study of two chicken meals. Int. J. LCA 13(7): 574-584.

Davis, J., Sonesson, U, Baumgartner, D., and Nemecek, T., 2009. Environmental impact of four meals with different protein sources: case studies in Spain and Sweden. Food Research Int. 43(7): 1874-1884.

Millstone, E. and Lang, T., 2008. The Atlas of Food: Who Eats What, Where, and Why. Earthscan, London.

MINTEL, 2011. Prepared Meals and Meal Kits - UK - May 2011. MINTEL, 2011. http://oxygen.mintel.com/ sinatra/oxygen/display/id=545271.

Stichnothe, H., Hospido, A. and Azapagic, A. 2008. Carbon Footprint Estimation of Food Production Systems: The Importance of Considering Methane and Nitrous Oxide. In: Glass, R; W Martindale, W. Proc. of Greening the Food Chain: Aspects of Applied Biology.

Zufia, J. and Arana, L. (2008). Life cycle assessment to eco-design food products: industrial cooked dish case study. J Cleaner Prod. 16(17): 1915-1921.

POSTER SESSIONS

1. Coupling LCA and GIS for the assessment of greenhouse gas emissions from global livestock production

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Usually life cycle assessments (LCA) are produced outside of any spatially explicit context even though the integration with a Geographical Information Systems (GIS) would provide the necessary tools to fully implement a spatially explicit LCA. The few examples available provide only a partial integration among the two, with the GIS used only for specific aspects of the LCA (e.g. land use). We provide an example of a complete integration between LCA and GIS with the general aim of assessing GHG emissions from livestock at the global level. In particular, using a process based approach, we estimated GHG emissions from different compartments, namely: feed production (including cultivation, induced land use change, manufacture of fertiliser and processing and transport), manure management, , enteric fermentation, energy use (embedded and direct), and post-farm emissions to the point of retail. The entire LCA was implemented in GIS using as inputs spatially explicit layers available at the global level from different sources, and representing the different variables included in the model (e.g. climate, agro-ecological zones, etc.). The approach that we propose has many advantages. It allows for: (1) a global analysis that still maintains a reasonable spatial resolution compared to more traditional national and/or regional analyses; (2) the inclusion of the many spatially explicit variables developed in the last few years by a wealth of international research centres, and; (3) a better integration of variables that are naturally highly variable in time and space (e.g. temperatures, yields, etc.) and that represent the main drivers of important GHG emission sources (such as feed production, manure management). In addition, using a spatially explicit database it is possible to combine, aggregate and/or extract the data depending on the particular question at hand, considering different spatial scales and different administrative regions (or other spatial aggregations). Outputs from the model can also be represented as GHG emissions maps, with a details that is by far greater than a simple country or regional result. Future developments of our approach are possible refining the number of variables and processes to be considered (e.g. including better estimates of transportation distances), improving the resolution and the accuracy of the data considered, and investigating livestock related impacts on nutrient balances, water consumption and biodiversity.

2. Combined mass and economic allocation

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Allocation is a common problem in Life Cycle Assessments. A common allocation situation in food production occurs when a production line produce one or several co-product(s) and by-product(s). Furthermore the distinction between waste and by-product is often unclear because although a waste fraction might be given for free, the transportation of the waste entails costs and the waste can be raw material for products with a commercial value.

Avoidance of allocation using the decision three given in ISO 14044 can be difficult because the processes cannot be split, systems expansion is not possible and no causality can be found. Systems expansion is often difficult because incorporating more functions in a Functional unit is not interesting if the aim is to study one product and systems expansion through substitution is impractical because a single alternative product cannot be identified.

Economic and mass allocation have in the past been the most commonly used allocation methods in food systems but both have their disadvantages. The use of economic allocation can be confusing for consumers, e.g. because the fact that a product of a high commercial value should have a higher environmental impact than a low value product coming from the same raw material and the same process is hard to understand. Mass allocation reflects only physical relationships thus avoiding this problem- One disadvantage of mass allocation is the fact that byproducts of a low value, e.g. fish skin and bones, carries the same environmental burden as the main products. The consequence might be that buyers of these by-products might have less incentive to use this resource. Another problem with mass allocation occurs when a by-product that was previously given for free to users is being sold instead. The result could be a significant shift in the environmental burdens from one assessment to another while no physical changes have been made.

One way to avoid the problems associated with these allocation methods is to combine mass and economic allocation. In the first step economic allocation can be used to distribute environmental impacts between products of very different usage. In the second step mass allocation is used to distribute impacts between products of the same usage. The concept has been investigated using two examples. In one example an animal gives several products going to human consumption, one product going to fertiliser and one to energy production. In another example carrots are sorted into four main products going to human consumption and one waste fraction given for free to be used for animal feed. In these examples the above mentioned disadvantages were avoided. Thus combined allocation proved to a good solution.

ISO 14044 does not seem to preclude such an approach to allocation except maybe the passage that states that the same allocation procedure should be uniformly applied in the assessment. This could, however, be interpreted to mean that consistency is required in similar situations, not that one single allocation method is applied.

References

Schau EM and Fet AM (2008). LCA Studies of Food Products as Background for Environmental Product Declaration. Int J LCA 13 (3) 255–264.

Ayer N, Tyedmers PH, Pelletier NL, Sonesson U and Scholz A (2007): Co-Product Allocation in Life Cycle Assessments of Seafood Production Systems: Review of Problems and Strategies. Int J LCA 12 (7) 480–487.

3. Animal- and environmentally friendly beef production: a conflict?

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Meat production faces many challenges today, like consumer demand for animal friendly production systems, the food supply of a growing world population and the diminishment of the environmental impacts of meat production. In order to provide a solid basis for decisions, the impacts of different production systems have to be quantified. This contribution presents a study of different beef production systems in Switzerland and in countries exporting to Switzerland as basis for the design of purchasing strategies. The data were derived from model farms of the project LCA-FADN (Hersener et al., 2011). For Switzerland, three production systems were analysed: A conventional bull fattening system and two animal friendly suckler cow systems (a conventional and an organic one). Additionally, a conventional bull fattening system in Germany and a very extensive suckler cow system in Brazil were analysed. The functional unit was kg meat ready for sale at point of sale.

The results show that for all systems the agricultural stage dominates the environmental impacts (Fig. 1). The most important contributions are the application of fertilisers and from field emissions, animal emissions and for the bull fattening systems the purchase of concentrates. Comparing the Swiss systems, the most intensive production system (conventional bull fattening) has the lowest impacts per kg live weight (LW) for most categories analysed (see also Alig et al., 2011). Exceptions are the categories deforestation, ecotoxicity and resource use potassium, where the conventional bull fattening system has the highest results, as well as resource use phosphorus (2nd highest results). This is due to the use of concentrate feeds with soy beans from Brazil compared to the mainly grass-based feeding in the suckler cow systems. The reason for the higher environmental impacts of the suckler cow systems is the general design of the production system itself: in a suckler cow system, the mother cow only serves to produce meat, whereas in a conventional bull fattening system the parent animal produces milk and meat. Therefore, its environmental impacts are allocated between these two products, whereas in the suckler cow systems, the full environmental load of the mother cow is allocated to meat production. This is especially apparent with methane emissions, which are more than 60% higher in the suckler cow systems than in the conventional bull fattening system (Fig. 2).

The German bull fattening system is mostly similar to or a little bit lower than the Swiss conventional system. It is more intensive than the Swiss system, i.e. more based on concentrates and maize silage. The Brazilian production system is a special case: it is very extensive, uses almost no external inputs but huge land area. This influences the results: in categories linked with the use of external inputs as energy demand, resource use or ecotoxicity the Brazilian system has very low impacts. On the other hand, it has very high results for land competition and deforestation and therefore also high values for eutrophication. Due to the long fattening period (over two years), water use and methane emissions of this system are also high.

In summary, there are no clear advantages for a certain system. The animal friendly suckler cow systems stand out due to their low use of arable land and their ability to mitigate the competition for food between man and animals. In order to have advantages in categories like energy demand and resource use, a suckler cow system has to be really extensive (e.g. Brazil). In Switzerland, the animal friendly suckler cow systems had overall higher environmental impacts than the conventional bull fattening system. This is to a great deal due to the system design, where the full environmental impact of the mother cow is allocated to the meat production. In order to develop animal and environmental friendly production systems, alternative systems have to be contemplated, e.g. a combined milk and meat production with dual purpose cows.

References

Alig et al., 2011. Ökologische Bewertung von Rind-, Schweine- und Geflügelfleisch. Schlussbericht Forschungsinitiative COOP-ART. In preparation.

Hersener, J.-L., Baumgartner, D.U., Dux, D. (Eds.), 2011. Zentrale Auswertung von Ökobilanzen landwirtschaftlicher Betriebe (ZA-ÖB). Forschungsanstalt Agroscope Reckenholz-Tänikon ART, Zürich/Ettenhausen.

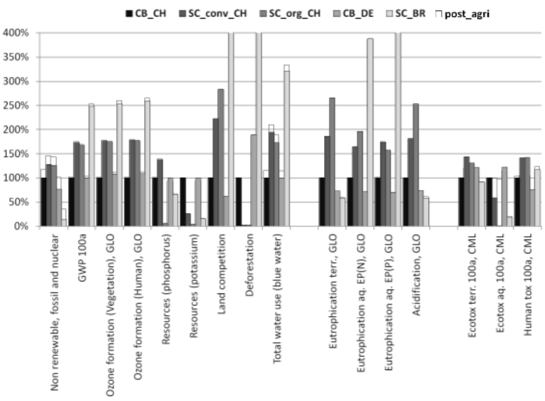

Figure 1. Overview of the environmental impacts per kg meat ready for sale of the five analysed beef production systems. CB_CH: agricultural stage conventional bull fattening Switzerland; SC_conv_CH: agricultural stage conventional suckler cow system Switzerland; SC_org_CH: agricultural stage organic suckler cow system Switzerland; CB_DE: agricultural stage conventional bull fattening Germany; SC_BR: agricultural stage suckler cow system Brazil; post_agri: post-agricultural phase (slaughtering and transports to point of sale).

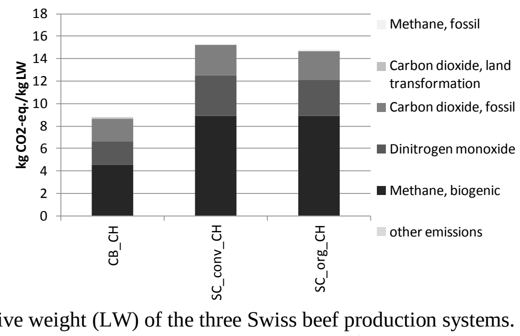

Figure 2. Global warming potential per kg live weight (LW) of the three Swiss beef production systems.

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4. Allocation procedures in the beef life cycle assessment

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The beef production is one of the food sectors with the highest environmental impact: this is mainly due to the feed production, the manure management and the methane emissions from enteric digestion processes. Even if the high impact is well known among all the LCA practitioners, it is quite important the definition of the hypotheses because some of them are quite relevant for the final result such the functional unit (meat boneless or not), the system boundaries (from where to where), the data quality requirements, etc. Probably, the most important hypothesis needed for the beef LCA is related to the definition of the allocation rules between the many by-products generated along the chain.
Considering the whole chain, for example, aspects that shall be considered are:

- how to consider the impact of reproductive cow used for the generation of calves;
- the allocation rules when the reproductive cow is mainly bred for the milk production; in that case it is necessary to define the portion of impact to be allocated to the veal (by-product of farms that produce milk).
- how to deal when the meat comes directly from milk cow or reproductive cow for calves production at the end of their life;
- how to consider the leather.

After the definition of the rules related to the system analysed and the eventual by-products generated along the chain, the other issue concern the approach used to allocate the impact: economic allocation, mass allocation or other alternative approaches (i.e. biological causality defined as the physiological feed requirements of the animal to produce milk, meat or other by-product).
The aim of this paper is to examine some allocation procedures and to present a sensitivity analysis of the chosen procedure on the final results; for example in Fig. 1 are illustrated the difference, in terms of Carbon Footprint, related to veal production chain considering different allocations rules for the impact of reproductive cow mainly finalised to produce milk.

References
Cederberg C., Stadig M., 2003. System Expansion and Allocation in Life Cycle Assessment of Milk and Beef Production, International Journal of LCA 8, 350-356.
Ponsioen T., Kool A., December 2010. Carbon footprint assessment of calf milk replacer, calves and veal, Blonk Milieuadvies Study.
Blonk H., Ponsioen T., Kool A., Marinussen M., April 2011. The Agri-Footprint method - Methodological LCA framework, assumptions and applied data - Version 1.0, Blonk Milieuadvies Study.
Barilla Center for Food and Nutrition (BCFN), 2011. 2011 Double Pyramid: Healthy Food for People, Sustainable for the planet, Supporting technical paper Version 2 of 14 July 2011.
Casey J. W., Holden N. M., 2006. Quantification of GHG emissions from sucker-beef production in Ireland, Agricultural Systems 90, 79-98.
Ecoinvent Swiss database, v.2.0, www.ecoinvent.ch.

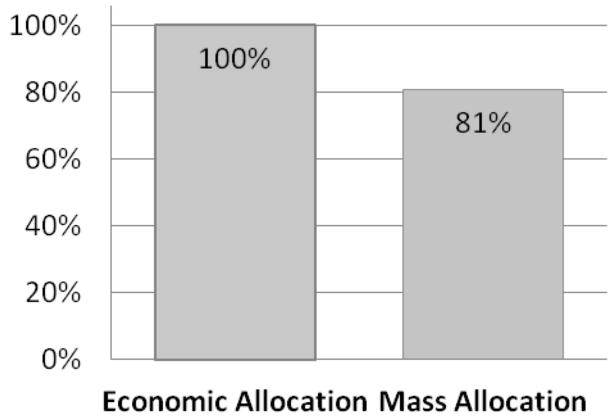

Figure 1. Carbon Footprint of 1kg of veal meat with different allocations rules for the reproductive cow impact.

5. Evaluation of the environmental impact of Belgian beef production systems through life cycle assessment methodology

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Environmental issues like GHG emissions, process of eutrophication and acidification, fossils fuels depletion, etc. received increasing attention over the last years by the European politic. In this context, the livestock sector is often pointed out. At the same time, consumers search more “green” products and require more information on food production process and origin.
The aim of this study is to highlight and adapt, based on literature review and on the characteristics of the main beef production systems identified in Belgium, the emission parameters which could be, in LCA (Life Cycle Assessment) methodology, adjusted to our national conditions. Indeed, beef livestock systems are based, in Belgium, on Belgian Blue breed characterised by a very high carcass yield associated to a very good feed conversion ratio.
The impacts taken into account for these processes will be the global warming, eutrophication, acidification, fossils fuels depletion, land use and occupation, and water use. In term of boundaries, the system that will be presented will add, to the classical cradle to farm gate approach, the slaughter house, carcass transformation and packaging processes. We expect that this analysis will help identify the best practices to improve environmental performances of this sector in order to advise its different actors.

6. Life cycle assessment on dairy and beef cattle farms in France

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In the current environmental context, as much as political (reduction of greenhouse gas emissions, preservation of biodiversity) and social (consumer demands for information concerning food products), a need to determine the influence of ruminant livestock on environment is incontestable. It is now crucial to quantify precisely the environmental impacts for different ruminant livestock systems by using Life Cycle Assessment (LCA). The French Livestock Institute has launched a work program to determine the environmental assessment of dairy and beef cattle systems at farm scale. In this context, a methodology based on life cycle assessment method has been built to assess many impacts which concern climate change, eutrophication, acidification and energy consumption. This methodology has been applied to several beef and dairy cattle systems from the French Breeding Network database (208 dairy farms and 268 beef farms) representative of the French cattle. Five types of dairy system, defined by farm typology based on part of maize in farm and location area, have been studied (Table 1). Milk gross carbon footprint varies from 0.8 to 1.5 kg CO_2eq/kg of milk produced and net carbon footprint vary from 0.1 to 1.4 kg CO_2eq including carbon sequestration. Concerning acidification, eutrophication and energy consumption for the five systems studied, the variation goes respectively from 0.005 to 0.010 kg SO_2eq, 0.001 to 0.0010 kg PO_4eq and 1.2 to 4.0 MJ, all expressed in kg of milk produced. Differences between systems are not very high, however the systems located in plain area contain more than 30% maize in the diet and present a higher productivity per cow, that result in a higher risk of eutrophication and a higher net carbon footprint than the other systems. In beef production, three specialised suckler-cattle systems have been studied (table 2), calf-to-weanling system producing weaners (9-10 months old), calf-to-beef system producing beef steers (over 30 months old) and calf-to-beef system producing young bulls (17 months old). French suckler cattle farm systems produce from 8.7 to 26.0 kg CO_2eq/kg of live weight. Calf-to-beef system producing beef steers, fattened on pasture, has the lower net carbon footprint (5.9 kg CO_2eq/kg of live weight) considering carbon sequestration and a lower risk of eutrophication. The energy used is quite similar for the three systems. In most cases, the intra-system variability of environmental footprints is higher than inter-system variability. The intra-system variability is related to technical and practices efficiency on farms. At equivalent systems, an important difference can be observed on the final impact between optimised and non-optimised farms. These differences are due to herd management, cultural practices, feed and fertiliser strategies, etc. For example, in relation with the nitrous oxide emissions, the most optimised farms, which consume less feed, less fertiliser, etc. have better nitrogen balance and lower environmental impacts. This study show link between environmental issues and highlight the relation between environmental issues and practices on farm, which propose some ways of mitigation adapted to the production systems. Finally, these investigations demonstrate that numerous mitigation actions can be identified in the livestock systems to reduce the environmental footprint of milk and beef meat at the farm gate. Some of them concern management practices (adjustment of dietary intake, fertilisation management, etc.) which result in substantial savings in agricultural expenses. Others require installation of new technologies which would require additional funds to improve the production processes.

References

De Vries M., De Boer I.J.M., 2010. Comparing environmental impacts for livestock products: A review of cycle assessments. Livestock Science, 120, 1-11.

Gerber P., Vellinga T., Opio C., Steinfeld H., 2011. Productivity gains and greenhouse gas emissions intensity in dairy systems. Livestock Science, doi: 10.1016.j.livsci.2011.03.012.

Veysset P., Lherm M., Bébin D., 2010. Energy consumption, greenhouse gas emissions and economic performance assessments in French Charolais suckler cattle farms: Model-based analysis and forecasts. Agricultural Systems, 103, 41-50.

Table 1. Environmental impact of milk on dairy farms

	Production system				
	Plain > 30% maize	Plain 10-30% maize	Plain < 10% maize	Mountain maize	Mountain grass
Number of farms	37	36	50	26	59
	Average *<min-max>*	Average *<min-max>*	Average *<min-max>*	Average *<min-max>*	Average *<min-max>*
Gross carbon footprint	1.06	1.1	1.1	1.1	1.2
kg CO_2eq/ kg milk	*0.8-1,3*	*0.8-1.4*	*0.7-1.4*	*0.8-1.5*	0.9–*1.5*
Net carbon footprint	1.0	0.8	0.7	0.9	0.7
kg CO_2eq / kg milk	*0.7-1.3*	*0.6-1.4*	*0.4-1.1*	*0.6-1.3*	*0.1-1.0*
Acidification	0.007	0.007	0.009	0.008	0.010
kg SO_2eq / kg milk	*0.005-0.009*	*0.005-0.011*	*0.005-0.012*	*0.005-0.013*	*0.006-0.013*
Eutrophication	0.006	0.004	0.003	0.005	0.004
kg PO_4eq / kg milk	*0.003-0.011*	*0.002-0.009*	*0.001-0.010*	*0.002-0.010*	*0.002-0.008*
Energy consumption	2.5	2.2	2.4	2.6	2.7
MJ / kg milk	*1.8-3.8*	*1.2-3.3*	*1.2-3.9*	*1.7-3.8*	*1.8-4.0*

Table 2. Environmental impact of meat on beef farms

	Production system		
	Calf-to-weanling system producing weaners (9-10 months old)	Calf-to-beef system producing beef steers (> 30 months old)	Calf-to-beef system producing young bulls (17 months old)
Number of farms	163	13	72
	Average *<min-max>*	Average *<min-max>*	Average *<min-max>*
Gross carbon footprint	14.7	13.2	13.5
kg CO_2eq / kg meat	*10.9-25.4*	*9.5-18.8*	*8.7-18.4*
Net carbon footprint	7.7	5.9	9.9
kg CO_2eq / kg meat	*0.3-17.3*	*3.8-8.5*	*5.6-15.0*
Acidification	0.120	0.109	0.115
kg SO_2eq / kg meat	*0.078-0.217*	*0.069-0.156*	*0.062-0.194*
Eutrophication	0.039	0.028	0.052
kg PO_4eq / kg meat	*0.019-0.113*	*0.016-0.048*	*0.021-0.130*
Energy consumption	20.4	21.0	20.6
MJ / kg meat	*5.6-35.6*	*10.8-38.7*	6.9-34.1

7. Life cycle assessment of four fattening calves systems in Spain

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The livestock sector is a very important element of stress for many ecosystems and for the entire planet (FAO, 2009). In Spain, livestock production contributes in a proportion of about 5% of the total equivalent CO_2 (De Blas, et al. 2008). Although intensive feedlot system is the most widespread in Spain, there are other systems (extensive and semi-extensive) whose environmental impact is interesting to assess.

We used the LCA methodology to asses four fattening systems of calves used in Spain. Two of these systems were of intensive fattening, where calves fed on concentrate of cereals; other system was of extensive fattening, calves fed on grass, and the last one was of semi-extensive fattening, with calves fatted in two phases, at the first one fed with grass and at the second one (named "finishing") with grain concentrate.

The objectives of this LCA study were firstly identify which unit processes generate more environmental impacts, and secondly compare the environmental impact of the those four systems of fattening. For each system of fattening were analysed: i) production of raw materials (soya, palm oil, grass, etc) used in the feedstuff, including fertilisation and tillage; ii) transport of raw materials to the farm where calves are fattened; iii) the fattening of calves on the farm, including enteric methane emissions and emissions from manure. Impact categories analysed were global warming potential (GWP), acidification potential (ACP) and eutrophication potential (EUP). Literature data of specific on site systems, transport calculation and different databases and references were used (Lartategui-Arias, 2010). The functional unit considered was ton of meat for consumption, once removed the entrails, skin, head, legs and fat coverage. The system limits of the study are shown in Fig. 1.

According to data from the agricultural process, fertilising and tilling, is the most polluting in GWP category in intensive farms (Table 1). At extensive and semi-extensive farms, fattening of calves are the most polluting in this category. In EUP category, fattening activity is the most polluting in three of four systems analysed, the two intensive and semi-extensive. In ACP, fattening is the most polluting activity in the four systems analysed. Adding all the unitary processes, semi-extensive system is the most polluting in EUP and ACP categories, primarily due to the process of fertilisation of the raw materials forming the feedstuff of the finish phase and fattening process. In GWP, the extensive system is the most polluting, primarily due to the fattening process, in which enteric methane emissions play an important role.

References

De Blas, C., García-Rebollar, P., Cambra-López, M. y Torres, A.G. 2008. El cebo de terneros en España, una actividad respetuosa con el medioambiente. Estudio de la repercusión de la producción de vacuno de carne en la emisión de gases con efecto invernadero. ASOPROVAC. Madrid, Spain.

FAO, 2009. La larga sombra del ganado, problemas ambientales y opciones. Roma. ISBN: 978-92-5-305571-5.

Lartategui-Arias S. 2010. Aplicación de la metodología de Análisis de Ciclo de Vida para la evaluación ambiental del cebo de terneros en España. Graduate Thesis, Universidad Politécnica de Madrid, Spain.

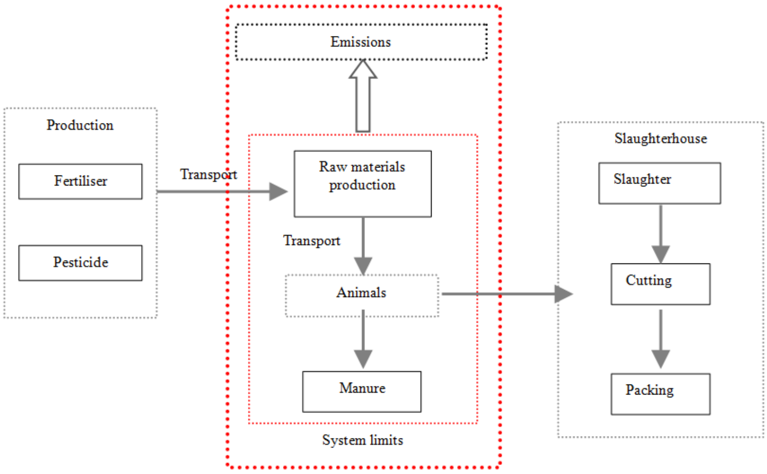

Figure 1. System limits of the LCA.

Table 1. Results of the LCA for the four fattening systems in GWP, EUP and ACP impact categories.

		Emissions kg/t meat		
Unitary process	**Fattening system**	**GWP (CO_2-eq)**	**EUP (PO_4-eq)**	**ACP (SO_2-eq)**
Fertilisation	Intensive 1	**3504.20**	**25.16**	4.44
	Intensive 2	2962.00	7.18	3.87
	Extensive	1444.00	6.33	3.39
	Semi-extensive	2810.00	23.53	**12.42**
Tillage	Intensive 1	53.70	**0.44**	**2.27**
	Intensive 2	107.00	0.33	1.85
	Extensive	41.80	0.13	0.72
	Semi-extensive	**109.00**	0.34	1.88
Transport	Intensive 1	**254.60**	**0.81**	**4.34**
	Intensive 2	153.00	0.45	2.42
	Extensive	30.60	0.05	0.25
	Semi-extensive	151.00	0.23	1.24
Fattening	Intensive 1	2372.10	21.55	11.13
	Intensive 2	1838.00	18.68	9.64
	Extensive	**6499.30**	20.26	10.47
	Semi-extensive	4319.00	**28.51**	**14.72**
Total	Intensive 1	6184.60	47.96	22.18
	Intensive 2	5060.00	26.64	17.78
	Extensive	**8015.70**	26.77	14.83
	Semi-extensive	7389.00	**52.61**	**30.26**

8. Environmental impact of beef – role of slaughtering, meat processing and transport

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Environmental impact of meat production is widely discussed and of increasing importance to customers and stakeholders. To find mitigation strategies it is important to identify important processes in the whole production chain from the agricultural stage up to the retail store. Several studies found that the environmental impact of meat is dominated by animal production (Roy et al. 2012, Foster et al. 2006). But is this also the case if meat products are transported over longer distances? Knowledge about the role of the processes after the animal production stage is important, especially when comparing domestic production with imports.

The aim of this study is to assess the environmental impact of beef produced in Switzerland and to compare it with beef imported from Germany and Brazil. Emphasis is set on the role of the processes after the animal production stage: slaughtering, meat processing and transport. The life cycle of beef is analysed from cradle to the sales point and the functional unit is 1 kg of meat ready for sale (packed). The agricultural phase is described by Alig et al. (2012). For slaughtering, meat processing and transport data from industry (meat production and retail business) and from literature are used.

The environmental impact of beef produced and sold in Switzerland is dominated by animal production, which is responsible for over 80% of all investigated environmental impacts. The stages after animal production account for around 15% of the impact categories 'non-renewable energy demand' and 'blue water use' and for less than 5% of all other environmental impacts (Fig. 1). The most important process within these post-agricultural stages is slaughtering and meat processing which contributes up to 15% to the total impact. The transport of living animals and of processed meat and the distribution centres contribute less than 2% to all impact categories (Fig. 1).

Beef imported from Germany is also dominated by animal production. Due to longer distances, transport has a slightly higher impact but still contributes less than 5% to all impacts (Fig. 2).

Beef imported from Brazil by ship is dominated by the agricultural production for most environmental impacts, despite the higher impact of transport, as the impact of transport by freight ship is relatively low. This is different for beef imported by aircraft. Here the transport from Brazil to Europe has an important impact (Fig. 2). E.g. it accounts for around 15% of the global warming potential and over 80% of the non-renewable energy demand.

Looking at the environmental impact of slaughtering and meat processing, the main contribution to most impact categories comes from direct energy use. Also important factors are packaging film, water use, sewage treatment and waste disposal.

In conclusion, animal production dominates the production chain for beef produced in Switzerland and imported from Germany and Brazil. An exception is the import of beef by aircraft from Brazil. Animal production is therefore the most important starting-point for mitigation strategies. However it is also important to reduce the environmental impact of the post-agricultural stages. All stakeholders along the whole production chain have to contribute to maximise the overall mitigation potential. Transport by airplane can have a high impact and should be avoided. Another important factor is the use of non-renewable energy during slaughtering and meat processing which could for example be reduced by replacing fossil fuels with renewable energy sources. *Acknowledgement: These research results were developed by ART with the support of COOP.*

References

Alig, M., Grandl, F., Mieleitner, J., Nemecek, T., 2012. Animal and environmental friendly beef production: a conflict? Abstract, 8th International conference on LCA in the Agri-Food sector.

Foster, C., Green, K., Bleda, M., Dewick, P., Evans, B., Flynn, A., Mylan, J., 2006. Environmental impacts of food production and consumption. A Final Report to the Department for Environment, Food and Rural Affairs, Manchester Business School, Defra, London.

Roy, P., Orikasa, T., Thammawong, M., Nakamura, N., Xu, Q., Shiina, T., 2012. Life cycle of meats: An opportunity to abate the greenhouse gas emission from meat industry in Japan. Journal of Environmental Management 93, 218-224.

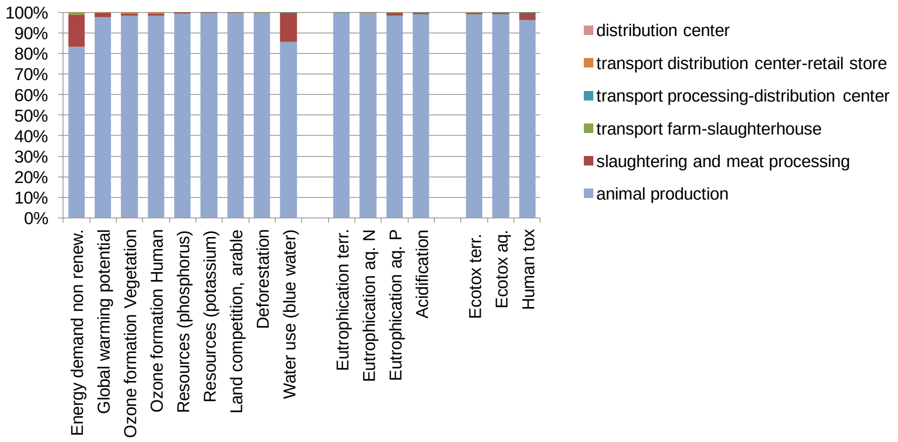

Figure 1. Environmental impacts per kg meat ready for sale for beef produced and sold in Switzerland.

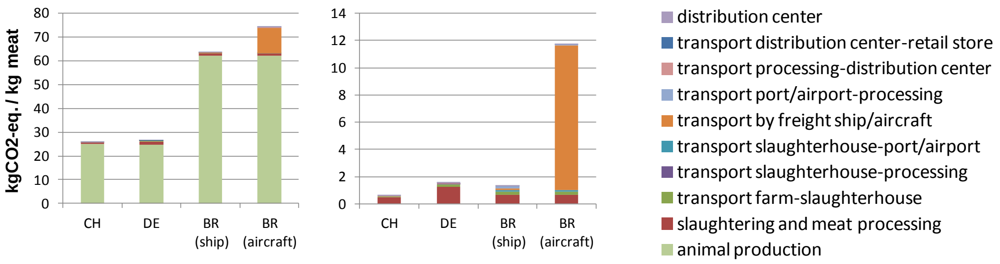

Figure 2. Global warming potential (GWP) per kg meat ready for sale at the point of sale in Switzerland. Left: Whole Chain. Right: slaughtering, meat processing and transports. CH: animal production in Switzerland, transport by lorry, DE: animal production in Germany, transport by lorry, BR: animal production in Brazil, transport by freight ship (ship) and transport by aircraft (aircraft).

9. Life cycle assessment of Mediterranean buffalo milk

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This study is part of a broader project carried out by CRA (Agricultural Research Council), in collaboration with ENEA, aimed at evaluating and identifying environmentally friendly livestock models, which could be applied to Italian agri-food production systems, in order to improve their environmental sustainability.

In Italy there are about 365 thousands Mediterranean Buffaloes. This population increased considerably in recent years, as consequence of the strong worldwide demand of “Mozzarella di bufala campana – DOP” (AIA, 2011).

At present no LCA study on buffalo milk production exists in literature, whereas many LCA studies have been performed on cattle milk production, both on farming systems and on the entire life cycle. In this study the standard ISO Life Cycle Assessment and ILCD Handbook methodology (ILCD, 2010) have been applied to the production of two buffalo dairy farms located in Southern Italy. The goal is to evaluate their environmental performance and to identify the hotspots in the production chain. The functional unit is 1 kg of Normalised Buffalo Milk at farm gate. An attributional approach has been applied according to the stated goal of the study.

System boundaries (Fig. 1) comprise crop production, as well as the activities related to buffalo feeding, breeding and milking. Specific primary data, referred to 2010, have been collected from the two buffalo farms for each of the above phases. In particular, the following items have been included in the system boundaries: number of producing buffaloes and replacement heifers; production and transport of purchased feeds; production and transport of seeds, fertilisers, and detergents; energy consumption related both to cropping, feeding and milking; disposal and treatment of waste produced at farms. Buildings, infrastructures and equipments have not been included in the system boundaries, but they are included in some database’s processes. The production of medicines and the milk-processing phase have not been included. Databases (mainly Ecoinvent) and literature have been used for the background data. Manure and slurry produced by buffaloes are spread as fertilisers on agricultural farms’ land. As regards emissions related to the use of chemical and organic fertilisers, N_2O airborne emissions and NO_3^- waterborne emissions have been calculated according to ISPRA (2008). NH_3 airborne emissions have been calculated according to ISPRA (2011a). Phosphorus waterborne emissions have been estimated according to the budget farm gate methodology proposed by Dalgaard et al. (2006). Methane emissions on farms due to enteric fermentation and manure management have been estimated referring to ISPRA (2008). As buffalo milk production at farms is a multifunctional process, the environmental impacts have been allocated between the main product (milk) and co-products (calves and culled buffaloes) on the basis of their economic value.

At the Conference the preliminary results, including the following impact categories, will be presented and discussed: Global warming, Photochemical Oxidation, Acidification, Eutrophication. The assessment of Land Use and Ecotoxicity due to use of pesticides and antibiotics will be performed in a second step of the study.

References

Associazione Italiana Allevatori (AIA), 2011. Quadro economico e relazione attività 2010.

Dalgaard, R., Halberg, N., Kristensen, Ib.,S., Larsen, I., 2006. Modelling representative and coherent Danish farm types based on farm accountancy data for use in environmental assessment. Agriculture, Ecosystems and Environment 117, 223-237.

International Reference Life Cycle Data System (ILCD), 2010. General guide for Life Cycle Assessment- Detailed guidance. European Commission, Joint Research Centre (DG JRC), Available at: http://lct.jrc.ec.europa.eu/assessment/assessment/projects#d (visited in February 2012).

IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories: volume 4: Agriculture, Forestry and other Land Use. Intergovernmental Panel on Climate Change. Available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html (visited in February 2012).

ISPRA, 2008. Agricoltura-Inventario nazionale delle emissioni e disaggregazione provinciale. Institute for Environmental Protection and Research. Rome, Italy. Available at www.isprambiente.it.

ISPRA, 2011. Agricoltura-Emissioni nazionali in atmosfera dal 1990 al 2009. Institute for Environmental Protection and Research. Rome, Italy. Available at www.isprambiente.it.

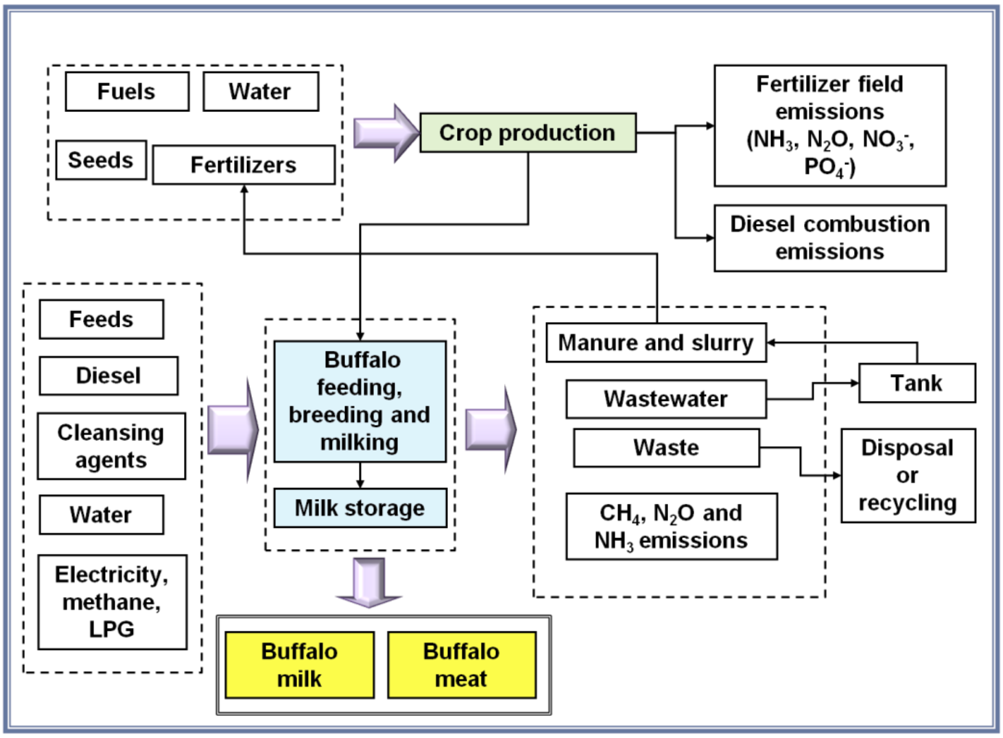

Figure 1. System boundaries.

10. Life cycle assessment of milk production in Italian intensive dairy farms

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Environmental concerns are having increasing priority upon political, social, and economic agendas, in particular when related to agriculture. Food production has an environmental impact, and as the global populations continue to increase, it is critical to produce sufficient high-quality food from a finite resource supply in order to mitigate the effects upon the environment (Capper et al., 2009). In the North of Italy favorable climatic and infrastructural conditions promoted a great concentration of livestock farms with intensive utilisation of natural resources (i.e. land, air, water). The objective of this study was to assess the environmental impact of milk production in intensive dairy systems, in order to identify farm characteristics that guarantee at the same time low environmental impact and economic sustainability. A cradle to farm gate Life Cycle Assessment (LCA) was performed on 41 intensive dairy farms in Northern Italy. In addition to the evaluation of greenhouse potential, impact categories as acidification, eutrophication, land use and energy use were considered. The functional unit was 1 kg Fat and Protein Corrected Milk (FPCM). Farm key parameters about crop production for feeding, livestock, manure management, purchased feed, fertilisers, pesticides, electricity and fuels, milk and meat sold were collected by personal interview to the farmers. LCA was carried out using LCA software package, SimaPro 7.3.2 (Pré Consultants, 2011). Gross margin, i.e revenues minus the direct production costs, excluding labour costs (expressed in €/t FPCM), was used as economic indicator. Database was analysed using the CLUSTER procedure (SAS, 2000). In order to identify different farming systems the following variables were considered: gross margin, feed self-sufficiency, dairy efficiency and stocking density. Two main clusters of farms were identified (A and B); moreover in each of the two clusters two subgroups of farms were defined (Table 1). Farms from cluster B were slightly less intensive than farms from cluster A: they had significantly larger farm land (ha), lower stocking density (LU/ha) and higher feed self-sufficiency (%). Economic results were similar between the two main clusters but ecological performances were better for farms from cluster B: nitrogen and phosphorus balances at farm gate (kg/ha) and the off-farm components of total climate change, acidification, eutrophication, energy use and land use per kg FPCM were significantly lower in cluster B than in A. In fact farms from cluster B had higher feed self-sufficiency and purchased less feed, reducing off-farms fraction of all impacts but increasing on-farm component of eutrophication, acidification and land use. Farms from cluster B impacted more in term of total eutrophication (on- and off-farm components) in comparison with farms from cluster A. On-farm crop production weighted for the 50% on eutrophication, because of the use of fertiliser which could determine nitrate leaching in the water and ammonia emission in the air. Considering the subgroups, farms from cluster 4 had better economic performances than cluster 3; they were characterised by low stocking density, high feed self-sufficiency and balanced partition of farm land among different crop production (lucerne: 15.0% ; grass: 14.9%; maize for silage 21.2% of farm land). Farm included in cluster 4 had lower nitrogen and phosphorus balances than cluster 3; they probably paid more attention in using fertilisers (134 *vs* 178 kg of N input from artificial fertilisers) and sold feed (446 *vs* 0 kg of N output from sold feed). The energy use of cluster 4 was lower than cluster 3 (P=0.10) as a consequence of reduced use of off-farm products, especially feeds. In the context of intensive dairy farming of Northern Italy cluster 4 identifies a type of farming system that can produce good economic performances without increasing environmental impact.

References

Capper, J. L., Cady, R. A., Bauman, D. E., 2009. The environmental impact of dairy production: 1944 compared with 2007. J. Anim. Sci. 87, 2160-2167.

Pré Consultants, 2011. SimaPro 7.3.2 PhD, LCA software. Printerweg, Amersfoort, Netherlands.

SAS II, 2000. The SAS System for Windows. In Book The SAS System for Windows, Vol. Relase 8.01.

Table 1. Characteristics of clusters (least square means)

	Cluster A		**Cluster B**						
	Cluster 1	**Cluster 2**	**Cluster 3**	**Cluster 4**					
n farms	**6**	**11**	**8**	**16**	**SE**	**P**	**A vs B**	**1 vs 2**	**3 vs 4**
Farm land, ha	22.8	38.1	57.5	52.9	11.1	0.07	0.01	0.28	0.70
Livestock Unit	175	224	326	189	50.2	0.07	0.17	0.43	0.01
Stocking density, LU/ha	9.05	5.84	5.53	3.79	0.87	<0.001	<0.001	0.01	0.07
Feed self-sufficiency,%	32.0	49.8	61.8	73.1	2.42	<0.001	<0.001	<0.001	<0.001
Milk production, kg FPCM/cow/day	26.8	29.4	29.0	27.6	1.35	0.30	0.86	0.12	0.31
N balance, kg/ha	853	587	614	350	78.8	<0.001	<0.001	0.01	<0.01
P balance, kg/ha	125	70.4	60.6	31.2	11.8	<0.001	<0.001	<0.001	0.02
Gross margin, euro/t FPCM	128.5	206.3	143.2	218.4	20.3	<0.001	0.42	<0.001	<0.001

Table 2. The effect of cluster on total climate change, acidification, eutrophication, energy use and land use per kg fat-and-protein-corrected milk (least square means)

	Cluster A		**Cluster B**						
	Cluster 1	**Cluster 2**	**Cluster 3**	**Cluster 4**					
n farms	**6**	**11**	**8**	**16**	**SE**	**P**	**A *vs* B**	**1 *vs* 2**	**3 *vs* 4**
Total climate change, kg CO_2-eq.	1.43	1.24	1.28	1.31	0.08	0.29	0.55	0.06	0.72
On farm	0.92	0.82	0.90	0.98	0.06	0.07	0.15	0.19	0.23
Off farm	0.49	0.40	0.37	0.33	0.03	<0.001	<0.001	0.03	0.24
Acidification, g SO_2-eq.	20.0	18.2	18.7	21.1	1.44	0.17	0.49	0.33	0.12
On farm	14.7	14.1	16.2	19.1	1.19	<0.001	<0.001	0.68	0.03
Off farm	5.15	4.03	2.50	2.01	0.61	<0.001	<0.001	0.15	0.45
Eutrophication, g PO_4^{3-}eq.	7.9	8.2	8.7	10.1	0.64	<0.001	0.02	0.76	0.04
On farm	4.83	5.78	7.07	8.76	0.56	<0.001	<0.001	0.18	0.01
Off farm	3.07	2.38	1.59	1.35	0.31	<0.001	<0.001	0.09	0.48
Energy use, MJ	7.13	6.07	5.62	5.65	0.51	0.10	0.03	0.11	0.96
On farm	2.09	1.83	1.85	2.55	0.28	0.04	0.31	0.48	0.03
Off farm	4.20	3.59	3.50	3.03	0.29	0.01	0.01	0.10	0.13
Land use, m^2	1.50	1.46	1.46	1.57	0.10	0.62	0.65	0.76	0.31
On farm	0.37	0.57	0.69	0.93	0.07	<0.001	<0.001	0.03	<0.01
Off farm	1.12	0.88	0.77	0.64	0.08	<0.001	<0.001	0.02	0.12

11. Milk and meat biophysical allocation in dairy farms

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For the dairy farming systems, where the main focus is to produce milk, the meat generated from surplus calves and culled dairy cows is an important co-product. In Life Cycle Assessments (LCA), the environmental burdens (GHG, etc.) must be distributed between these outputs. It is therefore necessary to determine total GHG emissions of the production system, which include dairy cows and heifers, and to allocate them between milk and meat. This issue has already been addressed in several studies (Cederberg & Stadig, 2003, Flysjö et al., 2011). However, the ISO 14044 suggests that the allocation should be avoided as soon as the system allows it, by subdivision of the multifunction process by sub-processes. This implies each sub-process has to be precisely defined as dedicated to the production of one of the co-products and the input and output fluxes of the whole system have to be attributed to each sub-process by a separated data collection or by the use of a technical distribution rule. Our investigation on French dairy systems is based on the causal relationship between the energy needed by animals on dairy farms and the milk and meat production. Then, the bio-physical allocation rule proposed is based on the technical functioning of the production system and consists to separate energy needed for dairy cows and heifers. It is considered that the total energy of the feed intake by cows is needed to produce milk (except pregnancy energy affected to the calf) and the total energy needed by heifers for their growth is to produce meat (final live weight before calving) in relation with meat avoided from suckler beef systems. In accordance to the IPCC guidelines 2006 to determine methane emissions, energy demand for each category of animals (dairy cows and heifers) is evaluated by distinguishing energy for maintenance, activity, growth, pregnancy and milk production.

This biophysical allocation has been tested on French dairy systems. The assessments highlight that energy affected to milk (maintenance, activity, growth and milk production) represent 73% of the total energy needed by the dairy herd (dairy cow + heifers) and the energy affected to meat (calving+ heifers) correspond to 27%. This ratio, applied to allocate GHG from dairy system to milk and meat, has been compared to milk/meat ratios obtained with other allocation approaches: protein allocation used by FAO, IDF allocation (IDF - 2010), system expansion and economic allocation (Table 1). The distribution of environmental burdens to milk and meat varies in a range of 72-88%. The ratio obtained with biophysical allocation is close to the one with system expansion (meat from beef production system) but far from values observed with protein and IDF allocations. Applied in French dairy systems, these different allocation rules have an important incidence on carbon footprint. For milk and meat, carbon footprints at farm gate range respectively from 0.79 to 0.97 kg CO_2eq/kg of milk and from 4.4 and 9.5 kg CO_2eq/kg of live weight (Fig. 2).

The allocation choice for handling by-product is crucial for the outcome of the final carbon footprint of both milk and meat. This choice is often taken from a dairy production point of view but it should also consider that culled dairy cows represent a significant share of the total cattle meat production (40-50% in France). Consistency concerning allocation in LCA studies on dairy and beef system, but also on all animal production (pigs, poultry) should then be found. This is allowed by biophysical allocation, which also has the advantage of being related to breeding practices (feed intake, forage, etc.) and showing the environmental gain allowed by mitigating techniques.

References

Cederberg C., Stadig M., 2003. System expansion and allocation in life cycle assessment of milk and beef production, Int J LCA, 350-356.
Flysjö A., Cederberg C., Henriksson M, Ledgard S., 2011. How does co-product handling affect the carbon footprint of milk? Case study of milk production in New Zealand and Sweden, J Life cycle assessments, 16, 420-430.
IDF, 2010. Bulletin of the IDF n°445/2010.
IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.
ISO 14044: 2006. Environmental Management - Life Cycle Assessment - Requirements and guidelines

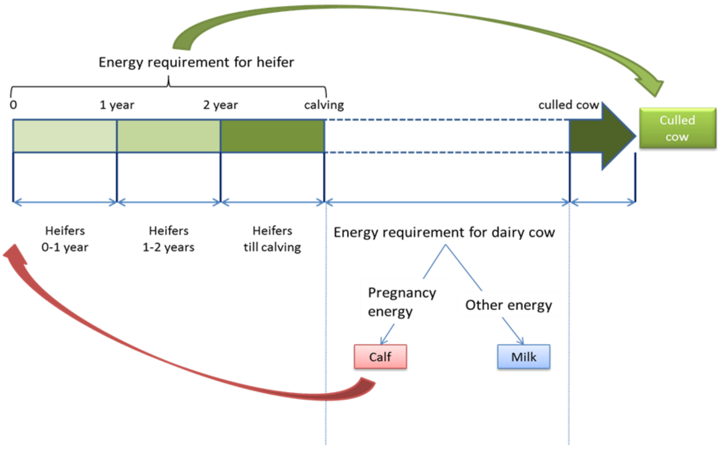

Figure 1. Energy calculation in dairy system

Table 1. Milk and meat ratios according to different allocation rules

Allocation rules	Milk	Meat
Protein	88%	12%
IDF	82%	18%
Economic	79%	21%
Biophysical	**73%**	**27%**
System expansion	72%	28%

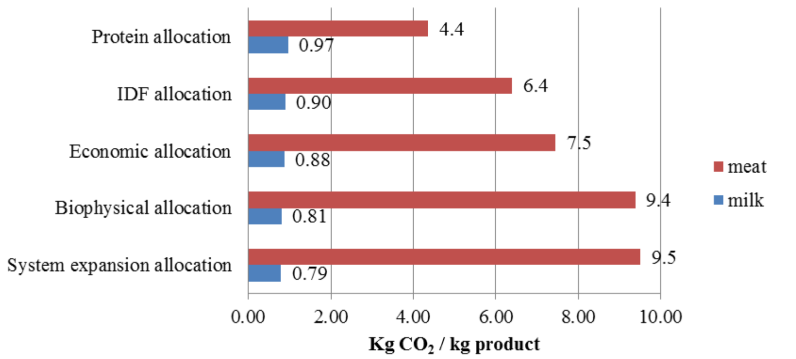

Figure 2. Milk and meat carbon footprint at dairy farm gate according to different allocation rules

12. Functional unit and reference flow in the dairy cow LCA

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Functional unit in LCA defines the functional performance characteristics delivered by the product system, here livestock. It serves as denominator in normalising the input and output data (environmental load: EL) of a product system. Normalised EL is intended implicitly and explicitly for comparison between processes and activities in a given product system, or between different product systems. Defining functional unit of an industrial product is less complicated compared with that of a livestock. This is mainly because of the difference in functional performance characteristics of the two, where the former possesses fixed attribute while the latter variable attributes. Reference flow is an amount of product needed to fulfil the function of a product system.
The objective of this paper is to investigate the effect of product attributes on the functional performance characteristics in defining functional unit and reference flow. A dairy cow was chosen as the target product for the livestock LCA and a typical size dairy farm of 65 heads of cows with different stages in growth in Korea was chosen to gather input and output data. A dairy cow undergoes different stages in its life cycle including calf, heifer, lactating cow and dry cow with a life span of average five (5) years. Different life cycle stages of a cow means composition of a cow in a farm during the life span of a cow of five years may influence the variability of the EL data from a cow. Thus, composition of a cow in a farm should be clearly defined in the reference flow.
Key findings of this paper include: functional unit should be defined based on the functional performance characteristics delivered by the product, reference flow should be one cow with known composition and life span, and composition of cows in a farm may vary depending on the number of heads the farm houses which will affect LCA results. A stable composition should be used for defining reference flow in the dairy cow LCA.

References

Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M., De Haan, C., 2006. Livestock's long shadow: environmental issues and options, FAO, Rome, Italy.
De Vries, M., De Boer, I.J.M., 2010. Comparing environmental impacts for livestock products - A review of life cycle assessments, Livestock Science, 128, 1-11.

13. Linking environmental impact of milk production to the territory: the Qualaiter project

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For the last decade, animal productions have been strongly criticised for their environmental impact. However, within a given food chain large impact variations between different systems of production are highlighted at world (FAO, 2010) or at regional scale (Casey et al.,2006). Variations that are worthwhile to explore. Therefore the Qualaiter project aims to quantify environmental impact of milk production using LCA approach, through the adaptation of EDEN methodology (Van der Werf et al, 2009) to the Belgian (Walloon) context, in link to territorial diversity recorded within Walloon area. This diversity, related to climate, geological and historical conditions, leads to associated agricultural practices diversity that potentially influence the environmental impact of the production systems. In order to discriminate the territorial from the management role on the environmental impact of dairy farms we identify three farms types that could be found in three contrasted area to compare their environmental performances.

References

Casey, J.W., Holden, M.N., 2006. Quantification of GHG emissions from sucker-beef production in Ireland. Agricultural Systems 90, 79-98.
FAO, 2010. Greenhouse Gas Emissions from the dairy Sector. A Life Cycle Assessment. Food and Agricultural Organization of the United Nations. Animal Production and Health Division. 94 p.
Van der Werf, H. M. G., Kanyarushoki C., Corson M. S., 2009. An operational method for the evaluation of resource use and environmental impacts of dairy farms by life cycle assessment. Journal of Environmental Management 90, 3643-3652.

14. A matrix approach to spatialise impacts of US milk production

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In many cases in production, goods are not consumed in the same place they are produced. This is particularly the case in agriculture. Crops are produced for a lot of purposes, which can be milk or meat production or processing for human consumption. The downstream production (eg milk or meat) does not necessarily take place in the same location where the crops were grown; some of those crops can be transported over very long distances before being consumed or processed. This is especially the case in the case of US milk, where corn grain for example is mostly produced in the Corn Belt, while it is consumed all over the nation.

On the other end and for some impact categories the impacts of crop production is very local. It is the case of water stress for example. Crop production is a water intensive activity, and water use and impacts vary greatly depending on region, crop irrigation and type of crop. In some regions, irrigation account for up to 90% of water withdrawn from available sources, while in some others with plentiful rainwater, irrigation is barely necessary.

This presentation introduces a generic model to properly account for the attribution of a flow or impact to the milk producing locations and grain producing locations, through a matrix approach at the state level. This approach allows an analysis in which an inventory flow in milk producing state j can be decomposed into inventories flows in grain producing states i. Furthermore, impacts from those grain and milk producing states are aggregated on the level of the inducer (the state producing milk, for which grain is grown in other states), the emitter (the states in which environmental emissions occur), or receiver (the states or other global regions in which the impacts of those environmental emissions are felt).

Overall, the water stress impact of 1kg milk in the US is equal to 109 liters in competition per kg milk, California representing 22% of the national milk production and 54% of the impact. This national impact incorporates the impact of each of the feeds at a state resolution. Looking at a particular feed production, corn grain, the national water impact is 54 liters in competition per kg corn grain, nearly half of this impact coming from one single state, Nebraska, combining two factors: relatively high production and relatively high water stress index. The impact of eutrophication from phosphorus takes place over the whole watershed downstream of crop production and application of organic and inorganic P fertiliser. The original matrix approach is key to correctly assess local impacts of a given industry accounting for the origin of its supplies, and can be used for different spatialised resolutions and industries.

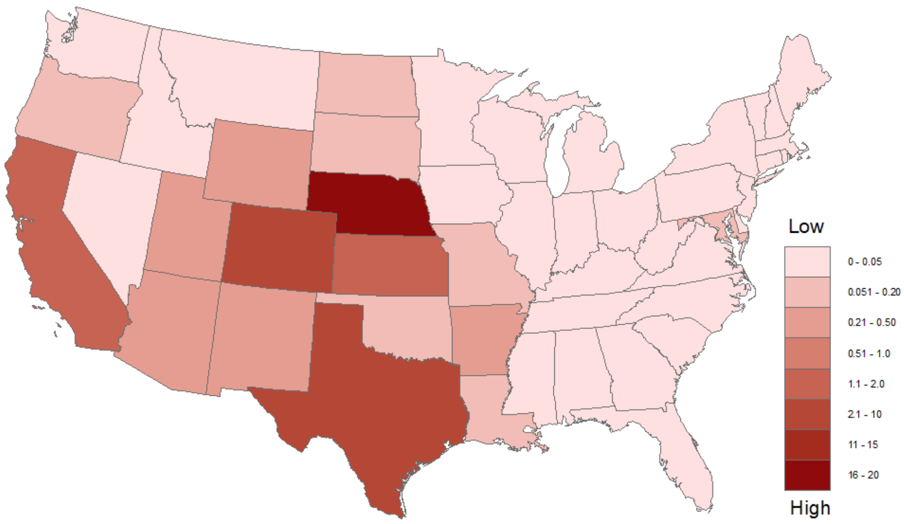

Figure 1. National assessment of water in competition for corn grain production in Leq in competition/ kg dry matter

15. Environmental and socioeconomic references of French conventional pig systems

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This study aims to produce multicriteria environmental references (using Life Cycle Assessment, LCA) associated with socioeconomic indicators for different types of pig units representative of the dominant French standard production systems. Eight systems are assessed, discriminated according to the size, the degree of specialisation and the location of the pig unit, the slurry management and the pig feeding strategy. The results are expressed per kilogram live pig produced and the LCA boundaries include the production and the supply of inputs, the production of buildings, the pig breeding and the management of slurry. The references bring a socioeconomic and environmental photography of the performance of the existing pig production systems and their variability between and within systems. The environmental results allow identification of the most strategic and easily attainable options of improvement. The effect of different improvement strategies are indentified in connection with feed formulation, improvement of animal performance, and the implementation of the recommended good environmental practices. The socioeconomic indicators of the systems show the various levels of access to the control levers of action.

References

Basset-Mens, C., Van Der Werf, H., 2004. Evaluation environnementale de systèmes de production de porcs contrastés. Journées Rech. Porcine, 36, 47-52.

Chardon, X., Rigolot, C., Baratte, C., Le Gall, A., Espagnol, S., Martin-Clouaire, R., Rellier, J.P., Raison, C., Poupa, J.C., Faverdin, P., 2007. MELODIE: A whole-farm model to study the dynamics of nutrients in integrated dairy and pig farms. In Oxley, L. and Kulasari, D. (eds) MODSIM 2007 International Congress on Modelling and Simulation. December 2007, 1638-1645.

CORPEN, 2003. Estimation des rejets d'azote-phosphore-potassium-cuivre et zinc des porcs. Influence de la conduite alimentaire et du mode de logement des animaux sur la nature et la gestion des déjections produites. Ministère de l'écologie, 41p.

Gac, A., Deltour, L., Cariolle, M., Dollé, J-B., Espagnol S., Flénet, F., Guingand, N., Lagadec, S., Le Gall, A., Lellahi, A. Malaval, C. Ponchant, P., Tailleur, A., 2010. GES'TIM: Guide méthodologique pour l'estimation des impacts des activités agricoles sur l'effet de serre. Version 1.2, 155p.

GIEC, 2006. Lignes directrices 2006 du GIEC pour les inventaires nationaux de gaz à effet de serre, Volume 4: Agriculture, foresterie et autres affectations des terres. www.ipcc.ch

Guingand, N., Aubert, C., Dollé, J.-B., 2010.Guide des bonnes pratiques environnementales d'élevage. Institut de l'élevage, IFIP, ITAVI, 303p.

Ilari, E., 2007. De 2000 à 2005, comment ont évolué les exploitations porcines françaises? Techniporc, 30 (6), 19-25.

Loyon, L., Guiziou, F., Beline, F., Peu, P., 2007. Gaseous emissions (NH_3, N_2O, CH_4 and CO_2) from the aerobic treatment of piggery slurry – Comparison with a conventional storage system. Biosystems engineering, 97, 472-480.

Marcon, M., 2008. Consommations d'énergie des bâtiments porcins: comment les réduire?. IFIP, France.

Massabie, P., 2001. L'abreuvement des porcs. Techniporc, 24 (6), 9-14

Rigolot, C., Meda, B., Espagnol, S., Trochet, T., Dourmad, J-Y. 2009. ACV de 5 systèmes porcins avec différentes hypothèses de comptabilisation des impacts. Journées Rech. Porcine, 41, 281-282.

Nemecek, T., Kägi, T., 2007. Life cycle inventories of agricultural production systems. EcoInvent report No.15. Zürich, CH. www.ecoinvent.ch

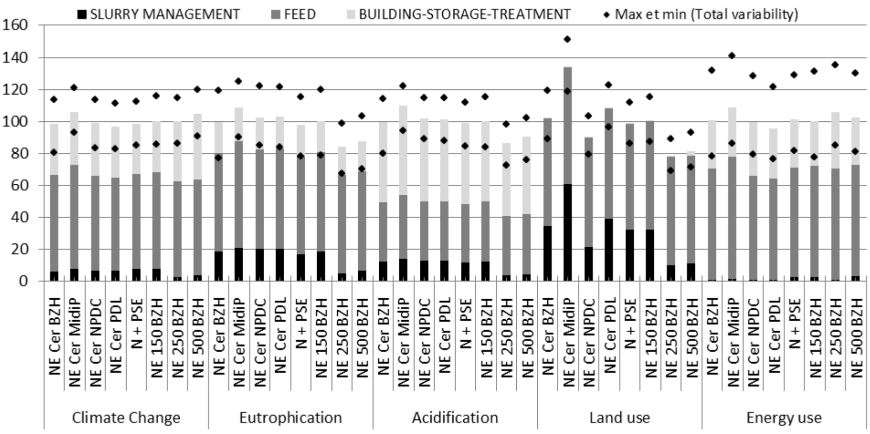

Figure 1. LCA Impacts of different types of pig units and variability (results in% of the pig unit NE 150 BZH).

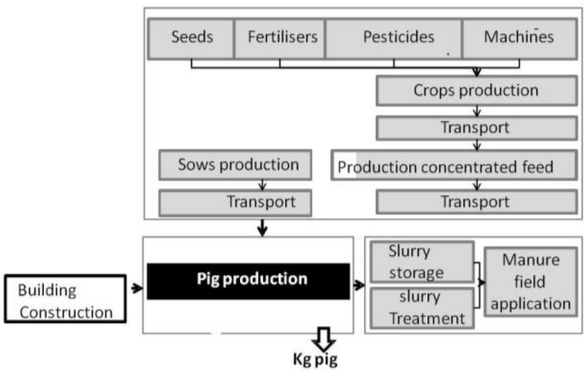

Figure 2. Flow diagram for LCA pig production.

16. Environmental impact of the pork supply chain depending on farm performances

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The aim of the study is to figure the effect of changes in farm performances on the environmental impact of pork production. The environmental assessment was performed using data representing the typical Northern German pork production in 2010 on the one hand. On the other hand, data of German pig farms with 25% highest and lowest efficiency in terms of net profit (economic success) was used. The data for the farms was gathered from an extension service for pig farms in Northern Germany (SSB, 2010). The database of the feed and slaughtering stage was composed of own data collection from specific companies and of literature. The system boundaries of the Life Cycle Assessment cover the feed production, pig housing as well as the slaughtering stage. Infrastructure, packaging, retail and consumption were excluded. The manure produced at the farm had also a value as a fertiliser, thus substituting synthetic fertiliser. The environmental impact of the whole production chain was expressed per '1 kg pork produced'. Three impact categories were considered: Global warming potential (GWP), Eutrophication potential (EP) and Acidification potential (AP), expressed in equivalents (eq).

Table 1 summarises the environmental performance with respect to the three impact categories. The average pork production results in a GWP of 3.62 kg CO_2-eq, an EP of 42 g PO_4-eq and an AP of 89 g SO_2-eq per kg pork. A higher efficiency on farm level reduces the estimated environmental impacts of GWP as well as EP. The GWP is improved by 358 g CO_2-eq per kg pork, whereas the reduction of EP reaches 0.37 g PO_4-eq per kg pork. In contrast, the average production results in a 1% increased AP compared to the production with a lower efficiency. However, the lowest AP arises out of the pork production with an enhanced performance on farm level. Nguyen et al. (2011) estimated a GWP of 3.1 kg CO_2-eq per kg carcass weight produced in Denmark. These results are in line with ours. In case of higher efficiency, the potential of reducing the GWP (2.8 kg CO_2-eq per kg carcass weight) was shown more clearly than in the present study. This could arise from the different method used or the fact that the higher efficiency was based on biological parameters.

For estimation of the contribution of these stages to the overall impacts, the production chain was divided into the stages of feed production, pig housing and slaughtering. Feed production is the main contributor in the case of GWP with a share of 80% (Fig. 1), followed by pig housing (15%) and slaughtering. The largest part of Eutrophication is caused by pig housing (51%) and feed production (48%). In the case of AP, pig housing plays a key role with an amount of 72%. Feed production is responsible for 27% of the AP, whereas only 1% of the AP originates from the slaughtering process. Over all the shown impact categories, slaughtering has only a marginal share (1-5%) to the environmental impacts of the pork supply chain.

Further calculations will include different scenarios by varying single parameters on farm level, as e.g. number of litters per sow and year, feed intake, daily weight gain and feed conversion rate. Results from the different LCAs will be compared to identify performance parameters with a high effect on the overall impacts. In order to illustrate the variation of the impacts, Monte Carlo methods will be used for further calculations.

References

Nguyen TLT, Hermansen JE, Mogensen L., 2011. Environmental assessment of Danish pork. Aarhus, Denmark: Aarhus University.
SSB, 2010. Schweinereport 2010. Schweinespezialberatung Schleswig-Holstein e.V.

Table 1. Results for the impact categories Global Warming Potential (GWP), Eutrophication (EP) and Acidification Potential (AP) for the three scenarios of pork production, related to 1 kg pork produced.

Impact category	+ 25% farm efficiency	Average production 2010	- 25% farm efficiency
GWP (kg CO_2-eq)	3.46	3.62	3.67
EP (g PO_4-eq)	42.48	42.84	44.88
AP (g SO_2-eq)	85.41	89.56	89.10

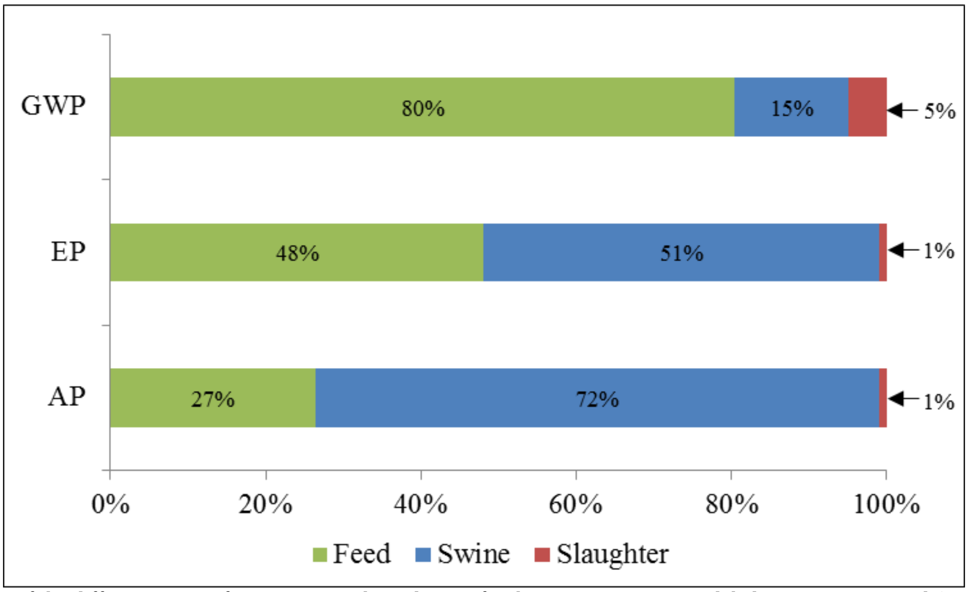

Figure 1. Percentages of the different stages of an average pork production for the impact categories Global Warming Potential (GWP), Eutrophication (EP) and Acidification Potential (AP) related to 1 kg pork produced.

17. Characterisation of the pig systems panel for the production of environmental data in the program Agri-BALYSE

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The program Agri-BALYSE is a French initiative which aims to develop a public LCI-database of French agricultural products by the end of 2012.This database has two goals: (1) it will provide data to set up environmental labeling for consumers; (2) it will also include environmental assessments of different contrasting production systems which will be more useful for the R&D and the identification of action levers.

Pig production/breeding is one of the agricultural products which is covered by the Agri-BALYSE-database. Given the fact that there exists wide variety of pig production systems in France, it has been necessary to choose the best panel of pig production/breeding systems in order to answer to the different objectives of the project. Actual representativeness of production systems was an important selection criteria but not the only one. Emphasis was given also to future representativeness as well as social desirability and agricultural practices. Three systems were defined to provide data for the environmental labeling: a national average standard production system, an organic production system as well as a pig system "fermier label rouge". Four other systems have been selected to analyse the incidence of specialisation levels and feed strategies which are considered to be the most important action drivers.

The chosen systems are qualified concerning their adaptability to the different uses by giving their actual and future representativeness, analyzing if the main levers of action are considered, considering system which are wanted by society. The final definition of the production system has also to consider if date and information are available and to see if it is (or will be) possible to trace system characteristics to the kilogram of pig.

References

IFIP, 2005-2009. Porc performances.

IFIP, 2009. Bâtiments d'élevage porcin et environnement: Analyse de l'enquête de novembre 2008 réalisée par le SCEES. France AgriMer, 272 p.

ITP, 2005. Compositions des effluents porcins et de leurs co-produits de traitement - Quantités produites, 68 p.

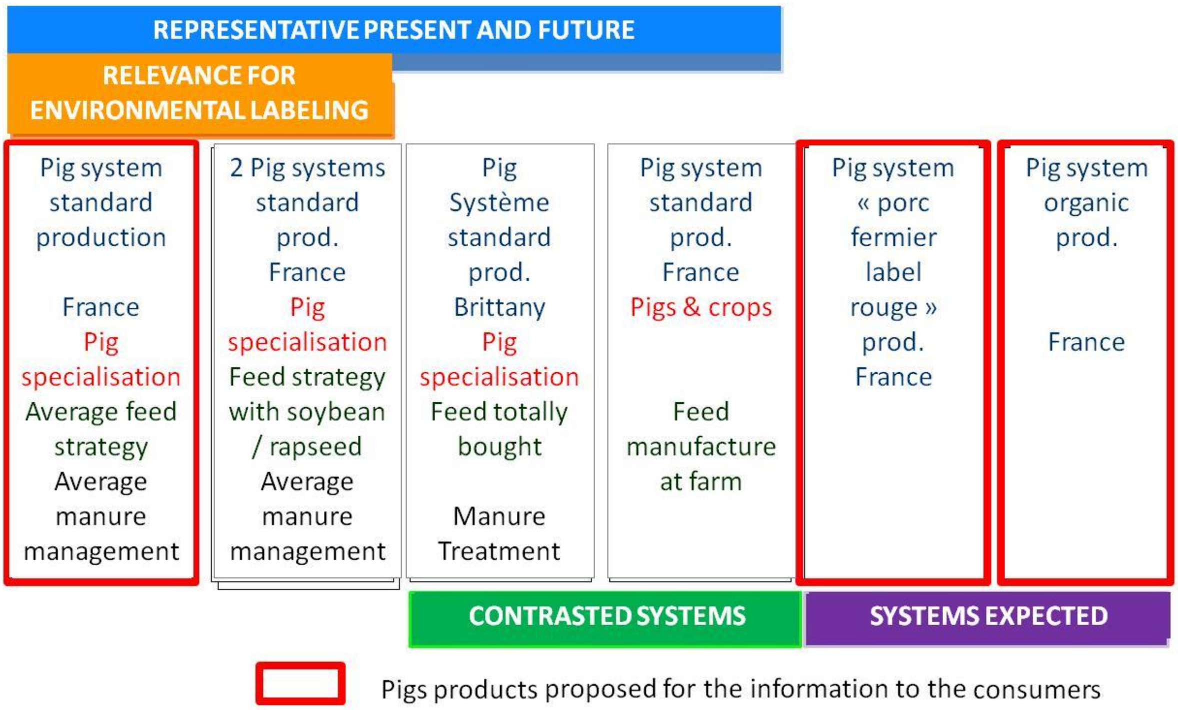

Figure 1. Pig systems for Agri-BALYSE

18. Life cycle thinking applied to an immunological product (vaccine) used for boar taint control in male pigs

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In 2009, Pfizer Animal Health decided to apply the LCA methodology to some innovative products, with a first case-study on Improvac®, an immunological product (vaccine) for male pigs that provides farmers with an alternative way to avoid the problem of boar taint: its use increases the efficiency of male pig production and could consequently provide life-cycle environmental benefits.

A meaningful LCA study of the vaccine required the collection, with a global perspective, of reliable data about the life-cycle environmental burden of an average farm that uses or not the product. Information from within-farm comparative studies was also integrated into the analysis. This led to an understanding of any possible environmental benefits of the vaccine's adoption by benchmarking against existing, traditional practices (castration).

The two most relevant phases contributing to the life-cycle environmental burden of the examined system are the production of feed given to pigs and pig slurry management (Fig. 1). Starting from the feed recipe, an interesting close examination was conducted on agricultural practices by country, providing a valuable description of how feed production burden changes according to local conditions (yields, fertiliser use, etc.). The same conclusion applies to different slurry management procedures and technologies. Overall, the LCA provided meaningful information for use by farmers who are interested in reducing their carbon footprint when rearing swine for pork meat.

The study shows a reduction in the environmental impacts considered for the vaccinated pig life cycle compared to the castrated one. In particular, the calculated carbon footprint for the Improvac pig system demonstrates a reduction vs. the physically castrated pig system of 3.7% in terms of kg live-weight; given the annual production of pigs reared globally for protein consumption (about 500M males), this carbon footprint reduction is incrementally significant and supports the adoption of Improvac over the traditional approach of castrating boars.

The product is approved for use and distributed in nearly all pig producing countries worldwide: from South America to the US and from Europe to Australia, including the world leader in swine production, China.

The Improvac Environmental Product Declaration was first published in January 2011 on the International EPD register and renewed in early 2012 after the required external review by a third party (www.environdec.com).

References

Allison J., McKeith F., C Souza, Boler D., Killefer J. Hennessy D., 2009. Impact of using vaccination with IMPROVAC® rather than physical castration on the carcass characteristics of finishing male pigs in ICOMST, 55th International Congress of Meat Science and Technology, Copenhagen 16-21 August 2009, Denmark, paper n° 7.38.

Basset-Mens C., Van der Werf H.M.G., Durand P., Leterme P., 2006. Implications of uncertainty and variability in the life cycle assessment of pig production systems. Int J LCA 11, 298-304.

Dunshea F., Colantoni C., Howard K., McCauley I., Jackson P., Long K.A., Lopaticki S., Nugent E.A., Simons J.A., Walker J., Hennessy D.P., 2001. Vaccination of boars with a GnRH vaccine (Improvac®) eliminates boar taint and increases growth performance. J. Anim. Sci. 79, 2524-2535.

European Commission, 2003. Integrated Pollution Prevention and Control (IPPC) Reference Document on Best Available Techniques for Intensive Rearing of Poultry and Pigs. JRC.

Fàbrega E., Velarde A., Cros J., Gispert M., Suárez P., Tibau J., Soler J., 2010. Effect of vaccination against gonadotrophin-releasing hormone, using Improvac®, on growth performance, body composition, behaviour and acute phase proteins. Livest Prod Sci 132, 53-59.

Pfizer Animal Health, 2011. Environmental Product Declaration of Improvac (N° S-P-00261). The EPD International System.

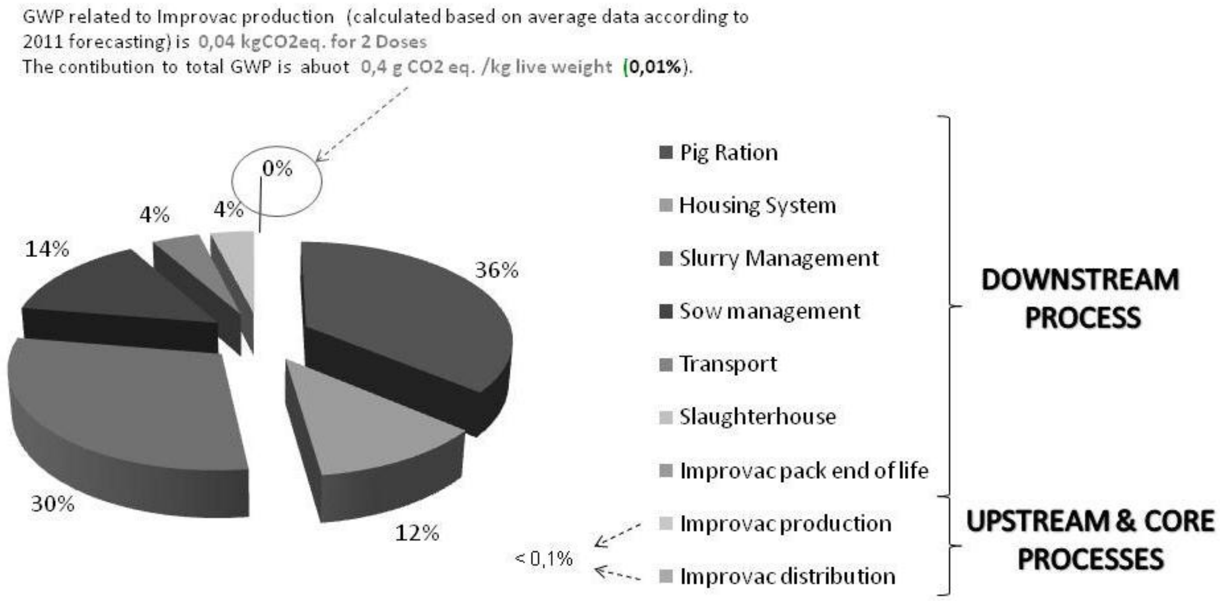

Figure 1. The most relevant contributors to the Carbon Footprint Indicator of the Improvac® system.

19. Emergy and life-cycle sustainability of pig meat products

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The effects of globalisation have inevitably an impact on food choices in relation to mass produced at low cost and greater usability at the expense of local products, which are often more expensive but with higher quality. One of these examples is represented by the meat of Cinta Senese, which is a typical pig race of the rural area of Siena, Italy. The breeding and production of this race is very different from that of the intensive white race (Large White). Indeed, Cinta Senese is reared in an almost completely natural way, within forests and usually without using industrial fodder (Basset-Mens et al., 2006). The aim of this work is to assess the sustainability of pig meat products by explicitly focusing on the breeding phase. We have compared the two races through the application of Life Cycle Assessment (LCA) and eMergy analyses. In this connection, eMergy (Odum, 1996) is considered to be complementary to LCA allowing for a broad assessment of resource consumptions and also of social and economic issues (Rugani et al., 2011). As shown in Fig.1, the application of LCA highlights that the production of 1 kg of Cinta Senese meat has lower potential impacts than the production of Large White within a set of impact categories considered (i.e. climate change, acidification and eutrophication). Indeed the production of 1 kg of Cinta Senese pig has a potential climate change impact of 2.25 kg CO_2eq, while for Large White is 3.6 kg CO_2eq (Fig.1). A greater discrepancy is observed on the potential impact related to acidification (0.016 kg SO_2eq for Cinta Senese and 0.045 kg SO_2 eq for Large White), while similar scores are depicted for the potential impact on eutrophication (around 0.23 kg NO_3eq). Fertilisers, water and agricultural machinery operations, used for fodder production, are the main responsible of all environmental impacts in Cinta Senese rearing system. On the other hand, results from eMergy evaluation show that Cinta Senese is less efficient than the White race in terms of yield. In fact, the specific eMergy of Cinta Senese was about 3.5 times greater than that of Large White: 7.53E+09 seJ/g and 2.57E+09 seJ/g respectively, this is principally due to the rearing system. During one year of growth, Cinta Senese living pig weighs 110 kg while Large White 140 kg and the available space for each head is 12.00E+03 m^2/head vs 0.23E+03 m^2/head, respectively. Emergy evaluation highlights that the production system of Cinta Senese, due to the large use of renewable and local resources, generates less direct and indirect environmental impacts than the Large White breeding (the percent of renewability is 21.03 and 2.15 respectively). The "monetary" value of renewable (R) and non-renewable (N) emergy flows, created by giving a price to the local environmental eMergy, is 9.80E+03 seJ/€ for Cinta Senese and 8.78E+03 seJ/€ for Large White. Results highlight higher relative contributions of labour for the production of Cinta Senese, demonstrating the wider relevance of direct human resources for this extensive system. The present study points out that it is possible to discuss the three fundamental pillars at the base of the sustainability concept (environment, society and economy) by using eMergy combined with a life cycle inventory. Emergy evaluation emphasised the peculiarities of the Cinta Senese system, in comparison to a conventional pig breeding system of White race pigs, and the importance of the local ecosystem for the entire process dynamics.

References

Basset-Mens, C., van der Werf, H.M.G., Durand, P., Leterme Ph., 2006. Implications of Uncertainty and Variability in the Life Cycle Assessment of Pig Production Systems. Int. J. Life Cycle Assess. 11, 298-304.

Dalgaard, R., 2007. The Environmental Impact of Pork Production from a Life Cycle Perspective. Ph.D. thesis, Aalborg University, Denmark.

Guinèe, J. B., Gorreèe, M., Heijungs, R., Huppes, G., Kleijn, R., de Koning, A., van Oers, L., Wegener Sleeswijk, A., Suh, S., Udo de Haes, H. A., de Bruijn, H., van Duin, R., Huijbregts, M. A., 2001. Handbook on Life Cycle Assessment. Operational Guide to the ISO standards, Kluwer Academic Publisher: Dordrecht, The Netherlands.

Odum, H.T., 1996. Environmental Accounting: Emergy and Environmental Decision Making. Wiley & Sons, New York, USA.

Rugani, B., Pulselli, F.M., Niccolucci, V., 2011. Emergy Assessment of Cinta Senese Breeding and Comparison with Conventional Pig Production, in: Emergy Synthesis 6. Theory and Applications of the Emergy Methodology. The Center for Environmental Policy, Gainesville, USA, pp. 347-358.

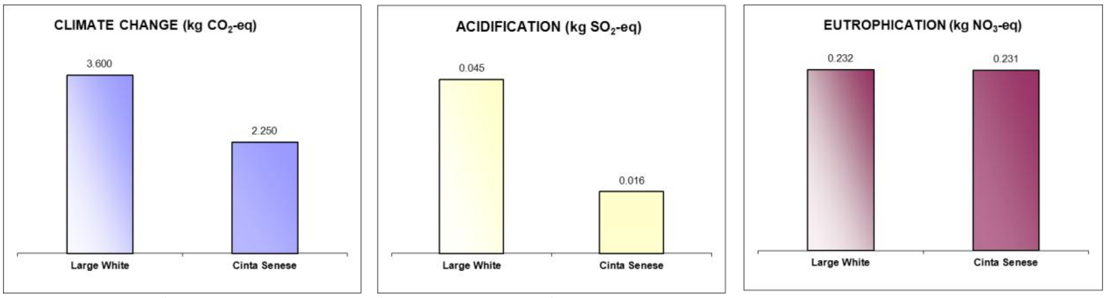

Figure 1. Results comparison of impact characterisation for the production of Cinta Senese and Large White (LW data source: Dalgaard et al. (2007); reference = 1 kg live pigs). Life Cycle Inventory (LCI) & Life Cycle Impact Assessment (LCIA) elaborated using SimaPro 7. Impact characterisation performed using CML2001 method, as proposed by Guinèe et al. (2001).

20. Life cycle assessment of an intensive Iberian pig farm

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Iberian pig production has been a major livestock practice in Spain for a long time, offering meat products destined to a niche market which demands a high sensory quality. Nowadays the most extended system is the intensive production of the crossbred Iberian x Duroc, reared during at least 10 months of age and slaughtered at approximately 150 kg live weight.. The recent unfavourable economic situation and increase in feed price has resulted in the closing at some farms, pushing them to improve their efficiency using the resources. Within this benchmark, an evaluation of the efficiency of the system is needed to assess farming viability by means of standardised tools. One of the main pillars of this efficiency is environmental impact, which was estimated by a Life Cycle Assessment in the present study, to be considered in an integrated sustainability evaluation. The results should determine weaknesses and strengths of the system, as well as numerical scores, which could be used as consumer information.
A representative closed cycle farm of Iberian pig production (Iberian x Duroc) located in Catalonia (Alt Empordà) was selected for the study. It has capacity for 450 sows, 1,120 piglets and 3,000 fatteners. One 150 kg pig at the farm gate was chosen as a functional unit. The system boundary is defined up to the farm gate, considering waste disposal, but not considering post stages such as slaughtering or commercialisation. Impact categories selected were midpoint impact categories defined by the CML (Guinée, et al., 2002).
Primary data were obtained from the representative farm object of the study. ECOGAN software from the Agriculture Department (MARM, 2011) was used to calculate the NH_3, NO_2 and CH_4 emissions and the resources used within each production stage. Secondary data were obtained from Ecoinvent database. Origin of feed ingredients was based on data from cereal producers in Spain. It was assumed that soybean came from Brazil. The software used for the assessment was the SimaPro version 7.2 (PRé Consultants, 2010), performing the compulsory phases of classification and characterisation. For the whole closed cycle, data were collected from the different production stages including gestation, lactation, rearing and fattening, they were considered as a part of the foreground (Fig. 1).
Table 1 shows the absolute values for each environmental impact category for a 150 kg pig and related to 1 kg of meat. It is important to bear in mind that an Iberian pig is less efficient than conventional pigs with regard to its conversion rate, and this elevates the values of the impacts because they consume more feed. Therefore it would be interesting to relate the impacts not only to kg of meat, but also to other quality indexes such as the percentage of intramuscular fat.
Crop and feed production, including grain and soybean production needed for their manufacture, were shown to be the main environmental constrains for impact categories such as eutrophication, air acidification and climate change, while the use of energy within maternity contributed to a larger extent to impacts related to energy consumption, such as abiotic depletion.
This study also provides information for the main drawbacks regarding the application of the methodology and will therefore need further research, especially if it is to be used in environmental communication or labels. Main drawbacks can be summarised as: lack of local datasets to be used in the background system; agreement and homogenisation among models used in the emission factors estimation, as well as emissions related to land use for imported feeds; consideration of nutritional qualities as functional units instead of meat quantity.

References

Ecoinvent, 2010. ecoinvent Data v2.2. Swiss Centre for Life Cycle Inventories.
Guinée, J. B., Gorrée, M., Heijungs, R., Huppes, G., R., K., de Koning, A., Wegener Sleeswijk A., Suh, S., Udo de Haes, H., Bruijn, H., Duin, R. v. and Huijbregts, M. A. J., (2002). Handbook on life cycle assessment. Operational guide to the ISO standards. Dordrecht, The Netherlands. Kluwer.
MARM, 2011. ECOGAN 2009.0.0 Software. Spain.
PRé Consultants, 2010. SimaPro 7.2. Amersfoort. The Netherlands.

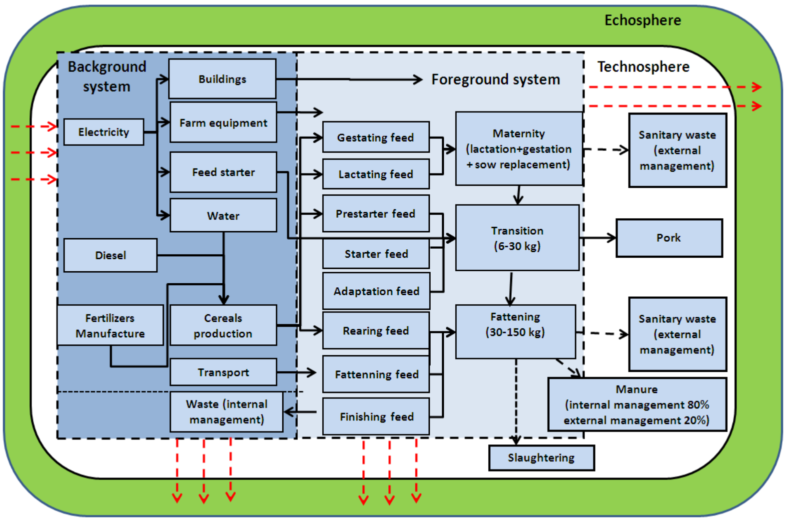

Figure 1. Flowchart of a representative closed cycle farm of intensive Iberian x Duroc pig production in Spain.

Table 1. The environmental impacts of pig production expressed per pig unit and kg pork.

Impact category	Units	per pig unit (150 kg)	per 1 kg pork
Air Acidification	kg SO_2 eq	5.05	0.03
Global warming	kg CO_2 eq	910.6	6.07
Abiotic depletion	kg Sb eq	2.56	0.02
Eutrophication	kg PO_4^{3-} eq	6.91	0.05
Photochemical oxidant formation	kg C_2H_4	0.79	0.005
Freshwater Toxicity	kg 1,4-DB eq	82.21	0.55
Human Toxicity	kg 1,4-DB eq	349.8	2.33
Terrestrial Toxicity	kg 1,4-DB eq	2.60	0.02

21. Comparison of environmental impacts of corn or sorghum as geese feed in *foie gras* production

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Innovations are needed to improve the sustainability of livestock production systems, i.e. to reduce their environmental impacts while maintaining or increasing their economic viability. The feed represents the greatest part of the economic and environmental costs of poultry rearing (Boggia et al, 2010). Therefore, changing feeding practices, i.e. the choice of raw materials, seems one of the promising ways. Raw materials should be chosen according to their environmental impacts and availability. To increase the number of raw materials usable improves the flexibility of systems, limiting the reliance on price fluctuating products. The feeding of waterfowl in the production of "*foie gras"* is based in large part on corn as an energy source during both the rearing and the overfeeding periods. Sorghum (*Sorghum bicolor*) has been chosen to substitute corn in "*foie gras*" production. Indeed, this cereal has similar nutritional characteristics to corn's ones (Sauvant et al, 2004), but is more drought-resistant. Thus, it is an interesting candidate to reduce the vulnerability of French agriculture to the water shortage risk (Amigues et al, 2006), by reducing the need of irrigation. Arroyo et al. (2012) showed that sorghum could be used as goose feed during growing-finishing period (GF period) and during overfeeding period (O period) of "*foie gras*" production. The aim of this work was to evaluate with LCA method, the environmental impacts of the effects of substitution of corn by sorghum during GF and O periods on "*foie gras*" production. Attributional LCA was conducted on different scenarios of partial and total substitution of corn by sorghum, based on experimental data (Arroyo et al., 2012) and the running on average goose farms. Ecoinvent was used as the source of secondary data, but specific data were generated for corn, sorghum and goose productions. The impact categories were calculated using mainly CML2 method: eutrophication (EP, kg PO_4- eq.), climate change (CC, kg CO_2 eq.), acidification potential (AP, kg SO2 eq.), terrestrial ecotoxicity (TE, kg 1.4- DCB eq.), cumulative energy demand (CED, MJ), water use (WU, m^3) and land occupation (LO, m^2 per year). The functional unit was 1kg of "*foie gras*". The impact calculation was conducted using SimaPro_ 7.2 software and mass allocation approach. 1kg of *"foie gras"* from geese fed with sorghum as the only cereal during both GF and O periods induced lower environmental impacts than the "*foie gras"* from the corn fed geese (i.e.: CC: 1,323 vs. 1,471 kg CO_2-eq respectively). For all the impacts, the highest values were observed for 1kg of "*foie gras"* from geese fed with sorghum during the G period, due to higher bird mortality during O period (1,623 kg CO_2-eq). Using sorghum during the O period only did not affect the environmental impacts compared to the use of corn (1,427 kg CO_2-eq). Present results suggested that total substitution of corn by sorghum in goose diet offers interesting perspectives for more sustainable feeding strategy in the production of "*foie gras".*

References

Amigues, J.P., Debaeke, P., Itier, B., Lemaire, G., Seguin, B., Tardieu, F., Thomas, A. 2006. Sécheresse et agriculture. Réduire la vulnérabilité de l'agriculture à un risque accru de manque d'eau. Expertise scientifique collective, synthèse du rapport, INRA (France), 72pp.

Arroyo, J., Auvergne, A., Dubois, J.P., Bijja, M., Lavigne, F., Fortun-Lamothe, L., 2012. Influence of feeding sorghum on the growth, gizzard development and carcass traits of growing geese. Animal (in press)

Boggia, A., Paolotti, L., Castellini, C., 2010. Environmental impact evaluation of conventional, organic and organic-plus poultry production systems using life cycle assessment. World's Poultr. Sci. J. 66, 95-114.

Sauvant, D., Perez, J.M., Tran, G., 2004. Tables of composition and nutritive value of feed materials: pigs, poultry, cattle, sheep, goats, rabbits, horses, fish. eds INRA Editions, Paris and Wageningen Academic Publishers, The Netherlands. 304pp.

22. Nitrogen content allocation to handle co-products in livestock systems – case study on a poultry supply chain

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In food sectors processes along the life cycle of a product can be multifunctional. ISO standards for Life Cycle Assessment specify rules in order to allocate the environmental burden between co-products. First recommendation is to avoid allocation with subdivision or system expansion. However when it is not possible, emissions and raw materials consumption allocation must reflect the physical relationship between products. Usually economic, mass or gross energy content allocation rules are used. But several problems remain for agricultural productions: economic allocation is highly sensitive to market fluctuations and mass and gross energy content allocations could lead to counter-intuitive results. Co-products may indeed weight or contain more energy than the product under study itself. For these points, allocation has always been considered as one of the most controversial issues in LCA and particularly for agricultural systems (Audsley et al., 1997).
Livestock productions are highly multifunctional (e.g. dairy farming produces milk, meat, and manure). In industrialised countries, its main function is the provision of proteins for human diet and its major environmental problems are linked to high nitrogen (N) losses occurring during manure management. For these reasons, we proposed in this study to compare results obtained with allocation rule based on product's nitrogen content with other classical allocation rules (Mass and economic allocation and economic allocation with system expansion to manure use). Effects of these different allocation rules were applied on a poultry supply chain in La Réunion (French Tropical Island). Allocation is applied at different production stages: i) breeders rearing where co-products are breeders and litter, ii) layer production with hatching eggs, cull animals and unfertilised eggs, iv) broiler production with broiler and litter, v) slaughterhouse vi) Incineration plant with production of feathers and blood meal as fertiliser and wastes management. For economic allocation we use the product price at process level. Manure price was estimated by on farm surveys. For system expansion, poultry litter was in this case replaced by mineral fertiliser which is imported from mainland France over ten thousand kilometres. The functional unit was defined as one tonne of chicken carcass at slaughterhouse gate. System boundaries are shown in Fig. 1. LCA was performed using CML 2 Baseline 2000 for Global Warming (GW), Energy Use (EU), Acidification Potential (AP) and Eutrophication Potential (EP) impact categories, and Cumulative Energy Demand method v1.08, all implemented in Simapro Software.
Impacts categories were significantly sensitive to the allocation rule (Fig. 2). Economic allocation leads to higher impact over all categories. System expansion reduced by 10% GW and EU and 5% EP and AP. Nitrogen content and mass allocation show results around 25% and 30% lower than economic allocation respectively. Most of differences were observed at farming stage with manure management.
Manure management patterns could differ a lot within a same territory that it is often difficult to establish a reasonable cost for economic allocation. Mass allocation has to be avoided because litter weight highly depends on moisture content. System expansion is not recommended in this case because of additionally maritime transport burden. Nitrogen content allocation seems to be an interesting option for livestock production environmental assessment and is in the range of other allocation rules. Finally, the choice of allocation rule for agricultural systems always depends on the manure value in the given system. Using this allocation rule, poultry litter takes however a high part of environmental burden of meat production, which seems consistent regarding its high value all over the world.

References
Audsley, A., et al., 1997. Harmonisation of environmental life cycle assessment for agriculture. Final report, Concerted Action AIR3-CT94-2028. European Commission DG VI, Brussels, Belgium.
Guinée, J.B., et al., 2002. Handbook on Life Cycle Assessment. An Operational Guide to the ISO Standards. Kluwer Academic Publishers, Dordrecht, The Netherlands.
ISO, 2006. ISO 14040—Environmental management—life cycle assessment—principles and framework. International Organisation for Standardisation, Geneva.

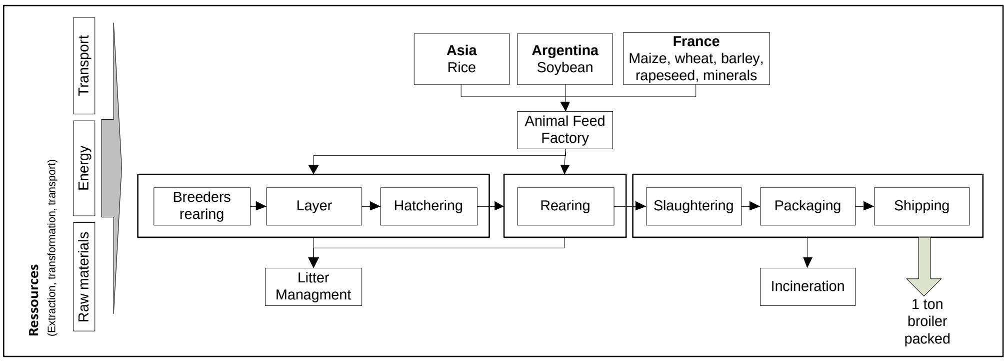

Figure 1. System boundaries for a cradle to slaughterhouse gate for 1 ton of broiler packed ready for transport

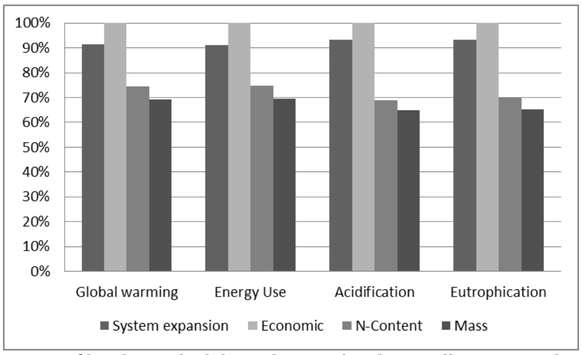

Figure 2. Results of impact assessment for 1 ton of broiler packed depending on the chosen allocation method

23. Influence of allocation methods and system boundaries in LCA of broiler production

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Although life cycle assessment is regulated by the ISO 14040 series, there are still several issues, such as described by Reap et al. (2008), in an LCA study that might generate questions and discussions. Definitions as system boudaries or allocation for example, which may induce to a misleading comparison between LCA studies. To develop this study we evaluated the broilers production in southern Brazil, ranging the composition of the chicken diet in two scenarios: (i) feeds with use of by-products derived in the abattoir process (animal origin), and (ii) substitution of by-products by an increase of soybeans (vegetable broiler). First were evaluated the broiler with the system boundary comprising the extraction of raw materials used for growing grain in the diet of chickens to the farm gate, and then were expanded the boundaries to the port for export, including the slaughtering process. This change in the boundaries makes necessary the use of allocations methods in the abattoir stage which depending of the adopted procedure adds high sensitivity in the final LCA results. Luo *et al.* (2009) studied the allocation's influence in LCA of ethanol from corn and concluded that the results are highly sensitive to the allocation method and a challenge from a scientific point of view. Therefore, the aim of this paper is to demonstrate the difference in the final results in a product's LCA using two different methods of allocation, mass and economic in the vegetable broiler, also intending to demonstrate the importance of defining the system boundaries. For the broiler with animal protein were used the mass allocation. The functional units were a ton of broilers live weight and a ton of broiler slaughtered, eviscerated and frozen at the port. The impact categories used for life cycle impact assessment were global warming potential from CML 2 baseline 2000 method plus the total cumulative energy demand. The results showed that the broiler feed with chicken by-products (animal protein) has a better environmental performance than the chicken with vegetable diet (without chicken by-products) for the evaluated impact categories. When the system boundary is increased for the broiler slaughtered at the port for export, it shows the high sensitivity of the results depending on the allocation procedure used in the slaughter process the outputs can either improve as getting worse the environmental performance of the vegetable broiler, as shown in Table 01 and Figure 01.

References

Associação Brasileira de Normas Técnicas – ABNT, 2009. NBR ISO 14044 Gestão Ambiental – Avaliação do ciclo de vida – Requisitos e Orientações. Brasil.

Luo, L., van der Voet, E., Huppes, G., Udo de Haes, H. A., 2009. Allocation issues in LCA methodology: a case study of corn-stover-based fuel ethanol. International Journal of Life Cycle Assessment, 14, 529-539.

Reap, J., Roman, F., Duncan, S., Bras, B., 2008. A survey of unresolved problems in life cycle assessment: Part 1: goal and scope and inventory analysis. International Journal of Life Cycle Assessment, 13, 290-300.

Table 1. Results for 1 ton of frozen broiler.

Life Cycle	Broiler with animal protein		Vegetable Broiler (MA)[a]		Vegetable Broiler (EA)[b]	
	GWP[c]	*CED*[d]	*GWP*[c]	*CED*[d]	*GWP*[c]	*CED*[d]
Total maize	*39.8*	*32.6*	*32.1*	*26.*	*39.5*	*32.6*
Total soybeans	*34.6*	*26.8*	*32.2*	*25.1*	*40.2*	*31.1*
Other feed ingredients	*7.3*	*14.9*	*6.3*	*9.6*	*8.2*	*12.1*
Feed subtotal	81.6	74.4	70.5	61.0	87.9	75.9
Eggs to hatch	6.3	8.5	5.4	7.2	6.4	8.6
Day-old chicks	0.4	0.8	0.4	0.1	0.5	0.8
Live poultry	17.4	22.5	15.1	19.6	17.5	22.6
Livestock transportation	3.3	4.6	2.5	3.7	3.3	4.7
Slaughter	3.5	7.7	3.2	6.5	3.5	7.7
Packaging	1.4	4.9	1.4	4.9	1.4	4.9
Total	113.9	123.3	98.6	103.2	120.5	125.0
Avoided fertiliser	13.9	23.3	11.5	19.3	14.1	23.7
Total	100.0	100.0	87.1	83.9	106.4	101.3

[a] Mass allocation., [b] Economic allocation., [c] Global Warming Potential, in%., [d] Cumulative Energy Demand, in%.

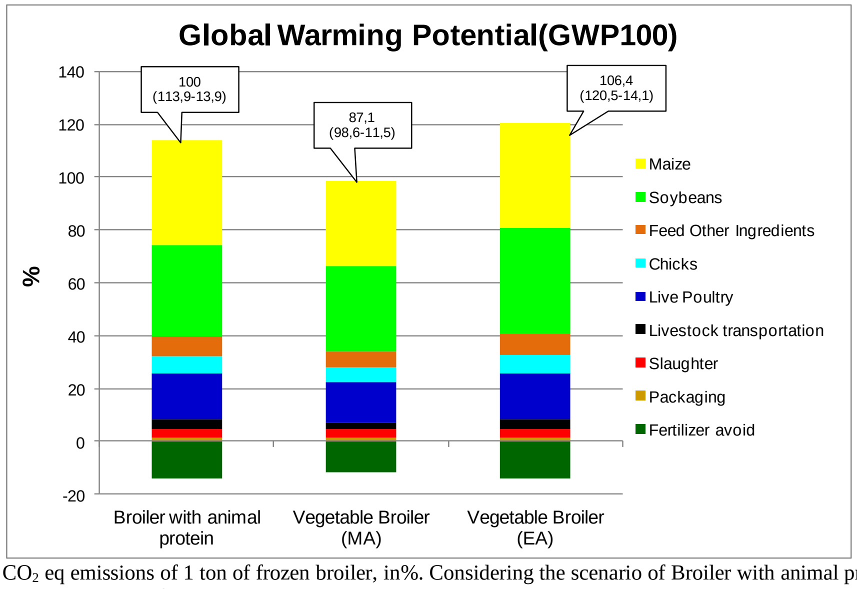

Figure 2. Comparison of CO_2 eq emissions of 1 ton of frozen broiler, in%. Considering the scenario of Broiler with animal protein as base of comparison, showing the difference in the results of the vegetable broiler with the allocations methods applied.

24. Reduction of GHG emissions from broilers fed a phytogenic additive

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Mitigation of greenhouse gas (GHG) emissions from broiler production may be achieved by various options, including increased performance, changes in diets and adaptations for housing and litter management systems (LMS). The overall aim of this study was to analyse GHG emissions from broiler production in Austria including a quantification of the impact of feeding the phytogenic feed additive "Biostrong® 510" (BSG; Delacon Biotechnik GmbH, Steyregg, Austria). Methods and emission factors for calculation of emitted NH_3 and GHG are based on IPCC (2006), Anderl et al. (2011), and Hörtenhuber et al. (2011). The reducing effect concerning NH_3 emissions is derived from experimental data (Jelinek et al. 2004). Performance data and data on nitrogen excretion were taken from van Krimpen (2011).

The calculated CO_2-equivalents per kg BSG are about 2.0 kg. The inclusion of BSG in broiler feed (150 ppm) does not increase the feed production-related GHG emissions (less than 0.1%) per ton of feed. Emissions from the basal diet (corn, soybeans, wheat) were found to be the most important drivers for GHG emissions for broilers (see Fig. 1). It was concluded that GHG emissions per kg live weight could be reduced by 5% (4 to 6%, depending on the origin and production methods for feedstuffs and raw materials), if the corn-soy-wheat diet was supplemented with BSG. According to van Krimpen (2011), who analysed 18 comparable trials with BSG, this reduction is achieved by: (1) Improved digestibility and thus a better feed conversion ratio (contributing 60% of the reduction), which also results in (2) less excreted nitrogen (responsible for 20% of the reduction); (3) saponins in BSG directly inhibit NH_3 formation (Weber et al., 2012; 20% of reduction). Considering that the use of this feed additive does not demand for major changes in supply chains or cost-intensive investments, the reduction of about 5% of GHG emissions is remarkable. Furthermore, it is possible to combine the feed additive's effect with other mitigation options (e.g. adaptations in LMS). The improved feed conversion and lower mortality (see van Krimpen, 2011) also result in a higher profit.

References

Anderl, M., Freudenschuß, A. , et al., 2011. Austria's National Inventory Report 2011. Submission under UNFCC and under the Kyoto Protocol. Vienna, Austria.

Hörtenhuber, S., Lindenthal, T., Zollitsch, W., 2011. Reduction of greenhouse gas emissions from feed supply chains by utilizing regionally produced protein sources - the case of Austrian dairy production. Journal of the Science of Food and Agriculture 91, 1118-1127.

IPCC (International Panel on Climate Change), 2006. Guidelines for National Greenhouse Gas Inventories. [Available at www.ipccnggip.iges.or.jp/public/2006gl/index.html].

Jelinek, A., Dědina, M., Plíva, P., Souček, J., 2004. Research of biological agents effects on reduction of ammonia concentration in stables of intensive farm animals breeding. Res. Agr. Eng., 50(2), 43-53.

van Krimpen, M., 2011. Assessing the effect of the phytogenic feed additive Biostrong® 510 on performance and ammonia emissions in broilers. Confidential report 281. ISSN 1570 - 8616.

Weber, T., Veit, M., Wendler, K.R., Weghuber, J., Höglinger, O., 2012. Evaluation of ammonia reduction potential of saponin containing plant materials by measurement of urease inhibition. In: Mair, C., Kraft, M., Wetscherek, W., Schedle, K. (Eds.), Proc. of the 11th BOKU-Symposium Tierernährung. Vienna, Austria, 19 April 2012. University of Natural Resources and Applied Life Sciences Vienna, Austria. pp. 213-215.

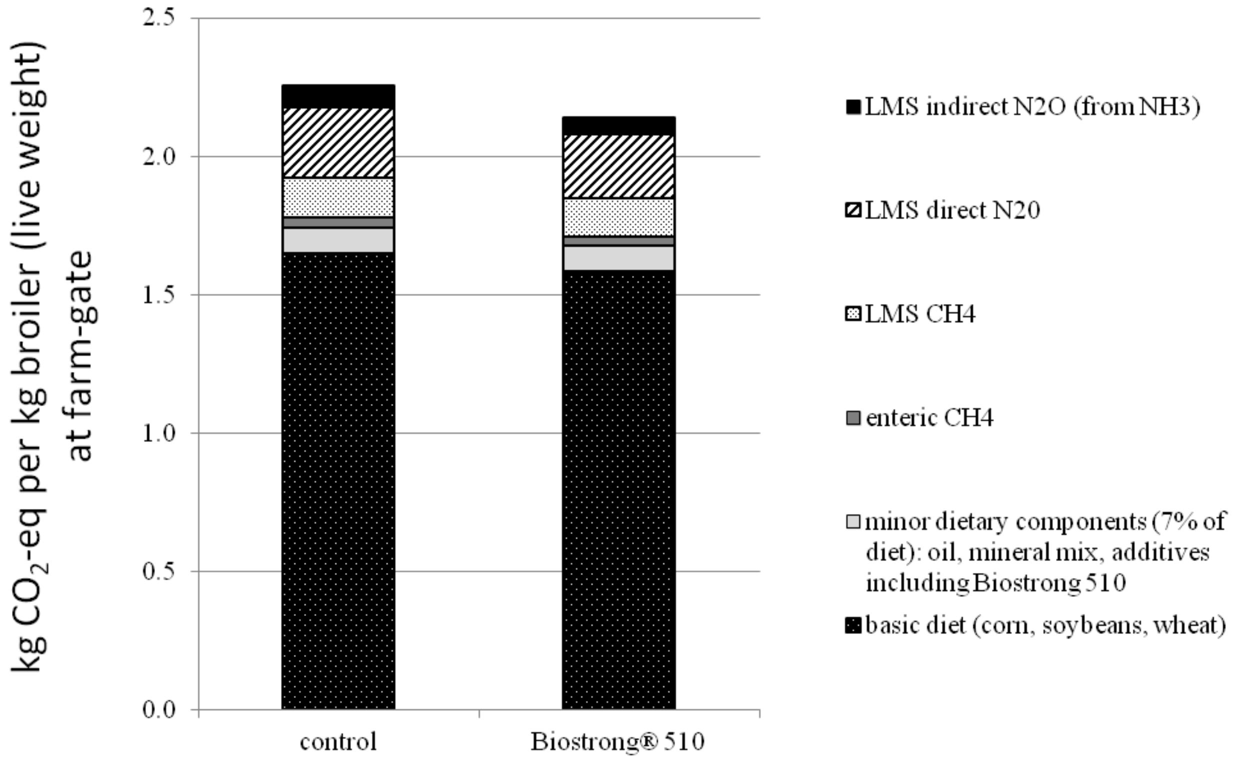

Figure 1. GHG emissions per kg of broiler with and without Biostrong® 510 supplementation (kg CO_2-eq per kg of live weight at farm gate before slaughtering).

25. Allocation between high value co-products from livestock: a case study from Australian sheep production

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Much of the Australian sheep industry is based Merino sheep, which produce high value wool and also sheep meat. In contrast to many other sheep producing regions of the world, wool is the primary product from Merino sheep, though sheep meat is also an important and high value co-product. Within the meat production component of the system, two grades of meat are produced; high grade (HG) meat from lambs and low grade (LG) meat from older cull-for-age (CFA) breeding animals. These co-production issues were investigated in a 'farm-gate' study of Australian sheep production. Handling of co-products for sheep systems has been investigated previously by Eady et al. (2011) for an Australian Merino sheep farm. Eady et al. (2011) investigated a biophysical allocation process based on partitioning the feed consumed by the breeding flock to either wool or lamb production and an economic allocation process. Impacts were found to be similar using either approach. Eady et al. (2011) determined that system expansion was difficult to apply to a sheep system because of the sensitivity around choices with substitution products for the meat. They also noted the difficulty in selecting substitution processes for other outputs from the flock such as rams, which are sold for breeding purposes. All other studies reviewed by the author for sheep production have used economic allocation to handle wool / sheep meat, though most of these studies have been for production systems where the wool produced is of low quality, and sheep meat is the primary product. Hence, no study has yet applied system expansion to Merino sheep production. A similar co-production issue exists in the dairy industry, where the cow herd produces both milk, calves (that enter the beef production system) and CFA cows (beef). Two studies (Flysjö et al. 2011; Cederberg and Stadig 2003) have specifically investigated the sensitivity of methodology choices around this co-production issue, applying a variety of methods including economic allocation, biophysical allocation and system expansion. Cederberg & Stadig (2003) argue that system expansion is a logical approach for accounting for beef produced in dairy systems, because this product directly enters the beef market affecting supply and demand. Both Cederberg & Stadig (2003) and Flysjö et al. (2011) note that using system expansion to handle meat (by substituting with beef from purpose grown beef herds) resulted in lower environmental burdens for the milk product. Co-production in dairy farming has some similarities to Merino sheep production, though sheep meat from Merino production is more important than meat from dairy systems in terms of total mass of product and economic value.

The aim of the study was to investigate the sensitivity of co-production decisions by applying three methods; economic allocation, a simplistic biophysical allocation based on the total mass of product, and system expansion. The farm selected for the study was a small Merino producer from a high rainfall region in New South Wales. The farm had 1500 ewes producing 4.1 kg wool / head.yr and 1200 lambs (80% weaning rate).

Allocation between HG and LG meat is not unique to sheep production. From a review of the literature, few beef and pork studies were found that differentiated between meat from young animals and older CFA animals. Allocation between these meat products depends on the definition of product function. The main differences between HG and LG meat relate to eating quality factors such as tenderness, meat colour and flavour, not the nutritional properties (mass of energy, protein etc). Hence, if the focus of a study is the provision of nutrition for human consumption, it is reasonable to group HG and LG meat together as they are functionally comparable. Further to this, the quality factors associated with HG and LG meat are market specific. For example, some Australian sheep meat markets (such as the Middle East) prefer LG sheep meat because the flavour is considered superior to HG meat. Applying an allocation process (such as economic allocation) therefore introduces market preferences and a wide range of quality factors, which need be reflected in the definition of the functional unit. This study chose to consider meat from HG and LG meat functionally equivalent, thereby avoiding the need for allocation at this point.

Co-production of wool (greasy weight) and sheep meat (live weight) was handled using three approaches; economic allocation, mass allocation and system expansion. Economic and mass allocation factors are provided in Table 1. The system expansion approach followed a similar approach used in the dairy industry by Cederberg and Stadig (2003). Meat from Merino systems enters the lamb and mutton supply chain in Australia where it is considered functionally equivalent (on a nutritional basis) with meat from 'purpose grown meat sheep' flocks. 'Purpose grown meat sheep' is used here to describe production systems that focus on meat production, which tend to use different sheep breeds that produce lower quality wool that has negligible value. Some purpose grown meat sheep systems produce no saleable wool because breeds have been selected that naturally shed their wool each year. Considering meat from Merino flocks is not differentiated in the meat supply chain (post slaughter), meat from purpose grown meat sheep was considered an appropriate substitution product.

Comparison of the three methods showed a four-fold difference in greenhouse gas (GHG) emissions for wool. The system expansion method resulted in total GHG of 7.6-9.2 kg CO_2-e / kg greasy wool. Economic allocation resulted in total GHG of 31.7-33.8 kg CO_2-e / kg wool. The simple mass allocation approach resulted in total GHG emissions of 8.1-8.3 kg CO_2-e / kg greasy wool, which was similar to the results using system expansion. The difference between the system expansion and economic allocation results were similar, though much more pronounced, than the findings of Flysjö et al. (2011) for dairy production, which showed system expansion to generate the lowest impacts for the primary product.

Economic allocation was sensitive to annual and cyclical changes in the value of wool and sheep meat. This changed the GHG emissions allocated to wool by ± 30% between different years (over a five year period). While mass allocation is generally not favoured, it has some merit for Merino systems. Because wool and meat are closer to a joint production system than a typical primary product/by-product system, it follows that the burdens should be allocated in a more even manner. Following a biological causality approach, wool and meat are both protein based products that require broadly similar processes within the animal for production. This offers a simple alternative to system expansion while generating similar results.

This study concluded that allocation was not required to differentiate between HG and LG meat, and highlighted the sensitivity of allocation processes between wool and sheep meat. System expansion offers a useful approach that reflects the dynamics of the Australian sheep meat market well, and is considered the most suitable approach for further research in this industry.

References

Cederberg C & Stadig M. 2003. System expansion and allocation in Life Cycle Assessment of milk and beef production. Int J LCA 8 (6) 350-356

Eady, S., Carre, A., Grant, T., 2011. Life cycle assessment modelling of complex agricultural systems with multiple food and fibre co-products, J. Cleaner Prod. Volume 28, June 2012, Pages 143–149

Flysjö, A, Cederberg, C, Henriksson, M & Ledgard, S 2011, How does co-product handling affect the carbon footprint of milk? Case study of milk production in New Zealand and Sweden, Int. J or LCA, vol 16, 420-430.

Table 1. Co-products and allocation factors for Merino wool production

Products	Mass Allocation Factors	Economic Allocation Factors	System expansion substitution products
Wool (greasy wool) kg	14-15%	55-65%	
Sheep sales (lamb + mutton – Live weight basis) kg	85-86%	35-45%	Purpose grown lamb and sheep meat from sheep meat enterprises. Substitution applied using a factor of 95% to account for higher dressing percentage of purpose grown sheep compared to Merinos

26. How to decrease farmed fish environmental burdens through feed formulation and feeding management

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The aim of this work is to quantify improvements in farmed fish (European seabass *Dicentrarchus labrax* and gilthead seabream *Sparus aurata*) environmental burdens resulting from the application of latest know-how in feed formulation and feeding management.

Environmental impacts from the whole aquaculture production chain were assessed according to the life cycle assessment (LCA) methodology in order to identify critical areas. The present paper reports results in terms of greenhouse gases emissions (GWP) and considerations about the reduction of pressure on wild fish stock.

The LCA was performed per 1 kg of farmed fresh fish considering the whole production chain from hatchery to fresh fish distribution platform (including the raw materials used for feed production). Results from this study show that the most significant phases in terms of GHG emissions are feed production and farming (Fig. 1).

On the basis of the results from the LCA, critical areas for improvement were identified, and the effects of possible actions quantified on the basis of practical data from the industry, with specific reference to the feed as the main variable affecting environmental burdens. Our study confirms that FCR improvement (through the use of nutritionally balanced formulations and careful feeding management) is the most efficient strategy to reduce environmental burdens (Fig. 2), together with flexible use of raw materials. Moreover, improved FCR, together with advanced nutritional know-how and freedom in raw materials choice, results in reduced fish meal and fish oil consumption in farmed fish production, hence alleviating pressure on wild fish stocks. As consumers recognise the importance of sustainability and the need to reduce environmental impacts from their food, the adoption of strategies such as the ones mentioned above should be promoted in specifications for high-value farmed fish.

References

Jackson, A., 2009. Fish in–Fish out ratios explained, Aquaculture Europe Vol. 34 (3).

van den Burg S.W.K. et al, Environmental performance of wild-caught North Sea whitefish, a comparison with aquaculture and animal husbandry using LCA, LEI report 2011-090, January 2012, Project code 2272000225, LEI, part of Wageningen UR, The Hague.

Winther U., Ziegler F., Skontorp Hognes E., Emanuelsson A., Sund V., Ellingsen H., 2009, Carbon Footprint and energy use of Norwegian seafood products, SINTEF Fisheries and Aquaculture.

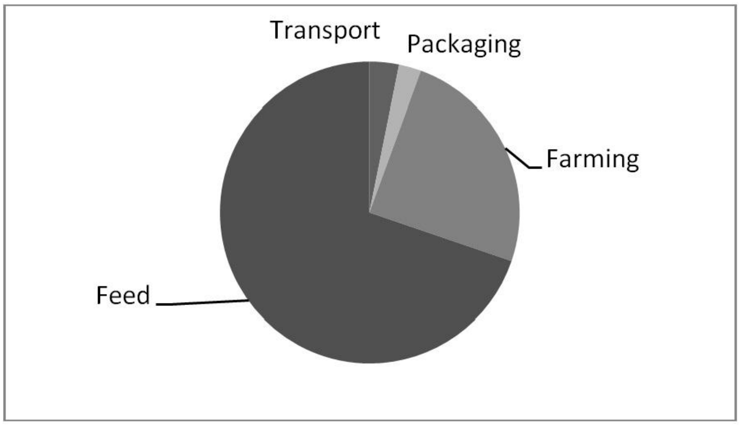

Figure 1. GHG Emissions per kg of fresh fish.

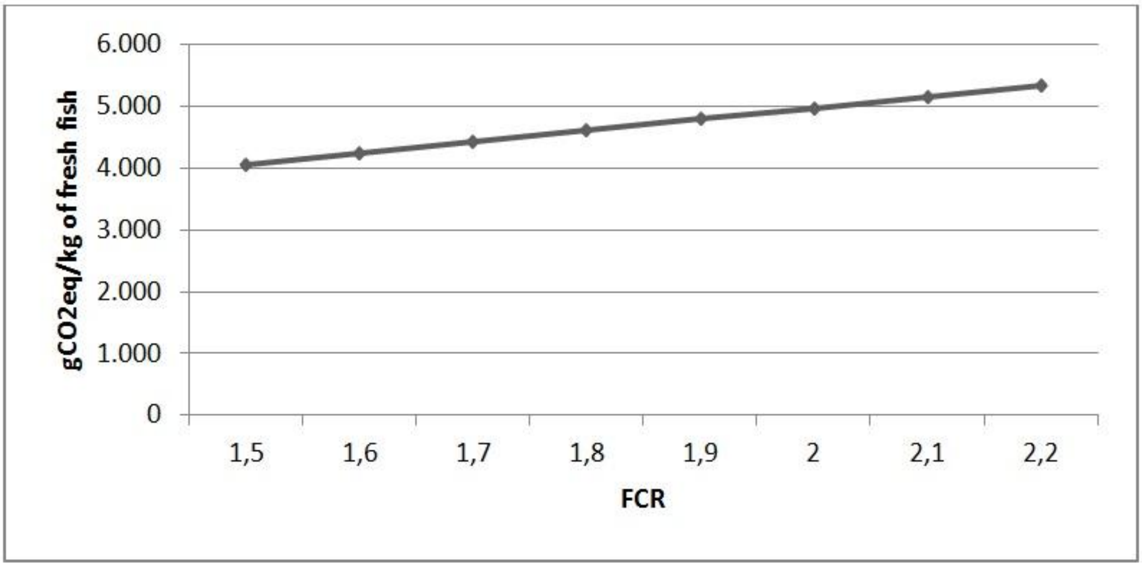

Figure 2. Correlation between the feed-consumption ratio (FCR) and GHG emissions.

27. A multi-scale method for assessing ecological intensification in aquaculture systems

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To meet the challenges of producing more while lowering impacts on ecosystems, new farming systems have to be designed. To define development strategies, a multi-scale assessment method that estimates the tradeoff between human demand and natural services, as well generates consistent performance indicators on utilisation of natural resources and environmental emission levels based on the same set of input data is needed. LCA estimates resource use and potential environmental impacts throughout a product's life cycle at global and regional scales (ISO, 2006) but does not consider the provision of ecosystem services or products (Ulgiati et al, 2006). Emergy accounting (EA) is an ecology-based tool developed to integrate all system inputs (environmental and economic values) using a common unit, solar emergy joule (Odum, 1996). EA inserts the productive cycle into a local environmental context and quantifies the energy flows between the environment and the production system. Through three contrasting fish-farming systems, we attempted to demonstrate the interest of a combination of LCA and EA to define the major components of environmental sustainability and ecological intensification of fish farming and more globally of agricultural systems.

The first system is a recirculating system (RSF) of Atlantic salmon depending highly on external inputs (feed and energy). The second one is extensive fish polyculture in a pond (PF1) with few external inputs. The last one is a small pond farm with use of external feeds. These systems were assessed according the ISO standards for attributional LCA during one production year. The assessment covered farm operations and transportation at all stages. Local emissions of nutrients were estimated using nutrient balance modeling and pond emissions were refined to include nitrogen-fate factors. LCA results are presented as traditional midpoint indicators according CML 2 baseline 2001and are expressed by tonne of fish produced. Emergy accounting [3] is based on LCA system definition but includes also the contributions of natural systems (sun, rain, groundwater, etc.) and provide indicators to evaluate the efficiency of energy use and its quality during the lifecycle. The chosen Emergy indicators are: Percentage of renewability (%R); the Emergy Yield Ratio (EYR, ability to rely on local resources; Environmental Loading Ratio (ELR, level of exploitation of nonrenewable resources compared to renewable ones).

For 1 tonne of living fish, RSF had higher potential impacts for NPPU and all the Emergy indicators (Fig. 1). PF2 had higher potential impacts in comparison with PF1 except for water dependence. However, RSF had lower potential impacts for climate change, eutrophication, land competition and water dependence than ponds, which reflects the level of intensification of the systems. The consumption of energy (calculated by LCA, Figure 2) was similar for RSF and PF1 and higher for PF2. But, the contributors to this impact differed among the systems (direct energy use for ponds and feeds and direct energy used for RSF). The difference in%R between systems was due to water origin: for RSF water was pumped whereas for ponds it came essentially from rain and water run-off. PF1 has a higher EYR, which means that it depends less on market resources than RSF. The RSF higher value of ELR (7.98) indicates a moderate environmental impact.

The combination of LCA and Emergy accounting on contrasting systems provides a perspective of what ecological intensification could mean in aquaculture: a decrease in potential impacts per unit mass of final products, especially for global warming, eutrophication and acidification; a decrease in dependence on market-based and external resources; and an increase in the use of renewable natural resources and input efficiency. This is particularly true for choices regarding feed ingredients and the origin of energy sources.

References

ISO, 2006. Environmental Management -Life Cycle Assessment- Principles and Framework. ISO 14040.

Odum HT. Environmental Accounting: Emergy and Environmental Decision Making. New York: Wiley; 1996.

Ulgiati S, Raugei M, Bargigli S., 2006. Overcoming the inadequacy of single-criterion approaches to Life Cycle Assessment. Ecol. Modell., 190:432-42.

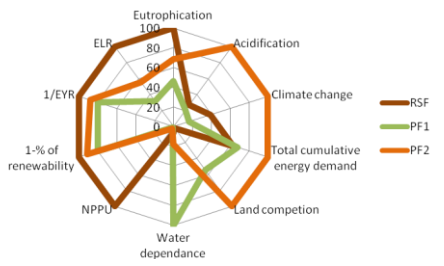

Figure 1. Comparison of the LCA and emergy impacts of the recirculating-system farm (RSF), large pond farm (PF1) and small pond farm (PF2). Impacts are represented as a percentage of the largest impact in each category. Certain emergy indicators were inversed accordingly. NPPU - net primary production use; EYR - Emergy Yield Ratio; ELR - Environmental Loading Ratio

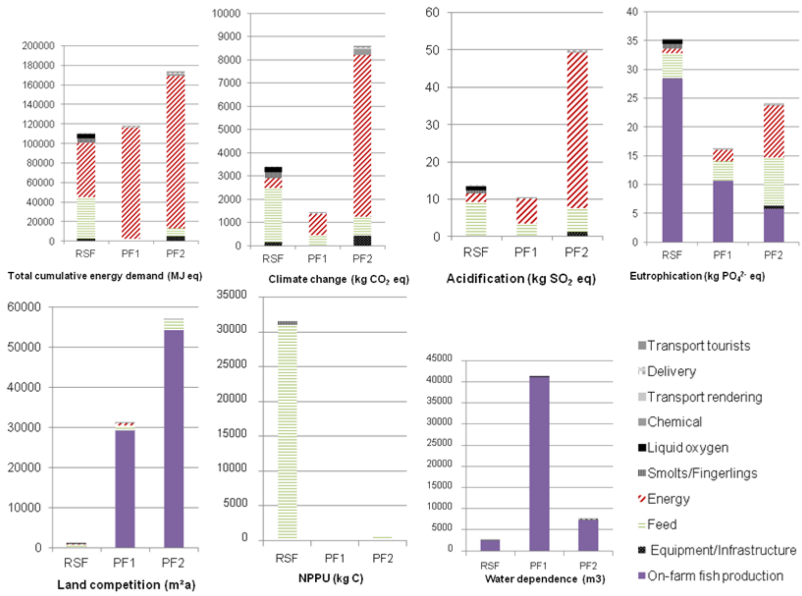

Figure 2. Environmental impacts (climate change, total cumulative energy demand, water dependence, acidification, eutrophication, and land competition) per tonne of fish of the recirculating-system farm (RSF), large pond farm (PF1) and small pond farm (PF2) calculated by LCA. For each environmental impact, the contribution of each input or production stage is indicated.

28. A participatory approach framework to integrate social aspects in LCA: the case of aquaculture systems

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The identification of relevant social impact indicators for a Social Life Cycle Assessment (SLCA) is still difficult and poorly documented (Jorgensen, *et al*, 2009). It requires the identification of the main social concerns for each considered case study and the adaptation of selected social impacts corresponding to the actual social situation and which can be easily appropriated by the actors of the value chain.

In the case of aquaculture system the studies based on social aspects are essentially focused on manpower or on conflicts with other activities. In the PISCEnLit project (Ecologically Intensive PISciculture, funded by the French National Research Agency), we aim at emphasising a larger vision of the social impacts of fish farming systems using a new approach of SLCA. We studied fish farming pond systems in France and Brazil. In this study, we focussed on the choice of the impact categories using the participation of stakeholders (James *et al.*, 2002). We emphasised the role of a participatory approach to identify and select the relevant social impacts to be assessed. From a practical viewpoint, the proposed approach consists in implementing surveys and focus groups about the social representations at different stages of the assessment process. Through this process, the opinions of the stakeholders about potential or real social impacts of aquaculture may be taken into consideration. However, the technical construction of the relevant impact indicators allowing evaluation of the impacts must be done by the researchers in the project.

Our presentation focuses on the advantage of using a participatory approach based on the Principle, Criteria and Indicator (PCI) method (Rey-Valette *et al*, 2008) to identify relevant social indicators for a SLCA in fish farming pond systems cases. This method provides a basis for discussion, allowing the stakeholders to rank and validate a list of impacts (Fig. 1). This list was constructed using international conventions (e.g. Human Rights Declaration), the well-being components of the Millennium Ecosystem Assessment, social aspects which appear in referential of aquaculture sustainable development (Rey-Valette *et al*, 2008) and results of the survey based on social representation. The adaptation of this method to the social LCA allows the comparison of different systems at the level of the principles without standardisation of social impacts.

References

James, K. L., Grant, T., Sonneveld, K., 2002. Stakeholder involvement in Australian paper and packing waste management LCA study. Int J Life Cycle Assess. 7, 151-157

Jorgensen, A., Hauschild, M. Z., Jorgensen, M. S., Wangel, A., 2009. Relevance and feasibility of social life cycle assessment from a company perspective. Int J Life Cycle Assess. 14, 204-214

Rey-Valette, H., Clément, O., Aubin, J., Mathé, S., Chia, E., Legendre, M., Caruso, D., Mikolasek, O., Blancheton, J-P., Slembrouck, J., Baruthio, A., René, F., Levang, P., Morrissens, P., Lazard, J., 2008. Guide to the co-construction of sustainable development indicators in aquaculture. © Cirad, Ifremer, INRA, IRD, Université Montpellier 1. Diffusion Cirad-Montpellier, Montpellier.

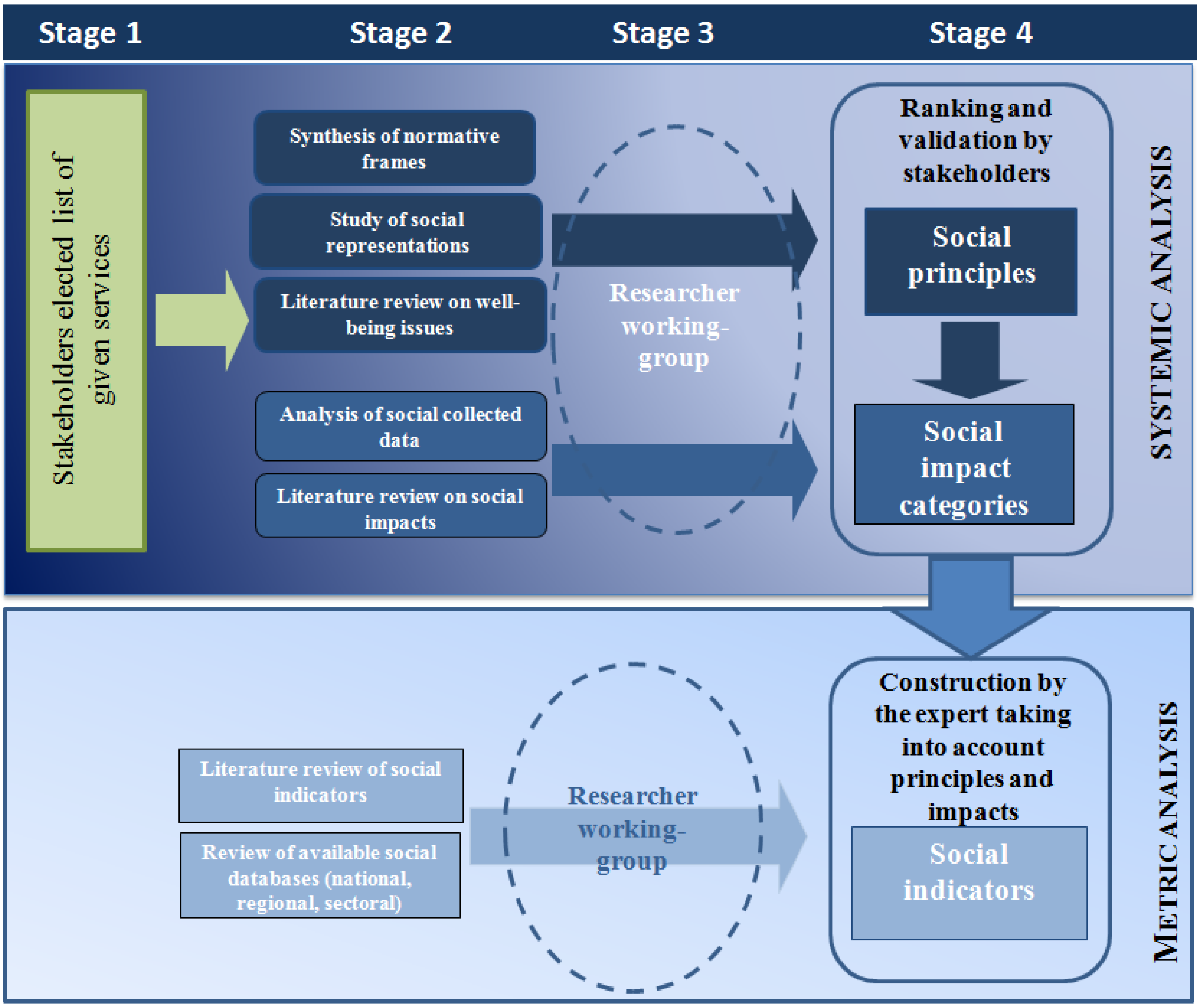

Figure 1. Methodological process integrating a participatory approach.

29. Comparing environmental impacts of wild-caught and farmed fish products - a review of life cycle assessments

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Many discuss the differences between fish products originating from aquaculture and fisheries. However, no systematic literature overview has been made yet. Most seafood LCA studies so far are limited to impact categories like energy use or global warming, or assess products on a national scale. We came up with a more extensive literature overview of the differences in environmental impact between aquaculture and fisheries, based on the same methodology.

The objective of this study was to compare environmental impact assessments of wild-caught and farmed fish products. We reviewed life cycle assessments (LCAs) of wild-caught plaice and cod, and farmed salmon, tilapia and pangasius, as these species are studied most often. Seven peer-reviewed studies were found that performed an LCA of these species, addressing diverse production systems. The following environmental impacts were discussed: energy use (EU), global warming potential (GWP), acidification potential (AP), eutrophication potential (EP) and land use.

To enable a comparison of EU and GWP among studies, we recalculated outcomes using the same functional unit (i.e. 1 kg of fresh fillet), allocation method (i.e. mass allocation) and similar characterisation factors. Most articles, however, did not address AP, EP, or land use. We estimated the AP, EP, and land use of the seven studies, using published technical parameters, complemented with data from *ecoinvent v2.2* and FAO. Next, the two systems were compared for GWP, EU, AP, EP, and land use using Wilcoxon rank-sum test.

Energy use (for wild-caught and farmed fish) varied between 11 to 273 MJ/kg of fresh fillet, whereas GWP varied between 0.7 and 22.9 kg CO_2-eq/kg of fresh fillet. Results of EU and GWP showed a similar pattern across studies, as especially in fisheries GWP is dominated by CO_2 emissions from fossil fuel combustion. The GWP from processing varied between 0.03 and 0.93 kg CO_2-eq/kg of fresh fillet (the fish with the highest value included freezing), the GWP due to transport between 0.05 and 3.36 kg CO_2-eq/kg of fresh fillet (the highest value comprised air transport).

Global warming potential, EU, and AP of farmed fish products were not different compared to wild-caught fish products ($P>0.05$; Fig. 1 shows GWP). However, EP and landuse were higher for farmed fish products ($P<0.05$; figure 2 shows EP). The EP was higher mainly due to ammonia emissions and leaching of nitrate during cultivation of feed ingredients. Land use was higher mainly due to the share of land that was required for aquaculture to cultivate feed ingredients. Differences in environmental impacts within each production system offer potential for improvement options. We do realise that the fishing industry affects the ocean, ocean floor and its biodiversity. These impacts have been roughly incorporated in a few studies, but are not yet established as to be applied in common seafood LCAs.

Based on this literature review, we concluded that GWP, EU and AP did not differ between farmed fish and wild-caught fish fillet, whereas EP and land use was higher for farmed fish compared to wild-caught fish fillet.

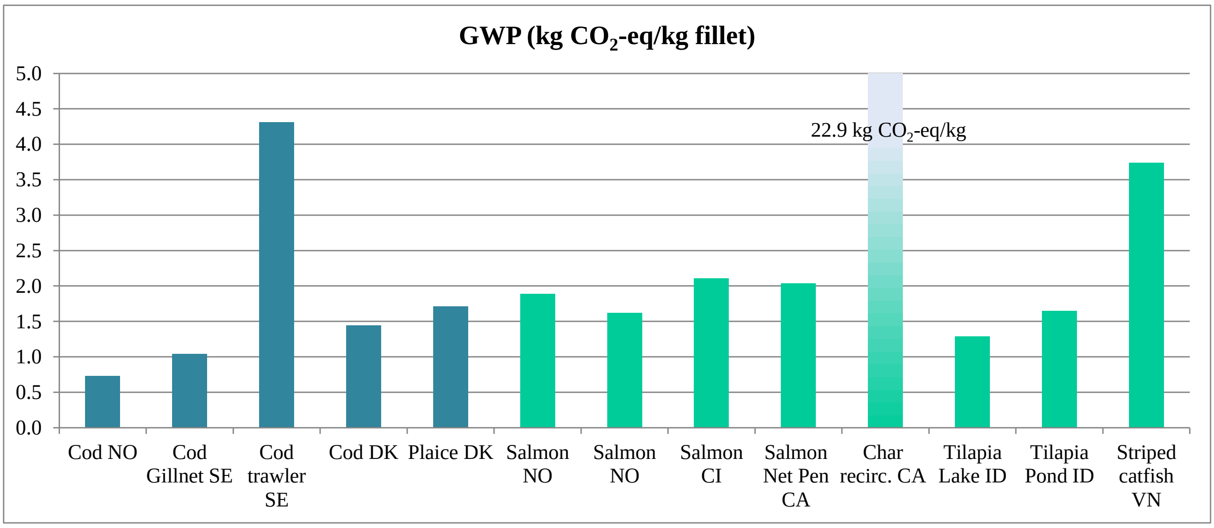

Figure 1. GWP of analysed systems (kg CO_2-eq/kg fillet). Abbreviations of country names: CA: Canada; CI: Chile; DK: Denmark; ID: Indonesia; NO: Norway; SE: Sweden; VN: Vietnam

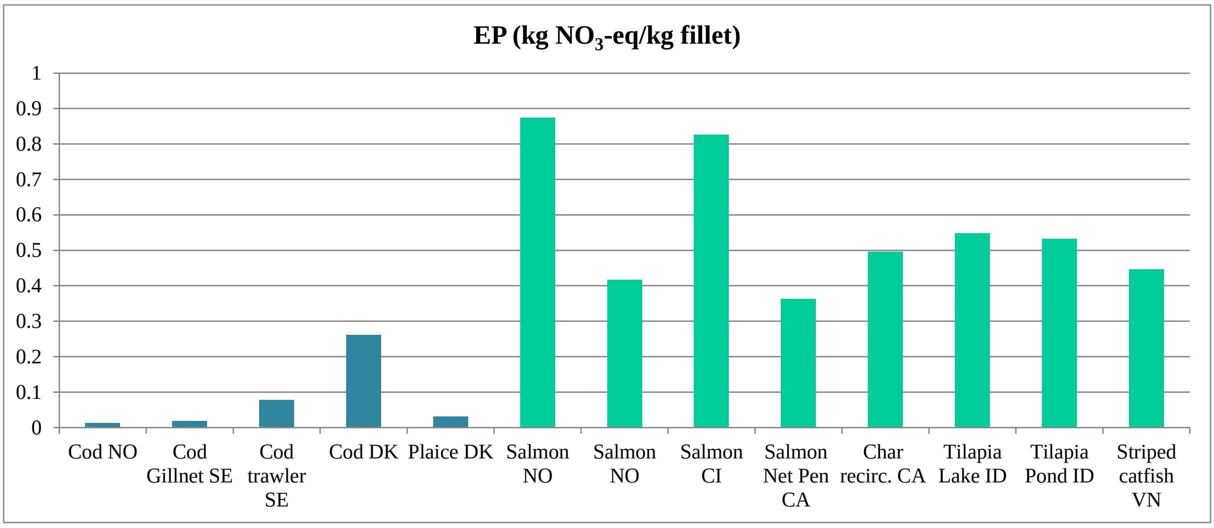

Figure 2. Eutrophication potential of analysed systems (kg NO_3-eq/kg fillet).

30. Environmental consequences of genetic improvement by selective breeding: a gilthead sea bream aquaculture case study

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Livestock genetic improvement is based on selective breeding of quantitative traits like growth or production yields. In fish farming, selective breeding has a high potential due to the recent domestication of the species. Genetic improvement (i.e. shortened duration of the production cycle or increased marketable size due to selection on body weight) could indirectly impact the use of production means and the valorisation of inputs. Consequently, the environmental performances of the production system can be modified. In order to explore the environmental consequences of genetic improvement in animal production and aquaculture, Life Cycle Assessment (LCA) was used to assess a sea bream (*Sparus aurata*) production system with expected genetic gain on growth or fillet yield.

Five scenarios were built using the results of expected selection response: initial unselected control, and 5 or 10% selection pressure on growth or fillet yield during 5 generations (15 to 20 years). The system boundary included the production of inputs such as feeds, fingerlings, production infrastructures, farm running, the commercial stage, purchase, the household cooking and consumption stage and the waste management. An attributional LCA was applied on the different scenarios, based on CML 2 (2000) and Cumulative Energy Demand methods, implemented in SimaPro 7.2 software, and the use of original data, and ecoinvent database. The calculated impact categories were climate change, eutrophication, acidification, cumulative energy demand, and net primary production use (Aubin et al., 2009). The functional unit was 1 kg of edible flesh.

For all the impact categories, the step of fish production (including the upstream processes) contributed for more than 80% of the impacts.

Due to the high influence of artificial feed production on the LCA results and to the hypothesis of lack of genetic correlation between the traits selected for and feed efficiency, selection on growth only had a limited effect on the different impact categories (less than 2%). This limited improvement was essentially due to the marginal improvement in the use of the infrastructure and the related energy use.

Selective breeding on fillet yield decreased environmental impacts from 10% to 22%. This decrease, calculated per kg of edible flesh can be explained by the positive genetic correlations between growth and fillet yield and by the decrease of waste at the household cooking and consumption stage.

This study is the first application of LCA as an assessment method of the environmental relevance of selective breeding in animal productions. It supports the lack of adverse effect of selection for the targeted traits (growth, or fillet yield) on the environment. This work is also a first step to introduce environmental goals into genetic selection schemes.

References

Aubin, J., Papatryphon, E., van der Werf, H. M. G., Chatzifotis, S., 2009. Assessment of the environmental impact of carnivorous finfish production systems using life cycle assessment. Journal of Cleaner Production 17, 354-361.

31. Environmental assessment of trout production in France: influence of practices and production goals

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Trout production is the main fish farming activity in France, producing 37 000 tonnes of fish in 456 companies (MAAP, 2011). It is mainly based on rainbow trout (*Oncorhynchus mykiss*), reared in flow through systems directly connected to rivers. The production level of trout declined of 20% for the 10 past years, which clearly raises the question of the sustainable development of this activity. The variable market price of fish, the increasing costs of feed ingredients and the higher pressure of environmental regulations threaten the durability of the activity. Life Cycle Assessment was chosen as a method to check the environmental sustainability of fish farming, combining efficiency measurement and multicriteria characteristics, in order to draw new perspectives for trout farming. In 2007, a survey was conducted on 20 farms throughout France, and covering all types of production. We classified the trout farms in two groups depending on the commercial size of fish produced: the pan-size-trout farms (11 farms) and the large trout farms (9 farms). The attributional LCA was conducted from cradle to farm gate, using one tonne of fish as the functional unit. Environmental impacts (eutrophication, acidification, climate change, net primary production use, land occupation, water dependence) were calculated using CML 2 (2000) method (Aubin et al.2009), and cumulative energy demand was added. On farm working time was recorded. Primary data were mainly used for feed ingredients and processing, and fish farm running. The secondary data stem mainly from ecoinvent database.

The comparison of the impact categories between the two groups of farms didn't show any significant differences, unlike previous studies results (Papatryphon et al., 2004). Net primary production use, water dependence and working time showed a tendency of a higher level in pan-size-trout farms. These impact categories values indicate a lower level of management and a lower efficiency of the production system. This remark is consistent with the high level of variability of the impacts in this group of farm. On the opposite, the large trout farms group had low levels of impact variability, which can be explained by a more standardised production and a higher level of technical competence. Despite the high contribution of feed production to the impacts (climate change, acidification, and cumulative energy demand) the correlation between food conversion ratio and these impacts was not significant in the group of pan-size-trout farms (unlike in large trout farms). This is probably due to the multiple factors determining the farms efficiency. These results show how the different production objectives (direct consumption and restocking for pan-size-trout farms, and filet production for large trout farms) influence the environmental impact variability of a production activity. This impacts variability indicates a higher level of system improvement in pan size trout farms than in large trout farms.

References

Aubin, J., Papatryphon, E., van der Werf, H. M. G., Chatzifotis, S., 2009. Assessment of the environmental impact of carnivorous finfish production systems using life cycle assessment. Journal of Cleaner Production. 17 (3), 354-361.

MAAP (Ministère de l'Agriculture de l'Alimentation et de la Pêche), 2011. Recensements 2008 de la salmonicultureet de la pisciculture marine et des élevages d'esturgeons, Agreste Les Dossiers, no. 11, April 2011, Paris,148p.

Papatryphon, E., Petit, J., van der Werf, H. M. G., 2004. The development of Life Cycle Assessment for the evaluation of rainbow trout farming in France. In: Halberg N., editor. Life Cycle Assessment in the Agri-food sector. Proceedings from the 4th International Conference. Danish Institute of Agricultural Sciences, Horsens, Denmark, 73-80.

32. LCA of locally produced feeds for Peruvian aquaculture

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The research presents and discusses a LCA performed on an aquafeed plants in the Iquitos area, Peru (inventories were collected for two plants but results are presented for the larger one only). The main goal of the analysis is to explore local utilisation of Peruvian anchoveta (*Engraulis ringens*) fishmeal in aquafeeds for both omnivorous and carnivorous cultured species. These results can be useful for the comparative study of seafood supply chains (e.g. Avadí & Fréon, this Conference).

Results from other Anchoveta-SC work on two fishmeal plants (Fréon et al., in prep.) and the Peruvian industrial anchoveta fleet contributed preliminary downstream data for the fishmeal (fishing and reduction stages). One fishmeal plant was fully modelled and one "average" 395 m3 holding capacity fishing vessel (the most representative category of anchoveta-targeting vessels, regarding historical landings) was modelled including rough estimations of the construction and end-of-life phases. Data for other feed ingredients were taken from ecoinvent, and adapted when necessary to fit the sourcing of Amazonian aquafeed ingredients and energy sources (i.e. the grid-disconnected Iquitos electricity supply is based on thermal oil-powered generation). Weighted average of different feed formulations produced was utilised for determining the "typical" feed composition for *Colossoma macropomum* (mostly herbivore, the third more cultured freshwater species in Peru) and Brycon melanopterus (omnivore), two important Amazonian species provided by the Iquitos aquafeed industry. This scenario was compared with a theoretical feed plant catering to carnivorous fish (rainbow trout, *Oncorhynchus mykiss*) cultured in the Puno region, by adjusting fishmeal and fish oil use and regional energy mix (Fig. 1 a,b). Moreover, Peruvian formulations were compared with northern hemisphere formulations. Life cycle impact assessments were performed with the ReCiPe method, but additional impact categories were calculated: Cumulative Energy Demand and Biotic Resource Use as appropriation of primary production. Sensitivity analysis was carried out by exploring and contrasting various sources/proportions of key feed ingredients.

As expected, most of the environmental impacts during the life span of the plants are due to the provision of feed ingredients (>65%), especially fishmeal (>35% for trout), corn, wheat and soy meals. An allocation strategy for fishmeal and fish oil is in preparation, but a preliminary gross energy content criterion (71:29) was used for preliminary results. The oil-based Iquitos grid energy determines a high contribution of electricity used (~268 kWh/t feed) to several impact categories. Soy meal used in Peru is mainly imported from Bolivia, and thus a Bolivian soy meal was adapted from an existing ecoinvent Brazilian soy meal by adjusting the extent of the natural land transformation impact (provision of stubbed land, based on the characteristics of expansion zones for soy production in both countries (Dros, 2004)). Seasonal flood system rice grown in Iquitos was adapted from US rice, by reducing chemical input and eliminating irrigation. Proxies for wheat and corn where used (US produce), but their important contribution to certain impact categories suggests a full adaptation to local conditions is needed.

It was observed, in line with previous LCA studies of seafood systems, that construction and maintenance of feed plants contributes negligibly to environmental impacts of aquafeed products. It was also demonstrated that increasing use of fishmeal and fish oil, as well as the source of agricultural inputs, contribute to important variations in certain environmental impacts. Comparison between similar feeds for carnivore fish from Peru and Northern countries showed the specificity of South American ingredients: roughly comparable performance of fishmeal and soy meal (except Brazilian). The sourcing of feed ingredients was found to be critical for the contribution of feeds to impacts.

References

Avadí, A. and Fréon, P. 2012. A framework for sustainability comparison of seafood supply chains. This Conference.
Fréon, P. Durand, H., Huaranca, S., Avadi, A. 2012. LCA of two Peruvian fishmeal plants. In preparation.
Dros, J. M. 2004. Managing the Soy Boom: Two scenarios of soy production expansion in South America. WWF Forest Conversion Initiative. AID-Environment. Amsterdam.

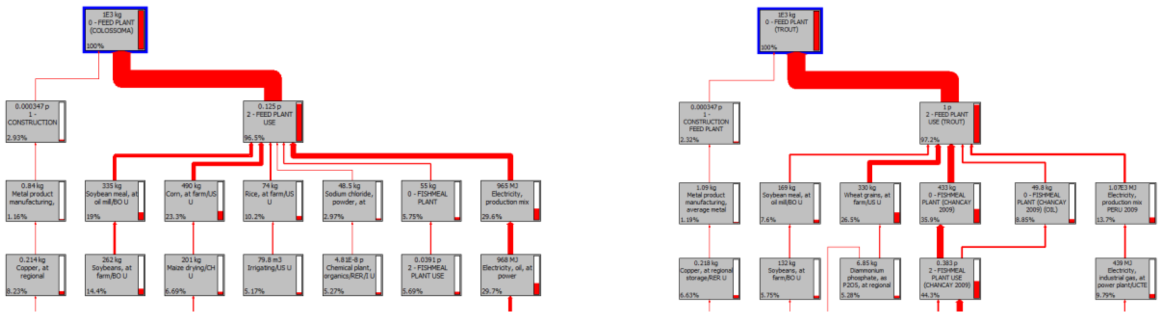

Figure 1. SimaPro-generated network view of (a) the studied Iquitos aquafeed plant (for Colossoma) and (b) the hypothetical Puno feed plant (for trout).

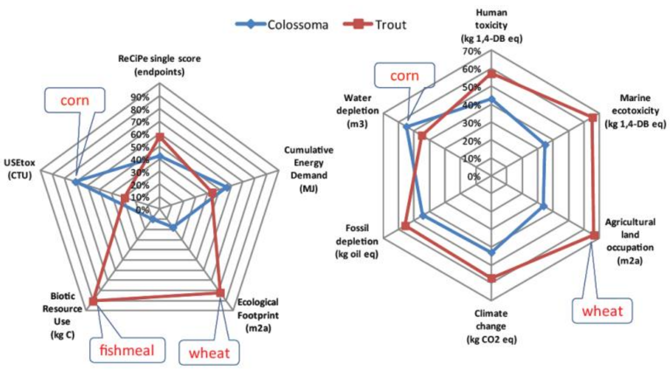

Figure 2. Comparison of two feed compositions (selected ReCiPe categories, additional categories). ReCiPe endpoints single score favours the Colossoma feed plant.

33. A framework for sustainability comparison of seafood supply chains

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The research, carried out in the context of the ANCHOVETA-SC project (http://anchoveta-sc.wikispaces.com), proposes a modelling and sustainability assessment framework for comparing competing seafood supply chains based on common inputs, in terms of a selected indicators focusing on environmental and socio-economic performance, with emphasis on environmental and energy performance. The approach allows for comparison of alternative stock exploitation scenarios and transformation strategies.

Competing seafood supply chains are modelled in terms of their material and energy flows and, from a life cycle perspective, several tools and approaches are combined and applied to assess their sustainability. LCA is used for environmental impact assessment (including seafood-specific impact categories), but further analyses on energy efficiency and nutritional value of feed ingredients and seafood co-products are carried out. Basic socio-economic data is also compiled and used for estimating socio-economic performance by means of key indicators. A trophic model of the exploited marine ecosystem sourcing the studied systems is integrated within the supply chain model in order to capture the ecosystem-fishery interactions. The resulting supply chain model is implemented in a material flow modelling tool. This framework thus extends the ecosystem/supply chain coupled model proposed by Christensen et al. (2011) by accounting for biophysical flows. To test the framework, scenario comparisons of supply chains based on Peruvian anchoveta (*Engraulis ringens*) fishmeal are carried out. Scenarios are generated by varying the fishing stage, in terms of catches volumes of anchoveta (and its predators) and the intended "fate" of landings (direct or indirect human consumption, served by different fleets and delivering different final products/species to consumers).

The material flow modelling tool used proves useful for representation of interdependent industrial processes (i.e. supply chains) as Petri nets (Fig. 1) and Sankey diagrams, as well as providing the programming environment required to code the required material, energy and monetary flows logic. LCA and other life cycle tools provided the data and methods for extending the material and energy flows analysis towards sustainability assessment, in such a way that basic mass and energy flows are complemented with specific biophysical flows (e.g. energy/nutritional value of substances). Indicators used (Fig. 2; Table 1), scaled respect to a functional unit, are based on a) energy use: Cumulative Energy Demand; b) energy efficiency: edible protein EROI (Tyedmers 2000); c) seafood-specific impact categories: Biotic Resource Use approximated from the primary production appropriation of feed ingredients, especially fish-derived (Pauly & Christensen, 1995) and a related ecological footprint; and d) nutritional value for the consumer: protein/lipid content of raw materials and co-products. Socio-economic factors considered are limited to the most accessible ones (employment, added value). Alternative exploitation scenarios along the whole ecosystem-supply chain are obtained by coupling models: outputs from a published trophic model (Ecopath with Ecosim) of the Humboldt Current ecosystem are used as inputs of a material flow analysis model (Umberto). The coupled model, indicators and communication devices are currently in progress.

Conclusions derived from the model will be suitable for policy recommendations regarding exploitation volumes and seafood processing strategies, aiming at different interests: ecosystem health, human nutrition, food security, energy efficiency, reduction of environmental impacts and rent redistribution.

References

Christensen, V., Steenbeek, J., & Failler, P., 2011. A combined ecosystem and value chain modeling approach for evaluating societal cost and benefit of fishing. Ecological Modelling, 222(3), 857-864.

Pauly, D., & Christensen, V., 1995. Primary production required to sustain global fisheries. Nature, 374(6519), 255-257.

Tyedmers, P., 2000. Salmon and Sustainability: The biophysical cost of producing salmon through the commercial salmon fishery and the intensive salmon culture industry. Ph.D. Dissertation. The University of British Columbia.

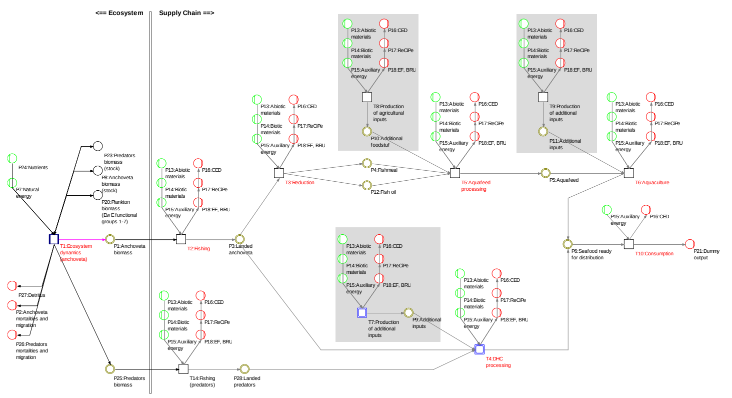

Figure 1. Proposed Petri net of a Peruvian anchoveta-based supply chains model.

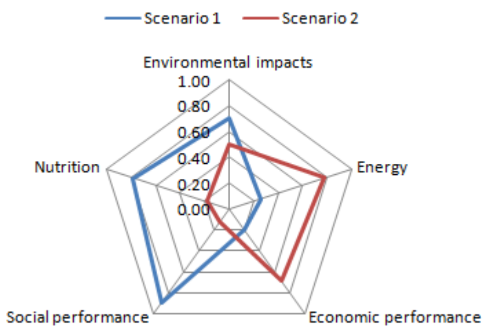

Figure 2. Proposed representation for sustainability scores of selected seafood supply chains based on Peruvian anchoveta (dummy values and scenarios).

Table 1. Key indicators calculated.

Indicators➔ / Comparison objects🡻	Gross Energy Content (MJ/kg) Based on fat & protein	Edible protein EROI (%)	Biotic Resource Use (g C/kg) Ecological Footprint (ha/t)	**LCA** Cumulative Energy Demand (MJ)	Socio-economic indicators
Feed ingredients	X		X	X	
Aquafeeds	X		X	X	
Seafood products		X	X	X	X
Supply chains / scenarios				X	X

34. LCA of Finnish rainbow trout, results and significance on different allocation methods

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An LCA of Finnish rainbow trout was conducted in 2010-2012 by MTT Agrifood Research Finland, Finnish Game and Research Insitute and Finnish Environment Institute. The functional unit of the study was one ton rainbow trout fillet at the gate of the fish processing plant. The system boundaries included product chain of feed raw materials, feed production, hatchery, fish farming plants, fish processing, packages and transports. The impact classes studied were climate change, acidification, eutrophication, tropospheric ozone formation and primary energy use.

One important part of the study was to make comparison to the previous LCA study of rainbow trout (Seppälä et al. 2001, Silvenius and Grönroos 2003, Grönroos et al. 2006). Because of the development of feed and more effective feeding of the fish, the environmental impacts of the rainbow trout product chain have reduced over 20%. The carbon footprint of the rainbow trout in this study was about 4300 kg CO_2/t of fillet (Fig. 1)and eutrophication impact 38 kgPO_4-eq/t of fillet.

Allocation is one of the most biggest challenges related to LCA-investigations. In our study, the effects of different allocation methods to the results was studied. There have been some earlier studies concerning effects of the allocation on the results of fish products LCAs (e.g. Winther et al. 2009, Svanes et al. 2011). In our study, allocations based on different existing LCA standards were compared (Table 1). The allocation situations studied were allocation between captured fish species used as raw materials for the fish meal and oil, allocation between fish meal and oil, allocation between soy meal and oil, rapeseed meal and oil and allocation between fillet and by-products of slaughtering and filleting. Additionally, scenarios for the possible utilisation of the by-products were made.

The chosen allocation method had high effects on the final results. The mass allocation between fish fillet and by-products of the slaughtering and filleting resulted in lowest figures for environmental impacts. However, when using mass allocation for fish meal and oil raw material fishing, and mass allocation between soy meal and soy oil the estimated environmental impacts were highest.

References

Grönroos, J., Seppälä, J., Silvenius, F. & Mäkinen T., 2006. Life-cycle assessment of Finnish cultivated rainbow trout. Boreal Environment Research 11:401-404.

Hartikainen, H. 2011. Allokointimenettelyt elintarvikkeiden elinkaariarvioinneissa. Helsingin yliopisto, Taloustieteen laitos, Ympäristöekonomia, Pro gradu–tutkielma, Marraskuu 2011.

Seppälä, J., Silvenius, F., Grönroos, J., Mäkinen, T., Silvo, K. & Storhammar, E. 2001. Kirjolohen tuotanto ja ympäristö. Suomen ympäristö 529. 164 pp.

Silvenius, F. & Grönroos, J. 2003 Fish farming and the environment. Results of inventory analysis. Suomen ympäristökeskuksen moniste 276, 71 pp.

Svanes, E., Vold, M & Hanssen, O., J. 2011. Effect of different allocation methods on LCA results of products from wild-caught fish and on the use of such results. Int J Life Cycle Assess 16:512-521.

Winther, U., Ziegler, F., Hognes, E., Emanuelsson, A., Sund, V. & Ellingsen, H. 2009. Carbon footprint and energy use of Norwegian seafood products. SINTEF Fisheries and Aquaculture, Norway.

Table 1. The carbon footprint of rainbow trout fillet calculated by different standards (Hartikainen 2011).

Standard	Carbon footprint
ILCD Handbook	4.2
ISO14040	4.2-4.4
GHG Protocol	4.1-4.3
PAS 2050	4.2
PCR Basic Module (2010a)	2.4-4.4

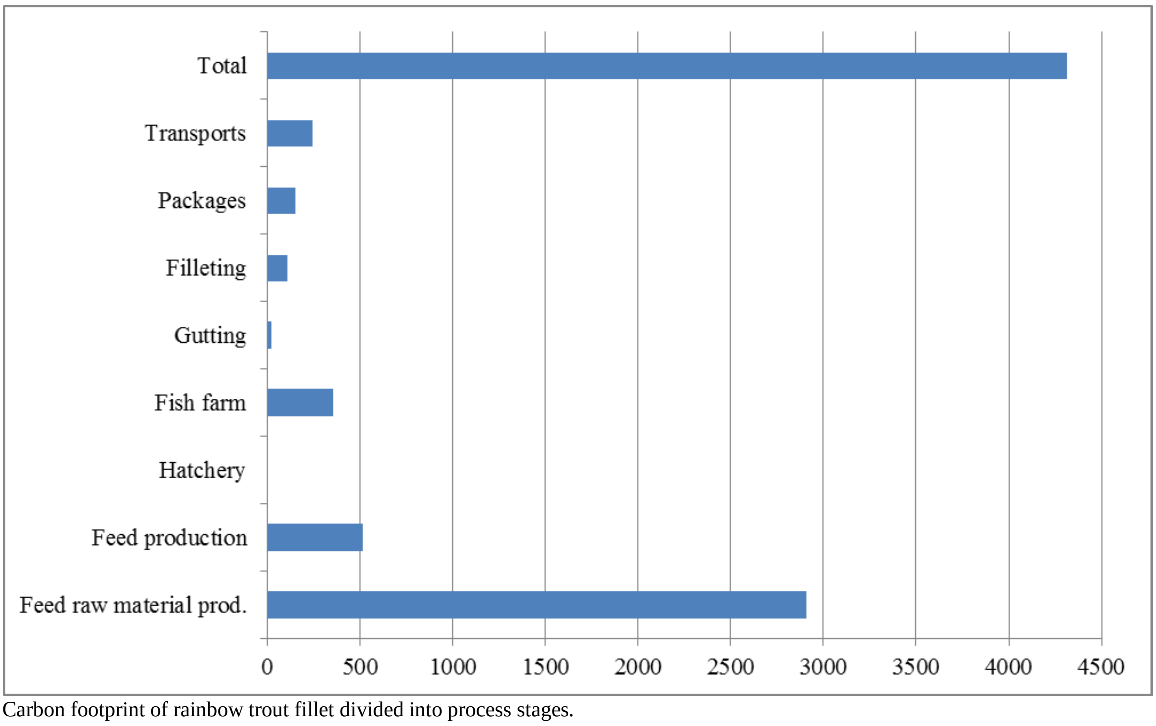

Figure 1. Carbon footprint of rainbow trout fillet divided into process stages.

35. Mainstreaming Life Cycle Management in the seafood sector: using a sector based and regional approach in Northern France

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Whilst Life Cycle Management (LCM) is becoming commonplace in larger corporations, or forward thinking governments, it is far from mainstream. To achieve sustainable production and consumption patterns, LCM needs to be taken up by whole supply chains that include many small and medium enterprises. These businesses typically lack the financial capacity or human resources to implement LC tools on their own, and are wary of working with support organisations outside of their sector or local area.
The French competitively cluster Aquimer is piloting an innovative study to develop a strategic action plan to integrate Life Cycle Approaches (including eco-design and product environmental labelling) into businesses, education and research organisations in the seafood sector. Supported by the Nord Pas de Calais Regional Council and the ADEME (French Environment and Energy Management Agency), the study for the seafood sector is being undertaken in parallel with the textile, packaging and mechanical sectors.
The general process consists of four steps: benchmark, sector maturity assessment, needs identification, action plan development and Implementation.
The benchmark identifies life cycle based initiatives and tools relevant to seafood sector, focussing on, but not limited to North West Europe. The maturity of businesses, education bodies and research centres in the region with in relation to LCM practices is undertaken via interviews with key stakeholders. Stakeholder engagement is a key aspect of the needs identification and action plan development phases, not only to ensure that the proposed LCM action plan "fits" the needs of the sector, but to create ownership for the implementation phase.
The paper will also explain how we develop an inventory and a multi criteria matrix to measure the environmental maturity level of the seafood industry considering a life cycle vision in Nord Pas de Calais based on two main criteria: Maturity and willingness of key actors for life cycle assessment and eco-design.
This innovative approach to mainstreaming LCM leverages sectorial and regional networks to help overcome barriers to implementation. From a business perspective, integration with existing professional organisations means that SMEs access advice and tools through organisations that they already know and trust.

References

UNEP/SETAC. 2009. Life Cycle Management: How business uses it to decrease footprint, create opportunities and make value chains more sustainable.
European Commission. 2003. COM Integrated Product Policy Building on Environmental Life-Cycle Thinking
Boeglin. 2011. L'expérimentation nationale de l'affichage des caractéristiques environnementales in Proceedings LCA Conference 2011, 3-4 November Lille, France

36. Life cycle assessment of integrated fish pond aquaculture of household farms in sub-Saharan Africa

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Life Cycle Assessment (LCA) of integrated pond aquaculture of household farms in sub-Saharan Africa was carried out from 2008-2010 to identify ways to improve the systems and better understand the contribution of fish-pond systems to regional sustainable development.
A total of 20 polyculture fish ponds corresponding to three types of integrated fishpond system (semi-intensive medium or small; extensive) were chosen after screening household farms with aquacultural activities. Thus, inland fish-farm production in two contrasting areas of Cameroun was analysed. The fish-production system were integrated in the farms with either pig- or crop-production systems. In all farms, fish production was a polyculture based on tilapia (*Oreochromis niloticus)* or a tilapia-catfish (*Clarias gariepinus*) association. Secondary species often were included depending on the type of fish farm. For example, Hemichromis fasciatus or the snakehead fish (Parachana obscura) could be included to control tilapia population size, while common carp (Cyprinus carpio) or Heterotis niloticus could be included (according to availability) due to their bottom-feeding activity.
LCA was conducted according to the CML2001 method adapted to aquaculture production using economic allocation (taking manure into account), one tonne of fish as the functional unit, and background data from Ecoivent. The system boundary included on-farm processes, production of feed and fertiliser, fingerlings, and transportation at all stages. Dynamics of nitrogen and phosphorus were evaluated using a nutrient mass-balance modelling approach.
With the exception of extensive systems, there was large variability in the magnitude of impacts within each type of system. The main processes contributing to impacts were fish production, manure fertilisation, and fry production. Environmental impacts of the semi-intensive systems analysed were high compared to similar aquatic systems in Brazil. Their low efficiency and the source and origin of their inputs determined the magnitude of impacts. A water-purification role of extensive systems was also observed. On the other hand, the amount of human labour, which plays a strong social role sub-Saharan Africa, was higher in all semi-intensive systems.

37. Distribution of Norwegian fresh fish fillets from an environmental and economic point of view

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Optimisation towards more sustainable distribution solutions for fish fillets are important topics in Norway. Several research projects have shown that it is important to consider the packaging system from a holistic point of view, where the whole value chain is included. More material intensive packaging systems might be more sustainable if this leads to less loss of product through the value chain. It is also important to consider how the effectiveness of packaging systems can be improved, through maximising the volume of product in relation to total pallet volume.

Sea food is one of the most important export products from Norway. During the past years relatively more fish have been distributed as filets, and it is a long term strategy to distribute as much as possible as filets. Packaging research in Norway has thus been focused on development of new solutions for sea food distribution. Through common projects financed by the Norwegian Research Council, new packaging solutions have been developed, tested and optimised. Important drivers for innovation have been to develop solutions that are less voluminous, less material intensive, more effective in the packing process, utilise transport capacity better and are easier to recycle after use and still preserve high quality and low product loss. In parallel, the traditional packaging solutions have also been improved, to meet competition from new solutions. For fresh products, time to market is a critical factor in distribution, and new solutions have also been developed to increase the shelf life of fresh seafood products.

This presentation will focus on experiences from industrial case studies of packaging systems and distribution of fish filets, with main focus on changes from conventional packing with ice to super freezing without ice and with new fibre based packaging. The presentation includes life cycle data for processes and handling, production of packaging materials, impacts on transport, converting to final packaging solutions and treatment of packaging waste resources (material, economic and energy data)

References

Rubach, S. & Hanssen, O.J. 2002. Nordic methods for documentation of packaging optimisation. Proposal for Nordic method – Part B. Benchmarking system, Østfoldforskning.

Hanssen, O.J. 1997. Sustainable product management. Dr.techn. thesis, Norwegian University of Science and Technology, Trondheim

Nyland, C.A., Rubach, S., Hanssen, O.J., 2006. Value Chain Analysis of Different Types of Distribution Packaging For Fresh Fish Fillets, Proceedings IAPRE Conference, Tokyo Oct. 2006.

Svanes E., Vold M. and Hanssen O.J., 2011. Environmental assessment of cod (Gadus morhua) from autoline fisheries. International Journal of Life Cycle Assessment, 16: 611-624.

Svanes E., Vold M., Møller H., Kvalvåg Pettersen M, Larsen H. and Hanssen OJ, 2010. Sustainable Packaging Design: a holistic methodology for packaging design. Packaging Technology and Science.

Vold M, Hanssen O.J., Svanes E., 2006. Value Chain Analysis of Different Types of Distribution Packaging of Fresh Fish Fillets, IAPRI conference,

38. System delimitation in life cycle assessment of aquaculture

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In the past two decades, life cycle assessment (LCA) is recognised as a standardised and structured method of evaluating the environmental impacts arising throughout the entire life cycle of a product, process or activity. However, methodological issues still exist, when allocating the environmental burden of a specific production system between products and co-products. According to the ISO standards, the first option is to avoid allocation by making use of a subdivision or to expand the systems investigated. Aquaculture system hardly applied system expansion whenever a multifunctional process has more than one functional flow. The objective of this study is to model the system expansion for aquaculture production. The different affected processes with co-products are selected for system expansion. Thus, in this study we have considered the system expansion in two different stages in the life cycle of the fish production: aquacultural stage, with case study of trout aquaculture; and feed manufacturing stage. Rainbow trout (*Onchorhynchus mykiss*) production was used as a case study to illustrate the method using different scenarios of system expansion. This article showed that system expansion best describes the environmental impact of systems affected by increase in demand of rainbow trout.

Table 1. Relative emission load of rainbow trout farming estimated following different scenarios of system expansion. The results are characterised results and are related to the functional unit: 1 kg of rainbow trout demanded in Germany.

Impact category	Unit	Scenario I	Scenario II	Scenario III	Scenario IV	Scenario V	Scenario VI
Acidification	kg SO_2 equiv.	0.0077	0.0083	0.0113	0.0113	0.0090	0.0086
Eutrophication	kg PO_4 equiv.	0.0600	0.0601	0.0604	0.0601	0.0599	0.0598
Global warming	kg CO_2 equiv.	0.7670	0.9000	2.3219	3.6333	2.5516	2.4500
Land competition	m²a	0.7422	0.7440	1.3030	1.0268	0.6013	0.5996

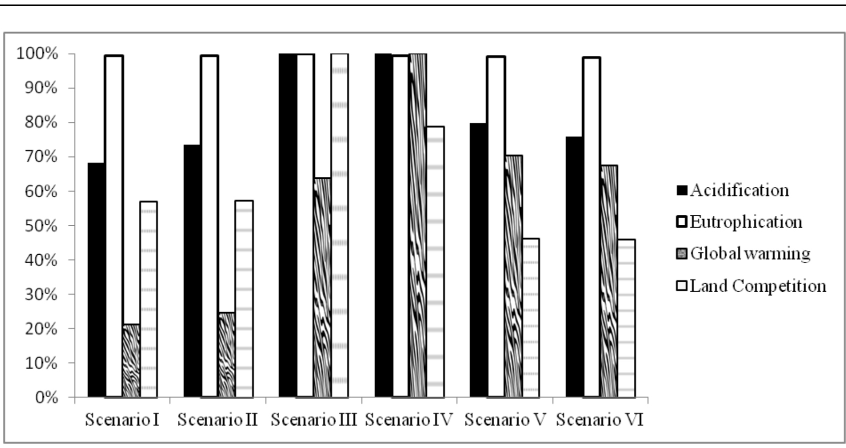

Figure. 1 Relative emission load of rainbow trout aquaculture using different system expansion scenarios.

39. The assessment of biodiversity within UK farming systems using an extended LCA ecosystem approach

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In 2009, the UK Government commissioned a three-year project to develop a methodology to assess the economic, environmental and social characteristics of UK farming systems. Thirty-two farming systems were identified to represent the diversity of UK agriculture and forty indicators were described to cover a wide range of economic, environmental and social parameters. The methodology uses a development of the existing Cranfield LCA model (Williams et al., 2007) combined with newly developed economic and social matrices. A matrix was constructed to accommodate the data generated by the 1280 farming system/characteristic combinations. The matrix uses both actual and normalised values to investigate the advantages and disadvantages that accrue from different farming systems. This overall approach is described as an extended LCA ecosystem approach model. This paper reports on the inclusion of an aggregated biodiversity indicator into the methodology.

One major difficulty in representing biodiversity is the definition and subsequent calculation of single or multiple indicators. Single indicator species groups such as birds or carabids may be used, but effects of management practices have been shown to be specific to the different indicator groups (Jeanneret et al., 2008). Meta-analyses have investigated the dose-effect relationships between pressure factors and biodiversity in agricultural landscapes (Reidsma et al., 2006; Alkemade et al., 2009). Following on from this work, ecosystem quality values (defined as the mean species abundance relative to the undisturbed situation) were assigned to each combination of land-use type, intensity level, and type of management (organic and non-organic). Using data from the UK's Farm Business Survey, an estimation of the remaining ecosystem quality of each farming system could then be made.

Highest ecosystem quality values were associated with the grass-based, low intensity systems, whilst the lowest scores were obtained by the most intensively housed livestock systems. Within production systems, the indicator was capable of differentiating between different types of management. For example, within pig production, outdoor bred/indoor finished systems scored higher than permanently housed systems. This methodology can be used to examine how changes in the farming landscape would affect levels of biodiversity; whether through land-use change, such as the conversion of grassland to arable land, through intensification, or through conversion to organic production.

References

Alkemade, R., van Oorschot, M., Miles., L. Nellemann, C., Bakkenes, M., ten Brink, B., 2009. GLOBIO3: A framework to investigate options for reducing global terrestrial biodiversity loss. Ecosystems 12, 374-390.

Jeanneret, P., Baumgartner, D. U., Freiermuth Knuchel, R., Gaillard, G., 2008. A new LCIA method for assessing impacts of agricultural activities on biodiversity (SALCA-Biodiversity). 6th International Conference on Life Cycle Assessment in the Agri-Food Sector 2008, Proceedings, 34-39.

Reidsma, P., Tekelenburg, T., van den Berg., M., Alkemade, R., 2006. Impacts of land-use change on biodiversity: an assessment of agricultural biodiversity in the European Union. Agriculture, Ecosystems and Environment 114, 86-102.

Willams, A.G., Audsley, E., Sandars, D.L. 2006. Determining the environmental burdens ands resource use in the production of agricultural and horticultural commodities. Final report for Defra project IS0205. Cranfield University, Bedford and Defra, London.

40. Proposal of a unified biodiversity impact assessment method

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Driven by the insight of society that biodiversity is worthy of protection, the decrease in habitats and species recently became a central topic in environmental policy. The European Union aims to study and to stop anthropogenic loss of biodiversity. In Germany this EU target led to the National Strategy on Biological Diversity (BMU 2007). Among others, one consensus point in environmental policy is that private and public actors need instruments to identify the "biodiversity performance" of product systems and services.

A team under the lead of the GaBi department at Fraunhofer Institute for Building Physics (IBP) launched a project in 2012 to develop a method for the assessment of the biodiversity impact of product systems. Regarding future application the crucial point is that this tool has to be broadly accepted by scientific and economic actors. Thus, knowledge and experience of the LCA community must be involved in the development of the method.

It is suggested that the assessment method includes a preliminary quick check to decide on the extent to which the full method should be applied (Fig. 1). Criteria may be land requirement or activities in biodiversity hot spots. The biodiversity impact assessment method fits in the general land use impact assessment framework described in Milà i Canals et al. (2007). There, the impact of a land using process is defined as:

$$\text{Impact} = \text{affected area} \times \text{duration of impact} \times \text{quality change of the area}$$

The biodiversity impact assessment method reflects the quality axis for the impact category "biodiversity". It is loosely based on the method proposed by Michelsen (2008) in that it employs region-specific characterisation models and allows aggregation across regions through weighting factors. Biodiversity is described by means of a multidimensional potential function (see figure 2). Setting the parameters of the function sets the biodiversity value for a certain process at a certain place. Comparison to the biodiversity value under given reference conditions allows the calculation of the quality change for the equation above. The form and parameters of region-specific biodiversity potential functions are derived from literature research about the state of the regional ecosystem(s), national/regional conservation goals, as well as expert judgement. Weighting factors for the aggregation across regions e.g. in global supply chains (Fig. 3) are derived from globally agreeable descriptors for biodiversity and/or ecosystem quality.

The proposed method allows relatively precise and accurate biodiversity impact assessment at the price of relatively high data acquisition. In the unified method, the detailed procedure described above is used for the most relevant elements of a product system, as determined by the quick check. A broad-brush impact assessment method is applied to fill in the blanks for less relevant elements of the product system.

References

BMU, 2007. National Strategy on Biological Diversity. Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), Public Relations Division, Berlin.

Michelsen, O., 2008. Assessment of Land Use Impacts on Biodiversity. Proposal of a new methodology exemplified with forestry operations in Norway. Int. J. LCA 13 (1), 22-31.

Milà i Canals, L., Bauer, C., Depestele, J., Dubreuil, A., Freiermuth Knuchel, R., Gaillard, G., Michelsen, O., Müller-Wenk, R., Rydgren, B., 2007. Key elements in a framework for land use impact assessment within LCA. Int. J. LCA 12 (1), 5-15.

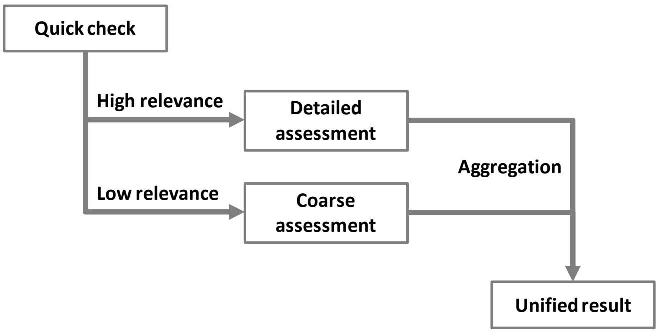

Figure 1. Methodology overview.

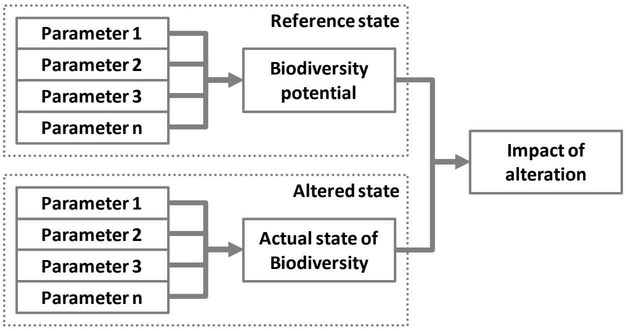

Figure 2. Region-specific impact model.

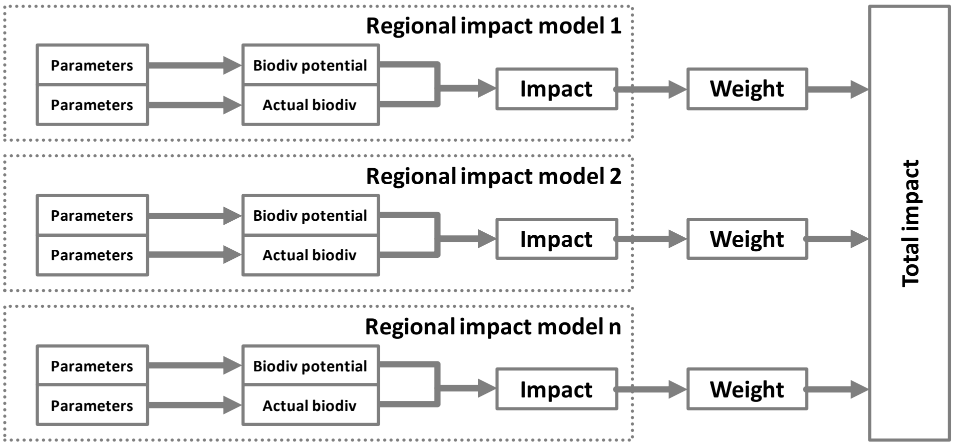

Figure 3. Aggregation of several regional impacts.

41. Displaying environmental footprints of agricultural products: a "biodiversity" indicator based on landscape features

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Sustainable household consumption can be an important engine for a greener economic growth. Introducing information about the environmental impacts of products throughout their life cycle is one way to make the global consumption system more sustainable. In France, the "Grenelle" environmental laws introduce the right for consumers to have information related to the multi-criteria environmental footprint of (mass market) products at the point of sale. A year-long experiment began in July 2011 involving around 160 volunteer companies and other relevant economic stakeholders. Because the agricultural and food sectors are concerned, it is expected that providing consumers with this environmental information could have a positive effect and lead the whole food chain, from farmers to retailers, to produce and market more sustainable goods.

This legislative pillar of the French system relies on the technical ADEME AFNOR platform (expertise and standardisation) building methodological documents with all concerned stakeholders. In the food, beverage and pet-food sector, the transversal methodological document finalised in April 2012 by the platform recommends using 100 mg or 100 ml as a functional unit and addressing the following environmental impact indicators, units (and degrees of precision) and calculation methods: greenhouse gas emissions (in kg eqCO_2, using IPCC 2007), water consumption (litres, using net consumption), water eutrophication (in g EqN, using ReCiPe), water ecotoxicity (CTUe, using USEtox), and impacts on biodiversity (but do not recommend any unit or method for this issue: it has to be defined).

The French Ministry of Ecology, Sustainable Development and Energy (MEDDE CGDD) decided to finance a study to propose such a product-level biodiversity indicator because i) a multi-criteria environmental footprint is more representative, ii) stakeholders of the ADEME AFNOR platform have identified biodiversity as an environmental challenge to address, iii) agriculture's contribution to both loss and preservation or improvement of biodiversity is important in the world and in France, and iv) existing LCA methods to address biodiversity impacts of food and agricultural products are unsatisfactory: based on land "occupation" or "consumption", they associate higher impacts with more extensive farming practices. The poster presents the main characteristics of this study, which will end in autumn 2012.

A call for tenders specified the type of biodiversity indicator to build. It i) has to express not only loss or impacts but also a positive contribution to biodiversity; ii) could be specific to the farm level, since major biodiversity impacts of food products are concentrated in the agricultural production phase; iii) has to be calculated as a ratio dividing a quantity of biodiversity by a quantity of product; and iv) has to be consistent with biodiversity indicators already used in existing agricultural policies (CAP good agricultural and environmental conditions, CAP second pillar subsidies for grasslands and French farm environmental certification scheme). Two companies, Solagro (an agro-environmental consultancy firm) and ACTA (French agricultural technical institutes), were selected to perform.

Consequently, "landscape features", which are "semi-natural, unfarmed or extensively farmed environments", were the proxy chosen to characterise biodiversity. Examples in the database cover extensive permanent grasslands and temporary grasslands with low nitrogen inputs, hedges, ponds, ditches, trees in a line or in a group, isolated trees, field margins and terraces, land left fallow, buffer strips, etc.

The year-long study is divided into 3 phases: i) stabilise methodology and definitions and start data collection (3 months); ii) calculate values of the biodiversity indicator for the selected agricultural products (6 months); and iii) discuss the results and properties of the indicator (3 months). Selected animal products are cow milk, cow meat (dairy or beef cattle), sheep meat, sheep milk, lamb meat, pig meat, chicken meat, chicken eggs. Selected plant products are wheat, barley, maize, sunflower, rapeseed, potatoes, protein crops, orchards, vineyard, sugarbeets, grapes, apples, tomatoes, vegetables, and fodder (silage maize, permanent and temporary grasslands, fallows).

Three different approaches are used to calculate this indicator: i) national statistical databases (National Forestry Inventory 2nd cycle, TERUTI-Lucas, National Agricultural Survey 2000), ii) representative farms for typical production systems (database of agricultural institutes) and iii) the farm database DIALECTE (containing around 2000 extensive agricultural units). "Landscape features" are measured at different levels depending on the database, for example, at the commune level (in the national database) or at the farm level. Since "landscape features" are of very different natures (grasslands, hedges, trees, etc.), four types of weighting coefficients are used to convert them into "biodiversity-equivalent area", an estimated real surface area for which all coefficients of different "landscape features" are equal to 1 (CAP and direct-aid eco-conditionality coefficients, developed-area coefficients and coefficients based on developed areas but that also consider agricultural practices).

Initial results show that it is possible to link an agricultural product with a quantity of biodiversity. Yet, much work is still required, for example, considering yield effects, allocation between co-products or biodiversity impacts linked to animal-feed production. Results will be verified and compared in phase 3, which will also consist of an analysis of the indicator's properties. Its main advantages are its existence (given the scarcity or absence of similar indicators), its practicality and feasibility (to calculate an indicator based on "landscape features" for several different agricultural products using several databases and entry levels), its consistency with other agricultural policy indicators, its ability to measure a positive contribution to biodiversity and its acceptability by farmers. Its main limits and drawbacks include that it is specific to the farm- and farming-production phase (it is thus not a life cycle indicator) and it is very recent (pioneering and opening a new international research agenda). We conclude by insisting on the urgent need to develop academic and operational research to consolidate this agricultural-product-level biodiversity indicator or to build a better one that contains the properties desired.

References

IPCC, 2007. Intergovernmental Panel on Climate Change.

MEDDE (French Ministry of Ecology, Sustainable Development and Energy), 2012a. Display of the environmental footprints of products: French developments. Online: http://www.developpement-durable.gouv.fr/Product-Environmental-Footprint.html

MEDDE (French Ministry of Ecology, Sustainable Development and Energy), 2012b. Expérimentation nationale de l'affichage environnemental. Online: http://www.developpement-durable.gouv.fr/-Experimentation-de-l-affichage,4303-.html

Solagro and ACTA, 2012a. Indicateur biodiversité pour l'affichage environnemental des produits agricoles. Rapport final de la phase 1 au MEDDE CGDD, February 2012, 82 p.

Solagro and ACTA, 2012b. Indicateur biodiversité pour l'affichage environnemental des produits agricoles. Rapport final de la phase 2 au MEDDE CGDD, June 2012, 107 p.

Solagro and ACTA, 2012c. Indicateur biodiversité pour l'affichage environnemental des produits agricoles. Rapport final de la phase 2 au MEDDE CGDD, October 2012.

42. Carbon footprint of the Chilean apple orchard system: study in the main southern hemisphere producer

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Chile is a major off-season fruit supplier and covers a significant portion of fresh fruit imports made by the United States, the European Union and Japan. Chile is the largest southern hemisphere producer and exporter of apple (CCM, 2010). Estimating carbon footprint of agricultural systems is becoming an important issue for country's horticulture sector. This study evaluated, using a life-cycle approach, the carbon footprint of the intensive apple orchard system in Chile. The methodology used is according to the PAS 2050 specifications (BSI, 2008). The system boundaries included all the life cycle stages from the cradle to the farm gate (harvested apples). The apple production analysed in this study corresponds to nationwide representative practices. The results indicated that mineral fertilisers caused the major contribution to the carbon footprint. In contrast, packaging waste had a minor influence. The application of the life-cycle approach helped to identify improvement measures to reduce greenhouse gas emissions of the orchard production system.

References

BSI, 2008. PAS 2050:2008 Specification for the assessment of the life cycle greenhouse gas emissions of goods and services. British Standards Institution (BSI). London, UK.
CCM (Centro de Competividad del Maule), 2000. Manzanos. Universidad de Talca, Talca.

43. Assessment of carbon footprint methodologies used to evaluate Mediterranean horticultural production in standard multi-tunnel greenhouses

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Evaluating the environmental behaviour of the agri-food products has become an essential issue, not only to avoid the pollution, but also to reduce potential threats to human health and to assure the provision of better quality food. Furthermore, novel demanding consumers are concerned about this information and they are also aware of the possible carbon footprint inflicted by their consumption habits. Carbon footprint has become a popular tool to measure the impact of products in the environment because it is easy to use and understand and the study times are shorter and cheaper than other environmental methodologies. One drawback of this approach is the different methodologies that simultaneously exist and that provide different, and sometimes contradictory, results regarding the environmental impact of products (Brenton et al., 2010).
This project aims to compare three well-known carbon footprint methodologies: The PAS2050:2011, the French Bilan Carbone and the WBCSD's GHG Protocol (see Table 1). The comparison highlights the different results due to variations in the procedure of each carbon footprint methodology when it is applied to agricultural systems (i.e. including capital goods, allocation criteria, inventory origin, system boundaries and expansion, carbon sinks, land use and/or transportation approaches among the most important variations). The study evaluates the environmental impact of five horticultural products: tomato, lettuce, beans, green peas and cucumber. The scope of the experiment also includes the evaluation of two fertilising treatments, including the application of mineral fertilisers and compost (Martínez-Blanco, 2011). The stages assessed include the fertilisers production and transport, the cultivation stage and the greenhouse phase.
The exclusion of capital goods represents a 4-16% decrease in the total CF when compared to the footprint measured by the GHG protocol and the Bilan Carbone. The inclusion of indirect processes (i.e. commuting employees) and the capital goods generate an increase of 12-50% in the CF. Additionally, when including the capital goods and adding a commercialisation stage (that includes packaging and transportation towards the retail markets) the CF suffers an increase of 6-40% from the one obtained under the PAS 2050 parameters. The packaging sub-stage provides 99% of the total impact within the commercialisation stage. These variations could be avoided if the system boundaries are extended to the end user stage, as suggested by the Bilan Carbone methodology; and including indirect processes, as considered by the GHG protocol. Paradoxically, still very few changes among the methodologies provide relevant variations (of more than 5%) in the carbon footprint calculations.

References

Brenton, P., Edwards-Jones, G., & Friis Jensen, M. Carbon Footprints and Food Systems. The World Bank Publications, 2010.
Martínez-Blanco, J. Muñoz, P., Antón A., Rieradevall, J. Assessment of tomato Meditarrean production in open-filed and standard multi-tunnel greenhouse, with compost or mineral fertilisers, from an agricultural and environmental standpoint, 2011. J Clean. Prod. 19, 985-997.
Martínez-Blanco, J. Rieradevall, J., Muñoz, P., Pascua, P., Oliver-Solà, J., Gabarrell, X., Gasol, C., 2012. Comparison of life cycle methodologies for the GHG assessment: CF and LCA in the horticulture sector . Int. J LCA.

Table 1. Main information of the Carbon footprint methodologies included in the study

Methodology	PAS 2050	Bilan Carbone	Greenhouse Gas Protocol
Developer	Bristish Standards Institute (BSI)	Agence de l'Environnment et de la Maîtrise de l'Energie (ADEME)	World Resources Institute (WRI) / World Business Council for Sustainable Development (WBCSD)
Country of origin	United Kingdom	France	United States
Last update	2011	2007	2007
Government sponsorship	Yes	Yes	No
Reach	Extensively used within the UK, but also in Japan, Western Europe and Northern Africa	Used only in France and Belgium	Used and promoted in the US, Brazil, Europe, India, China, Mexico and Australia
Annexes on agricultural products	Yes	Unidentified	Yes
Link	www.bsigroup.com	www.r-co2.com/Bilan-Carbone-ADEME--FRANCAIS	www.ghgprotocol.org

44. Carbon footprint and energy use of different options for greenhouse tomato production

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Rising sustainability awareness makes consumers increasingly interested in the environmental performance of the products on the market, concerning e.g. the emission of greenhouse gases (GHG). For this reason, there are market-driven environmental impact assessment tools, which can both inform consumers and be used by producers to highlight their sustainability efforts. The carbon footprint has been suggested as straightforward and resonant indicator for product environmental performance (Weidema et al., 2008).

In this case-study we report the carbon footprint and energy use of the production of *Cuore di bue* tomatoes in a greenhouse in Northern Italy with different energy-provision options. Despite the existence of other studies of this nature performed in Europe (e.g. Roy et al., 2009; Boulard et al., 2011), none has been performed in this region nor compares different energy supply configurations.

The conventional system consists of a polyethylene greenhouse supplied with grid electricity and heated through a natural gas boiler. The CO_2 released in the combustion is used to fertilise the plants. There are future plans to obtain heat through municipal solid waste (MSW) incineration and recover CO_2 from industry exhausts (scenario 1). Alternatively, both can be obtained from a co-generation facility (scenario 2), the latter providing also electricity. We assessed the life cycle GHG emissions and energy use of the present production chain and those alternatives. This exercise was performed according to appropriate official standards for life cycle assessment (ISO 14040-14044) and for carbon footprint (ISO 14067). Allocation was avoided by system boundary expansion. Assessment was made with software SimaPro® (PRé, the Netherlands), through the single-issue methods IPCC GWP 2007 100a and Cumulative Energy Demand (expressed in kg CO_2 eq and MJ eq, respectively). The functional unit is 1 kg of fresh tomatoes packed and delivered at the local market.

The carbon footprint of each kg of tomato produced in the current system is 2.33 kg CO_2 eq (Fig. 1-A). Coupled heating and CO_2 enrichment are responsible for 54% of GHG emissions. Construction of the greenhouse and fertilisation contribute 21% and 13%. The footprint can be decreased by 16% if MSW incineration supplies heat and CO_2 fertilisation (scenario 1). If the co-generation facility were to be installed (scenario 2), the carbon footprint would be lowered by 7% (2.15 kg CO_2 eq kg^{-1} tomato), owing to the excess electricity credited to the system. From the energetic point of view, the scenarios imply higher reductions (Fig. 1-B). While the energy use of the conventional system is 77 MJ eq kg^{-1} tomato, the co-generation and the waste valorisation options reduce it by 52 to 55, respectively. Heating and CO_2 fertiliser reach 75% of the energy input to the current system and 50% and 54% in scenarios 1 and 2 respectively. In all cases, construction and transport, packaging and waste disposal are the second and third energy consumers.

Literature presents wide ranges of GHG emissions and energy use of tomato production, influenced mainly by location and sophistication level of the system as described by Roy et al. (2009). These results are in line with averages from literature, even though *Cuore di bue* variety typically shows lower yields than conventional varieties.

References

Boulard T., Raeppel C., Brun R., Lecompte F., Hayer F., Carmassi G., et al., 2011. Environmental impact of greenhouse tomato production in France. Agron. Sust. Devel. 31(4), 757-77.

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

Weidema B., Thrane M., Christensen P., Schmidt J., Løkke S., 2008. Carbon footprint: a catalyst for Life Cycle Assessment? J. Ind. Ecol.12(1), 3-6.

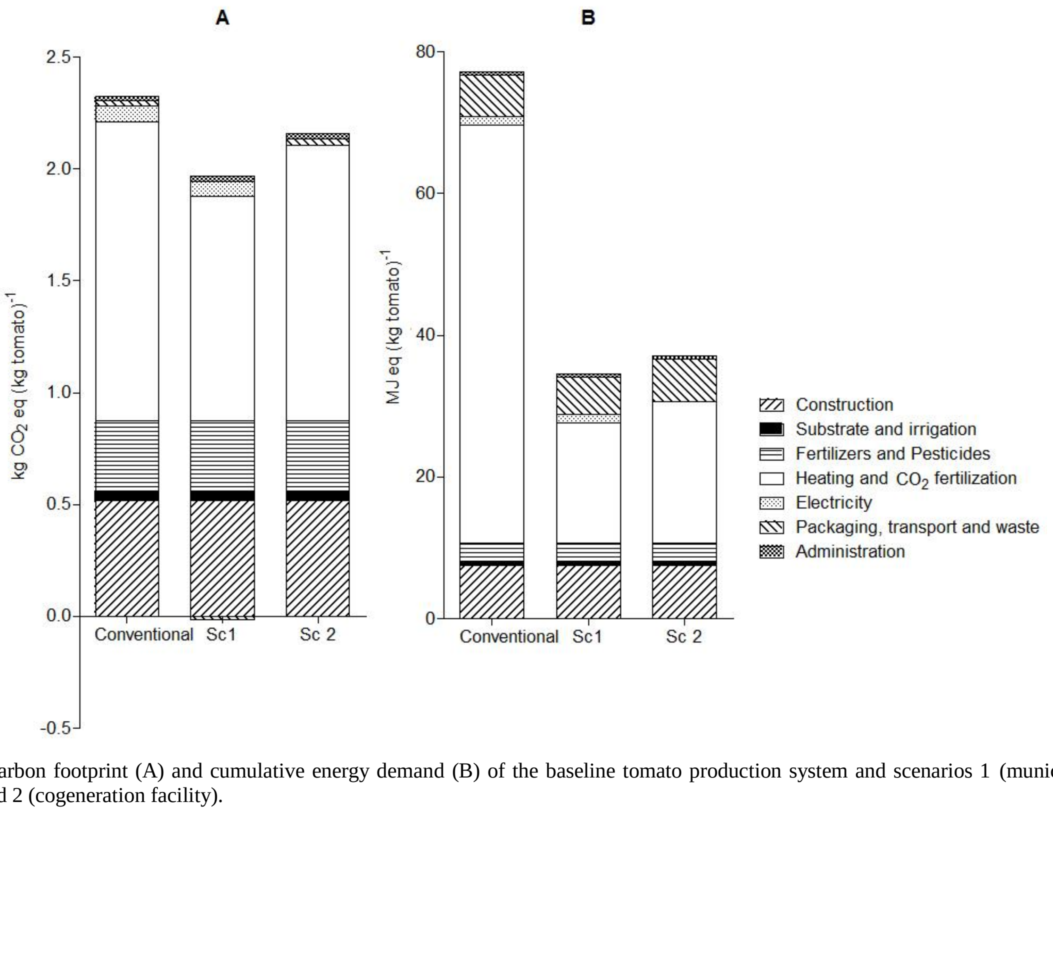

Figure 1. The carbon footprint (A) and cumulative energy demand (B) of the baseline tomato production system and scenarios 1 (municipal waste incineration) and 2 (cogeneration facility).

45. Assessment of Finnish cultivation practices with carbon footprint and energy index

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Finnish food chain effect on climate change is estimated to be 14% of total climate change effect of Finnish consumption. Most of the food chain emissions are originated from agriculture. These emissions represent 69% of the total climate change impacts from the food chain. (Virtanen et al., 2011)

A method for determining the energy efficiency and environmental impact of a production of cultivation plants and for increasing positive environmental impact has been developed for Raisio Group's contractual farmers. Environmental impact and energy efficiency are characterised from contractual farmers' agricultural input-output data. Production parameters for cultivation are selected and cultivation procedures are performed by farmers, and further, the performed procedures are documented to give required information for environmental impact assessment and energy efficiency calculation.

Farm specific input-output data is collected after a produced crop yield is harvested. A representative sample of the crop yield is delivered to laboratory analysis with the required information. The grain sample is analysed and energy content of the yield is measured. Energy index and carbon footprint of the crop yield are calculated using the representative sample information. The system boundary used for energy index and carbon footprint calculation is cradle-to-farm gate. Energy index represents a ratio of energy content of the crop yield per hectare and energy used in cultivation practices per hectare. Functional unit for carbon footprint is a grain tonne.

Agricultural input-output information has been collected from contractual farmers during harvesting seasons 2008-2011. The input-output database includes 2000 to 2500 grain variety specific datasets from every season. Energy index together with CO_2 emissions of contractual farmers farming practices are estimated since 2008. Other greenhouse gas emissions are taken into account and a carbon footprint of contractual farmers' grain yield is calculated since 2009. Development of the carbon footprint and the energy index trends are followed and the most significant factors for development are identified. Information is used for instructional purposes and also for product carbon footprint calculation.

References

Virtanen, Y., Kurppa, S., Saarinen, M., Katajajuuri, J-M., Usva, K., Mäenpää, I., Mäkelä, J., Grönroos, J., Nissinen, A., 2011 Carbon footprint of food - approaches from national input-output statistics and a LCA of a food portion. Journal of Cleaner Production 19: 1849-1856.

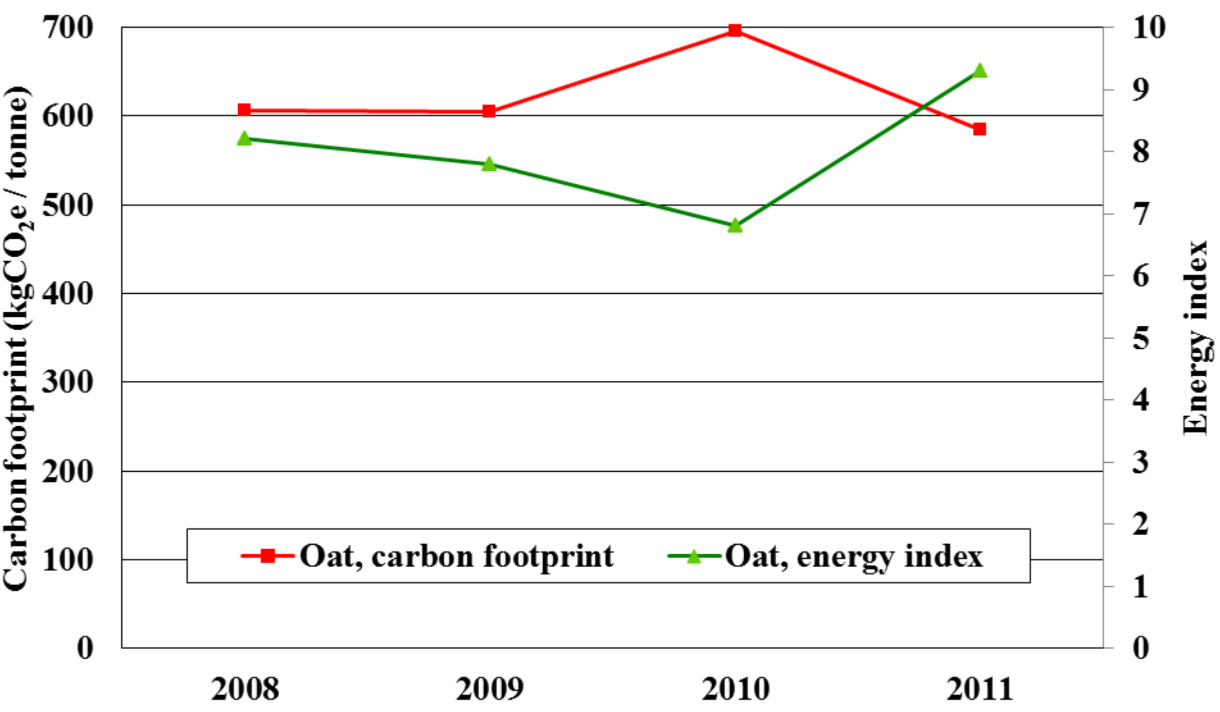

Figure 1. Average carbon footprint and energy index of oat produced by Raisio Group's contractual farmers during cultivation seasons 2008 to 2011.

46. Carbon footprint of Irish milk production

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The objective of this paper was to calculate the carbon footprint (CF) of Irish milk production on commercial dairy farms using life cycle assessment (LCA) to estimate the greenhouse gas (GHG) emissions to calculate CF. LCA of milk production has been carried out on commercial farms in Europe using both national statistics and ad hoc survey of farm-gate turnover. Most research has focused on comparing production types (e.g. organic vs. conventional), however relatively little work has examined how detail of farm management may influence CF.

In this paper, a four stage LCA was implemented following ISO 14040. The foreground data were based on a survey of specialist dairy farms, and the background data were taken from the Ecoinvent database. The functional unit was 1 kg energy corrected milk (ECM). Economic allocation was used for concentrate feed ingredients at the pre-farm stage. Emission factors (EFs) were taken from relevant literature while the EF for enteric CH_4 was determined by estimating net energy for maintenance, lactation, and pregnancy. Global warming potential of CH_4 and N_2O were taken as 25 and 298 times CO_2 equivalent. The system boundary was set at the farm gate and included production and transportation of fertiliser and concentrate feed and the on-farm activity. Infrastructure and machinery, soil carbon sequestration, pesticides, medicine and minor consumables were not included. In order to exclude on-farm activities not relevant to dairy production a proportioning rule was devised. This was done by (1) converting all animals into livestock unit (LU) equivalents according to the ratio of nitrogen excretion compared to a dairy cow as defined in the Irish "Statutory Instrument (SI) No. 610 (2010)"; (2) assuming the dairy herd consisted of dairy cows + replacement animals + bulls or suckler cows (if any), deriving the proportion factor of dairy herd as "dairy LU/total LU"; and (3) excluding from the farm GHG inventory electricity production, which was predominantly used by dairy herd, and multiply the rest by the proportion factor, and then adding back the electricity contribution to derive the dairy unit GHG. After proportioning, economic allocation between milk and meat (from surplus calves and culled cows) was performed based on farm sales records.

Much variation in the tactical management of the farms was found. For example, as much as 1.5-fold difference in fertiliser N input to support the same stocking density, and up to 2 fold difference in concentrate feed for a similar milk output per cow. The CF of milk production of the farms averaged 1.23 ± 0.16 kg CO_2 eq/kg ECM. CF was found to be correlated with various tactics using step-wise regression: milk per cow, economic allocation factor (both $P<0.001$) and diesel use per on-farm ha ($P < 0.005$), but no one indicator was a good predictor of CF. Effective sward management of white clover on a few farms appeared to lower the CF, but the signal was not all that clear because of other management tactics.

It was concluded that a combination of multiple tactics would determine CF of milk production on commercial dairy farms, and one of the most important indicators was milk output per cow, however this could not be used as a parsimonious predictor of CF on its own. The overall management efficiency of each farm is critical to achieving low CF for Irish milk.

References

Casey, J.W., Holden, N.M., 2005. The relationship between greenhouse gas emissions and the intensity of milk production in Ireland. J. Environ. Quality 34, 429-436.

GGELS, 2010. Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions. Joint Research Centre, European Commission.

Statutory Instruments (SI) No. 610, 2010. European communities (good agricultural practice for protection of waters) regulations 2010. Government Publications Sale Office, Sun Alliance House, Molesworth Street, Dublin 2, Dublin, Ireland.

47. Carbon footprint of the Australian dairy industry

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This abstract describes an overview of a carbon footprint project conducted (2010-12) by PE International, PE Australasia and a consortium of research partners. The project sponsor is Dairy Australia acting on behalf of the Australian national dairy industry. This abstract outlines the project aims, methodology, approach adopted and lessons learnt.

Overall the study aims to assist Australian dairy companies to understand the carbon footprint of their products, and develop long term strategies to reduce hot spots in the carbon footprint of dairy products. The overarching project aims are to:

- Quantify the carbon footprint of the major Australian dairy products produced for export, i.e. butter, cheese, fresh products, milk powders, nutritional and UHT-products, whey and lactose, from farm-to-distributor's warehouse or export harbour. Altogether, 12 products have been investigated.
- Represent the weighted Australian average product carbon footprint for selected products based on annual production figures by region and by farm practices;
- Establish an auditable monitoring system and framework for a reproducible carbon footprint reporting that can be updated and expanded to include other environmental impacts in the future.

Meeting the goals of the project requires collection of primary LCA data from approximately 150 farms and and 15 dairy representative processing sites across Australia operated by the major dairy companies.

The methodology for this study is in line with ISO standards on Life Cycle Assessment and the sector specific Carbon footprinting guidelines of the International Dairy Federation (2010). Following the IDF guidelines (IDF, 2010) raw milk intake and transportation is allocated on the basis of the milk solids content of the final product. Operations within the processing plant are modelled as detailed as the data availability allow. Three modelling and approaches are possible for addressing allocation issues at the processing plants.

The study includes all relevant activities from the growing of grass on farm to feed the cows, to the delivery of dairy products to warehouse or export harbour. On farm site this includes emissions from mechanical as well as non-mechanical sources. For the product processing the system boundary contains all relevant activities from collection of the milk from the farm, product processing, through to export harbours for export products, and for fresh products to the retailers' distribution warehouse.

The scale of data collection and complexity of modelling approach for this project is extensive. The software solution utilised is a linked solution, combining both GaBi and SoFi software packages from PE International (Fig. 1). Data was collected using customised web-based questionnaires in the SoFi software which allow individual producers to submit their data in a secure and auditable environment.

References

International Dairy Federation (2010) "A common carbon footprint methodology for the dairy sector", November 2010

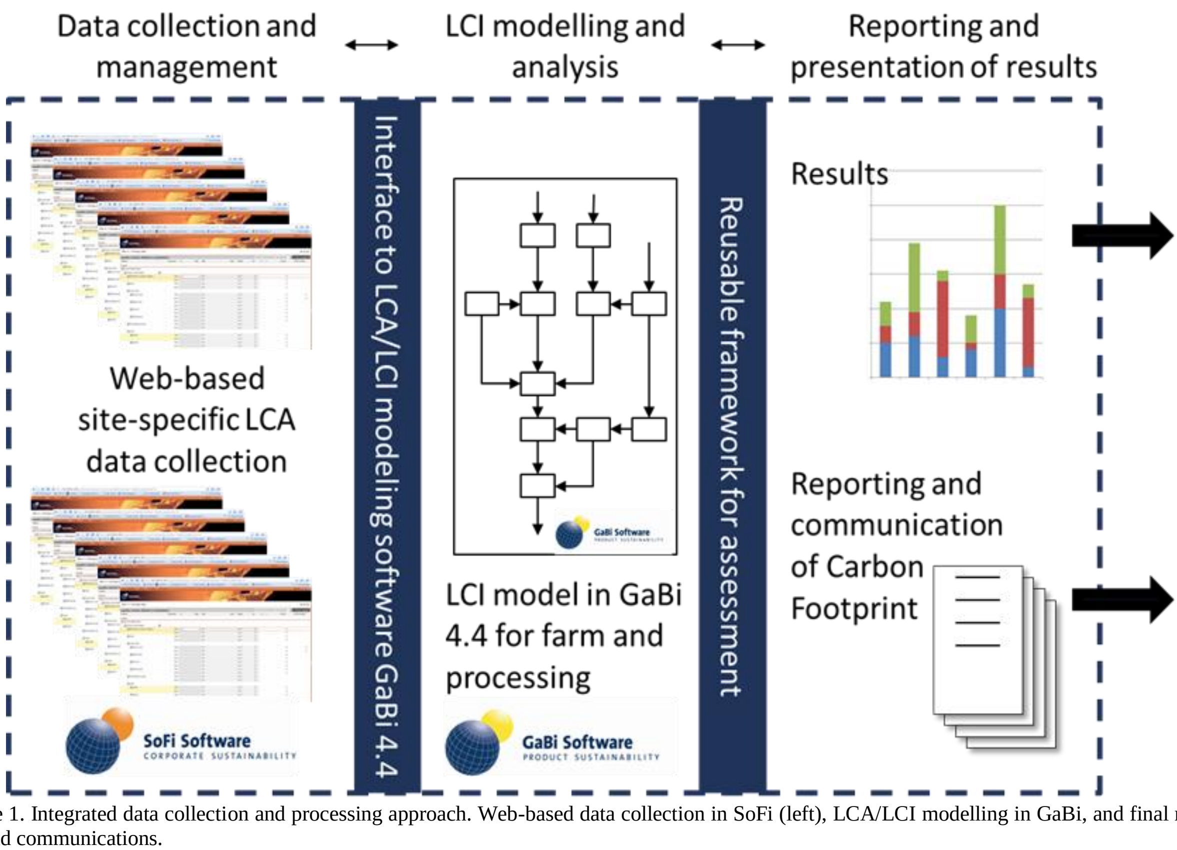

Figure 1. Integrated data collection and processing approach. Web-based data collection in SoFi (left), LCA/LCI modelling in GaBi, and final reporting and communications.

48. Contribution of packaging to the carbon footprint of canned tuna

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Packaging is an essential accompaniment of almost every food product. It performs multiple functions to ensure the safety and satisfactory condition of food products delivered to end users. Packaging helps minimise food losses, consequently reducing the environmental burden arising from excessive food production. In addition, packaging is a key element in creating new food products to meet consumer needs. For instance, canned foods discovered by a French chef, Nicholas Appert, more than 200 years ago have increasingly been presented in retort containers which are more convenient and attractive than metal cans.

Nevertheless, packaging has a negative impact on the environment, the extent of which depends significantly on the choice of materials and the efficiency of material recovery (Hospido et al., 2006; Humbert et al., 2009; Mungkung et al., 2010). These circumstances present an additional challenge to the food industry: selecting a packaging system which could increase consumer satisfaction while having less impact on the environment.

This study was thus initiated to identify and compare the carbon footprint of different packaging systems used to provide one single-serve meal of canned food which tuna was selected as a study product. It also aimed at enhancing the application of LCA study at the early stage of a new product development and a product improvement. The study was conducted in accordance with publicly available specification PAS 2050:2008 (BSI, 2008), with respect to LCA methodology covered by ISO 14040 and ISO 14044.

Single-serve packages selected were: (1) two-piece cans made of chrome-coated steel, with an aluminium pull ring tab on the top; (2) retort pouches made of polypropylene (PP), aluminium foil (Al) and oriented nylon (ON), referred to as PP/Al/ON/PP; and (3) retort cups made of PP and ethylene vinyl alcohol (EVOH), referred to as PP/EVOH/PP with lids made of polyethylene terephthalate (PET), aluminium foil, ON and PP, referred to as PET/Al/ON/PP. The system boundary, Figure 1, covered the production of tuna meat, the production of packages, product assembly, processing, packing, transport, and disposal, excluding consumption. Primary data were collected for each main activity in the production line, including filling, closing or sealing, sterilising, cooling, labelling, and unitising. As sterilisation is an energy-intensive and batchwise process, primary data on energy use and steam consumption were carefully measured.

The life cycle GHG emissions associated with a single serving of tuna using different packaging systems are shown in Figure 2. The manufacturing process of retort pouches and cups produced 60% and 70% less GHG emissions, respectively, than that of metal cans. However, the overall carbon footprint of canned tuna in retort cups was 10% and 22% less than when packaged in metal cans and retort pouches, respectively. Packaging and its associated processing constituted significant fractions of the product's carbon footprint, ranging from 20-40%. These findings show that the advantage of low GHG emissions embodied in plastic packaging might vanish if the associated processes are not optimally managed. To reduce a product's carbon footprint, the choice of food packaging thus depends not only on the materials but also on the further processing involved. Hotspots in the life cycle assessment of canned foods are packaging production and disposal, and product sterilisation. The improvement of retort operation in terms of capacity and energy utilisation, and the efficiency of post-consumption packaging material recovery, are the key factors responsible for the reduction of a product's carbon footprint. These issues present a challenge to both the food industry and local authorities.

References

British Standards Institute (BSI), 2008. PAS 2050:2008: Specification for the Assessment of the Life Cycle Greenhouse Gas Emissions of Goods and Services. British Standards Institute, London.

Hospido A, Vazquez ME, Cuevasc A, Feijoo G, Moreira MT., 2006. Environmental assessment of canned tuna manufacture with a life-cycle perspective. Resour. Conserv. Recycl. 47(1): 56-72.

Humbert S, Rossi V, Margni M, Jolliet O, Loerincik Y., 2009. Life cycle assessment of two baby food packaging alternatives: glass jars vs. plastic pots. Int. J. Life Cycle Assess. 14(2), 95-106.

Mungkung R, Gheewala SH, Kanyarushoki C, Hospido A, van der Werf H, Poovarodom N, Bonnet S, Aubin J, Moreira MT, Feijoo G., 2010. Practical issues of product carbon footprinting: experiences from Thailand. In Proc. of the 7th Int. Conf. on LCA in the Agri-Food Sector. Bari, Italy.

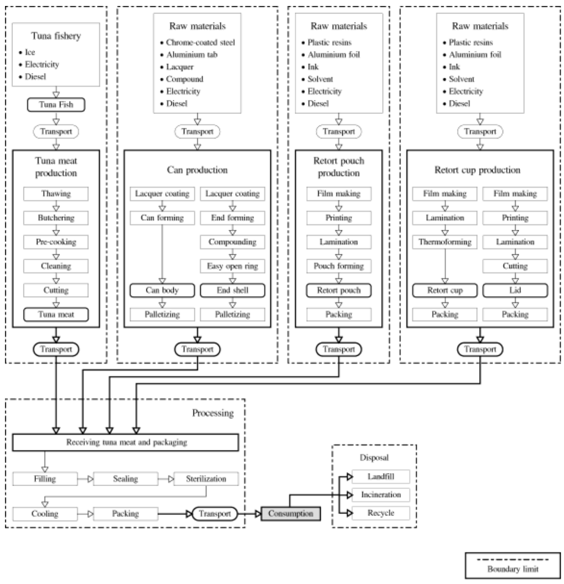

Figure 1. System boundary of carbon footprint assessment for canned tuna products, excluding consumption.

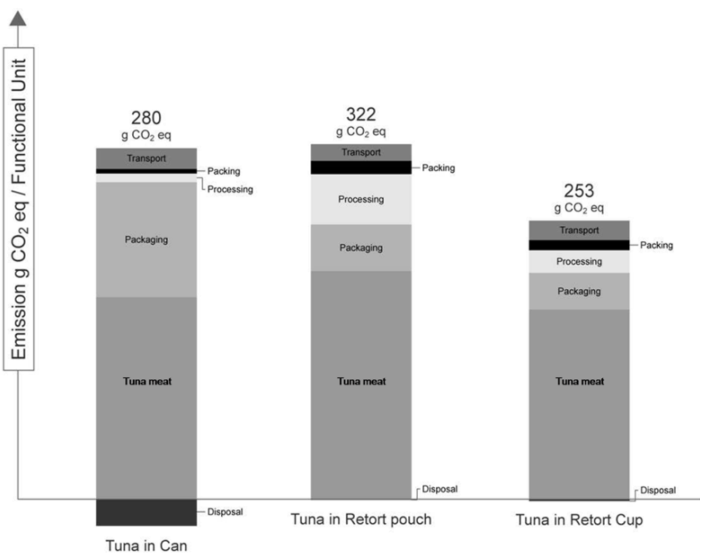

Figure 2. Total carbon footprint of different packaging systems for tuna.

49. Carbon footprint of Canadian dairy products: national and regional assessments

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The production of dairy products such as milk, cheese, butter and yoghurt results in a wide range of greenhouse gas (GHG) emissions per kg of product. A calculator, which was recently developed to estimate the magnitude of the GHG emission intensities of dairy products from cradle to the exit gate of the processing plants, at the provincial and national scales, will be presented (Vergé *et al.*, 2012). Estimates based on a regional assessment of farming and processing systems will be given for eleven dairy products for 2006 (Fig. 1). The on-farm GHG emission estimates, which are based on the IPCC Tier 2 methodologies adapted for Canadian conditions (e.g. Vergé *et al.*, 2006*;* Rochette *et al.*, 2008) also account for GHG emissions associated with farm inputs (Dyer and Desjardins, 2003a, 2003b). Much of this work is based on previous work from Vergé *et al.* (2007) and has been improved 1) to account for co-products allocation where relevant; 2) for a more comprehensive assessment of background processes and to be fed by yearly statistics instead of the five-year Census of agriculture data. For the processing phase, a top-down approach (e.g. for energy inputs gathered from yearly statistics) is used, and data gaps (e.g. packaging) have been filled with North-American generic data (Vergé *et al.*, 2011). The dairy plant is seen as a multi-product output plant and co-products allocation is performed using the physico-chemical approach described by Feitz *et al.* (2007), which has been modified to incorporate the solids characteristics (i.e. protein and fat content) of Canadian dairy products (Maxime *et al.*, 2011). The contribution of each step to the overall carbon footprint of dairy products will be discussed. Information on the magnitude of the carbon footprint is likely to become important information for dairy producers for selling their products on the international scene.

References

Dyer, J., and R.L. Desjardins. 2003a. Simulated farm field work, energy consumption and related greenhouse gas emissions in Canada. Biosystems Engineering 85(4), 503-513.

Dyer, J.A. and R. L. Desjardins. 2003b. The impact of farm machinery management on the greenhouse gas emissions from Canadian agriculture. Journal of Sustainable Agriculture 22(3), 59-74.

Feitz A.J., Lundie, S., Dennien, G., Morain, M., Jones M., 2007. Generation of an Industry-specific Physico-chemical Allocation Matrix. Application in the Dairy Industry and Implications for Systems Analysis. Int. J. LCA 12(2), 109-117.

Maxime D., Vergé, X., Arcand, Y., Desjardins, R., 2011. A cradle-to-gate assessment of the carbon footprint of Canadian dairy products. LCA XI Conference, October 4-6, 2011, Chicago IL (USA).

Rochette P., Worth, D.E., Huffman, E.C., Brierley, J.A., McConkey, B.G., Yang, J., Hutchinson, J.J., Desjardins, R.L., Lemke, R. and Gameda, S., 2008. Estimation of N_2O emissions from agricultural soils in Canada. II. 1990 2005 inventory. Can. J. Soil Sci. 88, 655-669.

Vergé, X. P. C., Worth, D., Hutchinson, J. J. and Desjardins, R. L. 2006. Greenhouse gas emissions from agro-ecosystems in Canada. Methane emissions: Methodology for calculations. Pages 38 Technical Report. Agriculture and Agri-Food Canada, Ottawa, ON.

Vergé X.P.C., Dyer, J.A., Desjardins, R.L., Worth, D., 2007. Greenhouse gas emissions from the Canadian dairy industry in 2001. Agricultural Systems, 94(3), 683-693.

Vergé X.P.C., Maxime D., Dyer, J. A., Desjardins, R.L. and Arcand Y., 2011. Carbon footprint model for Canadian livestock production - Presentation and application to the dairy sector. Technical report (August 2011); Contract # 01E86-110116/001/SS. 37p.

Vergé X.P.C., Maxime D., Dyer, J. A., Desjardins, R.L. and Arcand Y., 2012. Carbon footprint calculators for Canadian livestock production – The ULICEES and (cafoo)² models. Technical report (January 2012); Contract # 01E86-110116/001/SS. 47p.

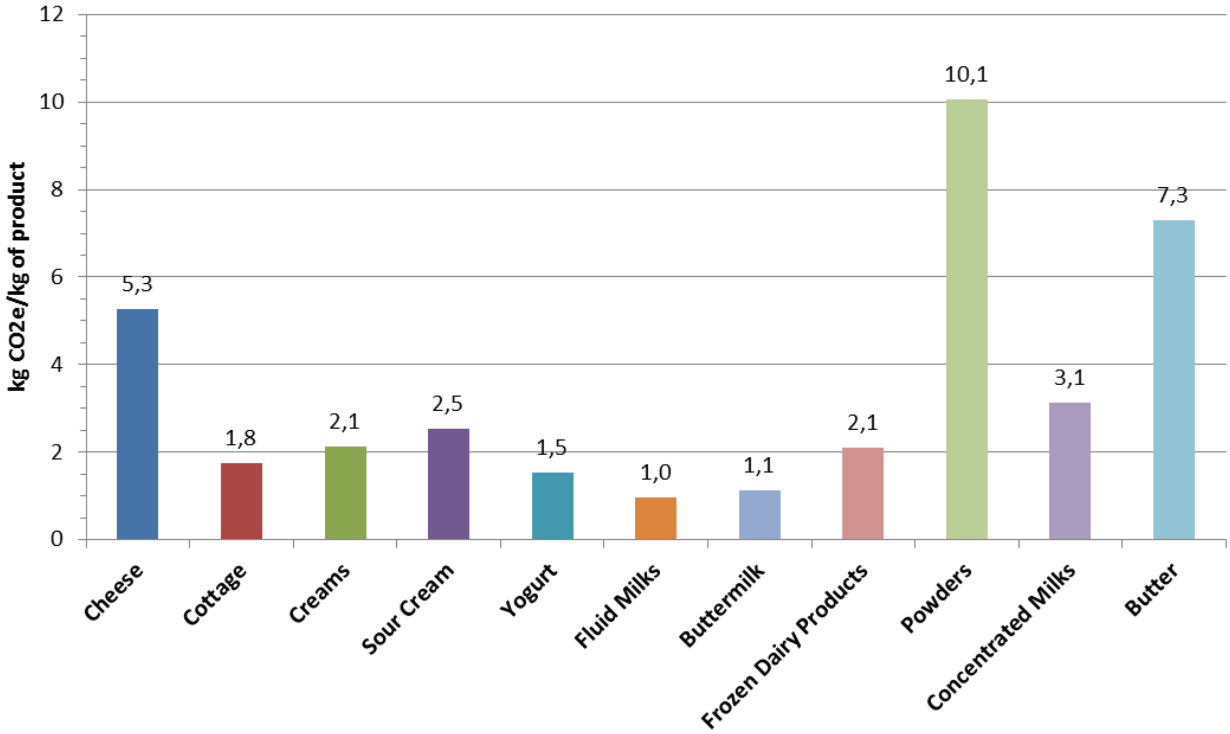

Figure 1. Cradle-to-gate climate change impact of Canadian dairy products in 2006.

50. Carbon footprint of Flemish livestock products

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The purpose of this study is to develop a monitoring tool for the carbon footprint of the Flemish livestock farming produce. A carbon footprint quantifies the climate change impact of an activity, product or service. Considering the current interest to mitigate the consequences of climate change, it is important to have a clear understanding of this impact. When developing a monitoring tool related to the impact of food production systems, horticulture and fishery products should also be taken into account, however this is not covered by the scope of this study. Currently there are several international carbon footprint calculation initiatives being developed. However, there is no one unambiguous international standard or specific rules for agricultural products.

Using the available international standards, a functional and transparent monitoring tool has been developed to determine the carbon footprint of the Flemish livestock farming products. This study focuses on the livestock industry and more specifically on the supply chain of beef, pork and milk. A method was formulated and applied to these product groups, revealing the influencing parameters and 'hotspots' within the parts of the food chain this study focused on.

Where the results show the most potential for reducing the emissions, the 'hotspots' identified will have recommendations on how these can be implemented. This can help the Flemish government or the stakeholders involved to develop a strategy for the reduction of greenhouse gas emissions. In this way, a carbon footprint may contribute to make the agro food chain in Flanders as well as the livestock industry in particular more sustainable.

For this the general standards about carbon footprinting such as the PAS2050 and the ISO14067 have been used. For milk, there was the additional use of the guidelines of the International Dairy Federation (IDF). Critical points of the methodology that have an influence on the carbon footprint are the choice of functional unit, the system boundaries and the allocation method (how to allocate the emission of greenhouse gases among the various co-products emerging from a single process). All these were addressed during the study.

Data and knowledge has been collected from the faculty of bioscience engineering of Ghent University, data of Bemefa, the farmers union (Boerenbond) and the ILVO. The data regarding other levels in the supply chain (mainly the processing industry) have been primarily collected through in-depth interviews and primary activity data. Within the current scope of the study, no primary data were collected at the farm level.

In general it can be stated that the data used are of good quality and represent livestock farming within Flanders. The principal part of the activity data originate from reliable sources, however there is always some natural variability. This is dependent of external factors (e.g. differences in breeds, farming yields will differ yearly, the composition of feed concentrates can vary depending on the available commodities and market prices). Furthermore a number of data points cannot be easily measured under real life conditions (e.g. the consumption of feed mixtures per animal and the number of days on the pasture), and estimation is necessary based on expert opinion. The data used were also verified and validated by the members of the steering committee. The emission factors originate from acknowledged life cycle inventory databases and literature sources, and can be considered as representative for Flanders. Other available sources were used to cross-check the values and are reported in a transparent way.

The carbon footprint results depend on the data quality of both the collected activity data and the available emission factors. The data and calculations in the developed carbon footprint models of the current project are highly detailed. In some cases however, reference values and standard formulas from relevant literature or other existing models were applied. In future, the current carbon footprint models could be refined and improved if additional data is collected. The shortcomings and restrictions of the current dataset are reviewed below. Recommendations are made to solve the identified knowledge gaps in Flanders.

Table 1. Overview of emission sources within the covered system boundaries

Name	Greenhouse gasses	Description
Feed mixtures and material for bedding of stables (own production)	CO_2 and N_2O	Diesel is taken into account within energy consumption. Production and transport of fertilisers, pesticides en lime. Impact of fertilisers and the use of lime (direct and indirect) and the impact of crop residues are taken into account according to the IPCC method (Tier 2 calculation).
Feed mixtures (purchased)	CO_2 and N_2O	Farming, transport, processing en land conversion is taken into account in de covered emission factors.
Animal (stomach-intestine fermentation)	CH_4	The IPCC method is applied (Tier 2 calculation).
Manure storage and disposal	CH_4 and N_2O	The IPCC method is applied (Tier 2 calculation).
Manure application (not used for own feed mixtures)	CH_4 and N_2O	Allocation between animal (40%) and vegetable production system (60%) on the basis of nitrogen uptake by plants.
Energy and water consumption[1]	CO_2, CH_4 and N_2O	Energy consumption (electricity; diesel; red diesel; gas) Water consumption (tap and ground water)
Transport of goods	CO_2, CH_4 and N_2O	Assumptions are being made for the goods entering and leaving the farm.
Processing materials	CO_2, refrigerant	Use of cleansing products and refrigerants

1: water is not a source of emission; however the use of energy for processing and transporting tap water is taken into account.

Table 2.Overview of the applied allocation method

Process	Products	Allocation method
Farming of crops	Products for human consumption (like flower); Products for animal consumption (like wheat starch) Other products (like straw)	Economic allocation
Dairy sector	Milk and meat	Physical relation registered by the IDF
Dairy products	Low-fat (skimmed), medium-skimmed and whole milk, cream, milk powder, yoghurt, butter, …	Physical relation registered by the IDF
Manure production	Stock farming products and farming of crops	Physical relation
Slaughtering and deboning of carcass	Meat, bones, fat, skin/hide, hart, blood, etc.	Economic allocation

51. Carbon footprint of organic crop production in Sweden

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The aim of the study was to assess the carbon footprint (CF) of Swedish organic crop production, and to explore the need of better statistics on organic crop production to improve environmental system analyses. The CF of organic crop production was compared to conventional production when possible. Improvements were suggested on how to reduce greenhouse gas emissions from organic cultivation. The analyses were based on five organic crop rotations reflecting the current situation on organic farms with typical operations (milk and arable farms) in three regions in Sweden. In this study the whole crop rotation was included in the environmental analysis since organic nitrogen applications and weed control is managed over the whole crop rotation and not for an individual crop for a single year. There was a lack of reliable statistics; hence information regarding crop rotations, yields, fertiliser management etc. was collected in cooperation with agronomic advisors. Statistics were used for geographic allocation of different crops and the use of organic fertiliser products to reflect the current Swedish situation. Greenhouse gas emissions were estimated according to IPCC (2006) and the functional unit was 1 kg crop at farm gate/farm storage.

The CF per kg organic crop was mainly affected by yield levels and nitrogen management strategy. High yield levels combined with moderate applications of organic fertiliser reduced the CF for organic cereal crops. Organic silage production (grass and clover) production had a lower CF than conventional silage due to relatively high yield levels and good crop management. An individual crop's sequence in a given crop rotation had also a substantial influence on the overall CF. The distribution of nitrogen emissions between individual crops in the rotation must be considered. In this study, the allocation was made between the nitrogen fixing crop and the subsequent crops as the N fixing crops are cultivated to provide other crops with nitrogen. Crop rotational effects are more evident in organic agriculture than in conventional and therefore there is a need to develop a uniform methodology to estimate the CF of organic production.

References

Cederberg, C., Wallman, M., Berglund, M., Gustavsson, J. 2011. Klimatavtryck av ekologiska jordbruksprodukter [In Swedish; Carbon footprint of organic crop production]. Report 830, SIK – The Swedish Institute for Food and Biotechnology, Göteborg.

IPCC. 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Vol. 4. Agriculture, Forestry and Other Land Use. Chapter 11. N2O Emissions from Managed Soils, and CO2 Emissions from Lime and Urea Application. http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

52. Guidelines on inclusion of land use change emissions in carbon footprints of food

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Currently there exist several methodologies for the calculation of greenhouse gas emissions resulting from a land use change, but no methodology has been commonly accepted for use in LCA. The methodologies produce differing results, because, for example, their emission boundaries differ (e.g. only some include the change of gas flux direction and magnitude). In Finland a harmonised national methodology for calculating carbon footprints of food is developed in 2009-2012. As a part of it a more practical methodology for the Finnish food industry to calculate emissions from land use change on a product level was also developed.

In Foodprint, the methodology for estimating carbon stock changes is based on the IPCC 2006 Guidelines. FAOSTAT statistics on trends of crop area expansion are used for assessing which land use changes have occurred, based on the methodology originally presented by Blonk et al. (2009). The trends of crop area expansion are calculated based on the mean of all annual crop area changes from the last 20 years, instead of using linear regression to predict the crop area trend, since it was realised that when large changes in crop area had occurred during a studied period, the predicted land use changes would be distorted.

The carbon storages and their changes due to land use change are to be evaluated according to the method described in European Commission guidelines (EC 2010), which itself is based on the IPCC 2006 methodology. FAO's *Global Forest Resource Assessment* is the preferred source for evaluating carbon stocks in above-ground, root and litter biomass. For assessing the change in carbon stocks, the GHGV approach (Anderson-Teixeira, 2011) was also considered, but it was seen that it did not provide remarkably more accurate results, while at the same time being much more work intensive.

The method used in the Foodprint guidelines for allocating emissions resulting from land use change to agricultural products, using the trends of annual crop area expansions and reductions according to FAOSTAT statistics, is specified in more detail in Ponsioen and Blonk (2010). The same method is also presented in GHG Protocol Product Standard. Other allocation methods were also analysed, such as using scientific articles and their results for estimations, e.g. one of Prudêncio da Silva (2010), which can be more accurate, but impractical for harmonising footprint calculations in Finnish food industry.

Further land allocation was studied, which utilises the Ponsion and Blonk methodology and an assumption that the deforested crop area does not remain as agricultural land, but ultimately ends up as pasture and secondary forests as well. It was though seen, that it can be too complicated for food companies to find such data from literature, and therefore this is optional in the Foodprint guidelines.

The Foodprint methodology was tested by assessing the increase in carbon footprint of a processed broiler product caused by land use changes. In the production chain, the methodology predicted that land use changes occurred only in the cultivation of Brazilian soya. The initial carbon footprint was 3.6 kgCO_2e/kg product, while the new (including emissions from land use changes) one was 4.1 kg CO_2e/kg product.

References

Anderson-Teixeira, K., DeLucia, E., 2011. The greenhouse gas value of ecosystems. Glob. Change Biol. 17, 425-438.

Blonk, H., Ponsioen, T., Scholten, J., 2009. Carbon Footprinting of Horticultural Products. Available at: http://www.tuinbouw.nl/files/page/carbon%20footprint.pdf.

EC, 2010. Commission Decision of 10 June 2010 on guidelines for the calculation of land carbon stocks for the purpose of Annex V to Directive 2009/28/EC.

Ponsioen, T., Blonk, H., 2010. Allocating greenhouse gas emissions from land conversion. Proceedings of LCA food 2010. 1, 551-556.

Prudêncio da Silva, V., van der Werf, H., Spies, A., Soares, S., 2010. Variability in environmental impacts of Brazilian soybean according to crop production and transport scenarios. J. Environ. Manage. 91, 1831-1839.

53. A simplified tool for the estimation of N and P emissions due to the use of fertiliser in a LCA study

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Emissions of nitrogen and phosphorus compounds from soil are among the most relevant sources of environmental impact in the life cycle of most agricultural products. The most important emissions in air are N_2O, which has a high Global warming potential and NO and NH_3 which contribute to acidification. The most important emissions in water are nitrates and phosphates, which contribute to eutrophication of water. Agricultural practices such as fertilisation and tillage could seriously affect these kinds of emission.
It is often difficult to estimate these emissions because they depend on a multitude of factors such as climate conditions, soil characteristics and cultivated crops. There are models in literature that enable to estimate them with a certain precision but in many cases they are too complicated and require input which would imply money and time efforts that are not always available in a life cycle study. On the other hand it is possible to estimate emissions using emission factors or equations which however are too simplistic and do not permit for example to appreciate differences among different farming systems. The aim of this study was to identify models that may be easy to handle and in the meanwhile enough accurate to take into account the main factors that influence the emissions. This is important in particular when performing a Life Cycle Assessment on a farm or on a territory level. With the individuated models a tool was then developed to permit the life cycle analyst to get the values of emissions by inserting a few required inputs. Particular attention in the choice of the models has been given to the responsiveness to different types and dosage of fertilisers. The models individuated are Bouwman et al. (2002) for direct N_2O emissions, IPCC (2006) for indirect N_2O emissions, Bouwman et al. (2002) for NH_3 emissions from mineral fertilisers, Dohler et al. (2002) for NH_3 emissions from organic fertilisers, Stehfest et al. (2006) for NO emissions, De Willigen (2000) for nitrates emissions and Prahsun (2006) for phosphorus emissions.
Most of the input required can be obtained by asking the farmer and by soil analysis. Other data required are the quantity of annual precipitation and the type of climate, which can be easily obtained from literature or from some meteorological database. Some factors required by the models are taken from literature and provided in the tool.
The result of the work was a tool that enables the life cycle analyst to easily get quite accurate estimates of nitrogen and phosphorus emissions from agricultural soils. The development prospect for the tool could enrich the internal database to make it more specific for determined crops or geographical areas.

References

Bouwman, A.F., Boumans, L.J.M., Batjes, N.H., 2002. Estimation of global NH_3 volatilization loss from synthetic fertilizers and animal manure applied to arable lands and grasslands. Global Biogechem. Cycles 16(2), 1024.

Bouwman, A.F., Boumans, L.J.M., Batjes, N.H., 2002. Modeling global annual N_2O and NO emissions from fertilized fields. Glob Biogeochem Cycles. 16(4), 1080-1107.

IPCC, 2006. Guidelines for National Greenhouse Gas Inventories

Prasuhn, V., 2006. Erfassung der PO_4-Austräge für die Ökobilanzierung. SALCA-Phosphor. Zürich, CH, Agrocope FAL Reckenholz.

Stehfest, E., Bouwman, L., 2006. N2O and NO emission from agricultural fields and soils under natural vegetation: summarizing available measurement data and modelling of global annual emissions. Nutrient Cycling in Agroecosystems. 74, 207-228.

54. Soil and biogenic carbon accounting in carbon footprint: potential and challenges

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Carbon sequestration in soil has the potential to counterbalance a significant proportion of life-cycle greenhouse gas (GHG) emissions associated with (at least) some horticultural products, as well as improving soil health and orchard productivity (Lal, 2010). Furthermore, potentially significant quantities of atmospheric CO_2 can also be stored in the standing biomass of perennial crops (Albrecht and Kandji, 2003).
However, the most widely used standard for GHG accounting, the PAS 2050 (BSI, 2011), currently does not include above-ground biomass and changes in soil carbon stocks as a result of land use (unless provided for in supplementary requirements). This is due to a lack of an agreed methodology, and uncertainty as to how to measure these parameters and integrate them into a carbon footprint. Indeed, at the inventory phase, it is difficult to measure accurately a change in the soil carbon stock over short time periods, whilst satisfying statistical significance and power levels (Post et al., 2001) because of the spatial variability of carbon stocks in soils and their small change with time. Measurement methods are costly and time consuming – and thus not easily implementable. Regarding methodology, the grower's potential to store carbon is site-dependent due to the variability in the carbon storing capacity of different types of soil; arguably, this should be reflected in a carbon footprint calculation. Furthermore the timeframe adopted for measurement of carbon stock changes can have an important impact on the carbon footprint results (Milà i Canals et al., 2007), because changes are often not linear over time. Lastly, maintenance of soil carbon is also important and it may be desirable to account for this aspect. In this poster, we describe the challenges and the requirements for the development of a reliable and practical methodology to measure soil and biogenic carbon stocks changes over time in apple orchards, summarise methodological issues related to their integration into carbon footprint, and discuss potential solutions.

References

Albrecht A, Kandji ST, 2003. Carbon sequestration in tropical agroforestry systems. Agriculture Ecosystems & Environment 99(1-3):15-27.

BSI, 2011. PAS 2050:2011 Specification for the Assessment of the Life Cycle Greenhouse Gas Emissions of Goods and Services. London, UK: British Standards Institute.

Lal R., 2010. Beyond Copenhagen: mitigating climate change and achieving food security through soil carbon sequestration. Food Security 2(2):169-77.

Milà i Canals L., Romanyà J., Cowell SJ, 2007. Method for assessing impacts on life support functions (LSF) related to the use of "fertile land" in Life Cycle Assessment (LCA). Journal of Cleaner Production 15:1426-1440.

Post WM, Izaurralde RC, Mann LK, Bliss N., 2001. Monitoring and verifying changes of organic carbon in soil. Climatic Change 51(1):73-99.

55. Using LCA to inform policy for biochar in New Zealand

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Biochar is carbonised biomass; the focus of this study is biochar obtained from sustainable sources and sequestered in soils to sustainably enhance their agricultural and environmental value under present and future management. Biochar has attracted international attention as a carbon sequestration strategy since it can take hundreds or thousands of years to decompose. Moreover, biochar offers opportunities in the energy, soil management, and end-of-life biomass (ELB) recycling sectors.

The quantity of ELB feedstocks in New Zealand that could potentially be used to produce biochar was assessed. In a highly optimistic scenario in which 80% of the available ELB is sourced to make biochar, over 1 million tonnes of CO_2 could potentially be sequestered every year. This translates to about 1.5% of NZ's total greenhouse gas emissions (based on 2009 data). Although this percentage is small, the relative contribution of using biochar on net greenhouse gas emissions may be much more significant when considering products in particular economic sectors from a life cycle perspective e.g., in determining the carbon footprint of agricultural products.

Although a number of biochar systems have been evaluated from a life cycle perspective, only two studies (Roberts et al. 2010; Hammond et al., 2010) and one life cycle inventory analysis (Kameyama et al., 2010) seem to have followed LCA methodology – and they all focus on just one impact category (climate change). Also, one LCA study of ethanol produced from a hectare of corn includes stover-derived biochar in the analysis (Kauffman et al., 2011). Using an LCA approach, the methodological issues concern the goal, scope and decision-context of the study; functional unit; multiple functions; system boundaries and allocation; choice of impact categories; indirect consequences; and reference scenario with which the biochar system is compared. At the forefront of these variables, it is not clear when and how to conduct attributional versus consequential LCA, and so results can vary considerably.

Therefore, particularly when considering future policy options to encourage or discourage production and use of biochar, it is important to carefully consider the different variables and their influence on the final results of an LCA study of biochar. This paper presents the results of a life cycle study on three different future management options for the woody ELB from apple orchards in the Hawke's Bay region in NZ undertaken with the goal of informing stakeholders and policy makers on the best use of biomass to mitigate climate change. Three different scenarios are compared: i) reference scenario, in which the woody ELB is mulched and left on orchard soils; ii) energy scenario, in which the ELB is used for energy generation; and iii) biochar scenario, in which the ELB is used for biochar production and application into the same area. The results show that the fuller trade-offs associated with alternative end uses of biomass need to be explored using a more complete system expansion perspective and representation of alternatives.

References

Hammond, J., Shackley, S., Sohi, S., Brownsort, P., 2011. Prospective life cycle carbon abatement for pyrolysis biochar systems in the UK. Energy Policy, 39, 2646-2655.

Kameyama, K., Shinogi, Y., Miyamoto, T., Agarie, K., 2010. Estimation of net carbon sequestration potential with farmland application of bagasse charcoal: life cycle inventory analysis through a pilot sugarcane bagasse carbonisation plant. Aust. J Soil Res.,48, 586-592.

Kauffman, N., Hayes, D., Brown, B., 2011. A life cycle assessment of advanced biofuel production from a hectare of corn. Fuel, 90,3306-3314.

Roberts, K.G., Gloy, B.A., Joseph, S., Scott, N.R., & Lehmann, J., 2010. Life Cycle Assessment of biochar systems: estimating the energetic, economic, and climate change potential. Environ. Sci. Tech., 44, 827-833.

56. Soil quality aspects in food LCA

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Soil quality is a crucial issue in food production and consumption from a sustainability point of view. However, there is no commonly accepted soil quality impact indicator in food LCA. Soil quality can be defined as "The capacity of soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health" (Doran and Parkin 1994). Soil properties are generally divided into three categories; biological, chemical and physical quality characters. The methodology of soil quality assessment should adequately reflect all the main soil characters and/or their interface.

The aim of this on-going study is to 1) review suggested soil quality indicators for LCA, 2) assess their practical applicability in process-based food LCA, 3) adapt or further develop the methodology for soil quality assessment in process-based food LCA, and 4) (preliminarily) assess soil quality of case-products. Through a literature survey we compiled some methods suggested for the assessment of land use impacts on soil quality in LCA (e.g. Muys and García Quijano 2002, Achten et al. 2008, Wagendorp et al. 2006). The methods include numerous indicators, and lack of data is one of the major challenges for practical application. Therefore, Milà i Canals et al. (2007) proposed a sole indicator, soil organic matter (SOM), to assess land use impacts on soil quality. However, SOM of arable land changes rather slowly from an annual measurements point of view. This reduces its flexibility as an indicator, restricting feedback for improvements. According to the ISO 14040 series, LCA impact category implies how production of a certain product affects nature; i.e. the reference situation is a natural stage. The suggested methods in the literature represent this approach, but the approach of sustainable development challenges it. Actually, the field should remain a field, and farming practices should maintain or improve soil quality so that farming can continue (within ecosystem boundaries). A concept of ecosystem service takes this aspect into account as it is based on the concept of sustainable use of natural resources. It was decided to take this as the theoretical basis for developing a soil quality indicator in this study.

Based on reviewing and assessing methods we concluded that a new methodology (incl. theoretical background) is needed. We initiated an interaction between specialists from different branches of soil science to establish which aspects should be included in the soil quality indicator to ensure that it is amenable to follow-up measurements and, for example, is sensitive to differences between organic and conventional cultivation methods.

The study is included in the project "Towards Sustainable Food Choices – Consumer Information on Nutrition and Environmental Impacts of Food in the Context of Sustainability" funded by the Finnish Ministry of Agriculture and Forestry and MTT Agrifood Research Finland.

References

Achten, W.M.J., Mathjis, E., Muys, B., 2008. Proposing a life cycle land use impact calculation methodology. Proc. 6th Int. Conf. on LCA in Agri-Food Sector, Zurich, pp. 22-33.

Doran, J.W., Parkin, T.B., 1994. Defining and assessing soil quality. In: J.W. Doran et al. (eds.) Defining Soil Quality for a Sustainable Environment. Soil Science Society of America, Madison, WI, Special Publication 35, pp. 3-22.

Milà i Canals, L., Romanyà, J., Cowell, S.J., 2007. Method for assessing impacts on life support functions (LFS) related to the use of "fertile land" in Life Cycle Assessment (LCA). J Clean Prod 15, 1426-1440.

Muys, B., García Quijano, J., 2002. A new method for Land Use Impact Assessment in LCA based on ecosystem exergy concept. Internal report.

Wagendorp, T., Gulinck, H., Coppin, P., Muys, B., 2006. Land use impact evaluation in life cycle assessment based on ecosystem thermodynamics. Energy 31, 112-125.

57. The influence of methodology on the water footprint of selected UK produced and consumed products

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Water footprinting is still evolving as a discipline and various methodologies and approaches exist to quantify the volumes of water withdrawn, used and consumed for food production and to assess any associated environmental impacts. The choice of methodology will influence the results and interpretation, a situation which has resulted in considerable variation in reported estimates on water use and its impacts for different agricultural and food products. Mindful of this, the UK Government commissioned research to explore the different approaches using selected UK produced and consumed products (potato, lamb, milk, strawberry, sugar and winter wheat) as case studies.
The study used three approaches:

1. The water footprint accounting framework developed by The Water Footprint Network (Hoekstra et al., 2011). This approach estimates the volume of green and blue water consumed during the different stages of production (evapotranspiration, irrigation, crop protection, livestock drinking, cleaning etc.)
2. The stress-weighted water footprint (Ridoutt and Pfister, 2010). This approach estimates the volume of blue water consumed during production and converts it to an assessment of local water stress using a water stress index (WSI) (Pfister at al., 2009)
3. The normalised water footprint, H_2Oe (Ridoutt et al., 2012) This is a development of the stress-weighted approach in which the stress-weighted value is divided by the global average WSI to give an assessment of water consumption relative to a global average.

The results show that the considerable influence that methodology has on the estimated values. The volumetric results are not directly comparable to the stress-weighted and normalised results since they are based on different criteria, but they are all commonly referred to as water footprints and clearly illustrate the potential for confusion that can arise in this discipline. Table 1 shows the results for UK and Israeli potato and allows the following interpretation.
In terms of volumetric water consumption, Israeli potatoes use one and a half times more water than UK production. However, where the impact of that water consumption is considered, Israeli potatoes can have a ten-fold greater impact on local water resources and a nineteen-fold greater impact at a global scale. The key to understanding and using these results is the omission of green water from the stress-weighed and normalised approaches which principally reflects the difference in evapotranspiration (and therefore climate) but also of irrigation practice, between the two countries.
The volumetric water footprint has been very successful in raising awareness of the use of water and is invaluable for water auditing purposes but we conclude that it has limited value for determining the local water stress of globally sourced products. A more balanced approach, especially within the LCA framework, is possible using the normalised water footprint alongside other environmental indicators, such as eutrophication and acidification. This will provide a more consistent and robust approach for environmental and sustainability studies.

References

Hoekstra, A.Y., Chapagain, A.K., Aldaya, M.M., Mekonnen, M.M. (2011) The water footprint assessment manual: Setting the global standard, Earthscan, London, UK.
Pfister ,S., Koehler, A., Hellweg, S. (2009) Assessing the environmental impacts of freshwater consumption in LCA. Environ. Sci. Tech 43, 4098-4104.
Ridoutt, B.G., Pfister, S. 2010. A revised approach to water footprinting to make transparent the impacts of consumption and production on global freshwater scarcity. Global Environ. Change 20, 113-120.
Ridoutt B,G., Sanguansri, P., Freer, M., Harper, G.S. (2012) Water footprint of livestock: comparison of six geographically defined beef production systems. International Journal of LCA 17: 165-175.

Table 1. The influence of methodology on the water footprint of UK and Israeli potato

Country	Volumetric (litres/kg)	Stress-weighted	Normalised (H_2Oe/kg)
UK	107	10	9
Israel	147	103	171

58. Water footprints of wheat and maize: comparison between China's main breadbasket basins

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As the most populous country in the world, China's food security has become an issue of broad concern. A critical factor which threatens food production is water scarcity. In recent decades, the water-scarce northern part of China has become the most important agricultural production area, supported in small part by water transfers from the South. Substantial volumes of food are being transferred from the water-scarce north to the water-rich south. In the context of China's food security, this complex arrangement has been the focus of much debate. However, science-based evidence to support an environmentally-sustainable increase in China's food production is rarely found in the literature.
This study compares the water footprints of cereal production (wheat and maize) in China's main breadbasket basins. Water footprints were calculated using an LCA-based water footprinting method (Ridoutt and Pfister, 2010) which uses a Water Stress Index (WSI; Pfister et al., 2009) to express the environmental relevance of water use. The water footprints are presented in the units H_2Oe (equivalent), where 1 L H_2Oe represents 1 L of consumptive freshwater use at the global average WSI.
Wheat grown in the Huang and Hai basins had much higher water footprints (1,262 L H_2Oe kg^{-1}) compared to wheat grown in the Chang basin (31 L H_2Oe kg^{-1}). The water footprints of maize grown in the Huang, Huai and Hai basins (515 L H_2Oe kg^{-1}) were also much higher than maize grown in the Chang and Songliao basins (35 and 44 L H_2Oe kg^{-1} respectively).
These results demonstrate a huge spatial differentiation of water use for cereal production in China's main breadbasket basins. It is suggested that the variability in crop water footprint between production systems should be taken into consideration in strategic decisions related to China's food production. National-scale cropping pattern adjustment and technological upgrade at the basin level are considered as important interventions to alleviate water stress from agriculture.

References

Ridoutt, B.G., Pfister, S., 2010. A revised approach to water footprinting to make transparent the impacts of consumption and production on global freshwater scarcity. Global Environ. Chang. 20, 113-120.
Pfister, S., Koehler, A., Hellweg, S., 2009. Assessing the environmental impacts of freshwater consumption in LCA. Environ. Sci. Tech. 43, 4098-4104.

59. Environmental impact of green beans: the relevance of water use

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About 80% of the world fresh water consumption is attributed to agriculture. Excessive water use can lead to water stress, one of the major environmental challenges in the future. As fresh water is getting scarcer due to climate change and due to increase irrigation amounts, the role of environmental impact due to water scarcity is growing in life cycle impact assessments.

The goal of this study (Kaegi et al. 2011) was to compare different green bean production and processing scenarios and to derive the contribution of water use to the total environmental impact. The functional unit was 1kg of green beans, ready to eat. All relevant life cycle phases were considered including cultivation of beans (field processes, fertiliser and chemical inputs, irrigation, direct field emissions), transportation, further processing (such as washing and then drying or canning or freezing) and cooking of the beans. Data for bean production was based on Lattauschke (2002) and data for direct field emissions were derived from Nemecek & Kägi (2007). The ecoinvent inventory V2.2 database (Swiss Centre for LCA 2009) was used for other secondary data (fertiliser production, transportation and other) and emission factors. For valuation of the different environmental impacts (such as global warming-, acidification-, eutrophication-, ozone depletion potential, ecological and human toxicity etc.) the ecological scarcity method (Frischknecht 2007) was used including regional water scarcity factors for the water use.

The high water scarcity in the Spanish region where the beans are grown leads to a large environmental impact. Beans grown in greenhouses show a similar high environmental impact due to fossil energy use for heating. Fresh beans from Egypt are flown to Switzerland which explains the high contribution from transportation. Further processing such as canning, freezing, drying lead to higher environmental impacts compared to fresh beans. However, when compared to irrigated beans from Spain, this seems to be irrelevant.

If the whole life cycle of ready to eat beans is considered the water impact can play a very important role. It contributes up to 85% of the total environmental impact in the case of beans from Spain. The implemented water impact in nowadays life cycle assessment methods covers a crucial and important environmental topic and helps to improve environmental consulting in the field of agriculture and water consumption.

References

Dinkel et al. (2006). Calculations for „Der kluge Einkaufswagen“ Unterrichtseinheit zu den Themen Umwelt, Konsum, Ökobilanzen. Bundesamt für Umwelt (BAFU)

Frischknecht et al. (2008) Frischknecht R., Steiner R., Jungbluth N. (2008) Methode der ökologischen Knappheit - Ökofaktoren 2006. Bundesamt für Umwelt (BAFU)/ÖBU.

Lattauschke, G, 2002. Hinweise zum umweltgerechten Anbau von Freilandgemüse im Freistaat Sachsen – Buschbohnen. Sächsische Landesanstalt für Landwirtschaft. http://www.landwirtschaft.sachsen.de/LFL

Nemecek T. & Kägi T. (2007). Life Cycle Inventories of Swiss and European Agricultural Production Systems. Final report ecoinvent V2.0 No. 15a. Agroscope Reckenholz-Taenikon Research Station ART, Swiss Centre for Life Cycle Inventories, Zurich and Dubendorf, CH, retrieved from www.ecoinvent.ch

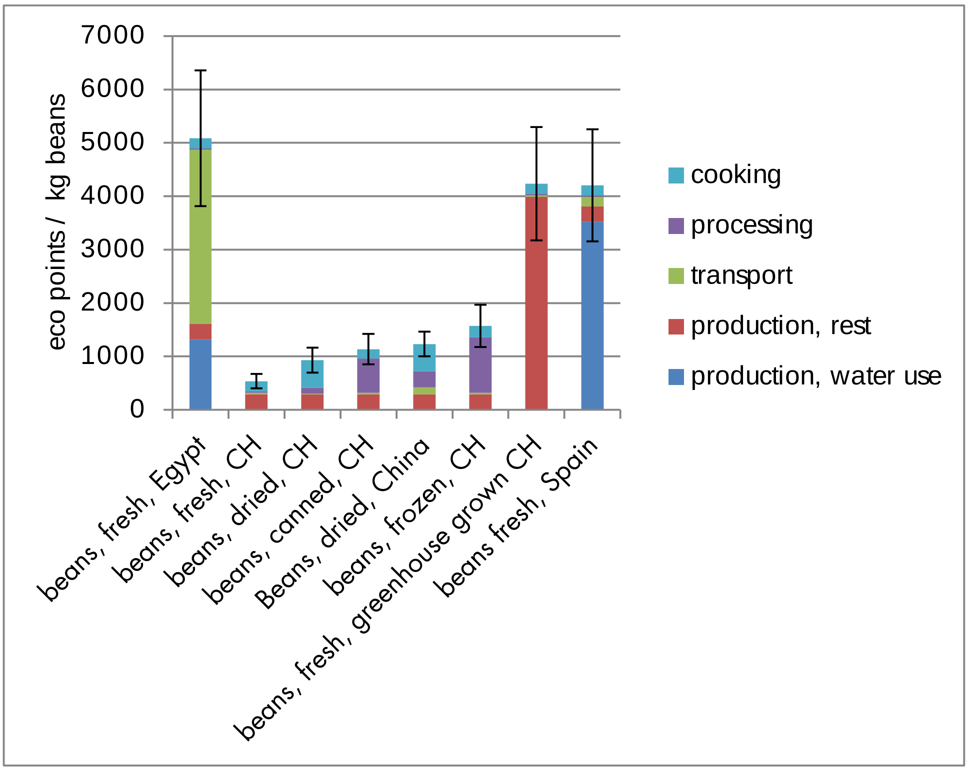

Figure 1. Environmental impact per kg beans, ready to eat.

60. Hands-on water footprinting: putting the assessment of agricultural fresh water use into practice

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Freshwater scarcity is now recognised to become one of the main environmental issues in the future. However, the consideration of fresh water consumption in life cycle modelling is still very young. The fact that no standardised method has evolved so far has led to a hesitant reaction of stakeholders towards the generally rising interest in the subject.

Agriculture contributes 80% to worldwide freshwater use (WWAP 2009), thus its key importance in sustainable water management practices is undoubted. But agricultural systems are particularly difficult to assess in an LCA framework, water use being no exception. PE INTERNATIONAL has implemented the latest methods developed by Pfister et al. (2009, 2011) in their balancing approaches and is now conducting complete water footprint assessments with consideration of regional water availability. The LCA software and database *GaBi* was updated (GaBi 2012) and contains complete and consistent water inventory data now, allowing assessment of fresh water use and consumption in an LCA framework using software solutions.

This paper describes how assessments of fresh water use in agricultural products can be put into practice using the latest software solutions. More than 100 agricultural products contained in the GaBi 5 database were updated to contain data on water use and consumption. Important lessons learned from this update process are presented. Results from a case study on cotton cultivation in the US are shown, including differentiation of water availability in four different cultivation regions in the US (Fig. 1). These results are considered to be a representative example for a variety of other agricultural products as well.

The experiences gained underline the relevance of agricultural processes, especially of irrigation, for the water footprint results of the complete value chain. It can also be seen that regional water availability needs to be considered in order to derive meaningful conclusions from water use assessments. Another important aspect is the necessity of consistent inventory data on water use and the difficulties to obtain these.

Water is an important aspect when considering the environmental impact of a product and should not be ignored any longer in LCAs. With the methods on hand, it is now possible to account for fresh water consumption in a LCA framework, also for agricultural products. However, large challenges lay ahead. Further advancements are needed in the development of a harmonised and standardised method, especially for the impact assessment phase. Finally, LCA is not meant to be a self-contained art. Not until companies, policy makers, civil society and private people understand the necessity of a responsible use of fresh water resources, the final goal of water footprinting will be reached.

References

GaBi, 2012. GaBi 5 - Software and Databases for Life-Cycle-Engineering, PE INTERNATIONAL AG, Copyright, TM. Stuttgart, Echterdingen. 1992 - 2012.

Pfister, S.; Koehler, A.; Hellweg, S., 2009. Assessing the environmental impact of freshwater consumption in LCA. Environ Sci Technol 43(11), 4098-4104.

Pfister, S; Bayer, P; Koehler, A; Hellweg, S, 2011. Environmental impacts of water use in global crop production: hotspots and trade-offs with land use. Environmental Science & Technology 45, 5761-5768.

WWAP, World Water Assessment Programme, 2009. The United Nations World Water Development Report 3: Water in a Changing World, UNESCO, Paris and Earthscan, London.

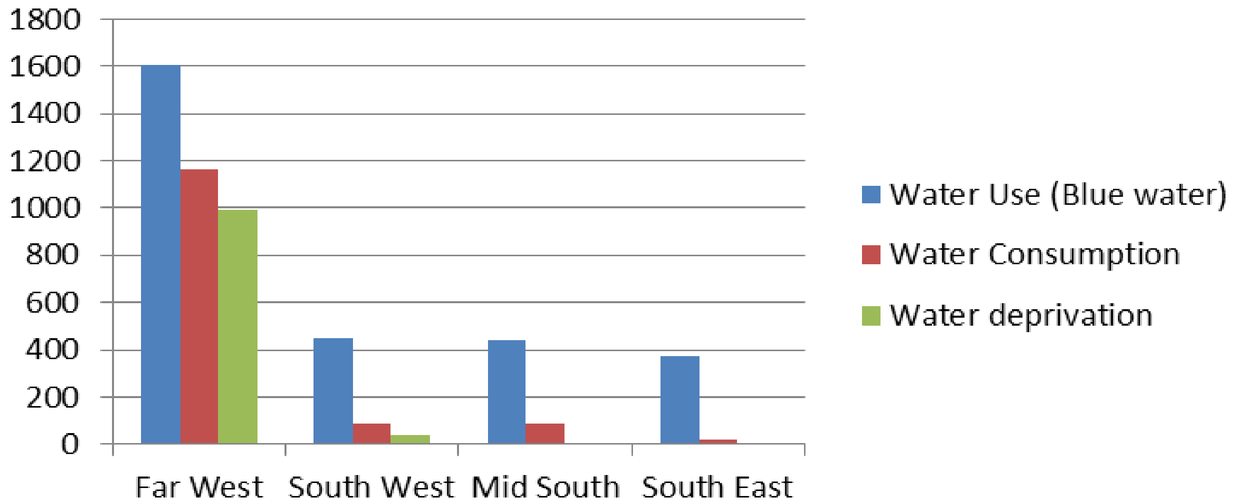

Figure 1. Example of a complete water footprint (in litres) of a processed agricultural product (cotton T-shirt) considering regional water availability

61. A method for estimating water use in food supply chains: liquid milk as an example

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A water-use (WU) method, based on Hoekstra et al. (2009), was modified and applied to Austrian agriculture, particularly livestock production. To meet the requirements of a life cycle assessment (LCA) approach, system boundaries include additional demand for water, e.g. from dairies, trade, supply of production inputs (mineral fertilisers) or for industrial processing of feedstuffs. The WU method accounts for effective or so called 'blue' water demand which is needed for irrigation, cleaning, livestock's drinking water or for cooling systems in dairies. Precipitation water which is evapotranspirated is summarised within the 'green' water, including a potential loss of precipitation in the case of preceding clearing of tropical forests. The WU method provides regionally differentiated water demand for effective evapotranspiration per kg yield for roughage, concentrates (grains, grain legumes, oilseeds or co-products from oil mills and distilleries) or bedding material, which is not only based on precipitation inputs but also reflects climatic and soil conditions, groundwater recharge and run-off. 'Grey' water partly integrates an eutrophication potential into the water footprint. For derivation of the grey water (i.e. dilution below nitrate limits 45 mg NO_3 per litre in drinking water), a detailed nitrogen (N) cycle model was used, including various N-inputs and outputs from agricultural production and its upstream and downstream processes. Co-products (beef from cull cows and calves) and water required for the rearing phase of dairy cow were also considered (see Hörtenhuber et al., 2010). Generally, results for livestock products' WU mainly depend on type (i.e. composition) and quantity of the diet needed to produce one unit of product (kg milk). The result for an alpine, grassland-based production system shows an overall water demand of about 940 litres per kg liquid milk at the supermarket (Fig. 1). This WU result agrees with findings from previous studies for milk, e.g. 800 and 990 litres of water demand (global scale) as reported by Chapagain and Hoekstra (2003) and Hoekstra and Chapagain (2006), respectively. However, some differences between these sources and our study are obvious, such as (1) a higher proportion of grey water and (2) a smaller proportion of green water in our result; (3) additional processes were included, which require water along the entire supply chain. A potential for the reduction of water demand was identified particularly for 'grey water' by implementing the following measures: (i) greening and catch crops instead of bare fallow, (ii) application of manure/fertiliser according to the requirement of crops at the optimum point of time, (iii) decreasing the input of external production factors (mineral fertilisers) or (iv) preferring organic over mineral fertilisers. Because of the limited water supply in many parts of the world, comprehensive WU or water footprint methods need to be developed and integrated into sustainability assessment schemes for agricultural products.

References

Chapagain, A.K., Hoekstra, A.Y., 2003. Virtual water flows between nations in relation to trade in livestock and livestock products. Value of Water Research Report Series No. 13, UNESCO-IHE.

Hoekstra, A.Y., Chapagain, A.K., 2006. Water footprints of nations: Water use by people as a function of their consumption pattern. Water Resources Management. 21(1), 35-48.

Hoekstra, A.Y., Chapagain, A.K., Aldaya, M.M., Mekonnen, M.M., 2009. Water footprint manual: State of the art 2009. Water Footprint Network, Enschede, Niederlande.

Hörtenhuber, S., Lindenthal, T., Amon, B., Markut, T., Kirner, L., Zollitsch, W., 2010. Greenhouse gas emissions from selected Austrian dairy production systems – model calculations considering the effects of land use change. Renewable Agriculture and Food Systems 25(4), 316-329.

Hörtenhuber, S., Lindenthal, T., Schmid, E., 2011: Water Footprint – Ein Beitrag zur Nachhaltigkeitsbewertung am Beispiel der Milcherzeugung, in: Proceedings of the 66th ALVA Conference, May 23-24 2011. Graz, Austria, pp. 87-89.

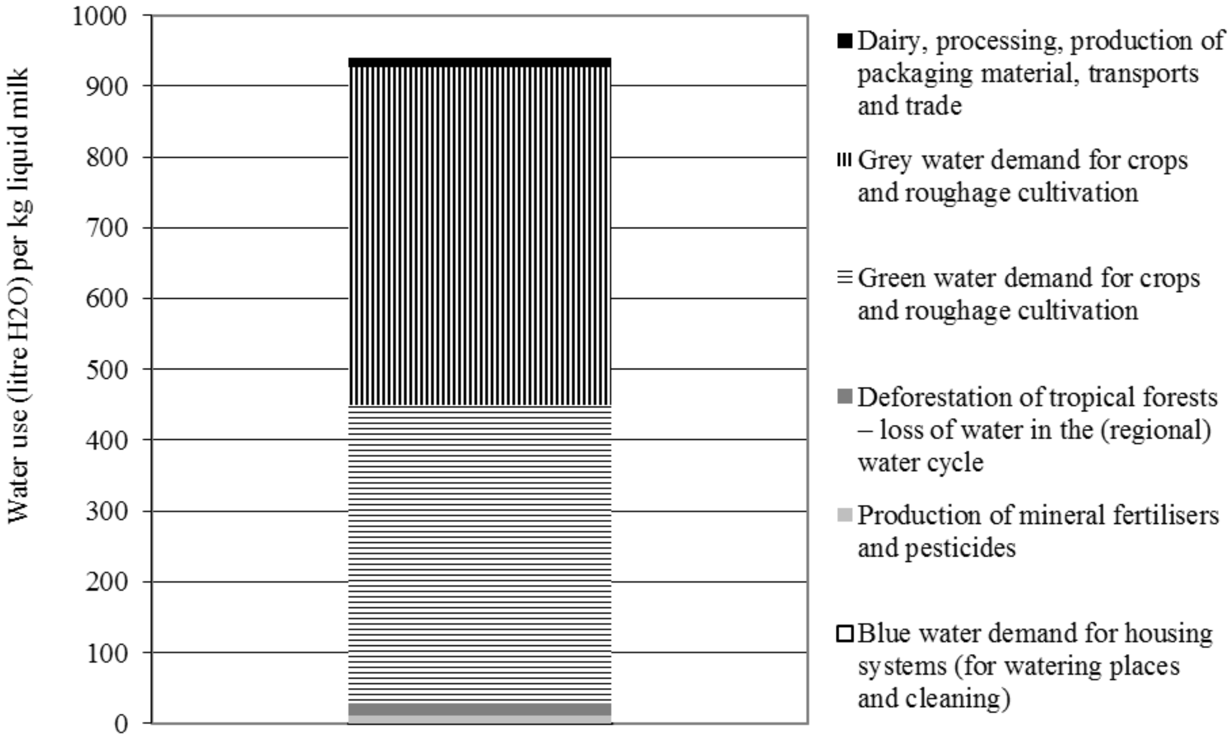

Figure 1. Results for a comprehensive evaluation of water use (litres H_2O) of 1 kg liquid milk from an alpine, grassland-based production system at the retailer level.

62. Irrigation systems used in water scarce locations: LCA of three contrasted scenarios for watermelon growing

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The agricultural productivity in arid and semi-arid regions greatly depends upon the access to irrigation. But irrigated areas are often charged with being water and chemical inputs intensive and consequently damaging the environment. In return, irrigated systems allow more diversified and intensified agricultural production. This is even more important when farmers shift from surface irrigation to drip irrigation that enable covered crops cultivation and use of mulch.

Environmental impacts arising from this twofold intensification process have to be addressed. Most of the LCA studies and guidelines have targeted temperate locations (Nemecek & Kägi, 2007) and this study contribute to adapt the method to southern contexts where the great variability of crop management practices leads to increased uncertainty (Basset-Mens, et al., 2006).

Based on a case study located in the Tunisian central Irrigated Plain of Kairouan, we choose to study the impacts per kg and per ha of three contrasted cropping systems of watermelon growing. They were identified among a typology of eight systems in total. The least intensive cropping system relies on surface irrigation rather than drip irrigation for the middle and high inputs intensive cropping systems. The most intensive cropping system combines plastic mulches and row covers. Because it was not possible to measure irrigation water volumes, they were modeled with PILOTE, a crop-soil model (Mailhol, 2004).

The most impacting cropping system per kg is the middle input intensive for almost all the impacts categories apart from those related to toxicity and ecotoxicity. Then comes the high input intensive cropping system whose impacts are balanced by the relative high yield obtained. The low input intensive system shows the smallest impacts either per kg or ha.

The drip irrigation equipment at field scale is drawn on figure 1 and figure 2 displays the environmental impacts of 1 hectare of drip irrigated middle input intensive watermelon growing. The most impacting field operation are fertilisation then irrigation and lastly soil preparation. More specific results of impacts caused by the drip irrigation device show the relatively high impact of energy for water pumping and thus suggest the related improvements to be done.

References

Basset Mens, C., Van der Werf, H.M.G., Durand P., Leterme P., 2006. Implications of uncertainty and variability in the life cycle assessment of pig production systems. International Journal of Life Cycle Assessment, 11(5), 298-304.

Mailhol, J. 2004. Analysis of irrigation systems and irrigation strategies for durum wheat in Tunisia. Agricultural Water Management, 70(1), 19-37.

Nemecek, T., Kägi, T. 2007. Life Cycle Inventories of Agricultural Production Systems, (15).

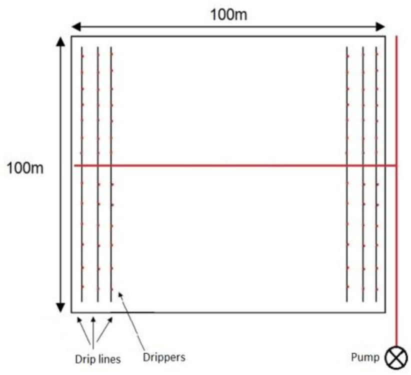

Figure 1. Field-scale drip irrigation system: irrigation elements for mid- and high-input intensive cropping systems.

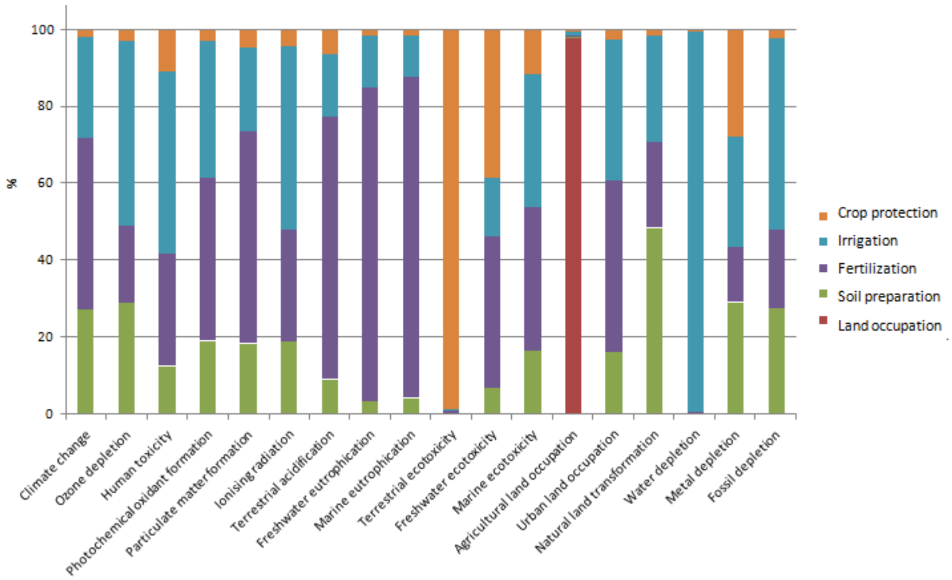

Figure 2. Characterisation of environmental impacts of the cultivation of 1 hectare of mid-input intensive watermelon, Recipe Midpoint (H).

63. Green, blue, and grey water use of Canadian wheat and maize

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Wheat (*Triticum aestivum* L.) and maize (*Zea mays* L.) are the major cereal crops of Canada and their use for producing bioethanol has heightened interest in their environmental footprint. In semiarid climates of western Canada, both green and blue water supply are a constant concern. Rainfed agriculture periodically requires "drought disaster" financial support from government. Irrigation is limited as water in major streams is fully allocated and water restrictions can occur during drought years. In contrast, water excesses are more often a concern than deficiencies in the more humid climates of central and eastern Canada.

We used the DSSAT model v4 to estimate 30-yr average green (evapotranspiration of *in situ* precipitation) and blue (from water withdrawals) use and yield across a range of important cereal production situations (Table 1). The model was validated with field data. Estimated blue water use embodied in inputs (pesticide, fossil fuel, machinery manufacture, fertiliser) was about 1 m^3 (t grain)$^{-1}$ based on withdrawals. Grey water use was calculated from P losses from the literature. The emerging Canadian guideline for total P in water to prevent eutrophication (0.02 mg L^{-1}) is 500 times lower than drinking water standard for N (10 mg L^{-1} as N-NO_3). Since total N losses are about 2 to 10 times greater than those of P, roughly 50-250 times more water is needed to dilute the P than the N (divide by about 100 to compare with N-based studies).

The total cereal water use in Canada was dominated by grey water (Table 1). Grey water use is higher in humid climates due to larger P loss in runoff and artificial drainage. Grey water use usually exceeds any precipitation surplus and this explains why P is the major environmental concern since there is often insufficient water to dilute the P to a desired concentration in cropland dominated watersheds. Total (green+blue+grey) water use decreased moving from humid to more arid climate. In contrast and as expected, the blue + green water use t^{-1} tended to increase moving to drier climate (e.g. London to Winnipeg, Lethbridge or Winnipeg to Swift Current). However, the relationship between climate and green+blue water use was less clear than total water use, probably due to confounding effects of other weather factors (temperature, rain timing, and sunlight) on production. As expected, maize was more water efficient than wheat under rainfed conditions but efficiencies between these cereals was similar under irrigation. In the most semiarid areas, summer fallow is still widely practiced where a crop is purposefully not grown in one year so as to use the soil-stored precipitation from that year to reduce drought risk for the crop grown the next year. A systems level calculation that considers the fallow year as an inseparable part of wheat production on summer fallow has the highest cereal water use t^{-1} in Canada while the simplistic non-systems analysis that considers the crop year only would indicate that summer fallow actually decreases water use t^{-1}; we believe only the systems-level analysis is valid. Excluding summer fallow production, green +blue wheat water use t^{-1} did not vary much across the diverse climates or with and without irrigation.

If lower green+blue+grey water use t^{-1} were used as the sole indicator of greater water security for cereal production in Canada, it would result in the nonsensical conclusion that production should be increased in the region with regular water shortages and decreased in regions with abundant water. This would exacerbate the impact of droughts in water-stressed regions to the whole of Canada. Inter-regional comparisons of green+blue water use were more difficult to interpret although there was an inconsistent trend of higher water use t^{-1} as climate became drier. Intra-regional comparisons of water use t^{-1} help identify crops and production methods that would, if selected, reduce water requirements for cereal production and lower natural resource requirements for biofuels produced from those cereals.

Table 1. Land use and green, blue, and grey water use for important cereal production situations in Canada across a range of climates.

Crop	Production Method	Land Use (ha t^{-1})	Water Use (m^3 t^{-1}) Green	Blue	Grey*	Green + Blue	Green +Blue + Grey
Semiarid (Swift Current: P=352 mm, PET=931 mm, MAT=3.9°C)**							
Spring Wheat	Rainfed on stubble	0.53	968	1	5260	969	6230
Spring Wheat	Rainfed on summerfallow excluding fallow area and evapotranspiration	0.38	804	1	3850	805	4650
Spring Wheat	Rainfed on summerfallow including fallow area and evapotranspiration	0.77	3850	1	15400	3850	19200
Semiarid (Lethbridge: P =385mm, PE=917 mm, MAT=5.8°C)							
Maize	Irrigated	0.17	407	356	2540	763	3310
Spring Wheat	Irrigated	0.22	400	378	3330	778	4110
Spring Wheat	Rainfed on stubble	0.45	818	1	4550	819	5370
Subhumid (Winnipeg: P =514 mm, PE=716 mm, MAT=5.0°C)							
Maize	Rainfed	0.19	821	1	4720	822	5540
Spring Wheat	Rainfed	0.38	908	1	9620	909	10500
Humid (London, Ontario: P =987 mm, PE=662 mm, MAT=7.5°C)							
Maize	Rainfed	0.11	449	1	6842	450	7290
Spring Wheat	Rainfed	0.23	707	1	14800	708	15500
Humid (Charlottetown: P =1173 mm, PET=512 mm, MAT=5.3°C)							
Spring Wheat	Rainfed	0.34	997	1	18600	998	19600

*based on desired P concentration to meet Canadian environmental objectives, divide by about 100 to compare with other studies based on drinking water NO_3 objectives.

**P=annual precipitation, PET=annual potential evapotranspiration, MAT=mean annual temperature

64. Virtual water of sugar production in Spain

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Food production and consumption contributes to water use and abstraction, mainly during the phase of cultivation. Water footprint of agricultural products is made up of blue, green and grey water. Green water is the rainfall water evapotranspirated from cultivated soils. Blue water is the fresh water used in irrigation, taken from water bodies that is used and not returned. Grey water is the volume of water required to dilute pollutants to such extent that the water quality reaches acceptable standards. Irrigated sugar beet crop in Spain accounts for 93% of the 70,000 ha of cultivated surface. Beet is the main source of sugar and every Spanish inhabitant consumes 5.5 kg per year, although 50% is imported.

The aim of this work is to evaluate the virtual water content of sugar beet crop and industrial sugar in Spain. The main provinces of sugar beet cultivation were considered. Virtual water content of the beet crop was calculated taking into account the root and sugar yield and the evaporative and non-evaporative water used for crop production. The water consumed in evaporation was made up of green and blue water. The green one was computed from rainfall and crop evapotranspiration plus soil evaporation computing a soil water balance with site specific soil data, climatic data and crop growth cycle. Reference evapotranspiration was computed with both Penman-Monteith and Hargreaves method. Blue water was obtained from soil water balance as the difference of crop evapotranspiration and rainfall and the efficiency of the irrigation system (gravity or sprinkler). Seedling emergence water applications were also accounted in sprinkler irrigated crops. Grey water was considered as the polluted water, and was calculated with the site specific fertilisation rate of the crop, estimated nitrate leaching and water quality standards.

The estimated water footprint per surface unit in Burgos and Valladolid provinces is shown in Figure 1. The volume of water is higher than 1,000 L per m^2. Total water footprint of Valladolid province is greater than that of Burgos. Blue water (irrigation requirements) is higher in Valladolid because the increased ETo values and the decreased rainfall in that province. However, green water is lower due to the less rainfall. As nitrogen fertilisation rates are higher in Valladolid than in Burgos, grey water is also higher. The water footprint is larger for gravity irrigation systems than for sprinkler ones, because their lower water application efficiency.

Water footprint estimated per kg of sugar is more than 800 L (Fig. 2). The most important component of sugar water footprint is the blue one, because the sugar beet is sown in spring and the maximum canopy development and water transpiration is during summer, when ETo is high and the rainfall is low. Green water is less than 35% of total water footprint, and it is lower in provinces with decreased rainfall values. Grey water account for 100-200 L per kg of sugar, and it depends on nitrogen fertilisation rates.

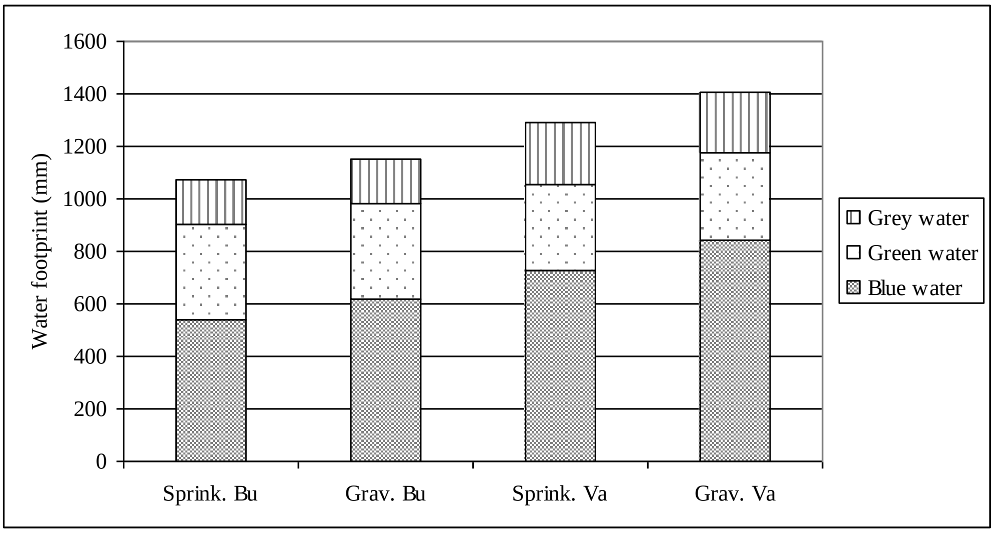

Figure 1. Estimated water footprint of sugar beet crop in two Spanish provinces, Burgos (Bu) and Valladolid (Va), with two different irrigation systems, sprinkler (sprink.) and gravity (grav.).

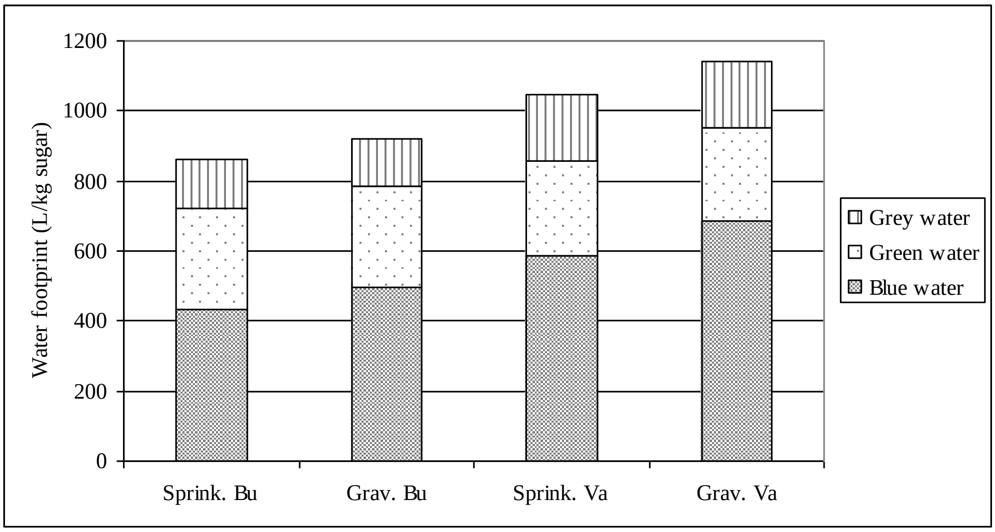

Figure 2. Estimated water footprint of sugar in two Spanish provinces, Burgos (Bu) and Valladolid (Va), with two different irrigation systems, sprinkler (sprink.) and gravity (grav.).

65. Modelling sugar beet water use in Spain

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Crop production has a great contribution to water use and abstraction. Sugar beet is an important crop in irrigated land in Spain and covers 70,000 ha. Crop and resources management are key factors for a sustainable agriculture. The aim of this work is to model the sugar beet crop growth and water consumption in order to quantify crop water use and virtual water content in different growing conditions.

In site daily meteorological data from SIAR (Magrama, 2011) automatic weather stations network were downloaded for the time period 2001-2010 for the main sugar beet growing provinces in Spain. Average farmers' data for sowing date were considered. Seedling emergence was computed using a thermal time model from literature data (120 ºC.day with a base temperature of 0 ºC). Biomass production of the crop was then estimated computing leaf and canopy development as a function of a thermal time model and the subsequent photosynthetically active radiation interception. Radiation use efficiency was estimated as a function of meteorological daily values of maximum temperature and vapour pressure deficit, despite neither water nor nutrient limitation (Arroyo-Sanz, 2002). Sugar yield was estimated considering an average harvest index (Arroyo-Sanz, 2002). Crop growth was then modelled with daily values of mean temperature and mean solar radiation until farmers' average harvest date for the 10 year period (2001-2010). A soil water balance was modelled and then green and blue water were estimated. Soil water balance included crop ET, drainage, rainfall, irrigation and soil moisture content. Crop ET was the product of reference ETo, from daily meteorological data (Penman-Monteith method), and evaporation or crop coefficients. Evaporation coefficients were estimated before and after harvest as a function of rainfall frequency and ETo. Crop coefficients were estimated considering canopy development. Rainfall daily values were included. In site soil texture defined readily available soil moisture as the difference of soil water content at 10 and 45 kPa (Arroyo-Sanz, 2002). A daily soil water balance was computed considering the drainage water the excess of rainfall over field capacity, effective rainfall that stored in the soil and used by the crop and irrigation water as the amount of water applied to refill the soil moisture until field capacity. Blue water was estimated as the irrigation needs divided by the system application efficiency. Green water was estimated as the sum of soil evaporation before sowing and after harvest, crop evapotranspiration from emergence until the first irrigation and effective rain during the irrigation period. Grey water was considered as the polluted water, and was calculated with the site specific nitrogen fertilisation of the crop, estimated nitrate leaching and water quality standards. Virtual water content was computed adding daily blue, green and grey water for the 10 year period (2001-2010).

The modelled biomass accumulation in Valladolid province in the period 2001-2010 is shown in Figure 1. The temporal trend of crop growth during the growing season shapes a sigmoid curve. Biomass at harvest is the last value of the curve. The most producing years are 2005 and 2007, so the value of the water footprint is relatively lower. The estimated value of sugar virtual water content is shown in Figure 2. The largest values are reached in year 2002 and 2003, the two wettest years. So, green water footprint (mm) is positively and highly correlated with annual rainfall. This relatively high rainfall does not affect the water consumption in irrigation nor the blue water footprint.

References

Arroyo Sanz, J.M. (2002). Influencia del riego sobre el crecimiento, el rendimiento, la calidad industrial y las eficiencias en el uso del agua de riego y de la radiación PAR en el cultivo de la remolacha azucarera (*Beta vulgaris* L.). Ph.D. Thesis. Universidad Politécnica de Madrid, Spain.

Magrama (2011). Sistema de información climática para el regadío. Ministerio de Agricultura, Alimentación y Medio Ambiente. In: http://www.magrama.es/es/agua/temas/observatorio-del-regadio-espanol/Sistema-de-Informacion-Agroclimatica-para-el-Regadio/default.aspx

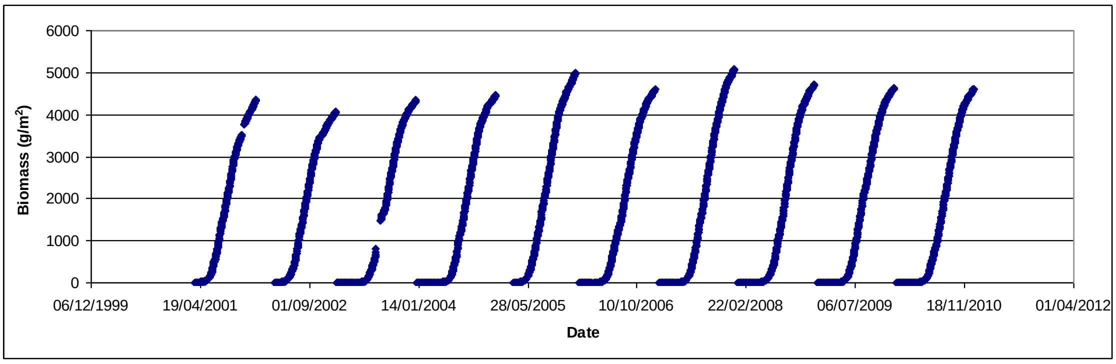

Figure 1. Simulated biomass accumulation of sugar beet crop in Valladolid province (Spain) from 2001-2010.

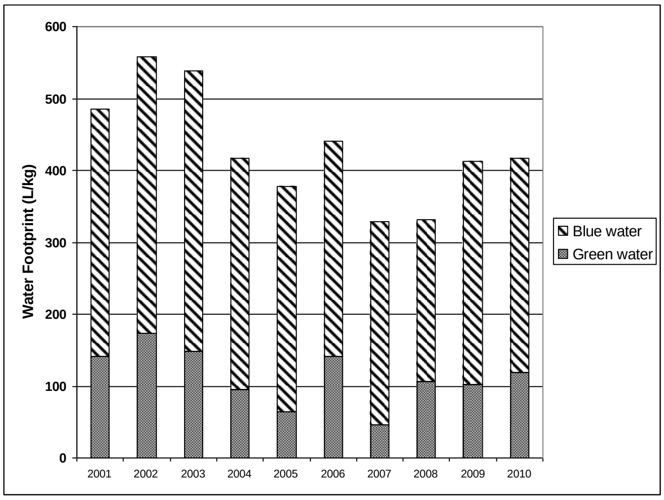

Figure 2. Estimated yearly virtual water content of sugar in Valladolid province (Spain) during the period 2001-2010.

66. Water footprint of milk at dairy farm

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The water resource preservation is becoming a new challenge for agriculture at local and global scales. It is assessed through water footprinting, an emerging methodology. The Water Footprint Network was a precursor for defining a water footprint methodology (Hoekstra et al. 2011) and provides figures focusing on livestock productions (Mekonnen & Hoekstra, 2012). The WFN methodology focuses only on specific types of water flow whereas the WULCA project of the UNEP SETAC LCA Initiative (Koehler & Aoustin 2008) and the future ISO 14046 Water footprint (under development) support that water footprinting should follow the same framework as LCA (ISO 14040 and 14044).
This study presents an application of the water footprint to dairy farms, adapted from Ridoutt and Pfister (2010). This stress-weighted water footprint is based on an assessment of the amount of freshwater withdrawn, consumed water and grey water generated by the production activity (Figure 1). A regionalised characterisation factor, the water stress index, is then multiplied with the inventory to obtain the Water Stress Assessment (WSA) (Figure 2) that reflects the potential for water uses to contribute to water scarcity.
This method has been tested in collaboration with Danone in 3 farms in 3 different countries (Spain, Poland and Saudi Arabia). The functional unit is to produce one kg of whole milk, at the farm gate. The physical flows of water inside the system were described to identify the different sources of freshwater use and consumption (withdrawal water, consumed water). The four main sources (Fig. 3) gather the animals (drinking water, transpiration of animals, water in milk and evaporation from manure), crops and pastures (irrigation and evapotranspiration of plants), the milking parlour (washing and evaporated water) and the farm inputs (diesel, electricity, fertilisers and off-farm feed production). Concerning the flows occurring on the farm assumptions, references and models were used to assess the water requirements and losses. Data about the farm inputs for different countries were provided by databases (ecoinvent v2.2, Quantis Water Database, access December 2011). The Grey water is calculated for the whole farm, based on N leaching potential. Only nitrogen is considered assuming that generally the quantity of water needed to assimilate produced nitrogen will be enough important to assimilate produced phosphorus as well as other pollutants.
The preliminary results show the importance of off-farm processes, especially feed production, on the total WSA of the milk. It occurs that the options for farmers to reduce the water footprint of their products would focus on decreasing the use of some inputs. Nevertheless, the consideration of physical flows at farm level remains important for appropriation of results by the farmers and also because actions to reduce water footprint can be more easily undertaken at this level than at the supply chain level. The study also underlines the fact that some methodological issues have to be improved: characterisation of the withdrawal water and assessment of the grey water, as well as implicit weighting of consumed water with grey water.

References
Hoekstra AY, Chapagain AK, Aldaya MM, Mekonnen MM. 2011. The water footprint assessment manual: Setting the global standard. London: Earthscan. p 203
ISO 14040: 2006. Environmental Management - Life Cycle Assessment - Principles and Framework
ISO 14044: 2006. Environmental Management - Life Cycle Assessment - Requirements and guidelines
Koehler A, Aoustin E (2008) Assessment of use and depletion of water resources within LCA. SETAC Europe, Warsaw
Mekonnen, M.M. and Hoekstra, A.Y., 2012. A global assessment of the water footprint of farm animal products, Ecosystems, doi: 10.1007/s10021-011-9517-8.
Ridoutt, B., Pfister, S., 2010. A revised approach to water footprinting to make transparent the impacts of consumption and production on global freshwater scarcity. Global Environmental Change 20, 113-120.

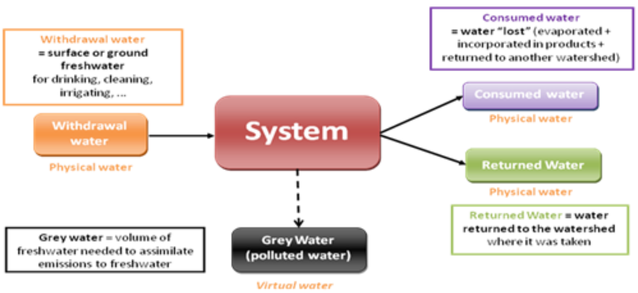

Figure 1. Type of water considered in the WSA methodology (from Ridoutt and Pfister, 2010)

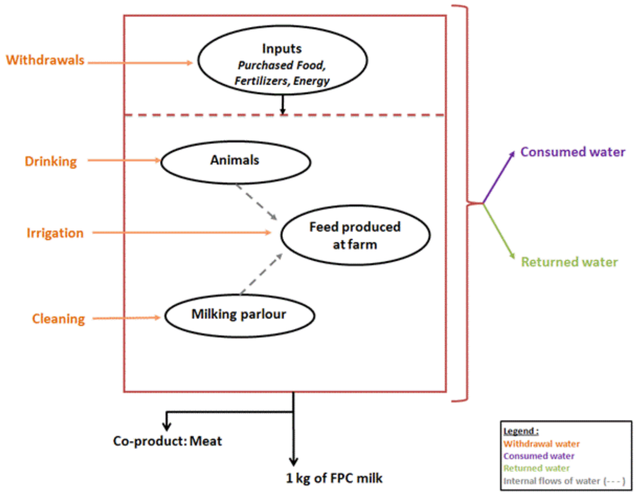

Figure 3. Physical flows of water (withdrawn, consumed and returned water) on a dairy farm

$$
\begin{aligned}
WSA\ (m^3) &= \text{Consumed water}\ (m^3) && *\ WSI \\
&+ \text{Grey water}\ (m^3) && *\ WSI \\
&+ \text{Withdrawal water}\ (m^3) && *\ 5\%\ *\ WSI
\end{aligned}
$$

Figure 2. Calculation of the Water Stress Assessment (adapted from Ridoutt and Pfister, 2010)

67. Food production in Brazil: challenges for water footprint accounting

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Due to the increasing pollution of the rivers as a consequence of industrial and agricultural activities, the importance of evaluating water use throughout the production chains in order to identify hot spots and then to implement improvements for water use reduction has gained more and more attention. That is why in the last decade water use methodologies have being developed by several researchers (Chapagain, Hoekstra, 2007; Milá i Canals.et al. 2009; Ridout, Pfister, 2010). So, nowadays there are more than 30 methodologies to account water use in the life cycle of products or processes.

In 2009, International Organization for Standardization – ISO launched the discussion on a new standard - ISO 14046 on the subject “Water footprint – Requirements and guidelines”. This standard has the aim of harmonising the water footprint criteria adopted to account the use of this resource, as well as the consistency with carbon footprint and other LCA approaches among others (ISO, 2012). By June 2012 the standard was submitted as a vote for CD (committee draft) by SC5 members and it is planned to be published in 2013-2014. According to ISO 14046, the water footprint can be represented by one or more parameters which quantify the environmental impacts of a process, a product or an organisation related to water as follow: 1) the water footprint indicator result (single impact category); 2) the water footprint profile (several indicator results) and 3) the water footprint parameter (weighted result).

ISO 14046 will establish what must be done, but not how to do it. So, the several methodologies for water footprint should follow the requirements of this standard. Despite many questions must be solved until the publication of this standard, one requirement already established by ISO 14046 is that even the single indicator category should consider both the quantity and quality of water resources.

Brazil has 12% of freshwater available in the world. However, approx. 74% of this water is in the Amazon hydrographical region, while the main food producing regions are located at Paraná, São Francisco, Atlântico Leste, Atlântico Sul and Atlântico Sudeste hydrological regions that have only 12.9% of the freshwater available in Brazil.

The Brazilian System for Controlling the Water Resources – SINGREH has an information system on water quantity well established, being the Brazilian Water Agency – ANA responsible for approx. 30% of the controlling points (ANA, 2007). Nevertheless, the water quality control is made only by approx. 12% of this amount of control points (Table 1).

Concerning water quality, only four basic quality parameters are controlled by ANA which are not proper to evaluate the water quality. However, the state and municipal environmental agencies from Minas Gerais, Paraná, Pernambuco, Rio de Janeiro, Rio Grande do Sul and São Paulo control a higher number of quality parameters for some of their main rivers (Table 1) (IBGE, 2010).

It is possible to conclude that the main challenges to account the water footprint of Brazilian food products are: 1) lack of quality data for many Brazilian rivers, and 2) many of quality water data are kept by the state and municipal environmental agencies as private data. So, much work should be done in order to get reliable water footprint of Brazilian products.

References

Agência Nacional de Águas – ANA, 2007. Evolução da rede hidrometereológica nacional. v. 1, n.1, 15p.

Chapagain, A.K., Hoekstra, A.Y., 2007. The water footprint of coffee and tea consumption in the Netherlands. Ecological Economics 64, 109 – 118.

ISO - International Organization for Standardization. ISO/CD 14046: Water footprint – Requirements and guidelines, 2012. (Working Draft 2)

Instituto Brasileiro de Geografia e Estatística – IBGE. Indicadores de desenvolvimento sustentável Brasil 2010. Rio de Janeiro. 442p.

Milá i Canals, L., Chenoweth, J., Chapagain, A., Orr, S., Antón, A., Cliff, R., 2009. Assessing freshwater use impacts in LCA. Part I – inventory modeling and characterization factors for the main impact pathways. Int. J. LCA**,** 14, 28-42.

Ridoutt, B.G., Pfister, S., 2010. A revised approach to water footprinting to make transparent the consumption and production on global freshwater scarcity. Global Environ. Change, 20, 113-120.

Table 1. Information system on water resources in Brazil (ANA, 2007; IBGE, 2010).

Aspects	Control points	Parameters evaluated
Water quantity	11,260	Discharge
Water quality [a]	1,340	pH Dissolved Oxygen Conductivity Temperature
Water quality [b]	----	BOD Water Quality Index - WQI [c]

[a] Brazilian Water Agency

[b] State and Municipal Environmental Water Agencies

[c] WQI calculated from pH, Temperature, Dissolved Oxygen, BOD, N, P, total soluble solids, turbidity.

68. A life cycle C3 commons: communicate, collaborate, connect

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Practitioners conducting life cycle assessments (LCA) are uniquely dependent on methodology, databases, and tools, as wells as applications of LCA developed by their peers (Gnansounou et al, 2009; Suh et al., 2004). Conferences such as LCA Food 2012 serve as a global forum. They provide a *physical* meeting place for LCA practitioners from around the globe to share knowledge, discuss topics of interest to the community and connect with peers. Unfortunately international conferences like LCA Food are annual at best and not all who would benefit are able to attend. There is an on-going need for a meeting place, with relevant community resources 'held in common'. In essence a virtual community commons where LCA practitioners can continue to communicate, collaborate and connect.

At LCA Food 2010 the authors presented a poster proposing an LCA community website. The proposal outlined a *virtual* meeting place for community members: to find and share information through searchable publication and data knowledgebases; to learn from each other by asking questions of authors, watching online video tutorials and participating in discussion forums and blogs; and to connect with colleagues with whom to collaborate.

The proposed LCA community website is being designed and developed now. The website is based on SilverStripe, an open source framework and configuration management system (CMS). An open source solution was selected in keeping with the design philosophy of a community commons. Once the community site is completed both the site and its software will be available as a community resource. It's hoped that the LCA C3 Commons website on its own will prove to be a valuable resource for the global LCA community. The solution in whole or in part will also be available for LCA organisations who wish to download it and host it for their own use.

A working prototype will be available for LCA Food 2012 conference attendees to trial. Feedback will be requested on existing features as well as suggestions for additional features.

References

Gnansounou E, Dauriat A, Villegas J, Panichelli L. Life cycle assessment of biofuels: Energy and greenhouse gas balances. Bioresource Technology, 100: 4919-4930.

Suh S, Lenzen M, Treloar GJ, Hondo H, Horvath A, Huppes G, et al. System boundary selection in life-cycle inventories using hybrid approaches. Environmental Science & Technology, 38: 657-664.

69. Assessment of the environmental impact of dietary intake habits in the UK

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The food system is estimated to account for 18-20% of total UK greenhouse gas (GHG) emissions, increasing to 30% factoring land use change (Audsley et al 2009), and food consumption habits make an important contribution to these emissions. With the introduction of legally binding commitments to reduce GHGE; the UK Climate Change Act (2008) set targets to reduce GHGE by at least 34% by 2020, this will require not only efficiency savings in food production and processing, but also adoption of lower impact diets by consumers. However, in the UK, few studies have assessed the impact of actual dietary habits and the environmental impact, measured in the form of GHG emissions. The current study aimed to investigate the potential of assessing the environmental impact of dietary intake habits using a novel approach to measuring and ranking the environmental impact of food consumption into high, medium and low levels of emissions and compare this with the nutritional quality of the diet.

A random sample to people living in the South West of Scotland were asked to completed an anonymised postal survey, 527 people, average age 58y (range 20-90y) returned the questionnaires. Habitual diet was measured using a food frequency questionnaire (FFQ) (www.foodfrequency.org), which asks for the frequency of consumption of 170 food and drink items and has been previously validated for dietary assessment. Food and nutrient intake and environmental impact were determined by linking, the FFQ response information to an in-house food nutrient composition and food related GHG emissions database. Estimation of average daily GHG emissions acted as a marker of environmental impact.

GHG emissions values for food items 'as eaten' were calculated from raw food commodities data from one of the most comprehensive lists of GHG emissions in the UK (Audsley *et al* 2009). These food commodity data did not represent the full 'cradle to grave' life cycle analysis (LCA), but rather the average GHG emissions for the production of raw food commodities up to the regional distribution centre (RDC). The RDC was described as a nominal boundary of agricultural and food ingredient production up to the point of distribution in the UK and estimated to account on average for 56% of the total LCA GHG emissions. The later stages of processing raw basic ingredients into edible food products ready for consumption were not included. These data were harmonised with the nutrient composition data to reflect food as eaten, with adjustments for edible portion, cooking gains and losses, and production of composite dishes and food products, such as lasagne, crisps and cakes, employing a proportion of ingredients approach,. It is important to note for example that GHG emissions for cooked meat will in relative terms increase due to weight loss whilst cooking, while the emissions for rice will fall with cooking due to weight gains through hydration. However it is important to highlight there is a lack of complete 'cradle to grave' LCA for commonly consumed foods.

Preliminary results indicate that though, as expected, increasing energy intake and levels of GHG emissions are closed linked, the actual quality of the diet from a health perspective does not appear to diminish. For example, the relative contribution of fat (34% of total energy), protein (16% of total energy), to total energy intake remains unchanged with increasing levels of GHG emissions from the diet. This study has lead to deeper insights into the interactions between diet, environment and health which will contribute to development of the population based approaches to reducing the environmental impact of dietary intake.

References

Audsley E, Brander M, Chatterton J, Murphy-Bokern D, Webster C, Williams A., 2009. How Low Can We Go? An assessment of greenhouse gas emissions from the UK food system and the scope for reduction by 2050. WWF-UK.

70. Fish or meat? Is this a relevant question from an environmental point of view?

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Nutrition accounts for about 30% of environmental impacts caused due to the final consumption of Swiss households (Jungbluth et al., 2011). It is thus the most important consumption sector from an environmental point of view. Out of this meat is the most important product group accounting for about 26% of impacts of food consumption (Jungbluth et al., 2012). Therefore, it is necessary to investigate and understand the environmental impacts of food consumption and possibilities for the reduction of environmental impacts. One option discussed for this is a reduction of meat consumption. Fish might be considered as a possible replacement by consumers.

Within a recent study we assessed the environmental impacts of different fish products sold in Swiss supermarkets (Buchspies et al., 2011). The life cycle inventory for different types of fish is based on published work by different authors. These data have been harmonised and implemented in the EcoSpold format. The defined functional unit is one kg of frozen cod, canned mackerel, canned herring or smoked salmon. The former three are caught and processed in Denmark; the latter is farmed and processed in Norway. Data for the production of different meat products were available from earlier studies (Jungbluth, 2000; Jungbluth et al., 2011). To evaluate environmental impacts, the ecological scarcity method 2006 and global warming potential 2007 are used.

When comparing the results with the ecological scarcity method 2006, high sea fish is at the lower end of range for all compared products. Fishing and packaging are main determinant in regard to environmental impacts of high sea fishing. Salomon's environmental impacts are nearly as high as those of veal. Feed production and the nutrient emissions into the sea are quite important for the total environmental impacts. In regard to the global warming potential, fish offers an alternative to meat. Depending on the type of fish, emission per kg of filet range between 3.7 and 6.6 kg CO_2-eq. For farmed salmon indirect N_2O emissions from nutrient emissions need to be considered. Fish cannot be regarded generally as a more environmentally friendly food product than meat, because environmental impacts of different fish products might be quite variable and be even higher than these of meat.

References

Buchspies B, Tölle SJ, Jungbluth N. Life Cycle Assessment of High-Sea Fish and Salmon Aquaculture [Practical training report]. Uster, CH: ESU-services Ltd.; 2011.

Jungbluth N. Umweltfolgen des Nahrungsmittelkonsums: Beurteilung von Produktmerkmalen auf Grundlage einer modularen Ökobilanz [Dissertation Nr. 13499]. Berlin, D: Eidgenössische Technische Hochschule Zürich, Umweltnatur- und Umweltsozialwissenschaften, dissertation.de; 2000.

Jungbluth N, Flury K, Büsser S, Stucki M, Frischknecht R. Life cycle inventory database on demand: EcoSpold LCI database of ESU-services. Uster, CH: ESU-services Ltd.; 2011.

Jungbluth N, Itten R. Umweltbelastungen des Konsums in der Schweiz und in der Stadt Zürich: Grundlagendaten und Reduktionspotentiale. Zürich: ESU-services GmbH im Auftrag der Stadt Zürich (unpublished); 2012.

Jungbluth N, Nathani C, Stucki M, Leuenberger M. Environmental impacts of Swiss consumption and production: a combination of input-output analysis with life cycle assessment. Bern, CH: ESU-services Ltd. & Rütter+Partner, commissioned by the Swiss Federal Office for the Environment (FOEN); 2011. p. 171.

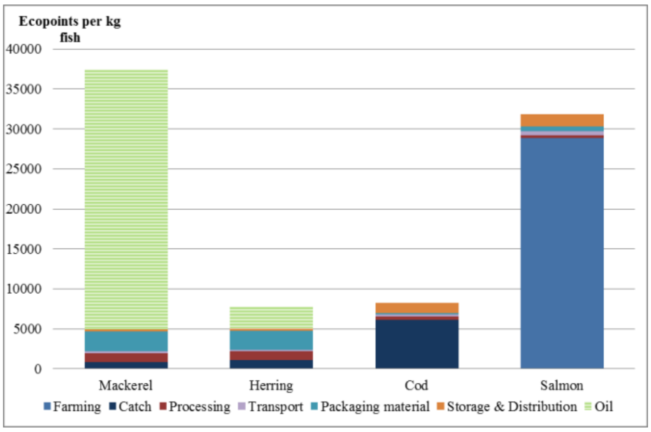

Figure 1. Distribution of eco-points for different life cycle stages

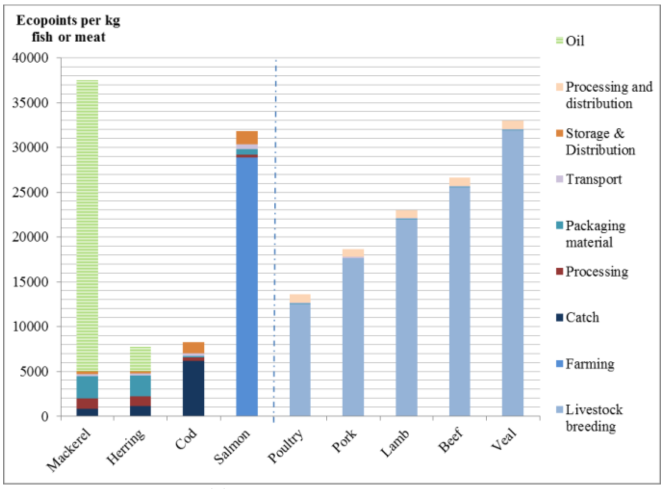

Figure 2. Comparison of fish and meat – ecological scarcity method 2006

71. The impacts of food choices on the state of the Baltic Sea - example of the EIOLCA study

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The Baltic Sea is a small and relatively shallow brackish body of water located in northern Europe. It is the second largest brackish water basin in the world and is also considered to be the most polluted. Low salinity also makes the Baltic's unique ecosystems sensitive to changes resulting from human activity. One of the biggest problems is accelerating eutrophication caused by nutrient inflow and deposit.

The food production chain is one the most resource demanding and polluting sectors. Agriculture and the food chain are largely responsible for eutrophication and pollution of waterways. Food consumption represents a significant part of the environmental load of households and, in addition, food can contain hazardous compounds resulting, for example, from farming and livestock production and traces of harmful chemicals, like those in fertilisers.

An average 3 600 tonnes of phosphorus and 78 000 tonnes of nitrogen were leached into the Baltic Sea from Finland annually between 2000 and 2006. Approximately 28% of the phosphorus and 36% of the nitrogen load were from natural sources. The runoffs of the food chain were estimated at 2 320 tonnes of phosphorus and 34 680 tonnes of nitrogen in 2005, corresponding to about 80% of the diffuse phosphorus load, and about 70% of the diffuse nitrogen load from socio-economic activities. Raw material production governs the total environmental load of the domestic food chain. Its contribution to the eutrophic emissions is 83% on average. About 95% of nitrogen and phosphorus leaching stems from raw material production.

Based on the results of the EIOLCA food chain model, the eutrophication intensity varies among different foodstuffs: beef has the highest eutrophication intensity of all meats, about three times higher than that of pork, and seven times that of poultry. The eutrophication impacts of plants also vary among species: grain has the highest intensity of the plant-based raw materials.

Eutrophication intensity was estimated for Estonian and Latvian food raw materials using the Finnish EIOLCA model, which was modified for the emission factors of the raw material production sectors. For Estonia eutrophication intensity estimates appeared higher than for Finland. For the Latvian cereals the estimate was considerably lower than for the Finnish ones. This reflected through grain fodder to pork, poultry and eggs.

The effects of diet were studied with help of the EIOLCA food chain model as part of a project on the coherency assessment of other policies with the environmental policies in Finland. The modelling results indicated that eutrophication caused by the food chain could be reduced by about 7% if the recommended diet were to have full effect on private food consumption. The eutrophication intensities, which are the gradients of the changes and are much higher for animal protein foods than for carbohydrate foods, explain the change.

Human activity and land-based agricultural operations exert key effects on the nutrient contents of the Baltic Sea. The most important factors are the total area of agricultural land, its local distribution, diversity and volumes of different crops produced, use of fertilisers, and other agricultural operations. Nutrient load into the Baltic Sea can be reduced by improving crop yields, by optimising crop selection and fertiliser use, and by practising efficient nutrient recycling.

72 Potential contribution of dietary changes to improvements in the environment and human health

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The consumption of animal products has a large environmental impact, both within and outside Europe. Livestock production is a large user of land and a source of greenhouse gas and nitrogen emissions. At the consumption side, European diets are characterised by a high intake of protein, dominated by animal protein and a relatively high intake of saturated fat, also mainly originating from animal products. Reducing meat and dairy consumption could have various beneficial effects and offer a scope for change on a European level.

For our study, we based consumption on supply data from the FAO. Health impacts were assessed by calculating the intake of proteins, saturated fats and red meat, and comparing these intakes against health recommendations. The recommendations were obtained from the World Health Organization (WHO) and the World Cancer Research Fund (WHO, 2003; WCRF, 2007). Environmental impacts – from land use, and greenhouse gas and nitrogen emissions – were assessed using a review of LCAs of animal products and the MITERRA-Europe model. The MITERRA-Europe model calculates annual nitrogen flows and greenhouse gas emissions from agriculture, following a life-cycle approach that reaches 'up to the farm gate' (Velthof et al., 2009; Lesschen et al., 2011).

We assessed scenarios with reductions of 25% and 50% in beef and dairy consumption (S1, S4) and other scenarios with similar reductions in pork, poultry and egg consumption and production (S2, S5). Furthermore, scenarios with a 25% and 50% reduction in all meat and dairy were assessed (S3, S6). The energy intake was kept at a constant level in all scenarios. Only the protein intake was decreased, taking into account the minimum amount of protein recommended by the WHO.

Our study showed that reductions in meat and dairy consumption in fact decreased the environmental impacts, due to the large differences in land use, and carbon and nitrogen footprints between food products. Currently, European diets contain more proteins than necessary as well as more saturated fat which mainly originates from animal products, than the maximum recommended amount by the WHO. Also, current intake of red meats is higher than recommended by the WCRF. Diets with lower meat and dairy products have been found to reduce the risk of various diseases. It was concluded that a decrease in the consumption of animal products in the EU27 may result in a large reduction in environmental impacts and could be beneficial to human health.

References

Lesschen J.P., van den Berg M., Westhoek H.J., Witzke H.P. and Oenema O. 2011. Greenhouse gas emission profiles of European livestock sectors. Animal Feed Science & Technology 166-167, 16-28.

Velthof G.L., Oudendag D., Witzke H.P., Asman W.A.H., Klimont Z., Oenema, O. 2009. Integrated assessment of nitrogen emissions from agriculture in EU-27 using MITERRA-EUROPE. J. of Environ. Quality 38, 402-417.

WCRF& AICR (2007), Food, nutrition, physical activity and the prevention of cancer: a global perspective. 2nd Expert report ed. World Cancer Research Fund, Washington D.C.

WHO (2003a). Diet, Nutrition and the prevention of chronic diseases. WHO technical report series 916, WHO, Geneva.

WHO (2003b). Food based dietary guidelines in the WHO European region. WHO-Europe, Copenhagen.

73. Benchmarking Swedish cod and herring products by spatial-temporal life cycle assessment

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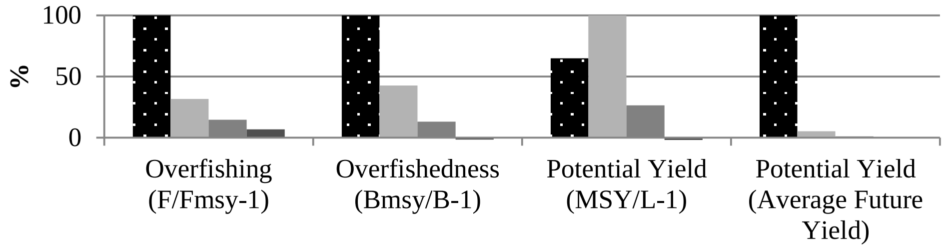
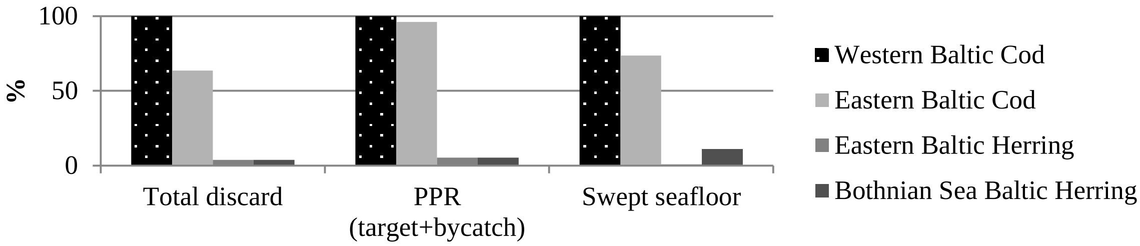
Fisheries today affect the environment and its ecosystems with a broad range of impacts. Methods to quantify and compare these lay within the Life Cycle Assessment (LCA) framework when traditional emission based impact categories are complemented with biological indices covering internationally acknowledged aspects of direct target stock damage (i.e. overfishing) and direct ecosystem damage. This study demonstrates the application of seafood LCA's by midpoint benchmarking the environmental performance of the Swedish trawl fleet in the Baltic Sea. It was done by comparing fishing activities on two stocks of cod and two stocks of herring in 2008 (spatial resolution) in terms of average products. In addition one stock of each species was compared over time in terms of key drivers, i.e. between 2002 and 2008 (temporal resolution). Newly developed/refined impacts categories of Overfishing, Overfishedness, Wasted Potential Yield, Primary Production Required and Swept Area were applied together with a full set of ReCiPe midpoint impact categories. The results showed major differences between stocks see figure 1, and positive or negative trends were highlighted by defined impact groups of target stock, ecosystem and emission impact. Temporal variation was found substantial in all categories in relation to key drivers. The case study also demonstrated the weakness of generally using low fuel consumption as an indicator for good stock status due to technical differences influencing the catchability. Data availability was discussed as a limiting factor for applicability and a sensitivity analysis of the model assumptions performed. Trade-offs were discussed and final scores evaluated in relation to decision support and the future role of seafood LCA's. With the inclusion of biological impact categories in the methodology, LCA´s are concluded to be a useful complementary tool for fisheries managers, seafood industry or seafood labelling/consumer guides. But without directly addressing and quantifying the biological effects on target stock and ecosystem any future seafood LCA could easily be misinterpreted or even deliberately misused as a biased proxy for holistic "environmental" damage.

A – Target Catch



B – Ecosystem



C – Emissions

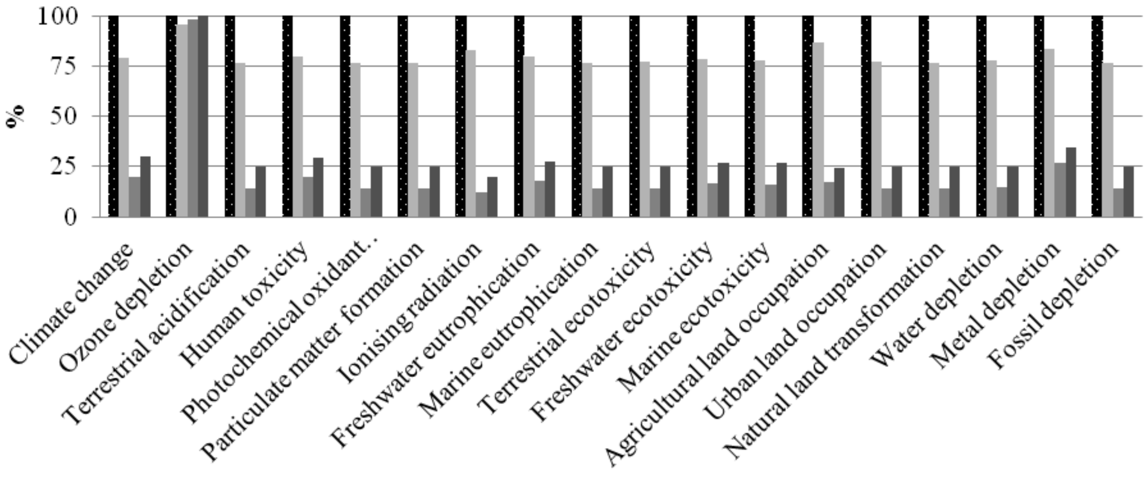


Fig. 1a-c. Comparison between environmental performances of four Baltic fish stocks during 2008 over three groups of impact categories: A – Direct target stock impact, B – Direct ecosystem impact. C- Indirect emission impact.

74. Linking geographical certification and environmental declaration of food products: the apple Mela Rossa Cuneo (PGI) case study

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Protected Geographical Status (PGS) is a legal body defined in European Union law in order to protect the names of regional foods. In this framework the Protected Geographical Indication (PGI) is a well known name used on certain products originating from a specific geographical location (e.g. a region or a country). The use of a PGI is also a certification that the product possesses certain qualities or is made according to local traditional methods. As PGI foods enjoy a certain reputation, due to their geographical origin, they are of higher commercial value both on local markets and in wholesale retail systems, in which PGI foods from several national areas are usually collected under specific brands in order to differentiate them from other products.

PGI foods are connected to specific quality traits without considering impact on the environment during the production. However, as the PGI seal reflects a standardised production, it may also be associated to standardised environmental impacts. Therefore it may be possible to combine the geographical certification with some sort of environmental declaration which may thus result in a positive effect of the commercial performance of such product. Even though the production of PGI foods are standardised to a certain extent, the application of an environmental assessment methods to a PGI food is complicated because of the variability of the production process (e.g. diverse production systems may merge to the same PGI) and production sites.

Therefore, the aim of this research is to evaluate the suitability and the methodological requirements for the application of the Environmental Product Declaration (EPD®) system to a PGI food case study. The focus will be the red apple "*Mela Rossa Cuneo*", which is a PGI product from the province of Cuneo (Piedmont, Italy). This apple is characterised by an intense red colouring of the peel and particular bright and shiny shades of colour. The PGI is constituted by a small list of apple varieties and their clones deriving from a strict quality selection of the varieties still grown today.

According to the EPD® system, the specific Product Category Rules (PCRs) for fruit and nuts products where applied to the *Mela Rossa Cuneo* in order to quantify the environmental impacts of the production. A cradle-to-gate LCA has been performed in accordance with the guidelines and requirements of the ISO 14040. Data regarding agricultural inputs, consumption and orchard management have been obtained directly from the growers, using a questionnaire for the season 2010-2011, and by consultation of the Italian protocols for such production. The environmental aspects of the production of fertilisers and pesticides have been included within the boundaries.

75. Eco-labelling and information asymmetry: independent consumer information through eco-labels in Bulgaria

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Third party eco-labelling can serve three functions in the marketplace: 1) it can provide independent evaluation and endorsement of a product; 2) it can act as a consumer protection tool; and 3) it can be a means of achieving specific environmental policy goals (Boström and Klintmann, 2008; Nilsson et al., 2004; Rubik and Frankl, 2005).

Eco-labelling is a means to narrow the information gap: independent third parties assure the consumer that the producer has complied with published, transparent, environmentally friendly standards. In recent years a number of critical research studies have been published which evaluate the reliability of eco-labels (Amstel van Saane et al., 2008; D'Souza et al., 2007; Koos, 2011; Nilsson et al., 2004).

An identification and analysis of third parties eco-labelling foods schemes in Bulgaria is presented. Discussion focuses on the coverage, promoters/owners and stakeholder inclusion in such schemes, and consideration of their impartiality, accessibility, independence and transparency. The disclosure of information to consumers by third parties eco-labelling certification (organic labels) is explored. Conclusions are drawn regarding their potential role in future shifts towards efficient consumer information practices in Bulgaria.

References

Amstel van Saane M., Driessen P., Glasbergen P., 2008. Eco-labelling and Information Asymmetry: a Comparison of Five Eco-labels in the Netherlands. Journal of Cleaner Production 16 (3), 263-276.

Boström M., Klintmann M., 2008. Eco Standards, Product Labelling and Green Consumerism, Houndmills: Palgrave Macmillan.

D'Souza C., Taghian M., Lamb P., Peretiatko R., 2007. Green Decisions: Demographics and Consumer Understanding of Environmental Labels. International Journal of Consumer Studies. 31 (4), 371 – 376.

Koos S., 2011. Varieties of Environmental Labelling, Market Structures, and Sustainable Consumption Across Europe: A Comparative Analysis of Organizational and Market Supply Determinants of Environmental-Labelled Goods. Journal of Consumer Policy. 34, 127 - 159.

Nilsson H., Tuncer B., Thidell A., 2004. The Use of Eco-labelling like Initiatives on Food Products to Promote Quality Assurance—is There Enough Credibility?. Journal of Cleaner Production. 12, 517–526.

Rubik F, Frankl P., 2005. The Future of Eco-labelling. Making Environmental Product Information Systems Effective, Sheffield: Greenleaf Publishing Ltd.

76. SENSE: harmonised environmental sustainability in the European food and drink chain

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The food and drink industry in Europe, of which 99% are SMEs, is highly fragmented, and food chains are very complex. Hence, to assess the environmental impact of a product there is a need for applying integrated, harmonised and scientifically robust methodologies, together with appropriate communication strategies for making environmental sustainability understandable to the market. However, there are difficulties in developing a commonly agreed methodology for environmental impact assessment that still need to be overcome, notably: complexity of food chains, large number of agents involved, different indicators depending on the business sector, regional differences, high data intensity, costs and expertise required.

Considering the previous difficulties, SENSE project will deliver a harmonised system for environmental impact assessment of food and drink products. The research will evaluate existing relevant environmental impact assessment methodologies, and consider socio-economical, quality and safety aspects, an approach that have been rare up till now, to deliver a new integral system that can be linked to monitoring and traceability data.

By means of incorporating a simplified data gathering system, a matrix of key environmental performance indicators and a certification scheme into the new methodology the project will provide a tool to effectively reflect the sustainability profile of any product. The e-information will allow food and drink chain actors, and especially industrial SMEs, to set realistic environmental sustainability goals and improve their competitiveness towards a more sustainable production culture to all levels of the production process.

The sustainability information collected along the production cycle of any food stuff will be finally reflected into an Environmental Identification Document (EID) which will contribute to enhanced environmental sustainability motivation of the usual purchasing behaviour of consumers and provide a competitive advantage to those products (and companies) which choose to use this approach.

The communication of the information will have a visual presentation that will be intuitively understandable by all the stakeholder of the food and drink sector, and especially the consumers. By means of a comprehensive environmental communication between the industry and consumers will lead those to choose for the food products communicated as being environmentally friendly.

The main results of SENSE will be:

- Standard key environmental performance indicators (KEPI) and specifically for three food and drink chains from three regions (Northern Europe, Mid-Eastern Europe and Mediterranean Europe)
- Harmonised methodology for environmental impact assessment
- SENSE-tool for simplified environmental data collection
- Environmental Identification Document (EID) and EID-Communication Platform
- Certification Scheme Concept (CSC) for sustainability based on EID
- Road map for policy and governance implementation

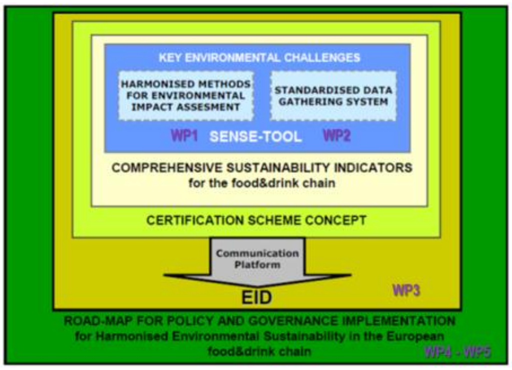

Figure 1. Diagram of objectives of SENSE

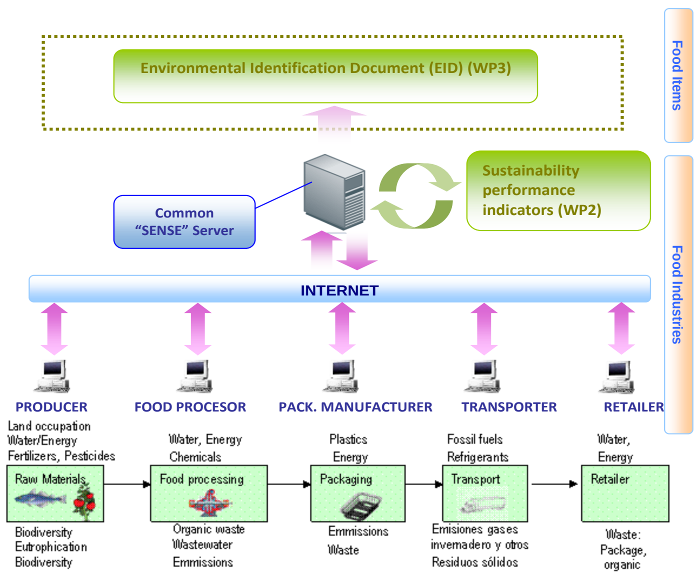

Figure 2. Proposed web-based system to enable users to input key environmental information from different supply chain stages in food chain following a data traceability approach.

77. Life cycle assessment of rapeseed and sunflower oils

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The aim of the study is to provide all necessary information to fit to the French national experimentation of environmental labeling for two standard oils: sunflower oil and rapeseed oil. The results of this study are a relevant overview of all sunflower and rapeseed oils produced in France, and are usable as standard values for both producers and users of vegetable oil. Industrials of oil sector use these values to compare to their own process values and to evaluate the improvement due to their ecodesign strategy. For example, the use of a biomass boiler, the reduction of packaging, different choices for the suppliers of the seeds lead to a lower LCA score.

The complete life cycle of oils has been studied from the seeds production to the end of life of the packaging. Only storage and use have been excluded from the study because of a lack of data. The life cycle inventory is illustrated in Fig. 1. In this graph, the cells in dotted line are the steps excluded from the study. All the other ones are included. An energetic allocation has been done to the co-products (with a grey frame in the graph).

The data were collected from different industrial sites belonged to Sofiproteol group that illustrate the diversity of all the French crushing, refining and packaging sites. About 4.5 million seeds were crushed in 2010 by Sofiproteol group, which represents 80% of French crushing. A focus has been made on the impacts of crushing and chemical refining. The industrial data are specific to edible oils. Note that refining of edible oil (chemical refining) differs from the refining of oil used for biofuels (physical refining).

For the agricultural step, data has been gathered from ADEME (2010) on first generation of biofuels used in France and has been rounded off by CETIOM expertise (water consumption). Life cycle inventories (LCI) come from the LCA database ecoinvent.

The indicators used are congruent with the French national experimentation of environmental labelling: greenhouse gases (GHGs) and water consumption. The most important point in the results (Table 1) is that the agricultural step is responsible of most impacts on the studied indicators (from 58-71% of GHG and 47-73% of water consumption). The other steps that contribute the more are the industrial step, the transport and the packaging.

References

ADEME - Direction Production et Énergies Durables, 2010. Analyses de cycle de vie appliquées aux biocarburants de première génération consommés en France. Final report. 236 pages.

ADEME, AFNOR, 2011. BPX 30-323 - Principes généraux pour l'affichage environnemental des produits de grande consommation - Partie 0: principes généraux et cadre méthodologique.

Shonfield, P.K.A., Dumelin E.E., 2005. A life cycle assessment of spreads and margarines. Lipid Technology, 17: 199-203.

Schmidt, J, 2007. Life cycle assessment of rapeseed oil and palm oil, Ph.D. thesis.

Wightman. P., Eavis, R., Batchelor, S., Walker, K., Bennett, R., Carruthers, P., Tranter, R., 1999. Comparison of rapeseed and mineral oils using life-cycle assessment and cost-benefit Analysis. OCL – Oleagineux, Corps Gras, Lipides, 6: 384-388.

Table 1. Results of LCA on rapeseed and sunflower oils

		Rapeseed oil		Sunflower oil	
Indicator	**Unit**	**Refining oil**	**Packaged oil**	**Refining oil**	**Packaged oil**
GHG emissions	g CO_2 eq	127	154	89	112
Water consumption	litres	0.7	1.0	1.7	1.9

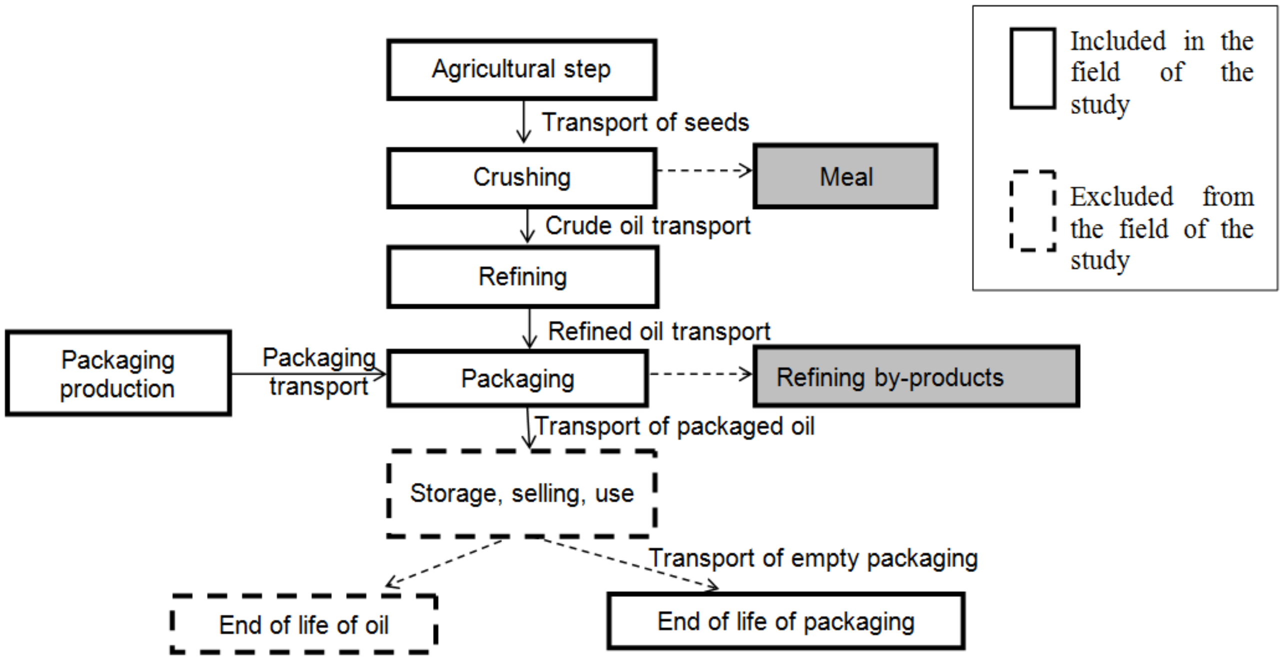

Figure 1. LCI considered for the LCA of rapeseed and sunflower oils.

78. Effect of carbon footprint label on food purchase behaviour

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Consumer interest on products' environmental profile is constantly increasing. Several eco-labels are published worldwide to inform consumers about products' environmental performance. Raisio Group, an international plant-based foods and feeds company, was one of the first companies to introduce a carbon footprint label for food products in 2008. Since, Raisio's carbon footprint label has been revised in compliance with customer feedback. Nowadays, Raisio has labelled more than 30 of its own products and the label is also in use in more than 15 other companies' food products including poultry and honey products.

A consumer web survey was organised together with Raisio Group and WWF Finland in July 2011 in Finland. The survey was organised to determine which aspects Finnish people value when making decisions concerning food. Information about the survey was spread through social media, Raisio's consumer newsletters and WWF Finland's newsletter. Most important questions were how Finnish consumers take food chains different sustainability aspects into account in their purchase decisions, the market penetration of Raisio Group's carbon footprint label and the relation of carbon footprint and other factors when making purchase decision.

The respondents were assumed to be environmentally conscious or aware of current discussion about food environmental impacts and sustainability as a whole in Finland. The results of the survey show that approximately 40% of 4960 respondents have seen Raisio Group's carbon footprint label on a food product package. Almost 54% of the respondents stated that a carbon footprint label should be mandatory for food products. More than 60% suppose that mandatory carbon footprint label would have effect on purchase decision. Other key factors in decision making are food products purity and safety, healthiness and price.

Figure 1. Raisio Group's carbon footprint label

79. Bittersweet comparability of carbon footprints

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Comparability of results from life cycle assessments is a critical topic, especially when results are used for communication and product labelling. The main sources of variation are (1) different system boundary definitions, (2) data handling and assumptions, (3) different databases for background data (Kägi et al. 2011). In our study of three types of chocolate, the carbon footprint is performed by the same person in order to eliminate the first and second cause for variation. The carbon footprint was performed using two different tools, Footprint Expert (FPX) of the British Carbon Trust Footprinting Company Ltd., and EMIS 5.6 from Carbotech AG. Both tools provide an integrated database for background data, the FPX Reference Database 3.3 and ecoinvent 2.2, respectively. The calculation of agricultural products was performed with the FPX Crop Calculator. In the EMIS model, direct emissions were calculated following the methodology used in ecoinvent (Nemecek & Kägi, 2007) and the IPCC 2006 Guidelines. The aim of this study is to find out if the results of the footprints are comparable or not. The study is performed according to PAS 2050. Primary data were collected for cocoa and sugar cane farming and the production stages. Secondary data were mainly taken from the databases of the tools.

The study shows that the final results from both tools are in the same magnitude order, with differences of less than 15 per cent. Larger differences could be observed for the single production stages (Fig. 1 and Table 1). The calculated greenhouse gas (GHG) emissions from cocoa beans were higher using the ecoinvent methodology compared to those from the FPX Crop Calculator. For sugarcane, the result was different, as the emissions calculated with the ecoinvent methodology were lower than those from the FPX Crop Calculator. GHG emissions from transport were higher when calculated with FPX compared to the transport emissions based on ecoinvent. Especially for sea freight, ecoinvent emission factors are much lower, which is in line with the results from other studies analysing sea freight (Emanuelsson et al. 2010).

Both tools, FPX and EMIS, have their advantages and disadvantages. FPX is a tool with a strict guideline and especially designed for carbon footprinting. Therefore it can be used by non-professionals, allowing them to calculate carbon footprints of good quality. The aim of FPX is to standardise carbon footprinting in order to enable comparable results, even if footprints are performed by different organisations. However, the tool is limited to carbon footprinting. EMIS is a tool for life cycle assessments (LCA). Therefore it can be used for other impact categories and includes more functionality such as input-output analyses or uncertainty analyses. It allows a more differentiated analysis of products. However, as it is more flexible in its use, comparability of studies performed by different people is lower.

Often product carbon footprint analyses are conducted mainly for marketing reasons. It has to be emphasised that the communication of results on product labels is a difficult topic. Indicating an exact number may be misleading to customers, as it pretends an accuracy that cannot be achieved by current methodologies. However, standardised tools like FPX together with an accredited certification body do provide comparable results that may help customers to choose climate friendly products.

References

Emanuelsson, A., Skontrop Hognes, E., Ziegler, F., Sund, V., Winther, U., Elligsen, H., 2010. Life cycle approach to Norwegian seafood logistics – new ways to model food transports, in: Notarnicola B., Settanni E., Tassielli G. Giungato, P. (Eds.), proceedings of LCAfood 2010, Bari, Italy

Kägi, T., Wettstein, D., Schmid, H., Azapagi, A., Amienyo, D., Contreras, A., Sanchez, M., Villegas Costa, L., Ménard, J.F., Bécaert, V., Kanzaki, M., 2011. LCA Comparative Study on Beer. 5th PCF World Summit, Zurich, 7-8 April 2011

Nemecek, T., Kägi, T., 2007. Life Cycle Inventories of Agricultural Production Systems. ecoinvent report No. 15, Zurich and Dübendorf, Switzerland.

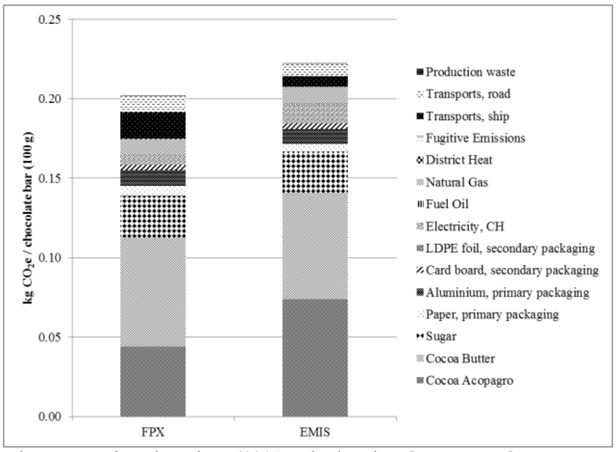

Figure 1. GHG emissions from the chocolate „Peruvian chocolate 60%“, calculated with EMIS and FPX.

Table 1. Emission sources and differences between EMIS and FPX results.

Emission source	Difference of EMIS result compared to FPX result
Cocoa Acopagro	+68.0%
Cocoa butter	-2.3%
Sugar	-2.3%
Paper, primary packaging	-23.0%
Aluminium, primary packaging	-5.7%
Cardboard, secondary packaging	+10.5%
LDPE foil, secondary packaging	+25.0%
Electricity, CH	+93.5%
Fuel oil	-0.5%
Natural gas	+9.3%
District heat	-
Fugitive emissions	-
Transports, ship	-59.8%
Transports, road	-22.5%
Production waste	+56.8%
Total	**+10.3%**

80. Life cycle assessment as a basis for eco-labelling of fish food products

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Life cycle assessment (LCA) is a valuable tool for documenting environmental performance of food products. This is also true for fish food products – a commodity providing income for millions and food for billions of people worldwide (FAO Fisheries Department, 2010) – even though most effort has been invested in the sustainable harvesting of fish resources. The life cycle management in the food industry is mainly driven by policy makers, consumers and the industry itself on the emerging problem of climate change. In the fish industry, there is an urgent need for strategies, tools and communication with the market that emphasise the whole life cycle of the fish food product from catch to consumption. Taking this into account, carbon footprint declaration (after the planned ISO14067 (ISO/DIS 14067, 2012)), the coming European environmental footprint of products (European Commission, 2012), and the Environmental Product Declarations (EPD) - following the ISO14025 standard (ISO 14025, 2006) - are all suitable for communicating results from food products LCAs. The EPD, mainly developed for business to business communication, can also be used for communication to the other important stakeholders, like environmental organisations and consumers. However, the special challenges with declining fish resources need to be taken into account. This contribution presents results from a PhD-project on life cycle assessment of the fish food product with emphasis of the fishing phase (Schau, 2012). The results from the LCA of Atlantic herring landed in Norway and consumed in Germany, shows that the fishing vessel, and especially the diesel use is the main contributor to most impact categories investigated. Besides from presenting the LCA results, the EPD also gives information on the status of the fish stock the product comes from. In addition, this contribution investigates how life cycle environmental impacts from fish food products can be presented in the carbon footprint declarations and in the coming European environmental footprint of products.

References

European Commission, 2012. Environmental footprint of products. Retrieved 24 Jan 2012 from http://ec.europa.eu/environment/eussd/product_footprint.htm.

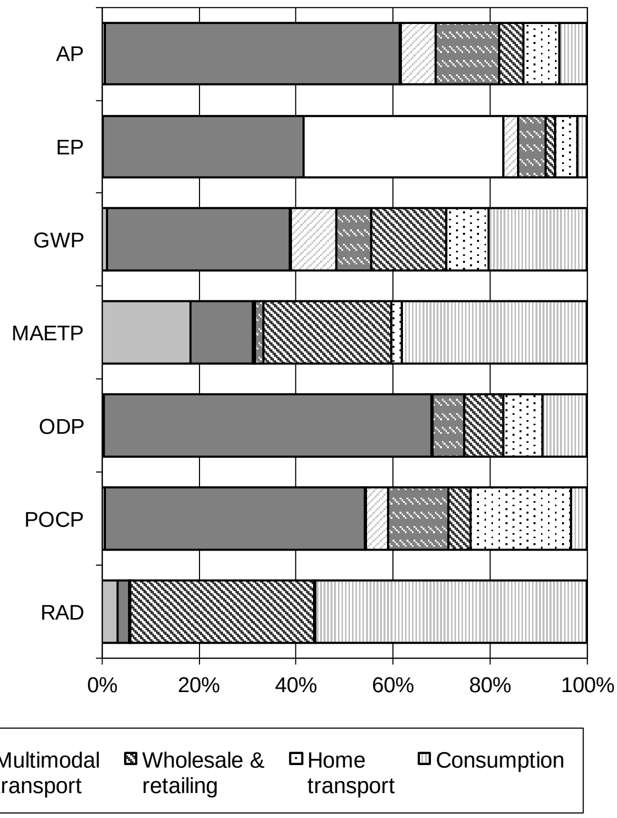
FAO Fisheries Department, 2010. The State of World Fisheries and Aquaculture - 2010. Rome, Food and Agriculture Organization of the United Nations.

ISO 14025, 2006. Environmental labelling and declarations - Type III environmental declarations - Principles and procedures (ISO 14025:2006). Geneva, ISO.

ISO/DIS 14067, 2012. Carbon footprint of products - Requirements and guidelines for quantification and communication. Berlin, Secretariat DIN: 52.

Schau, E.A.M., 2012. Environmental life cycle assessments of fish food products with emphasis on the fish catch process. Trondheim, Norway, NTNU, Norwegian University of Science and Technology.

Impact category	Total
Acidification Potential (AP) [g SO_2-equivalent]	17.1
Eutrophication Potential (EP) [g PO_4-equivalent]	4.4
Global Warming Potential (GWP) [kg CO_2-equivalent]	2.14
Marine Aquatic Eco-toxicity Potential (MAETP) [kg DCB-equivalent]	67.2
Ozone Layer Depletion Potential (ODP) [mg R11-equivalent]	0.836
Photochem. Ozone Creation Pot. (POCP) [g Ethene-equivalent]	2.03
Radioactive Radiation (RAD) [DALY]	3.56×10^{-9}



Abbreviations: DCB : 1,4-dichlorobenzene
DALY: disability-adjusted life year

Figure 1. LCA results from the Atlantic herring (*Clupea harrengus*) case study. The fishing life cycle phase dominates several impact categories (Schau, 2012).

81. Agrifood products: a comparison of existing carbon footprint systems in the world

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In 2011, EVEA and Savin Martinet Associés carried out a study on behalf of the French Food and Agriculture Ministry (MAAPRAT 2012). The aim of this study was first to compare the different product carbon footprint (PCF) systems of agrifood products around the world, and second to give a risk analysis of competing distortion from a world trade point of view.

Thirty-eight PCF systems were checked off. These systems are disseminated worldwide: Europe (France, Germany, England, Sweden, Switzerland, etc.), North America, Asia, Australia and New Zealand. Distinctions were made firstly by system category (PCF, labels, or tools), and secondly by origin (public or private, retailer). From these 38 systems, 14 of them providing existing PCF of agrifood products on the market were deeply analysed, 10 of which in Europe and 2 in Asia. This consisted in reporting and analysing general information (country, owner of the system, number of committed enterprises, number of PCF labelled products, etc.) and more specific information about the structure of the PCF system such as existing PCR, verification process, tools for computing, underlying database, etc. Furthermore, a comparison of PCF of several products was carried out. Around 300 PCF of products were reported from the 14 analysed systems and some detailed comparisons were made for 9 specific products (milk, wine, ham, bread, rice, olive oil, yogurt, potatoes, and French beans) both within a same system (intra-comparison) and between different systems (inter-comparison). Table 1 shows an example for the comparison of several milk footprints.

Each time, interpretation has been conducted from these comparisons confronting on one hand the PCF figures and on the other hand available information related to these PCF (calculation rules, allocation, etc). Three criteria were defined: level of available information, estimated level of methodological divergence, objective comparability. For each product and each PCF system, this analysis led to identify the main influencing parameters (packaging, organic production or not, origin, varieties, recipe, etc.) and their respective level of influence on the PCF result (as shown on table 1).

Moreover, a juridical analysis was carried out in order to confront the PCF systems to the regulation rules of the 4 main following international organisations: WTO, OECD, European Union, and FAO. Indeed, regarding the specific French context about environmental labelling, the issue was: can a mandatory environmental labelling system for consumer products be authorised on the French market by international organisations?

Regarding the risk of a competing distortion that would be a case of no-compliance with the rules of the world trade, the main conclusions from this juridical focus are that such systems cannot be imposed as mandatory by a country except if they fully respect three conditions:

- Transparency about the elaboration process of the standard (methodology for calculation): the elaboration process must reach an international consensus and must be opened to all stakeholders.
- No-discrimination about origin: results (PCF) must not lead to discriminating products based on their production process and geographic origin.
- Proportionality of the means regarding the claimed objectives (encourage a sustainable consumption): such a system must not engage costs that could be judged to be excessive for companies, in particular SMEs.

The study leads to the following conclusions:

- The different PCF systems present a great diversity regarding their respective features and in particular regarding the applied methodologies
- There is a huge variability of the PCF of products, and some methodological divergences have been demonstrated. Furthermore, very little information is usually available and most of the systems are absolutely not transparent and thus are not compliant with the only internationally recognised standard (ISO 14020). All these items lead to the conclusion that for a same product different PCF calculated within different systems are objectively not comparable. This can be problematic for customers when different systems co-exist in the same market (eg. in France).
- For now none of the existing labelling systems could be considered compliant with the rules of the world trade for a state to make it compulsory.

References

Bolwig, S., Gibbon, P., 2009. Emerging product carbon footprint standards and schemes and their possible trade impacts. Report, 2009, Technical University of Denmark, DTU Climate Center.

MAAPRAT, 2012. Comparaison des ACV et affichages carbone utilisés sur les produits agroalimentaires – Etude technique et juridique. Report, EVEA and Savin Martinet Associés, February 2012.

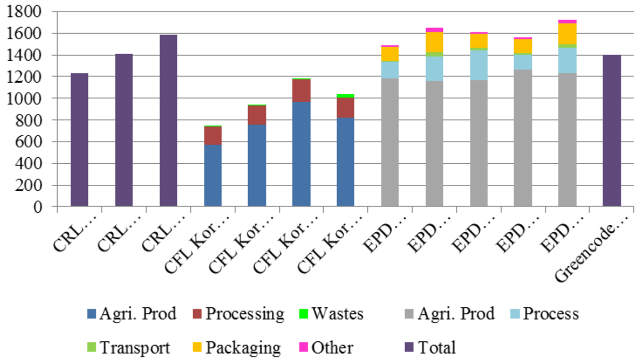

Figure 1. Comparison of milk carbon footprints (g CO_2 eq.) per 100 cl

Table 1. Influence of parameters on carbon footprints.

Parameter		Product/ PCF system	Level of influence
Packaging	Sale unit	Ham / Casino (France)	Strong
		Yaourt / Casino (France)	Strong
		Ham / CFP (Japan)	Weak
		Rice / CFP (Japan)	Strong ?
		Potatoes / CRL Tesco (UK)	Weak
		Milk / EPD® (Sweden)	Important
	Storage (ambient temperature or frozen)	Bread / EPD® vs. others	Weak
		French beans / Greenc. Info® (France)	Strong
Type of production	Organic vs conventionnal	Wine / H. de Carbono (Spain)	Strong (up)
		Wine / EPD® (Sweden)	Important (down)
		Olive oil / H. de Carbono (Spain)	Strong (down)
		Milk / EPD® (Sweden)	Weak
		Milk / CFL (Korea)	Strong (up)
		Rice / Climatop (Switzerland)	Strong ?
	Dry vs. immersed	Rice / Climatop (and CFP Japan ?)	Strong

82. Finnish carbon footprint protocol "Foodprint" for food products

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In the Foodprint - research project harmonised methodology for assessing carbon footprints of food products was developed in collaboration with the Finnish food sector in 2009-2012. Many international standards, protocols and guides are published but no common approved standard nor communication method evaluating food products' climate impacts is available. In addition, the published ones are too generic and they do not give practical instructions for companies to produce comparable carbon footprints.

However, international standardisation, developments and best practices on evaluating climate impacts of the food products' entire life cycle were taken into account when national specific guidelines were prepared. Some of the most challenging issues tackled in the methodology and protocol work are described in this paper.

There are many situations in assessing carbon footprints where decisions are often done case by case. These issues are critical as they affect comparability and the magnitude of carbon footprint results. Attributional approach was selected as s starting point of the protocol. The methodology development work was carried out as an iterative process between research, companies and other stakeholders to ensure practical methodology and implementation.

To harmonise methodology and future carbon footprint assessments, detailed instructions were given to different life cycle phases and many clear requirements have been established. All life cycle phases from raw material extraction to waste treatment shall generally be included. Different requirements were also made for cultivation and for animal production. Cut-off rules are also applied in the methodology and more detailed instructions for their use are given. Capital goods are excluded from the system boundaries.

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

New updated emission factors were also developed. National emission factors for N_2O emissions from agricultural soils derived from field measurements were launched in the project to describe better national circumstances. This means that new default will give considerable higher emissions to grains and vegetables (outdoor) grown in open fields due to the northern conditions.

Another area of improvement and generation of defaults were national emission factors for different electricity production types. The protocol proposes that specific emissions factors related to the actual electricity supplier should be used. This means that when the production profile of the supplier is known (as in Finland is the case by law), the new national defaults for different production types shall be used.

Different existing methodologies to include land use changes, especially deforestation, were also analysed based on the Finnish case studies. Emissions resulting from land use change were proved to have a large impact on the final carbon footprint of food products. Thus they shall be included in the assessment, and presented separately from total results. The methodology and some practical guides are presented in the protocol and additional material of the project.

It is seen that in the near future, when climate impacts are understood and tackled by companies and they have suitable tools for that, this also directs proactive companies to develop more comprehensive methods, to consider issues such as water and nutrient footprints.

83. How to measure sustainable agriculture? The GLOBAL 2000 adaptive sustainability assessment approach for agricultural products

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Eco-labelling has been suggested as an approach to manage towards a more sustainable world by several authors and organisations (e.g. de Snoo 2006, Bruce & Laroiya 2006, Rigby et al 2001, UNDP (CSD) 1996). Although approaches to "measure" sustainability have often been criticised we follow the opinion of Gomez-Limon & Sanchez-Fernandez (2010) that the "*design and use of such indicators can be extremely useful in that they force those involved in the discussion of sustainability to identify the key aspects of sustainable agriculture and to assign weights to them.*" In such a context the often very general and theoretic discussions about sustainability are confronted with real world practices and problems and are requested to come up with workable solutions and improvements.

This poster presents the GLOBAL 2000 adaptive sustainability assessment approach (ASAP), with which the environmental performance of agricultural products is measured from field to shelf. Also first product specific results and lessons learned during the implementation phase will be presented.

The aim of the approach is to arrive at a comprehensive understanding of the environmental impacts of a certain agricultural product and the connected life cycle. Furthermore, it strives to set incentives for farmers to adopt a more sustainable production mode and to help consumers make deliberative consumption choices, by informing them about the environmental impacts of products.

Five field-level based indicators (N-balance, P-balance, humus-balance, pesticide use and energy intensity) and five based on "material input per service unit" (MIPS) indicators (carbon-footprint, biotic and abiotic material input, water input and area used) are used. We calculate the indicators based on date provided by each producer and company along the production chain. The approach uses a stepwise process that explicitly involves stakeholders in the refinement and adaptation of monitoring and benchmarking and serves as a discussion and knowledge transfer arena.

Our method is applied in the context of the REWE International AG, GLOBAL 2000 and Caritas Sustainability Program for Fruits Vegetables and Eggs and is used for the REWE label Pro Planet (www.pro-planet.at) in Austria. This program provided the necessary frame and infrastructure to further develop the methodology and tools in an applied context.

References

Bruce C. and A. Laroiya, 2007. The Production of Eco-Labels. Environmental and resource Dynamics, 36: 275-293.

de Snoo, G. R., 2006. Benchmarking the Environmental Performances of Farms. The International Journal of Life Cycle Assessment, 11:22-25.

Gomez-Limon, J.A., G. Sanchez-Fernandez, Empirical evaluation of agricultural sustainability using composite indicators, Ecological Economics, 69: 1062-1075.

Rigby D., P. Woodhouse, T. Young, M. Burton, 2001. Constructing a farm level indicator of sustainable agricultural practice. Ecological Economicsm 39: 463-478.

UNDP (CSD), 1996, Eco-labeling United Nations Commission on Sustainable Development. Available at: http://www.un.org/documents/ecosoc/cn17/1996/background/ecn171996-bp8.htm

84. Product carbon footprint for a line of production of cookies

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A line of cookies, from a Latin-American company, has been analysed in their life cycle, taking the impact on GHG emissions. A total of 16 references were analysed. The methodology used for the study was the PAS2050: 2008. The study includes the GHG emissions from materials extraction, transportation, manufacturing, packaging, use and disposal of packaging.

The study uses the Umberto for carbon footprint software ® v 1.2, with ecoinvent 2.2 datasets. Primary data from process are included, taking energy consumptions for each stage, process and mass efficiency in lamination process and baking process.

The cookies included in the study are healthy line with less fat and less sugar content. This cookies uses raw materials like wheat flour, bran, oat flour, corn flour, palm oil, sugar and water. The baking uses natural gas. The packaging of the product uses PET/BOPP/Met, PET/BOPP, Folding boxboard and Corrugated cardboard. In the study the distribution is in truck and distances are calculated with the sales registers for 2011. See Fig. 1 with the system for assessment.

For a cookie raw materials account for 55-68% of the carbon footprint associated mainly with wheat flour, followed by product packaging that represents between 17 and 30%, the process is in between 9 and 17%. The carbon footprint of each cookie depends of its formulation (Fig. 2).

In the analysis, it appears that within the same line of cookies can have different levels of baking and variables as the percentage of waste in the lamination and baking and drying curve for the product, become representative in the product's carbon footprint, due to increased raw material requirements.

Having the overall product carbon footprint, it was multiplied by the total production, and it allows calculate the Product Carbon Footprint contribution for the line of cookies (Fig 3). The Honey reference has 41% of the total carbon footprint of the entire line; it is because it has the major sales.

The wheat is the most important raw material for the cookie production and for the product carbon footprint too. The importance of this will be associated to the risk of one company against climate change.

Change traditional wheat for organic one, was evaluated, but the organic production is small and it cannot produce the enough raw material needed for the production of the company. Otherwise, the quality requirements of the organic wheat do not meet demands of the product.

For the products uses different packaging with aluminium and it increases the carbon footprint. The folding box board and the corrugated cardboard are very important in the emissions for the product.

References

Carbon Trust, DEFRA, BSI, 2008. PAS2050:2008. Specification for the assessment of the life cycle greenhouse gas emissions of goods and services. BSI: London, 43p.
ISO. ISO 14040:2006. Environmental management -- Life cycle assessment -- Principles and framework
ISO. ISO 14044:2006. Environmental management -- Life cycle assessment -- Requirements and guidelines
Bimpre, M. 2006. Life Cycle Assessment of the production of homemade and industrial bread in Sweden. KTH. 25 pages.

Table 1. Carbon footprint contribution per life cycle stage (%).

Life Cycle Stage	Raw Material	Processing	Packaging	Distribution	Disposal
Sesame SKU1	63.7	17.0	16.5	2.4	0.3
Sesame SKU2	61.2	16.2	19.2	3.0	0.3
Oatmeal Chocolate SKU1	65.0	10.0	22.1	2.6	0.4
Oatmeal Chocolate SKU2	62.2	10.1	25.2	2.1	0.3
Oatmeal and Red Berries SKU1	58.5	11.5	26.5	3.0	0.4
Oatmeal and Red Berries SKU2	56.5	11.0	29.2	2.9	0.4
Oatmeal Granola SKU1	59.9	12.4	24.4	2.9	0.4
Oatmeal Granola SKU2	54.9	11.2	30.5	3.0	0.4
Chocolate Bs. 6x2	63.3	8.6	25.1	2.6	0.4
Fruits and Cereals	67.2	11.1	18.7	2.9	0.1
Grain Fusion SKU1	63.2	15.4	18.2	2.8	0.3
Grain Fusion SKU2	66.5	10.6	19.3	3.1	0.6
Honey SKU1	67.0	11.4	18.5	2.7	0.3
Honey SKU2	67.6	11.5	17.6	2.7	0.5
Vanilla	60.2	8.9	26.7	3.7	0.5
Yogurt Strawberry Bs x 6	55.1	14.3	27.0	3.2	0.5

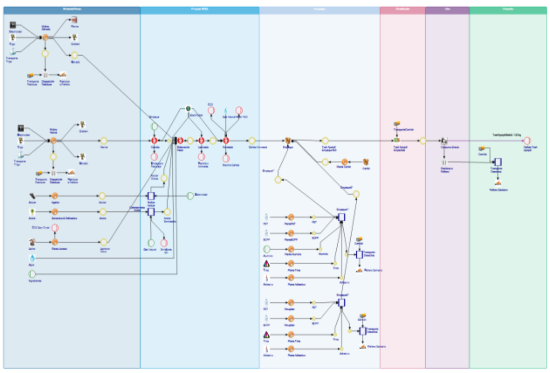

Figure 1. System diagram for cookie production.

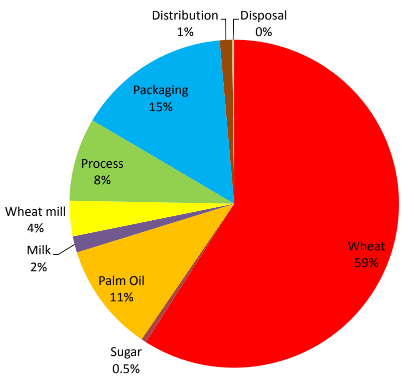

Figure 2. Example for raw material contribution in the product carbon footprint

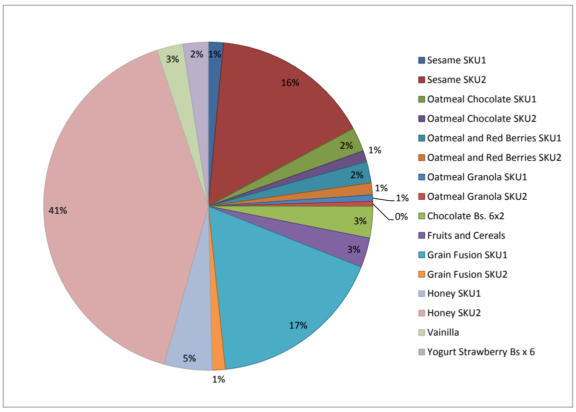

Figure 3. Product carbon footprint contribution by reference.

85. LCA in organic and conventional product comparison: a review

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Life cycle assessment (LCA) is an important assessment tool to evaluate the environmental impacts of agricultural products. One focus of assessments within agriculture has been the comparison of organic and conventional production systems to evaluate whether organic or conventional agricultural products are more environmental friendly. In different studies it has been shown that organic farming has benefits for the environment when focusing on the farming practice (e.g. Mondelaers et al. 2009). However, when using LCA to calculate impacts on a per unit product basis organic products show higher impacts for certain categories mostly due to lower yields. If they are calculated per area*time unit basis the impact is lower due to lower inputs of agricultural means. Though, there are studies showing a better performance of organic products for both functional units (e.g. the global warming potential of milk in Cederberg and Mattsson (2000) or Hörtenhuber et al. (2010)). Basically, there are two reasons for contradicting results of LCA studies comparing organic versus conventional products: Firstly, real differences in performance of organic and conventional products (from farm to farm and supply chain to supply chain) secondly, methodological artifacts within LCA. To elucidate these presumed reasons we reviewed LCA studies on organically and conventionally grown products of different product groups (fruits and vegetables, cereals, dairies and meat), systematically analysing the parameters listed in Tab. 1.

We identified shortcomings on different levels that impair the comparison of LCA studies between organic and conventional products. The most stringent is that system-specific characteristics of organic agriculture are not fully reflected on the inventory level, which can lead to bias in certain impact categories (e.g.: climate change, eco-/human toxicity, photo-oxidant formation, acidification and eutrophication). This is either due to a lack of data or due to insufficient data quality. For example calculations of nitrous oxide emissions do not consider the different transformation processes of organic fertilisers (which act mainly via the soil N pool) but treat them as mineral fertilisers; heavy metal contents of manure from organic farms are based on measurements of manure from conventional agriculture; or carbon sequestration usually is not included or the interdependence of the C- and N-fluxes in soils is not reflected. Further, currently used allocation rules within the livestock sector (milk and meat) seem to bias LCA results from organic and conventional production systems (Flysjö et al. 2012). Since milk and meat production are interlinked and changes in the one production will affect environmental impacts in the other system expansion should be used instead of allocation. On the LCIA-level, environmental impact categories such as soil quality and functional biodiversity, which are important impact categories for the analysis of agricultural systems, are not considered when comparing organic and conventional agriculture products. We conclude based on present LCAs that an inter-comparison of products from organic and conventional agricultural products is difficult and improvements can be reached on the inventory and impact assessment level. With such adaptions LCA can become even more important to evaluate the environmental impacts of agricultural products.

References

Cederberg, C., Mattsson, B., 2000. Life cycle assessment of milk production - a comparison of conventional and organic farming. J. Clean. Prod. 8, 49-60.

Flysjö, Anna , Christel Cederberg, Maria Henriksson, and Stewart Ledgard. 2012. The interaction between milk and beef production and emissions from land use change e critical considerations in life cycle assessment and carbon footprint studies of milk. J. Clea. Prod. 28, 134-142.

Hörtenhuber, S., Lindenthal, T., Amon, B., Markut, T., Kirner, L., Zollitsch, W., 2010. Greenhouse gas emissions from selected Austrian dairy production systems - model calculations considering the effects of land use change. Renewable Agric. Food Syst. 25, 316-329.

Mondelaers, K., Aertsens, J., Van Huylenbroeck, G., 2009. A meta-analysis of the differences in environmental impacts between organic and conventional farming. Br. Food J. 111, 1098-1119.

Table 1. Parameters reviewed in the analysis of LCA studies.

Parameter
Attributional or consequential LCA
Goal of the study
Temporal and geographical system boundaries chosen
Functional unit(s) used
Assumptions made regarding agricultural production (including yields)
Inventory data basis used
Site-specific emission and characterisation factors used
Allocation rules applied
Impact categories assessed
LCIA-methods used
Sensitivity analyses to choices of methods conducted
Uncertainty analyses of results conducted

86. Environmental impacts and resource use in feed production for Atlantic salmon aquaculture

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As a part of the development of salmon feeds with reduced content of fish meal and fish oil the occupation of agricultural land; marine primary-production-required; GHG emissions and cumulative energy demand was assessed for a set of different feed diets for Atlantic salmon. The assessments were performed with LCA methodology and covered the salmon production system from growing and catch of feed ingredients till the salmon was ready for slaughter. The results were compared with Swedish chicken and pig production. Data on the feed compositions was delivered by the three of the world's largest salmon feed producers.

LCAs of Norwegian seafood have mainly focused on potential climate impact and cumulative energy demand (Winthur et al., 2009). This project expanded the scope of environmental impacts by addressing the reliance on agricultural land and marine resources (Pelletier and Tydemers, 2007), the latter by including the marine primary production required (PPR) to sustain the marine ingredients (Pauly and Christensen, 1995). The PPR was calculated by combining the trophic level of each fish species with catch location and average primary production per square meter ocean surface for that location. This method has important uncertainties from deciding the tropic level of the species and the average primary production per surface area for each fishing location.

A salmon that is fed the average Norwegian feed diet, in 2010, has a carbon footprint of 2.6 kg CO_2 equivalents; it occupies 3.3 m^2 agricultural land and requires 115 m^2 of sea primary-production area. Studying both potential climate impact and primary production required made it possible to study trade-offs between them, but also discover where there are no trade-offs. E.g. reducing the content of American marine ingredients would increase both the carbon footprint and the PPR, since the American species, used in these feeds, have a low trophic level and are sourced by very energy efficient fisheries.

Increasing or decreasing the use of marine ingredients may alter the carbon footprints by ± 7%. One reason for this is that the marine ingredients are replaced with soy protein concentrate that is attributed with a high carbon footprint since it contributes to deforestation. Deforestation has previously rarely been included in the GHG assessment of salmon feed production.

The comparison with pig and chicken concluded that salmon has the lowest climate impact and occupies the least agricultural land. Even an almost "vegetarian" salmon occupy less agricultural land than chicken. Pig had the highest carbon footprint and the highest occupation of agricultural land.

Important parts of the current and future feeds are derived from by-products from fisheries (pelagic and whitefish species) and from poultry by-products, The use of by-products highlighted the importance of the allocation strategy, here mass allocation was used and thus the by-products contributed significantly to the carbon footprint and this highlights the importance of evaluating how future standards for GHG assessments should treat allocation requirements. This LCA study was part of a bigger project by Nofima Marin on the resource utilisation and eco-efficiency of Norwegian salmon farming in 2010 (Ytrestøyl et al., 2011).

References

Pauly D, Christensen V. Primary production required to sustain global fisheries. Nature. 1995;374: 255-257. [With erratum from 376: 279]

Pelletier N, Tyedmers P. Feeding farmed salmon: Is organic better? Aquaculture. 2007;272(1-4):399-416.

Winther U, Ziegler F, Skontorp Hognes E, Emanuelsson A, Sund V, Ellingsen H. Project report: Carbon footprint and energy use of Norwegian seafood products www.sintef.no/Fiskeri-og-Havbruk-AS/Prosjekter/2011/Miljoregnskap-og-klimasporing-av-sjomat/. Trondheim, Norway: SINTEF Fisheries and aquaculture; 2009.

Ytrestøyl T, Aas TS, Berge GM, Hatlen B, Sørensen M, Ruyter B, et al. Resource utilisation and eco-efficiency of Norwegian salmon farming in 2010 Norway: Nofima; 2011.

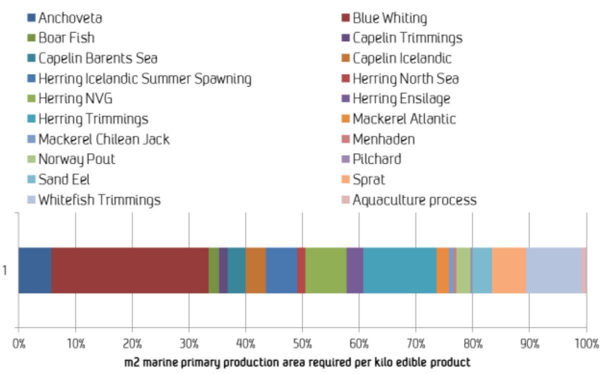

Figure 1. Contribution to marine primary-production-required per kg edible salmon from 2010 diet

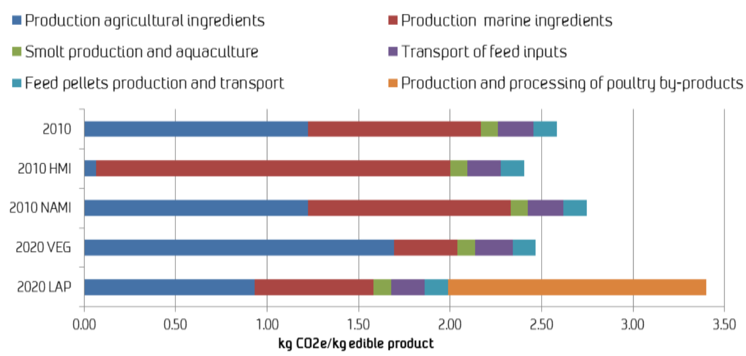

Figure 2. Total carbon footprint per kg edible product for each diet. 2010=Average Norwegian diet in 2010; HMI=High level of Marine Ingredients; NAMI=No American Marine Ingredients, VEG=Low content of marine ingredients; LAP=Use of poultry by-products.

87. EPD of extra-virgin olive oil: an Italian experience

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The Environmental Product Declaration (EPD) is a document based on the ISO 14025 standards; it contains information about environmental performance related to a product. The quantification of environmental performance is calculated using Life Cycle Assessment methodology, thus following the principle guides of ISO 14040 standards. Nowadays many EPDs have been issued by the International EPD System®, especially for the agro-food sector, due to the increased interest of companies and customers in this environmental communication tool. Recently, the EPD has also been made available for extra-virgin olive oil (PCR 2010).

To obtain the EPD, LCA methodology was applied to the life cycle of a pitted extra-virgin olive oil packed in a 1-litre glass bottle. The functional unit (FU) is 1 litre of extra-virgin olive oil, while the system boundaries include: a) the olive production (agricultural phase), b) the transportation of the olives from the olive grove to the oil mill, c) the process used for producing pitted extra-virgin olive oil (industrial phase), d) the packaging process involving putting the oil into 1-litre glass bottles, e) transportation to distribution, f) the "end of life" of the product and packaging disposal. An allocation procedure was only carried out for the phases of olive oil extraction and packaging (CORE); this distinguished between: olive oil, pomace and pit. Allocation was calculated considering two factors: mass and economic value of the co-product.

Data referring to the production of the raw material are all primary data, exception for the information about fuels, lubricants, and machines, for which the ecoinvent v.2 database was used. As for transportation, distances were estimated by referring to average values, while emissions were calculated by using the PE – International database (updated July 2010). Data relating to olive oil production are all primary data directly collected in the oil mill. As far as electricity production is concerned, the Italian power grid mix derives from the literature (AEEG and GSE, 2011). Data referring to packaging production comes from the Plastic Europe and PE-International database. As for the "use phase", the percentages of recovery and landfill disposal of glass, as well as the data regarding cardboard and plastic, derive from reports published by the National Packaging Consortium. Collected data were elaborated using GaBi 4.4 software, with reference to the functional unit represented by 1 litre of pitted extra-virgin olive oil (weighing 0.92 kg) packed in a 1-L glass bottle. To obtaining one litre of extra-virgin olive oil, 5.29 kg of olives, harvested on a surface of 18.9 m^2, are needed. In accordance with the indications of PCR clause 10, an environmental impact assessment was carried out distinguishing the use of resources, potential environmental impact and other indicators. The agricultural phase would benefit from more non-renewable material and energy resources, while the extraction process requires more renewable material resources, water and electricity. Finally, the packaging phase would need more renewable energy resources. The feedstock energy is only linked to the PVC production: it is almost 0.003 kg of crude oil and 0.002 kg of natural gas per functional unit.

As for the assessment of the potential environmental impacts, the Global Warming Potential (GWP) is more affected by the agricultural phase, followed by the packaging phase. This impact derives from the fuel consumption (for the soil cultivation) and from the production process of the primary packaging (glass bottle and PVC capsule). The value of CO_2 equiv. per FU is over 1 kg, and over 50% of this derives from the olive-production while 30% derives from the packaging: The same trend is detected for the categories of Acidification, Photochemical Ozone Creation and Abiotic Depletion, while, as far as the Ozone Layer Depletion is concerned, the packaging phase is the most pollutant. As for Eutrophication, the most pollutant phase is the olive oil extraction, due, in particular, to the higher pollutant charge of the wastewater (washing water, vegetation water and water added in the extraction process). Analyzing the impact calculated as kg of phosphate equiv., almost 90% of the total value per FU (about 16 g) is linked to the extraction phase (wastewater).

As for the impact categories referring to toxicity, except for Terrestial Ecotoxicity, the packaging phase is again the most pollutant. Here too, the explanation is linked to the production of the glass container, which accounts for over 80% of the total impact.

The analysis of the environmental performance includes the assessment of the impact categories of Land Use by using the Eco-indicator-99 (Land Use and Land Conversion) and IMPACT 2002+ (Land Occupation) evaluation methods. For all these categories, over 90% of the total impact derives from the agricultural phase. Then other indicators are analysed; the "Material subject for recycling or other use" category includes pruning residues (agricultural phase), leaves and little branches (extraction phase) and recycled packaging (glass, plastic and cardboard). The production of "Hazardous and environmentally active waste" is nil, as is the production of toxic emissions. With regard to other types of waste, the wastewater deriving from the extraction phase and the waste disposed in landfill (not recycled) must be indicated. Finally, pruning residues and by-products of the olive oil extraction (leaves and little branches, pomace and pit) are included among the waste that could be recovered as renewable energy.

The LCA study enables us to detect some improvements which could be adopted for the agricultural phase (as reducing to the minimum the employment of non-renewable energy resources and water, preserve the fertility of the soil or recovering the energy value of pruning residues, by the controlled burning carried out in a boiler for the thermal energy production) and for the processes of olive oil extraction and packaging, (as improving the management of waste and wastewater during the extraction phase or studying other types of container). While in order to reduce the environmental impact of the end of life, efforts must be made to improve the communication with consumers, by stating more information on the label, with the aim to guide consumers towards sustainable methods of packaging disposal.

The critical analysis of PCR developed by the International EDP® System aims to elaborate some consideration about the possibility of Italian firms adopting these rules or submitting to some modifications after the expiry date (31 Dec 2013), on the basis of elements which are more representative of the Italian olive oil industries. From this critical analysis we can assert that PCR could be adopted by the Italian olive oil firms without any particular problems. As for the environmental performance developed in paragraph 10 of PCR, some suggestions might be made in order to explain the impact of toxicity and land use better. The analysis of toxicity would be more complete if the two toxicity categories developed by Ralph K. Rosenbaum et al. in the UseTox method are considered (Ralph et al, 2008): Human Toxicity (expressed as no. of cases x kg) and Freshwater Ecotoxicity (expressed as kg DCB-equiv.). These suggestions could be relevant in consideration of the need to assess the toxicity for the processes in which there is an agricultural phase involving a high impact in terms of toxicity, deriving from the use of pesticides.

In the same way, as for the land use categories, indicators could be better shown, as Baitz (2002) suggests, by distinguishing: Erosion Resistance; Mechanical Filtration; Physicochemical Filtration; Groundwater Replenishment; Biotic Production. Finally, some considerations regarding the CO_2 balance; to achieve a correct balance, the CO_2 quantity immobilised into soil from olive trees and herbaceous biomass (winter and spring weeds, grass cover etc) should be indicated. Frequently, this information is not indicated, or only partially, due to the lack of experimental data able to evaluate it in an appropriate way, even if some studies (Sofo et al., 2005) determined for Mediterranean areas the year-1 of CO_2 fixed in an olive grove.

References (selected)

Alberti F., Neri P., Cecchini F. 2005. LCA applied to the Olive Oil Chain – standard study (in Italian). Thesis of Master in Environmental Development and Management of the Agro-Environmental Systems. University of Bologna, ENEA-PROT-P135-100.

Baitz, M. 2002: Die Bedeutung der funktionsbasierten Charakterisierung von Flächen-Inanspruchnahmen in industriellen Prozesskettenanalysen. Ein Beitrag zur ganzheitlichen Bilanzierung. Dissertation. Shaker (Berichte aus der Umwelttechnik), Aachen

Carli G. 2002. The Environmental Impact of the Olive Oil Production: application of the Life Cycle Assessment (LCA) methodology (in Italian).

International EPD Consortium (IEC). 2009. General Programme Instructions for Environmental Product Declaration EPD, Version 1.0, of 29/02/2009.

PCR 2010:07; CPC 21537 – PCR for virgin olive oil and its fractions; ver. 1.0, 2010-04-27.

88. Communication strategies for product sustainability messaging aimed at end consumers

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The proliferation of communication guidelines for environmental claims and conflicting eco-labelling schemes has caused industry organisations to acknowledge the need to provide consumers with a more harmonised set of sustainability labels and claims in the marketplace (Ryan Partnership Chicago/Mambo Sprouts Marketing, 2011). Government and industry organisations also widely recognise the need for more scientific research to help us understand how to effectively communicate sustainability information to end-consumers (Ernst & Young, 2009; Galatola, 2011; Ryan Partnership Chicago/Mambo Sprouts Marketing, 2011). Initial reports conclude that consumers prefer to be presented with grades or scores of a product's sustainability performance, rather than the absolute values, ratios, and physical units found in most LCA studies (Ernst & Young, 2009). Consumers' intent to use product level sustainability disclosures is also highly dependent on the message being presented at the point of sale and verified by an independent organisation (Ernst & Young, 2009; Ryan Partnership Chicago/Mambo Sprouts Marketing, 2011).
Building on these industry reports, The Sustainability Consortium launched an applied research project to answer some of the key questions posed by leading retailers and brand manufactures in the Consumer Goods industry. This particular empirical study seeks to understand, from a consumer's perspective, how the design and format of LCA-generated scores presented with products at the point of sale affects the message's understand-ability, believability, comparability, and usability. Researchers also attempt to measure consumer preferences for 13 sustainability attributes (see figure 1) and 22 messaging formats (see figure 2) on product level disclosures. To examine variance in consumer preferences across product categories, the attribute and format variables are tested in combination with five different product category variables such as cereal, paper towels, and laundry detergent. Variance in consumer preferences across geo-political scales is also examined by sampling consumers from four different sovereign nations, including France.
Qualitative and quantitative results from ten focus group sessions and three online surveys suggest there are ample opportunities for establishing scientifically-grounded best practices for communicating LCA-generated information. From a global perspective, the data indicates 1) the presence of a scoring scale and attributes with a positive tone are critical for establishing understand-ability among consumers 2) consumers are most likely to prefer a messaging format that's grounded in the percentages scoring technique 3) scores accompanied by stoplight colour coding that identifies three thresholds of relative industry performance substantially enhance usability. Further research is ongoing and scheduled for completion in May, 2012.

References

Ernst & Young, 2009. Pistes pour un etiquetage environnemental lisible et efficace – Resultat d'enquete consommatuer.
Galatola, M., 2011. The role of the ILCD Handbook as methodological basis for robust life cycle based environmental policies, SETAC 2011. Milan
Ryan Partnership Chicago/Mambo Sprouts Marketing, 2011. One Green Score for One Earth Consumer Sustainability Survey.

Figure 1. A sample of the sustainability attributes

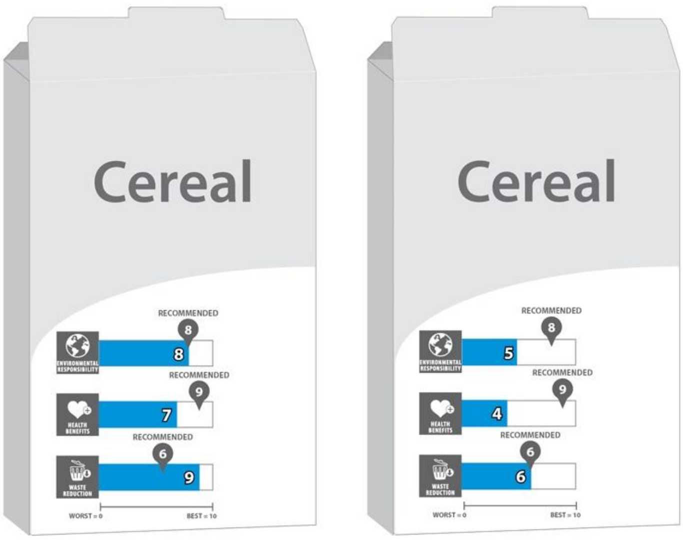

Figure 2. An example of one of the messaging formats

89. The good egg in the basket: improvements in egg production within the Pro Planet eco-labelling scheme

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Eco-labelling has often been proposed as a valuable instrument for the implementation of higher environmental and social standards. For instance, Gereffi et al. (in Honey 2002, p.51) suggest that "*While certification will never replace the state, it is quickly becoming a powerful tool for promoting worker [...] rights and protecting the environment in an era of free trade*".

The poster shows actual quantifiable improvements in egg production using the GLOBAL 2000 adaptive sustainability assessment approach. The results are based on five indicators (carbon-footprint, biotic and a-biotic material input, water input and area used) calculated for the most relevant stages of the product life cycle. For example, it can be illustrated that the mere replacement of Brazilian soy with soy produced in the EU more than halves greenhouse gas emissions of the whole egg production process due to different land use patterns (cf. Hörtenhuber and Zollitsch, 2010; Nemecek and Kägl, 2007). This coincides with favourable conditions for rising European soy production: first, the latest price increases on the market; second, the spreading of the corn woodworm in some European countries and the need for crop rotation to avoid extensive use of nicotiniod-based insecticides.

Both the method used and the results refer to the eco-label Pro Planet (www.pro-planet.at) as part of the REWE International AG, GLOBAL 2000 and Caritas Sustainability Program for Fruits, Vegetables and Eggs.

References

Honey, M., 2002. Ecotourism and certification: setting standards in practice; Island Press

Hörtenhuber, S. and Zollitsch, W., 2010. Greenhouse gas emissions of regionally produced alternative feedstuffs rich in protein for Austrian dairy production. In: Building sustainable rural futures, IFSA, Vienna, pp. 1349-1356.

Nemecek, T. and Kägl, T., 2007. Life Cycle Inventories of Swiss and European Agricultural Production Systems. Final report evoinvent V2.0 No 15a. Agroscope Reckenholz-Taenikon Research Station ART, Swiss Centre for Sustainable Life Cycle Inventories, Zurich ans Dübendorf, Switzerland.

90. Carbon labels worldwide- a review of approaches and indices

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This contribution does not provide a simple summary of carbon labels worldwide, but a critical review of existing international labelling policies and their background and ways of communicating their LCA foods results to the consumer. Advantages and disadvantages from both the manufacturer and consumer angle are presented.

Carbon Footprint is a tool to allocate products or services a numeric value for their specific impact on climate change based on Life Cycle Assessment (LCA). Accounting greenhouse gas emissions over the whole life cycle of products or services allows allocating each product a unique Carbon Footprint. This is a first steps to communicate the sustainability performance of products or services to the consumer.

A thorough market analysis conducted in 2011 resulted in the categorisation of seven schemes, into which the carbon labelling and consumer communication of carbon footprint LCA Foods results can be categorised:

(1) Presentation or label of a single static numeric value on the product in the shop; examples are activities by the Carbon Trust, UK and the single carbon footprint value as operated by Tesco's supermarkets in the UK (but not in Tesco's stores abroad). However, this labelling policy is restricted to ca. 20 food and non-food products (orange juice, skimmed milk, Walker's crisps, sliced bread, and light bulbs as the non-food product) out of their ca. 70,000 in-store products viz 0.03% of products on offer. A similar policy is operated by KEITI with their "CO_2 low label" or "COOL" in South Korea. The consumer, however, may find it difficult to judge and memorise numeric values, particularly if expressed on different units (e.g. packet size, litre, 100 g). Similar schemes operate in Thailand and Japan.

(2) Carbon reduction labels (Climatop) offer an answer or alternative to the static CO_2 value. They indicate the activity in the field of carbon footprint, without giving a single static CO2 value. Climatop in Switzerland is presented as an example and labels for green and white asparagus are discussed. Climatop labels have a life-span of two years, which encourages the manufacturer to further improve the carbon footprint.

(3) The colour schemes offer another alternative, where consumers do not need to memorise or interpret a carbon label. The French Casino supermarkets react to the French carbon footprint laws, "Grenelle 2" and Grenelle 2" by operating a green- yellow colour code called 'Indice Carbone', where the product is visually ranked within the best and worst product in the market.

(4) Air freight labels on the produce, operated by Tesco and Marks and Spencer in the UK (and KaDeWe in Germany and CoOp , Switzerland) indicate the food items with the largest carbon footprint, are easy to handle by the supermarkets and understand by the consumer; they also give regional produce a chance, if within that season.

(5) Carbon Zero initiatives like the CarboNZero in New Zealand and CarbonFree in the USA may cause ambiguity and the consumer think the production of this particular food is carbon neutral. These schemes, however, are based on a thorough carbon footprint or complete LCA and subsequent purchase of golden carbon certificates.

(6) QR codes on the products are a fairly new alternative since 2011, where the new generation of mobile phones access the internet in the shop and relevant information is available e.g. for a carbon footprint, which varies seasonally or the LCA is more complicated than a single value.

(7) Sustainability reports are the last option, favoured e.g. by companies in Germany, to report their carbon footprint both in the printed and online versions of their sustainability report, which have to follow the standards and guidelines for sustainability reports, e.g. by dnv.

Table 1. Overview of carbon footprint /water footprint / LCA Foods results to the consumer.

Types of communicating carbon footprint /LCA food results to the consumer	Examples of schemes or organisations	Examples in the food sector
(1) carbon value on produce[a]	Tesco "COOL" by KEITI, S. Korea	Milk, orange juice, bread, sugar, potato crisps
(2) Carbon reduction label	Climatop, Switzerland	sugar
(3) Colour schemes (green to yellow)	Casino France	All products on offer.
(4) Air freight labels on produce	Marks & Spencer (UK), Tesco (UK), KadeWe (D), Coop (CH)	Asparagus, pittaya, pineapple, lemon grass
(5) Carbon Zero or Carbon-free initiatives	CarboNZero, New Zealand CarbonFree, USA	
(6) QR codes on produce or package	Announced for the future	
(7) Sustainability reports	e.g. Unilever, Barilla etc.	All products

91. Food waste amounts and avoidability in Switzerland

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A key element in making our food system more efficient and sustainable is the reduction of food losses across the entire food chain (Quested and Johnson, 2009). Nevertheless, in many LCA analyses food losses are missing. The first step in developing efficient measures is the analysis of the present situation and the identification of hotspots. This paper aims to quantify the food losses in Switzerland at the various stages of the food chain (agricultural production, postharvest handling and trade, processing, food service industry, retail, and households), to identify hotspots and analyse the reasons for the losses. Twenty-two food categories are modelled separately in a mass and energy flow analysis, based on data from 31 companies within the Swiss food chain, as well as from public institutions, associations, and from literature.

The energy balance shows that 48% of the total produced calories (edible crop yields at harvest time and animal products, including slaughter waste) is lost across the whole food chain. Half of these losses would be avoidable. The allocation of the avoidable food losses to the various stages of the food chain identifies agricultural production, the processing industry and households as playing a key role. Households waste 45% of the edible calories lost over the entire food chain. However, there are various uncertainties in quantifying food losses. A major uncertainty lies in the quantification of losses in agricultural production, which are mainly caused by quality sorting and omission of harvest due to high fluctuations in demand and inappropriate organisation. Further research to quantify losses and to develop strategies for optimisation is especially important in this field.

A broader scenario focuses on the potential increase in food availability by replacing animal products relying on feed grown on arable land by vegetarian products. In Switzerland, livestock relies up to one third on feed that is grown on arable land. If one third of the animal products were substituted by vegetarian products, 45% more calories would be available for consumption. If, additionally, all the edible parts of the food produced for Swiss consumption were eaten by humans, 50% more calories would be available (Fig. 1).

References

Quested, T., Johnson, H., 2009. Household Food and Drink Waste in the UK: A report containing quantification of the amount and types of household food and drink waste in the UK. Report prepared by WRAP (Waste and Resources Action Programme). Banbury.

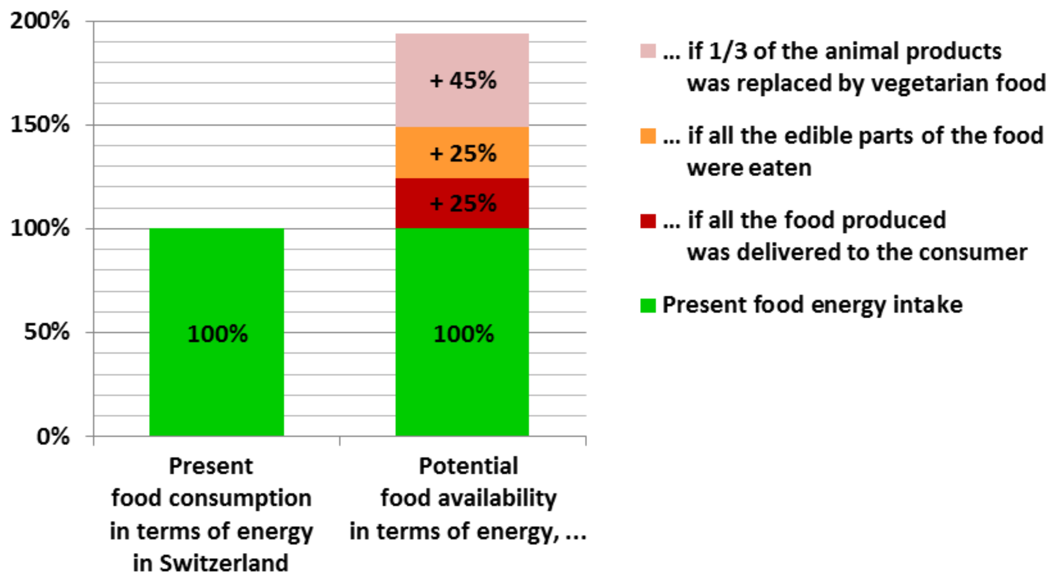

Figure 1. Total potential of avoiding food losses in Switzerland: In a theoretical scenario of perfect distribution, optimal methods of cooking and preparation, and the replacement of one third of the actually consumed animal products by vegetarian food, 195% of the presently consumed food calories would become available for consumption.

92. Life cycle assessment of alginate production

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Algal polysaccharides, also called phycocolloids, are the main commercial seaweed extracts: their production for sale reached 86,100 t over the world in 2009, considering agar, alginates and carrageenans productions (Bixler and Porse 2010). They are mainly used in the agri-food sector, as texturing agents, stabilisers, gel formers of film forming agents. Many other industrial applications exist, as microbiological and electrophoresis media for agar, use in textile printing and paper coating for alginates and in toothpaste, cosmetics and pharmaceutics for carrageenans (Bixler and Porse 2010). To our knowledge, their environmental assessment using Life Cycle Assessment (LCA) has not been performed yet, despite this large use at industrial scale.

We performed the LCA of phycocolloid production including seaweed cultivation. The Recipe method (Goedkoop et al. 2009) was used, with a hierarchist perspective using the ecoinvent v2.2 database and the SimaPro 7.3 software to carry out the impact assessment. The functional unit was to produce 1 kg of hydrocolloid. The study is a prospective for European countries, considering pilot and semi-industrial data from the North-Eastern Atlantic zone (data from Aleor, French seaweed producer). Bibliographic data were also used for electricity consumption (Mafart 1997). We modeled the production of food-grade phycocolloid, because this use is the main market for phycocolloids (Bixler and Porse 2010). Brown seaweeds are considered due to their high growth rate potential. In the present study, seaweed was *Saccharina latissima*, commonly found in this area, and reaching high alginate content, with high levels of guluronic to mannuronic acid ratio. It was cultivated on long-lines in coastal waters, after plantlet production in nursery, as described in Langlois et al. (2012). Seaweeds were treated straight after harvest, with common techniques of sodium alginate production (McHugh 2003). Seaweed were first washed, crushed and treated with alcohol. After acid lixiviation and dewatering, an alkaline extraction was carried out to solubilise alginates, followed by dewatering using filter press. An acid precipitation with blending was then operated, followed by a last dewatering and the addition of sodium carbonate before drying.

Contribution analysis results highlight the importance of the sodium alginate production itself (see Fig. 1). On average on every impact categories, the seaweed production accounts for less than 1% of the total impacts, even allowing bioremediation to marine eutrophication thanks to the nutrient uptake offshore. Electricity is the main contributor to environmental impacts for 12 over 18 impact categories analysed, reaching 39% of the total impacts on average. It is followed by the use of chemical (mainly because of hydrochloric acid), accounting for 26% of the total impacts on average. Heat and cooling requirements, wastewater and waste treatments, and the use of freshwater and mineral filter aid have only secondary impacts compared to them. This work underlines the key elements to improve for an ecodesign of phycocolloids production.

References

Bixler, H.J., Porse, H., 2010. A Decade of Change in the Seaweed Hydrocolloids Industry. J Appl Phycol 23 (3), 321-335.

Goedkoop, M., Heijungs, R., Huijbregts, M. et al., 2009. ReCiPe 2008, a Life Cycle Impact Assessment Method. Ministerie VROM, Den Haag, pp. 125

Langlois, J., Sassi, J.-F., Jard, G., et al., 2012. Life Cycle Assessment of Biomethane from Offhsore-cultivated Seaweed. Accepted in Biofuels Bioprod Bioref.

Mafart, P., 1997. Génie Industriel Alimentaire, Tome 1: Les Procédés Physiques De Conservation, vol.1. Technique Et Documentation. France: Lavoisier.

McHugh, D., 2003. A Guide to the Seaweed Industry. FAO Fisheries Technical Paper, 441. Rome. pp.118. Available online: http://www.fao.org/docrep/006/y4765e/y4765e00.htm

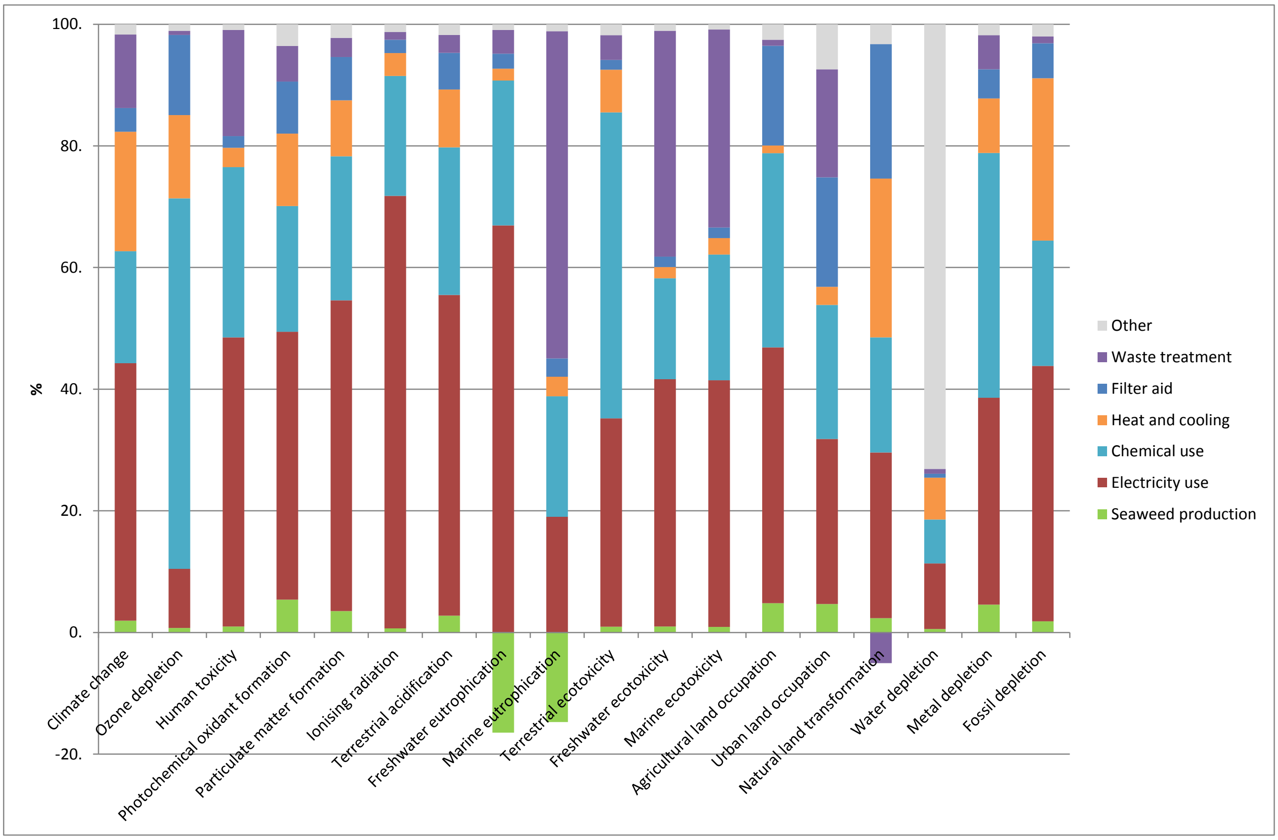

Figure 1. Contribution analysis for environmental impacts of sodium alginate production from offshore cultivated seaweed in European countries

93. Salinalgue project: designing a sustainable production system of biofuel and by-products from microalgae

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Future developments for the microalgae sector are looking promising with high production yields and no direct competition with arable lands (Chisti, 2007). However, there remain some major bottlenecks related to the process chain where energy and water issues challenge the industrialisation of microalgae-based processes (Lardon et al., 2009).

In addressing these challenges, Life Cycle Assessment (LCA) has become an essential eco-design tool in the R&D step of algorefinery projects. As a consortium of 13 institutional and private partners, the Salinalgue project deals with the current environmental challenges underlined in several LCA studies on algal systems. This system features a culture set in an old farming salty land in the aim of reconversion with an extremophile native species. This ensures there will be no contamination and no competition against arable lands. Moreover thanks to the proximity with an industrial area, microalgae may be supplied with industrial CO_2 from exhaust gas. LCA aims at paving the way towards building more sustainable systems. Figure 1 gives an overview of the process chain: from the culture of biomass, its transformation by downstream processes to the use of oilcake and its conversion into energy and digestates which can later be recycled as inputs of the system. Below are the 4 key points addressed by the LCA study on the Salinalgue project:

(1) As there are no industrial facilities yet (even at pilot-scale) (Brentner et al., 2011), most of data is scaled up according to partners' knowledge and literature review. LCA helps to foresee the environmental impacts of emerging technologies. Several process technologies are considered at each step: such as green extraction by new technologies.

(2) Taking up the biorefinery concept, LCA helps partners by pointing out the hotspots, comparing options and informing eco-choices. This approach is reiterated at each stage of the system. For example, several CO_2 supply chains for the algae culture have been compared.

(3) The whole life cycle is analysed: from the production of algal nutrition to the recycling of nutrients contained in the oilcake (with the liquid fraction being recirculated towards cultivation ponds) (Collet et al., 2011). Thereby, LCA provides a holistic point of view. This is useful in such a collaborative project where each partner is mostly focused on its respective operation stage.

(4) Salinalgue is a multi-output system. In such a complex system, it is critical to deal with all the by-products in the LCA study, which raises some methodological issues such as allocation or substitution.

Salinalgue is a two-stage project, where an industrial scaling-up of the system will follow the experimental R&D stage. A step by step approach where the most preferable technology is selected will provide a roadmap towards the most sustainable process chain to yield biofuel and bioproducts from microalgae.

References

Brentner, L. B., Eckelman, M. J. et Zimmerman, J. B., 2011. Combinatorial Life Cycle Assessment to Inform Process Design of Industrial Production of Algal Biodiesel. Environ. Sci. Technol. 45 (16) pp.7060-67.

Chisti, Y., 2007. Biodiesel from microalgae. Biotechnology Advances 25 (3) pp.294-306.

Collet, P., Hélias, A., Lardon, L., Ras, M., Goy, R.-A. et Steyer, J.-P., 2011. Life-cycle assessment of microalgae culture coupled to biogas production. Bioresource Technology 102 (1) pp.207-14.

Lardon, L., Hélias, A., Sialve, B., Steyer, J.-P. et Bernard, O., 2009. Life-Cycle Assessment of Biodiesel Production from Microalgae. Environ. Sci. Technol. 43 (17) pp.6475-81.

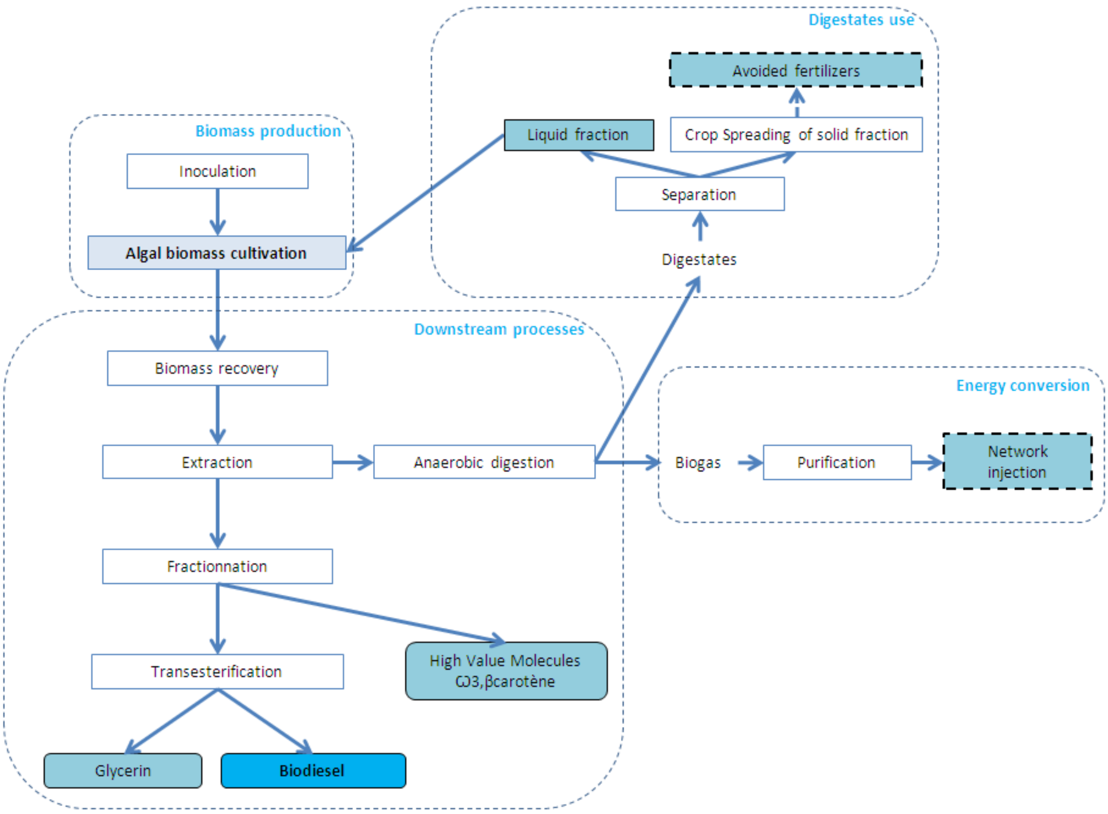

Figure 1. Process chain of the Salinalgue project overview

94. Using life cycle analysis to compare the environmental performance of organic and conventional apple orchards

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Although the conventional farming system for apple production remains the common practice worldwide, the organic farming system is developing. Although organic farming is generally claimed to be environmentally friendly, very few global assessments of the environmental impacts of organic orchard systems are presently available. In this work, we analyse with life cycle analysis (LCA) weak and strong points of the environmental performance of two organic and one conventional apple orchards, using a pluri-annual dataset from experimental orchard systems located in the middle Rhone valley in France. The analysis was performed with the SALCA method (SALCA-Crop, V3.1 adapted for pome fruit) and included relevant impact categories using characterisation models mainly from the methods EDIP97 and CML01.

Seven impact categories including ecotoxicity and human toxicity, as well as energy consumption and other environmental impact categories were calculated and are here presented. From this first insight, the organic systems were globally less impacting than the conventional system when considering the functional unit (FU) per hectare (ha*year), but among the highest impact –except for toxicity- when considering the (kg*year) FU because of low yields. High-yield conventional systems globally presented the opposite trend. The basic substitution of conventional by organic inputs or mechanical work was not sufficient to radically improve the overall environmental performance of the orchard system. This work also highlighted the importance of the cultivar in the orchard design towards more environmentally friendly apple production systems; a disease-susceptible cultivar such as Golden Delicious was more impacting than a low-susceptibility cultivar such as Melrose under the same cropping system. Only one-year results are here presented, to be further validated after several years of full production.

This study is the first apple LCA based on a multi-year system experiment, which provided all information requested to compute a LCA in a liable and high quality dataset, as it was collected on purpose in orchards under the same influence of the site or field context and management. The interest of such system experiments to create references for agricultural productions newly assessed with LCA methodology is discussed. Moreover the potential contribution of LCA to the design of innovative and less input dependant production systems is analysed: the calculation of the overall environmental impact potential (no focus on one aspect) of different farming systems, followed by an analysis of their weak and strong points, permits to propose some improvement of the farming systems.

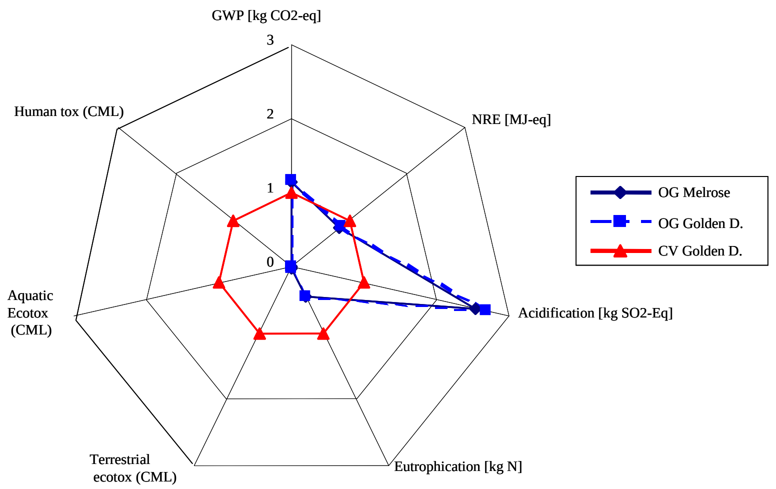

Figure 1. Seven impact categories (one-year data) of the two organic farming systems (OG Golden Delicious and OG Melrose) relatively to the conventional (CV) Golden Delicious farming system which was set up to the value 1 for each calculated impact category (functional unit: per ha*year).

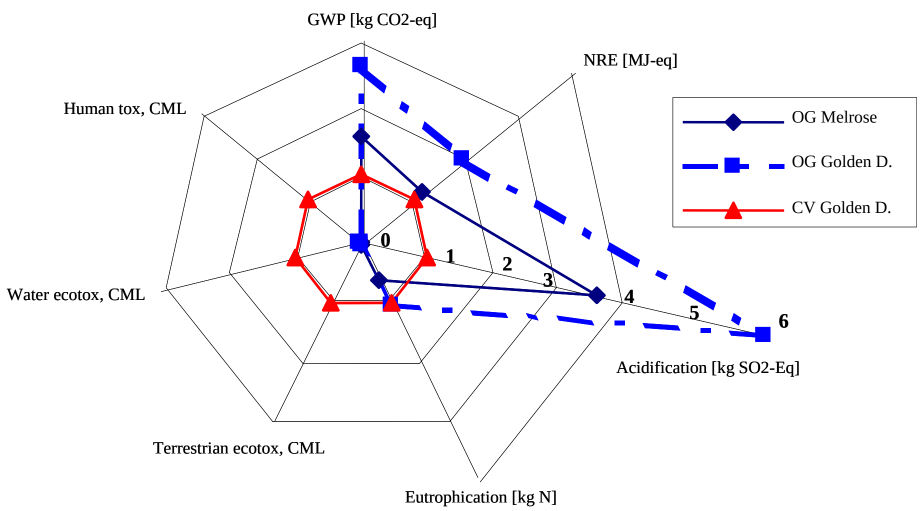

Figure 2. Seven impact categories (one-year data) of the two organic farming systems (OG Golden Delicious and OG Melrose) relatively to the conventional (CV) Golden Delicious farming system which was set up to the value 1 for each calculated impact category (functional unit: per kg*year).

95. Assessing environmental sustainability of apple ancient varieties in Northern Italy

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Until the middle of the last century, hundreds of different cultivars of apples were grown in Italy, as in many other fruit producing countries. However in the Sixties, with increasing orchard commercialisation, the use of commercial varieties became more common. Ancient cultivars were gradually replaced by commercial varieties and Italian fruit-growing practices underwent significant changes. Indeed more than 70% of the orchards in the Piedmont Region (Northern Italy) only have one cultivar, the commercial variety Golden Delicious. In this region alone, ancient apple germplasm actually consists of about 350 cultivars, 130 of which were recently noted for their qualitative, morphologic and agronomic traits. Ancient varieties are characterised by very unconventional quality traits, such as alternative fruit shapes, skin colour, nutritional values and organoleptic traits (such as crispness, juiciness and flavour). Because of this, they constitute a well defined niche market.

The commercial appeal of such products (and the following marketing) is based both on uncommon quality traits and claimed smaller environmental impacts due to the original vocation of the agronomic properties of the land. Nevertheless specific environmental assessment of the varieties have not been conducted yet.

Therefore, the aim of this research is to conduct a life cycle assessment (LCA) that compares the production of a representative ancient apple cultivar with Golden Delicious production, in order to evaluate significant differences in the environmental impacts. In particular, the objectives of this research are (I) to qualify and quantify the main environmental aspects of ancient apple varieties in Piedmont in order to establish parameters for the sustainability of that product; (II) to evaluate any significant differences with the environmental impact of the Golden Delicious supply chain and (III) to highlight where such differences are located along the supply chain.

The assessment covers the whole supply chain, including agricultural production and its inputs: processing, cooling, storage and transportation up to the consumer's phase. Storage and consumption within the consumer's house have not been included because they are considered to be the same regardless the supply chain. The functional unit was 1 kg of apples delivered to the consumer. The study was performed in accordance with the guidelines and requirements of the ISO 14040 standard series and with the cradle-to-gate approach as the basis for the Life Cycle Inventory (LCI) of the study. Data regarding agricultural inputs, consumption and agrotechnique have been obtained directly from the growers, who filled in a questionnaire for the season 2010-2011, and by consultation of Italian production protocols. The environmental aspects of the production of fertilisers and pesticides have been included within the boundaries. Data regarding resource use and supply chain properties have been obtained from retailers through interviews and field surveys.

96. Life cycle GHG and energy balance of organic apples: a case study in Italy

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The main household environmental impacts are concentrated in food, transport and building sectors. The food sector is responsible for 20-30% of the various environmental impacts due to the final consumptions, and in the case of eutrophication for even more than 50% (Tukker at al., 2006).

Every stage of the production and consumption chain of food, from growing crops, to transportation and storage, manufacturing, distribution, purchasing and consumption, and treatment of waste, has environmental effects. Consumers choices can significantly influence the environmental impacts of production, retail and distribution phases of food (EEA, 2005). In particular, they can choose to consume more organic food, which represents a key factor in the food productive sector, due to the added value of its products, to the socio-economic benefits for the producers and the positive effects on the environment and human health.

The present study is part of a research developed within the project "BIOQUALIA – Nutritional and organoleptic quality and environmental impact of organic productions", and aims to evaluate the energy and environmental impacts of 1 kg of organic apples cultivated in the north of Italy.

The analysis was based on the Life Cycle Assessment (LCA) methodology as regulated by the international standards of series ISO 14040 (UNI EN ISO 14040, 2006a; UNI EN ISO 14044, 2006b).

In detail, the authors identified the supply chain flow charts, the relevant mass and energy flows and the key environmental issues for the assessed product, following the approach "from farm to fork". Particular attention was paid on key issues, such as primary energy consumption, water exploitation and fertilisers use in agricultural activities.

The application of LCA allowed assessing the incidence of each life cycle step of apples on the total impacts and identifying "hot spots" of the examined supply chain, by the identification of phases and processes that are responsible of the largest impacts.

In detail, the results showed an average primary energy consumption of about 7 MJ/kg and a global warming potential of about 0.5 kg CO_{2eq}/kg. A relevant incidence on the total impacts (about 70% of primary energy consumption and global warming potential) was related to the transport of apples to final users, hypothesising that the product is distributed on local (10% of the product), national (49%) and international markets (50%). The use of insecticides and the consumption of diesel for agricultural machines were found to be also significant in the overall energy and environmental impacts of apples. Finally the authors carried out a comparison between the outcomes of the presented study and the eco-profile of non organic apple production.

References

European Environment Agency, 2005. Household consumption and the environment. EEA report No 11/2005.

Tukker, A., Huppes, G., Guinée, J., Heijungs, R., de Koning, A., van Oers, L., Suh, S., Geerken, T., van Holderbeke, M., Jansen, B., Nielsen, P., May 2006. Environmental Impact of Products (EIPRO). Analysis of the life cycle environmental impacts related to the final consumption of the EU-25. Technical Report EUR 22284 EN. European Commission.

UNI EN ISO 14040, 2006a. Environmental management – Life cycle assessment – Principles and framework.

UNI EN ISO 14044, 2006b. Environmental management – Life cycle assessment – Requirements and guidelines.

97. Life cycle assessment combined with eMergy for the evaluation of an organic apple production system

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Traditionally organic farms aim to limit as much as possible external inputs to concentrate the production towards more sustainable systems. Organic systems aim to favouring the preservation of ecosystems and the conservation of the landscape and of local complexity. But the management of a farm by means of organic practices does not always assure its sustainability. In this work we combined Life Cycle Assessment (LCA) and eMergy to study the sustainability and environmental performance of an organic farm producing fresh apples and apple-juice. The parallel application of these two methodologies allows obtaining more significative and comprehensive results and it emphasises the necessity of a link between ecological and economic analyses in agricultural systems (Odum, 1996). The farm examined is situated in the south of Tuscany (Italy), with an annual yield of 34 ton/ha. The farm is managed in conformity to organic farming rules, paying particular attention to the preservation of biodiversity and to the respect of natural resources. The use of drinking water is almost completely substituted by the capture of rainwater and by the renewable use of well water. The farm is equipped with a photovoltaic system that satisfies the own electricity demand. For the analysis, the production process was divided in three phases: in Phase 1 apples are cultivated and collected; in Phase 2 apples are washed and selected, a part is destined to the fresh market and a part is transformed in apples-juice (Phase 3). LCA analysis was performed using SimaPro 7.3 (PRè Consultants); for the characterisation we have selected impact categories from CML 2 Baseline Method 2000 (Guinèe et al., 2001): Acidification (AC), Eutrophication (EU), Global Warming Potential (GWP100) and Photochemical Oxidation (PO). Despite what is usually observed in literature for conventional farms (Milà-i-Canals et al., 2006), LCA results showed that Phase 1 is the less critical of the system (AC 7%, GWP 7%, EU 17% and PO 6%). These results are justified by the fact that the farm, according to regulations, reduces at minimum the use of fertilisers and pesticides, decreasing the generation of an important relevant share of many impact categories considered in LCA for this process. Phase 2 and 3 represent the most detrimental (Phase 2: AC 24%, GWP 30%, EU 21% and PO 17%, Phase 3: AC 68%, GWP 64%, EU 62% and PO 76%). In Phase 2 machineries, transport and fuels represent the major impacts, while in Phase 3 the most critical input corresponds to the glass packaging phase. Emergy results highlight a quasi-self-sufficiency of the considered system. In fact the imported flows (F) are very low and it is remarked also by the EIR indicator. The% renewability (%R) is nearly 80%. Transports have a considerable weight in the amount of impacts due to the purchase of apples from other regions that the farm sells as fresh market. The transport of fruits through long distances has usually a relevant impact, and the farm should limit or totally eliminate this unsustainable scenario. Finally, glass represents another major input of the farm and probably the use of a lighter type of glass would decrease impacts related to the bottling phase. Results obtained from the two methodologies provide a wide range of useful information to better identify environmental hotspots of production systems and also to communicate to producers the opportunities to improve their sustainability.

References

Guinèe, J. B., Gorreèe, M., Heijungs, R., Huppes, G., Kleijn, R., de Koning, A., van Oers, L., Wegener Sleeswijk, A., Suh, S., Udo de Haes, H. A., de Bruijn, H., van Duin, R., Huijbregts, M. A., 2001. Handbook on Life Cycle Assessment. Operational Guide to the ISO standards, Kluwer Academic Publisher: Dordrecht, The Netherlands

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

Odum, H.T. 1996. Environmental Accounting: Emergy and Environmental Policy Making. John Wiley and Sons, New York. 370 pp.

98. Preliminary research on the analysis of life cycle assessment in the production of rapeseed and biodiesel in Poland

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The aim of the project is to gather necessary information to perform LCA analysis on rapeseed production and its conversion to biodiesel, the execution of these studies according to ISO standards adopted by LCA software as well as a professional presentation of the survey results at different levels of administration and biodiesel production plants.

Poland, like every other country in the EU is committed to reducing greenhouse gas emissions. The main road leading to this is to be the increased use of RES. In this situation, particularly important research, studies, analysis and technical-organisational measures are aimed at securing the implementation of its obligations for Directive 2009/28/EC of 23 April 2009. From the moment when the Directive comes into force in order to promote RES, bioethanol or biodesiel must ensure the reduction of greenhouse gas emissions by 35% and from 2017 by 50%, moving up to 60% in 2018 compared to conventional fuels. Reducing emissions is to be determined by life cycle analysis (LCA).

The developed database contains the information on energy costs over the cycle of cultivation, harvesting and storage and processing of biomass under Polish conditions. Survey (200) was conducted on farms producing rapeseeds for biofuel production.

The average GHG emission was 24.5 g eq. CO_2 MJ^{-1}. The LCA analysis for the production and processing of biomass to biodiesel were performed with SimaPro. The greenhouse gas emissions were incorporated into an assessment of environmental impacts such as acidification, eutrophication, loading with organic compounds, inorganic, toxicity to humans and ecosystems, and carcinogenic impact. The results from the research will be adjusted to a scale of administrative regions in accordance with the requirements from the European Commission, where member states are obliged to present the results of LCA for liquid biofuels for administrative units NUTS-2.

References

Directive 2009/28/EC. The European Parliament and of the Council on the promotion of the use of energy from renewable sources amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.

99. The construction of a database for the evaluation of greenhouse gas emissions from cultivation of crops for biofuels in Poland

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Poland, like every other country in the EU is committed to reducing greenhouse gas emissions. The main road leading to this is to be increased use of Renewable Energy Sources (RES). In this situation, particularly important research, studies, analysis and technical-organisational measures aimed at securing the implementation of its obligations Directive 2009/28/EC of 23 April 2009. From the moment when the Directive comes into force in order to promote RES, bioethanol or biodesiel must ensure the reduction of greenhouse gas emissions by 35% and from 2017 by 50%, moving up to 60% in 2018 compared to conventional fuels. Reducing emissions is to be determined by life cycle analysis (LCA).

The study included farms producing raw materials that can be used to produce liquid biofuels. The farms (1500) producing winter wheat, maize and oilseed rape were selected at random and surveyed thoroughly. The sample size was set at 3% the number of farms producing or likely to produce raw materials for biofuels production purposes. These farms produced raw materials in different soils and different weather conditions between 2005 and 2010 with the exception of extreme conditions (especially farms located in flooded areas in 2010).

References

Directive 2009/28/EC. The European Parliament and of The Council on the promotion of the use of energy from renewable sources amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

100. Environmental implications of using biomass versus fossil fuels for energy production: the case of willow, an energy crop

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Fossil fuel use for energy production is facing serious problems related to resource depletion and environmental degradation, notably climate change. Biomass fuels e.g. wood waste, crop residues, energy crops, in contrast, are considered renewable and carbon neutral. Unlike fossil fuels that take millions of years to be available as an energy source, biomass can be regenerated relatively quickly through photosynthesis. Biomass burning releases CO_2 back to the atmosphere but this biogenic CO_2 is not counted as contributing to global warming. Apart from wood waste and crop residues, energy crops e.g. willow and miscanthus have recently received large attention as a potential source of renewable energy. Whereas biomass is "carbon neutral" when burned, the inputs used to produce it may be a source of CO_2 and other GHG emissions.

Our research questions were: (1) What if the upstream impacts of energy production from biomass fuels, i.e. those connected with biomass cultivation and distribution, are included?, (2) In addition to global warming and non-renewable energy, what about other impact categories like acidification, eutrophication, ecotoxicity, human toxicity, etc., and 3) How to account for trade-offs among different impact categories? A thorough and comprehensive analysis is thus necessary to assess the sustainability of substituting biomass for fossil fuels in energy production. The task is not only to include more impact categories than global warming and non-renewable energy but also to perform the analysis at a more aggregated level, i.e., translating impacts in different mid-point categories into a single unit so that they can be weighted and added together to give a single score value.

In this paper, we present as a case study the results of an LCA study on electricity generation from willow produced on arable land, in comparison with fossil fuels. Inventory data for the entire process from willow cultivation to energy production were from Nielsen and Illerup (2003) and Uellendahl et al. (2008). Midpoint impact categories considered were global warming, non-renewable energy, acidification, eutrophication, respiratory inorganics, human toxicity, ecotoxicity, photochemical ozone and nature occupation. All mid-point impacts were then translated into a single monetary unit. The LCIA method used was Stepwise 2006 (Weidema, 2009). For a verification of the monetarisation scheme used in the Stepwise2006 method versus that used in previous studies, a sensitivity analysis was also performed.

The midpoint impact assessment shows that substitution of willow for fossil fuels would bring both environmental benefits and costs. The substitution for coal offered environmental benefits in all impact categories considered except for nature occupation and eutrophication. The substitution for natural gas reduced impacts on human toxicity, ecotoxicity, global warming and non-renewable energy but increased nature occupation, eutrophication, respiratory inorganics, acidification and photochemical ozone. The results at the aggregated level show that energy production from willow scores better than from coal (0.11 *vs.* 0.12 EUR/kWh) but worse than from natural gas (0.11 *vs.* 0.06 EUR/kWh). Much of this inferior performance is accounted for by the impact on nature occupation of biomass fuel crops; nature occupation is by far the main contributor with a share of approx. 80% of the aggregated single score. Nature occupation thus remains a major environmental hotspot for bioenergy development, stressing the importance of seeking improvements in relation to this indicator in order for biomass fuels like energy crops to be a viable fuel source.

References

Nielsen, M., Illerup, J.B., 2003. Emissionsfaktorer og emissionsopgørelse for decentral kraftvarme, Eltra PSO projekt 3141, Kortlægning af emissionsfaktorer fra decentral kraftvarme, Delrapport 6, Faglig rapport fra DMU, nr. 442.

Uellendahl, H., Wang, G., Moller, H.B. et al., 2008. Energy balance and cost-benefit analysis of biogas production from perennial energy crops pretreated by wet oxidation. Water Sci Technol. 58, 1841-1847

Weidema, B.P., 2009. Using the budget constraint to monetarise impact assessment results. Ecological Economics 68, 1591-1598.

101. Influence of allocation methods in the quantification of the environmental impacts of compost application

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Fertilisation has been reported as one of the key factors for the environmental performance of horticulture products, which are often highly nutrient-demanding, particularly for systems of low technology (Antón et al., 2005; Romero-Gámez et al., 2011). An special case, among fertilisers, is compost. Our previous studies have indicated that compost fertilisers have higher environmental impacts than mineral ones in some impact categories when yields are used as reference flow (Martínez-Blanco et al. 2011).

Compost is also known to be a slow-release fertiliser, usually applied for periods of 1-2 years, considering the nutritional necessities of the annual or biannual crop cycle, in order to avoid individual environmental burdens of transport and machinery for each crop. Therefore, compost is applied at the beginning of the rotation, but is supplying nutrients to all the considered crops.

Therefore, when the burdens of compost production and application have to be distributed among the crops in the cycle, a multifunctional problem arises. According to ISO 14044, wherever possible, allocation should be avoided by dividing the unit process or expanding the product system. Where allocation cannot be avoided, the inputs and outputs of the system should be partitioned between its different products underlying physical relationships, as a first option, or other relationships (e.g. economic value).

Accordingly, the main goal of our study is the comparison of the environmental performance of four crops in a rotation, which are applying compost and mineral fertilisers, when several methods for compost burdens distribution are used.

For the study, four experimental Mediterranean crops (chard, tomato, cauliflower and onion) in a rotation are compared and the reference flow hectare is selected. Three main stages are included within the boundaries of the system: fertiliser production, transport and cultivation. Most of this data were obtained experimentally in the fields and the composting plants, by the authors or from previous research of the group (Martínez-Blanco et al., 2011). When local information was not available, bibliographical sources and the database v2.0 were used. The environmental assessment is following the obligatory classification and characterisation phases defined by the ISO 14044 and four mid-point impact categories are considered (acidification, eutrophication, abiotic depletion and global warming).

Four alternative approaches for compost burdens distribution are compared here: (1) system expansion, i.e. the impacts of mineral fertilisers avoided due to compost use are subtracted from the total burdens; and three allocation alternatives (2) according to compost delayed mineralisation; (3) according to nitrogen crop requirements; and (4) according to economic allocation using cost-benefit values.

Compost burdens distributions are different for the four approaches and thus impact differences with the mineral fertiliser traditional option, for each one of the crops in the rotation, are detected.

References

Antón, A., Montero, J.I., Muñoz, P., Castells, F., 2005. LCA and tomato production in Mediterranean greenhouses. Int. J. Agric. Resour. Gov. Ecol. 4(2), 102–112.

Romero-Gamez, M., Anton, A., Soriano, T., Suarez-Rey, E.M., Castilla, N., 2011. Environmental impact of screenhouse and open-field cultivation using a life cycle analysisi. The case study of green bean production. J Cleaner Prod. On-line, doi:10.1016/j.jclepro.

Martínez-Blanco, J., Muñoz, P., Antón, A., Rieradevall, R., 2011. Assessment of tomato Meditarrean production in open-filed and standard multi-tunnel greenhouse, with compost or mineral fertilizers, from an agricultural and environmental standpoint. J Cleaner Prod. 19, 985-997.

102. How to overcome time variation in LCA

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When performing an environmental impact analysis of food products and processes, LCA appears as a suitable tool. However, there are a number of uncertainties that need to be faced. Current studies regarding life cycle analysis assessment of food products have reported high variability on the results depending mainly on the quality, reliability and significance of the inventory data of the process or product. Functional unit and allocation or selection of system boundaries are other factors that influence directly on results.

All those mentioned factors have been deeply studied; nevertheless, time dependant variations are, still today, a poorly studied variable (Reap et al, 2008). It has been shown that regarding to primary production, and more specifically to the extraction of wild resources, this time scale could lead to an important variability on the obtained results (Ramos et al, 2011). This is due to unpredictable external factors that affect the performance of the activity such as environmental conditions or whether episodes. Regarding food chains there are several sub-sectors which are susceptible to show variations on the impact characterisation depending on the selected period of time.

On the topic of fisheries, recent study has shown great differences on the Global Warming Potential per ton of landed fish when performing a Time-line LCA of the purse seine Basque fleet (Ramos et al, 2011). Furthermore, significant variation in agricultural yields has been also suggested. Thus, in recent study on winemaking by Vazquez-Rowe et al, 2012, significant variability of about 20% is also described for the eutrophication potential in a range of 4 years.

To overcome timeline matters, an approach with Basque trawling fleet have done using Data Envelopment Analysis (DEA) combined with LCA (Iribarren *et al*, 2010). DEA was implemented to identify possible variations between different years for each impact category along the selected period of time. This methodology analyses differences in the efficiency of every single ship of each year and compare different impact categories between the years and between each ship.

Results reported variations up to 25% in all the environmental impact categories between studied years. However, when comparing operational efficiencies between fishing vessels on each year, variations up to 10% have reported. Therefore, DEA+LCA analysis suggest that for the Basque trawling fleet there is no considerable potential to reduce the environmental impact due to the fact that almost all the ships showed similar efficiencies.

On the whole, there is a need to evaluate a wide range of years when performing a primary production LCA. Moreover, it is suggested that combining LCA with DEA could lead to an eco-efficiency benchmarking analysis, in order to support decision-making.

References

Iribarren D, Vázquez-Rowe I, Moreira MT, Feijoo G. Further potentials in the joint implementation of Life Cycle Assessment and Data Envelopment Analysis. Sci Total Environ 2010;408(22):5265–72.

Ramos, S., Vázquez-Rowe, I., Artetxe, I., Moreira, M.T., Feijoo, G., Zufia, J.. 2011a. Environmental assessment of Atlantic mackerel (*Scomber scombrus*) in the Basque Country. Increasing the time line delimitation in fishery LCA studies. Int J of Life Cycle Assess 16 (7), 599-610.

Reap, J., Roman, F., Duncan, , Bras, B. 2008. A survey of unresolved problmens in life cycle assessment – Part 1: goal and scope and inventory analysis. Int J Life CyCle Assess 13:290-300.

Vazquez-Rowe., I, Villanueva-Rey, P. Moreira, Feijoo, G. 2012. Environmental analysis of Ribeiro wine from a timeline perspective: Harvest year matters when reporting environmental impacts. Journal of Environmental Management 98:73-9.

103. The role of spatial modelling using GIS in the development of life cycle inventory for Australian agriculture

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In Life Cycle Assessment, spatial data has been used in a range of applications: to enable site or region specific impact assessment, to track the flow of pollutants through the environment, for biodiversity assessments of land use, and for developing new impact categories such as desertification. However, there has been limited application of spatial data to generate underlying life cycle inventory. This paper examines how spatial data can assist in building a national inventory for agriculture, where a consistent approach across the nation is required, and detailed data collection at all sites or regions is not feasible.

One of the first tasks in establishing national life cycle inventory for agriculture is to define the major production systems that represent the country's production. In some instances, this can be approached using GIS layers to describe land systems within which the production of an agricultural commodity is likely to be relatively consistent. This approach has been applied to Australian wheat and wool production systems, with combinations of GIS layers for soil type, rainfall and land use being used to identify relatively homogeneous regions for production. The goal of national inventory is to present data with a structure that allows both regional differences in production systems to be identified as well as inventory in a format that is appropriate for the next user in the supply chain. GIS layers can be used to provide data to make this inventory spatially explicit.

Emissions to the environment are often dependant on the geo-location of the agricultural production system; this includes emissions such as pesticides, nutrient discharge to waterways and indirect N_2O emissions from fertiliser and animal waste, where regional differences in rainfall, temperatures and soils can be major determinants of flows to the environment. By geo-locating agricultural production these flows can be estimated in a consistent manner across the nation by using appropriate GIS layers.

Inputs from the techno-sphere for a number of important agricultural operations are influenced by factors related to the geo-location of the production system. As part of the AusAgLCI project we have been investigating means of using GIS data layers to standardise and simplify the choice of inventory for agricultural production, so that important factors determining variation in inputs are accounted for without the need for detailed individual research by the LCA practitioner. As long as the geo-location of the production system is known, standard data can be accessed to give appropriate inventory for that region. These include inputs such as pumping energy required for irrigation (largely determined by the height water needs to be pumped) and fuel inputs for cultivation (largely determined by clay content of the soil). With GIS data now at the scale of $5km^2$ or less, it becomes feasible to use this resource to accurately represent the local conditions for agricultural production.

There are a number of ways in which GIS data can be used to enhance the development of LCI, in a manner that assists with consistency for national databases, allows a level of automated updating, and improves the accuracy of data inputs for production systems. The challenge is in turning these opportunities into reality, with the provision of easy to use interfaces between GIS data and LCI, a step that is only just commencing for enabling the use of GIS data.

104. Using spatial data to define industry sub-sectors for Australian wheat

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A Life Cycle Inventory (LCI) for Australian agriculture is currently in development. Within each industry (e.g. crops, livestock, horticulture) sub-sectors need to be identified so that the LCI can be structured in such a way users can identify the most appropriate on-farm production process for their supply chain. For instance, major users of Australian wheat purchase grain based on grade (grain hardness and protein content) rather than the region or production system employed to produce the wheat. However, primary sources of information to describe production data don't necessarily relate well to grade classifications, as grain quality expectations can be affected due to environmental interactions or manipulated through blending of various sources of grain to meet market specifications post-farm gate.

Therefore, in developing a national inventory for wheat it is necessary to define these production systems as regional sub-sectors of the industry, decide how many sub-sectors are needed to represent important differences in environmental impacts, and from these systems construct inventory processes that have utility to the downstream users of Australian wheat.

This paper will explore the GIS methodology needed to define regional sub-sectors for the Australian wheat industry, using a combination of industry expertise and spatial data on land use, soil types, rainfall and other available statistical boundaries and biophysical parameters to capture regional differences which translate into differentiated production systems with differentiated environmental impacts.

105. Improving pesticide accounting in agricultural life cycle assessment: a review of existing LCA practice and available LCA and Ecological Risk Assessment models

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Pesticides require special attention in agricultural Life Cycle Assessment (LCA) because: i) relative to other chemical LCAs pesticides are intentionally applied to the biosphere; ii) they are designed to effect a target group of organisms; and iii) for comparative purposes, they are a characteristic that distinguishes organic and conventional cropping systems (Hauschild 2000). In a complementary paper, van Zelm *et al*. (submitted) characterise an overlap or gap that may exist between LCI (inventory) and LCIA (impact assessment) phases for the toxicity assessment of pesticide emissions in agroecosystems. Specifically, conceptual models or available experimental data used to assess pesticide fate should be compatible with the respective LCI and LCIA phases when considering temporal and spatial scale. This was identified to be an outcome of limited guidance being available for combining location-specific LCI and globally estimated LCIA outputs. However, as LCA has been moving toward more locally explicit impact assessments, similar to that of Ecological Risk Assessment (ERA) (USEPA 1998), accurate characterisation of more complex interactions become increasingly important and the models used in LCI and LCIA phases should be adapted.

An important conceptual difference between LCA and ERA is that they respectively estimate "potential" global and "true" local impacts. It is common in LCA that generic emission factors are used to estimate the extent of chemical distribution between the air, water and soil phases of the environment, with limited accounting of fate beyond the agricultural parcel gate. In contrast, ERA accounts for more complex fate phenomena to define the distribution and emission of pesticides beyond the farm gate, as accurate accounts of these processes are important for risk management. The development of more complex emission models (e.g. PestLCI; Birkved and Hauschild 2006) has seen LCA move toward this level of complexity. However, an inventory of pesticide application and fate management techniques (e.g. buffer zones, etc) according to crop type is needed to improve accurate estimations of chemical distribution and fate for such modelling efforts. This paper presents a review of how LCAs have typically accounted for pesticide fate and distribution in the field together with the main available fate models benchmarked against environmental fate (including transport, transfer and degradation) characterisation approaches typically used in ERA, and proposes some methods to improve this area of research.

References

Birkved, M., Hauschild, M.Z., 2006. PestLCI - A model for estimating field emissions of pesticides in agricultural LCA. Ecol. Model. 198, 433-451.

Hauschild, M. Z. 2000. Estimating pesticide emissions for LCA of agricultural products, in Weidema, B.P., Meeusen, M.J.G (Eds.), Agricultural data for life cycle assessments, vol. 2. LCANet Food, The Hague, pp. 64-79.

United States Environmental Protection Agency (USEPA) 1998. Guidelines for Ecological Risk Assessment, USEPA, Washington.

van Zelm, R., Larrey-Lassalle, P., Roux, P., (submitted). Bridging the gap between LCI and LCIA for toxicological assessments of pesticides used in crop production: application to banana growing, in: 8th International Conference on LCA in the Agri-Food Sector, Saint Malo, France, 2-4 October 2012.

106. Comparison of assessment methods for the environmental impacts of pesticide production

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With regard to the environmental impact of agricultural production systems, the proportion of pesticide production is smaller than that of, for example, chemical fertiliser production (Hayashi, 2011). Although life cycle inventory (LCI) analysis of pesticides has been limited, there have been recent development in estimation techniques for the environmental impacts of pesticide production (Wernet et al., 2008) and for the LCIs of pesticides (Sutter, 2010). However, the differences between the various assessment methods are not well understood, and the practical implications for LCI data construction are not known. Therefore, this study compares different assessment methods for the environmental impacts of pesticide production.

The assessment methods considered in this study include (1) assessment based on ecoinvent 2.2 (hereafter, ecoinvent), (2) estimation using the Finechem tool (hereafter, Finechem), and (3) estimation using emission factors derived from input-output tables for Japan (hereafter, IO). We conducted two comparisons, namely, one between ecoinvent and Finechem, and the other between ecoinvent and IO. Twenty active ingredients were analysed in the first comparison, and 52 pesticide products (13 active ingredients) were assessed in the latter. Global warming (IPCC 2007 GWP 100a) was used as the impact category. S-PLUS (TIBCO Spotfire S+® 8.1J for Windows) was employed for statistical analyses such as regression analysis.

The result of the first comparison showed that it is difficult to find a correlation between the results obtained from ecoinvent and from Finechem (Fig. 1). In general, the variability (standard deviation) in the case of Finechem was larger than that in the case of ecoinvent. The result of the second comparison demonstrated that the determination coefficients of the regression analyses were sufficiently large, and that the regression coefficients were significant at the 1% or 5% levels. The estimated values based on IO tended to be 5 times or 10 times larger than those based on ecoinvent (Fig. 2, Table 1).

These results indicate that under the assumption that estimated values based on ecoinvent are reliable, further study is necessary for developing reliable estimation methods. In addition, although the values obtained from ecoinvent can be predicted from the values obtained from IO, adjustments may be necessary because of the tendency to overestimate in the latter. The dependence of the results on the selection of the assessment method is expected to be resolved by further development of life cycle inventories.

References

Hayashi, K., 2011. Assessing management influence on environmental impacts under uncertainty: a case study of paddy rice production in Japan, in: Finkbeiner, M. (Ed.), Towards Life Cycle Sustainability Management. Springer, pp. 331-340.

Sutter, J., 2010. Life cycle inventories of pesticides, Swiss Centre for Life Cycle Inventories, St. Gallen.

Wernet, G., Hellweg, S., Fischer, U., Papadokonstantakis, S., Hungerbühler, K. 2008. Molecular-structure-based models of chemical inventories using neural networks. Environ. Sci. Technol. 42, pp. 6717-6722.

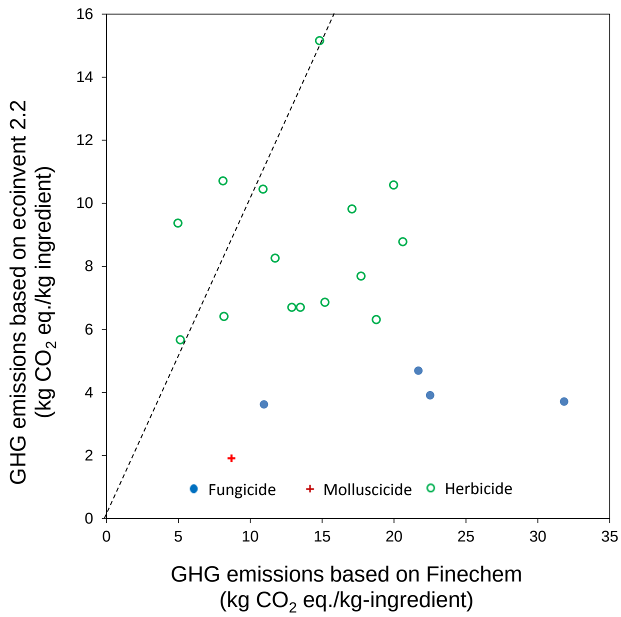

Figure 1. The relationship between greenhouse gas (GHG) emissions based on Finechem and those based on ecoinvent 2.2.

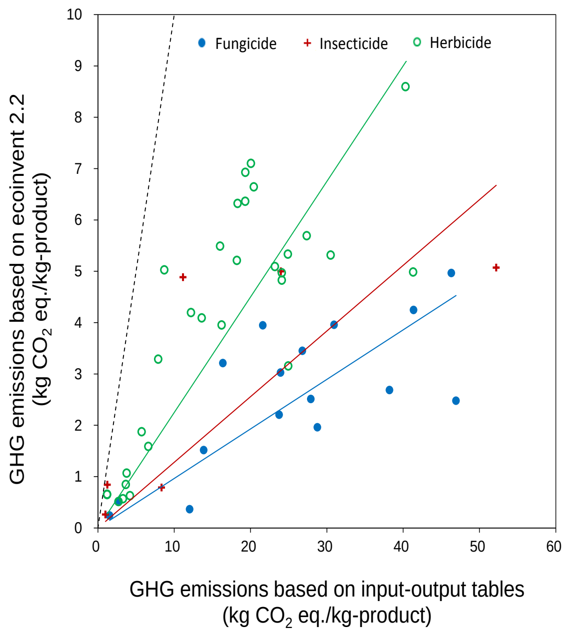

Figure 2. The relationship between greenhouse gas (GHG) emissions based on input-output tables and those based on ecoinvent 2.2.

Table 1. The results of regression analysis without intercepts

Type of pesticide	Adjusted R-square	Regression coefficient
Fungicides	0.881	0.097**
Insecticides	0.702	0.128*
Herbicides	0.880	0.225**

* Significant at 5% level.
** Significant at 1% level.

107. Implementing decision making in irrigation management based on productive and environmental indicators

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Irrigated agriculture faces the need to improve water management practices at a farm level from a productive, social and environmental point of view. To evaluate the performance from a productive and water use efficiency point of view, some indices have been traditionally used (Hoffman et al., 2007; Fessehaziona et al., 2011 and Stirzaker, 2011). They could be classified in three categories: first, Water Productivity or Irrigation requirements based on water consumption, yield and evapotranspiration (ET) estimations; second, Leaching fraction or drainage requirements for soil and water salinity control; and third, Irrigation system performance. To be useful to the irrigator, these indexes should be calculated for each Farm Management Unit (FMU), which may correspond to a particular field where water consumption, potential water crop requirements (ETc), yield, manpower, machinery and other parameters could be assigned. At the end of the season, these indicators could help assessing its strategy, by benchmarking the FMUs performance, think about changes or improvements that may have a beneficial impact on the crop and water use performance of the farm. To be able to steer irrigation management along the growing season and make tactical decisions, reliable information should be obtained at different scales (FMUs, farm and watershed). Assessing practices to reduce the environmental impact of irrigation (mainly, avoiding consumptions beyond real necessities and reducing the impact of leaching and erosion) will have to be done at a FMU scale and be integrated into the manager's dashboard. Therefore, the quantification of water use sustainability indicators should be based on a solid and simple conceptual model, so it can be integrated into the farmer's decision making processes.

This work presents an attempt to implement an inventory procedure at a Management Unit level with the aim of calculating production, water use and environmental indicators to quantify and assess the impact of irrigation, and to integrate it into the managers' dashboard to make strategical decisions. We believe that the results from this project could help orienting the application of the much more complex Life Cycle Assessment (LCA) to quantify and assess the environmental impact of irrigation considering a system beyond the limits of the farm. As a practical trial of assessment of sustanaibility and decision making a case study was carried out in the Ebro Valley near Lleida (NE Spain) where three irrigated farms where chosen during the 2011 growing season. The crops were vineyard, nectarine and corn for silage. In this first year, the goal of the project was to construct a web-based program to calculate the basic production and water use efficiency indicators, based on real data and a solid conceptual model. The idea behind was to validate the results for the studied FMUs, to test if this procedure can be used at a larger farm scale (with many FMUs) and to assess the eventual insertion into the software of environmental sustainability indicators.

By and large, there are several criteria and methods to assess environmental sustainability at farm level, so it provides some increasing variability and uncertainty. Hence, it is needed assessing that from statistical point of view or from large regions. However, that issue lead us to discuss about underestimating or overvaluing the sustainability, highlight the importance of geographical reference units and quantify the uncertainty that these decisions could have to choose the correct criteria for decision makers.

References

Fessehaziona, M.K., R.J. Stirzaker, J.G. Annandale, C.S. Everson.2011. Improving nitrogen and irrigation water use efficiency through adaptive management: A case study using annual ryegrass. Agriculture, ecosystems, environment 141 (2011): 350-358

Hoffman, G.J., R.G. Evans, M.E. Jensen, D.L. Martin, R.L. Elliott (Eds.). 2007. Design and operation of farm irrigation systems. 2nd Edition. ABABE, MI, USA.

Stirzaker, R.J. 2011. Strategy, tactics and heuristics for managing solutes in horticultural crops. Proc. 6th IS on Irrigation of Horticultural crops. Ed.: S. Ortega-Farias and G. Selles. Acta Hort. 889, ISHS 2011

Table 1 Results for the studied Farm Management Units (FMUs) in 2011.

FMU	Area (ha)	Yield (kg ha^{-1})	Water consumption[1] (m^3 ha^{-1})	Energy consumption[2] (kWh)	Acc[3]. ETo (mm)	Acc[3]. Precip. (mm)	WUE[4] (kg m^{-3})	EUE[5] (kg kWh^{-1})
Vineyard	4.2	11,935	2,040	2,859	838	93	4.36	4.17
Nectarine	12.5	44,780	5,424	3,300	897	272	5.86	13.57
Corn	70.0	14,286	6,750	3,000	595	81	1.96	4.76

[1]The irrigation season for each crop was as follows: Vineyard (28 March to 26 Sept 2011; 26 weeks), Nectarine (7 March to 31 Oct 2011; 34 weeks) and Corn (23 May to 12 Sept, 2011; 16 weeks). Irrigation uniformity and application efficiency of the irrigation system was estimated from default values, with sprinklers in the corn and drippers in the other two crops.

[2] Energy consumption (kWh) was provided by the farms' manager.

[3]Weekly weather data (Precipitation and Reference ET) was gathered from nearby automatic monitoring weather stations considering the irrigation season for each crop. Crop coefficients (kc = ETc/ETo) were obtained from local extension agents.

[4]Water Use Efficiency (WUE), considering applied water + effective precipitation.

[5]Energy Use Efficiency (EUE), considering the energy used to pump the water.

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108. LCAs for a large repertoire of Finnish outdoor plant products

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The paper presents results of LCA for a large repertoire of outdoor crops produced in Finland in two resource use categories (land and energy) and three impact categories (climate change, eutrophication and acidification). Assessed crops were cereals, potato, rapeseed, pea, broad bean, carrot, beetroot, yellow turnip, parsnip, Chinese cabbage, onion, strawberry and blackcurrant.

The functional unit of LCAs is the kilo of a product at the farm gate (without packaging). System boundaries include production of agricultural inputs and energy in the upstream phases, and use of agricultural inputs and energy, and mechanical work in the production phase on farms. However, potential packaging and storage on farms, and transportation of agricultural inputs to the farm were excluded from the product systems. Emissions from organic soils were excluded. Data on agricultural input manufacture were obtained from industry, which produces most agricultural inputs used in Finland. Energy consumption was based on the Finnish average grid values. Data on the use of inputs for crop production were based on the national agricultural database, comprising data on the cultivation instances of various crops, i.e. primary data. Data on mechanical work were based on physical models. Data represent average Finnish production. Emissions and impacts from domestic animal production (including manure-based emission from animal shelter and storage) were not allocated to the manure used as fertiliser for plant production. There were no other significant allocation issues.

For the climate impact calculation, estimation of N_2O, CO_2 and indirect N_2O emissions from the field were based on the IPCC method and data (IPCC, 2006). Data on NH_3 emissions from the application of fertilisers were estimated based on models from the EEA (European Environmental Agency, 2006). For the assessment of eutrophication, site-specific nitrogen and phosphorus leaching models and site-dependent factors were applied.

The climate impact and acidification of rapeseed was by far the highest, and the lowest was for root vegetables and potato (Table 1). The eutrophication potential of broad bean was highest, followed by Chinese cabbage, and the lowest eutrophication potential was for carrot, followed by oat and barley. Production of rapeseed consumed most energy, and root vegetables the least. Source of energy varied considerably among products.

It is concluded that the priority order of products varies according to impact category, as indicated in Table 1. CO_2 and N_2O are the main emissions that impact climate. Their share differs for different plants. Figure 1 illustrates the significance of different emissions for climate impact.

The study was part of the ConsEnv-project. The results have been used in the LCA for lunch portions (Saarinen et al., 2012) together with LCA results for animal-based products (Usva et al., 2012).

References

European Environment Agency (EEA) 2006. EMEP/CORINAIR Emission Inventory Guidebook - 2006. Web publication. Available at: http://www.eea.europa.eu/publications/EMEPCORINAIR4

IPCC, 2006. IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4. Agriculture, Forestry and Other Land Use. IPCC-NGGIP Publications

Saarinen, M., Kurppa, S., Virtanen, Y., Usva, K., Mäkelä, J. and A. Nissinen, 2011. LCA approach to the impact of homemade, ready-to-eat and school lunches on climate and eutrophication. J Cleaner Production. 28, 177-186.

Saarinen, M., Kurppa, S., Virtanen, Y., Usva, K., Mäkelä, J. and A. Nissinen, 2012b. LCA approach to the impact of homemade, ready-to-eat and school lunches on climate and eutrophication. J Cleaner Production 28, 177-186.

Usva, K., Nousiainen, J., Hyvärinen, H. and Y. Virtanen 2012. LCAs of average animal products pork, beef, milk and eggs in Finland. Abstract for LCA Food 2012 Conference.

Table 1. Results of LCAs for plant products produced in Finland.

Product	Climate impact, kg CO_2 eq/kg	Eutrophication, g PO_4 eq/kg	Acidification, g AE/kg	Land use, ha/1000kg	Total energy use, kWh/kg
Barley	0.60	1.27	0.67	0.28	0.557
Rye	0.86	2.00	0.80	0.34	0.656
Wheat	0.68	1.44	0.62	0.26	0.554
Oat	0.62	1.26	0.89	0.29	0.588
Potato	0.08	0.25	0.08	0.04	0.054
Rapeseed	1.48	3.39	1.42	0.71	0.949
Pea	0.41	1.55	0.57	0.41	0.516
Broad bean	0.43	4.56	0.58	0.37	0.641
Carrot	0.06	0.11	0.05	0.02	0.024
Beetroot	0.08	0.21	0.07	0.04	0.027
Yellow turnip	0.08	0.20	0.08	0.03	0.039
Parsnip	0.21	0.37	0.16	0.05	0.050
Chinese cabbage	0.25	0.41	0.21	0.05	0.376
Onion	0.13	0.31	0.11	0.05	0.053
Strawberry	0.47	2.59	0.37	0.30	0.703
Blackcurrant	0.45	2.94	0.36	0.33	0.743

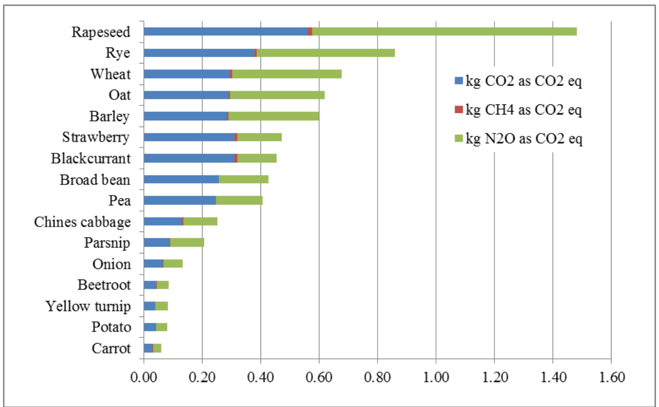

Figure 1. Climate impact per kg product divided by main emissions.

109. Life cycle assessment of long-lived perennial cropping systems: almond and pistachio production in California

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This study characterises typical almond and pistachio orchard production systems in the U.S. state of California. These industrialised agro-ecosystems are of great economic and environmental importance, encompassing more than 361,300 ha of the state's agricultural land and yielding more than 85% of global almond exports and 50% of global pistachio exports. In 2009, 240,000 tonnes of almonds and 82,000 tonnes of pistachio were imported by the European Union (USDA 2009). Commercial nut orchards in California's Central Valley demand significant agrochemical inputs, irrigation, and fuel for mechanised field operations throughout their lifespan - up to 25 years for almond (Duncan et al 2011) and 80 years for pistachio (Beede et al 2008). Due to high-intensity inputs and long lifespans of these systems, the California nut industry is responsible for significant emissions of greenhouse gases (GHGs) and other atmospheric pollutants.
Orchards have the potential to sequester carbon in soils and/or biomass (Kroodsma and Field 2006). In California, much of this biomass is used to produce electricity at regional electricity generation plants, widely distributed in California (Wallace 2007). The potential for sequestration versus emissions offset through use of waste biomass as an energy feedstock is dependent on management characteristics, orchard lifespan, and other factors. Here we present a comparative assessment of the net GHG footprint of California almond and pistachio production, accounting for material and energy inputs of production up to farm gate, excluding processing and distribution as well as annual variation in operations and inputs as trees mature. The study also explores the potential for carbon sequestration and GHG offset under several possible scenarios for both pistachio and almond. Data were gathered from cost-return studies, farmer surveys, and published literature. Transportation characteristics, in-field emissions from fuel combustion, and soil ecological processes were independently modelled. Our analysis provides information for growers on where to focus GHG reduction efforts and offers insights regarding the trade-offs between energy and material inputs and field emissions under different management scenarios, as well as providing an assessment of the typical greenhouse gas and energy footprint of an economically important export commodity.

References

Beede R. H., Kallsen C. E., Holtz B. A., Klonsky K. M., Moura R. L. D., 2008. Sample costs to establish an orchard and produce pistachios: San Joaquin Valley South – Low volume Irrigation. University of California Cooperative Extension. Davis CA.
Duncan, R. A., Verdegaal, P. S., Holtz, B. A., Doll, D. A., Klonsky, K. A., Moura, R. L. D., 2011. Sample costs to establish an orchard and produce almonds: San Joaquin Valley North – Microsprinkler Irrigation. University of California Cooperative Extension. Davis CA.
USDA Office of Global Analysis, 2009. Tree Nuts: World Markets and Trade. United States Department of Agriculture, Foreign Agriculture Service. Washington, D.C.
Wallace H. N., 2007. Feasibility of a California Energy Feedstock Supply Cooperative. California Center for Cooperative Development. Davis, CA.

110. Land use key parameters to be addressed in life cycle assessment study of soybean grains

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Brazil is considered as one of the largest exporters of agricultural products in the world. The growth of Brazilian agriculture in a continuous and solid way is extremely important to improve the quality of life of millions of Brazilians. A great part of this growth has come from the soy complex (grain, meal and oil) whose exports have more than quadrupled over the last 10 years, reaching the value of US$ 23.8 billion in 2011. In 2011, Brazil produced 74.3 million tons of soy, being ranked as the second largest world producer of soy with 26% of the world crop, estimated at 263.7 million tons. The cultivation of soy occupies the largest area (35.7%) among the products of the annual and perennial crops of the country. Soy is planted practically all over the country with the Center-west (49%) and South (34%) being two of largest areas. The recent expansion of the crop has taken place in areas of degraded pasturelands. Due to the importance of this crop to the country, the objective of this work is to select important parameters relative to the land use which can be considered in a life cycle assessment study of soy grains. The first selected parameter is the occupation of agricultural lands for this crop. The country has an area of 8.5 million of km^2 of which 37.3% is used for general agricultural and pasture purposes and 25.6% for cultivation of food products such as meat and vegetables. As the parameters for land use have not been established yet for LCA purposes in the country, 2.18 million of km^2 was considered as the reference area for normalisation of land for food production. The average land occupation for the soy crop 1.12 m^2yr per ton produced in 2010. Besides the territorial occupation itself the authors suggest that the total amount of fertilisers in relation to the nitrogen, phosphorus and potassium macronutrients as well as the total amount of pesticides (only actives) used per hectare could be indicative of the human interference on the land. These indicators are independent of the climate, temperature, relief, type of the soil or other factor that minimises the anthropogenic interference due to the capability of nature recovering. They are also independent of time, a key parameter in agricultural impacts. The impact of land use could be evaluated by soil organic matter content as this measure is considered as the one of the best stand-alone indicator of life support functions of land. Soil organic matter, consisting mostly of C, is the largest terrestrial pool in the C biogeochemical cycle. Soil organic matter, although occupying only 5% of the total soil volume, has an important influence in soil physical, chemical and biological properties, directly influencing the productivity of soybean. Management systems capable of maintaining and even increasing the soil organic carbon may stocks contribute to maintaining the productive capacity of soils and to mitigate the problem of increasing atmospheric CO2.

References

Milà i Canals L., Romanya J., Cowell S.J., 2007. Method for assessing impacts on life support functions (LSF) related to the use of 'fertile land' in Life Cycle Assessment (LCA). J. Clean. Prod., 15, 1524-1440.
Guinée JB et al, 2001. Life Cycle Assessment – An operational Guide to the ISO Standards, Leiden.
Instituto Brasileiro de Geografia e Estatística - IBGE, 2012. SIDRA- Banco de Dados Agregados. Produção agrícola municipal.
Associação Brasileira das Indústrias de Óleos Vegetais, 2012. Dados estatísticos do complexo soja.
Brady NC, 1989. Natureza e propriedade dos solos. São Paulo, McGraw-Hill, 878p.
Campos BC et al, 2011. Long-term C-CO_2 emissions and carbon crop residue mineralization in an oxisol under different tillage and crop rotation systems. Rev. Bras. Ciênc. Solo, 35, 819-832.

111. Comparison of the sustainability of different potato production systems: use of AgBalance methodology to identify strengths and weaknesses of organic, conventional and genetically modified (GM) disease-resistant potato cultivation

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AgBalance is a new LCA-based methodology to assess sustainability in the agricultural value chain in a comprehensive and holistic way. AgBalance is based on BASF's Eco-Efficiency and SEEBALANCE Analysis, to which, in consultation with international stakeholders and experts, new indicators specific for agriculture were added. AgBalance integrates over 200 data points in up to 70 indicators covering ecological, economical and social aspects of agriculture and received a validation of coherence and functionality from Det Norske Veritas (DNV), TÜV Süd as well as the National Sanitation Foundation (NSF) in the US.

Herein we present a case study using the AgBalance methodology, that investigated the factors determining the sustainability of different potato production systems in Germany. In general terms, potatoes are cultivated either using organic standards as defined by the EC Regulation 834/2007 or using conventional cultivation practices.

Potato late blight is a fungal disease caused by *Phytophthora infestans*, which accounts for annual losses (costs of control and damage) estimated at more than € 1,000,000,000 in the EU alone. BASF has developed a potato with a full and durable resistance against late blight through introduction of resistance genes from a wild potato by genetic modification (GM) technology into a modern European potato variety

We compared the sustainability of organic, conventional and genetically modified (GM) disease-resistant potato cultivation using the AgBalance method. Agronomic input data is taken from KTBL publications, the state office for agriculture in Lower-Saxony, federal ministry agriculture statistics and further public databases such as EUROSTAT. This data is representative of the 2007/08 growing season. Average yields are assumed to be 45 t/ha for the conventional and GM-, and 25 t/ha for the organic cultivation system.

Under conditions of moderate Phytophthora infestation, the aggregated sustainability impact score of the GM potato is similar to conventional varieties. The organic cultivation system receives a somewhat worse impact score, mainly due to the lower yield and the use of copper hydroxide in relatively high amounts. Applying scenario analysis, the effect of increased levels of infestation pressure is shown to result in significant environmental and economic benefits of the GMO potato, as conventional and organic production systems are affected by increased application rates of fungicides and yield losses. At the level of individual impact categories, there are marked strengths and weaknesses in each of the three alternatives. The GMO and conventional production are associated with fewer burdens through land use, acidification potential and emissions to water. Organic potato on the other hand is associated with less pressure on biodiversity in agricultural areas, less energy and resource consumption and global warming potential. On the economic side, there are no major differences in macro-economic indicators such as farm profits and subsidies, but production costs for organic potatoes are much higher. The differences in the social stakeholder categories are rather small, which is partly related to trade-offs between indicators that relate to benefits (positive implication, e.g. wages) as well as to burdens (negative implication, e.g., working accidents).

Taken together, AgBalance has proven to be a useful methodology to look at the sustainability of potato cultivation in a holistic way. AgBalance identifies the strengths and weaknesses of the different potato production systems and can deliver guidance for sustainable development in potato cultivation.

References

KTBL: Betriebsplanung Landwirtschaft 2006/7, 20. Auflage 2006. ISBN: 3-939371-07-6

Saling P., Kicherer A., Dittrich-Kraemer B., Wittlinger R., Zombik W., Schmidt I., Schrott W., Schmidt S., 2002. Eco-efficiency Analysis by BASF: The Method. Int. J. Life Cyle Assess. 7, 203-218.

Kölsch, D., Saling P., Kicherer A., Grosse-Sommer A., Schmidt I, 2008. How to measure social impacts? A socio-eco-efficiency analysis by the SEEBALANCE® method. Int. J. Sustain. Dev. 11, 1 – 23.

Schöneboom J.C., Saling P., van Gelder R. 2012. AgBalance – Holistic Assessment of Sustainability in Agriculture. Submitted to Int. J. Life Cycle Assess.

112. Modelling Estonian field crop farm types for LCA

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Food and beverage final household consumption in EU accounts for 22–34% of total life-cycle impacts in all environmental impact categories (except eutrophication that accounts 60%) (Tukker et al. 2006). Furthermore, different agricultural production practices have different impacts on environment. Thus, assessment through life cycle is needed to choose the best practises and mitigate pressure on environment.

Although, field crops have significant share in Estonian agricultural production, no agricultural LCA studies have been done in Estonia so far. There are huge variability in resource use and environmental impact between farms because of the variation in actual practises (Halberg 1999). Most of the LCA-s are based on data from case studies (Pfefferli and Gaillard 2000). To ensure the representativeness and to aim more general validity, assessment should be based on a larger sample of farm data. There are huge differences between countries in agricultural practices, therefore country-specific inventory data about farm practises is needed. In addition, environmental assessment through the life cycle taking account local conditions is necessary.

The aim of this paper was to create representative farm type models of Estonian arable crop farms based on different characteristics – main product type, management type, animal density (in case of mixed farming) – for further life cycle assessments. Different data sources were used to create inventory data of Estonian field crop farm models: systematic statistics, farm accountancy data networks, experiments, surveys, recommendations and expert opinion. Data of land area, energy and fertiliser use, yields and other characteristics are presented for each farm type. Challenges on creating farm type models are discussed.

References

Halberg, N., 1999. Indicators of resource use and environmental impact for use in a decision aid for Danish livestock farmers. Agriculture, Ecosystems and Environment 76 17-30.

Pfefferli S., Gaillard, G., 2000. Development of a new management tool by combining LCA and FADN. In: Weidema, BP., Meeusen MJG., (eds.), Agricultural data for life cycle assessments, Vol 2., Agricultural Economics Research Institute, The Hague, The Netherlands, 137-144.

Tukker, A., Huppes, G., Guinee J., Heijungs, R., de Koning, A., van Oers, L., Suh, S., Geerken, T., van Holderbeke, M., Jansen, B., Nielsen, B., 2006. Environmental impacts of products (EIPRO). European Science and Technology Observatory and Institute for Prospective Technological Studies, Seville, Spain. Available from: http://ec.europa.eu/environment/ipp/pdf/eipro_report.pdf

113. Developing innovative technical agronomical practices in sunflower cultivation for industrial applications: experience from central Italy

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At worldwide level biomass is mostly exploited for producing materials rather than for energy use. Within the PSR Umbria project (Piano per lo Sviluppo Rurale - Cooperazione per lo sviluppo dei nuovi prodotti, processi e tecnologie nei settori agricolo e alimentare e in quello forestale) a biodegradable hydraulic lubricant was developed starting from sunflower oil with high oleic acid content. Such a lubricant, functionally equivalent to the fossil-based one, is characterised by a lower persistence in the environment since it is biodegradable. The PSR project was focused also on the development of innovative (low impact) technical agronomical practices for sunflower cultivation. Basically two high oleic sunflower cultivars (i.e. VarA and VarB) have been selected and tested with three different agronomical practices: "normal input" (i.e. traditional cultivation with a normal input of fertilisers and pesticides), "low input" (i.e. fertilisers were reduced by 50%) and "zero input" (i.e. no fertilisers applied but green manure before sunflower sawing). The lower input practices have been tested because the inputs to the agricultural phase (e.g. fertilisers, pesticides etc.) are generally higher than the actual needs of the crop as confirmed by experimental data reported in Table 1, where it is interesting to notice that the crop yield for the "low input" and "zero input" is equivalent or even higher compared to the "normal input". In reference to the "zero input", it is important to point out that, according to previous filed trials performed elsewhere, it was observed that green manure practice in sunflower cultivation, provides the right amount of nutrients (e.g. nitrogen) without generating a depletion of them,in the soil, rather they increase. Further the crop yield remain constant and similar to that generally obtained in a "normal input" practice also in the long run but with the advantage that the green manure practice protects the soil from erosion as well.

These practices have been assessed by LCA analysis where the functional unit was defined as the production of 1 kg of oleic acid. Also the oil cake (the co-product of mechanical oil extraction) uses (i.e. animal feed or energy utilisation) have been included in the analysis. LCIA results show that the highest benefits were reached in the "zero input" where the oil cake is used for energy purposes.

Basically it has been demonstrated that the right match between the sunflower cultivar, the geographic area, the integrated production of sunflower oil, contribute to reduce loads to the environment making the whole agricultural system particularly efficient.

References

Raschka, A., Carus, M.,2012. Industrial material use of biomass. Basic data for Germany, Europe and the world. Nova-Institute GmbH Chemiepark Knapsack, Industriestrasse, Hurth (Germany).

Laureti D., Pieri S., 1999. Fertilizzazione Biologica del Girasole. L'informatore Agrario, supplemento al n.10, 20-23. Istituto Sperimentale per Colture Industriali di Bologna – Sezione di Osimo (Ancona)

Laureti D., Pieri S., 2001. Sovescio di leguminose nella fertilizzazione del girasole. L'informatore Agrario, n.30. Istituto Sperimentale per Colture Industriali di Bologna – Sezione operativa periferica di Osimo (Ancona)

Table 1. Experimental data (2011) – Silveri farm

Agronomic pathway	**Sunflower cultivar**	**Yield (t/ha)**	**Moisture (%)**	**Dry matter DM (kg/kg fresh seeds)**	**Oil (% on DM)**	**Oil extraction yield (%)**	**Extracted oil (kg/kg fresh seeds)**	**Oleic acid content (%)**	**Sunflower seeds (kg fresh matter per kg of oleic acid**
NORMAL INPUT	VarA	2.3	4.8	0.952	51.2	80	0.390	89.0	2.9
	VarB	2.5	5.1	0.949	42.8	80	0.325	88.5	3.5
LOW INPUT	VarA	3.0	5.1	0.949	48.5	80	0.368	89.8	3.0
	VarB	2.8	6.2	0.938	39.1	80	0.293	88.4	3.8
ZERO INPUT	VarA	2.7	6.8	0.932	48.5	80	0.361	89.9	3.1
	VarB	2.2	6.4	0.936	45.1	80	0.338	88.5	3.4

114. Effects of different crop management on durum wheat GHGs emission

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Having all the impacts, associated with different management typology of the agro-ecosystem, assessed through the use of LCA methodology according to an implementation of the data collected directly from the field to minimise data uncertainties, could be a very sensitive model which can support the current political action plans for reduction of the impacts which lead to the environmental effects. Moreover, the use of this kind of model to identify more sustainable combination of agricultural practices could satisfy the agronomists, economists as well as environmentalists once the productivity of the system is being maintained with as low inputs and emissions as possible.
For that, an on farm field trial in Southern Italy (Basilicata Region) was conducted to evaluate alternative agricultural practices that could help farmers to reduce reliance on fossil fuel, lower the input costs and decrease the GHG emissions of durum wheat production systems through life cycle assessment (LCA) method. The focus of this study was specially oriented to the potential GHGs emitted (expressed as CO_2-eq) as a consequence of the different levels of soil tillage (intensive (IT), reduced (RT) and conservative (CT) combined with different nitrogen fertilisation rates (90, 60, 30, 0 kg N ha^{-1} as urea). A special attention was given to grain yield as this represents the main farmers' objective and was being further correlated to the emissions.
The LCA analysis considered the entire system of the field experiment in which each treatment was replicated three times and the farm gate was considered as the system boundary. Inventory data of all agricultural operations in the field including tillage, seeding, fertilisation, herbicide application and harvesting, have been collected. Then, all data were used to estimate and compare (Through SimaPro 7.3 using the IPCC 2007 GWP 100a method for comparison) the impacts of different wheat production systems. Furthermore, in spit of all the data collected directly from the field, nitrogen balance was also calculated as the differences between nitrogen inputs and outputs of total nitrogen in the soil, grain, straw and plant residues sampled.
This study showed that there was a higher proportion of energy consumption and GHG emissions attributed to N fertiliser and to the ploughing operations for the production of wheat. The GHG emissions of different wheat production systems showed statistically significant differences within the treatments (tillage and N fertiliser rate), but no significant differences found in the interaction between tillage and N fertiliser applications.
Going deep into the analysis, we found that the highest CO_2-eq emissions was reported in the intensive tillage (IT) with 90 kg N ha^{-1} mainly because of the high emissions associated with the fertiliser and fuel production. The overall emissions were lower in conservation tillage (CT) and in reduced tillage (RT) systems compared by intensive tillage (IT) system due to the diesel fuel consumption which resulted from the high number of field operations.
On the basis of this first year of activity, conservation tillage (CT), represent a more environmentally-friendly system of wheat cultivation, which could sequester more CO_2, and as a consequence gave lower emissions and impact on the environment than both other systems. In contrast, intensive tillage (IT) was the worst in all scenarios.

115. Environmental and economic life cycle assessment of organic and conventional olive systems

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The environmental awareness of the agricultural sector has been increasing during the last decades. Covering the environmental impacts of any agricultural product or service became a fundamental trend towards the optimal selection between different alternatives to improve the production. Organic farming has been reported to be an innovative system that contributes to the reduction of environmental impacts of agricultural practices. This study will investigate this assumption through a comparison of the environmental impact and the economic performance between two production systems of olive cultivation in Apulia region-Italy.
Based on a survey for farms selection, two olive farms have been selected for a case study of organic and conventional management systems. The criteria of farms selection was based on the similarity of general characteristics (location, olive variety, trees age, irrigated, planting system) and the dissimilarity of agricultural practices management, particularly fertilisation, soil management, pest and weed control.
LCA based methodology, adopting the Eco-indicator 99 method, has been used for assessing the environmental impact. Data collection has been analysed by SimaPro software considering 1 hectare as a functional unit with a system boundary limited to olive production (cradle to farm gate).
The olive life cycle was assumed to extend over 50 years and was divided into three phases: juvenility phase (4 years), growing phase (13 years) and productive phase (33 years). The environmental impacts were roughly similar during the juvenility and growing phases due to the likeness of the conventional managements in both case studies. Environmental results below are associated to the productive phase when the organic farm was certified organic and the conventional farm changed into no-tillage conventional system.
Fertilisation and soil management activities resulted in a higher environmental impact in the organic system compared to the conventional one, in terms of both single impact category and damage categories (damage to the human health, ecosystem quality and resources). This is due to the emissions induced by the transportation and application of animal manure as well as the higher fuel consumption for managing the soil in the organic system compared to no-tillage conventional one. Nevertheless, the total environmental impact of agricultural practices was lower in the organic system compared to the conventional one, mainly the lower impact on the fossil fuel depletion as a result of the more recurrent weed and pest control activities in conventional system. In fact, the total environmental impact caused by pest control activity was higher in the conventional system even if carcinogenic effects, ecotoxicity and minerals depletion impact categories were higher in the organic system, as a result of copper products uses for pest control.
LCC methodology has been used for assessing the economic performance of both systems by calculating all costs and revenues over the life cycle. No large differences were registered between the farms in terms of costs and revenues in juvenility and growing phases, while bulk differences were recorded in the productive phase. The organic system resulted in higher total costs and lower yield compared to the conventional one. However, it showed higher revenue and consequently higher net income thanks to the higher selling price. Both systems had a positive Net Present Value (NPV), showing a positive investment. Furthermore, the Internal Rate of Return (IRR) resulted, in both farms, higher than the bank interest rate (1.25%). The organic system resulted to have a higher NPV and IRR than the conventional one. Therefore, according to the farming price system and based on the profitability and financial analyses, the organic system can be considered a more profitable investment system than the conventional one.

116. A life cycle assessment of rice cultivation

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Rice cultivation represented about 22% of the world´s grain crops area in 2008 (FAO 2010). It is cultivated across a vast area spanning wide ranges of temperate, subtropical and tropical climates. Various climatic and socio-economic conditions at different locations effect the rice cultivation and the environmental impacts going along with it. Rice cultivation however is a major source of green house gasses, especially methane (CH_4) (e.g. Sass 2005; Yan 2005). However, the alternation in wetting and drying to mitigate methane emissions can increase nitrous oxide (N_2O) emissions through enhanced nitrification and de-nitrification (Akiyama 2005a & b). Complex mechanisms impact not only global warming potential (GWP) but also acidification (AP), eutrophication (EP) and photochemical ozone creation (POCP). The objective of this study was to assess the environmental performance of different rice cultivation systems in various countries and climates.

Eight cropping systems have been chosen for data collection on precipitation, soil type, irrigation system, fertilisation, field operations, and pesticide use: conventional, irrigated, lowland rice cultivation in China (CC); deepwater rice cropping system in India (DWI); irrigated, conventional, lowland rice cultivation in India with rice straw incorporation (II) and with rice straw burning (IB); irrigated, conventional, lowland rice cultivation in the Philippines with two cropping cycles (IP2) and with three cropping cycles per year (IP3); irrigated, organic rice cropping system in Japan (OUJ) and a rain-fed, conventional, upland rice cultivation system in Japan (UJ). Rice systems were compared on a hectare (ha yr-1) as well as a product (kg ha-1) basis. The life cycle assessment followed ISO 14040. The inventory quantities fossil/renewable primary energy demand (PED) and water use (WU) were analysed. GWP, AP, EP and POCP were computed according to the CML method (Guinée 2002).

Upland rice systems (UJ and to some degree OUJ) showed lowest impacts among the rice-cropping systems tested in WU, GWP, AP and POCP and one of the lowest in PED and EP. OJ performed well in PED, GWP, POCP, AP and WU. On the other hand, the highest environmental impacts was caused by the systems IP2 and IP3, due to high inputs of fertiliser, diesel etc. along with low yields. The main emissions were released in the field by decomposition of nitrogen into NH_3, NO_{3-} and carbon into CH_4. Fertiliser production and diesel combustion in tractors and diesel generators of irrigation pumps were identified as additional sources of emissions. A removal of straw for bio-energy or burning on the field reduces nitrogen (i.e., N_2O, NO_x, NO_3^-) and carbon related emissions (CH_4). At the same time potential accumulation rate of soil organic carbon decreases and consequently increase PED and GWP due to the additional demand for mineral fertiliser. The main challenges were identified as the water regime and organic inputs, as well as the type of soil, the climate, the field management and the production and intensity of fertiliser use.

References

Akiyama, H., Yagi, K., Yan, X., 2005. Summary of N_2O emissions from rice paddy fields: Summary of available data. Global Biogeochemical Cycle 19: 1005.

FAO (2010). FAOSTAT database, Food and Agriculture Organization (FAO). Rome

Guinée, J. B., 2002. Handbook on LCA: Operational Guide to the ISO Standards. Netherlands

Watanabe, A., Kimura, M., 1999. Influence of chemical properties of soils on methane emission from rice paddies. Commum Soil Sci Plant Anal. 30: 2449-2463.

Yan, X., Yagi, K., Akiyama, H., Akimoto, H., 2005. Statistical analysis of the major variables controlling methane emission from rice fields. Global Change Biology 11 (7): 1131-1141.

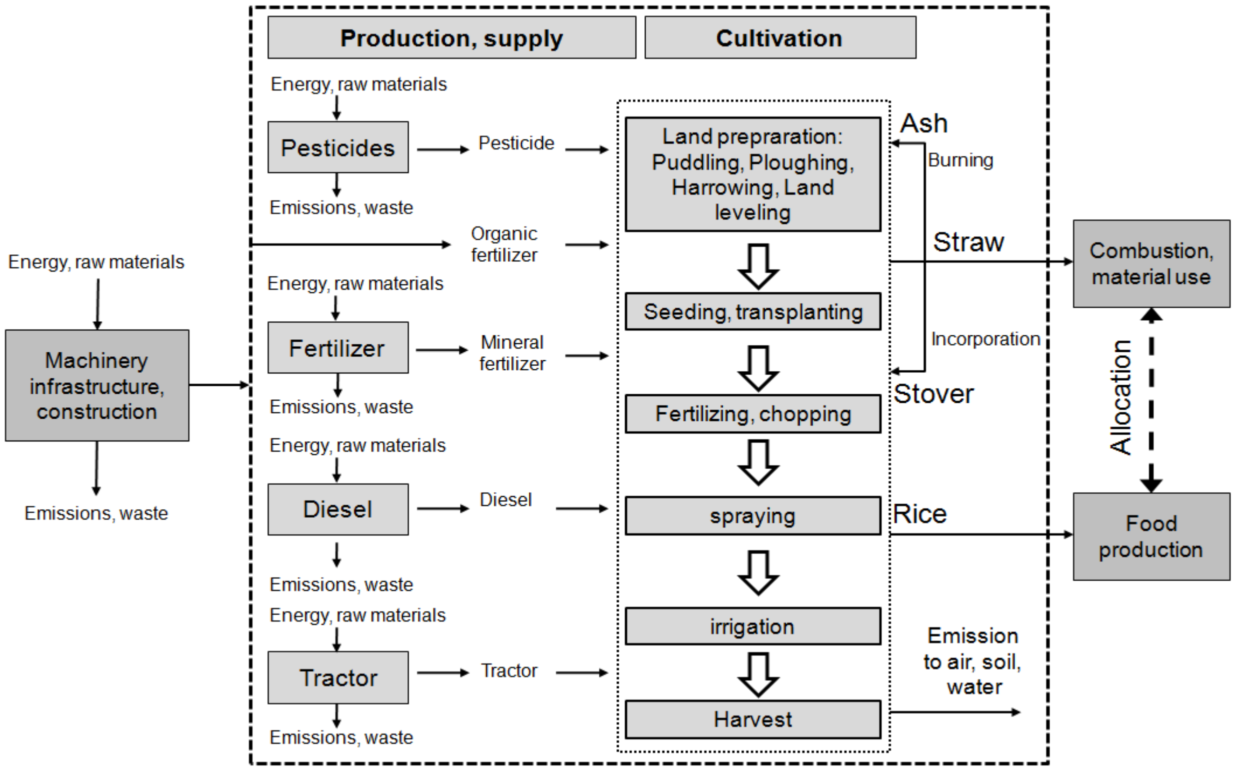

Figure 1. System boundaries of the LCA study applied for the various rice cropping systems.

117. Environmental assessment of rice production in Camargue, France

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In a context where environmental labelling tends to become certain, life cycle inventories of agricultural productions are key elements for the food product assessment. The herein study focuses on rice crops in the Camargue area (south of France), and the functional unit is "to produce one ton of rice".

The system is limited to the field operation, and does include transportation after harvest and recycling of agricultural machinery. The inventory is based on generic data available in the ecoinvent database. Cultural practices and crop yield from real data of Sud Céréales (an agricultural cooperative, main rice producer to Camargue) are used to describe the system. In this context, consistent with the regulation, crop residues are ploughed in. Models proposed in the literature are used to assess the emission from fertilisation, and methane release from rice fields is calculated using the IPCC model (IPCC 2006).

The life cycle impact assessment is carried out with the Impact 2002+ method (except for climate change where characterisation factors over 100 years are used). Results are put in front of American rice production available in the database. This comparison shows the environmental benefit of the Camargue rice (a decrease of 42% for greenhouse gas emissions) mainly due to more efficient submersion practices. Fertilisation (production and crop emission) is the most polluting step for all impacts; methane release is also a problem (Fig. 1). A sensitivity analysis underlines the lesser importance of agricultural machinery and the importance of the model chosen to assess the fertilisation. A decrease in yield would also cause greater damage to the environment; this is in accordance with a "mass based" functional unit.

References

IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme. Eggleston, H.S., Buendia, L., Miwa, K., Ngara, T., Tanabe, K., (Eds). IGES, Japan.

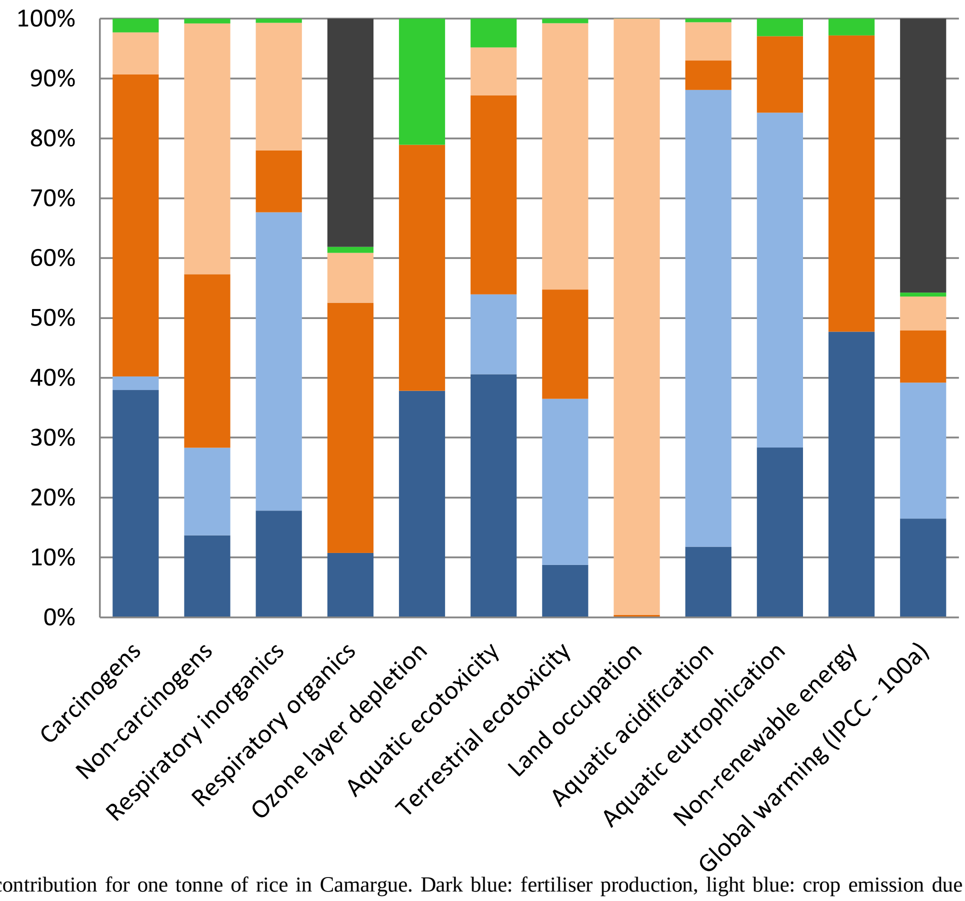

Figure 1. Process contribution for one tonne of rice in Camargue. Dark blue: fertiliser production, light blue: crop emission due to fertiliser, dark orange: machineries and fuel production, light orange: crop emissions due to agricultural acts, green: pest treatment consequences and grey: submersion practice.

118. Allocating environmental burdens from fertilisation to crops in a rotation

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Allocation is a complex issue for LCA practitioners. Due to many allocation methods, the choice between them can have a significant impact on the results. It is particularly relevant when applying LCA to assess fertilisation impacts as all nutrients brought by fertilisers are not all taken up by the crop in the system under study but remain available for future crops in rotation. Crop residues also produce nutrients which return to soil after harvest. Hence, these nutrients can be considered as co-products from the crop.

Fertilisation contributes highly to different potential impacts for crops: it induces in particular 30-60% of the primary energy consumption, 60-80% of the global warming potential, 90% of the eutrophication potential, 80-90% of the acidification potential (personal communication from ARVALIS and UNIP). Thus, allocation method used to allocate fertilisers to crops can be decisive for the LCA outcomes.

Allocating burdens from fertilisation is a subject of concern since the beginning of agricultural LCA and different reports dealt with this issue (Audsley et al. 2003; Gac et al., 2006). Recently, a working group (Agri Footprint Method, Blonk 2010) made recommendations to take into account mineral and organic nutrients from synthetic fertilisers, manure and crop residues. However, these references rarely lead to common accepted rules in term of methodology or their suggestions are not always easy to apply because of data availability.

In the framework of a project aiming at assessing environmental impacts of crop fertilisation by LCA, a bibliography review has been conducted to identify the different solutions involved in LCA literature regarding allocation rules for PK nutrients in synthetic fertilisers, N from manure and N from crop residues (Table 1).

Considering this large range of choices, allocation rules have been selected in order to be tested on study cases which will simulate levers to reduce impacts from fertilisation such as cover crops introduction and the use of different types of fertilisers (mineral and organic). These simulations will assess the rules feasibility and identify the most consistent. This work will result in recommendations about cropping plan allocation for mineral and organic N, P, K nutrients and for crop residues, regarding the aim of the study and the data availability.

References

Audsley et al. 2003, Harmonisation of environmental life cycle assessment for agriculture, final report DG VI Agriculture 2003, 101p.

Blonk et al. 2010, Methodology for assessing carbon footprints of horticultural products - A study of methodological issues and solutions for the development of the Dutch carbon footprint protocol for horticultural products Blonk Milieu Advies p.36-40

European Commission 2010, ILCD Handbook, General Guide for Life Cycle Assessment – detailed guidance, 394p.

Gac et al. 2006, GES'TIM Guide méthodologique pour l'estimation des impacts des activités agricoles sur l'effet de serre, Version 1.2, 156p.

William et al. 2006, Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities. Defra project report IS0205, 97p.

Table 1. Allocation rules proposed in the literature for PK nutrients in synthetic fertilisers, N from manure and N from crop residues

Reference	Allocating PK	Allocating N from manure	Allocating N from crop residues
ILCD Handbook 2011	Attributional or system extension recommended	Attributional or system extension recommended	Attributional or system extension recommended
Blonk et al. 2010	To each crop in rotation according to recommended quantities	Slowly degradable N fraction equally to the crops in rotation, quickly degradable N fraction to the current crop	According to surface areas
Gac et al. 2006	To each crop in rotation according to the requirements	According to degradation dynamic or equally between the crops in rotation (between two applications)	-
Williams et al. 2006	To the current crop except if it is an exigent crop (ex. Potatoes). In that case: surplus P to each crop according to requirements	To the current crop	-
Audsley et al. 2003	To each crop in rotation according to the recommended quantities	To each crop in rotation according to the recommended quantities	-

119. Designing sustainable crop rotations using life cycle assessment of crop sequences

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The project CAS DAR PCB (Amélioration des performances économiques et environnementales de systèmes de culture avec Pois, Colza et Blé) aimed at analysing and optimising crop rotations in three French regions by the selection of crops in a crop rotation, defining their sequence and by different nitrogen fertilisation levels. An LCA study of a large number of crop rotations is very time consuming. Therefore the different sequences of previous crop-main crop were defined and analysed by LCA, considering the effects of a specific previous crop on cultivation, fertilisation, yield and emissions of the main crop. These crop sequences were subsequently combined to analyse 58 crop rotations. Two functional units were used in this analysis: hectare per year and € gross margin II. The study focused on the effect of legumes and reduced N fertilisation on environmental impacts.
Production data were collected by the Chambers of Agriculture for a typical cultivation in Burgundy, Beauce, and Moselle for the reference period 2002-2008. The yield data were taken from survey of field level by the Chambers of Agriculture. Background data describing infrastructure, inputs and processes stemmed from the ecoinvent database version 2.01 (ecoinvent Centre, 2007). The direct field emissions (NH_3, N_2O, P, NO^{3-}, heavy metals and pesticides) were estimated by models described in the SALCA method (Nemecek et al., 2010). The analysis included the production from cultivation up to the delivery at farm gate, as well as the environmental impacts linked with input factors and the direct field emissions. The selected rotations are given in Table 1. The gross margin II was calculated based on mean prices in the reference period.
To illustrate the results the global warming potential (GWP) is shown for selection crop rotations in Fig. 1. Following Nemecek et al. (2008) a difference of 4% between two crop rotations can be considered as significant. The same tendencies were found across all impact categories. The alternative crop rotations with pea (P1 to P3) consistently reduced the GWP as compared to the standard rotations without pea (S1 and S2), both per hectare and year and per € gross margin II. The effect was similar whether barley in the standard rotation was replaced by pea (P1) or pea was added (P2 and P3). The global warming potential per ha and year was reduced by around 10% and per € gross margin by around 12%. In P2 pea is inserted before the stubble wheat in rotation S2. This reduced the GWP by around 14% per ha and year and 19% per € gross margin II compared to S2. Looking at the second option, the reduced fertilisation, comparing the conventional and integrated rotations in Beauce shows that the impact per ha is reduced, whereas the impact per € gross margin II remains constant due to lower revenues. Combining introduction of pea with reduced N fertilisation (Beauce_Int P1-P3) seems to be the most effective way to reduce the GWP.
The analysis illustrates that peas allow to decrease impacts per ha and year on a rotational level and to increase the eco-efficiency (lower impacts per € gross margin II). This is caused by positive rotational effects (e.g. higher yields or a lower fertilisation in succeeding crops). Therefore this strategy is favourable compared to a reduced fertilisation in single crops. Combining both measures is the most effective strategy when looking at impacts, but on the other hand the gross margin II is reduced by around 40 € compared to the standard rotations.

References

ecoinvent Centre (2007): ecoinvent Data - The Life Cycle Inventory Data. Swiss Centre for Life Cycle Inventories, Dübendorf, ISBN 3-905594-38-2 available at http://www.ecoinvent.org.
Nemecek, T., Freiermuth Knuchel, R., Alig, M. & Gaillard, G. (2010): The advantages of generic LCA tools for agriculture: examples SALCAcrop and SALCAfarm. In: 7th Int. Conf. on LCA in the Agri-Food Sector, Notarnicola, B. (eds.). Bari, Italy. 433-438.
Nemecek, T., von Richthofen, J.-S., Dubois, G., Casta, P., Charles, R. & Pahl, H. (2008): Environmental impacts of introducing grain legumes into European crop rotations. European Journal of Agronomy, 28: 380-393.

Table 1. Crop rotations analysed in the regions Beauce, Burgundy and Moselle. S1 and S2 are the standard rotations without pea, P1 to P3 are the rotations with pea.

		Rotation				
		S1	S2	P1	P2	P3
Beauce Int/Con	1	Oilseed rape				
	2	Winter wheat				
	3	Malting barley	Winter wheat	Winter pea		Malting barley
	4	Oilseed rape	Malting barley	Oilseed rape	Winter wheat	Winter pea
	5	Winter wheat		Winter wheat	Malting barley	Oilseed rape
	6	Malting barley		Malting barley		Winter wheat
	7					Malting barley
Burgundy/Moselle	1	Oilseed rape				
	2	Winter wheat				
	3	Malting barley	Winter wheat	Spring pea		Malting barley
	4	Oilseed rape	Ma./Fe barley	Oilseed rape	Winter wheat	Spring pea
	5	Winter wheat		Winter wheat	Ma./Fe barley	Oilseed rape
	6			Ma./Fe barley		Winter wheat
	7					Ma./Fe barley

ma. = malting in Beauce and Bourgogne ; fe. = feed en Moselle

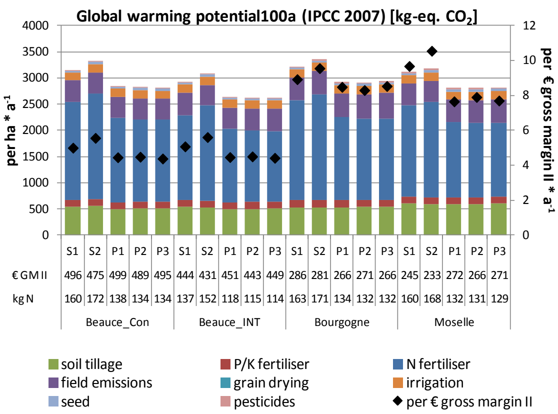

Figure 1. Global warming potential of crop rotations analysed in Beauce, Burgundy and Moselle in kg CO_2-equivalents per ha*a^{-1} (indicated by the columns) and per € gross margin II (diamond symbols). Beauce_CON = conventional production in Beauce, Beauce_INT = integrated production with reduced nitrogen fertilisation.

120. Life cycle assessment of various fertilisation systems in open field vegetable production, Flanders, Belgium

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In Flanders, many farmers and horticultural growers wonder how they can lower the residual nitrate on their parcels to satisfy the fertiliser regulations set up by European legislation. Currently this threshold is set at a residual soil nitrate value of 90 kg/ha; for many farmers a limit hard to comply. In open field vegetable production like leek and cauliflower an overuse of fertiliser is very common. In this sector, less then 40% of the cultivated parcels were found under the imposed limit (Vlaamse Milieumaatschappij (VMM) 2006). One of the reasons of this excess on fertiliser application is the need of farmers to procure a good yield with a high quality to be competitive on the domestic market. Lowering the nitrogen application rate however, with current recommended fertiliser schemes (i.e. KNS-system (Lorenz et al. 1985)), does not yet give sufficient guaranties to uphold these demanding standards.

In 2010 an experiment has been set up to monitor and evaluate the influence of different fertiliser application rates and strategies on the growth, yield and quality of a cauliflower crop, and with a special emphasis on the amount of nitrate leaching to soil and surface water. The experiment consists of 8 plots, treated with two different fertiliser doses and two application strategies, to create a two by two completely randomised factorial design, replicated in two blocks. Each plot was fitted with an impermeable foil to capture and sample the drainage. Destructive and non-destructive plant samples were taken to follow up growth evolution of the plant and at harvest measurements were done to evaluate the overall product quality.

The experiment was chosen in such a way that a comparison could be made between common cultivation practices and ‘improved’ management schemes developed with the intention of lowering the nitrate leaching. For the common practices a broadcast fertilisation with calcium ammonium nitrate is assumed and, based on the recommendation of the KNS-system, a split fertilisation of 150 kg N/ha at planting and 240 kg N/ha 7 weeks later is applied (*i.e.* the high dose), the mineral N present in the soil profile included. In attempt to achieve lower nitrate leaching, the improved strategies consist of: a) the same broadcast split fertiliser application but with a low dose of 50 kg N/ha at planting and 100 kg N/ha 7 weeks into the growing season, b) a weekly fertigation of ammonium nitrate with the high dose, and c) the same fertigation scheme with the low dose.

As expected, differences in yield have been found among the various tested fertilisation systems (*i.e.* broadcast high yielded 70,99 ton/ha, broadcast low 55.26 ton/ha, fertigation high 67.28 ton/ha and fertigation low 53.44 ton/ha). When aiming only at high productivity, one would not distinguish between the broadcast and fertigation application of fertiliser, but with current pressure on the environment more objectives come into consideration. For this reason a life cycle assessment (LCA) has been carried out (Guinee et al. 2002). Comparing each fertilisation system the LCA focuses on the differences in input loads and their corresponding environmental impacts in terms of resource depletion, global warming, toxicity, acidification and eutrophication with special attention to nitrate leaching. This way policy makers and farmers can consider to what extent the quantity or quality is influenced by a reduction in fertilisers and/or different treatment inputs regarding their impact on the environment. In this way, the LCA supports decision making regarding optimisation of the fertilisation system and adaptation to severe constraints about energy demand and emissions to air, water and soil.

In contrast with expectations, no large differences in impact have been found and even more surprising, the fertigation treatments did not score all too well. The nature of environmental impact with respect to the used fertilisation system, however, did change. This suggest that, even though a progressive split fertiliser application and fertigation are perceived as environmental conserving techniques, the problem is more complex and the larger context in which the farming activity takes place has to be considered in first instance before being able to make proper unambiguous fertiliser management recommendations.

References

Guinee, J. B., Gorrée, M., Heijungs, R., Huppes, G., Kleijn, R., de Koning, A., van Oers, L., Wegener Sleeswijk, A., Suh, S., Udo de Haes, H. A., de Bruijn, H., van Duin, R., Huijbregts, M. A. J., 2002. Handbook on life cycle assessment. Operational guide to the ISO standards. I: LCA in perspective. IIa: Guide. IIb: Operational annex. III: Scientific background. Kluwer Academic Publishers, 692

Lorenz, H., Schlaghecken, J., Engl, G., 1985. Gezielte stickstoffversorgung - Das Kulturbegeleitende Nmin-Sollwerte System., 13, 646 - 648

Vlaamse Milieumaatschappij (VMM), 2006. MIRA-T 2006 Milieuindicatoren in zakformaat.

121. Comparison of CO_2 emissions in the wine production from traditional and organic farming techniques. A Spanish case study

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Over the last several decades there is a growing demand for products made in a natural way with less intervention of chemicals. However, the concern arising from the generation of greenhouse gas (GHG) emissions from the different production systems entails an assessment of their energy consumption, as well as of their emissions.

Nowadays, the traditional crop has a number of technological elements added by the man which has been experiencing and acquiring more knowledge about the process over the past decades. In this sense, the traditional crop is defined as an industrialised method that currently is used by the largest systems of production of grape. However, the organic farming which differs from the traditional crop mainly because it avoids the use of agrochemicals such as fertilisers and non-organic plant protection products, is gaining a high interest in the last decade.

This paper shows the results obtained by the estimation of CO_2 equivalent emissions using SimaPro v.7.2 and ecoinvent 2.1 (PRé 2007) database, in order to assess the environmental impact of the traditional and ecological winegrowing. Although organic farming has as main objective the obtaining of maximum quality food while respecting the environment, preserving the fertility of the earth through the optimal use of resources and without the use of synthetic chemical products; the results show that this technique has associated higher amount of CO_2 equivalent emissions i.e. 22% more compared to the traditional crop.

122. Grape life cycle assessment: which methodological choices for a combined assessment with grape quality?

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Social, market and institutional pressure is growing on wine producers for more environment friendly production strategies, while high quality wine are more than ever necessary in a very competitive globalised market. Identification of the best trade-offs between environmental performance of the vineyard management and quality of the wines would help producers in adapting their technical choices to these requirements. Consequently, we are building a combined method assessing grape production practices on qualitative and environmental aspects through the combination of LCA and quality evaluation of the grapes.

Within the LCA results published about wine production (Petti et al.,2010;Vázquez-Rowe et al.,2012), we have to improve the detailed analysis of the agricultural practices contributions in a wide diversity of technical management paths and taking into account the entire life of the vineyard.

Grape LCA is calculated in our project for existing contrasted vineyard management strategies in parallel of quality measurements on grapes. The aim of the project is to identify (i) if trade-offs are needed between quality and environment and (ii) for which specific part of production process (Renaud et al.,2010). This poster presents the methodological choices done for LCA application to viticulture in this purpose. It exposes examples of the choices made.

The main types of vineyard management strategies of Chenin Blanc Grape production for dry PDO wines in the Middle Loire Valley region, France were determined through typology methods applied on a detailed survey conducted on 77 diverse parcels. Five main types of vineyard management paths were identified resulting to the choice of 5 representative winegrowers plots used for collection of grapes and data for LCA.

The key methodological questions about LCA that were answered concern all the steps of LCA process: (i) Goal and scope definition: the most suitable functional unit for grape production is not only a grape quantity but also a production surface unit because of the importance of yield in wine quality elaboration (Renaud et al., 2010).

(ii) System boundaries: the entire life of the vineyard is taken in the system, including pre and post productive phases of the vineyard management, like vine planting, nursery, uplifting of the vineyard.

(iii) Data collection from the winegrowers and suppliers: all data have been detailed (machines, buildings, infrastructure, operations, fertilisers, pesticides, fuels, working time, transport) but some have in the future to be more lightly informed. A data collection tool was built for LCI implementation and direct emissions calculation.

(iv) Inventory: direct emissions calculation models suitable for viticulture have been identified and compared on literature basis for their choice (see an example in table 1) for pesticides, erosion, nitrogen, phosphorus, and heavy metals. They are applied for calculation.

(v) Impacts calculation: processes which need to be detailed and calculated specifically for viticulture are identified and relevant impacts categories for viticulture are chosen.

(vi) Interpretation: contributions analysis, sensitivity analysis and comparisons with literature give information on which processes need to be more detailed than others through the iterative process of LCA.

This poster is a contribution for LCA practitioners who want to deal with viticulture or more widely perennial plants. It proposes solutions about the main methodological choices to be made on the agricultural part of wine production. This study gives an assessment based on detailed data collected on real contrasted vineyard management systems in order to identify practices contributions for linking them to grapes quality results. It needs to be confirmed by further iterative calculations and two more vintages of observations.

References

Audsley E, Alber S, Clift R, Cowell S, Crettaz P, Gaillard G, et al. Harmonisation of environmental life cycle assessment for agriculture, Final Report Concerted Action AIR3-CT94-2028. In: Commission E, editor. Community Research and Technological Development Programme in the field of "Agriculture and Agro-Industry, including Fisheries" AIR 3: European Commission DG VI Agriculture; 2003. p. 129.

Birkved M, Hauschild MZ. PestLCI--A model for estimating field emissions of pesticides in agricultural LCA. Ecol. Modell. 2006;198(3-4):433-51.

Jolliet O, Crettaz P. Fate coefficients for the toxicity assessment of air pollutants. Int. Journal of Life Cycle Assessment. 1997;2(2):104-10.

Margni M, Rossier D, Crettaz P, Jolliet O. Life cycle impact assessment of pesticides on human health and ecosystems. Agriculture, Ecosystems & Environment. 2002;93(1-3):379-92.

Petti L, Ardente F, Bosco S, De Camillis C, Masotti P, Pattara C, et al. State of the art of Life cycle Assessment (LCA) in the wine industry. In: Notarnicola B, Settani E, Tassielli G, Giungato P, editors. LCAFood 2010. Bari (IT),: Universita degli studi di Bari; 2010. p. 493-8.

Renaud C, Benoît M, Jourjon F. Trade-offs between quality and environment in wine production: presentation of a research program for their combined assessment. In: Notarnicola B, Settani E, Tassielli G, Giungato P, eds. LCA Food 2010. Bari, (IT): 2010. p. 241-6

Thiollet M. Construction des indicateurs viti-environnementaux de la méthode INDIGO. Colmar: INRA; 2003.

Vázquez-Rowe I, Villanueva-Rey P, Moreira MT, Feijoo G. Environmental analysis of Ribeiro wine from a timeline perspective: Harvest year matters when reporting environmental impacts. Journal of Environmental Management. 2012;98(0):73-83.

Webb J, Hutchings N, Amon B. Agriculture other: Use of pesticides and limestone. EMEP/EEA emission inventory guidebook European Environmental Agency; 2009.

Table 1. Comparison of five pesticide emission models and indicators of use in LCA of wine-grape production.

Model	Data aspects considered											
	Volatilisation to air	Wind drift	Emissions to surface waters	Leaching to surface waters	Mode of application	Active substance properties	Agricultural practices	Crop species	Crop phenological stages	Application scale	Adapted to grapevine (Yes / No)	Quantitative (Yes / No)
(Audsley et al., 2003)	●		●	●		●				national / regional	no	yes
EMEP / CORINAIR (Webb et al., 2009)	●	●								national / regional	no	yes
PestLCI (Birkved et al., 2006)	●	●	●	●	●	●	●	●	●	plot	partly	yes
I-Phy (INDIGO) (Thiollet, 2003)	●	●	●	●	●	●	●	●	●	plot	yes	no
CST (Jolliet et al.,1997), (Margni et al., 2002)	●		●	●		●				national / regional/ plot	no	yes

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123. Ecodesign opportunities for a farmer's bread. Two case studies from north-western France

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Bread is a staple food item for Europeans. Its history can be traced back to the beginning of our civilisation. However, due to industrialisation and urbanisation, its production processes have notably changed over time. Some consumers believe that organoleptic and nutritional qualities of the product were affected as a result of these changes. There are farmers in Brittany and Pays de la Loire regions, who reintroduce many of the forgotten bread production methods from pre-industrial era. They collect ancient varieties of cereals and cultivate them in an organic way. Some use horses for traction. The grain is milled on-farm and the bread is baked and sold locally. This way, a unique product is created. Sometimes though, this is done at the expense of the environment as traditional methods are not necessarily more ecoefficient. Van Holderbeke et al. (2004) compared environmental impacts from bread production in Belgium in the year 1800, 1900 and 2000. The life cycle carbon footprint results were 1.2 kg CO_2eq kg^{-1}, 1.1 kg CO_2eq kg^{-1} and 0.6 kg CO_2eq kg^{-1} respectively. The goal of this study was to measure environmental impacts of French farmer's bread and explore opportunities for changes in the design of production and distribution processes that would allow minimising environmental impacts while maintaining the positive attributes of this distinctive product to the consumer.

Data on farming practices, processing and distribution of bread were collected from two producers in north-western France. Recent version of Swiss Agricultural Life Cycle Assessment (Nemecek et al., 2008) tools and ecoinvent database were used to assess environmental impacts from the field to the consumer's table. The functional unit was 1 kg of bread delivered at home and ready for consumption. End-of life processes- human excretion and wastewater treatment were excluded from the analysis. Impact categories were selected to reflect a broad range of environmental effects, including global warming contribution, the use of natural resources and potential toxicity. Results of the studies were disseminated to the farmers. Semi-structured face-to-face interviews were conducted to choose promising ecodesign strategies- ones that would be effective in reducing environmental impacts and also accepted by the producer and his consumers.

Table 1 shows a comparison of LCA results expressed per 1 kg of bread. Factor 8 differences in total result exist between the two farms for some impact categories. This suggests significant differences in ecoefficiency may be achieved with different production methods. Fig. 1 shows the contribution of the particular production stages into the overall environmental impact in Case 1. Most environmental impacts come from the wheat cultivation, followed by distribution and baking. There are strategies that can improve the ecoefficiency and would be accepted by the producer. The first solution would be to expand the relative area with the cereals and use mechanical traction, instead of using the land to produce feedstuff for horses. At the same time, wheat variety currently cultivated by the farmer provides relatively low yields in the given soil conditions. It is expected, that choosing a variety better adapted to local conditions would improve the product environmental performance. It may also be possible to change the proportion of flour in the bread recipe. A higher proportion of crops that grow better than wheat, such as rye could be used. It may also be feasible to optimise baking and distribution processes. Fig. 2 shows results for the second producer. Changing the crop or variety can also be considered here. A large share of the impact comes from the baking process. This is mainly done in the oven at consumer's home. Baking the bread on-farm in a more efficient oven or forming a partnership with the baker could potentially add value to the sold product and at the same time reduce environmental impacts.

References

Nemecek, T., von Richthofen, J., S., Dubois, G., Casta, P., Charles, R, Pahl, H. 2008. Environmental impacts of introducing grain legumes into European crop rotations. Eur. J. Agron. 28, 380-393.

Van Holderbeke, M., Sanjuán, N., Geerken, T., De Vooght, D. 2004. The history of bread production. Using LCA in the past, in: Halberg, N. (Ed.), Life Cycle Assessment in the agri-food sector. Danish Institute of Agricultural Sciences, pp. 255-260

Table 1. Selected environmental impacts from 1 kg farmer's bread at the consumer's table of two case study farms in North-Western France.

Impact categories		Unit	Total impact (per 1 kg bread)
Non-renewable resource use - fossil and nuclear	Case 1	MJ eq	23.8
	Case 2	MJ eq	14.3
Global Warming Potential	Case 1	kg CO_2 eq	1.90
	Case 2	kg CO_2 eq	0.61
Eutrophication potential (terr., global)	Case 1	m^2	0.53
	Case 2	m^2	0.06
Aquatic ecotoxicity	Case 1	kg 1,4-DB eq	2.8×10^{-4}
	Case 2	kg 1,4-DB eq	0.2×10^{-4}
Land competition	Case 1	m^2	13.96
	Case 2	m^2	4.58
Total water use (blue water)	Case 1	dm^3	11.60
	Case 2	dm^3	5.84

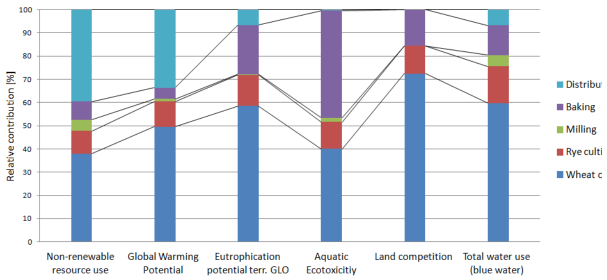

Figure 1. Case 1 - contribution of production stages into the environmental impacts of farmer's bread.

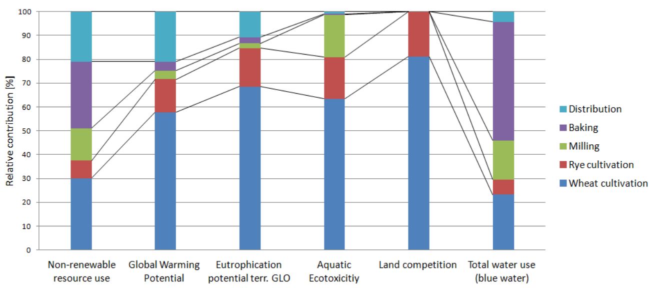

Figure 2. Case 2 - contribution of production stages into the environmental impacts of farmer's bread.

124. How to adapt generic LCI data to be reliant on the original recipe: case study of a biscuit

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In 2011, EVEA and Eco-Concevoir carried out an LCA study of a biscuit for NUTRITION & SANTÉ, a leading company in Europe for health and organic agrifood products. It engaged in a global ecodesign process, carrying out several LCAs, of which one was the LCA of a biscuit.
Input data for LCIA were the different ingredients of the recipes and LCA practitioners had to deal with the lack of data or generic or inconsistent data from ecoinvent and LCA about specific ingredients or processes. To make LCIA results consistent as far as possible we had to adapt data from ecoinvent. For agricultural data, we developed a procedure to create the required data (Fig. 1, Table 1). Once the inventory was performed, we conducted the life cycle impact assessment of the biscuit. We compared results of the LCA of the biscuit with generic data and adapted data.
Adapting data for cultural processes in our case study increased the impacts by 10-75% on 7 impact categories (Fig. 2). If we assume an average uncertainty of 30% on each indicator, these increases are significant on 3 indicators: water consumption, eutrophication and acidification. These changes are mainly due to adaptation of yield which is lower in organic cultures than in conventional ones and introduction of irrigation for the specific country where sugarcane is produced. We can also note that the adaptation leads to a decrease of 22% of the impact of the product on water ecotoxicity. It can be easily explained by the adaptation of pesticides use that was removed for organic cultures. However, this change cannot be considered as significant regarding the high level of uncertainty on this indicator.
It is interesting to note that even in a cradle to gate system (including packaging fabrication and end-of-life, biscuit production, distribution, etc.) the parameters related to agricultural step can have significant influence on the final results. In the case of generic agricultural data adaptation, LCA practitioners should pay attention with priority to main parameters (here, yield, irrigation and pesticides) and main ingredients.

References

Gopinath, K.A., 2011. Organic Sesame Production. Technical Bulletin, Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad, Andhra Pradesh, India. 34p.
Gudoshnikov Organic Sugar, 2001. Niche Commodity In The Mainstream Market, FO LICHT International Sugar and Sweetener Report, Vol 133, No 22 of 24th July 2001.
Nemecek, T., Kägi, T. Life cycle inventories of agricultural production systems. Data v2.0 (2007), ecoinvent report n°15, December 2007.
Toolseeram Ramjeawon, 2004. Life Cycle Assessment of Cane-Sugar on the Island of Mauritius, Int J. of LCA, 9 (4), pp. 254-260.

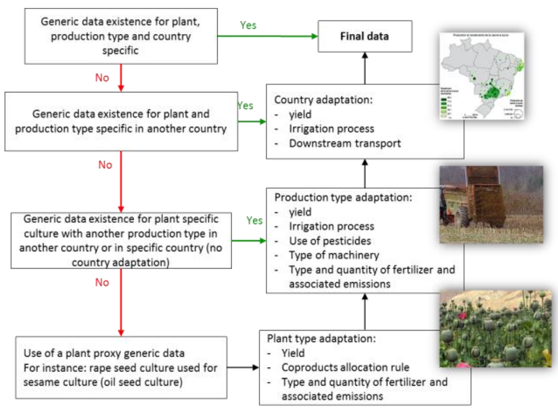

Figure 1. Process for adapting data

Table 1. For two ingredients used in the biscuit, the processes included, the generic data used, and the main adaptations performed on these data.

Ingredients	Ingredients production steps	Generic data used	Adaptations
Organic brown sugar	Sugarcane culture	Ecoinvent data Sugarcane, at farm/BR	Country specific yield for organic production
			Country specific irrigation process
			Mineral fertilizer substitution by organic fertilizer
			Fertilizer needs (N, P, K) for organic production and related field emissions adapted
			Removal of pesticides inputs
	Sugar production	Ecoinvent data Sugar, from sugarcane, at sugar refinery/BR	Country specific yield for organic production
Organic toasted complete sesame seeds	Organic sesame culture	Ecoinvent data Rape seed organic, at farm/CH	Country specific yield for organic production
			Fertilizer needs (N, P, K) for organic production and related field emissions adapted
	Toasting	Data creation	

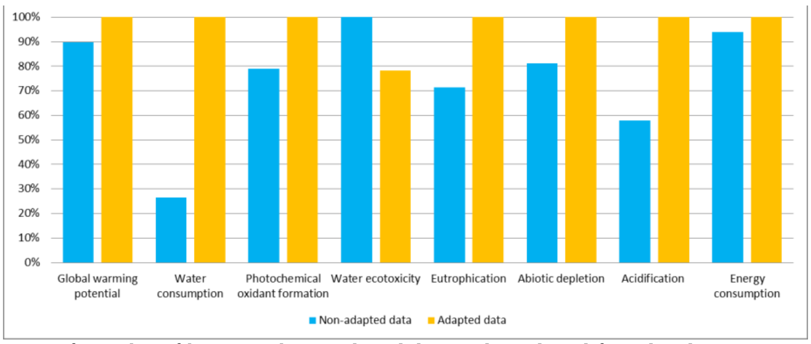

Figure 2. Environmental impacts of a packet of biscuit with non-adapted data or data adapted for cultural steps. LCIA performed with SimaPro 7 software, according BPX30-323 guidelines (2011)

125. Prioritising retail food waste prevention - potatoes, tomatoes or carambolas?

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Loss of food is a major problem world-wide with regard to the environment and to food security. To prevent waste efficiently, a better understanding of the conditions behind the wastage is needed. This study is part of a research project focusing on food wastage at the retail level of the Swedish food supply chain, conducted by the Swedish University of Agricultural Sciences during 2010-2013 (www.slu.se/foodwastage). After identifying the main products driving the food wastage, the question of how to prioritise prevention options arises. In the present study, the fruit and vegetable department at six Swedish retail stores were studied. Data on sold and wasted quantities for 2010 and 2011 were obtained from the retail company. The resulting top lists of wasted items, in tonnes and as a percentage of sold volumes, gave a quantitative background necessary for the subsequent task to priorities between mitigation targets. Potatoes and lettuce dominated the wastage by mass, while rare exotic fruits had the highest waste percentage. In the next phase, the product specific carbon footprints were multiplied with the wasted amounts to quantify the carbon footprint of each waste fraction. These LCA-based results shifted the list, so that tomatoes and sweet peppers now dominated the impact. In absolute numbers, the carbon footprint of food wastage was highest for tomatoes and peppers, leading to a possible conclusion to target these products for waste prevention measures at the fruit and vegetable departments studied. However, an alternative evaluation method was also tested in order to relate the burdens from the wasted fraction to the benefit of the respective product. The benefit of each product was indicated with its sold volume, reflecting the food supply capability of the product. In this additional analysis the wastage carbon footprint was divided by the sold quantify of each product type to give an index of the unnecessary environmental impact per kg sold product. The result gave that rare exotic fruits totally dominated this recalculated list, where the carbon footprint of the wastage from bulk products added grams to the total results, while the corresponding figure for each kg sold rare exotic fruit was 7.2 kg CO_2-eq extra to the (already high) product specific carbon footprint of 11 kg CO_2-eq. When relating the environmental burden of the wastage to the sold quantity of products, the conclusion became that rare exotic fruits should be prioritised for waste prevention measures at the vegetable departments of the retail chain studied.

References

Carlsson-Kanyama, A., D Gonza´lez, A., 2009. Potential contributions of food consumption patterns to climate change. The American Journal of Clinical Nutrition 89(5), 1704-1709.

Cellula, M., Ardente, F., Longo, S., Mistretta, M., 2010. Life Cycle Assessment (LCA) of protected crops: an Italian case study, 449-454, in: Proceedings from LCAfood 2010 VII International conference on Life Cycle Assessment in the agri-food sector, volume 1. Notarnicola, B., Settanni, E., Tassielli, G., Giungato, P. (Eds.). Universita Degli Studio di Bari Aldo Moro, Bari, Italy.

Davis, J., Wallman, M., Sund, V., Emanuelsson, A., Cederberg, C., Sonesson, U., 2011. SIK report 828, Emissions of Greenhouse Gases from Production of Horticultural Products. The Swedish Institute of Food and Biotechnology, Gothenburg, Sweden.

Karlsson, H., 2011. Seasonal Vegetables - An Environmental Assessment of Seasonal Food. Master Thesis, Norwegian University of Life Sciences, Department of Plant and Environmental Sciences.

Müller-Lindenlauf, M. and Reinhardt, G., 2010. Food import versus regional production: comparison of energy demand and greenhouse gas emissions 487-492, in: Proceedings from LCAfood 2010 VII International conference on Life Cycle Assessment in the agri-food sector, volume 1. Notarnicola, B., Settanni, E., Tassielli, G., Giungato, P. (Eds.). Universita Degli Studio di Bari Aldo Moro, Bari, Italy.

Röös, E., Sundberg, C., Hansson, P-A., 2010. Uncertainties in the carbon footprint of food products: a case study on table potatoes. The International Journal of Life Cycle Assessment 15(5), 478-488.

Table 1. Yearly sold and wasted fruit and vegetables at six Swedish retail stores

Product	Sold (tonne/yr)	Wasted (tonne/yr)	Waste quota (%)	Product carbon footprint kg CO_2-eq/kg product	Wastage carbon footprint tonne CO_2-eq of yearly wastage	Wastage carbon footprint per quantity sold g CO_2-eq/kg product
Potato	1616	10	0.62	0.12[1]	1.2	0.7
Lettuce	349	7.3	2.1	1.0[2]	3.6	10
Tomato	743	6.8	0.90	0.9[3]	6.1	8.2
Sweet pepper	271	5.4	1.9	1.1[4]	5.9	22
Carrot	439	4.5	1.0	0.18[5]	0.8	1.8
Banana	768	4.4	0.57	1.1[6]	4.8	6.3
Rare exotic fruits (Tamarillo, Pithaya, Pepino, Prickly pear, Carambola, Rambutan)	0.6	0.39	39	11[7]	4.3	7200

[1] Röös et al., 2010
[2] Müller-Lindenlauf and Reinhardt, 2010
[3] Karlsson, 2011
[4] Cellula, et al., 2010
[5] Davis et al., 2011
[6] www.dole.com (accessed 2012-02-10)
[7] Carlsson-Kanyama and D. González

126. LCA of waste from olive oil manufacturing

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Competition on both national and international olive oil markets is becoming increasingly intense, thus forcing organisations to identify new and diverse competitive advantages, particularly by increasing the efficiency within the firm. So far, the prevailing action undertaken by firms, with regards to this, has been to search for process innovations that also entailed a reduction of unit production costs (Notarnicola et al., 2003). However, the current development paradigms show that in order to obtain the best results, the entire supply chain must be designed as a whole, trying to foresee the flows going through the whole economic system rather than just one firm or process.

This aspect becomes particularly relevant for the olive oil supply chain, in which alternative options can be found in both the cultivation stage (traditional, super-intensive) (De Gennaro et al., 2012) and the industrial processing stage (two or three phases) and the alternative oil products (Nicoletti et al., 2001). Each option generates final outputs together with solid and liquid waste with very different characteristics.

In this research a comparison between various alternative options for producing olive oil – discontinuous, two-phase and three-phase systems – is performed by means of LCA. Particular attention is placed on the treatment of waste that is generated in each processing stage of the olive oil supply chain, for each alternative option.

These processes differ in terms of the yields and the organoleptic quality of the finished product, but the principal differences regard the quantity and quality of waste: variation of the humidity levels of the pomace and the concentration of vegetation water.

The outcomes of this study show the environmental profile of the systems considered, and they are expected to contribute to the current debate on whether a three phases-system, which is widely adopted in some areas like the Apulia region in Italy, should be transformed in a two phases-system, by means of economic incentives supporting the replacement of the old plants too.

References

De Gennaro B., Notarnicola B., Roselli L., Tassielli G., 2010. Innovative olive-growing models: an economic and environmental assessment. J. Cleaner Production, doi:10.1016/j.jclepro.2011.11.004

Nicoletti G. M., Notarnicola B., Tassielli G., 2001. Comparative LCA of virgin olive oil vs. seed oils. The International Conference LCA in Foods, Goteborg 25-27 April 2001.

Notarnicola B., Tassielli G., Nicoletti G. M., 2003. LCC and LCA of extra-virgin olive oil: organic vs. conventional. 4th International Conference: Life Cycle Assessment in the Agri-food sector, Horsens, 6-8 October 2003.

127. Environmental impact of animal food products and their substitutes

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Land use, greenhouse gas emissions (GHG) and nitrogen (N) emissions are the main causes of global loss of biodiversity and damage to ecosystems (Rockstrom et al., 2009). Major impacts on the environment, and thus also on biodiversity, are caused by the production of meat, dairy and fish. In this study, different protein sources, such as meat, dairy, fish, eggs and meat substitutes, are compared for their environmental impacts.

In order to identify the range of impacts, their most important related factors, as well as the main causes of the differences between products, 44 life-cycle assessment (LCA) studies were analysed, containing 96 LCAs of animal and vegetal sources of protein. Moreover, the results for agricultural products were compared to results from the model Miterra-Europe. The Miterra-Europe model was used to calculate greenhouse gas and nitrogen emissions from agriculture, following a life-cycle approach that reached 'up to the farm gate' (Lesschen et al., 2011).

Compared to other review studies, such as De Vries and De Boer (2010), Yan (2011), Roy et al. (2009), Flachowsky and Hachenberg (2009), and González et al.(2011) containing a selection of LCA studies on animal products and mainly focused on greenhouse gases, our review study presents a broader view.

There are very large differences in carbon footprints and land requirements between the various protein sources in the human diet. Greenhouse gas emission levels from the most climate-friendly protein sources are up to 100 times lower than those from the most climate-unfriendly protein sources. For land use, comprising both arable land and grasslands, this varies even more strongly. In the case of grasslands, there are also large differences in the quality of land use in terms of biodiversity. Vegetal sources, poultry products and certain seafood have well below average environmental impacts, while those of ruminant meat and some other types of seafood are well above the average.

The impact differences between the various products were found mainly to be due to differences in production systems. In the life cycle of protein sources, in general, the farm phase is the most important. Further processing, transportation and packaging are of less importance.

The differences in scores, both between and within the various product categories, offer chances for lowering the environmental impact of our protein consumption. Shifting consumption towards other sources of protein has a large potential for reducing the impacts on biodiversity and climate change.

References

De Vries, M., de Boer, I.J.M., 2010. Comparing environmental impacts for livestock products: A review of life cycle assessments. Livestock Science 128, 1-11.

Flachowsky, G., Hachenberg, S., 2009. CO2 Footprints for Food of Animal Origin – Present Stage and Open Questions. Journal für Verbraucherschutz und Lebensmittelsicherheit 4, 190-198.

González, A.D., Frostell, B., Carlsson-Kanyama, A., 2011. Protein efficiency per unit energy and per unit greenhouse gas emissions. Food Policy, In Press.

Lesschen, J.P., van den Berg, M., Westhoek, H.J., Witzke, H.P. and Oenema, O., 2011. Greenhouse gas emission profiles of European livestock sectors. Animal Feed Science & Technology 166-167, 16-28.

Rockstrom, J., Steffen, W., Noone, K., Persson, A., Chapin, F.S., Lambin, E.F., Lenton, T.M., Scheffer, M., Folke, C., Schellnhuber, H.J., Nykvist, B., de Wit, C.A., Hughes, T., van der Leeuw, S., Rodhe, H., Sorlin, S., Snyder, P.K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R.W., Fabry, V.J., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P., Foley, J.A., 2009. A safe operating space for humanity. Nature 461, 472-475.

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

Yan, M.J., Humphreys, J, Holden, N. M., 2011. An evaluation of life cycle assessment of European milk production. Journal of Environmental Management 92, 372-379.

128. Industrial ecology and agri-food sector. Perspectives of implementation in an Italian regional cluster

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Over the last fifty years, the development of the agri-food sector has been characterised, in many developed countries, by significant structural, technological and organisational changes, which have led to the involvement and integration, in traditional food production chains, of a number of activities, such as: food processing, manufacturing of technical equipment, packaging industry, transportation, storage, distribution, marketing, catering. The spontaneous agglomeration of agricultural activities in favorable geographic areas, has often led to the development of clusters of SMEs, recognised as agri-food clusters. Agri-food clusters are characterised by typical environmental impacts, such as: land use, CO_2 emission, energy and water consumption, use of agricultural inputs such as fertilisers, pesticides, feed additives and irrigation water. However, the involvement of agro-industrial activity in the same area highlights other significant sources of waste related to auxiliary materials and different types of packaging used during agricultural activities and food processing (materials such as polystyrene, polyethylene, polypropylene, wood, paper). Industrial Ecology, through a more efficient management of material and energy flows, helps to reduce loads and environmental impacts of production activities without compromising their competitiveness. Major applications of Industrial Ecology principles in the agri-food sector, concern the valorisation of animal and vegetable by-products, leading to the implementation of so-called Agro-Eco-Industrial Parks. The purpose of an Agro-Eco-Industrial Park is to provide a base for companies and service organisation in achieving a transition to sustainable farming, improving the value of their output and gaining market channels. In an agri-food cluster, alternative and effective solutions can be also implemented to manage waste flows deriving from auxiliary materials used in agro-industrial activities, through the adoption of closed loop approaches, especially considering technical features of such flows: high volumes, high percentage of non-hazardous materials, homogeneity in composition, and regular (or cyclic) flows. This paper presents a preliminary analysis of one of the most representative agri-industrial clusters in the production of horticultural products, the area of Fucino in Abruzzo Region (Italy). The cluster covers an area about 15,000 ha, for a total of 3,700 small and micro-sized enterprises that produce mainly carrots, potatoes, endive and lettuce (Fig. 1). The study aims to analyse the main vegetable and not vegetable waste flows to propose alternative options for managing them in the perspective of an Agro-Eco-Industrial Park. The preliminary qualitative analysis shows that efficient solutions can be potentially implemented through recycling, recovery and repair activities, materials substitution and alternative energy production, exploiting synergies of the existing cluster (Fig. 2).

References

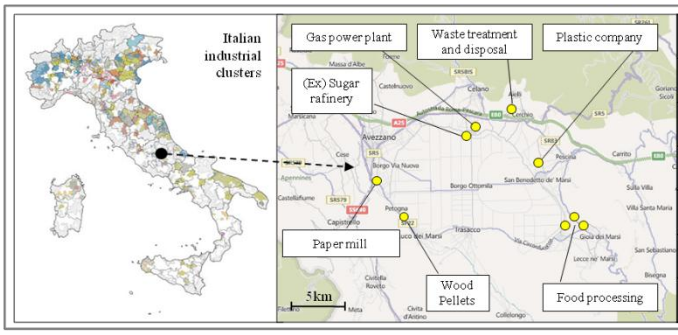
Ayres, R., Ayres, L. W., 1996. Industrial Ecology: Towards closing the material cycles, first ed. Edward Elgar, Cheltenham.

Indigo Development, 2005. Creating systems solutions for sustainable development through Industrial Ecology. Developing Agricultural Eco-Industrial Parks in China. Available at http://indigodev.com/AEIPwhitepaper.html. Accessed January 2012.

Kroyer, G. Th., 1995. Impact of food processing on the environment – an overview. LWT – Food Science and Technology 28, 547-552.

Nguyen Ngoc, U., Schnitzer, H., 2010. Environmental understanding of agro-based industrial systems and sustainable development. International Journal of Environment and Sustainable Development 9, 149-180.

Taddeo, R., Simboli, A., Morgante, A., 2011. Symbiotic exchanges and hazardous wastes in Chemical Industry. A "Path-Dependent" Case Study, 21th Setac Europe Annual Meeting, Milano Convention Centre, 15-19 May. Proceedings.



CROP	ha
Corn	975,6
Potato	4378,0
Grass	381,9
Carrot	2303,9
Lettuce	1660,8
Other	3387,0

Figure 1. The Fucino agri-food cluster and its main productions (2011).

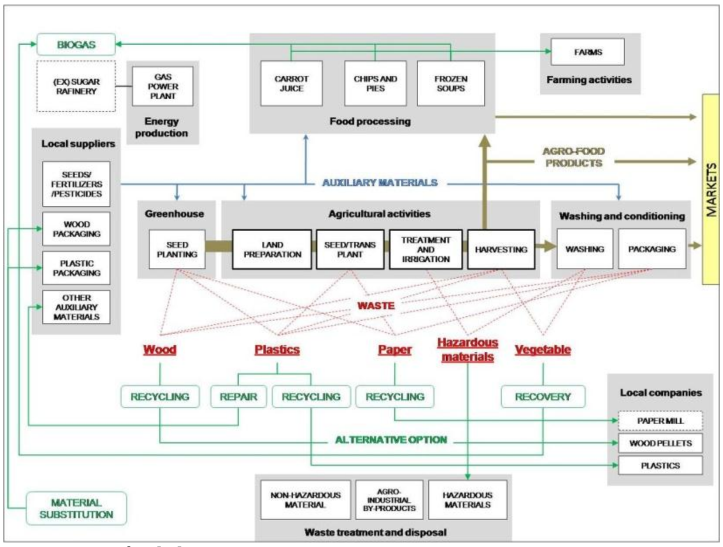


Figure 2. Potential solutions in the Fucino agri-food cluster.

129. LCAs for animal products pork, beef, milk and eggs in Finland

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This paper presents results of LCA for pork, beef, milk and eggs produced in Finland. Environmental impact categories assessed were climate change, eutrophication and acidification and, additionally, land and energy use. Several LCAs had been implemented on Finnish food products earlier, but there was a need for comprehensive environmental impact assessment of most important food products. Both plant and animal products were assessed.

The functional unit of LCAs is kg of a product at the farm gate (without packaging). System boundaries include animal production (heating, lightning, mechanical work) on the farm, as well as complete chains of the animal feeds, fuels and power which supply that. The supply chains include all significant industrial processing, product packaging, energy and transports. Data for the supply chains were obtained from the industry, which produce the majority of the inputs used in the animal production in Finland. Energy was assumed according to the Finnish average grid. Data on the use of inputs at crop and grass production were based on the national agricultural database consisting of data on the cultivation instances of various crop species and grass, i.e. it is primary data. Data on mechanical work were based on physical models.

Animal production models were used to assess partly the inventory data and partly the impacts of animal production. Animal models consist of animal population age-classes, their specific feed consumption and diet composition. This information in utilised in simple balance calculations (nutrient intake in feeds – nutrient retention in growth and products) of nitrogen and phosphorus and gross energy intake that is necessary in methane production estimation. Models were based on e.g. national statistics and calculation based on feeding norms. Methane emissions were estimated according to models used in Finnish greenhouse gas inventory. Nitrogen amount in excrement and urine was assessed by animal model (nitrogen balance) and assessment of NH_3 and N_2O emissions in animal shelter and manure storage were based on this.

Emissions from manure storage were allocated to animal production. Emissions from manure spreading on the field were allocated to the those plants the manure was used as fertiliser for. Allocations were needed also to allocate inputs and emissions especially in beef and milk –case between milk and meat. In Finland most of the beef production is connected to milk production. For pork and beef allocations were done between different qualities of meat. Allocations were calculated accomplished economic values of different products. In egg production all inputs and emissions were allocated to eggs.

Results of LCAs in terms of climate change, eutrophication and acidification are shown in Fig. 1-3. Environmental impacts of beef are more than twice as much as impacts of pork. In case of climate change the methane emissions from bovine are higher than from pigs. In terms of eutrophication, most of the impacts derive from feed production in Finland. Pigs and chickens use soy which do not cause as much eutrophication impact as Finnish feeds. NH_3-emissions from manure are the main reason for acidification impact. An important thing is, that feed conversion ratio of pigs and chickens are better than bovines'.

Food stuffs are one of the most important consumer goods in terms of environmental impacts of consumption. Animal models are a strong base for emission assessment in animal shelters and manure storage. Machinery work models represent a typical situation in Finland as well as feed production models based on national agricultural data. As such the results of the LCAs represent the typical Finnish animal products. Together with LCAs of plant products they are very valuable in comparing the environmental burdens of different food stuffs in Finland. Results may be utilised in communication to consumers, political decision-making and improvement of animal product supply chains and production systems.

References

Grönroos, J., Mattila, P., Regina, K., Nousiainen, J., Perälä, P., Saarinen, K. and Mikkola-Pusa, J. 2009. Development of the ammonia emission inventory in Finland. pp. 15-19.

Saarinen, M., Virtanen, Y. and Hyvärinen, H. 2012. LCAs for a large repertoire of Finnish outdoor plant products. Abstract for LCA Food 2012 Conference.

Statistics Finland 2011. Greenhouse Gas Emissions in Finland 1990-2009. pp. 248-253.

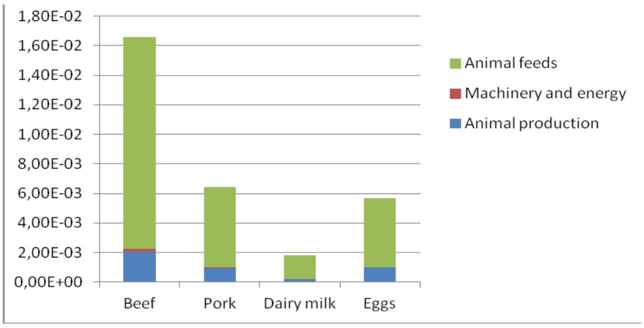

Figure 1. Eutrophication impact of animal products (kg PO_4 eq./product kg).

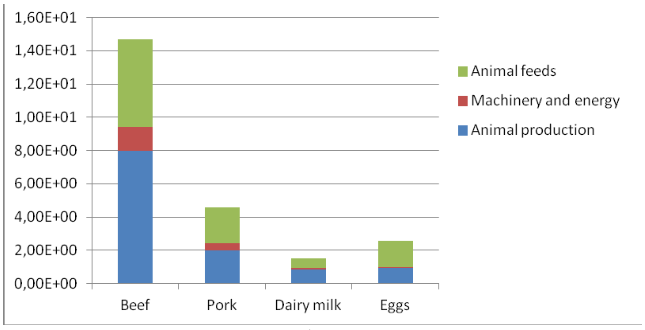

Figure 2. Climate change impact of animal products (kg CO_2 eq./product kg).

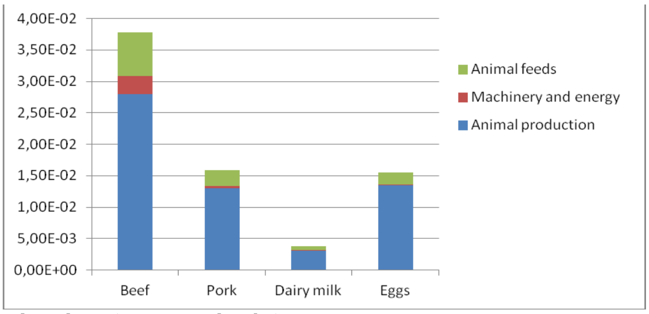

Figure 3. Acidification impact of animal products (AE eq./product kg).

130. Greenhouse gas emissions related to saturated fat, sodium and dietary fibre content of food products

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The Dutch Health Council concludes in her 2011 advice that a healthy diet according to the Wheel of Five model is usually also environmentally friendly. Furthermore, she states that there is a strong correlation between various indicators of sustainability, such as greenhouse gases (GHG), energy and land use (Health Council 2011). The Italian double pyramid shows that there is an inverse relationship between breakdown in health gain and environmental impact, expressed as carbon, water and ecological footprint (Buchner, Fischler et al. 2010). Our study investigates and quantifies this hypothesis with Dutch data.

Data sources: food composition (RIVM 2011); land use and energy use (Gerbens-Leenes 2006) water use (Hoekstra and Chapagain 2004) and GHG (CLM, klimaatweegschaal.nl; 2009 not published). Correlation between GHG, energy use, water use and land use was calculated with a Spearman rank correlation test. Further analyses were only done with the GHG data as indicator (n=403). Products were divided into 6 categories according to the Wheel of Five education model. A Kruskal Wallis and a Mann-Withney U test were performed to determine differences between groups of products (Fig. 1).

To find whether a healthy food pattern could be in line with a sustainable food pattern, the products were divided into a broad accepted division of Preference, Neutral and Exception, based on saturated fat, sodium, added sugar and fibre content (Voedingscentrum 2011). Differences in GHG of these groups were explored. To further investigate whether this mentioned nutrients affects the emission of GHG, the nutrients were included in a regression analysis (for this analyses GHG data was log transformed).

We find a correlation between GHG and land, energy and water use (all r>0.354, p<.01; Table 1). There is a significant difference in GHG between the Wheel of Five groups ($\chi 2(5)$= 175.51, p<.001). Follow up analyses show a significant difference between the animal protein rich product group and all other groups (p<.001). Analyses indicate that less healthy food items are also less sustainable. A difference in GHG was found between the Preference, Medium and Exception category ($\chi 2(2)$= 30.131, p<.001). The categories low in GHG (Cat. A & B) consist almost entirely of preferred products, whereas exceptional foods mostly fall into higher emission categories (Cat. D & E) (Fig. 2). The products in the Exception category has a 2 times higher median compared to the products in the Preference category (200g vs 408g CO_2eq/100g p<.001). The finding that unhealthy foods have a higher GHG was confirmed in the regression analyses; in the model saturated fat and sodium are positively associated with GHG, whereas dietary fibre was negatively associated with GHG. An exception was added sugar which was also negatively associated with GHG.

GHG (CO_{2eq}) = 10×((2.356 + (saturated fat g *.019) + (sodium g *.279) – (dietary fibre g *.024) – (added sugar g *.021)).

About 23% of the variability in the GHG can be explained by these predictors. The results strongly support the concept that Dutch health advices are in line with sustainability indicators. Lowering consumption of products high in animal protein, saturated fat and sodium, is a clear consumer advice. Using more Preference products, like fruits and vegetables rich in dietary fibre, instead of Exception products helps consumers to eat a more healthy and sustainable diet.

References

Buchner, B., C. Fischler, et al. (2010). Double Pyramid: healthy food for people, sustainable food for the planet. Milan, Barilla Center for Food & Nutrition**:** 150 p.

Gerbens-Leenes, P. W. (2006). Natural resource use for food: land, water and energy in production and consumption systems: 155p.

Health Council (2011). Guidelines for a healthy diet: the ecological perspective. The Hague, Gezondheidsraad**:** 92p.

Hoekstra, A. Y. and A. K. Chapagain (2004). Water footprints of nations: Volume 1: Main Report, Value of Water Volume 2: Appendices. Delft, Unesco-IHE**:** 80 p.

RIVM (2011). NEVO-tabel: Dutch nutrient files (in Dutch). Bilthoven, RIVM.

Voedingscentrum (2011). Guidelines for food choices (in Dutch). The Hague, Voedingscentrum**:** 61p.

Table 1. Indicators of sustainability are strongly correlated, except water use with energy use.

	GHG	Virtual water		Energy use		Land use	
GHG	1.000	**0.668**	**	**0.584**	**	**0.354**	**
Virtual water		1.000		0.132		**0.794**	**
Energy use				1.000		**0.294**	*
Land use						1.000	

*** p<0.01; * p<0.05*

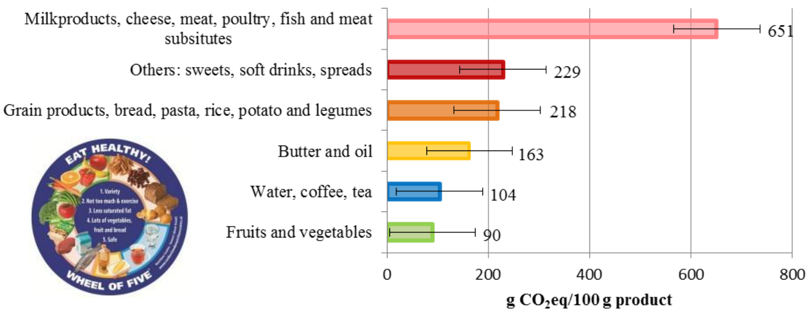

Figure 1. Protein rich animal products have significant (3 to 7 times) higher GHG emissions than other food groups.

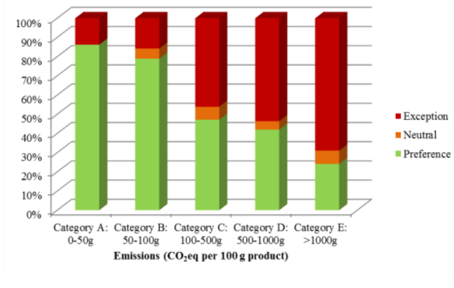

Figure 2. Exceptional foods from health point of view have higher GHG emissions (Cat. D & E).

131. Harmonising LCA methodology: A collaborative approach in a search for allocation rules for food sector

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There are several general and more specific life cycle assessment (LCA) calculation guides. However, the food sector is lacking a common guide that is taking into account the special features of the sector and, thus, giving practical and harmonised guidelines for calculating food products' footprints. There are few initiatives, such as, the methodology for food products structured by the European Food SCP Round Table. Another initiative is the Finnish project called "Foodprint" (2009–2012). The project's aim is to create harmonised and practical attributional LCA methodology and guidelines for, particularly Finnish, food sector. The key objectives of the project are: 1) to actively follow and influence the harmonisation of LCA methods both internationally and nationally, 2) to involve Finnish food chain actors into the development process (via pilots, steering group meetings, workshops, seminars), and 3) to attain more supply chain specific data from the entire food chain. The last target is both to improve the food chain's operations and to give more both reliable and comparable information to consumers of the environmental impacts of the food product in question.

When drafting the Finnish LCA methodology for food products one central question found out to be the allocation rules, especially in the multi-output systems. As well known, LCA's aim is to assess environmental impacts associated with all the stages of a product's lifecycle. The problem is that allocation is lacking unambiguous basis and, thus, jeopardising the credibility of the LCA methodology. Allocation decisions are easily influenced by the analysts' perspectives and worldviews and, thus, there are arguments from different angles whether, for instance, economic, biophysical or mass-based allocations are suitable or not in different case-studies/decision-making situations.

The discussion about allocation methods has been going on and on in the research community but methods' usefulness in reality is not always fully considered. Therefore, the actual barriers for the acceptable (depends on the viewer) allocation methods are easily forgotten. In the Foodprint project, besides a broad literature review and active following of international discussion on allocation methods, there have been several discussions with the Finnish food chain actors to discover allocation methods that are simultaneously comprehensive, suitable and practical. In these discussions, for instance, biophysical allocation (read e.g. IDF 2010: allocation between milk and beef (Appendix B)) raised interest but its complexity and limited use were considered its definite drawbacks. Additionally, internationally widely preferred economic allocation was seen problematic for many reasons. First of all, the market prices fluctuate and are easily influenced by various external factors. Secondly, if earlier prices (e.g. products' values prior to any further processing) are used, these prices depend on producers' pricing strategies, and thus, not on the 'actual values' of products. These prices are also often trade secrets. All in all, in economic allocation the allocation proportions are usually heavily influenced by many factors. Therefore, in order to improve the appropriateness of the use of economic allocation one should pay more attention to its uncertainties and weaknesses - at least uncertainties should be revealed when communicating the results.

Another important issue brought into the discussion by the Finnish food chain actors was that in order to receive harmonised results one needs strict allocation rules instead of rules that are loose and open to interpretations. It was stated that since food sector comprises several different food products, it would be best to agree on the best allocation methods or on the least bad alternatives in a more case specific level. This leads us closer to the product category rules' (PCRs') ideology, i.e. closer to product specific rules. Furthermore, it was stated by food chain actors that these more case specific discussions should also take into account different types of food product chains in order to attain more uniform allocation rules.

Altogether, the aim of the discussions and preferred practices in Finland is not to differentiate Finnish practices from international practices. On the contrary, the aim is to strengthen the international harmonisation and, thus, to share Finnish experiences and discuss them. We believe that the attempt to harmonise LCA calculation, to fully understand the weaknesses of allocation practices, and to find more appropriate approaches requires collaboration among the research community and, moreover, strong inclusion of the food chain actors into these discussions.

References

IDF (International Dairy Federation). A common carbon footprint approach for dairy, The IDF guide to standard lifecycle assessment methodology for the dairy sector, Bulletin of the International Dairy Federation 445/2010.

132. Assessment of the life cycle of a Portuguese wine: from viticulture to distribution

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This study assesses the life cycle assessment of a wine produced in Portugal, i.e., the white green wine, designated as vinho verde branco. This is to identify the environmental impacts occurring along the wine life cycle. The stages considered include activities taking place during 1) Viticulture, 2) Wine production (from vinification to storage), 3) Distribution and 4) Bottles production.

Materials and energy consumption as well as the emissions to air, soil and water from the wine campaign of 2008/2009 were reported to the functional unit (0.75 litres of white green wine). A Portuguese company, located in the northern part of Portugal, responsible for the production of about 20% of the current total production of white green wine, supplied specific life cycle data, including information regarding transportation of grapes, wine, must and other wine production related products. Information concerning the distribution of this wine consumed worldwide is also made available by the company in terms of the amount sold to each country and the transportation mode.

The life cycle approach taken shows Viticulture as the stage that mostly contributes to most of the impact categories. The production of glass bottles appear as the second larger contributor and Wine Production and Distribution appeared as the third larger contributors. The Production of wine products and the transportations of grapes, wine products and wine and must have a comparatively negligible effect. Sensitivity analysis results show that some parameters are very influential.

133. Can you afford to make an eco-diet?

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The EU Commission has set the agricultural sector a recommended target of reducing greenhouse gas emissions by 50% by 2050, which would require a 35% reduction by 2030. Our aim was describe some possible changes in the Finnish diet that can help cut the emissions, while at same time benefitting public health, by e.g. preventing heart diseasesand overweight. Meanwhile, big changes in food patterns are usually difficult to achieve, we created several small adjustments all through the diet, keeping all the time the nutritional recommendations in mind. We assumed that this approach would be much more successful than recommending for example a vegan/vegetarian diet for everyone.

Our Eco-Diet's main aim is to decrease the environmental impacts of food chain, while it simultaneously encourages healthy eating patterns, is more economical to the consumer, and improves animal welfare.

In Eco-Diet, we propose that meals in general contain less meat and more vegetables, and we prefer seasonal products. Our Eco-Diet is a model that is easy to adapt to everyday life by everybody, without requiring any specific knowledge or education, or particular motivation for shifting towards vegan/vegetarian diet. Both of our benchmarked diets, the eco-diet and conventional diet used as a reference include meat, fish and dairy products.

We termed our conventional diet Basic Diet, and it was composed based on average Finnish diet with average amount of calories. The other one we termed Eco-Diet, which took into consideration climate change, water eutrophication, nutrition recommendations including appropriate amount of calories, and food waste. Both diets covered a full week of five working days and two days of weekend; each day having three meals: breakfast, lunch and dinner. Breakfast consisted of juice, bread or porridge, vegetable oil margarine, and some vegetables or fruit. Lunch and dinner consisted of meat, fish or bean main course and a side dish such as potatoes or rice. In addition, lunch and dinner included also a salad, bread, spread and drink.

The Eco-Diet included various kinds of meals; home cooked meals, convenience food and meals cooked in school canteens in communal food services. In our model we used school meals for lunch, home cooked meal or convenience food for dinner, and a home cooked breakfast. Here school meals were seen as an equivalent to office lunch. For the weekends, lunch and dinner were home cooked or convenience food meals, and breakfast was made at home.

We demonstrated that by following Eco-Diet for one week there was ca 40% decrease in carbon footprint, while the impact on water eutrophication was even more significant. Differences in environmental impacts between single food plate portions are remarkable: the highest animal based portions can have 5 times the environmental impact when compared to the lowest vegetarian/vegan portion. In Eco-Diet we managed cut off the highest impacts of the single food plates to such an extent that the difference between lowest and the highest impacts was only about three times, in both carbon footprint and water eutrophication.

We compared the cost of the Eco-Diet to the conventional diet, and found that for a consumer economy the Eco-Diet is a feasible, money saving alternative. Thus, we could oppose the preconception and correct the thinking that environmental enhancive diet would be more expensive and as such regarded as a premium diet. At the same time with saving the environment we can also save our money.

In Finland households are wasting about 5% of all purchased food[8]. Production of food that is lost in the food supply chain causes remarkable, unnecessary environmental and economic impacts. We assumed that Eco-Diet does not waste any food.

134. Value of a life cycle approach in evaluating the environmental impacts of packaging for food and beverage applications

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The nexus between security and safety and environmental performance of packaging in food and beverages is a key question driving the market for sustainable packaging today. Therefore, an articulation of the benefits of the life cycle approach to design, manufacturing, use and end of life management of packaging for food applications is important to further examination of the role of packaging.

Key items of focus for this research and analysis included:

- What is the value of a life cycle approach for beverage and food products and packaging?
- What is the value of including all life cycle stages in evaluating the packaging/food systems to reduce overall life cycle impacts?
- What is the value of including multiple impacts in evaluating the packaging/food systems to reduce overall life cycle impacts?
- What is the value of including the food and/or beverage into an evaluation of the packaging life cycle impacts?
- What characteristics of future LCA studies should be considered when evaluating the food/packaging life cycle?

Examples of how the waste management hierarchy and LCA results interface/connect

This presentation will present the results of study to examine the value of a life cycle approach in evaluating the environmental impacts of packaging for food and beverage applications. The UNEP/SETAC Life Cycle Initiative brought to the project a unique combination of benefits that cannot be obtained from other sources. These benefits include:

- Neutral, objective, authoritative, and recognised forum for advancing understanding of packaging life cycle for food applications
- Global dissemination of the report
- Proven 10-year history of solid project deliverables

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References

Valdivia, S., Vigon, B., Fava, J., Flanigan, L. Value of a Life Cycle Approach in Evaluating the Environmental Impacts of Packaging for Food and Beverage Applications. UNEP/SETAC Life Cycle Initiative. Expected publication June 2012.

135. Spatial food-print to supply livestock products to Paris, 19th-21st centuries

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When cities import food to sustain their metabolism, they virtually import land resources from the surrounding local and distant rural territories that generate the food. We refer to this vital physical substrate of urban metabolism as the spatial urban food-print (or food-print). The food-print locates where the food and animal feed crops are grown and its size depends on various parameters that can be divided into three categories: urban diets, crop yields and "feed to food" conversion ratios (Chatzimpiros and Barles, 2010).

In this proposal we determine the food-print to supply cereals and livestock products (beef, pork, chicken, dairy products and eggs) to the Paris metropolitan area since the early 19th century. Over this period, the food-print of fast growing occidental cities like Paris was the substrate of fundamental changes in the structure of agro-ecosystems and the common ground for transformations in both agricultural productivity and urban diets. Until the early 20th century, food supply to Paris is calculated from data records of the city's food markets. After that date, data become scarce due to progressive increases in the number of food supply chains and retail markets and, as for today, urban food consumption is not specifically known for any French city. Since the 1960s though, dietary discrepancies across France are low enough to allow deriving urban food supply from data on national food availability (production, plus imports, minus exports). We thus derived a time series of food supply to Paris since the early 19th century which we express as nitrogen (e.g. protein) and convert into land requirements for food production – the food-print of Paris – using data on food and feed crop yields (Statistique agricole annuelle) and nitrogen conversion efficiencies (NCE) in livestock production. For pork, beef and dairy production we used model-derived data of NCE for the early 19th, 20th and 21st centuries (Chatzimpiros, 2011). For chicken and egg production, we used data covering the second half of the 20th century (Lambier and Leclercq, 1992, Smith, 1997, Smil, 2002). We interpolated/extrapolated data on NCE over time proportionally to key variables such as biomass production rates.

Fig. 1 shows Paris population and its food-print since the early 19th century. Between 1850 and 2008, population grew 7-fold, food supply 8.5-fold and the food-print 2-fold. In Fig. 2, per capita supply (kg N/cap) is plotted with land requirements for production (ha/kg N) (land requirements decrease with time). The resulting curves show increases in the consumption of livestock products with low land requirements. As long as beef was the cornerstone of agrarian systems (<1950), urban consumption of beef was high.

References

Chatzimpiros P. and Barles S., 2010. Nintrogen, land and water inputs in changing cattle farming systems. An historical comparison for France, 19th–21st centuries, Science Tot. Environ., 408(22), 4644-4653.

Chatzimpiros P., 2011. Les empreintes environnementales de la consommation alimentaire: Paris ses viandes et lait, XIXe – XXIe siècles, Thèse de doctorat: Université Paris Est, Marne-la-Vallée, 368 p.

Larbier M. and Leclercq B., 1992. Nutrition et alimentation des volailles, INRA, Paris.

Smil V., 2002. Nitrogen and food production: Proteins for human diets. Ambio 31: 126-131.

Smith A. J., 1997. L'élevage de la volaille. Maisonneuve et Larose, Paris.

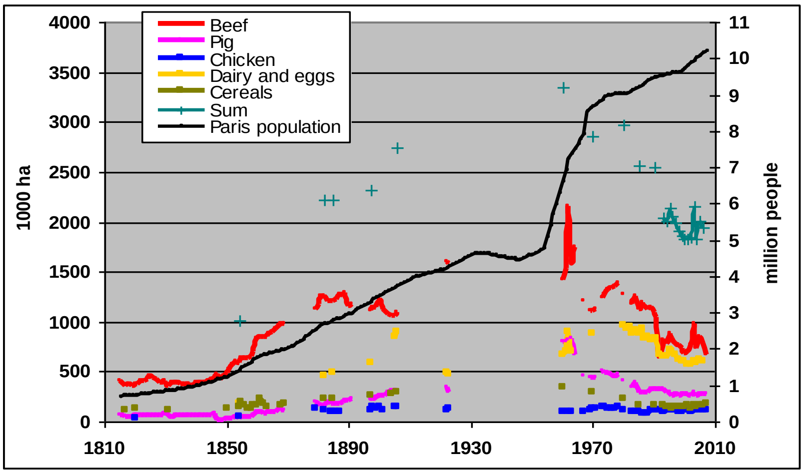

Fig 1: Food-print of Paris for cereals and livestock

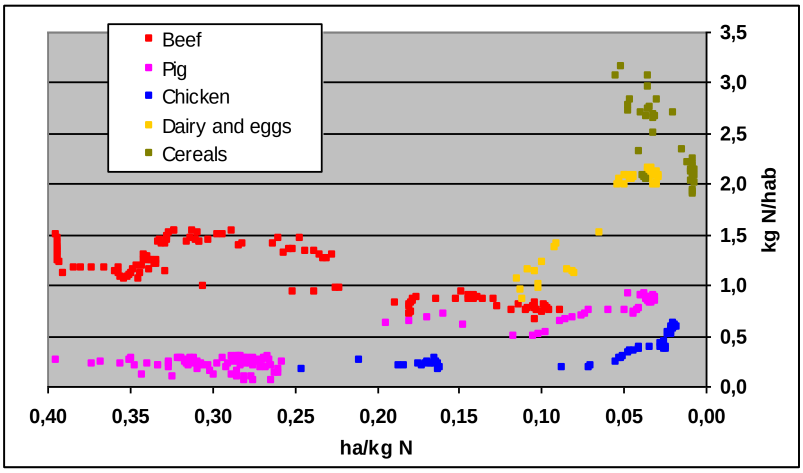

Figure 2. Land requirements and per capita consumption

136. Analysis of material and energy flow associated with food production and consumption in Japan

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The potential load on the environment due to food systems has been discussed for years. In the existing research (Shindo *et al.*, 2010; Oda, 2006) on food systems, nitrogen accumulation in Japan is attributed to increase in food import, increase in chemical fertiliser input, and changes in food consumption patterns. Life cycle thinking plays an important role in understanding the comprehensive flow of energy, carbon, water, and other important materials associated with the systems for food production/consumption and biomass (food waste) utilisation. Such evaluation is required for estimating the comprehensive effect of future changes in consumption patterns, biomass policy, and agricultural technologies.

In this study, the material flow associated with food systems, including waste treatment and recycling, is evaluated. In particular, we focus on the energy flow, including some indicators that reflect the energy effectiveness of food systems and the utilisation level of biomass and food waste.

The energy flows investigated in this study are related to the following types of energy:

1. Cumulative non-renewable energy
2. Feedstock energy related to food and biomass
3. Nutritionist's calories of food

In this study, we evaluated 47 commodities of food. They were evaluated on the basis of the following indicators:

a. Effectiveness of utilisation of food waste and co-products (EF-w)

$$(EF-w) = \frac{EP + AE - EC + FSE_2}{FSE_1}$$

Here, FSE_1: Feedstock energy before treatment/utilisation of food waste and co-products; *EP*: Energy production via utilisation of food waste/co-products; *AE*: Alternative effect of material recycling; *EC*: Energy consumption during treatment/utilisation of food waste and co-products; FSE_2: Feedstock energy after treatment/utilisation of food waste and co-products.

b. Energy effectiveness of food supply/consumption (EF-f)

$$(EF-f) = \frac{FE}{TI - EP - AE}$$

Here, *TI*: Cumulative non-renewable energy used; *FE*: Total energy intake for a food system

The data pertaining to material flow and food transportation are collected from statistics, reports, and experts. The data pertaining to energy consumption during food production are collected from papers or calculated from production-cost data.

Fig. 1 shows the material flow of food products in Japan in 2005. The amount of input from crop farming to animal farming is roughly the same as that to that from food manufacturing. The flow from food manufacturing to animal farming denotes the flow of rice and wheat bran. The internal flow related to crop farming consists of the incorporation of residues. The comprehensive approach employed in this study can be used to evaluate the effect of active utilisation (for example, bioethanol production or composting of straw) by considering alternatives for organic materials used in farmlands and future change in grain consumption, which are necessary for deciding long-term policies.

References

Shindo J., Okamoto K., Kawashima H., Konohira E, 2010. Nitrogen flow associated with food production and consumption and its effect on water quality in Japan from 1961 to 2005. Soil Sci. Plant Nutr., 55(4), pp. 532-545

Oda K., 2006. Trends in nitrogen flow since the 1980s in the food and feed system in Japan. Jpn. J. Soil Sci. Plant Nutr., 77, pp. 517-524 (in Japanese with an English abstract)

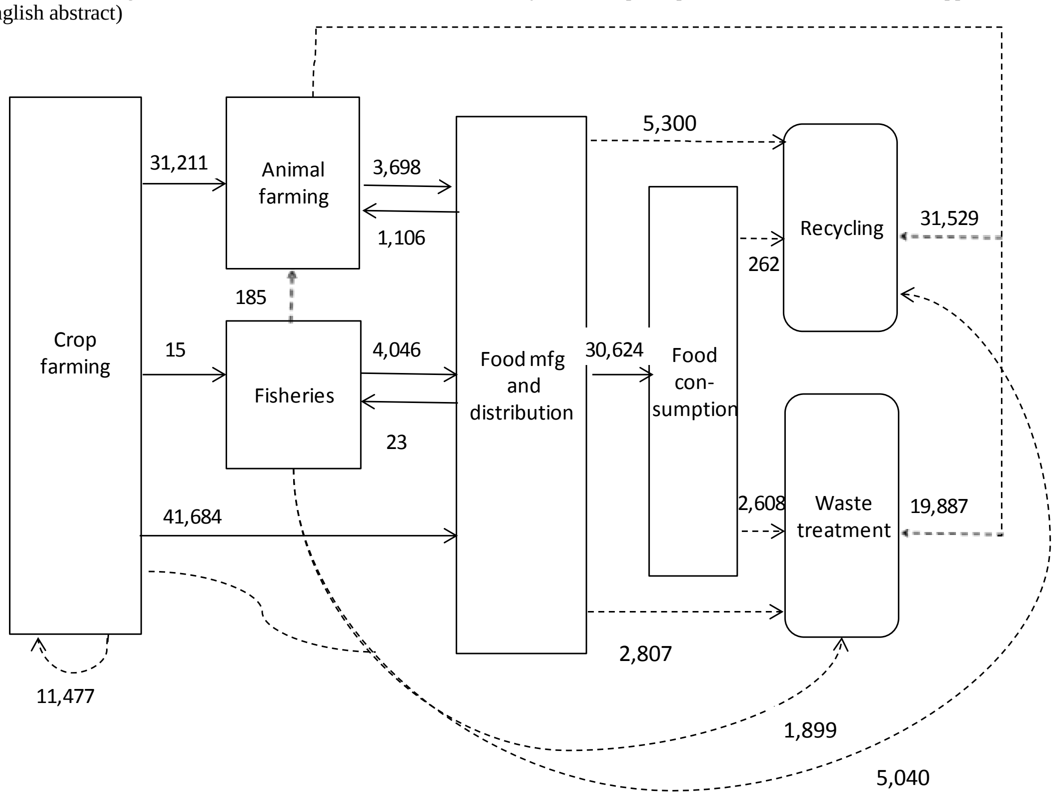

Figure 1. Material flow associated with food production and consumption in Japan in 2005 (Unit: thousand tonnes, wet).

137. Environmental impacts of pasta cooking

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Sustainability has now entered in the agendas of companies, policy makers and a fraction of "green consumers". Companies work to achieve environmental impact reduction, while policy-makers work to define strategies aimed at improving the sustainability of production and consumption chains. Consumers are asked to prefer products that demonstrate compliance with these requirements.

Though the production phase always seems to be the most important in terms of environmental impacts, in some cases the consumer use bears even more impact than production itself: pasta falls into this case and, therefore, this paper presents elaborations aimed to the calculation of the environmental impacts of the cooking phase.

The starting point is constituted by a full life cycle assessment of Barilla's pasta production that was published in a verified Environmental Product Declaration in which the carbon, ecological and water footprint were illustrated in utmost clarity.

Aside from this, a detailed study on the cooking impacts was made, and the carbon footprint of different cases evaluated. Normally pasta makers recommend using 10 times the water in comparison to the amount of product being cooked: 500 g should therefore use 5 litres of water. It is interesting to consider how the use of different amounts of water can affect energy consumption and the relative impacts in terms of CO_2 equivalents.

At this point, it is interesting to examine how the various environmental impacts vary in relation to the amount of water used for cooking. The diagram below represents the impacts for both a smaller and a larger amount of water used for cooking 500 grams of pasta; some considerations were made changing the quantity of water used to cook pasta, moving from 4 to 6 litres This abstract also accounts for the Italian energy-mix for electricity production. Data about energy production and use come from ecoinvent database.

It is interesting to assess how a variation of the quantity of water used yields significant differentiations of impact: -20% water corresponds to -7% GHG emissions for gas cooking procedures (Fig. 2).

The carbon footprint of the pasta cooking phase is similar to that of production. That is why correct consumer behaviour is as important as corporate efforts aimed at reducing impacts. In particular, it is quite important to use the right amount of water, cover the pot while waiting for the water to boil, and add salt only when the water is boiling. This aspect of the cooking phase is directly linked to the consumer's behaviour. That is the reason why proper consumer information is crucial for achieving sustainability, learning how to avoid useless waste and be more environmentally friendly.

References

Baldo, GL, M. Marino, S. Rossi, 2008. Analisi del Ciclo di Vita LCA, nuova edizione aggiornata, Edizioni Ambiente.

Barilla, 2011. Environmental Product Declaration of durum wheat semolina dried Pasta in paperboard box (brand Barilla), Published on the International EPD system register. www.environdec.com (Rev. 2.1; approved the 10/03/2011, Reg. S-P-217).

Barilla Center for Food and Nutrition (BCFN), 2011. 2011 Double Pyramid: Healthy Food for People, Sustainable for the planet, Supporting technical paper Version 2 of 14 July 2011.

Ecoinvent Swiss database, v.2.0, www.ecoinvent.ch

Foster C., Green K., Blea m., Dewick P., Evans B., Flynn A., Mylan J., 2006. Environmental impacts of Food Production and Consumption – a Report to the Department of the Environment, Food and Rural Affairs (DEFRA), Manchester Business School, London.

Nilma, Italian manufacturer data sheets, www.nilma.it

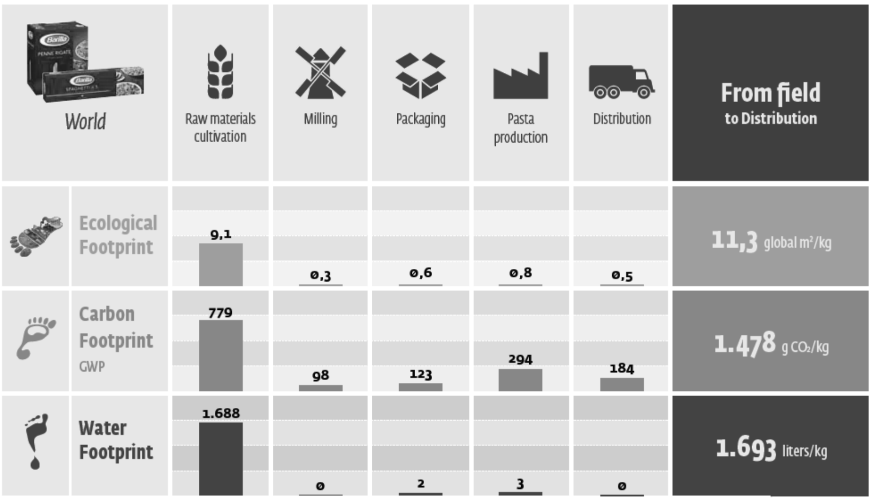

Figure 1. Footprint of pasta production (Barilla, 2011)

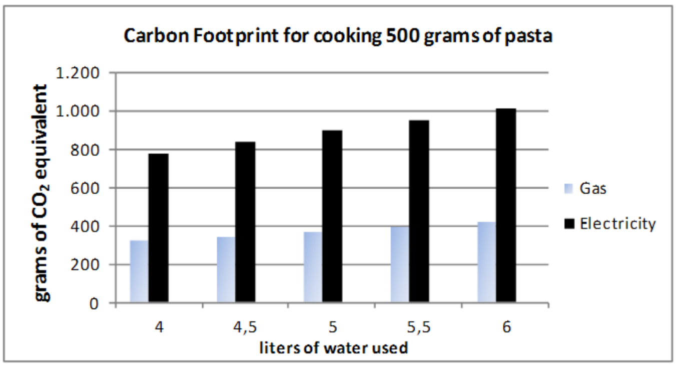

Figure 2. Carbon footprint for cooking 500 grams of pasta assuming a variable pasta/water ratio of ± 20% and a cooking time of 10 minutes. A total of 5 litres of water were used as recommended by the producer (BCFN, 2011).

138. The development of robust Life Cycle Analysis for mycoprotein and the meat free brand Quorn™

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The global food supply system is experiencing increased protein demand pressures that are dependent on feed and livestock production systems that have received much attention in LCA research (FAO, 2006). Several internationally led assessments of wider impacts of livestock production raise the importance of Indirect Land Use Change (ILUC) associated with production and trade in livestock products. An area that has received less attention and one where we believe we are ready to report robust LCA data is that of industrially produced proteins (Finnigan et al., 2010 and Toumisto 2010). We believe that industrially produced proteins offer significant benefits to the current world protein supply system that are currently unrealised by meat producers, food manufacturers and policy makers.

To define the potential of meat free ingredients we have developed a LCA based approach to defining the production impact of the mycoprotein ingredient for the Quorn™ brand of food products that is retailed in 22 countries. Mycoprotein is produced industrially from the fungal fermentation of wheat derived glucose in the United Kingdom. An LCA programme within the mycoprotein and Quorn™ manufacturing facilities provided GWP measurements of 3.1 for mycoprotein and typically 4.2 for Quorn™ products (see **Table 1**). This initial LCA provided important targets for future investigation within the Quorn™ supply chain. These were (1) energy balance and the use of co-product steam in Quorn™ manufacture from nearby ammonia fixation plant, and, (2) the use of Egg White Protein (EWP) in the manufacture of Quorn™ from mycoprotein. A further outcome, was a more detailed investigation of the Quorn™ ingredient supply chain in the terms of embodied GHG's and energy.

Development and improvement of the existing LCA has identified GWP reductions of at least 30% over a three year period committing to the company to significant investment in LCA based on the very clear business case that implementing LCA procedures improves production efficiencies and identifies cost reduction. Furthermore, Quorn Foods Ltd has aligned current methodologies with the Carbon Trust Footprint Expert LCA Model. This approach has further detailed knowledge of the mycoprotein and Quorn™ supply chain in terms of embodied resources and environmental impact associated with the product. It has further identified the reality of fixing LCA boundaries around a brand that has over 90 discrete Stock Keeping Units (SKU's).

We show that aligning commercial and marketing information with a international standard such as PAS2050 is still in a developmental stage. There is a requirement to develop applied statistical methods so that companies can obtain typical data for supply chains that are not just 'snapshots' but represent integrative data of supply chains over realistic commercial time periods accounting for production, waste and proportion of product consumed by consumers. This is critical to food supply chains and others where there are seasonal changes in the LCA of ingredients and selective consumption of specific parts of products. We present research that defines our approach in developing the functional unit of initial LCA of 1 tonne of mycoprotein to a 300g of retail product purchased. In achieving this we have identified important considerations for the global protein production system where industrially produced proteins have a critical role to play in optimising land use.

References

FAO, 2006. Livestock's Long Shadow. ISBN 9789251055717

Finnigan T., Lemon T., Allan B., and Paton I., 2010. Mycoprotein, Life Cycle Analysis and the Food 2030 challenge. Aspects of Applied Biology 102, 81-90.

Tuomisto H., (2010). Food security and protein supply- cultured meat a solution? Aspects of Applied Biology 102, 99-104.

Table 1. The protein and eco-system service attributes of mycoprotein compared to wheat and beef

Protein source	Protein g/100g	GWP	Land use
Wheat	12.7	0.80	0.53
Beef	22.5	15.80	3.44
Mycoprotein	11.0	3.11	0.53

139. Environmental evaluation of French olive oil production

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Olive oil production is an important agro-industrial sector in the Mediterranean region of Europe, which has to face environmental issues. The OiLCA (2011) research program has been elaborated partly in order to reduce the carbon footprint and to optimise waste management of the olive oil sector in SUDOE area (Spain, Portugal and France). However, French production is different when compared to Spanish or Portuguese because it is more traditional. The present work proposes a life cycle assessment of the French olive oil production sector.

The study is led in accordance to the ISO 14040 (2006) and ISO 14044 (2006) standards. Functional unit is the production of one litre of olive oil. Transport of workers, olive tree culture, harvest, cold extraction, solid residues (leaves, branches and grounds) management, wastewater management, storage and bottling are the main identified steps of the system. Valorisation of waste is accounted like avoided impacts of a product with the same function. Matter and flow data come from 21 French enterprises contacted for the OiLCA project. All indirect extraction and emissions is calculated with the ecoinvent database. Then, impact assessment is realised with the impact methods Impact 2002+ and ReciPe 2008. The SimaPro® software is used for the impact calculation.

First results have permitted to define all the scenarios for olive oil production in France based on the different olive production techniques (with or without irrigation, mechanical or not, organic or not), the different extraction processes (pressing, centrifugation two phases or centrifugation three phases) and the different waste management (incineration or spreading). Raw data from enterprises have been collected. Expected results are the comparison of all the scenarios in order to identify parameters that influence environmental consequences of olive oil production.

References

OiLCA, 2011. Enhancing the competitiveness and reducing the carbon footprint of the olive oil sector through waste management optimization and the establishment of an ecological label, http://www.oilca.eu/index.htm

140. LCA of food packaging: soy-protein based films versus PP film

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Food packaging protects food against external environment to maintain its quality during storage and extend its shelf life. Conventional packaging plastics impact heavily on the environment because of its end of life and, furthermore, they are derived from non-renewable sources, so biobased materials could be considered friendlier for the environment than petroleum-based materials. In this context, soy proteins could be a potential replacement of conventional polymers because they are abundant, renewable, and biodegradable. Moreover, soy protein-based films can be processed to exhibit good mechanical and barrier properties for food packaging (Guerrero et al., 2011), using techniques such as extrusion (Guerrero et al, 2012), which are employed for industrial applications.

In this study, a comparative life cycle assessment was carried out between two different food packaging systems: a commercial food packaging film based on polypropylene (PP) and a new biodegradable soy protein-based film manufactured in our labs. The functional unit was 1 m^2 of packaging film. Three main stages were considered: resource extraction, film manufacture, and waste disposal. The data relating to PP packaging films were obtained from Ecoinvent v2.0 database. The life cycle inventory for soy protein production was taken from literature and film manufacture data was measured directly by our research group in the lab. The selected method for comparison of the films was EcoIndicator 99. The disposal scenario considered for soy protein-based biofilm was composting, due to the fact that the film is based on natural raw materials, while different waste scenarios were studied for conventional PP film: landfilling, incineration, and recycling.

As seen in Fig. 1, impact categories in which the biofilm exhibited a significant environmental charge were carcinogens, respiratory inorganics, climate change, land use, and fossil fuels. The responsible for the main impact in carcinogens and the high environmental burden associated to land use category was the cultivation of soybeans and the use of pesticides, fertilisers, diesel, and machinery associated to this cultivation. The environmental load in respiratory inorganics and climate change categories were principally owing to the emissions from wood burning and clear-cutting for land transformation, and the fuel consumption in this land transformation was the main cause of the impact in fossil fuels. Regarding to PP film, films disposed in landfill exhibited higher impact in carcinogens. Emissions of carbon dioxide, hydrocarbons, methane, and volatile organic compounds (VOCs) generated by waste treatment in landfilling were the main responsible for this impact (Sundqvist, 1999). In addition, the environmental burden in fossil fuels impact category was also very high for landfilling. On the other hand, when the end of life was incineration, the film showed high impact in climate change and fossil fuels categories, being raw materials extraction the stage that originated this environmental burden. Recycling waste scenario showed the lowest impact due to the fact that raw material was considered as avoided product in the recycling of the film, so that the emission associated to the extraction of PP was much lower than in the emission associated to the other end of life scenarios.

References

Sundqvist, J.O., 1999. Life cycle assessments and solid waste – Guidelines for solid waste treatment and disposal in LCA. Final Report. IVL, Swedish Environmental Research Institute.

Guerrero, P., Beatty, E., Kerry, J.P., de la Caba, K., 2012. Extrusion of soy protein with gelatin and sugars at low moisture content. Journal of Food Engineering, 110, 53-59.

Guerrero, P., Stefani, P.M., Ruseckaite, R.A., de la Caba, K., 2011. Functional properties of films based on soy protein isolate and gelatin processed by compression molding. Journal of Food Engineering, 105, 65-72.

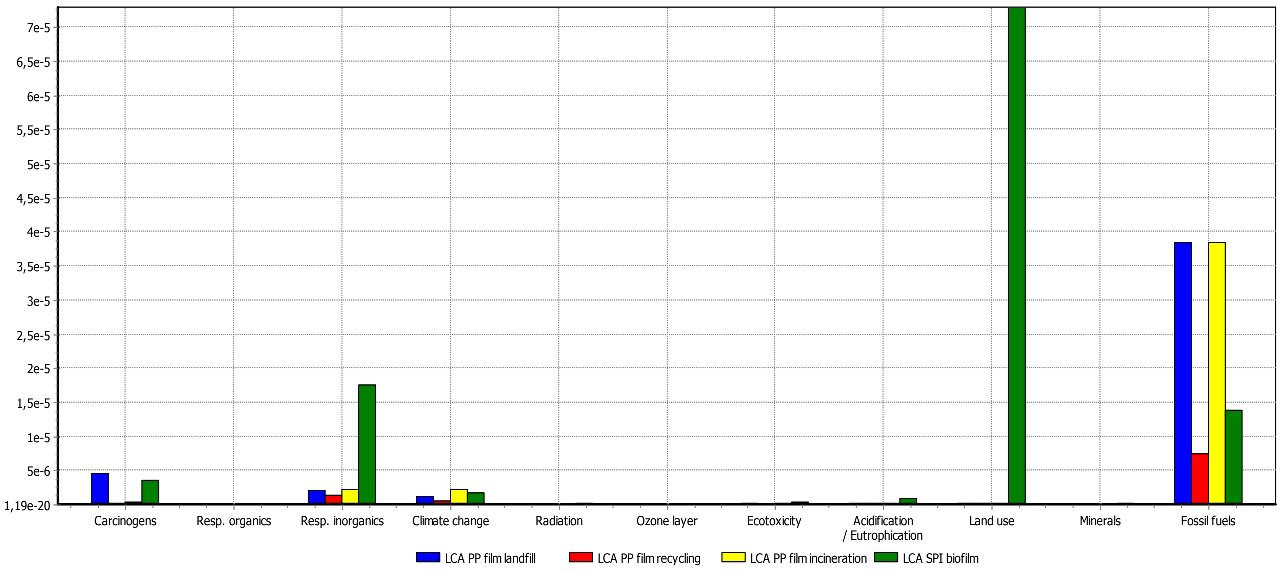

Figure 1. Normalised results of the comparative environmental assessment.

141. Comparative LCA of reconstituted milk and recombined milk processing

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The Algerian dairy industry operates mainly on the basis of milk powder and anhydrous milk fat (AMF). Technologically, two transformation processes allow us to obtain pasteurised milk: reconstitution and recombination. The first process involves rehydrating the whole milk powder while in the second process, the finished product is obtained from a mixture of reconstituted milk, based on skim milk powder and AMF.
This study, carried out in a dairy processing situated in Boudouaou (Algiers), aims to provide a comparative analysis of environmental impacts generated by these two processes. The approach used here is based on the life cycle assessment (LCA). This powerful and recognised method, standardised in the International Organization for Standardization (ISO 14040 to 14043) is used in practice.
Only the most significant impacts were considered in this study: Respiratory inorganic, terrestrial ecotoxicity, terrestrial acidification, land occupation, global warming and non-renewable energy consumption. The results obtained demonstrate the advantage of the recombination process compared to the reconstitution of milk. Indeed, the addition of AMF in the transformation process has reduced the impact by a factor of 3 to 6%. These results can be explained by the substitution in the scenario 2 a volume (5 tons) of milk powder by the AMF and also by its nature. Since it is a co-product, the impacts attributed to the AMF are negligible compared to those assigned to the milk powder, which is the main product. In the light of the obtained results, it seems more optimal to favour the recombination of milk-based AMF.

References

Cederberg, C., Mattsson, B., 2000. Life cycle assessment of milk production- a comparison of conventional and organic farming. Journal of Cleaner Production 8, 49-60.
Feitz, A.J, Lundie, S., Dennien, G., Morain, M., Jones, M., 2007. Generation of an industry-specific physico-chemical allocation matrix. Application in the dairy industry and implication for systems analysis. International Journal of LCA 12 (2) 109-117.
Høgaas Eide, M., 2002. Life Cycle Assessment (LCA) of Industrial Milk Production. International Journal of LCA 7: 115-126.
Hospido, A., Moreira, M.T., Feijoo, G., 2003. Simplified life cycle assessment of galician milk production. International Dairy Journal 13, 783-796.
Jensen, G.K., Nielsen, P.M. (1982). Milk powder and recombination of milk products. Reviews of the progress of Dairy Science. Journal of Dairy Research 49, 515-544.
Thomassen, M.A., Van Calker, K.J., Smits, M.C.J., Iepema, G.L., De Boer, I.J.M.(2008) Life Cycle Assessment of conventional and organic milk production in The Netherlands. Agric Syst 96:95–107.

Table 1. AMF contribution to different impact categories. (for 1 kg of milk)

Impact category	Unit	Scenario1	Scenario2	Difference	%
Respiratory inorganic	kg PM2.5 eq	6.93E-04	6.67E-04	2.64E-05	3.82
Terrestrial ecotoxicity	kg TEG soil	2.38E+00	2.22E+00	1.59E-01	6.67
Terrestrial acidification	kg SO_2 eq	6.39E-02	6.13E-02	2.58E-03	4.04
Land occupation	m^2org.arable	4.33E-01	4.15E-01	1.77E-02	4.10
Global warming	kg CO_2 eq	5.22E-01	4.96E-01	2.65E-02	5.07
Non-renewable energy	MJ primary	3.84E+00	3.62E+00	2.18E-01	5.67

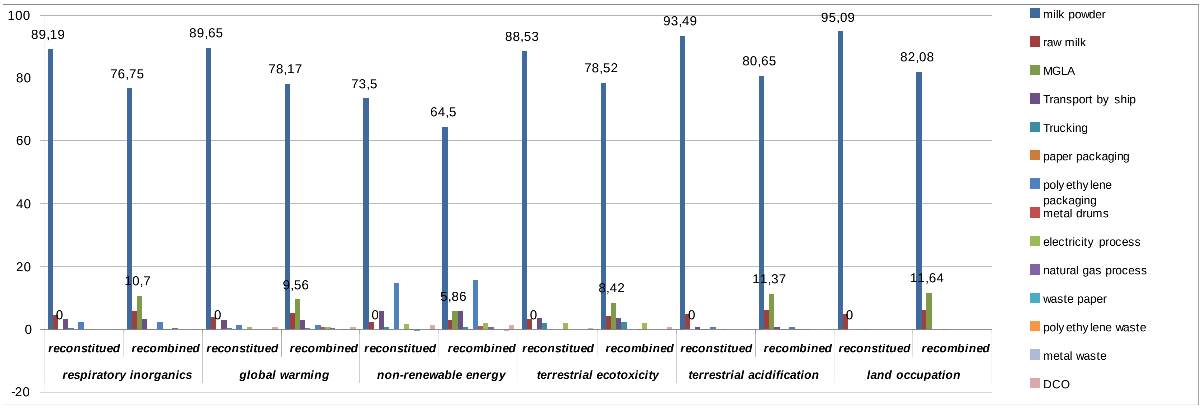

Figure 1. Contribution of the two processes to various impacts

142. Improving the efficiency of agricultural and food systems by introducing biodegradable and compostable products in strawberry supply chain: experience from northern Italy

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Bioplastics can be used to make biodegradable products for agriculture. Biodegradability can contribute to alleviating the waste problem of this sector. The FRUITGEST project aimed to increase the efficiency of strawberry supply chain by introducing biodegradable products at different levels of the supply chain itself. The first task interested the strawberry agricultural phase. Here the traditional mulch film made of traditional plastic (non-biodegradable) is replaced with the biodegradable one. By doing so the waste passes from 260 kg per ha up to zero. The second task was focused on the development of innovative strawberry packaging systems (i.e. flowpack). Aim was to increase the shelf life of the product, thus decreasing food losses, and to increase the efficiency of waste management at supermarket level. As a matter of fact, the packaging and its content (i.e. expired strawberry) are suitable to be collected along with organic fraction without any operations since the packaging is compostable according to EN13432. These changes in the strawberry supply chain were assessed by means of LCA using a consequential approach. Results have shown that the most important benefits were those related to the increase of shelf life of the product; this avoids wasting food (i.e. strawberry). Furthermore, also the use of biodegradable mulch film and packaging has positive consequences. Basically this project has demonstrated that, in particular circumstances and applications, the use of biodegradable bioplastics is beneficial, especially for the effects in waste treatment systems.

143. LCA of one cup of espresso coffee: how to collect and validate LCA data along the coffee supply chain

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The management of life-cycle inventory data is a complex and time-consuming task in LCA, especially due to upstream and downstream processes outside the company's system boundaries. The data collection is often hampered by the complexity of these processes, a lack of involvement of supply chain stakeholders and associated confidentiality issues. Being a key-player in the coffee supply chain Lavazza SpA, in collaboration with one of its suppliers, has attempted to overcome these barriers as illustrated in the LCA of espresso coffee.

The LCA of espresso coffee has been conducted in order to support Lavazza's ecodesign activities, a main part of the corporate social responsibility strategy and in order to create a truthful and correct environmental communication. Espresso coffee is a rather elaborated food system with a diversified supply chain, involving coffee plantations around the whole world (e.g. Brazil, India, Vietnam, Ethiopia), green coffee suppliers, packaging suppliers (especially Goglio Cofibox SpA), the coffee manufacturer (Lavazza SpA), the distribution chain, consumers and finally waste disposal management.

A crucial moment of the LCA execution has been the choice of Lavazza and Goglio Cofibox to work together, which has proved to be a successful partnership. The handling of the complexity of the multi-layer packaging is guaranteed by the Goglio Cofibox's packaging experts, while Lavazza is in the position to involve other actors in the supply chain.

The data used in the LCA comes directly from coffee manufacturers and suppliers. Energy consumption and greenhouse gases emissions impact categories are screened using IPCC 2007 and CED assessment methods, following the international standards ISO 14040 (2006) and ISO 14044 (2006). The results, consistent with other studies published on coffee (Humbert et al., 2009), show that about half of the environmental footprint occurs at a life cycle stage under the control of the coffee producer or its suppliers (coffee cultivation, treatment, processing, packaging up to distribution) and the other half at a stage controlled by the user (appliances manufacturing, use and waste disposal).

The success of this project depends on the company's ability to able to increase the awareness and commitment of the key players involved in the entire supply chain in supporting the improvement solutions. The validation and yearly updating of LCI data is also made easier in this respect, transforming initial barriers into mutual opportunities to understand the potential ecological footprint impact of each phase and to enhance the environmental market position of all chain stakeholders.

References

Humbert , S., Loerincik, Y., Rossi, V., Margni, M., Jolliet, O., 2009. Life cycle assessment of spray dried soluble coffee and comparison with alternatives (drip filter and capsule espresso). Journal of Cleaner Production 17, 1351-1358.

ISO 14040, 2006. Environmental Management – life Cycle Assessment – Principles and Guidelines. International Organisation for Standardisation (ISO), Geneva, Switzerland.

ISO 14044, 2006. Environmental Management – life Cycle Assessment – Requirements and Guidelines. International Organisation for Standardisation (ISO), Geneva, Switzerland.

144. Life cycle assessment of an artisanal Belgian blond beer

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In the framework of the Wal-Aid project funded by Wallonia aiming namely at developing valorisation means for co-products of the agro-food industry, a life cycle assessment applied to the production of artisanal Belgian blond beer of ‘ Brasserie des Légendes’ was carried out.

This analysis focuses on the production of a golden triple beer and the packaging step. The functional unit is the production of 1 litre of beer and the used method is ReCiPe endpoint. This production is carried out in six steps: (1) culture of barley, malting, grinding and transport of malt flour at the brewery, (2) brewing (heating and mixing) of malt flour and water in two steps, heating at 62-63°C during 70-90 minutes, then 73°C for 10-15 min. (3) Boiling wort at 105°C during 2h30 with steam generator. Hop is added to wort but only transport of this material is considered. (4) Then beer is kept at 4°C during 25 days, (5) packaging in brown glass bottle of 33 cl with a crown cap chrome steel. The mass of steel capsule is estimated at 2 g and 0.3 g of label’s paper. (6) Washing of spent grain recovered after brewing with H_2SO_4.

Most used data in this analysis come from the industrial site except for the production of barley malt and packaging. Information about these steps are taken from the literature. Generic data come from the ecoinvent v2.2 database (www.ecoinvent.org). Analysis was performed using SIMAPRO 7.3.2 software from PRé Consultants.

Electricity consumptions were calculated on the basis of energy balances and Belgian energy mix of 2008 released by the International Energy Agency. This mix shows that Belgian electricity is mainly produced from nuclear energy (57%), gas (31%) and coal (9%).

Figure 1 shows the percentage contribution of environmental impact for production’s steps of one litre beer in bottles. The most penalising step is glass packaging with 74.1%; then we find the preparation stage of malt flour with 19.8%. This stage represents culture of barley, malting, malt grinding and its transport at the brewery. Washing of spent grain step does not appear in this table because its impact can be considered as negligible.

Figure 1 shows the single score results of the production of one litre of beer and compares this production with and without packaging in glass bottle. First, we note that the packaging step greatly increases the overall impact of production process. Secondly, whatever the system boundaries, i.e. with or without packaging, the most important impacts are fossil depletion and climate change human health due to the energy demand of packaging step for the production of glass bottles and energy for growing, grinding and transporting malt flour. Impact of agricultural land occupation remains the same whatever the system boundaries as the packaging step is primarily energy consumption and no culture is associated. For the rest, climate change ecosystems, particulate matter formation and human toxicity are consequences of use of fossil resource to produce electricity and fuel.

This analysis shows that the most penalising step in the production of this artisanal beer is the packaging. So, it is on this step we have to work to reduce the environmental impact of this beer. In this study, we consider a packaging in brown glass bottles and it seems interesting to analyse a packaging of 20 litres in a keg and compare the results.

Acknowledgments: The authors gratefully acknowledge the Walloon Region of Belgium for the financial support of Wal-Aid Wagralim project.

References

Kloverpris, J. H., N. Elvig, et al. (2009). Comparative life cycle assessment of malt-based beer and 100% barley beer, Novozymes A/S, Harboes Bryggeri.

Table 1. Environmental contribution of production stages.

Step	Contribution (%)
Production of malt flour	19.8
Brewing	0.1
Boiling wort	3.9
Keep at 4°C	2.1
Glass packaging	74.1

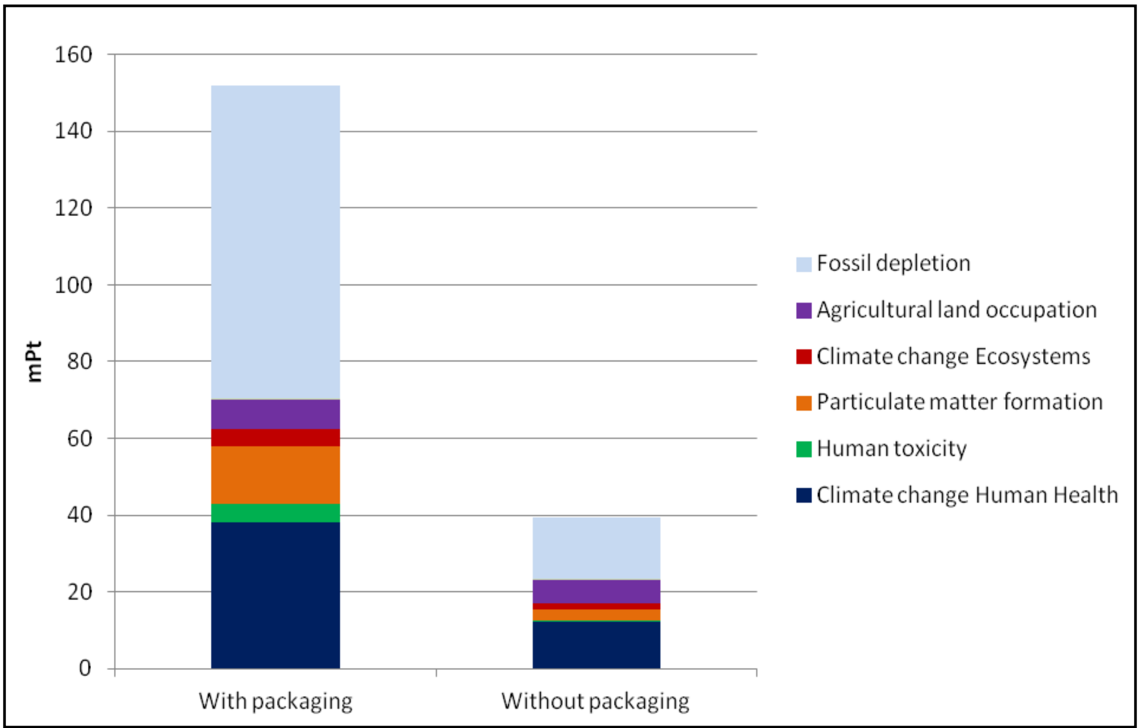

Figure 1. Single score results of 1 litre of beer production.

145. Tracking environmental impact of food production chain: a case study on fresh carrot chain in Italy

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It is recognised that food product supply chains contribute to the environmental impact of goods production and consumption. In the last years, an increasing number of food chain partners and public authorities have promoted many initiatives to provide information about the environmental performance of food products (Peacock et al., 2011), with an initial interest focused only on the carbon footprint analysis (Hillier et al., 2009; BSI 2011). Adoption of differences approaches, methodologies and objectives could confuse consumers and stakeholders, while scientifically defensible information concerning food production and food product and production systems are required by policymaker and producers (Schau and Fet 2008).
Here we proposed a new method specific for food products and production chains eco-labelling based on LCI built on modular phases integrated within questionnaires. The food chain system boundary was defined so as to include four main phase: agricultural phase, processing and packaging, delivery to platform and to retail store. Consumer phase was not included, except for waste management. The LCI considered all the inputs, both energy and material, involved in the production process, and the outputs for each phase of the food chain, including all transports until the supermarket. Special attention was devoted to the agricultural phase, for all field operations data were tracked in a field trial notebook and all the direct field emissions were included. This method was applied to a complex food product chain of a large-scale retail trade company. The examined production was fresh carrot within a real case study in Italy, using an approach similar to that of food traceability. 1 kg fresh carrot packed in a plastic tray was chosen as functional unit (FU), and the production chain was organised in farm production, processing and packaging in Abruzzo Region, delivery to distribution platform in Lombardy Region and to one single retail store located in the same region (Fig. 1). The data collection was referred to 2009; primary data were collected by questionnaires, filled out by farmers or technicians responsible of each phase. Secondary data were from GaBi embedded database and literature (GaBi, 2012). CML 2001 method was used for impact assessment for seven main impact categories (IC): Global Warming (GWP), Acidification (AP), Eutrophication (EP), Freshwater Aquatic Ecotoxicity (FAETP), Terrestric Ecotoxicity (TETP), Photochem. Ozone Creation (POCP), Human Toxicity (HTP). Results presented in Fig. 2 show that packaging and storing phases were responsible of the largest impact level in each considered ICs, mainly due to the estimated electricity consumption for refrigeration. It is important to notice that also the distribution at platform, rarely included in the literature, could significantly affect the results in some IC, 33% in FAETP and 27.5% in HTP. On the contrary, the cultivation phase showed low impact levels in average, with exception for EP, where it was responsible for the 39% of the estimated impact. The proposed approach was able to describe and analyse the impact of a real food production chain. The questionnaires allowed building a simple and clear method for a detailed data collection. This approach helped to develop a standardised system boundary for food products and subsequently to carry out robust and easily comparable LCA analyses.

References

BSI, 2011 PAS 2050:2011 - Specification for the assessment of the life cycle greenhouse gas emissions of goods and services. BSI British Standards, London.
GaBi, 2012. GaBi software. http://gabi-software.com
Hillier, J., Hawes, C., Squire, G., Hilton, A., Wale, S., Smith, P., 2009. The carbon footprints of food crop production. Int J Agric Sustain, 7(2), 107-118.
Peacock, N., Camillis, C., Pennington, D., Aichinger, H., Parenti, A., Rennaud, J.-P., et al., 2011. Towards a harmonised framework methodology for the environmental assessment of food and drink products. Int J Life Cycle Ass, 16(3), 189-197.
Schau, E. M., Fet, A. M. 2008. LCA Studies of Food Products as Background for Environmental Product Declarations Int J Life Cycle Ass, 13, 255-264.

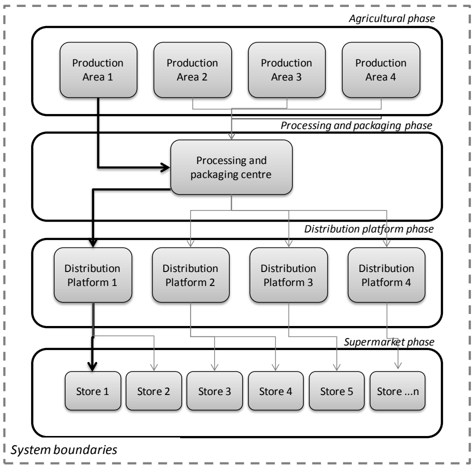

Figure 1. System boundaries of 1 kg fresh carrot plastic tray production chain. The black arrow identifies the system analysed.

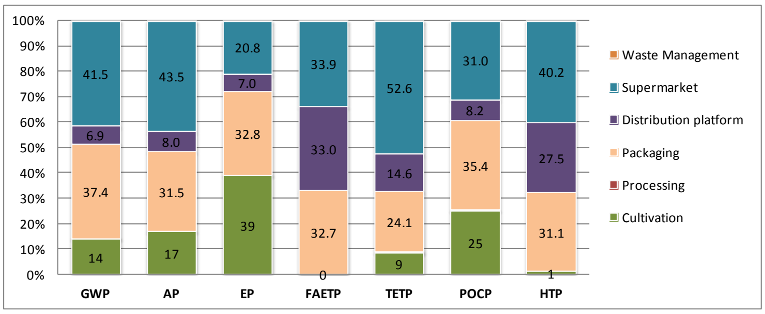

Figure 2. Impact assessment for 1 kg fresh carrot plastic tray for food chain phase.

146. Life cycle assessment of an Italian sparkling wine production

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The environmental impacts of food products and methods to identify and minimise those impacts are drawing the attention of producers. Wine producing firms are particularly interested in these topics in order to demonstrate that along with the quality of the product they are also committed in developing a proper environmental management of the production chain. To meet the requirements of an important Italian wine producer the environmental performance of a sparkling wine made by a winery of a Trentino province, has been investigated.

This paper presents the results of the a life cycle assessment (LCA) applied to an Italian sparkling wine from vineyard operations, winery activities from grape crushing to bottling, and to packaging.

The main objective of the study was to quantify input flows of raw materials and energy in order to detect the environmental impacts associated with output flows and releases at any stage, from cradle to gate, of wine to evaluate the environmental performance. Furthermore, quantification of environmental impacts enables the identification of the hot spots of the activities and stages and the definition of management practices to improve environmental performance.

Foreground data were collected from Cantina Rotari (Gruppo Mezzacorona) and refer to production year 2005. Background data were derived from different databases such as EcoInvent and Corinair. The inventory table was constructed for one bottle of wine (0.75 L) using the LCA software SimaPro and data were assessed using the Eco-Indicator 99 method.

The characterisation result graph shows that bottle production contributes to all the 11 impact categories considered with high percentage values for Ecotoxicity (88%) and Acidification (55%). A further step to better understand the magnitude of the category indicator results is normalisation, which shows (Fig. 1) that fossil-fuel extraction is the prominent impact category being bottle production and pesticides the major contributors.

As regards the single process contribute to the three damage categories (Human Health, HH; Ecosystem Quality, EQ; Resources, R) glass production is the first process for both HH and EQ whereas crude oil utilisation is the first process for R followed by glass production.

Finally, the Ecoindicator single score assessment (Fig. 2) shows the impact of each process to all the damage categories being the glass production and the crude oil utilisation the ones that more contribute to the damage categories considered.

This LCA study pointed out that in this specific sparkling wine production there are two processes that mainly affect the overall environmental impact: the bottle production that accounts for 36% of the total impact and the pesticides production and utilisation that account for 27.3%.

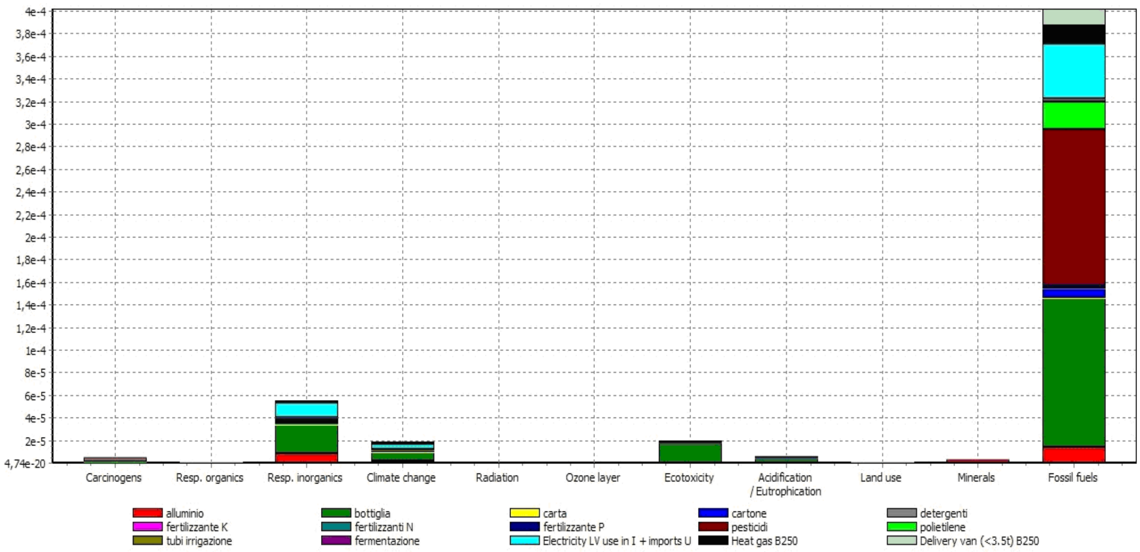

Figure 1. Sparkling wine production – Impact assessment normalisation.

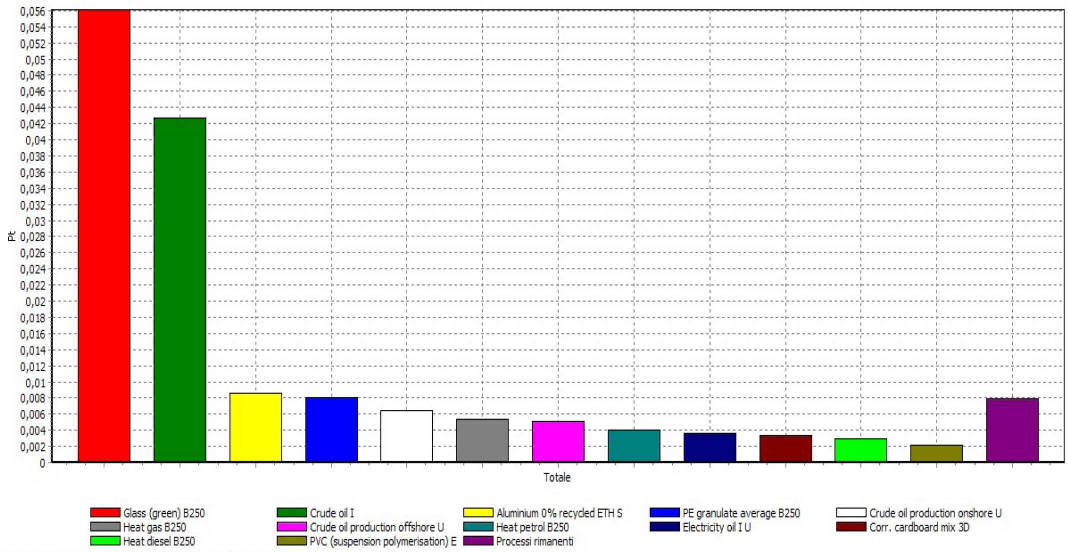

Figure 2. Sparkling wine production - Process contribution, single score.

147. Influence of transport on environmental impacts of the production chain of poultry in Brazil

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Brazil is among the five largest exporters of poultry meat (Burnquist et al., 2011, USDA, 2011) solidifying as one of the majors exporter of livestock products, Brazilian's production is benefited by favourable climatic conditions and its vast territory, besides the high government investment in the sector. These production chains, such as poultry, pigs and cattle, in particular, are able to produce all raw materials that it's used in animal feed. That feature brings interesting advantages for Brazilian companies when evaluated the environmental impacts of its products since livestock production is responsible for a major impact on the environment as noted by de Vries and de Boer (2010), so the choice for a more sustainable product can mitigate some of these impacts. Although the chain can be self-sufficient in production of grains, the large distances of a continental country between the stages in the life cycle added to the lack of kinds of transportations may eventually supplant that environmental gain. Thus the aim of this paper is to evaluate from the environmental point of view, different kinds of transportation and their influences on the productive chain of frozen chicken for export. We evaluated two scenarios: (A) Poultry produced and exported in South with the grains coming from the Central West; and (B) Poultry and grains produced in Central West with the exportation placed in South East. The functional unit is a ton of poultry delivered in the port for exportation. The method used through the software SimaPro® was the CML 2000 with modifications, from where we choose by the easier level of communication with the stakeholders, the impact categories of global warming and total cumulative energy demand. The results of the LCA of the usual scenarios, indicates South Poultry as that with the worse environmental performance, due the transportation of grains. For the category of global warming the difference between the South and the Central West, in tons of CO_2 equivalent emitted, only from the transportation of grains and the final product are about 49.6%, with the possibility of this difference decrease 19%.

References

Burnquist, H. L., da Costa, C. C., de Souza, M. J. P., Fassarella, L. M., 2011. Composite Index of Market Access for the Export of Poultry from Brazil. International Centre for Trade and Sustainable Development (ICTSD), Geneva, Switzerland.

United States Department of Agriculture (USDA), 2011. Livestock and Poultry: World Markets and Trade. Foreign Agricultural Service.

de Vries, M., de Boer, I.J.M., 2010. Comparing environmental impacts for livestock products: A review of life cycle assessments. Livestock Science 128, 1-11.

148. A methodological comparison of Life Cycle Sustainability Assessment of fruit and vegetable logistics

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For packaging fruit or vegetables, wooden boxes, cardboard boxes and plastic crates are most commonly used. While the first two are non-returnable packaging systems and normally disposed of or partly recycled after one use, plastic crates as a rule are returnable packaging, washed and reused many times.

The environmental impacts of the European wide fruit and vegetable distribution have been analysed by different institutions in different countries during the last decade. Some studies have analysed different transport packaging systems, but their understanding of the important life-cycle aspects and the sensitivity of the parameters within the life-cycles of the different packaging solutions is not homogeneous.

In this review, we analyse mainly the reports of three studies performed by Ecobilan (2000), ITENE (2005) and University of Stuttgart (2009). It is very interesting to note the differences from the commissioning organisation to how the study has been communicated. In between, methodological differences can be found in relation to each methodological step. Differences can be found in: the goal and scope of the study; how sustainability is addressed; the assumptions to key parameters (such as number of rotations of plastic crates, from 10 to 100); how complex and close to reality is logistics taken (from single trips to international networks); how open-loop recycling is calculated; which combination of data sources is used, the treatment of biogenic CO_2; the extend of the sensitivity analysis or the inclusion of different scenarios and, in fact, how the interpretation phase of LCA is addressed; who and how performed a critical review; etc.

As per the results and the ones from the Fenix project, it is relevant to see that LCSA does not give a unique and static answer. While the study in 2000 showed that the multiple-use option was environmental preferable to the cardboard format for most of the environmental impact categories assessed and quite similar to the wooden study, the study in 2005 showed the opposite, i.e. that the environmental impact of single use cardboard boxes is always lower than that of reusable plastic in six of the 10 categories analysed. Finally, the study in 2009 shows a very similar result (with not totally equal numbers) than the first one.

Will a new study arise soon to balance the match scores? Is this a game or is it a serious matter with millions at stage? How should scientists respond to market pressure? Is LCA still being used as a throwing weapon nowadays? We are looking forward to a "fruit"-full discussion.

References

Ecobilan, 2000 (in French). Life cycle assessment of wood, corrugated board and plastic crates for apples.

ITENE, 2005 (in Spanish). A comparative study of the environmental and economic characteristics of corrugated board boxes and reusable plastic crates in the long distance transport of fruit and vegetables, Universitat Politècnica de València.

University of Stuttgart, 2009 (in English). The Sustainability of Packaging Systems for Fruit and Vegetable Transport in Europe based on Life-Cycle-Analysis – Update 2009.

149. Comprehensive life cycle assessment for cheese and whey products in the U.S.

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A comprehensive life cycle assessment (LCA) has been carried out to determine a benchmark for the environmental impacts associated with cheddar and mozzarella cheese consumption in the United States. This includes specifically product loss at various stages of the supply chain, as well as consumer transport and storage of products. The scope of this study was a cradle-to-grave assessment with particular emphasis on the unit operations of typical cheese processing plants.

A functional unit of 1 metric ton of cheese consumed (dry solids basis), or 1 metric ton of whey delivered (dry basis) was adopted. The ecoinvent database was used for 'upstream' unit processes. Operational data from 17 cheese manufacturing plants representing 24% of mozzarella production and 35% of cheddar production in the US. Allocation procedures follow the ISO 14044 hierarchy. System separation was used when sufficient information was available, primarily as plant-specific engineering estimates. Incoming raw milk, cream or dry milk solids are allocated using a milk solids mass balance. Revenue-based allocation was used for remaining in-plant processes.

Life cycle impact assessment was conducted using the ReCiPe and USEtox frameworks. Greenhouse gas (GHG) emissions are of significant interest, and on a dry milk solids basis, the carbon footprint of both cheddar and mozzarella is approximately 13.0 metric tons CO_2e (IPCC 2007 factors) per metric ton of cheese consumed (inclusive of product loss across the supply chain). The 95% confidence interval ranges from 9 to 18 metric tons CO_2e per metric ton of cheddar cheese (dry solids basis) consumed. For an average solids content of 63.2% for cheddar as sold at retail, the cumulative GHG emissions are 8.5 kg CO_2e per kg cheddar cheese consumed, and for an average solids content of 51.4% for mozzarella, the GHG emissions are 7.3 kg CO_2e/kg consumed. Fig. 1 shows the relative contribution from different supply chain stages to both the cradle to grave impacts and the post-farm gate impacts (that is impacts excluding milk).

This study provides a benchmark for the US cheese manufacturing industry to gauge improvement over time and showed that energy use, especially electricity, across the supply chain is relevant to several impact categories, including climate change, cumulative energy demand, photochemical oxidant formation, and human toxicity (USEtox). The impacts to ecosystems (ReCiPe) are driven almost exclusively by agricultural land occupation (63%) while the aquatic ecotoxicity (USEtox) impacts are driven significantly by fly control pesticides which are used in dairy operations and to lesser extent crop protection chemicals. Improvement opportunities focused on reducing energy consumption will have broad beneficial impacts, both economic through cost savings, as well as environmental due to the emissions reduction.

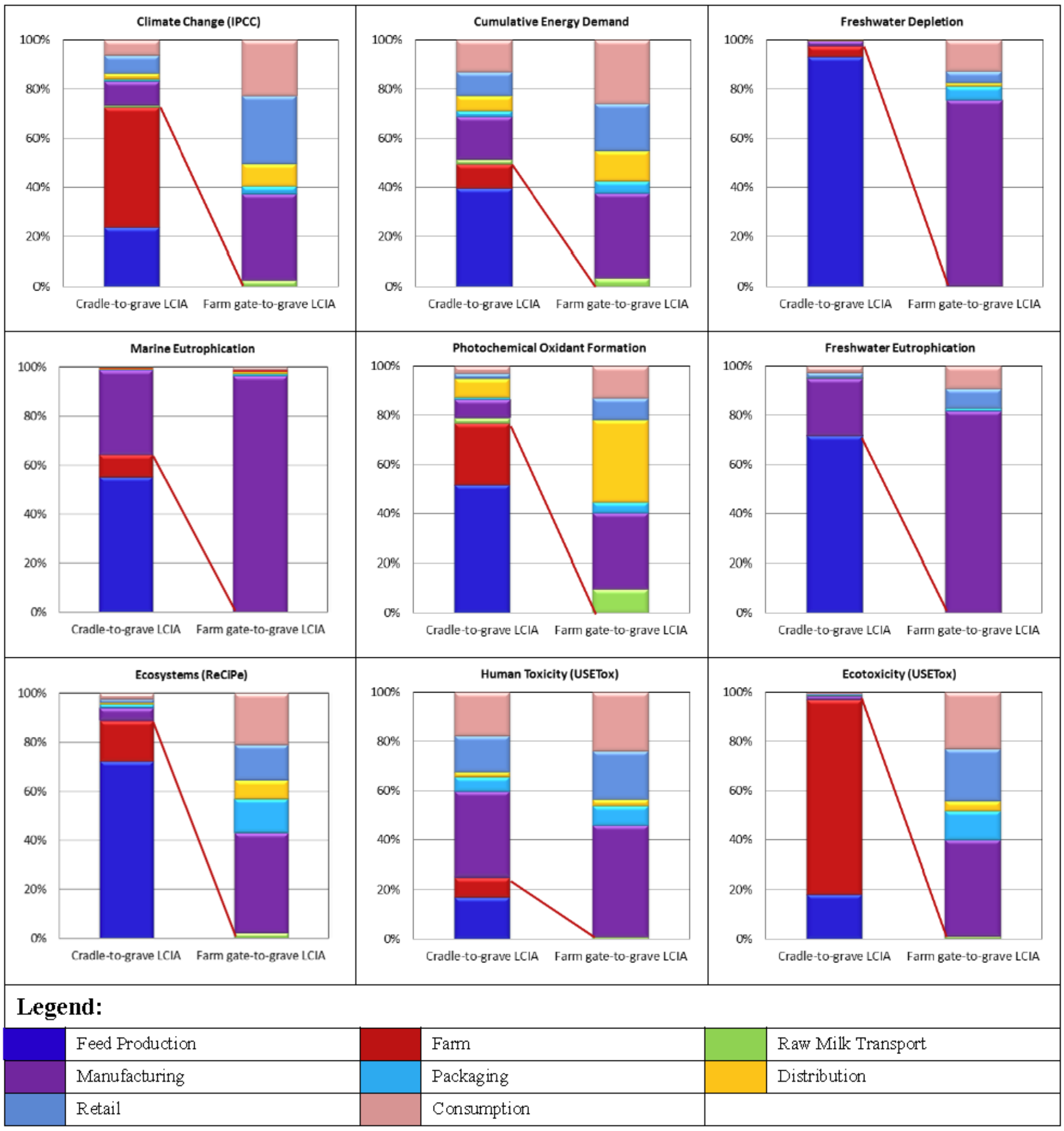

Figure 1. Summary of cradle-to-grave and farm gate-to-grave life cycle impact assessment results for cheddar cheese supply chain.

150. Comprehensive life cycle assessment of fluid milk delivery systems

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In 2009 U.S. Dairy Management Inc. has set up a target to reduce greenhouse gas emissions of fluid milk supply chain of 25 percent by 2020, as a part of U.S. Dairy Sustainability Commitment. The focus of this research is the LCA of fluid milk delivery systems emphasising assessment of environmental impacts of 18 fluid milk packaging and delivery options. The study provides results of the life cycle impact assessment for various standard and emerging fluid milk packaging options.

The objective of this project was to conduct a cradle-to-grave LCA of fluid milk delivery systems focused on quantifying use of non-renewable energy sources, emissions to air, water, and land, consumption of water and other natural resources; and assessment of the impacts of these inventory flows on climate change, resource depletion, human health, and ecosystems. The LCA provides data for the dairy industry enabling the industry to identify and engage in more sustainable approaches and identify opportunities for improvements leading to mitigation of environmental impacts across the dairy delivery life cycle.

The main goal of this work was to equip milk delivery industry stakeholders (milk processors, packaging material manufacturers and retailers) with timely, science-based information in order to incorporate environmental performance into decision-making and drive innovative new products, processes, and services. Fluid milk delivery systems can be distinguished by their final consumption, delivery type, container material composition and size. The life cycle impact assessment methods chosen include: ReCiPe Midpoint, ReCiPe Endpoint, and USEtox. They were used to create results that include the relevant inventory indicators and range of midpoint/impact and endpoint/damage categories. The selection includes two inventory indicators: ReCiPe's Water depletion [m^3] and Cumulative Energy Demand Non-renewable, fossil [MJ]. For the purpose of result interpretation and clarification of the importance of certain impact category in the context of dairy delivery systems, each system was analysed using normalisation step of the IMPACT 2002+ Method for U.S., and World ReCiPe normalisation.

A summary of the fluid milk delivery systems under study based on their final consumption function, delivery option, container composition, size, and total weight is presented in Fig. 1. Fig. 2 presents the overall results for gallon sized HDPE container based delivery, as this represents approximately 65% of fluid milk consumption in the United States.

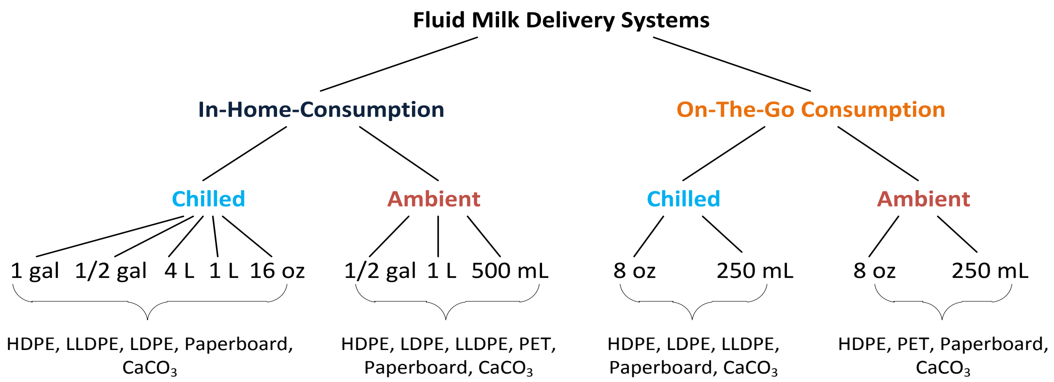

Figure 1. Summary of fluid milk delivery systems under study.

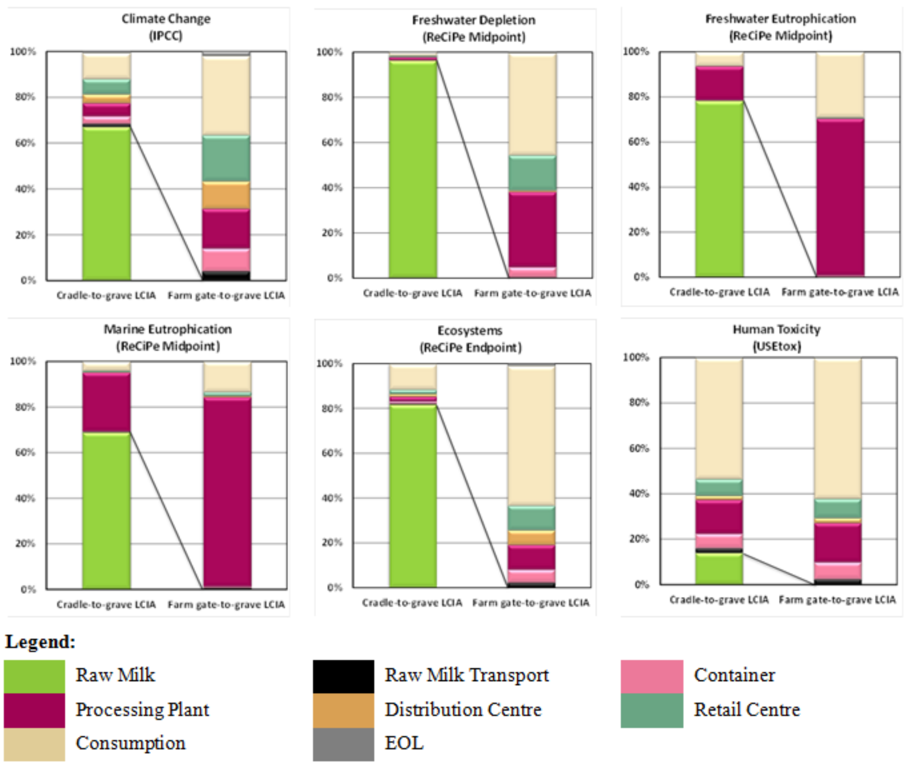

Figure 2. Cradle-to-grave and farm-gate-to-grave life cycle impact assessment results [%] of mono-layer HDPE fluid milk delivery system for nine impact categories

151. AusAgLCI – building national lifecycle inventory for Australian agriculture

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There has been substantial growth in the development of Life Cycle Assessment (LCA) in agriculture in Australia and globally over the past five years. A recent survey of activity by University of Queensland identified more than 20 LCAs of Australian agricultural commodities; many of these sponsored by industry associations. However, the consistency of these studies is low in terms of their system boundaries, impact categories, modelling of co-products and data quality. There is a need to develop a national life cycle inventory (LCI) for agricultural products to support environmental impact studies and to provide data for important export commodities, so that importers of Australian agricultural commodities can access representative data to complete LCAs.

The Rural Industries Research and Development Corporation has initiated a project to develop an agricultural LCI database (AusAgLCI) in alignment with the Australian Life Cycle Assessment Database Initiative (AusLCI). The project began in December 2011 and will run for 20 months. The project will draw on the extensive research and data collection undertaken in Australia by industry research bodies, state departments of industry, universities and CSIRO. The first task will be to define important industry sub-sectors to give appropriate representation of agricultural products that reflect differences in environmental impact and market segments required by downstream users of the data. Using existing data, the project will align data quality, breadth of data coverage in terms of the impact categories included (global warming, water and land use, eutrophication, ecotoxicity) and standardise the documentation of inventories. Resulting unit processes from cradle-to-farm gate will be reviewed and published. As part of the project, approaches to key methodological issues are being resolved such as joint production from mixed farming systems, scope of water flows to be included, carbon fluxes and land use for future impact assessment developments. At the completion of the project priority areas for additional data collection will be identified.

The project will assess and develop tools to quickly and accurately determine flows to the environment and inputs from the techno sphere. These will explore the use of spatial data to inform inventory development, such as spatial layers for nitrogen and phosphors flows from agricultural land use and spatial layers for soil type for determining fuel consumption for land cultivation.

152. The French agricultural LCA platform

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The French Agricultural LCA Platform has been created in 2009 under the impetus of the French technological mixed network on Livestock and Environment (Réseaux Mixte Technologique Elevage et Environnement). This network gathers research, technical and education institutes and aims at diffusing management tools for animal production systems to improve their environmental performances. This open LCA platform is gathering among 40 Agricultural LCA-practitioners from different institutes (agricultural research institutes, agricultural technical institutes, agriculture council institutes, professional organisations). The platform purpose is sharing collectively knowledge, data and methodological positions to manage LCA on agricultural products and systems, in taking into account French specificities of this sector. This includes actions to ensure common knowledge among the members by training organisation session and experiences sharing, to mutualise material resources (Using Simapro Multiuser license) and to validate collectively methodological choices (organisation of workshops about allocations, references for imported products in particular concerning land use, biodiversity and water impacts, and watch on international initiatives of mutualising LCA data). A specific action is to mutualise LCA and LCI data from 8 partners in a common database, and to work for the recognition of LCI data into international databases. This implies first collecting data among partners, describing precisely the methodology that has been involved, qualifying data quality and assessing their limits. This methodology will allow identifying the best references for users' purpose.

153. A software and database platform for multi-criteria assessment of agri-food systems

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INRA, the French National Institute for Agricultural Research, aims to improve the environmental, societal and economic performances of agriculture, and to favour healthy and sustainable food systems. Research conducted to reach these objectives should consider and integrate many criteria. The development of tools for the multi-criteria assessment of the production and transformation of agricultural products is of strategic importance, to guide the evolution towards sustainable agri-food systems. INRA has therefore decided to develop an in-house platform for the multi-criteria sustainability assessment of agri-food systems. The objectives of the platform are:

- To develop user-friendly multi-criteria assessment tools and associated databases for agri-food systems,
- To train future users, give support to users
- To provide a science and technology watch on multi-criteria assessment

Many methods have been proposed for the multi-criteria assessment of the environmental, societal and economic impacts of farming systems (van der Werf and Petit, 2002; Bockstaller et al., 2008). These methods present a similar structure, often consisting of eight stages (Acosta-Alba and van der Werf, 2011): 1) Definition of the sustainability dimensions to be assessed, 2) Identification of objectives for each dimension, 3) Selection or conception of indicators for each objective, 4) System definition, 5) Definition of calculation algorithms for each indicator, 6) Technical description of the system, 7) Calculation of indicator values, 8) Interpretation of results, identification of improvement options (Table 1).

In spite of their similar structure, these methods present an amazing diversity in their implementation, and the outcome of studies using different methods to assess contrasting systems depends to a large extent on the characteristics of the methods used (van der Werf et al., 2007). Methods differ amongst others with respect to system definition (inclusion of inputs to the system assessed), issues of concern considered, type of indicators (means-based vs effect-based) and expression of results (per ha or per kg of product) depending on identified functions.

Initially the platform will focus on the multi-criteria assessment of environmental impacts through Life Cycle Assessment (LCA). The implementation of societal and economic dimensions in methods for multi-criteria assessment will be pursued, in particular, but not exclusively, via the concept of Life Cycle Sustainability Assessment. The platform will allow the implementation of both LCA-type methods and other methods for the multi-criteria assessment of agri-food systems (e.g. Ecological Footprint, Emergy). This will be done by conforming the architecture of the platform to the eight stages of multi-criteria assessment methods outlined above (Fig. 1).The platform will be complementary to other INRA software platforms, and in particular to the RECORD platform (http://www4.inra.fr/record), for the modelling and simulation of crop and farm systems.

References

Acosta-Alba, I., van der Werf, H.M.G., 2011. The use of reference values in indicator-based methods for the environmental assessment of agricultural systems. Sustainability, 3, 424-442.

Bockstaller, C., Guichard, L., Makowski, D., Aveline, A., Girardin, P., Plantureux, S., 2008. Agri-environmental indicators to assess cropping and farming systems. A review. Agron. Sustain. Dev. 28, 139-149.

Van der Werf, H.M.G., Petit, J., 2002. Evaluation of the environmental impact of agriculture at the farm level: a comparison and analysis of 12 indicator-based methods. Agr., Ecosyst. Environ., 93, 131-145.

Van der Werf, H.M.G., Tzilivakis, J., Lewis, K., Basset-Mens, C, 2007. Environmental impacts of farm scenarios according to five assessment methods. Agr., Ecosyst. Environ., 118: 327-338.

Table 1. Stages of multi-criteria assessment methods for farming systems

	Stage	Description
1	Sustainability dimensions defined	Some methods only assess environmental impacts; other methods also assess societal and/or economic impacts and/or overall sustainability.
2	Objectives identified	Dimensions of sustainability cannot be directly quantified; a set of more specific objectives (issues of concern) for each dimension is required.
3	Indicators defined	To quantify the extent to which objectives are attained, indicators serving as assessment criteria are required. This stage may involve the definition of thresholds or reference values, which help to interpret indicator values.
4	System definition	The system is characterised, its boundaries and functions are defined.
5	Calculation algorithms defined	This stage involves the determination of calculation algorithms for the indicators. Calculation algorithms can be very simple (e.g. emission factors) or much more sophisticated (dynamic simulation models).
6	System technical description	Farmer production practices including amounts and timing of inputs used are described, technical parameters (feed efficiencies, crop yields) are quantified, pedoclimatic conditions are defined.
7	Indicators calculated	Indicator values are calculated for each of the systems or scenarios to be compared. A partial or total aggregation of indicator values may facilitate their interpretation.
8	Interpretation	Interpretation of results, identification of improvement options. This stage obviously is crucial; unfortunately few methods explicitly include this stage.

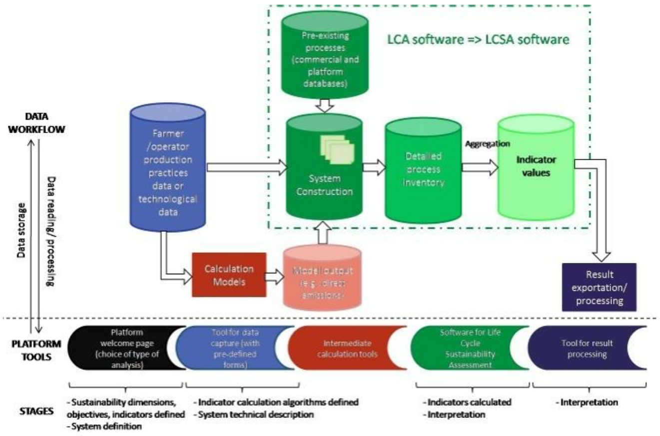

Figure 1. Representation of the platform's architecture and tools, allowing the implementation of different methods for the multi-criteria assessment of agri-food systems.

154. Availability and completeness of LCI of cereal products and related databases

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In 2011, EVEA carried out a study on behalf of Intercéréales (Inter-branch association of the French cereal sector). The aim of this study was first to analyse the different product labelling systems of cereals products around the world, and second to analyse available data in existing LCI databases, regarding cereals (wheat, barley, maize, sorghum, rice and rye) and cereal-containing products.

The study provided information on the existing databases that contain LCI of cereals and cereals-containing products. The analysis was conducted on ten French and international databases, eight of which include cereals-related data (ecoinvent, DiaTerre, LCA Food, Bilan Carbone®, AUSLCI, CPM Database, USLCI, and Agri-Footprint; Probas and BUWAL 250 do not include cereals-related data).

Each database was analysed by gathering general information (country, public or private status) and a description of the available data in the cereals sector. The following data are to be found in the databases: raw materials, inputs, processes, and cereal-based finished products (Table 1, Fig. 1).

The ecoinvent Database is by far the most complete database, with Swiss and European data for agricultural raw materials, inputs and processes. Data about some cereals-based finished products can be found in the LCA Food Database (wheat, bread, pastries, oat flakes) and in the French Bilan Carbone® database. However, very little data can be found in the databases about agricultural processes, food industry processes, storage or mass-market retailing, and the lack of data makes it difficult to implement an environmental labelling of cereal-based products based on present data available. Only ecoinvent Database and LCA Food Database provide specific geographic data: Swiss data in ecoinvent and Danish data in the LCA Food Database. The existing databases lack specific French data.

The study raised the issue of methodological comparability: all databases set their own hypothesis and methodological rules (allocation, cut-off rules…) and major differences can be found between data from different databases.

For example, the allocation method is not the same in all major databases. Among two of the main databases for cereals products, the ecoinvent database resorts to economic allocation whereas the LCA Food Database uses substitution (avoided impacts). As a consequence, for example, the impact of one kg of wheat, which is evaluated in 5 different databases, ranges from 0,401 kg CO2 eq. (USLCI) to 0,959 kg CO2 eq. (CPM Database), but this variability cannot be explained solely by obvious differences in yield, agricultural techniques or climate. This variability makes it difficult to implement an environmental labelling of cereal-based products with sufficient accuracy and comparability.

This study lead to the conclusion that existing databases cannot be used as a strong and detailed basis about cereal product environmental labelling. Two major programs have been launched in France in order to collect data for the environmental assessment of agricultural-based products:

- Agri-Balyse for the creation of French average data about the environmental impacts of agricultural productions.
- Acyvia about the impacts of agri-food transformation processes.

The conclusion of the Intercéréales study is that its members should take part in the Acyvia project in order to improve the completeness of the data about their products.

References

Abelmann, A. 2005. Environmental Potential of Increased Human Consumption of Grain Legumes: An LCA of food products. Report No. 2005:10.

Blonk, H. et al. 2011. The Agri-footprint method Methodological LCA framework - assumptions and applied data. Report Agri FootPrint

Nemecek, T., Kägi, T., 2007. Life Cycle Inventories of Swiss and European Agricultural Production Systems. Final report, Ecoinvent v2.0, No. 15a, September 2007.

LCA Food Database, 2007. www.lcafood.dk.

Table 1. Data availability for cereals and cereal-based products in 8 LCI databases

Database	Country of origin	Generic or specific to the agriculture sector?	Agricultural raw materials	Fertilisers	Other agricultural inputs	Processes	Finished products (cereal-based)	Total number of data
ecoinvent	Switzerland	Generic	21	25	110	3	1	160
DiaTerre	France	Specific	10	10	24	0	3	47
LCA Food	Denmark	Specific	10	7	5	0	11	33
Bilan Carbone®	France	Generic	2	8	3	0	9	22
AUSLCI	Australia	Generic	1	18	1	0	0	20
CPM Database	Sweden	Generic	1	8	0	0	3	12
USLCI	United States	Generic	3	2	0	0	0	5
AGRI FOOTPRINT	Netherlands	Specific	0	0	0	0	2	2
Total	48	78	143	3	29	301		

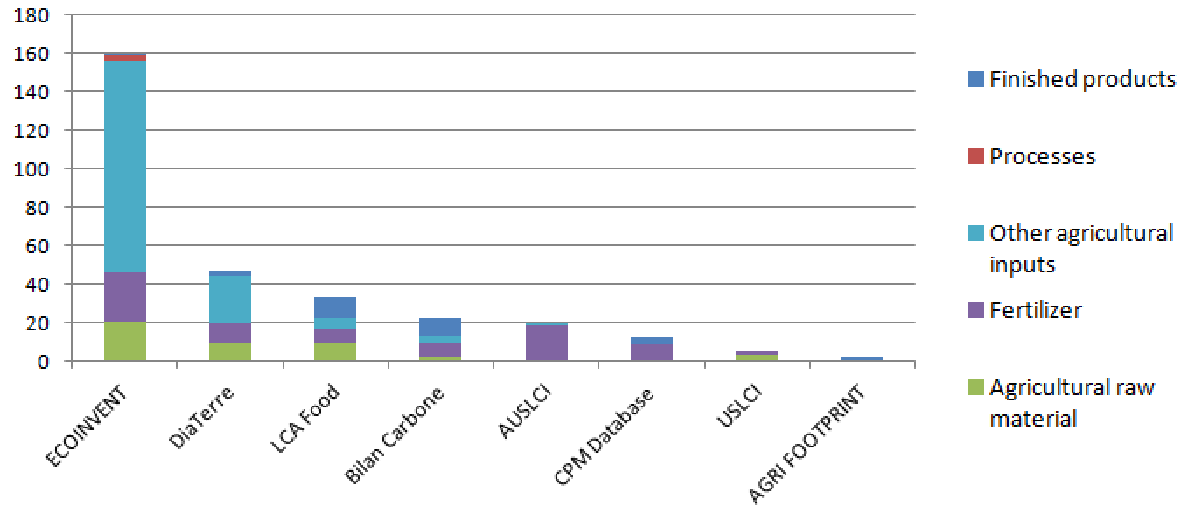

Figure 1. Data availability for cereals and cereal-based products in 8 LCI databases

155. The LCA world food database project: towards more accurate LCAs on agricultural and food products

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The food and beverage sector is moving rapidly regarding sustainability issues (such as labelling purposes or "food eco-design"). This concerns both institutional and private organisations; consumers and environmental organisations also claim for more transparency on the environmental performance of food and beverage products. Life cycle assessment (LCA) has proven to be an effective method to assess the environmental impact of a product or service throughout its life cycle. However, currently, major limitations in doing such analyses are the lack of inventory data on food products and processes and a lack of consistency between existing food datasets. Therefore, there is a need to develop detailed, transparent, well documented and reliable data in order to increase accuracy of food LCA.

In this context, Quantis, the Agroscope Reckenholz-Tänikon Research Station ART and some leading companies in the food sector have decided to launch in 2012 the LCA world food database project.

The database will include datasets concerning agricultural raw materials (including, when possible and relevant, differences between production systems such as organic or non organic, intensive or extensive), inputs (such as pesticides and fertilisers), infrastructures (agricultural buildings, equipment and machinery), processes, processed food products, food storage, food transportation and food packaging. A consistent, but transparent, consideration of deforestation will also be included giving the possibility to assess it using different allocation rules. The data will come from existing LCAs on food products (partners' LCA, ART and Quantis existing databases), literature review on LCA of food products, statistical databases of governments and international organisations (such as FAO), environmental reports from companies, technical reports on food and agriculture, partners' information on food processes as well as collected primary data. Background datasets from the ecoinvent database will be used and new datasets will be compatible with ecoinvent.

To guarantee its transparency, the database will be fully documented, unit processes will be visible (except for confidential data provided by the companies) and information sources identified. The user will be able to differentiate among different stages of the process (e.g. agricultural production vs. food product manufacturing) and to identify the main contributors of a specific dataset (e.g. irrigation, fertiliser use, etc.).

The food database will be updated each year and will be compliant with quality requirements from major standards (ILCD Handbook, Sustainability Consortium, United Nations Environment Programme (UNEP), etc.) as well as with ecoinvent.

The project will start in March 2012 and will be completed in March 2015. The presentation will present the project (results of the literature review of the existing food datasets, involved companies, time schedule) as well as current state of the results (existing and new datasets, influence of consistent incorporation of deforestation, results and challenges associated with organic and non organic as well as extensive and intensive agricultural and animal systems).

References

Ecoinvent, 2010. ecoinvent database v 2.2. Available at www.ecoinvent.ch

Jolliet, O., Margni, M., Charles, R., Humbert, S., Payet, J., Rebitzer, G., 2003. IMPACT 2002+: a new life cycle impact assessment method. International Journal of Life Cycle Assessment 8 (6), 324–30. Version adapted by Quantis (http://www.quantis-intl.com).

European Commission, Joint Research Centre, Institute for Environment and Sustainability, 2010. International Reference Life Cycle Data System (ILCD) Handbook, General guide for Life Cycle Assessment, Detailed guidance. Publications Office of the European Union.

156. Seeds4green, a collaborative platform for LCA

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In 2009 and 2010, DEFRA (UK) joined forces with ADEME (French Environmental and Energy Management Agency) to sponsor the development of a collaborative LCA website with the technical support of the EU's Joint Research Centre. Seeds4Green is a wiki platform that aims to provide an easy way gather and share documents linked to environmental sustainability. Both agencies support the transparency and sharing of data and view this as a one of the solutions that allows a wider range of users to acquire LCA information more easily and promote sustainable goods and services.

We anticipate that the information stored here could be used by many audiences - from purchasers to eco-designers, businesses, eco-labelling teams within public authorities as well as LCA practitioners, researchers and students throughout the world. Currently summaries are in both French and English.

The purpose of the platform is to collaboratively build knowledge on the environmental quality of goods and to diffuse the results of LCA studies. It provides purchasing guidelines and systemised criteria making green purchasing operational and eco-labels even more transparent and comprehensive. Seeds4green intends to cover all product categories. Several LCA studies are available for agriculture goods. The platform provides a large range of topics such as organic vs conventional product or links towards food product LCA database.

The presentation/poster will explain the features of the platform including detailed examples of data summary sheets making it immediate accessible and showing its ease of integration in individual work habits. http://seeds4green.net/

Date de mise à jour	Titre	Type	Code
12/24/2011 - 08:33	Life cycle greenhouse gas emissions of 96 foods in US (per mass and per calorie)	ACV	Food, Plants
10/13/2011 - 00:46	Analyse de Cycle de Vie : production et transformation du lait	ACV	Food, Plants
10/10/2011 - 21:39	Life-cycle-assessment of industrial scale biogas plants	ACV	Gardening/Agriculture /Industry Energy Food, Plants
08/25/2011 - 17:17	Soil and Plant Nutrition Adapted to Organic Agriculture	ACV	Gardening/Agriculture /Industry Food, Plants
08/25/2011 - 15:53	Évaluation environnementale de systèmes de production laitiers : comparaison des systèmes conventionnels et biologiques avec l'outil EDEN	ACV	Gardening/Agriculture /Industry Food, Plants
08/24/2011 - 16:50	Environmental Evaluation of Greenhouse tomato production in France	ACV	Food, Plants
08/24/2011 - 09:38	Evaluation environnementale de la production de tomate en serre en France	ACV	Food, Plants
08/23/2011 - 17:45	Energy and environmental burdens of organic and non-organic agriculture and horticulture	ACV	Gardening/Agriculture /Industry Food, Plants

Figure 1. Extract of the available studies for the food-related products

157. ACYVIA: creation of a public LCI/LCIA database of the French food industry

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In the context of the Grenelle laws aiming at an environmental labelling on consumer goods, the ADEME, the French Environment and Energy Management Agency, has been mandated to set up a national LCI/LCIA database, in parallel with the development of Product Category Rules by the ADEME/AFNOR platform (Fig. 1). In terms of format, ADEME's database is based on the ILCD Dataset format defined by the JRC. In terms of content, three methods will be used to feed the database. The first and main one relies on the adaptation of existing processes and on the purchase of the requisite rights from data developers through framework contracts. For sectors with lacks of data, the ADEME is setting up collaborative projects to develop sectorial databases that will be merged to ADEME's database. The third mode will allow third-parties to propose the integration of isolated supplementary data.

A first three years collaborative project called Agri-BALYSE has been launched in 2010 with INRA, ART, CIRAD and ten agricultural institutes to develop a public LCI/LCIA database for the main French agricultural productions as well as some importations (see http://www2.ademe.fr/servlet/KBaseShow?sort=-1&cid=96&m=3&catid=12908). ACYVIA is a similar project aiming to deal with the next step of the food supply chain: transformation.

ACYVIA will apply a consistent methodology for the establishment of life cycle inventories of food transformation processes from the farm gate to the exit gate of the transformation plant. The methods used and the data format will be in accordance with ISO norms, the ILCD handbook and the general methodology adopted for the environmental labelling of consumer goods in France (BPX 30-323). The inventory data should allow the calculation of the indicators identified for environmental labelling, but also of other frequently used LCA impact categories.

The project will be carried out in collaboration by the following partners:

- ADEME will fund the project and assure its leadership and co-ordination.
- Food technological institutes (wine, spirits, dairy products, fats and oils, baking and pastry, meat industry, appertised or dehydrated food) will collect representative data and contribute to the methodological developments and the establishment of the inventories.
- Quantis and ART will lead the methodological developments and the computations of the life cycle inventories.

ACYVIA will systematically look for a consensus among the concerned experts, not only for the data used to produce the LCI, but also about major methodological questions such as allocation procedures. This is seen as a prerequisite for the success of the database: the involvement of interested stakeholders should favour the broad adoption of ACYVIA across the food chain. ACYVIA's database will be made of three levels of deliverables, corresponding to the needs of each partner:

- aggregated and averaged processes for ADEME's database;
- disaggregated and un-averaged processes to help the technical institutes assessing and lowering the environmental impacts of their supply chain;
- disaggregated and averaged processes.

This "vertical" construction of the database will be completed by a "horizontal" one consisting in the generation of "child" processes based on "parent" processes and ensuring a greater level of homogeneity for the database. For each child process, the values and relative proportions of the parameters of a given parent process are adapted to fit with the technical, geographical and temporal representativeness of the child process. For instance, a "parent" process "processing and packaging of milk" can be declined in several "child" processes specifically constructed to represent the geographical and/or technological specificities of a producer (e.g. PAST vs. UHT during sterilisation process)

The presentation will show the latest developments and the architecture of the database, the structure of the collaboration, and the main features of the database, such as:

- the expected processes to be included in the database
- the public availability;
- the homogeneity;
- the link with the ADEME database
- the wide range of usage: supporting the environmental labelling for customers and helping producers to decrease their impacts.

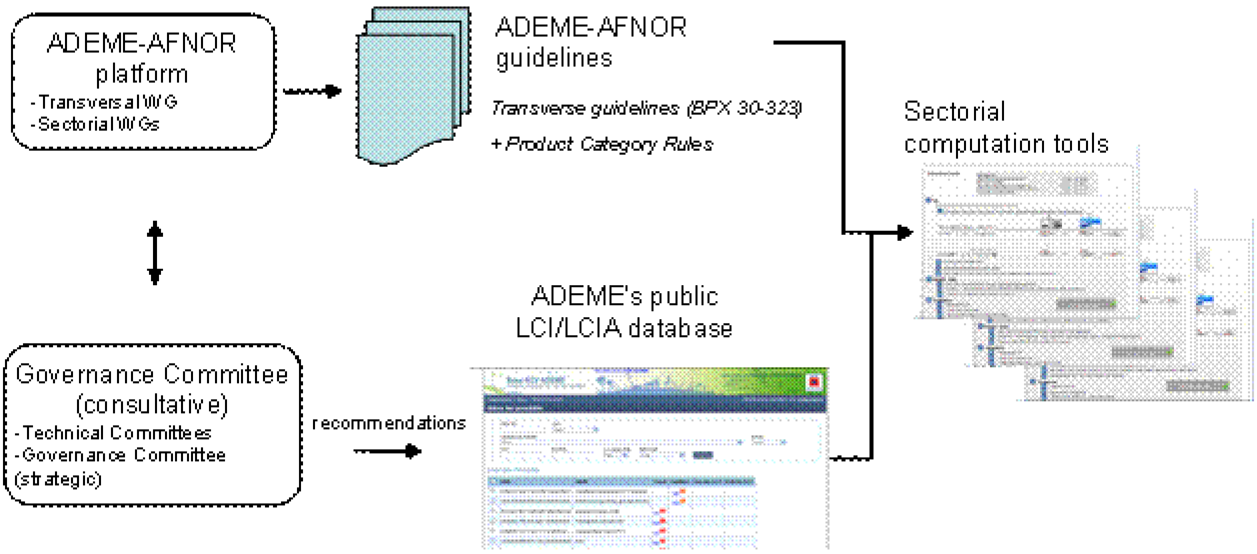

Figure 1. Overall context of ADEME's database

158. LCA as an evaluation tool for new food preservation techniques

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Alongside with new technology development it is becoming more common to evaluate the environmental impact using LCA. (e.g. Hospido et al., 2010, Sonesson, 2010).The demand for environmentally sustainable food products is increasing and it is a challenge for the food and drink sector to reduce environmental impact along the food chain while at the same time maintaining and improving quality. These demands have resulted in an increased focus on environmental quality aspects during the development of new food products and new technologies. Freeze protection with anti-freeze protein (AFP) (Phoon et al., 2008) and carbon dioxide (CO_2) drying (Agterof et al., 2005) are new preservation technologies under development. Soft vegetables and fruits such as strawberries (*Fragaria ananassa*) are suitable for both preservation methods. Both technologies lead to complete new products as freeze protected fruits can be thawed without cell damage and can be used as fresh fruits and dried fruits can be rehydrated resulting in recovered natural turgor. The environmental benefits of the new preservation technologies is the possibility of extending shelf life and substitution of imported fresh fruit and vegetables when out of season. The aims of this study were to (1) compare the environmental impact from cradle to retail of fresh, AFP freeze protected and CO_2-dried strawberries and (2) identify the key environmental issues after "farm-gate" to be able to evaluate the supply chain from processing to retail to support the technology development. Frozen / CO_2-dried and fresh strawberries were assumed to be cultivated and processed in Sweden and Egypt respectively. The study was performed using LCA methodology with a functional unit of 1 kg of ready to use strawberries. Global warming potential (GWP) and fossil energy use (MJ, data not shown) per functional unit in terms of primary energy was calculated. The resulting preliminary GWP for fresh, freeze protected and CO_2-dried strawberries after LCA was carried out were 4.6, 0.63, and 2 kg CO_2eq/kg strawberry respectively. The novel preservation technologies emitted less greenhouse gas emissions than the current method of freezing and the fresh imported strawberries (Fig. 1). The energy required for the novel technologies at the processing step accounted for 60-80% of the total GWP post-farm (Fig. 1). The results also demonstrate the importance of taking the full chain into account when evaluating new process technologies. An increased impact in one step may still lead to an overall improvement of the chain under given conditions. This study demonstrates how LCA can be applied to support the development of new technologies for food processing in an early stage by identifying potential hot spots early the development phase and by pinpointing suitable applications in relation to choice of inputs and production site.

References

Agterof, W.G. M., Bhatia R., Hofland G. W., 2005.Dehydration method. Feyecon Development & Implementation December 2005: WO 2005/122776

Hospido, A., Davis, J., Berlin, J. & Sonesson, U. 2010, LCA of novel products – Application to food processing, Int. J. Life Cycle Assess. 15, 44–52

Phoon, P.Y., Gomez Galindo, F., Vicente, A., Dejmek, P., 2008. Pulsed electric field in combination with vacuum impregnation with trehalose improves the freezing tolerance of spinach leaves. J. Food Eng. 88, 144-148

Sonesson, U., Novel Processing and Sustainability – a perfect match or not? New Food, Issue 5, 2010

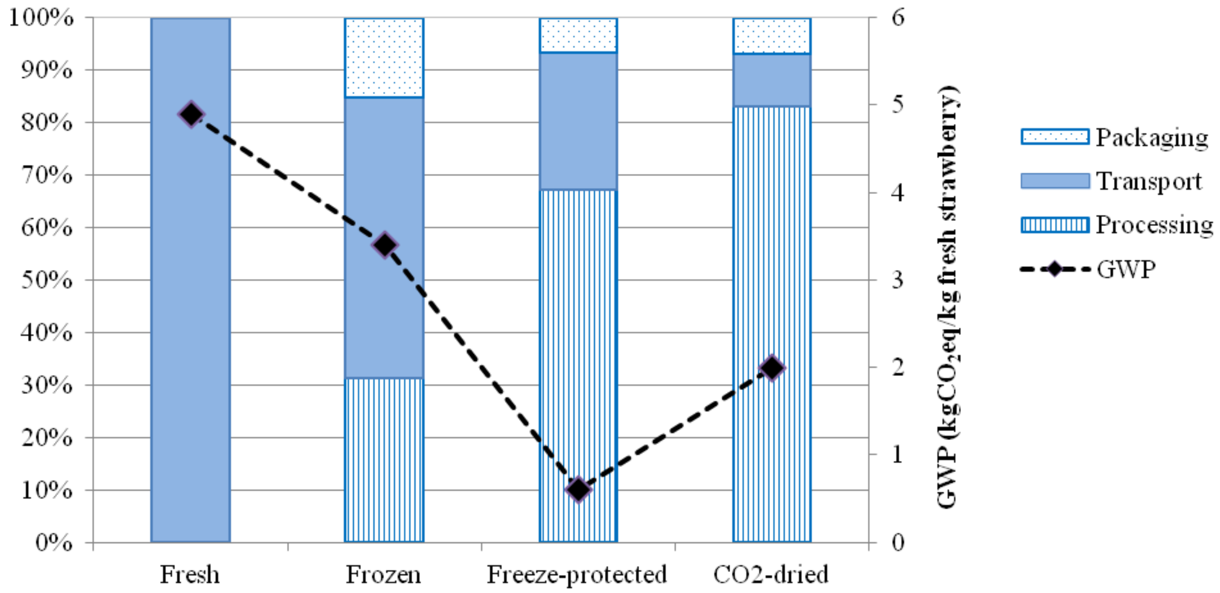

Figure 1. The GWP (secondary y-axis) and the contribution of packaging, transport and processing in percentage to the GWP (primary y-axis) of post-farm fresh, frozen, freeze protected and CO_2-dried strawberries.

159. Ecodesign of plant-based building materials using LCA: crop production and primary transformation of hemp

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France has ambitious environmental goals regarding climate change and energy use, in particular since the so-called Grenelle de l'Environnement laws were passed. The building and housing sector is a major contributor to these impacts. New building materials, in particular thermal insulators, using plants like hemp as a raw material as presented by Korjenic et al. (2011) and Kymalainen and Sjoberg (2008), have appeared in the building materials market in recent years. These new products are often qualified as "green" low-impact materials because of their renewable origin.
A full life cycle assessment (LCA) of the material will be made for the following stages: crop production, industrial transformations, use and end-of-life. The environmental assessment of these materials using LCA is however complex, due to their multi functionality in buildings, and the lack of data on major life cycle stages, such as their behaviour in the use phase.
One of the main scientific challenges of this work is to develop and implement an LCA approach combined with a sensitivity analysis, in order to quantify the contribution and variability of technological, environmental and methodological factors to life cycle impacts (Fig. 1). This information will then be used to eco-design scenarios for the production, use, and end-of-life stages of plant-based building materials. The aim is to highlight the environmental hotspots of the life cycle of these materials and to reinforce the robustness of results of the LCA results by testing several scenarios.
The present article is focused on the production step of hemp fibres and shives: the agricultural system and primary transformation. Several scenarios are compared. Various sources of variability are taken into account: (i) technological variables such as the hemp cultivar, the various crop production modes (tillage intensity, harvest of seed and fibre or fibre only), primary industrial processes; (ii) environmental variables such as the soil type and the climate, (iii) as well as LCA methodological variables such as models (emission factors vs. dynamic simulation models) used to estimate direct emissions (e.g. nitrate) during crop production and allocation methods (based on mass, economic value or plant physiological mechanisms).
The repercussions of the variability of these input parameters are examined at the output i.e. the life cycle impact assessment. Using these results, eco-design scenarios for hemp fibres and shives production including crop production and primary transformation are proposed using processes which present interesting environmental potentials, and future improvements for each process are proposed.

Acknowledgments: The authors acknowledge the financial support of the French Agency for Environment and Energy Management (ADEME) and the Pays de la Loire region.

References

Korjenic, A., Petranek, V., Zach, J., Hroudova, J., 2011. Development and performance evaluation of natural thermal-insulation materials composed of renewable resources. Energy and Buildings 43:2518-2523.
Kymalainen, H.R., Sjoberg, A.M., 2008. Flax and hemp fibres as raw materials for thermal insulations. Building and Environment 43:1261-1269.

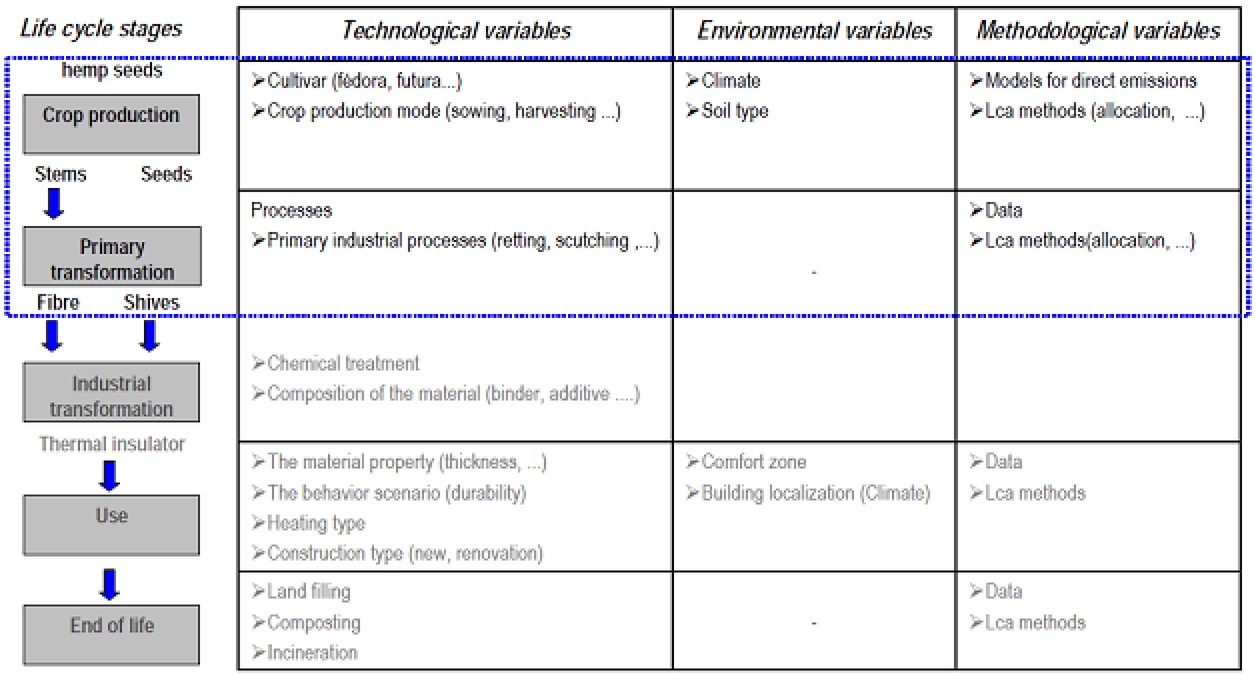

Figure 1. The life cycle of hemp-based building materials and major technological, environmental and methodological variables affecting life cycle impacts. This paper focuses on crop production and primary transformation.

160. Comparison of two milk protein separation processes: chromatography vs. filtration

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Chromatography is the reference technology for protein fractionation at a large scale when high purity and targeted functionality are required. Fractionation of proteins by membrane operations such as micro- and ultrafiltration has however deserved a high attention over the last years, mainly due to their acceptable investment and operating costs. The aim of this study is to compare the environmental performances of two ways of fractionating whey proteins (chromatography and membrane filtration) into the two following added value products: powder of α-lactalbumin with a 70% purity and powder of β-lactoglobulin with high purity (> 95%) and high foaming properties. The study consists in a comparative attributional LCA, conducted within the context of the ECOPROM project (Eco-design of membrane processes). Project carried out with the financial support of the French national Research agency (ANR) under the Programme National de Recherche en Alimentation et Nutrition Humaine (Project ANR-06-PNRA-015").
The whey comes from processes commonly performed in a classical dairy: it corresponds to the aqueous phase of milk, obtained after microfiltration of skimmed milk (Omont et al., 2010). The whey is concentrated before its transportation into the upgrading plant where proteins will be purified and dehydrated. The system studied includes the entire process implemented, from the entry of the whey into the upgrading plant to the production of the two dehydrated fractions of purified proteins. The system takes into account all the processing operations, the cleaning phases and the associated equipment. It excludes the facilities (buildings, lighting, etc.). Its geographic scope is France. In this country, electricity is mainly produced by nuclear power and has a low CO_2 impact. As membrane processes are high electricity consumers (Notarnicola et al. 2008, European Commission 2006, Omont et al. 2010), a sensitivity analysis has been tested between French and European electricity mixes. The inventory of the foreground system was carried out with specific data given by the industrial partners of the project. Generic data derived from the ecoinvent V2.2 data base. The impact assessment was calculated by the IMPACT 2002+ method using the Simapro 7.2 software. A water flow indicator was defined for the first level processes. The "chromatography system" and the "membrane filtration system" are described on the Table 1. The fractions outgoing from the chromatography are more diluted. In order to generate the same concentrated α-lactalbumin and β-lactoglobulin fractions before drying, the ultrafiltration concentrations following chromatography were resized.
Drying steps consume the same amount of natural gas for the two processes. The environmental load of the "chromatography separation process" is mainly attributed to the ultrafiltration operations which consume more electricity due to the resize. The Chemical Oxygen Demand contained in the non-regenerated brine and in the column cleaning wastewater contributes to this load too, because their wastewater treatment consumes electricity. It is noticeable that sodium chloride is not decomposed by the wastewater treatment plant; its discharge into the water is then not assessed by the method IMPACT 2002+, which results in an under-estimation of the environmental load of the chromatography process. The environmental impact of the "membrane filtration process" is mainly linked to the heating, the microfiltration and the ultrafiltration which consume natural gas, electricity and water due to diafiltration. As shown in Figures 1 & 2, the environmental load of chromatography tends to be higher than the membrane filtration. But the highest difference does not exceed 15%. The water consumption directly linked to the processes is 25% higher in case of chromatography.

References

European Commission, 2006. Intergrated Pollution Prevention and Control, reference Document on Best Available Techniques in the Food, Drink and Milk Industries

Notarnicola B., Tassielli G., Renzulli P., Settanni E., 2008. Life cycle assessment of a pilot plant for the must enrichment by reverse osmosis, Proc. of the 6th Int. Conf. on LCA in the Agri-Food Sector, Zurich, Nov. 12–14, 2008, pp.115-122.

Omont S., Froelich D., Osset P., Thueux F., Rabiller-Baudry M., Beudon D., Tregret L., Buson C., Auffret D., Gésan-Guiziou G., Eco-design of cascade membrane processes for the preparation of milk protein fractions: Approach and LCA results, Proc. of the 7th Int. Conf. on LCA in the Agri-Food Sector, Bari, Sept. 22-24, 2010, pp.197-202.

Table 1. The two systems studied.

Processes	Chromatography system	Membrane filtration system
1- Separation of the two proteins	Heating to 10°C, Chromatography separation, Brine recycling (Nano filtration and reverse osmosis)	Heating to 50°C, Acidification, Dilution, Microfiltration
2- Concentration of α-lactalbumin	Ultrafiltration of the α-lactalbumin fraction	Cooling, Re-solubilisation, Ultrafiltration, Cooling, Ultrafiltration
3- Concentration of β-lactoglobulin	Ultrafiltration of the β-lactoglobulin fraction	n/a
4- Powder formation	Drying of the α-lactalbumin; Drying of the β lactoglobulin	n/a

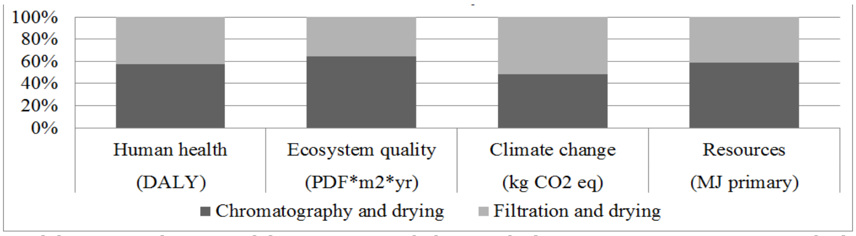

Figure 1. Chromatography and drying vs. Filtration and drying: LCIA with the French electricity mix, impact 2002+ method, SimaPro 7.2.

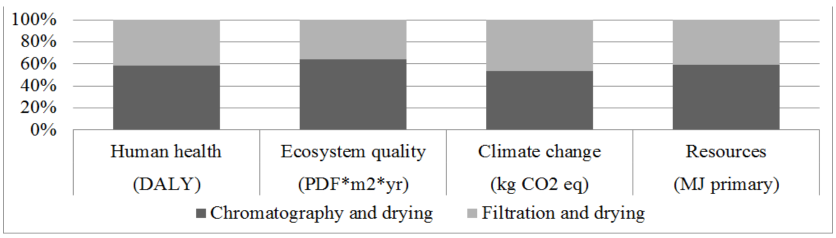

Figure 2. Chromatography and drying vs. Filtration and drying: LCIA with the European electricity mix, impact 2002+ method, SimaPro 7.2.

161. Design of a model for estimating LCI data by means of the Farm Accountancy Data Network. A citrus case study

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To carry out a Life Cycle Assessment means collecting a large amount of data. In agricultural production systems gathering of LCI data is specific for each study by surveying farmers or building scenarios after interviews with experts. According to Roches et al. (2010) different strategies are used to overcome the lack of relevant LCI and LCIA data: use of proxy data and generalisation, streamlined LCA and adaptation/extrapolation of inventories. In this work we have used a proxy methodology in order to obtain a straightforward procedure so as to estimate the order of magnitude of inventory data in agricultural systems

The main source of the model is the Farm Accountancy Data Network (FADN). FADN is an instrument for evaluating the income of agricultural holdings and the impacts of the Common Agricultural Policy. It gathers accountancy data from farms, mainly production costs and revenues. In each country a structured cost sheet is available for each family crop, region and economic size. Each cost sheet represents the average farm in each group. Additionally our model uses specific data of each crop and geographical area. Fig. 1 shows the outline of the model.

Thus the objective of the model is to estimate the LCI from the data of the FADN and then to carry out an impact assessment. To test and contrast the model a case study in orange citrus has been built comparing the results with Ribal et al. (2010).

This model would allow obtaining environmental impacts at a macro level in order to quantify eco-efficiency of crop production or to measure the value added integrating environmental impacts.

References

Ribal, J.; Sanjuan, N.; Clemente, G.; Fenollosa, M.L. 2009. Medición de la eco-eficiencia en procesos productivos en el sector agrario. Caso de estudio sobre producción de cítricos. Economía agraria y recursos naturales. 9, 125-148.

Roches, A.; Nemececk, T.; Gaillard, G.;Plassman, K.; Sim, S.; King, H.; Milà i Canals, L. 2010. MEXALCA: a modular method for the extrapolation of crop LCA. International Journal of Life Cycle Assessment. 15,842-854.

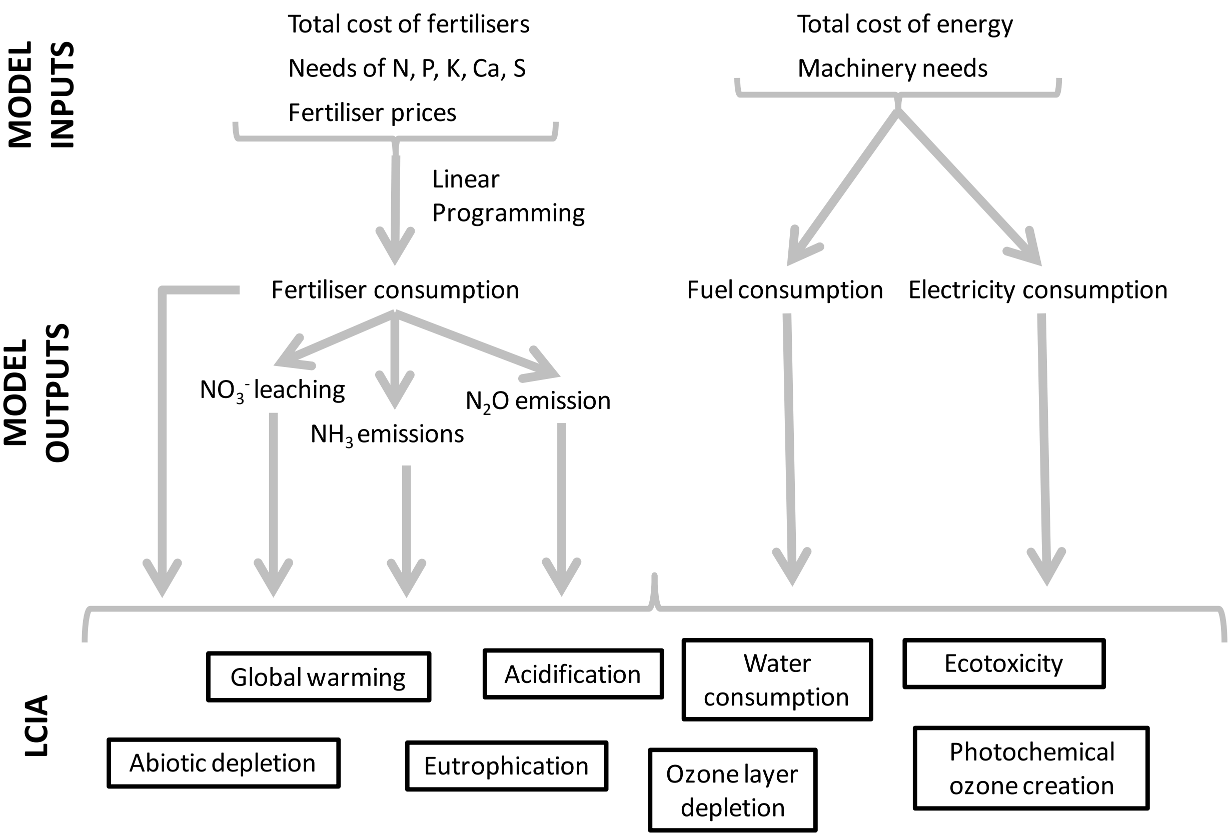

Figure 1. Outline of the LCI-FADN proxy model.

162. A simple model to assess nitrate leaching from annual crops for life cycle assessment at different spatial scales

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Life cycle assessment of food products show that nitrate leaching during crop production contributes significantly to their eutrophication potential (Xue X, Landis AE, 2010). Different dynamic field-scale models enable LCA-practitioners to estimate nitrate leaching taking into account detailed data about agricultural practices, soil type and climatic conditions. In the meantime, their use at a higher spatial scale (production area, region) requires collecting a high number of data on a representative sample of fields. In this study, we estimate average potential nitrate emissions for twenty annual French crops, using an easy to perform method based on the COMIFER (French Committee for the Development of Rational Fertilisation) methodology. This methodology was previously established from experimental results to diagnose nitrate leaching risk at different scales (watershed, small agricultural region, production area) and allows to classify the risk considering agricultural practices (from a very low to a very high level in function of duration without N absorption, absorption capacity of the following crops, slurry and droppings spreading in autumn, N input from crop residues, see figure 1) and some important site-specific related soil parameters (water retention capacity, volume of drained water and soil organic matter content). The nitrate leaching amounts were attributed to each risk level (see figure 2), based on results from the experimental database of the institute. Statistical data from the French Ministry of Agriculture about agricultural practices and our soil database were used to assess, at the region scale, percentages of crop area corresponding to each risk level and then to estimate an average regional nitrate leaching amount. Results will be compared with experimental results on particular sites and model results on watershed scale provided by bibliography.

This work shows that we can easily use this methodology in the framework of LCA to provide potential nitrate emission estimations at a regional scale. While these estimations may be less precise at smaller scale than those from dynamic field-scale models as the comparison with experimental results could show it, it requires collecting much less data and it takes into account the most impacting parameters to differentiate contrasting situations.

Different emissions (N-gases, plant protection products) from crop production are very variable due to conditions and practices. To estimate precisely these emissions, LCA-practitioners have often to face with an important need for data. In the meantime, our work suggests that it is possible to establish structured and simplified methods that can quickly and pertinently discriminate situations.

This work contributes to the Agri-BALYSE project which is aimed at providing a Life Cycle Inventory (LCI) database for agricultural products. Average LCI representative of the French production will be supplied for around twenty annual crops.

References

COMIFER, 2001. Lessivage des nitrates en systèmes de cultures annuelles. Diagnostic du risque et proposition de gestion de l'interculture. COMIFER Ed. 41 p.

CORPEN, 1991. Interculture. CORPEN Ed. 40 p.

Cohan J.P., Laurent F., Champolivier L., Duval R., 2011. Diagnostic du risque de lixiviation du nitrate et leviers d'actions. In « Cultures intermédiaires: enjeux et conduite ». Ed. ARVALIS-CETIOM-ITB-ITL ; pp. 128-136.

Xue X, Landis AE, 2010. Eutrophication Potential of Food Consumption Patterns. Environmental Science and Technology 2010, 44, 6450-6456.

Risk level regarding absorption capacity after harvest

Capacity absorption of the following crop	Number of months between harvest and seeding of the following crop			
	< 1 month	1-3 months	3-6 months	> 6 months
No cover crop*	2	3	4	5
Cover crop or oilseed rape as following crop	1	1	2	2

*** Risk regarding fertilisation**

Add + 1 to the risk in the absence of cover crop when slurry or droppings are spread on the following crop in autumn or when N inputs exceed crop needs.

Risk level regarding available N quantity from crop residues

Crop	Straw exported ?	Risk level
Cereals	No	5
	Yes	1

→ Risk inherent to agricultural practices

Figure 1. System of classifying risk inherent to agricultural practices established on the basis of COMIFER's method and the database of the institute (1: very low risk, 5: very high risk), example of cereals.

		Risk inherent to agricultural practices				
		1	2	3	4	5
Risk inherent to the site	1	5	10	20	25	30
	2	10	15	25	30	40
	3	15	20	30	40	50
	4	20	30	40	55	60
	5	30	40	40	60	80

Figure 2. Nitrate leaching amount (kg $N\text{-}NO_3^-$/ha) regarding risks (1: very low risk, 5: very high risk) inherent to practices (see figure 1) and to soil parameters (water retention capacity, volume of drained water and soil organic matter content).

163. Life cycle sustainability assessment of fertilising options

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Sustainability describes a development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brutland report, 1987). It comprises three "pillars" – environment, economy and society– which are addressed by Life Cycle Sustainability Assessment, LCSA, (Finkbeiner et al., 2010). The study aims to overview the three dimensions related to mineral fertilisers and compost, from a life cycle perspective and considering a real case study –the tomato production in the Mediterranean region (Martínez-Blanco et al., 2011).
The unit of available nitrogen in the short-medium term (1kg N) from the applied fertilisers to the tomato crops is the functional unit considered here. Fig. 1 shows the system boundaries of the two systems compared: compost and two mineral fertilisers (nitric acid and potassium nitrate). For the present study, fertiliser production and transport are taken into account as well as those stages of the cultivation being different between the two fertilising options, i.e. fertirrigation emissions and application works.
Data sources for the environmental and the economic assessment are mainly referred in previous works from the authors, whereas social evaluation uses sector data from Social Hotspot DataBase, Gabi 5, governmental and non-governmental organisations (such as ILO and OECD), corporate websites, sustainability reports, national statistics and literature.
Environmental Life Cycle Assessment (LCA) is following the obligatory classification and characterisation phases defined by the ISO 14044. Ten mid-point impact categories are considered as well as an energy flow indicator. For Life Cycle costing (LCC) we select three internal costs, which are involving all the chain process costs. Regarding Social Life Cycle Assessment (SLCA), upstream processes and mainstream processes of the production chain are taken into account. For the former, the indicators are referred to the stakeholder "worker", "local community", "society" and "consumer" – as proposed in the S-LCA guidelines (UNEP, 2009) – as well as a specific stakeholder related to the citizens collecting the waste. Social impacts related to upstream processes have so far not been considered in the few existing SLCA case studies. In our study some social indicators addressing the stakeholder "worker" are included for the upstream processes in the life cycle of compost and mineral fertiliser production (such as transport, energy, water, etc.). The number of working time which is spent on each unit process is used to score the relevance of each process in the product chain.
Life Cycle Sustainability Dashboard (LCSD) – an adaptation of the Dashboard of Sustainability, developed to assess environmental, economic and social life cycle impacts of a product (Finkbeiner et al., 2010) - was here selected to present and to compare the sustainability performance of the case studies. LCSD is using software that allows represent a certain number of indicators for LCA, LCC and SLCA, and their values, in order to be able to interpret the results.

References
Finkbeiner, M., Schau, E.M., Lehmann, A., Traverso, M., 2010. Towards life cycle sustainability assessment. Sustainability 2, 3309-3322.
Martínez-Blanco, J., Muñoz, P., Antón, A., Rieradevall, R., 2011. Assessment of tomato Mediterranean production in open-field and in standard multi-tunnel greenhouse with compost or mineral fertilisers from an agricultural and environmental standpoint. J. Clean. Prod. 19, 985-997.
UNEP, 2009. Guidelines for Social Life Cycle Assessment of Products, UNEP-SETAC Life-Cycle Initiative, Paris.

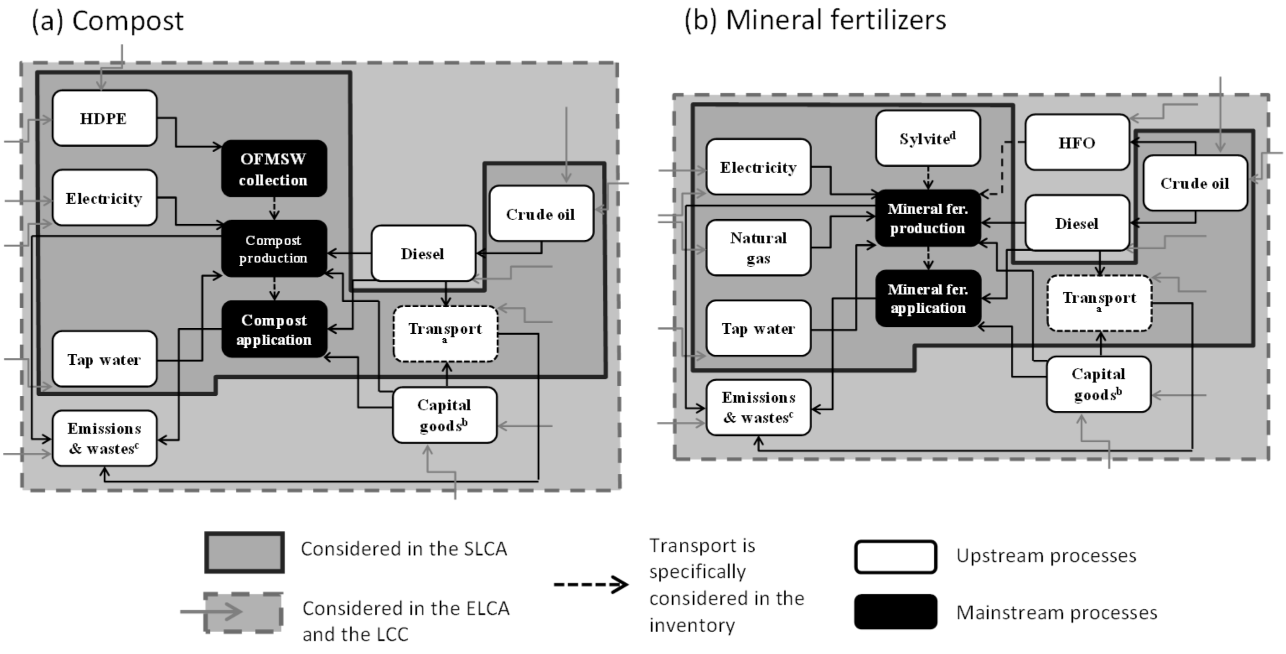

Figure 1. Compost and mineral fertiliser system boundaries for the three LCA approaches.
[a]Dotted arrows are involving transport processes/companies/costs.
[b] Capital goods include machinery, buildings and infrastructures.
[c] For fertiliser production, emissions are included in costs as technologies to reduce emissions, while no real money flows are occurring for emissions produced during fertiliser application.
[d] Sylvite is only included for KNO_3 production. HFO, Heavy fuel oil, HDPE, high density polyethylene.

164. Get SET, an innovative holistic approach to implement more sustainable nutrition

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Feeding the world 2050 and beyond is a challenge particularly, when it comes to sustainable nutrition. It is now time for the industry to optimise the sustainability of their products step by step. To succeed, it is necessary to have a holistic, "cradle-to-grave" approach which involves stakeholders throughout the entire value chain while focusing on consumer goods. This paper shows how applied science and value chain management through BASF's SET Initiative meets those needs.

In principle, today SET is built on three pillars:

1. *Hot Spot Analysis,* a qualitative assessment tool, which helps identify major concerns and perceptions related to the sustainability of a product based on structured stakeholder interviews and relevant publications dealing with the entire value chain.
2. *Eco-Efficiency Analysis,* a life cycle assessment approach for measuring a product's environmental impact from cradle to grave. It includes at least 11 impact categories, such as greenhouse gas emissions, resource consumption, photochemical ozone formation or land use and transformation. Trade-offs between different impact categories can only be overcome by assessing all possible parameters, not only one aspect such as global warming potential, reflected with a product's carbon footprint. The identified impact is then contrasted with the final product's economic value and reveals the parts of the value chain that respond most sensitively to greater sustainability.
3. A *whole chain traceability program* that helps companies to make their supply chain more transparent – a prerequisite for managing sustainability. Traceability not only helps trace all of the components that lead up to a final product through the value chain, but also – and more importantly – makes it possible to follow a tailored plan of action and track the progress made over time.

Multiple projects have been carried out in the food- and feed industry, which show how current and future sustainability opportunities can be leveraged for everybody's benefit. Examples for the three pillars mentioned above are presented from studies on the sustainability optimisation in feed/food value chains. All stages of a life cycle are considered, for example for the production of pork: all aspects of the feed production phase, the animal breeding/fattening, meat/carcass processing, distribution, retail display, as well as consumption and disposal. Using BASF's SET Initiative, the dynamic and different perceptions of several supply chain actors are understood. The involvement of suppliers and customers up and down the value chain enables the producers to counter current hot spots and to drive towards more sustainable nutrition products. The value chain partners and customers can benefit through a proof of sustainable practices, sustainability optimisation and product or brand repositioning and differentiation in the market. SET also identifies potential for product innovation and generates additional brand equity. Along the way, this value adding partnership program enables the customers to gain a higher reputation in the market as a sustainable acting business.

165. Subcategory assessment method: stakeholder workers

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Social Life Cycle Assessment (S-LCA) is a technique to evaluate potential positive and negative impacts along the life cycle of a product (UNEP and SETAC 2009). S-LCA follows four phases, similarly to an (environmental) LCA: goal and scope definition, inventory analysis, impact assessment and interpretation; nevertheless it requires adaptations (Grießhammer, Benoît et al. 2006). Going from data to impact assessment in S-LCA is still a challenge. UNEP and SETAC (2009) have presented a contribution by providing a list of 31 subcategories related to 5 stakeholders (workers, consumers, local community, society and value chain actors) that can be either aggregated to impact categories or modelled, through pathways, to endpoints. Thereafter, methodological sheets for each of the subcategories were elaborated, including definition, contribution for the sustainable development, unit and even possible data sources (UNEP and SETAC 2010). Some Life Cycle Impact Assessment methods, to subcategory level, were also proposed (Dreyer, Hauschild and Schierbeck (2006); Ciroth and Franze (2011)). The first one is limited to worker stakeholder and the second is not clear how to evaluate from data to the subcategory and how to aggregate subcategories into impact categories. The aim of this study is to propose a Subcategory Assessment Method (SAM) to decrease the variability of the evaluation of subcategories in S-LCA studies. A proposal for stakeholder worker and a case study to test it are presented. SAM includes 8 subcategories (freedom of association and collective bargaining, child labor, fair salary, working hours, forced labour, equal opportunities/discrimination, health and safety, social benefits/social security) from the stakeholder worker of UNEP and SETAC (2009). SAM enables the analysis of the organisation in four classes (A, B, C and D) for each subcategory. Fulfilling Class A means that the organisation shows a proactive behaviour compared to the basic requirement. The basic requirement is defined for each subcategory, based on International Agreements. Class B means that the organisation follows the basic requirement. Classes C and D identifies the organisation which does not meet the basic requirement and are differentiated due to generic data which provides background information concerning the possibility of the environment to have a positive outlook to social issues. SAM was applied in a small winery to evaluate stakeholder worker. The case study showed that it was possible to collect data and evaluate a company using SAM. Results show that S-LCA is as time and work demanding as (environmental) LCA, since the issues are specific and change from company to company, sector to sector, and region to region. SAM may also be implemented for the whole product life cycle. Future development of SAM will include the other subcategories, adapting the basic requirement for each one.

References

Ciroth, A., Franze, J., 2011. LCA of an Ecolabeled Notebook – Consideration of Social and Environmental Impacts along the entire Life Cycle, Berlin.

Dreyer, L.C, Hauschild, M., Schierbeck ,J., 2006. A framework for social life cycle impact assessment. Int J Life Cycle Assess. 11, 2, 88–97.

Grießhammer, R., C. Benoît, et al., 2006. Feasibility study: integration of social aspects into LCA. Available from http://www.saiplatform.org/uploads/Library/UNEP-SETACLifeCycleInitiativeTFonSocialIssues-FeasibilityStudy.pdf Last visited on 13/01/2012.

UNEP and SETAC, 2009. Guidelines for social life cycle assessment of products, United Nations Environment Program, Paris SETAC Life Cycle Initiative United Nations Environment Programme.

UNEP and SETAC, 2010. Social Life Cycle Assessment: Methodological Sheets of Sub-Categories of Impact for Social LCA. Available from http://fr1.estis.net/builder/includes/page.asp?site=lcinit&page_id= D45A9A8F-10FA-4501-BF93-FB9AEAE4D163 Last visited on 23/01/2012

166. Supply-demand balances of food and energy in mountainous rural areas to help ensure regional sustainability

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Regional sustainability with resilience is becoming an important concept. In particular, securing potential of self supply for food and energy within local communities, together with local independence, is one of the essential conditions for realising regional sustainability. In order to discuss such potential of self supply for food and energy, re-valuing local natural resources and enhancing a proper balance between supply and demand of renewable resources within a region is of critical importance. However, studies which address this aspect are very scant. In addition, in an attempt to achieving regional sustainability, it is essential to provide information useful and practical enough for making action plans or policy making for local governments. For this purpose, it is required to understand the causal relations among sustainability indicators and materials and energy flow within a certain boundary, in addition to the construction of database.

In Japan, hilly and mountainous areas are approximately three-quarters of the total land areas, and cover the forty percent of the total cultivated areas. These areas hold the key to regional sustainability in Japan. Shinjo village is located in the mountainous area in western Japan. The village is a unique municipality trying to enhance self-reliance in terms of food, energy and financial conditions, aiming to avoid a possible merger with other bigger cities. Unique visions and proper measures are needed for the village to keep the self-reliance viable and to pursue regional sustainability especially at a time when the labor force is shrinking due to the aging population and resultant declining local economy.

In this study, we aim to discuss the outlooks of self-reliance level for Shinjo village from the viewpoint of supply and demand of food and renewable energy, especially biomass energy such as firewood and wood/rice husk charcoal. We first looked into geographical data and examined ecological conditions and local landscapes, which serve as the basis for evaluating local natural resources. We then developed inventory data of food and renewable energy available within the region by applying material flow analysis and life cycle assessment methodology. Based upon the information we demonstrated the assessment of the regional sustainability from the viewpoint of demand and supply balance for food and energy as well as self-reliance of economic conditions.

Figure 1 illustrates the natural resources flow in Shinjo village. The flow chart consists of forestry, agriculture, livelihood, and composting process. We found that Shinjo village has sufficient food production while it heavily relies on energy inflow for fossil fuels. On the other hand, the village has large supply potentials for renewable materials and energy. We proposed institutional and technical options as well as policy measures, which utilise these rich resources, to further enhance regional sustainability of the village.

We conclude this paper by proposing the following as key research questions for this regional sustainability: conducting assessment of ecosystem services in a rigorous and comprehensive way, which includes a completion of a material flow chart for the entire region, and exploring the ways to utilise those ecosystem services along with the establishment of systems to mobilise human resources, money, and materials between the rural and urban areas.

References

Tsuda, K., Nakakubo, T., Umeda, Y., Morioka, T., 2011. Potential accounting of regional urban-rural partnership for constructing resource-circulating systems, in: Morioka, T., Hanaki, K., Moriguchi, Y. (Eds), Establishing a resource-circulating society in Asia: Challenges and opportunities. United Nations University Press, Tokyo, pp. 184-200.

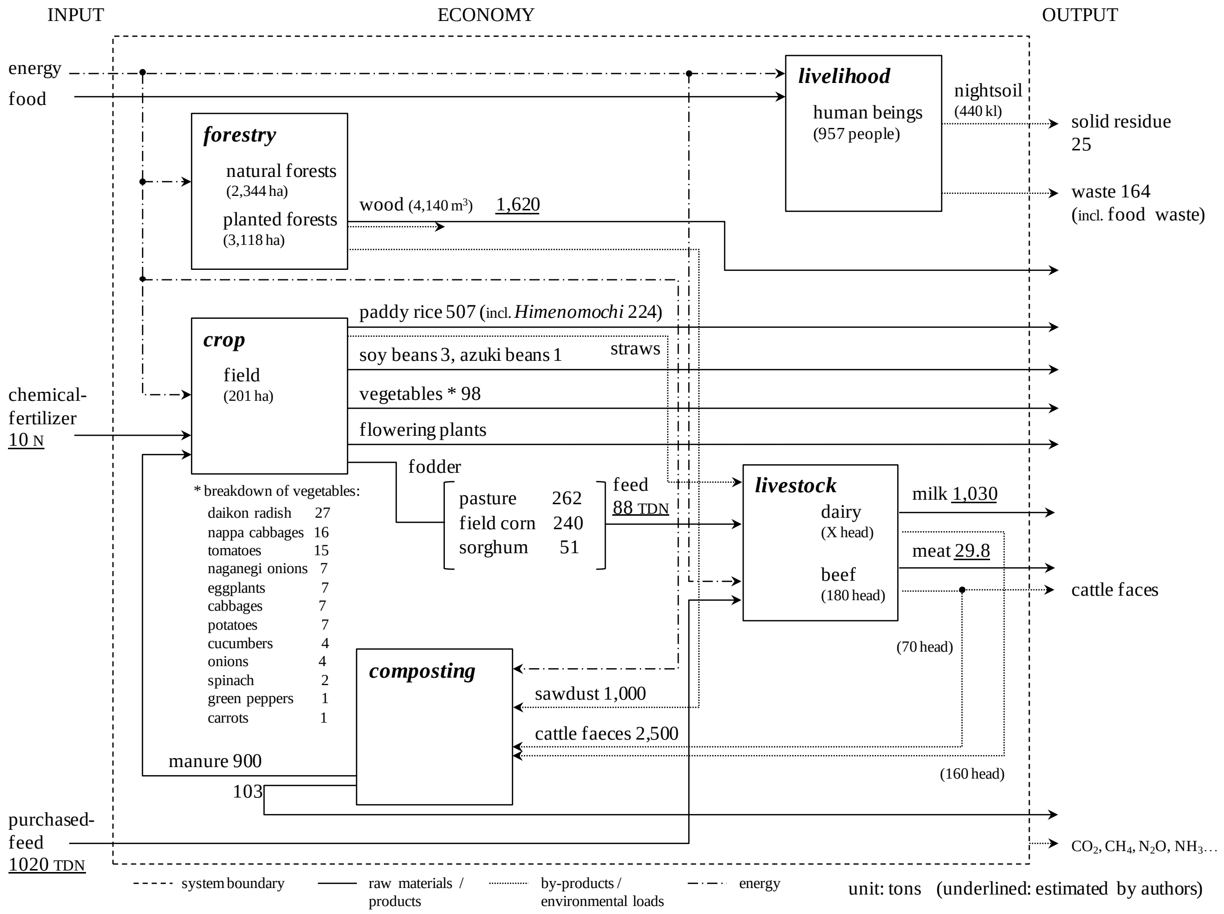

Figure 1. Natural-resource flows of Shinjo village, Okayama, Japan.

167. AgBalance – holistic sustainability assessment of agricultural production

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Life Cycle Assessment (LCA) and approaches based thereon, e.g., Eco-Efficiency Analysis and SEEBALANCE, have proven useful tools for quantitative sustainability assessment along value chains and across industry sectors, particularly for industrial manufacturing and consumption. While these approaches are commonly also applied to assess the sustainability of agricultural products or production systems, there is a need for further development in order to adequately evaluate specific impacts of agricultural activity, particularly relating to biodiversity and soil quality.
Herein, we present a new method for sustainability assessment in agriculture, named AgBalance. Based on the environmental impacts and life cycle costs assessed in BASF's Eco-Efficiency Analysis, and the social impact indicators in SEEBALANCE, AgBalance additionally serves to record and evaluate a range of specific agricultural management indicators. AgBalance thus combines environmental LCA, social LCA and life cycle costs with ecological, economic and social sustainability indicators related to agricultural production, which are generalised to varying spatial scales. Its flexibility allows consideration of variable upstream and downstream processes, includes all three dimensions of sustainability in an integrated approach, and is suitable for application in different regions.
AgBalance comprises up to 70 indicators, based on a significantly larger number of input data and parameters. The indicators show different impacts and are grouped into 16 categories. They are then aggregated in the three dimensions environment, society and economy. Specific impacts on biodiversity in agricultural areas are assessed by a set of indicators: biodiversity state/endangered species, protected area coverage, agri-environmental schemes, pesticide eco-toxicity potential, nitrogen surplus, intermixing potential, crop rotation elements, and farming intensity. Impacts on soil quality in agricultural areas evaluate the indicators nutrient balances, soil organic matter balance, compaction potential and erosion potential. Social indicators include, in addition to those covered in SEEBALANCE, societal representation of agriculture, observation of food law requirements, access to land, trade balances and fair trade benefits for producers. Economic indicators cover farm profitability and productivity, in addition to life-cycle costs.
Both, detailed in-depth results of individual impact indicators, as well as aggregated results and a single sustainability evaluation score are output of AgBalance. Sensitivity analyses can be employed to study the robustness of the model results, and to investigate trade-offs or the response to external influences. Scenario Analyses can model different situations by simulating new sets of inputs followed by an assessment of improvement potentials of the analysed system. AgBalance is useful for assessing and managing sustainable development in agriculture for farmers, business in the food value chain, decision making and policy making and for public communication.

References

Saling P., Kicherer A., Dittrich-Kraemer B., Wittlinger R., Zombik W., Schmidt I., Schrott W., Schmidt S., 2002. Eco-efficiency Analysis by BASF: The Method. Int. J. Life Cyle Assess. 7, 203-218.
Kölsch, D., Saling P., Kicherer A., Grosse-Sommer A., Schmidt I, 2008. How to measure social impacts? A socio-eco-efficiency analysis by the SEEBALANCE® method. Int. J. Sustain. Dev. 11, 1 – 23.
Schöneboom J.C., Saling P., van Gelder R. 2012. AgBalance – holistic assessment of sustainability in agriculture. Submitted to Int. J. Life Cycle Assess.

168. Social life cycle assessment of milk production in Canada

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The agricultural sector in general and the livestock and dairy sectors in particular have been over the years increasingly blamed for their environmental impacts, especially in regards to their greenhouse gases emissions (Steinfeld et al. 2006). In the same time, there has been a growing awareness that farming activities equally induce significant social and economic impacts over a wide range of stakeholders (Van Calker et al. 2005). As new challenges arise from this context, the sector needs to improve his sustainability level to respond to critics.
In this regards, the Life Cycle Assessment (LCA) approach, which addresses the environmental impacts throughout a product's life cycle, has become a widely used tool to identify hotspots and to foster actions to improve a product' environmental sustainability. With the recent development of the Socio-economic Life Cycle Assessment (S-LCA) methodology, this approach now also enables to assess, in an integrated way, for the social and economic aspects of sustainability. In order to document the Canadian milk sector' sustainability, this integrated LCA framework has thus been used in this project to comprehensively define the environmental and socio-economic impacts of the sector's whole life cycle.
However, whereas E-LCA now relies on a well-defined methodology, S-LCA is a new technique whose methodological underpinnings have only been recently specified in the UNEP's Guidelines for Social Assessment of Products released in June 2009 (UNEP 2009). Based on those Guidelines, this project has developed a fully operational assessment methodology adjusted to the Canadian milk sector' specificities. More specifically, two assessment frameworks have been used to assess the social and economic impacts induced all along the Canadian milk sector's life cycle. For enterprises found within dairy farms' sphere of influence, a Specific Analysis has been performed by using a set of indicators related to the sector' specific issues of concern and stakeholders categories. A Potential Hotspot Analysis has been used instead to assess, outside the dairy farms' sphere of influence, the potential misbehaviours of enterprises in regards to acknowledged social norms.
In addition of offering a detailed set of socio-economic indicators reflecting the particular social issues of concern found within the agricultural sector, this project contributed to the advancement of the S-LCA methodology by clarifying the steps to conduct such an assessment in practice, in particular in regards to the two unique and complementary assessment frameworks. It proposes furthermore to integrate to the social and economic dimensions of sustainability with the environmental one in one broad assessment methodology.

References

UNEP/SETAC, 2009. Guidelines for Social Life Cycle Assessment of Products. United Nations Environment Programme. Paris.
Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M., De Haan, C., 2006. Livestock's long shadow: Environmental issues and options. FAO [Food and Agriculture Organization of the United Nations], Rome, 391 p.
Van Calker, K.J., Berentsen, P.B.M., Giesen, G.W.J., Huirne, R.B.M., 2005. Identifying and ranking attributes that determine sustainability in Dutch dairy farming. J. Agri., Food, and Human Values Society 22, 53-63

169. Environmental impact and social attributes of small- and large-scale dairy farms

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In recent years a growing interest was observed from public opinion in the concept of "sustainability" of farming systems (Van Calker et al., 2005). A common perception is that a dairy farm based on pasture, with low-input and low number of cows is more respectful from the environmental point of view than an intensive and large dairy farm (Capper et al., 2009). The aim of this work is to study the environmental impact and the social attributes of intensive dairy farms characterised by different scale in terms of number of lactating cows. We selected 22 dairy farms located in the Po valley in the North of Italy. All the farms were members of the same cooperative feed industry and belonged to one of the two groups: ≤ 70 or ≥ 150 lactating cows. The environmental impact of each dairy farm was calculated with a detailed ''cradle-to-farm-gate'' LCA. All the processes related to the farm activity (i.e. forage and crop production, energy use, fuel consumption, manure and livestock management), and all external factors or inputs (i.e. production of fertilisers, pesticides, feed, energy and fuels, litter materials, replacing animals) were considered as part of the system. The functional unit chosen was 1 kg fat and protein corrected milk (FPCM, 4.0% of fat and 3.3% of protein content). LCA was carried out with SimaPro 7.3.2 (PRé Consultants bv., 2011). Gross margin, i.e. revenues minus direct production costs, excluding labour cost (€/t FPCM) was used as economic indicator. The social attributes of the farming systems were studied using an on-line questionnaire sent to a large sample of stakeholders with different age (18 to more than 60). Daily milk production, stocking density and feed self-sufficiency were not significantly different between the two group of farms; also the production efficiency and economic performance, expressed as dairy efficiency and gross margin, were similar (Table 1). Large scale farms had higher percentage of farm land sown with maize for silage, lower percentage of grassland in comparison with the other group. Nitrogen and phosphorus balances at farm level did not show any significant difference among farms. Climate change and acidification potentials per kg FPCM showed significantly lower value in the large scale farms ($P < 0.05$) compared with smaller ones (Table 2). The results in terms of climate change potential were in agreement with previous studies of Rotz et al. (2010); this could be due to the reduction of methane emission determined by the higher intake of maize silage and high moisture maize silage of cows in large scale farms in comparison with the other group (9.7 vs 7.7 kg DM) (Cedeberg and Flysiö, 2004). Energy use was higher in small dairy farms compared to large ones. The results of the survey (n=479) showed that common perception of some aspects of farming systems sustainability is frequently far from our data, in particular for climate change, eutrophication potential and energy use most of the people considered that large farm impact more than small ones. The results showed that intensive dairy farms with a high number of lactating cows fed with maize-based diet reduced the environmental impact of milk production particularly for greenhouse emission, energy use and land occupation compared with similar intensive farms but with lower number of cows. The study suggests that ecological sustainability is not compromised by increasing farm scale.

References

Capper, J.L., Cady, R.A., Bauman, D.E., 2009. The environmental impact of dairy production: 1944 compared with 2007. J. Anim. Sci. 87, 216-217.
Cederberg C., Flysjö A., 2004. Life cycle inventory of 23 dairy farms in South-Western Sweden. SIK report no. 728.
Rotz, C.A., Montes, F., Chianese, D.S., 2010. The carbon footprint of dairy production systems through partial life cycle assessment. J. Dairy Sci. 93, 1266-1282.
Van Calker K.J., Beretsen, P.B.M., Giesen, G.W.J., Huirne R.B.M., 2005. Identifying and ranking attributes that determine sustainability in Dutch dairy farming. Agr. Human Values 22, 53-63.

Table 1. Characteristics of two group of farms (least squares means)

	≤ 70 milking cows	**≥ 150 milking cows**	**SE**	***P***
N observations	11	11		
Daily milk production, kg FPCM/cow	28.0	29.2	1.02	0.413
Stocking density, LU/ha	4.40	5.83	0.68	0.150
Farm land, ha	25.1	78.0	7.5	< 0.001
Feed self-sufficiency,%	63.6	61.8	4.72	0.790
Production intensity, GJoule/ha	98.4	120	8.87	0.105
Gross margin, €/t FPCM	209	175	19.0	0.224
Dairy efficiency, kg milk/kg DMI	1.29	1.34	0.04	0.433
Lucerne,% farm land	16.9	18.0	3.66	0.833
Grass,% farm land	23.1	8.5	6.89	0.149
Maize for silage,% farm land	15.7	25.6	3.98	0.097
N balance, kg/ha	431	547	62.4	0.206
P balance kg/ha	54.3	54.9	10.40	0.968
N farm efficiency,%	27.3	28.0	0.78	0.555
P farm efficiency,%	28.3	31.2	0.95	0.044

Table 2. Environmental impact of the two groups of farms, expressed for kg of fat-and-protein-corrected milk (least squares means)

	≤ 70 milking cows	**≥ 150 milking cows**	**SE**	***P***
No. observations	11	11		
Climate change, kg Co_2-eq.	1.35	1.18	0.050	0.036
Acidification, g SO_2-eq. per kg	21.10	17.90	1.05	0.042
Eutrophication, g PO^{-3}_4-eq. per kg	9.74	8.15	0.590	0.072
Energy use, MJ	6.52	5.23	0.300	0.006
Land occupation, m^2	1.56	1.35	0.070	0.045

170. Guidelines for addressing environmental and social LCA within Quebec's food processing industry – Part 1: environmental aspects

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Many food industries are now developing responsible purchasing policies and challenging their suppliers by asking for guarantees with regards to their environmental and social practices. In response to such product and company-specific needs, life cycle assessment (LCA) is becoming a fundamental method widely used to support informed decisions within a broader sustainable management. Based on a holistic approach, LCA is a decision-support tool used for the assessment of potential environmental impacts of a product over its entire life cycle. Such a meaningful assessment helps to identify environmental hotspots where actions can be taken to reduce inefficiencies and energy cost while developing greener and socially acceptable products.

In an effort to provide a beneficial and competitive advantage for the food processing sector industries located in Québec (Canada), a framework is being developed addressing both environmental and social aspects. On one level, the outcome of this project encourages and facilitates the implementation and the achievement of a company and/or product LCAs from SME's to larger companies. Additionally, it can help position both product and company in a green market influenced by the increasing demands of consumers.

However, since LCA results are conditioned by several choices to be taken from the very beginning of a project, it is necessary to refine the scope and boundaries. This aspect is quite unique in this approach as only few studies have considered both aspects of sustainable development, up until now. In addition, the framework provided establishes a series of guidelines and rules that are built according to the ISO standards (14040-14044), the guidelines for social life cycle assessment of products (UNEP, 2009) and Product Category Rules (PCRs) development.

Such guidelines allow for an integrated and standardised approach for implementing a comprehensive LCA, in order to ensure quality, consistency and comparability among studies for various food processing sectors. In addition to providing information on how to define the functional unit, data quality requirements and other requirements of the LCA, the guidelines help to find the best data available for a specific sector in a specific region. The latter include sectors such as dairy products, poultry, juice and drinks, food packaging and many others.

The process of developing such an initiative for the sector as well as the guidelines' environmental requirements will be presented. This includes a list of stakeholders who participated in the guidelines' development and the integration process of the socio-economic and environmental issues. Gains made by food processors will also be shared.

References

UNEP/SETAC (2009). Guidelines for Social Life Cycle Assessment of Products. United Nations Environment Programme. Paris.

171. Guidelines for addressing environmental and social LCA within Quebec's food processing industry – Part 2: socio-economic aspects

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The growing demand of consumers for environmentally friendly products and socially responsible practices is becoming a major issue for the food processing industry. As new regulations are enacted and responsible procurement practices policies become widespread among large retailers, processors have to adapt and provide credible information on the environmental and social impacts induced by their products and activities. In order to support the Quebec's (Canada) food processing industry facing these new challenges, guidelines have been produced to allow processors operating in one of the five participating sectors (dairy, poultry, juice and drinks, processed vegetables and animal feed) to conduct Life Cycle Assessment (LCA) over their enterprise.

Although the LCA approach has become to be known as one of the most effective and rigorous method to assess the impacts of a product over its entire life-cycle, it traditionally focuses on environmental impacts, thus failing to provide a complete assessment of the product' sustainability. Doing so would require taking also into account it social and economic impacts. Based on recent theoretical developments, these guidelines propose a Sustainability-LCA framework to assess the social and economic impacts as well as the environmental ones.

Drawn from the UNEP's Guidelines for social life cycle assessment of products (UNEP 2009), the Social-LCA part of these Guidelines provides a fully operational framework in which impact sub-categories have been related to a set of readily measurable socio-economic indicators. Although the framework relies on a common and standardised assessment methodology, it also allows for adaptations to take place in order to take into account sectors' specificities. More fundamentally, by clarifying the S-LCA's terminology, steps of realisation and the indicators' selection criteria, these Guidelines enhanced this tool's methodological foundations to facilitate its use in other contexts and for other subjects.

In sum, in addition of being one of the first attempts to develop an integrated assessment framework to perform a Social and Environmental LCA, these Guidelines propose a practical, simplified and sector-oriented S-LCA methodology that will facilitate the conduct of such an assessment in the participating food processing sectors and beyond.

References

UNEP/SETAC, 2009. Guidelines for Social Life Cycle Assessment of Products. United Nations Environment Programme. Paris.

172. Aggregated indicators of sustainable agricultural production and food security in the Central Maghreb

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A sustainable food production and supply for a growing human population is a major challenge for the next years and decades. Food security, including supply and demand factors as physical and economic access and wealth and assimilation of nutrients, must be performed by a sustainable agricultural production that ensures the long term agricultural productivity and ecosystem services. The region called the Central Maghreb includes Algeria, Morocco and Tunisia in the North of Africa. In these countries, despite the great economic differences, the agro-ecological characteristics are homogenous and are limiting productivity: arid and semiarid climates, with low rainfall values along the year and concentrated in the sea-side land stripe, where are located also the most suitable farming soils. These ecological constraints are aggravated with political and socioeconomic ones that have resulted in a dual agricultural structure: high yield export-oriented vegetable and fruit farming systems and low-yield inner-consumption-oriented cereal farming systems. In these low input systems the technological use is scarce and there is an important yield gap between actual yields and potential ones. The production and inner supply of basic products as cereals or milk is mainly supplied by external imports from international markets, whereas vegetables and fruits are exported to foreign countries. In both cases, Spain and the EU are key actors in trade, agriculture, food, health and development policies.

This multidimensional challenge must be studied with a holistic approach, where sustainability and food security may be assessed by a number of indicators that reveal the strengths and weaknesses, as well barriers and drivers operating in each country in a multinational scenario and a multilevel assessment. This assortment of indicators should be synthesised into an appropriate unique indicator that in spite of containing much information, is easy to understand by the end-users (policy-makers, scientific, technicians, etc.). Aggregated indicators help to communicate the information succinctly and to make easier to distinguish patterns in the data by formalising the aggregation process that is often done implicitly, subjectively and intuitively. Indicator sets may be built up within a framework according to two conceptions of sustainability: goal or property oriented. The latter is based on systemic properties, such as existence or effectiveness, etc. The aim of this work is to assess the sustainability of the agricultural production and food security in the Central Maghreb making operational the systemic framework and incorporating multivariate statistical tools.

The hierarchical structure of the framework was based upon three subsystems: human (food security and social dimension), natural (environmental dimension) and support (production and economic dimension). Indicators were organised according to Bossel´s seven basic orientors (Table 1). The methodology was an iterative process consisting on several steps: system definition, selection of indicators and aggregation of indicators. This analysis was multinational, including Mediterranean countries, Middle East countries and others with ecological, sociological or economic similarities, such as South Africa, Norway and Iran. These countries were selected as the observation set. For each country, 21 indicators were computed (7 orientors x 3 subsystems). The data were obtained from FAO, United Nations, Worldwatch Institute, World Resources Institute and other international organisations. LCA was performed with some of the basic data.

Synthetic indicators were calculated by principal components analysis, using STATGRAPHICS software. The aggregation of data into single indices was done using coordinates of the countries with the principal components and the eigenvalues from the analysis. The indicator set considered for the selected countries is shown in Table 1. The selected indicators explained with good agreement the differences in sustainability and food security between the different countries and the synthetic indices ranked them all. The specific indexes that characterised the countries from the Central Maghreb were analysed in order to evaluate present and short term strengths and weaknesses to propose a development strategy.

Table 1. Indicator set for each selected country.

Basic orientor	Natural system	Human system	Support system
Existence	Impact of agricultural production per ha	%energy per capita intake by minimum requirements	Production per capita
Effectiveness	Eco-efficiency of agriculture	Agricultural production vs rural population	Cereal yield^{-1}
Freedom of action	Water footprint vs rainfall	Food consumption diversity	Net food imports per capita
Security	Anthropogenic nitrogen inputs	Basic food supply	Cereal yield stability
Adaptability	Rate of EF trend	Minimum food requirements	Slope of cereal yield trend over time
Coexistence	Share of basic and technical energy use	Undernourished population	Cereal yield gap
Psychological needs	EF vs. biocapacity	Life satisfaction	Input productivity

173. Consistent inclusion of deforestation in food life cycle assessment

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Deforestation is recognised as being one of the major cause of greenhouse gas (GHG) emissions and destruction of ecosystems. It is also recognised that the majority of deforestation of natural ecosystems is associated with agriculture and agroforestry. On a world scale, GHG emissions from deforestation associated with agriculture and agroforestry are of the same order of magnitude as all other GHG emissions associated with agriculture and agroforestry production systems. The sector of food and beverage is rapidly incorporating the method of life cycle assessment (LCA) to address issues such as labelling, "food eco-design" but also to inform consumers and non-governmental organisations asking for more transparency on the environmental performance of food and beverage products.

However, among major limitations in doing LCAs on food and beverage products is the lack of consistent consideration of impacts associated with deforestation in inventory database and impact assessment results. Therefore, there is a need to develop and incorporate transparent and reliable data on deforestation in inventory databases and impact assessment results in order to increase accuracy of food and beverage LCAs.

Different approaches exist to address deforestation in LCA: the most common approach is to actually neglect this issue; the GHG protocol suggests to allocate deforestation to the cultures that have grown in the country where deforestation occurs; another approach is to allocate deforestation equally to all land cultivated in a specific area (normally the country); finally, another approach is to allocate deforestation to the culture on the boarder of the forest being deforested, assuming that it is this culture that causes deforestation.

In any cases, deforestation is most of the time not considered, which can be a significant bias for products produced in countries experiencing significant deforestation such as those in the tropics. In this context, at Quantis, we are evaluating the influence of incorporating deforestation consistently in inventory databases and impact assessment results, using the different approaches as sensitivity studies.

The presentation will show the contribution of deforestation in overall food and beverage LCA studies, using different allocation systems.

Results show that neglecting deforestation can cause a major underestimation of GHG emissions and other ecosystem impacts associated with products produced in tropical countries, such as palm oil, coffee, sugar cane, soybean or beef. In some cases, deforestation can double the GHG and ecosystem impacts as compared to when deforestation is neglected. For example, if considering the average annual Brazilian deforestation rate of 0.8% (in ha deforested/ha used for farming), the GHG emissions associated with green coffee production can double.

In addition - and this is something even more neglected in most LCA food studies - to be consistent, impacts of deforestation should also be considered in studies indirectly using such products, as for example, potential impacts from deforestation in LCAs of European milk production where part of the dairy cows fodder is based on soybean produced in regions where deforestation occurs.

This presentation will highlight the cases when deforestation should be considered with care to evaluate the actually potential environmental impacts of food and beverage products.

174. Comparison of current guidelines to calculate the carbon footprint of carrots

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The Carbon Footprint of carrots grown in South-Eastern Norway was calculated using a calculation method following the principles of ISO 14067 and harmonised with the PAS 2050 and GHG Protocol Products Guideline. No calculation method for the CFP of carrots exists but some guidelines for vegetables do: The "Fruit and Vegetables" PCR from the Japanese CFP Pilot Programme, the "Vegetables" PCR from the International EPD system and the guideline for calculating CFP of Horticultural Products from Productschap Tuinbow. In addition the sector guidance for horticultural products PAS 2050-2 was evaluated. These guidelines are not identical.

The Carbon Footprint was found to be 0.38 kg CO_2-eq./kg carrot sold to consumer. The product system stopped at retail but included the waste handling for the materials wasted in the consumption stage. The total Cradle-to-Grave carbon Footprint was 0.55 kg CO_2-eq./kg carrot, but there are large uncertainties in the calculations of emissions from the consumer stage.

The effect of applying different methodological choices in the calculation of Carbon Footprints was examined using the abovementioned PCR and Horticultural guideline as example. All guidelines excluded Capital Goods on the basis that the impact is low but for carrots the effect was found to be >1% of the cradle-to-gate CFP. Some issues are not adequately addressed in the guidelines. Emissions from electricity can be very different depending on whether the national grid or some multinational is considered, and whether or not green electricity schemes such as the European Guarantee of Emissions scheme is being accounted for. In some cases the guidelines give different recommendations. The allocation in recycling and recovery is a prime example.

This study shows that there is a need for more harmonisation between CFP and EPD schemes around the world. It also shows that it might be necessary with more detailed guidance than guidelines covering a whole sector or a whole range of products ("Horticulture products", "Vegetables" or "Vegetables and fruits"). The study has resulted in recommendations for a standard method for carrots and similar products.

References

Blonk, H, Kool A, Luske B, Ponsioen T and Scholten J, 2010. Methodology for assessing carbon footprints of horticultural products. A study of methodological issues and solutions for the development of the Dutch carbon footprint protocol for horticultural products. Blonk Milieuadvies. http://www.blonkmilieuadvies.nl/en/pdf/engels%20rapport%20pt%202010.pdf

ISO DIS 14067. International Standards Organisation 2012. http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=59521

BSI (British Standards Institute) (2011). Publicly Available Specification 2050. http://www.bsigroup.com/en/Standards-and-Publications/How-we-can-help-you/Professional-Standards-Service/PAS-2050/PAS-2050/

WBSCD (World Business Council for Sustainable Development) and WRI (World Resources Institute) (2011): Greenhouse Gas Protocol. Product Life Cycle Accounting and Reporting Standard.
http://www.ghgprotocol.org/standards/product-standard

The International EPD system (2011): Product Category Rules for CPC Group 012: Vegetables. http://www.environdec.com/en/Product-Category-Rules/Detail/?Pcr=8074

The Japanese Carbon Footprint Pilot Project. Product Category Rules for Vegetables and Fruits (approved PCR ID:PA-BF-02). http://pcr-library.edf.org.tw/data/japan/Vegetables%20and%20Fruits.pdf

175. Establishing a reference carbon calculator and policy options to promote low carbon farming practices in the EU

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The direct emissions of greenhouse gases (GHG) from agriculture accounted for around 10% of total European Union (EU) emissions in 2010. It has been estimated that in the United Kingdom the agri-food sector as whole contributes around 19% of GHG emissions when life cycle emissions are taken into account. To reduce the farming-related GHG emissions appropriate policy instruments and supporting tools that promote low carbon farming practices must be developed. This paper describes an on-going project that aims at assessing the policy options to promote low carbon farming practices in the EU. The project includes: i) a review of existing climate-related certification and labelling schemes in agri-food sector, ii) the development of a user friendly open-source carbon calculator suitable for assessing the life cycle GHG emissions from different types of farming systems across the whole EU, and iii) the design/assessment of policy options for promoting low carbon farming practices. The carbon calculator quantifies direct and indirect GHG emissions according to the general-level and sector-specific international standards and guidelines on Life Cycle Assessment and carbon footprint. In addition to the GHG emission quantification, the tool also proposes mitigation options and sequestration actions suitable for single farms. The recommendations of the specific farming practices are based on emission reduction potential, potential leakage effects, inherent costs of implementation, and impact on other environmental issues. The practicality and acceptability of the carbon calculator has been tested on around a hundred farms across the EU. Finally, a range of options for making widespread use of the carbon calculator will be outlined, including e.g. public or private certification schemes, incentive payments to farmers, and legal obligations for farmers to reduce GHG emissions.

References

European Environment Agency, Approximate EU GHG inventory, Early estimates for 2010, in EEA Technical report No 11/2011.

Garnett, T., Cooking up a storm – Food, greenhouse gas emissions and our changing climate. 2008. Food Climate Research Network, Centre for Environmental Strategy, University of Surrey. p. 155.

European Commission, Joint Research Centre, International Reference Life Cycle Data System (ILCD) Handbook – General guide for Life Cycle Assessment – Detailed guidance (2010) Luxembourg: Publication Office of the European Union.

176. Surveying tools and methods for LCA in the agri-food sector

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The objective of the present paper is to understand how Life Cycle Assessment (LCA) practitioners make choices between different tools, depending on their objectives. In order to do so, we divided our work in two stages:

1. The first state was making a review of how many tools are in the LCA market, and which are their main characteristics. We reviewed 63 tools out of more than 100 that are available, 11 of which we tested to some extent.
2. The second part was conducting a survey on LCA practitioners, trying to understand how those tools are used and to what end. The basis for this work was an adaptation of the questions by Cooper and Fava (2006). The survey was announced in the PRe Consultants LCA discussion list, and sent by e-mail to the Bluehorse Associates (BHA) mailing list. A total of 117 LCA practitioners answered at least one question in the survey. Since BHA is a sustainability metrics company specialised in the food industry, there was a high share of replies by LCA practitioners in agriculture and food. This inherent bias was intended for this study. Our objective is to understand, from the standpoint of an informed LCA practitioner, which solutions are available, what differentiates them, and how they adapt to each specific objective of the studies.

Our first finding was that the frontier between "full LCA" (ISO compliant) tools and simplified, non-standardised tools (simplified LCA) is now much fuzzier. Simplified tools are becoming more accurate, while full LCA tool developers are coming up with their own simplified tool versions. Simplification is today a synonym with user-friendliness and practicality, not necessarily lack of rigor.

Part of the explanation for this has to do with political context. There is now a need for more practical, business-oriented tools that respond to the high demand created by the generalisation of product LCA. Other part of the explanation was found during the survey (Teixeira and Pax, 2011). Even though most respondents claim to follow some kind of standard, they do not always submit their studies to peer review (Table 1). Research and development, innovation and eco-design are the most mentioned objectives of LCA studies today, and all of these are internal to companies. In fact, almost all tool providers organise seminars, webinars or some other forum to communicate with users. Learning and knowledge transmission from developers to users is now a key concern, as many companies do not have in-house LCA expertise, but LCA is progressively done in-house. Since the focus is no longer on communication, simplification has gained in importance against standardisation.

Still, practitioners quote data availability as their main challenge. Simplified methods, for example those based on large quantities of secondary data, address this concern. The tool review confirmed that the number of data providers is still very low, and data availability is a fair concern.

Another interesting finding was that most tools do not easily display trial versions or disclose much information about the tool and databases included. In many cases pricing models are either very complex or absent from public display. So, the task of a practitioner selecting the best-suited tool for the project's objectives is difficult, due to the disappearing frontier between full LCA and simplified LCA, the many similar options available, and the lack of transparency in price and use. Unless the practitioner has previous pointers or well-defined targets to start with, it is very difficult to make an informed choice without spending time and resources surveying the market for a long period of time. In the future, it is highly recommendable that tools become transparent about what they can deliver to clients and how they are different from their competitors.

References

Cooper, J.S., Fava, J., 2006. Life-Cycle Assessment Practitioner Survey Summary of Results. Journal of Industrial Ecology, 10, 12-14.

Teixeira, R., Pax, S., 2011. A Survey of Life Cycle Assessment Practitioners with a Focus on the Agri-Food Sector. Journal of Industrial Ecology, 15, 817-820.

Table 1. Answer to the multiple-choice question "Are your LCAs peer-reviewed?".

Are your LCAs peer-reviewed?	Number of practitioners
Yes, always	6
Yes, sometimes	35
Yes, occasionally	24
No	26
Total	91

177. PISC'n'TOOL: an operational tool for assessing sustainability in aquaculture systems

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To meet challenges of producing more while lowering impacts on ecosystems, new fish-farming systems have to be designed. The first step before any changes in farming systems is to make a diagnosis on environmental impacts, economic viability and social aspects of the activity. The assessment step has to be as complete as possible, adapted to the system and scientifically robust, but also convenient for the user. To fulfil this complex combination, we designed an operational tool for fish-farm systems assessment based on LCA conceptual framework and Emergy accounting: PISC'n'TOOL. This tool was created in the PISCEnLit project (Ecologically Intensive PISciculture project) funded by the French National Research Agency.

PISC'n'TOOL aims to analyse environmental farm scale impacts of a fish farm according to LCA attributional approach, to determine the contribution of the farm's components and environmental intervention to its impacts and also to analyse farm's performances (zootechnical, economical, and social). The targeted users are researchers and agricultural advisors for fish farming in France, Indonesia and Brazil. PISC'n'TOOL applies a cradle to farm gate analysis; the farming system evaluated focuses on the fish farms and its main inputs (Fig. 1). For fish farms associated to livestock (i.e. integrated pig -fish farming system), the terrestrial production are outside of the system boundaries, meaning manure/slurry used for fish production is considered as an input with specific allocation rules. Temporal coverage of PISC'n'TOOL is a period of 1 year or one production cycle in order to be adapted to the evaluated system. According to the multiple functions of a farm, PISC'n'TOOL defines 5 functional units: one tonne of fish produced, one m^3 of water used, one on-farm hectare, one human labour unit, and 1000 $ of farm income, calculation depending on specific user's data or incremented data base. The farm's environmental inventory is based on tables of energy carriers, infrastructures, equipments, vehicles, chemicals and veterinary products, water consumption, feeds (up to 10 different feeds with 15 ingredients are allowed) and fry/fingerlings. These data stem from previous aquaculture LCA studies or new data collected during PISCEnLIT project. Farm emissions (N, P, solids emissions) are calculated using mass balance modelling (Cho et al., 1990). Emission and consumption data are aggregated into midpoint indicators (included also Net Primary Production Use) according to CML 2 baseline 2001 (version 2.04) method and endpoint indicators (human health, Ecosystem and resources) according to Recipe endpoint H Eur H/A method.

PISC'n'TOOL allows also to provide Emergy indicators (based on LCA data), but also zootechnical, economic efficiency level and social indicators (Fig. 2). Results are systematically given in tables for each functional unit or in graphical form. The resultants ensure an easy comparison between different running scenarios for one farm or for different systems as well. Despite a large interne database, this tool requires additional data from the users to perform the LCA.

PISC'n'TOOL is a practical tool for the multidimensional evaluation of farming system. The tool allows the identification of the environmental, economical and social hotspots of fish farm, and thus can help to define improved strategies and scenarios for farm evolution.

References

Cho CY, Kaushik SJ. Nutritional energetics in fish: energy and protein utilization in rainbow trout (*Salmo gairdneri*). World Rev Nutr Diet. 1990;61:132-72.

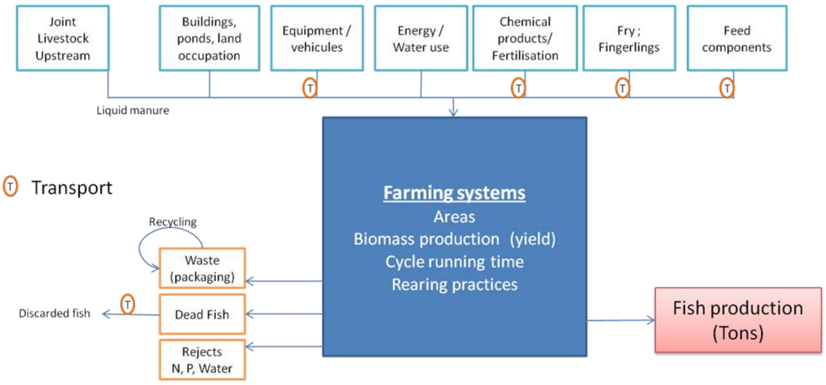

Figure 1. Fish farm system boundaries

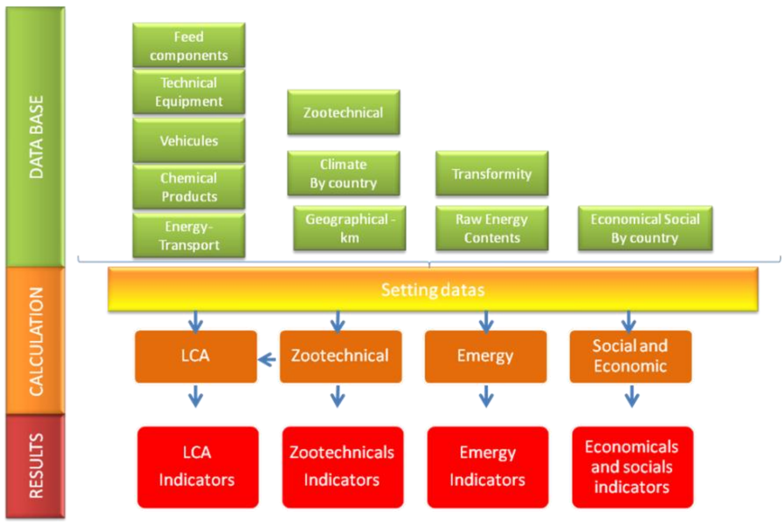

Figure 2. Simplified representation of PISC'n'TOOL framework

178. Food and climate change: FOODprint as a tool to support GHG reduction in the Thai agri-food sector

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As a leading food producer and a major exporter, Carbon Footprinting (CF) and Labelling are seen as useful tools in Thailand to quantify GHG emissions and identify the priority areas for GHG reduction for climate change mitigation and to stimulate the development of innovative technology/management to produce lower-carbon food products. CF was initiated through academic-industrial collaborative projects and national pilot projects leading to the development of the national CF guideline as well as carbon footprint labelling scheme. Though it has been well taken by the Thai agri-food industry for a few years already, it is still very difficult for them to identify the required data, data sources and collection methods particularly for background and secondary data. More importantly, they echoed the need for quick CF calculation for effective business decisions which was limited by their lack of understanding of the underlying scientific background and methodological issues (Mungkung et al., 2010). These issues are critical especially for small and medium enterprises (SMEs) who do not always have the necessary competence. This has led to the initiative in developing a carbon footprint calculation tool so called "FOODprint", for the Thai agri-food industry, which will serve as a means for capacity building. The development of FOODprint is being carried out by VGREEN-KU, JGSEE and the Federation of Thai Industries together with 40 Thai food companies; the studied products covering different sectors: agriculture, livestock, fisheries and aquaculture. FOODprint is based on spreadsheets, with the flexibility to add on new sets of databases specific to a supply chain. The data requirements and calculation methods are based on PAS 2050: 2011 (BSI, 2011). Specific templates for data input and for CF calculation for plant/animal-based production systems, processing, packaging, transport of inputs/distribution, sales, pre-consumption, and post-consumption waste management are included. A user guideline of FOODprint provides the principles, methodology and practical approach for data collection, transformation and input. The CF results are illustrated in tables and graphs showing contribution analysis, including comparison with similar products from previous studies for benchmarking. Possible strategies to reduce GHG emissions are suggested for further analysis and the high-level analysis of each option is calculated and compared for management decisions. This also fits well for developing Nationally Appropriate Mitigation Actions (NAMA), supporting wider application of carbon footprinting and labelling, as well as to anticipate the market requirement of carbon labelling both for domestic and export products, which will contribute to climate change mitigation and promote low-carbon trade between Thailand and EU. This will also lead to a synergistic effect of this project with the EU's existing Integrated Product Policy (IPP) which aims to improve the environmental performance of products along their life cycle. As Thailand is the very first country in ASEAN taking initiative on carbon footprinting and labelling, the knowledge and experiences gained from this project can be shared with other ASEAN countries through the collaborative framework of "ASEAN Climate Change Initiative: ACCI" for joint response and efforts to combat climate change.

References

Mungkung R., Gheewala, S., Bonnet, S., Hospido, A., Kanyarushoki, C., van der Werf, H. and Poovarodom, N. 2010. Carbon Footprinting and Labelling: Experiences from the Thai food industry Available online: http://www.thaicarbonlabel.sci.ku.ac.th/

BSI, 2011. PAS 2050:2011. Specification for the assessment of the life cycle greenhouse gas emissions of goods and services. British Standards Institution

179. Determining greenhouse gas emissions profiles for Australian agricultural products at a regional scale: methodological opportunities and obstacles

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Life Cycle Assessments (LCAs) of greenhouse gas emissions associated with agriculture have commonly been conducted at a farm scale (case study) or emissions are calculated at a national scale. However, until recently, there has tended to be a scarcity of regionally-applicable assessments. This may be partly due to difficulties in obtaining representative data that account for variability in agricultural production systems.

However, for national policies to be regionally applicable and for landholders to identify opportunities for practice change, it is essential that inter- and intra-regional differences be better understood. We contend that by accommodating variability, highly robust regional LCAs can be built and that this broader analysis will improve our understanding about the representativeness of existing case-studies.

We have found the greatest opportunity for emissions reduction in cropping systems to be replacing synthetic nitrogenous fertilisers with biologically fixed N, with emissions from a legume-based system found to be 33% of those from a non-legume system (Fig. 1; Table 1). Other factors which greatly influence calculated emissions per unit of product are yield variation across seasons and the choice of direct nitrous oxide emissions factor (Brock et al. accepted; Herridge et al. 2011; Schwenke et al. 2011). We have also found variability in emissions from sheep enterprises, ranging from 39% reduction for change in enterprise emphasis from wool to meat production (Table 2), to approximately 28% variability for change in wool price or calculation method, to 23% variability for change in fibre diameter, to 10% variability for change in fleece weight (Brock et al. in preparation.; Graham et al. 2010).

To account for this variability, we are:

1. obtaining regional-level data, including measures of variability, from research and extension staff
2. providing detailed documentation about the variables and discussing other environmental effects
3. testing the sensitivity of the emissions profile by changing the parameter values for formulas constructed in SimaPro and checked against FarmGAS
4. applying data from instrumented regional field trials
5. testing the effect of changes in economic allocation in animal production systems
6. using data from modelling packages, such as GrassGro, to compare long and short term variability.

The variability associated with many LCA inputs and lack of enterprise-level seasonally-specific data makes farm-scale (case-study) assessment problematic. It seems highly desirable for there to be greater focus on regional-scale LCA, to support both testing of national policies and on-farm emissions reduction.

References

Brock, P., Madden, P., Schwenke, G., Herridge, D. Greenhouse gas emissions profile for 1 tonne of wheat produced in Central Zone (East) New South Wales: A Life Cycle Assessment approach. Crop and Pasture Science, accepted.

Brock, P., Graham, P., Madden, P. Greenhouse gas emissions profile for 1 kg of wool produced in the Yass Region, New South Wales: A Life Cycle Assessment approach. Animal Production Science, in prep.

Graham, P. 2010. Bookham Grazing Demonstration Results. Department of Primary Industries, Yass NSW.

Herridge, D., Schwenke, G., Brock, P. 2011. Nitrogen-fixing chickpea underpin productive, sustainable farming systems in Australia's Northern Grains Region. Proceedings of the 25th Latin American Conference on Rhizobiology, 9 Sep 2011, Uruguay.

Schwenke, G., Brock, P., Herridge, D. 2011. Nitrogen-fixing legumes in farming systems reduce greenhouse gas emissions. Proceedings of the 17th International Congress on Nitrogen Fixation, 27 Nov - 1 Dec, Fremantle, Western Australia.

Table 1. Total greenhouse gas emissions for canola-wheat and chickpea-wheat production systems with different levels of fertiliser N, i.e. zero (0N) or 80 kg N/ha (80N)

Rotation[A]	Pre-farm and on-farm emissions year 1 (kg CO_2-e/ha)	Pre-farm and on-farm emissions year 2 (kg CO_2-e/ha)	Total emissions per ha over 2 years (kg CO_2-e)
Canola (80N)–wheat (80N)	896	908	1804
Chickpea (0N)–wheat (80N)	306	848	1154
Chickpea (0N)–wheat (0N)	306	297	603[B]

[A]The canola and chickpea crops yielded 1.8 t/ha; the three wheat crops yielded 3.0 t/ha; [B]Total emissions from chickpea (0N)–wheat (0N) are 33% of those from canola (80N)–wheat (80N); using ecoinvent and the Australasian LCI database updated May 2012.

Table 2. Sensitivity of the emissions profile for sheep enterprises to changes in enterprise from wool dominance to the production of first-cross lambs

Enterprise type	Value of wool (%)	Value of mutton (%)	Value of lamb/live animal (%)	Enteric methane (kg /ha)	Total emissions (kg CO_2-e/kg greasy wool)
19-micron wool production	56	32	12	99.1[A]	25.6
19-micron ewes joined to Dorset rams for meat production	30	11	60	94.0 + emissions from production of feed and replacement ewes	15.5[B,C]

[A]Based on daily modelling for the 51-year long-term average period; [B]Includes emissions from the production of wheat (0.157 kg CO_2-e) and replacement ewes (2.29 kg CO_2-e); [C]Emissions decreased by 39% due to change in enterprise emphasis.

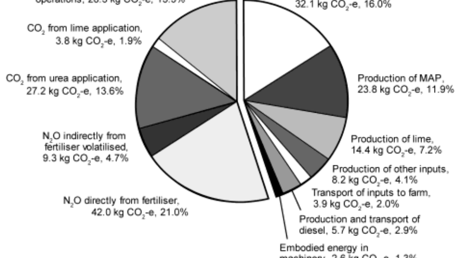

Figure 1. Greenhouse gas emissions (kg CO_2-e) from the production of 1 tonne of wheat in Central Zone (East) NSW, Australia.

180. Energy analysis of agricultural systems: uncertainty associated with energy coefficients non-adapted to local conditions

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Among studied impacts in Life Cycle Analysis, fossil energy use has been widely considered. But choice of energy coefficients from the literature and their ability to express accurately local conditions is questioned for territories where references for inputs life-cycle are lacking. This study measured fossil energy use in dairy farms and assessed uncertainty associated to energy coefficients in order to improve energy analysis methodology of agricultural systems.

Fossil energy use for forty two dairy farms from Poitou-Charentes (PC) and thirty from Reunion Island (RI) have been analysed using PLANETE for PC (Bochu, 2002) and PLANETE MASCAREIGNES for RI (Thevenot et al., 2010). Uncertainty analysis and sensitivity analysis has been conducted through the SIMLAB tool (Saltelli et al., 2004). Uncertainty analysis consisted in a Monte-Carlo methodology: 30,000 sets of energy coefficients have been randomly drawn from a uniform law between minimum and maximum values found in the literature for each energy coefficients. Uncertainty is expressed by 95% confidence interval of average fossil energy use in megajoule per litre of milk produced ($MJ.l^{-1}$). Estimation of sensitivity of energy coefficients is based on similar drawn and has been studied through the calculation of the Standardised Regression Coefficient (SRC).

Estimated probability distribution is reported in Fig. 1. Minimum and maximum values for 95% confidence interval are respectively 3.6 and $5.0MJ.l^{-1}$ for PC and 5.8 to $8.2MJ.l^{-1}$ for Run. The corresponding variabilities from mean were ±16% and ±17% respectively for PC and RI. Whereas they could appear low, these values question comparison of systems from different territories. Among the set of coefficients chosen, difference between the territories could appear large or conversely equal when considering higher values for PC and lower values for RI. This results highlights need for a common methodology for calculation of energy coefficients. This could enable to calculate energy coefficients adapted to local conditions and to produce accurate values of energy use of agricultural systems. Such method should concern clear definition of system boundaries in indirect energy assessment and promote precise investigation of the technology used in the different processes.

SRCs obtained for the different energy coefficients (Table 1) showed that the most sensitive energy coefficients are not the same in the two territories. Energy coefficient for concentrate feeds is mainly responsible of this uncertainty for RI farms whereas it is a combination of several energy coefficients for PC farms (electricity, concentrate feeds, animal buildings, fuel, N fertiliser). Calculation of adapted energy coefficients could be associated to a preliminary sensitivity analysis through minimum and maximum values of energy coefficients found in the literature in order to focus on the most influential energy coefficients and to fit an appropriate value for them. This will avoid adapting all energy coefficients which could be time-consumer. Nonetheless, energy coefficients do not represent the only source of uncertainty in energy analysis. Uncertainty related to inputs data could be decrease as done in our study with large surveys of real farms and individual economic follow-up surveys based on representative years. Uncertainty related to the methodology could be decrease, in addition to common methodology for energy coefficients, by common choice of allocation method.

References

Bochu, J.L., 2002. PLANETE: Méthode pour l'analyse énergétique des exploitations agricoles et l'évaluation des émissions de gaz à effet de serre. Colloque national: Quels diagnostics pour quelles actions agroenvironnementales? Toulouse, France.

Saltelli, A. Tarantola, S., Campolongo, F., Ratto, M., 2004. Sensitivity Analysis in Practice. A Guide to Assessing Scientific Models. Probability and Statistics Series, John Wiley & Sons Publishers.

Thévenot A., Vigne M., Vayssières J., 2011. Référentiel pour l'analyse énergétique et l'analyse du pouvoir de réchauffement global des exploitations d'élevage à La Réunion. CIRAD-FRCA, Saint-Pierre, France.

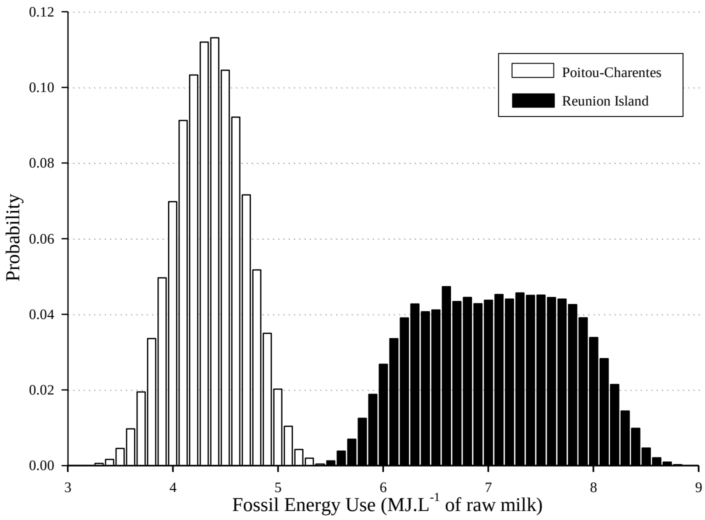

Figure 1. Probability distribution of energy use for dairy farms from (a) Poitou-Charentes and (b) Reunion Island calculated with the 30,000 sets of energy coefficients

Table 1. Standardised Regression Coefficients (SRC) of the five most influential energy coefficients for Poitou-Charentes and Reunion Island dairy farms

Poitou-Charentes		Reunion Island	
Energy coefficients	SRC	Energy coefficients	SRC
Electricity	0.53	Concentrate feeds	0.91
Concentrate feeds	0.51	Tractor	0.25
Animal buildings	0.47	Fuel	0.17
Fuel	0.38	Electricity	0.15
N fertiliser	0.27	Animal buildings	0.14

181. Uncertainty analysis in a comparative LCA between organic and conventional farming of soybean and barley

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There are several methods based on different approaches to quantify and analyse uncertainty (Lloyd and Ries, 2007). One of the main advantages of the uncertainty analysis method used within Ecoinvent database (Frischknecht et al., 2005) is to determine a correlation between data quality and the uncertainty of LCIA results (Cooper and Kahn, 2012).

The objective of this research is to test the effectiveness of the uncertainty analysis methodology developed by Scipioni et al. (2009) in the case of a comparative Life Cycle Assessment. The uncertainties on the LCA input come from a qualitative assessment by data quality indicators based on the pedigree matrix. The research considered two different cultivation techniques: organic (system A) and conventional (system B) farming of a 3-year crop cycle for the production of soybean in the first and third year and barley in the second year of the triennial crop. The LCA study was conducted in accordance with the ISO 14040 standards (ISO 2006a,b), using the ReCiPe 2008 methodology for the LCIA step (Goedkoop et al., 2008). The functional unit was 1 kg of seeds, composed respectively by 2/3 kg of soybean from first and third years of the 3-year cycle and 1/3 kg of barley from second production year. The results of the comparison between the two farming systems at damage category level (Fig. 1.)

Concerning the damage category resources, conventional farming presents higher impacts than organic, because of the resources (oil and gas) used in the production of triple superphosphate and urea fertilisers. On the other hand the damage to ecosystems is higher for organic farming, because of the lower crop yields. Within human health end-point category results, it is controversial to determine which is the best option, because of the minor differences among the two farming systems. The first step of the uncertainty analysis allowed the selection of the main parameters contributing to the uncertainty for both the systems under study, through a contribution analysis at the damage assessment level, with 1% cut-off and the assignment of a probability distribution. The most influencing input data for the human health category are shown in Table 1. The second step included the quantitative uncertainty analysis through Monte Carlo simulation (10^3 iterations), considering the number of comparison runs in which organic farming (A) is larger than conventional farming (B) (Fig. 2).

The methods developed by Scipioni et al. (2009) showed its effectiveness when applied to comparative LCA. The results confirmed that for human health there are no significant differences among the two farming systems. Finally, the application of the two step methodology for the quantification of uncertainty connected with the results allowed to define to which extent the LCIA results at damage level are reliable.

References

Cooper, J.S., Kahn E., 2012. Commentary on issues in data quality analysis in life cycle assessment. Int J Life Cycle Assess doi10.1007/s11367-011-0371-x.

Frischknecht, R., Jungbluth, N., Althaus, H.J., Doka, G., Dones, R., Heck, T., Hellweg, S., Hischer, R., Nemecek, T., Rebitzer, G., Spielmann, M., 2005. The ecoinvent database: overview and methodological framework. Int J Life Cycle Assess 10 (1), 3–9.

Goedkoop, M., Heijungs, R., Huijbregts M, De Schryver, A., Struje, J., van Zelm, R., 2009. ReCiPe 2008. A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and then endpoint level. First edition, Report I: Characterisation.

ISO, 2006a. Environmental management. Life cycle assessment. Principle and Framework. ISO 14040:2006. International Organization for Standardisation, Geneva, CH.

ISO, 2006b. Environmental management. Life cycle assessment. Requirements and Guidelines. ISO 14044:2006. International Organization for Standardisation (ISO), Geneva, CH.

Lloyd, S.M., Ries, R., 2007. Characterizing, Propagating, and Analyzing Uncertainty in Life-Cycle Assessment. A Survey of Quantitative Approaches. J of Ind Ecol 11(1), 161-179.

Scipioni, A., Mazzi, A., Niero, M., Boatto, T., 2009. LCA to choose among alternative design solutions: The case study of a new Italian incineration line. Waste Manege 29, 2462–2474.

Table 1. Contribution analysis for the damage category Human health.

Inventory data	Organic (A)	Conventional (B)
Emission from soil management (N_2O, NO_x) - soybean	63.2%	43.9%
Emission from soil management (N_2O, NO_x) - barley	21.5%	22.0%
Diesel consumption	8.8%	6.3%
Organic compost	2.9%	-
Triple superphosphate	-	20.0%
Soybean seed	1.7	2.4%
Urea	-	3.3%
Other processes	2.0%	1.5%

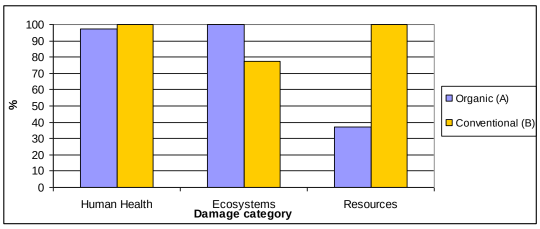

Figure 1. LCIA results from the comparative LCA between organic and conventional farming of soybean and barley

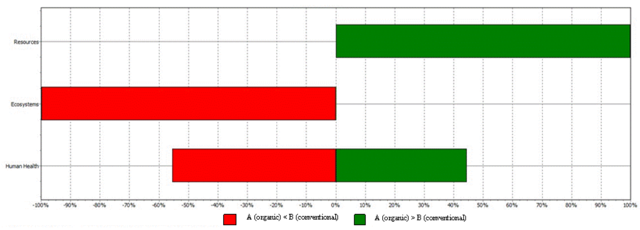

Figure 2. Monte Carlo results of the comparison between organic (left) and conventional (right) farming of soybean and barley

182. Analysis and propagation of uncertainty in agricultural LCA

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The confidence in LCA results depends primarily on the quality of source data and their pertinence for the system studied. However, the need for large amounts of data leads to much uncertainty in impact estimates due to the data themselves: measurement, use in calculations, and final transformation into impact estimates. The main sources of uncertainty in the data chain include not only statistical uncertainty (mean and standard deviation) of the data, but also methodological choices in LCA, such as hypotheses made to represent the system of interest, data representativeness, impact assessment methods, and allocation of impacts between co-products. Therefore, consideration of uncertainty in LCA would provide more scientific information for decision making. This topic is the focus of doctoral research recently begun at INRA that aims to (1) identify sources of uncertainty in agricultural-production systems, (2) analyse their propagation, and (3) estimate their relative contributions to the overall uncertainty in calculated impacts.

Although some texts describe uncertainty generally as a lack of knowledge, its definition may change depending on the LCA steps in which it occurs (Huijbregts, 1998). Therefore, uncertainty is often classified according to its nature and source (e.g., "natural" (i.e., variability) vs. "epistemic"; Van Asselt and Rotmans, 2002). Epistemic uncertainty has been subdivided into three sources: scenario, model and parameter (Fig. 1). This first step allows uncertainties from each source to be evaluated by corresponding approaches.

Monte-Carlo analysis is used most frequently to evaluate uncertainty in LCA (Basset-Mens, 2009). With it one can estimate the influence of uncertainties in input variables (using their probability distributions) on predicted potential impacts. However, this approach suffers some methodological bias due to correlations between variables and poorly-known response rules. For example, the selection of appropriate distributions is usually based on literature, expert judgment, or empirical studies in other systems, which may increase the complexity of model and parameter uncertainty. Moreover, Monte-Carlo simulation is commonly used for assessing the influence of uncertainty in emission factors in LCIA, but it may not be appropriate for uncertainty in other steps, such as the definition of scope or functional unit or the interpretation of results that consist of both subjective and objective uncertainty (Fig. 2). Although it is not necessary or possible to consider all uncertainties in LCA, subjective uncertainty should not be overlooked. More complex approaches (e.g., fuzzy logic) exist, but their use remains marginal. Currently, the methods used to describe uncertainty propagation in LCA have not tried to differentiate the various types of uncertainty but rather to aggregate them. Thus, more research is necessary to overcome barriers to analysing uncertainty in LCA.

Thesis work will begin by identifying and classifying uncertainty in each LCA step, especially uncertainties frequently encountered when assessing agricultural systems. With case studies, the research will identify the most important uncertainties, develop methods to categorise them, and work to estimate the contribution of each source of uncertainty to the overall uncertainty in output. By considering uncertainty in agricultural LCA, more complete information about environmental impacts can be given to decision-makers, who should consider uncertainty as an important part of decision analysis.

References

Basset-Mens, C., Kelliher, F.M., Ledgard, S., Cox, N., 2009. Uncertainty of global warming potential for milk production on a New Zealand farm and implications for decision making. Int. J.LCA 14, 630-638.

IPCS, 2008. Uncertainty and Data Quality in Exposure Assessment. Geneva, World Health Organization, International Programme on Chemical Safety (Harmonization Project Document No. 6).

Huijbregts, M.A.J., 1998. Application of uncertainty and variability in LCA. Part I: a general framework for the analysis of uncertainty and variability in life cycle assessment. Int. J. LCA 3, 273-280.

Van Asselt, M.B.A., Rotmans, J., 2002. Uncertainty in integrated assessment modelling. Int. J. LCA 54, 75-105.

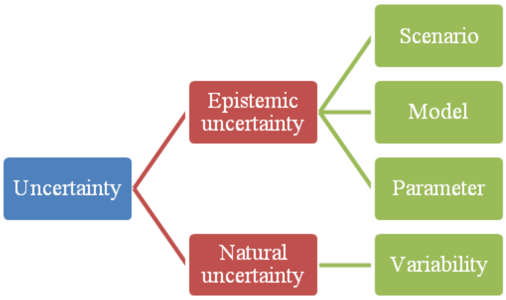

Figure 1. Classification of uncertainty types (Van Asselt and Rotmans, 2002; IPCS, 2008).

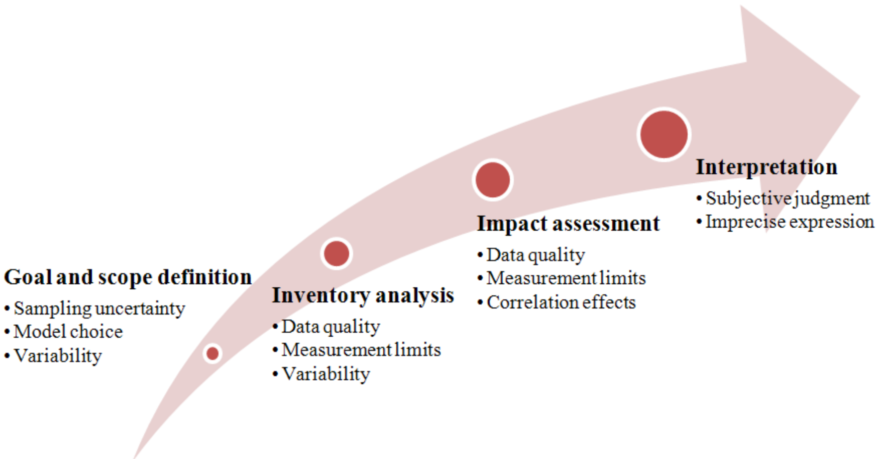

Figure 2. Uncertainties in different steps of LCA.

183. Quantifying the impact of in-data variability and uncertainty on the life cycle assessment of dairy products

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Calculating the Carbon Footprint (CF) of consumer goods is of increasing importance. Many “cradle-to-retail” CFs are dominated by the climate impact resulting from the production of raw materials especially animal based raw materials. In many cases processing, transportation and production processes are playing minor roles. Within this context, the ratio of animal raw materials to the overall recipe weight is of particular relevance. Given the current degree of standardisation in CF calculations and the accuracy of existing Product Category Rules (PCR), differences, variability and uncertainty of CFs is highly contingent on assertions, methodological choices, different assumptions, geographical and temporal scopes, data selection and data aggregation. For instance, as Henriksson et al. (2011) have shown, the CF of milk varied between -17% and +17% from the mean due to management differences between Swedish dairy farms. The present study contributes to the quantification and analysis of the uncertainty in CFs. The study’s findings concerning the causes, magnitude and sources of variability and uncertainty in CFs can provide the basis for the definition of PCRs and contribute to the overall understanding of CFs.

This study examines the influence of different assumptions pertaining to the dairy sector on the results of a CF for 1kg energy-corrected milk (ECM). This study concentrates on in-data variability and uncertainty concerning the pre-farm-gate phase. Besides focusing on in-data variability a parameter relating to methodological choices is included by analysing the influence of economic allocation. (For parameters see Table 1.) To quantify the uncertainty in the CF and to identify a realistic range of results, empirical boundary values are identified and assigned to each parameter. The subsequent multi-scenario-analysis examines the impact of these parameters on the uncertainty in the CF.

While keeping the output data like GHG emissions per kWh electricity etc. on a constant level the CF for 1 kg ECM is 1.11kg CO_2e without allocation. From all 6 examined parameters, the assumed average milk yield has the greatest influence on the end-result CF. While using an empirically supported upper and lower threshold for the milk yield, the CF of the 1 kg ECM varies between -17% and +15% (Table 1).

The findings from this study can contribute to the definition of PCRs in the dairy sector. Relatedly, the study emphasises that PCRs should be evaluated with regard to their potential for reducing the volatility of CFs. The study identifies the crucial influencing parameters for this purpose. Particular emphasis is given to determining the impact of the assumptions concerning the average milk yield on the CF.

References

Belitz, Hans-Dieter, Hrsg. (2010) Calculations of emissions from German agriculture 2010/2008. Braunschweig: vTI, Johann-Heinrich-von-Thünen-Institut.

Ciroth, A., Fleischer, G., Steinbach, J. (2004). Uncertainty calculation in life cycle assessments. Int J LCA, 9(4).

Dorfner, Gerhard, und Guido Hofmann. (2011). Milchreport Bayern 2010 Ergebnisse der Betriebszweigabrechnung Milchproduktion 2009/10. Bayerische Landesanstalt für Landwirtschaft.

Flachowsky, G., Brade, W. (2007). Potenziale zur Reduzierung der Methan-Emissionen bei Wiederkäuern. Züchtungskunde, 79(6), 417–465.

Hirschfeld, Jesko, Weiß, J., Preidl, M., Korbun, T. (2008). Klimawirkungen der Landwirtschaft in Deutschland. Berlin: IÖW.

Huijbregts, M. A. J., Gilijamse, W., Ragas, A. M. J., & Reijnders, L. (2003). Evaluating Uncertainty in Environmental Life-Cycle Assessment. Environmental Science & Technology, 37(11), 2600-2608.

Henriksson, M., A. Flysjö, C. Cederberg, und C. Swensson. (2011). Variation in carbon footprint of milk due to management differences between Swedish dairy farms. animal 5, 1474-1484.

Statistisches Bundesamt (2009), Milcherzeugung und –verwendung, Fachserie 3 Reihe 4.2.2.

Table 1. Parameters, boundary values, and change in carbon footprint (CF).

Parameter	Boundary values			Change of CF in%	
Milk yield (kg ECM/cow and year)	6072	6977	8446	15%	-17%
Feed DMI (kg DMI(cow and year)	5653	6242	6830	-6%	6%
Share of concentrated feed in DMI (% per kg DMI)	0,18	0,32	0,46	-2%	2%
Lifespan (years)	3,10	3,60	4,10	3%	-2%
Quantities of enteric fermentation (kg CH4 per kg DMI)	0,02	0,02	0,03	-7%	3%
Allocation% to milk (based on economic values)	100%		85%	0%	-12%