lcafood 2010
VII international conference on life cycle assessment in the agri-food sector

bari, italy • september 22 • 24 2010

editors

Bruno Notarnicola
Ettore Settanni
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Cleaner Production

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Graphic design: Pagina soc. coop. - Bari, Italy

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September 2010
Printed by Serigrafia Artistica Pugliese Solazzo s.r.l.
- Cassano delle Murge (Ba), Italy

ISBN 978-88-88793-29-0

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Preface

The "International Conference on Life Cycle Assessment in the Agri-Food Sector" that has taken place from September 22nd to September 24th, 2010 in Bari (Italy) – *LCA Food 2010*, in short – is the seventh in a series of events that include Brussels (1996, 1998), Göteborg (2001, 2007), Horsens (2003), and Zurich (2008). All the previous editions have been successful in terms of both participation and scientific quality of the presented papers, thus really contributing to build a reputation as a reference event for the Food LCA scientific community.

The topics the Conference deals with are of great interest, since the contribution of the products in the food and drink sectors to the environmental impact of the private consumption has been estimated to be about 20 to 30% in the EU. Recently, the European Parliament in the Regulation (EC) No 66 on the EU Ecolabel has extended the possibility of using the EU Ecolabel in all sectors for which environmental impact is a factor in consumer choice, by stating also that for food and feed product groups, a study should be undertaken to ensure that criteria are feasible and that added value can be guaranteed. To complete this framework, a call for tender titled "EU Ecolabel for food and feed products – feasibility study" (ENV.C.1/ETU/2010/0025), has been published recently. At the same time, in the Strategic Research Agenda 2006-2020 the European Technology Platforms Food for Life have defined sustainable food production as the most important challenge that will be faced by the European food industry. An outcome of this process is the recently published FP7 Call for 2011 under the theme Knowledge-Based Bio-Economy (KBBE / Food, Agriculture and Fisheries, and Biotechnology), especially KBBE.2011.2.5-01 Environmental sustainability in the European food and drink chain.

In order to find the possible directions to sustainable food production and consumption, LCA has been applied for more than 15 years to agricultural and food systems, identifying their environmental impacts throughout their life cycle and supporting environmental decision making. A variety of databases and methodological approaches have been outlined over this period to support the applications of LCA to food systems.

The objectives of the conference have been:

– to show the recent developments in the methodology, approaches, databases and tools;
– to present applications of the LCA methodology to food product systems and to food consumption patterns;
– to increase the use of LCA and other industrial ecology tools in agricultural and industrial food products;
– to support information sharing and exchange of experience regarding environmental conscious decision making in the agri-food chain.

In organising this edition, the aim has been to keep the usual high scientific quality of the Conference, while providing an occasion to involve the relevant stakeholders, including some key players from the Agriculture, Industry, and Distribution sectors, the Institutional bodies and the Households. Ultimately, this edition has addressed all the key issues for future LCA research that have been outlined during the previous edition (Zurich, 2008).

The structure of this book of Proceedings reflects the structure of the event: Volume 1 includes all the papers presented orally, which have been organized according to the Session, either plenary or parallel, in which they have been discussed. Also, the same Volume includes the contributions from the distinguished keynote speakers coming from the Institutions and from the Academic field, which have been presented during the opening of the event.

Volume 2 of this book of Proceedings, instead, includes those papers that correspond to the posters that have been displayed throughout the duration of the Conference. Also Volume 2 has been structured according to the topics discussed, since each poster presentation has been assigned to a specific Session, as well.

About 300 participants coming from the four Continents have joined the event, and slightly more than 200 works have been presented at the Conference. Besides 6 keynote lectures, they include 86 platform and 114 poster presentations that have been peer-reviewed by the 21 members of the Scientific Committee, who are widely-recognized scientists in the field of Food LCA. In addition, a selection of 15 papers among the platform presentations will be further reviewed and published on a special forthcoming issue of the *Journal of Cleaner Production*. A special thank goes to Don Huising, editor of the journal.

The positive feedback received so far has motivated me and my colleagues and friends to work at the best of our capabilities. For this reason I would like to express special thanks to those who have made the LCA Food 2010 possible: the Rector of University of Bari Aldo Moro Professor Corrado Petrocelli, the institutions who kindly gave their patronage to the conference, the companies and institutions who have sponsored the event, the members of the Scientific Committee, who have assured the scientific quality of the works presented at the conference, the Organising Committee and the Local Organizing Secretary headed by Mario Colonna. And, most importantly, I would like to thank all the participants who have shared with us this amazing scientific and social experience, putting together the scientific community and the representatives of businesses and institutions.

A special thank goes to Ettore Settanni for his precious collaboration during the life cycle of the conference.

Much work is still to be done in this field, but an increasing emphasis on the topics of Food LCA is leading to the next edition that will take place in Rennes, France in 2012.

Bruno Notarnicola
Conference organizer
II Faculty of Economics, Taranto
University of Bari Aldo Moro, Italy

PLENARY SESSION 1

Keynotes

Sustainability, food and the future

Thomas Ohlsson [1,*]

[1]SIK - The Swedish Food Institute, Gothenburg, Sweden (Retired)

ABSTRACT

The ability of future generations to meet their needs is inherent in the definition of Sustainability from 1987. One of the most essential needs of future generations is the secure availability of safe, affordable, healthy and tasty foods. However studies show that most food chains are not sustainable. A range of LCA studies have demonstrated the lack of environmental sustainability. Limitation in the socio-economic dimension of sustainability is demonstrated by e.g. lack of fairness and justice in the food chain. Sustainability does have a global dimension but improvements must be made on the local scale, by each country, organization, company and individual. A number of scenario studies have been presented on the sustainability problems facing food production in the coming decades taking into account implications of climate change, demography and economic development. The implications of these alternative futures will be summarised.

Keywords: Sustainability, food chain, environment, socio-economic

1. The growth of sustainability

Sustainablity became an important concept for the future after the publication of the report "Our common future" from the Brundtland commission, (WCED, 1987). The often cited definition reads:"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs". The report was also important in defining the need to evaluate any proposed initiative with reference to three fundamental criteria: Environmental, Economic and Social (sometimes referred to as Equity/Equality, and thus the Three Es). The WCED had its roots in the 1972 Stockholm UN (United Nations) conference on the Human Environment, which was the first major international activity in the field of environment. The Stockholm meeting resulted among other things in that many national environmental protection agencies were formed as well as the UNEP, the Environmental Development agency of UN.

At the Earth Summit in Rio in 1992 the necessity to not think of the three elements of sustainability as isolated was further stressed. The famous Agenda 21 activities were developed from the 27 principles for sustainability agreed on at the Rio Earth Summit. At the Johannesburg World Summit on Sustainable Development in 2002 plans for implementation and a declaration for sustainable development were important outcomes, focusing on poverty eradication, health concerns and sustainable production and consumption issues.

From the environmental perspective of food production the publication of Rachel Carson's Silent Spring (1962) set of an alarm that the food production system used in USA (and Western Europe) did have a devastating impact on spreading toxins coming from agriculture pesticides. The consequences on animals and possibly humans set off a revaluation of the limits to the ecosystem. The coming scarcity of water for food production and the related conflicts regarding water availability in many parts of the world was also discussed in many books by Georg Borgström, (1964).

* Corresponding Author. e-mail: th.ohlsson@hotmail.com

An important contribution towards improving the understanding of the global ecological situation was made by the Club of Rome, a NGO involving about 100 concerned scientists, politicians and businessmen. The key purpose was to perform technological forecasts taking into account the interconnectivity of ecology, economics, demography and the resource sector. Their report entitled "The limits to growth" had a shocking effect on the society and was perceived as a doomsday prediction, although it presented a number of alternative future possible events, rather than the future itself. It made the informed public aware that the exponential economical growth has limits, set by the ecological capacity of the earth. During the 70ties and 80ties many other books discussing the present and emerging problems for food production were presented. Among the most influential was and indeed is the annual "State of the world" published by the Worldwatch Institute.

These reports and books did raise the awareness, both among politicians and the general public, about the limits to growth including for the growth of food production. But as pointed out by the authors to the report of the Club of Rome 20 years after the publication of the original report, the limits of sustainability were already surpassed. Of course, the UN lead conferences mentioned above were important actions in the line of supporting sustainable development, but in all essential part the development continued and still continue along the "business as usual" path.

2. Sustainability problem in the food chain

The environmental impact of food production started to be in issue in the 80ties, when the ecological consequences of the effluents and sewage from the food production became more evident. The most evident problem was and still is the nitrogen (and to some part the phosphorous) leakage from the use of fertilisers in the agriculture leading to eutrophication. The food production system (mainly agriculture) is responsible for between 60 and 75 % of the eutrophication in many industrialised countries. Eutrophication fertilises water bodies resulting in unnaturally high rates of plant production and accumulation of organic matter that degrade water and habitat quality with risks of total depletion of the oxygen at the bottom of the water body. Large areas in e.g. the Baltic Sea and the Mexican Gulf are subjected to this problem.

Another environmental problem for the food production is related to the presence of toxic compounds, such as heavy metals (e g Cd, Hg) in grains and dioxins in fish. Many of these compounds show very persistent toxicity with low rates of disappearing even after the actual source of contamination is eliminated.

Today the most known problem regarding environmental sustainability in the food production is the impact on climate change through the energy use. Modern food production has an extensive dependence on fossil fuels for e g fertiliser manufacturing and vehicle fuel. It has been estimated that food production in the industrialised countries uses around 20% of all energy used in society. The contribution to global warming is higher however, estimated to close to 30%. The major reason for this is the contribution of methane and nitrogen compounds from meat production to global warming. It can also be noted that about 25 % of the highway transportation is connected with food.

The food sector is using about 70% of the available fresh water in the world, corresponding to about 3 tons of water per capita per day. There are many problems with the present use of water in the food sector with poor water management and with deteriorating water quality. Furthermore in many parts of the world, the availability of water is becoming more on more of a problem with sinking water tables and influx of salt into the fresh water.

From a biological point of view the accelerating losses of biodiversity is a major problem caused by the methods used in food production and indeed many other activities in society. These losses of biodiversity will jeopardise food availability and security by reducing the "safety-net" provided by the availability of alternative plants for future food production and other factors affecting human well-being.

The social dimension of sustainability are concerned with the effects of the activities in the food production on the people directly involved and affected by the food production but also its effect on the society as a whole. Fairness in working conditions for the people involved in the whole food chain must be ensured, with the UN declaration of human rights as a minimum requirement. The role of the different actors in the food chain in the society, where they are active, is another social factor of importance. The corporate social responsibility is of importance for fulfilling a good level of social sustainability. In addition the social sustainability is often also addressing the effect and contribution to the health and wellbeing of the consumers of the foods produced.

In the economic sector sustainability is most often interpreted as the ability of a commercial activity to produce a good level of return of investment (ROI) to the owners consistently over time. This assessment of economic sustainability involves looking not only at ROI but also on plans for management of risks and market crisis. Furthermore economic sustainability involves efficient use of the resources employed in the production, or in short a well run company. Factors such as prevention of bribery and corruption are assessed for external partners. A socio-economic point of view is the ensuring of fair distribution of revenues to the many actors involved in the food chain, giving each actor a possibility for a sustainable livelihood.

3. Sustainability and the food industry

After the Stockholm conference many countries established "Environmental Protection Agencies" (EPA), which often had cleaning the effluents from industries (and municipalities) as their major plan of action. Thus the first impact on the food industry of the increased concern for the environment was the requirements from the EPAs to reduce the biological material in (BOD) the waste water from the industries. Thus the food industry started to invest in sewage treatment operations, cleaning up the effluents emanating from the production.

Another important environmental measure which affected the food industry considerably was the new legislation on packaging waste imposed in many countries in Europe and in Japan during the 90ties. The costs involved in these packaging waste systems (e g Die Grüne Punkte) drove a development to lower packaging weights and thus packing volumes without reducing the performance of the packaging.

In response to the growing interest and awareness in environmental and sustainability issues in the late 90ties, such as the many activities driven under the name of "Agenda 21", a number of initiatives were taken by the industry and their organisations for promoting sustainability. The UN Global Compact was started with partners from industry, governments, unions and NGOs, committed to aligning their operations and strategies with ten universally accepted principles in the areas of human rights, labour, environment and anti-corruption. The industry started the "World Business Council for Sustainable Development" after the Rio congress in 1992, with the aim to provide business leadership for change toward sustainable development. Gradually also the food industries identified the issues related to sustainability as important, realising the advantages of reducing the use of input resources such as energy, water, ingredients, possibly with the experiences from the reductions in packaging use as a guide. Many food industries and retailers today present sustainability reports demonstrating the efforts to reduce the use of energy, water and production of waste. These sustainability reports also demonstrate the company's contribution to social and economic sustainability. This might encompass sourcing the agricultural raw materials from sustainable agriculture in developing countries or supporting sustainability related labelling schemes such as "Rainforest Alliance" or "Fair-trade".

The food and the retail industry do also market many "organic" or "biodynamic" food products as part of their sustainability profile, using a myriad of labels. However the market segment often only captures a few % of the total market, so the impact on the global sustainability is rather limited.

Research on Life Cycle Assessment (LCA) of food production within the national and international research programs in the last decennials has given an important contribution to understanding the environmental sustainability of a range of food production chains, particularly in Europe. The LCA method is today highly regarding as a method for objective assessment of environmental impact of food products. Thus it is often used a foundation for developing modern labelling systems such as "carbon footprints". A number of initiatives have also been taken to combine some of the factors of social and economic sustainability with LCA in order to develop a method for assessing sustainability.

Finally it should be mentioned that sustainability has been and still is an important "buzz word" in many food research programs, nationally and internationally. At times the connection in these programs to the issues in sustainability as presented here have been small. However more recently, major research programs such as the 7th EU frame work research program has a more profound approach to sustainability. It is also an essential part of the industry driven "Food for Life" European Technology Platform research program, (ETP-Food for Life, 2007).

4. Sustainability and the future food production

In the future the sustainability of food production will be severely challenged. Scenarios of the environmental future of the world, in e. g. "UN Millennium Ecosystem Outlook2 and "UNEP Global Environmental Outlook" predict that the degradation of ecosystem services could grow significantly worse during the first half of this century. Pressures will also increase on coastal ecosystems in most parts of the world. Particularly in the tropical part of the world there is increasing risk of land degradation. Growing populations and increased food production will lead to increased demand for freshwater. The water withdrawals are expected to increase in all sectors, leading to an expansion of areas with severe water stress. The absence of effective policies to reduce emissions of carbon dioxide and other greenhouse gases is predicted to lead to significant increases in global warming over the next 30 years, (UN MEA, 2005 and UNEP GEO-4, 2002, IPCC, 2007).

It is obvious that the dramatic climate changes predicted by the UN International Panel for Climate Change (IPCC, 2007) will greatly challenge the food production. In the tropical and subtropical parts of the world temperatures will be higher and the already dry areas will be dryer, which will make food production more limited. On the other hand food production in the more temperate areas of the world might benefit from a warmer and wetter climate. In addition more extreme weather systems will be more frequent and the rising level of the sea will make food production more hazardous in many low laying areas.

Interestingly scenarios for the future of food production in Europe, a part of the world not so severely affected by the climate change, predict that the changed conditions for food production in the coming 30- 40 years will also have impact on many other societal factors related but not part of food production. Climate change will induce migration from the dry and hot parts of Europe toward the more temperate parts as quality of life deteriorates there. This will also lead to strong competition for land use and most probably more inequality. In most of the scenarios local and regional markets dominate over the global. The scenarios predict a stronger legislation to support measures to improve sustainability with more concerned and active consumers and societies as drivers, (SCAR-Foresight, 2007 and ESF/COST Forward Look, 2008)

It is evident that food production is facing many major challenges in the future to meet sustainability demands. In 2050 it is predicted that there will be almost 9 billion people on the earth. The supply of adequate and good food to almost 50% more that we are today will require enormous efforts on improving the efficiency of the food production and supply system. And this must be done by using less energy than today; a figure of a 50% reduction is often cited.

On the social dimension of sustainability the "Millennium Goal" of reducing by 50% the number of really poor people in the world (those living on less than 1USD per day) has not progressed in the last year, due to the food price crisis and the present economic crisis. These "Millennium Goals" will continue to form an important part of the future demands on a sustainable future as part of the human solidarity, formulated within the "Universal Declaration of Human Responsibilities", where article 9 reads: "All people have a responsibility to make serious efforts to overcome poverty, malnutrition, ignorance, and inequality. They should promote sustainable development all over the world..." (Inter Action Council, 1997)

On the economic dimension of sustainability it is noteworthy that a number of economists are questioning the possibility to reach a more sustainable future if the present economic system based on the need for constant growth continues, (Jackson, 2009). As almost all human activities mean extraction of natural resources as well as dispersing of the residues back to nature it is obvious that there is a limit to how far the growth of these activities can continue. A number of alternative economic systems have been presented and the debate is very active among environmental economists, but the political interest is surprisingly low.

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Sustainability of supply chains: meeting consumer expectations

Roland Clift[1,*]

[1]Centre for Environmental Strategy
University of Surrey, Guildford, Surrey GU2 7XH, UK

ABSTRACT
To assess and report the sustainability of the supply chain of a consumer product requires evaluation not just of environmental impacts, including carbon and water footprints, but also the extent to which the supply chain provides an equitable distribution of benefits to the different actors in the chain. This requires a new approach: rather than the "hard system" approach of LCA, a "soft system" approach is needed which exposes the governance relationships controlling the supply chain. Such an approach is introduced here and applied to three food products – tea, grapes and water cress – to illustrate how it can be developed and what it can reveal. This kind of approach is proposed as a route to reporting performance in ways which will be useful to both retailers and consumers.

Keywords: Sustainability, Equity, Supply chains, System analysis, Fair trade.

1. Introduction

Amongst the multitude of definitions and articulations of "sustainability"; one of the most succinct is due to Tim Jackson (2010):

"Sustainability is the art of living well, within the ecological limits of a finite planet."

Here, *living well* is to be interpreted in a moral sense, not merely equated with material consumption or physical comfort; introducing the concept of *equity within constraints* which is central to the discourse on sustainability. Sustainabilty is often expressed in terms of three dimensions or "pillars": techno-economic efficiency, environmental impact and social benefit (see e.g. Mitchell *et al.*, 2004). These dimensions are already present in consumer expectations through price, quantified environmental impacts and the activities of movements such as "Fair Trade". Ways to report environmental impacts in transparent form are already being developed, using conventional LCA. "Carbon labelling" of consumer products is an obvious example. Water use appears set to become the next issue of concern for food products, probably followed by land use linked to impact on biodiversity. While these labels are supposedly intended to provide information to guide consumer purchasing, they are in reality "policed" and used by retail organisations who are the actors driving the development of environmental labels (e.g. Clift *et al.*, 2005 & 2009).

2. Supply chain equity

The price and "footprints" of a consumer product indicate the overall economic and environmental efficiency of the supply chain but not how equitable it is; assessing the sustainability of a product requires more disaggregated information, distinguishing between the different stages in the supply chain. Particularly for social equity, this will require a new

* Corresponding Author. e-mail: r.clift@surrey.ac.uk

approach to assessment, investigating how much benefit the activity brings to the different actors along the supply chain.

One approach to assessing supply chain equity compares the economic added value and environmental impact associated with each stage in the supply chain (see Clift & Wright, 2000; Clift, 2003), using added value as a measure of the economic benefit to the country or sector within which each stage is located. For the majority of products investigated to date, the early stages in the supply chain are typically associated with disproportionately high environmental damage and/or low added value. In other words, primary producers typically receive disproportionately low economic benefit compared to the environmental impacts of their activities, while other actors further along the supply chain – notably retailers – receive much larger economic returns and can claim better economic performance.

This analysis has a number of important implications. It underlies the international concern for the phenomenon of "carbon leakage"; i.e. the migration of highly polluting industries to developing countries, usually without adequate economic benefits (see e.g. Clift *et al.*, 2010), and explains why the carbon footprint of consumption in a country can be very different from the domestic emissions of greenhouse gases (GHGs) (see e.g. Peters & Hertwich, 2006). By undervaluing primary resources, this value chain structure represents an economic disincentive to re-use and recycling (Jackson & Clift, 1998). It also suggests that developing economies should concentrate on industries with high value and low impact (Clift & Wright, 2000), a point which is picked up later in this paper.

By contrast with the economic and environmental impacts of product supply chains, there is as yet no general consensus on methodology or approach to assessing social impacts beyond the principle that consultation with all relevant stakeholders is essential (see e.g. Blowfield, 2003; Leipziger, 2003): "to be valid, [social indicators] need the kind of public acceptance which can only be achieved through well-structured participatory decision processes" (Clift, 2003). However, there is no consensus on how this is to be realised.

One possible approach is represented by the UNEP/SETAC (2009) initiative on social life cycle assessment of products which aims to be as similar as possible to conventional environmental life cycle impact assessment. Whether this approach will prove fit-for-purpose and achieve general acceptance remains to be seen. It recognises the different, and sometimes conflicting, interests of different stakeholders but omits some obvious stakeholder groups, notably shareholders in companies in the supply chain. It proposes a check-list of social impacts but does little to recognise that the significance of each depends strongly on local context. To take an obvious example, the UNEP check-list includes child labour, without recognising that child labour can be desirable if the alternative is not education but destitution, prostitution or forced military service.

A somewhat different approach has been proposed by Sim (2006), working with the UK-based retailer Marks & Spencer (M&S). Socio-economic issues were prioritised by reviewing the websites and literature of a range of stakeholders: company employees, suppliers and customers; government departments; Non-Governmental Organisations (NGOs) and the media, supplemented by customer focus groups organised regularly by the company. Average annual wages of workers, particularly in the lowest pay band, emerged as a common concern. Wages are preferably expressed relative to national *per capita* GDP, to reflect differences in purchasing power not reflected in currency exchange rates. Unemployment levels are also relevant: where unemployment rates are high, the value of a job is likely to be greater than indicated by wage level alone. Issues which empower people to effectively govern their own lives are also important, particularly health and education, especially where these are enhanced by participation in the supply chain rather than being prerequisites to working in the supply chain.

A further difference between Sim's approach and the UNEP/SETAC guidelines lies in the approach to assessing the life cycle, with the aim of understanding the governance of the supply chain; i.e. the relationships between the different agents. LCA is a form of "hard system" analysis: relationships are analysed quantitatively in terms of exchanges of materials and energy. LCA was originally developed for industrial manufacturing and processing operations, where the performance of a process or operation is determined more strongly by the technology deployed than by the management regime. Amongst the problems in adapting LCA to agricultural production is the wide variability between the performance of different producers or farms, even in the same geographical region; i.e. management has a very strong effect on performance. The relationships between agents in the supply chain therefore needs to be examined by a form of "soft system" analysis, recognising the ways in which they affect, influence or control each other's management regime. Sim (2006) proposed that such an approach can be developed by adapting a form of analysis from the literature on international development, used extensively by the Institute for Development Studies at the University of Sussex (e.g. McCormick & Schmitz, 2002; Humphrey, 2003). The approach is, rather confusingly, termed Value Chain Analysis (VCA) although it is different from the economic VCA which is used, for example, in assessing how economic value builds up along the supply chain (see Section 2.1).

Following McCormick and Schmitz (2002), relationships between agents in the supply chain can be classified on the following spectrum of governance patterns:

1. Hierarchical or vertically integrated: usually, the agents are part of a single organisation;
2. Directed: the buyer or, more rarely, the producer dominates the relationship;
3. Balanced: neither buyer nor producer dominates the relationship;
4. Market-based or "arm's length: the buyer purchases inputs through a homogeneous market.

McCormick and Schmitz (2002) have given a list of indicators which enable relationships to be classified on this spectrum; more details are given by Sim (2006). Figure 1 shows a grid which can be used to display relationships classified in this way.

3. Three case studies

Sim (2006) applied this analysis to three specific M&S products: grapes sourced from South Africa; tea from Assam and Kenya used in extra strong tea bags and watercress from the UK, Portugal and the USA. Governance patterns were classified, as suggested by McCormick and Schmitz (2002), using structured interviews at the retail and first-tier supplier stages of the chains. Information on more remote growers and intermediaries (e.g. brokers) was obtained by means of questionnaires. Figure 2 shows the ranges of governance patterns between retailer and suppliers, in the form of Figure 1.

The grape supply chain was found to be strongly buyer-driven - perhaps surprising given that there has been some vertical integration between South African growers and exporters and those operating in other source countries. Wages were low compared to *per capita* GDP in South Africa, even allowing for the fact that agricultural workers in most countries and supply chains receive wages around half the per capita GDP (Sim, 2006). However, unemployment rates are notoriously high and some education and training is provided.

Supply chains for tea displayed a range of governance patterns, as indicated in Figure 2. This product is sourced via one primary supplier from Kenya and Assam. The relationship is generally buyer-driven but with some features of more balanced relationships, most significantly that decisions regarding blend and flavour are strongly influenced by the supplier who is also responsible for monitoring compliance of the product with technical specifications, particularly the quality of the raw material. Smallholders growing tea receive low incomes, especially in Kenya, much as for South African grape growers. The cultivation stage is also associated with a low level of added value, illustrating the kind of economic inequity along the supply chain outlined in section 2.1. However, larger estate growers in Kenya and their workers fare better in this supply chain.

Watercress presents a different picture, with a more balanced relationship between supplier and buyer, primarily because the buyer deals with a single supplier who can produce cress to the quality standards required. This supplier produces watercress at two sites in the UK – Hampshire and Dorset – and one in Portugal. Wage levels range around the national *per capita* GDP, even in Portugal where the product is grown in an area of notoriously high unemployment.

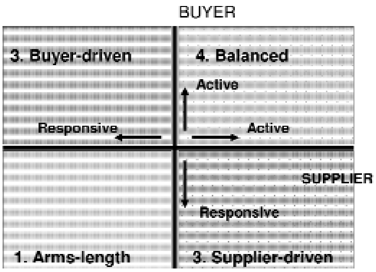

Figure 1: Proposed categorisation of supply chain governance relationships.

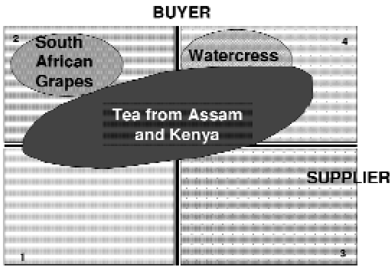

Figure 2: Comparison of supply chain governance for three consumer products.

4. Implications for supply chain sustainability

A natural hypothesis is that the distribution of benefits along a supply chain is a result of the governance structure, with lead organisations realising the largest profits and their workers the highest wages and other benefits. These three case studies are consistent with this hypothesis but also show that average wages at any stage in a supply chain are not well correlated with added value; i.e. the distribution of economic value along the supply chain is not a reliable proxy for the distribution of social benefit (Sim, 2006). This emphasises the importance of governance structure in determining supply chain sustainability. These three supply chains cover the range of governance patterns in food supply chains, predominantly buyer-driven, and there is thus some reason to expect the qualitative findings to have general validity. Understanding supply chain governance patterns can inform the development of management mechanisms to ensure that the needs of all agents in the supply chain are met. Two mechanisms can then be suggested to enhance supply chain equity. Retailers, who are usually lead agent, need a sustainability framework which recognises this responsibility and guides their choice of suppliers. They also need "toolkits" or reference guides which can be used to encourage investments in local communities which enhance people's abilities to engage in the activities making up the supply chain, focussed on actors with the lowest levels of governance who are most at risk of becoming economically marginalised.

Watercress also illustrates a further aspect of the sustainability of food supply chains. Figure 3 shows how added value and environmental impact, represented by contribution to global climate change, build up along the supply chain. In Europe, the impact per added value is distributed unusually equitably, consistent with the balanced governance of these supply chains. However, in winter when the European producers are unable to meet demand, the buyer sources watercress from Florida and transports it by air. the product is not differentiated at point of sale, so that the total added value is the same regardless of source. Figure 3 shows that the environmental impact is dominated by transport, a common feature of produce delivered by air freight (see e.g. Sim *et al.*, 2006), illustrating how providing fresh produce out of season, the practice sometimes called "permanent global summer time" (Lawrence,2004), can have serious environmental consequences.

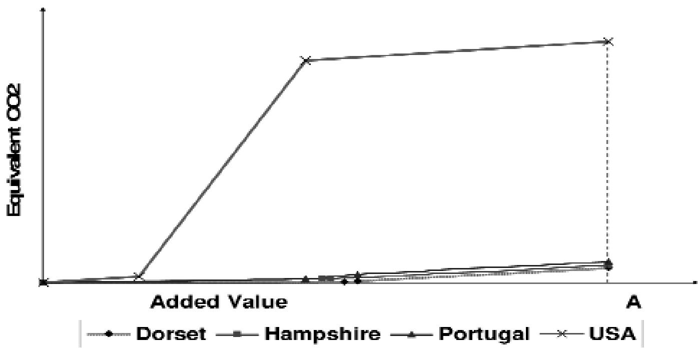

Figure 3: Added economic value and accumulated contribution to climate change along the supply chain for watercress: cultivation; transport; packaging and distribution.

5. Conclusions and implications: future directions in product labelling

Changing patterns of food production are recognised as one of the principal components of more sustainable consumption (e.g. Clift *et al.,* 2010; Girod and de Haan, 2009; Hertwich, 2006; Tukker *et al.,* 2010), involving not only dietary changes away from meat and dairy produce but a shift towards more expensive, high quality or luxury produce. An example of a commodity which has already shown the shift towards luxury purchasing is olive oil: high quality "extra virgin" oil has taken an increasing share of the market. This shift has been accompanied by increasing interest in the source of the product. This trend in consumer interest would extend to processed foods the approach to "field to fork" tracking which the industry is following for fresh produce. The success of the Fair Trade movement has shown that there is a widespread interest in products which can demonstrate supply chain equity as an important characteristic of sustainability. Increasing consumer interest can therefore be anticipated in labelling to show how products from clearly identified sources perform against the equity and social benefit components of sustainability.

Attempts to force social assessment into a format like environmental life cycle impact assessment will continue to be problematic. It has been argued here that some form of "soft system" approach will be needed, based on the relationships which determine the governance of the supply chain and hence highlighting where and how the agent dominating the chain – usually the retailer – recognises its responsibility and has a systematic approach to selection and support of its suppliers. Transparent policing of claims based on such qualitative assessment represents one of the next challenges in LCA.

Acknowledgements*: This paper has developed from discussions and collaboration with many people, especially my doctoral students. I particularly thank Dr. Sarah Sim, who is currently on maternity leave from her post as Environmental Scientist with Unilever Research.*

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Towards the EU framework methodology for the environmental assessment of food and drink products

Camillo De Camillis*, David Pennington, Marc-Andree Wolf

European Commission, Joint Research Centre (JRC)
Institute for Environment and Sustainability,
via Enrico Fermi 2749, T.P. 27, JRC, 21020 Ispra (Va), Italy

ABSTRACT

"Food and drink" products are the basis of life. They are also widely recognized contributors to the environmental impacts associated with European production and consumption. It is therefore essential to quantify and improve the environmental performance of food and drink product life cycles. This must be done in a coherent and quality assured manner. The European Commission's Joint Research Centre (JRC) is directly involved in this commitment in order to support business and policy makers. This is achieved by working together closely with business representatives through projects such the European Platform on Life Cycle Assessment (LCA) and the Food Sustainable Consumption and Production (SCP) Round Table. Key objectives and deliverables of these projects as well as the related processes and stakeholders involved are highlighted in this paper.

Keywords: Food SCP Round Table, European Platform on LCA, ILCD Handbook, ILCD Data Network, ELCD, LCA, LCI

1. Introduction

Life Cycle Thinking (LCT) is essential in the development, implementation, and monitoring of a growing number of policies and business instruments. LCT is a core theme of the European legislation in the Sustainable Consumption and Production/Sustainable Industrial Policy (SCP/SIP) Action Plan (EC, 2008), the Integrated Product Policy (IPP) (EC, 2003), the Thematic Strategy on the Sustainable Use of Natural Resources (EC, 2005), and the Thematic Strategy on the Prevention and Recycling of Waste (EC, 2005).

Food and drinks are essential. Their supply significantly contributes to the consumption of resources and environmental impacts, as well as to our economy. This has recently been reiterated in several studies (Druckman and Jackson 2009; Huppes *et al.*, 2006; Tukker *et al.*, 2006). Quantifying the environmental performance of food and drink product supply chains, communicating this information along the supply chain and to consumers, as well as identifying opportunities for improvement is important in the context of sustainable consumption and production.

The European Commission's Joint Research Centre (JRC) provides in-house support for the conception, development, implementation, and monitoring of European policy. The JRC carries out numerous research projects associated with agriculture, fisheries, transport, as well as other activities associated with food and drink product supply chains. In this paper, we highlight two particular activities supporting life cycle thinking: the European Platform on Life Cycle Assessment (LCA), which provides support for coherence, quality assurance,

* Corresponding Author. e-mail: camillo.de-camillis@jrc.ec.europa.eu

and information availability at a general level as well as the European Food Sustainable Consumption and Production Round Table.

2. The European Platform on Life Cycle Assessment (LCA)

In its Communication on Integrated Product Policy (EC, 2003), the European Commission concluded that LCA provides the best framework for assessing the potential environmental impacts of products currently available. In the Communication, the need for more consistent data and consensus on LCA methodologies was underlined. The European Platform on LCA was, thus, constituted by the Commission to facilitate coherence, quality assurance, and the availability of life cycle information.

The objective of the Platform is to help promote life cycle thinking in business and in policy in the European Union. Amongst others, the Platform has developed or coordinated:

- the International Reference Life Cycle Data System (ILCD);
- the European Reference Life Cycle Database (ELCD);
- the LCA Resources Directory;
- the LCT Forum Mailing List.

Especially the ILCD has been developed in extensive consultation with the EU Member States, Commission services, representatives of non-EU national LCA projects, United Nations Environment Programme (UNEP), advisory group from European-level business associations, an advisory group of LCA software and database developers, and an advisory group of Life Cycle Impact Assessment method developers.

2.1 International Reference Life Cycle Data System (ILCD)

The International Reference Life Cycle Data System (ILCD) is composed of a Handbook and a Data Network.

The ILCD Handbook (EC, 2010a) is a set of technical guidance documents providing goal and scope dependent practice guidance to ISO 14040 and 14044.

- The "General guide for Life Cycle Assessment" consists of both a comprehensive, detailed guide as well as a "cook-book"-style guide for experienced LCA practitioners. It covers all aspects of conducting an LCA: defining the objective and target audience, gathering data on resource consumption and emissions that can be attributed to a specific product, calculating the contribution to impacts on the environment, checking the robustness and significance of results and conclusions, and reporting and reviewing to ensure transparency and quality.
- The "Specific guide for Life Cycle Inventory (LCI) data sets" builds on the general guide. It provides more detail for the generation of specific types of data. For example, it describes how to create LCI data sets that best reflect the average situation regarding emissions and resource consumption.
- The "Life Cycle Impact Assessment (LCIA) guide" provides requirements for assessing the emissions and resource consumption associated with a product in terms of impacts on the environment, human health, and resources depletion. It outlines criteria against which models and indicators for use in LCIA should be evaluated, covering both scientific aspects and stakeholder acceptability.
- The guide on "Review schemes for Life Cycle Assessment" presents the minimum requirements for review for life cycle data or assessments for different applications. The guide on "Reviewer qualification" specifies the requirements on the experiences and expertise of reviewers, the "Review scope, methods and documentation" provides the detailed review guidance.

With the ILCD Handbook providing guidance across all kinds of life cycle studies and direct applications, sector and product-group specific guides are foreseen to further increase reproducibility as well as easing the work-flow, minimising the effort for LCA studies and data development. Such specific guides are typically developed by industry and - if inline with the ILCD Handbook's general provisions - form a recognised part of the ILCD Handbook guides.

The ILCD Data Network will provide a registry of consistent and quality-assured life cycle inventory (LCI) data sets, inline with provisions based on the ILCD Handbook. Globally, businesses, governments, national LCA networks, academia, and consultancies will be able to provide their data via the network to the users, upon their own license conditions. This openness ensures that no dependencies are created from single providers and that market principles can work to provide the most efficient solutions and the broadest possible supply of quality-assured and consistent data. Emphasis is put on the user to ensure the coherence and quality of the data, while the data is maintained and published decentralised by the respective owner.

2.2 European Reference Life Cycle Database (ELCD)

The ELCD database version II (EC, 2010b) provides reference Life Cycle Inventory data. These are data on the emissions and resources used that are associated with the provision of core materials, energy carriers, transport, and waste management. These data are representative of the European market and are regularly needed to conduct Life Cycle Assessments. As far as possible, the data are provided or approved by European business associations. The data sets of the ELCD are accessible free of charge and without access or use restrictions for all LCA practitioners. They are foreseen to also contribute key European data to the upcoming ILCD Data Network.

2.3 LCA Resources Directory

This Directory (EC, 2010b) eases the access to life cycle information, including tools, databases, service providers, and (in preparation) to assessments, Type III Environmental Declarations, Ecolabel criteria, and others.

2.4 LCT Forum Mailing List

This information mailing list and discussion forum (EC, 2010b) facilitates knowledge exchange. It is open to all to ask technical questions on LCA and related applications like Eco-Design, Eco-Labels, Carbon Footprints, as well as to announce LCA conferences and open positions.

3. European Food SCP Round Table

The European Food Sustainable Consumption and Production (SCP) Round Table is an initiative co-chaired by the European Commission and food supply chain partners and supported by the UN Environment Programme (UNEP) and European Environment Agency. There are 24 member organisations representing the European food supply chain. Participation in the European Food SCP Round Table is also open to consumer representative organisations and environmental/nature conservation NGOs.

The European Food SCP Round Table's unique structure, with participation of all food supply chain members at European level on an equal footing, enables it to take a harmonised, life cycle approach and facilitates an open and results-driven dialogue among all players along the food chain. The Round Table's vision is to promote a science-based, coherent approach to sustainable consumption and production in the food sector across Europe, while taking into account environmental interactions at all stages of the food chain.

3.1 Guiding Principles

The Guiding Principles (draft document under approval) are the starting point of the work of the European Food SCP Round Table on the voluntary environmental assessment of food and drink products and the voluntary communication of environmental information along the food chain[1]. These Guiding Principles (see Table 1) shall be respected in the development of a harmonised framework methodology for the environmental assessment of food and drink products and shall form the basis of voluntary communication of environmental information along the food chain, including both business-to-business (B2B) and business-to-consumers (B2C). The Guiding Principles aim at promoting consistency among approaches applied across Europe and to facilitate the provision of environmental information that is scientifically reliable, consistent, understandable and not misleading, while being practical to use and focussed, so as to enable informed choice.

Table 1: The Guiding Principles of the European Food SCP Round Table: summary list (draft)

The lead principle Environmental information communicated along the food chain, including to consumers, shall be scientifically reliable and consistent, understandable and not misleading, so as to support informed choice	
I. Principles for the voluntary environmental assessment of food and drink products	
1.	Identify and analyse the environmental aspects at all life-cycle stages
2.	Assess the significant potential environmental impacts along the life-cycle
3.	Apply recognised scientific methodologies
4.	Periodically review and update the environmental assessment
II. Principles for the voluntary communication of environmental information	
5.	Provide information in an easily understandable and comparable way so as to support informed choice
6.	Ensure clarity regarding the scope and meaning of environmental information
7.	Ensure transparency of information and underlying methodologies and assumptions
III. Principles for both voluntary environmental assessment and communication	
8.	Ensure that all food chain actors can apply the assessment methodology and communication tools without disproportionate burden
9.	Support innovation
10.	Safeguard the Single Market and international trade

3.2 Workshop and Road Map

In the framework of the ongoing activities of the European Food SCP Round Table, the JRC organised a scientific workshop in Ispra (Italy) on 14-15 June, 2010. The main goals were:

- develop a common understanding of what is involved in reliable and robust environmental assessments of food and drink product supply chains, current limitations, and how to go towards more straightforward/focused criteria/guidance/tools from detailed assessments;
- preliminary definition of the road map for the development of the common harmonised framework methodology for the environmental assessment of food and drink products in the European Food SCP Round Table.

[1] For readability reasons, the term "food chain" is used in the Guiding Principles document as a synonym for "food and drink chain". It includes suppliers to the agricultural sector, agriculture, agro-food trade, food and drink processors, the packaging supply chain, transport & logistic operators, retailers and restaurants, consumers, including public procurers, and end-of-life operators.

To address the first goal, selected experts were invited to present key insights from their research activities and industry application experiences on the first day:

- Frank Brentrup (Yara International, Germany) focused on the comparison of agricultural practices and fertiliser intensities through LCA;
- Key considerations on methodological issues from LCA case studies in the food and drink sector were briefly illustrated by Andrea Raggi (University "G. d'Annunzio", Pescara, Italy);
- Friederike Ziegler (SIK- The Swedish Institute for Food and Biotechnology) stressed the key environmental issues of seafood production systems;
- By presenting the current activities in assessing the environmental performance of Unilever's food and drink products, Nicole Unger (Unilever) provided methodological and operational insights to group food and drink products and to take into account the water footprint and land use in detailed assessments;
- Urs W. Schenker (Nestlé) underlined the necessity to prevent the pollution by using reliable eco-design tools and he raised the issue of assessing the environmental performance of packaging separately;
- Sára Balázs (Febe Ecologic, Italy) described how to go from detailed assessments to practical criteria by illustrating an LCA case study on olive oil to define criteria of a regional eco-label scheme. Data availability, data quality and other challenges in carrying out detailed assessments by SMEs were also key topics dealt with this presentation;
- Jean-Pierre Rennaud (CIAA, Danone and co-chair of working group 1 of the Round Table) focused, first, on the company strategy to cut down the carbon footprint of its products and, second, on the current work of "Agence de l'Environnement et de la Maîtrise de l'Energie" (ADEME) in defining methodological approaches for the environmental labelling of products and services for the French market.

The second day of the workshop was organised into two parts:

The first part was a brainstorming session to identify key points to be addressed in the harmonised framework methodology for the environmental assessment of food and drink products. To support the discussion on this point, Marc-Andree Wolf (JRC) presented a set of proposed key elements that could be included in the framework methodology document. In particular, he illustrated an approach of deriving food and drink product group specific guidance documents, tools and simplified criteria starting from the main insights from the first day of the workshop and previous meetings of the Food SCP Round Table.

In the second part of day 2, a road map to design, develop and test the framework methodology was proposed by Camillo De Camillis (JRC). Tasks should be completed in a two year time frame. They may include the following steps: workshop and road map definition; detailed analysis of existing environmental assessment methodologies, approaches and studies; drafting the harmonised framework methodology; public consultation and revision; implementation and testing; and fine-tuning of the harmonised framework methodology.

These developments may also facilitate other voluntary activities such as the provision of life cycle data, tools, and criteria from different associations in relation to their products and activities.

4. Conclusions

Quantifying the environmental performance of food and drink product supply chains, communicating this information along the supply chain and to consumers, as well as identifying opportunities for improvement is important in the context of sustainable consumption and production. This is supported by the European Commission.

Life cycle thinking and assessment are supported with a knowledge base by the European Platform on Life Cycle Assessment. This includes facilitating the European Reference Life Cycle Database (ELCD), the International Reference Life Cycle Data System (ILCD), as well as providing a LCA Resource Directory and a discussion forum. The Platform supports coherence, quality assurance, and the availability of associated life cycle information.

The European Food Sustainable Consumption and Production Round Table is an important initiative founded together by the European Commission with organisations representing the European food supply chain. This will develop the European methodology framework for the environmental assessment of food and drink product supply chains.

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Promoting the use of Life Cycle Assessment for a sustainable agri-food industry

Mary Ann Curran[1,*], Donald Huisingh[2,3]

[1]U.S. Environmental Protection Agency, Office of Research & Development
26 W. Martin Luther King Dr., Cincinnati, OH 45268, USA;
[2]University of Tennessee, Institute for a Secure and Sustainable Environment
2232 Delta Way, Knoxville, TN 37919-9107 USA;
[3]Editor-in-Chief, Journal of Cleaner Production (http://ees.elsevier.com/jclepro/default.asp)

ABSTRACT

The number of studies that address the holistic human health and environmental impacts related to food, feed, and bio-based fuel production has steadily increased in recent years. Studies on agricultural systems have identified environmental issues ranging from greenhouse gas emissions and energy use to land use, water use (availability), soil quality, water quality, biodiversity, and human health. However, threats that stem from other issues, including the development of genetically-modified organisms (GMO's), global climate change, desertification, pesticide exposure, antibiotic-resistant strains of microorganisms, growth hormone residues in food, are not adequately addressed by Life Cycle Assessment (LCA) systems or their users. In addition, the increased production of bio-based materials and biofuels potentially increases risk of famine as valuable agricultural lands are diverted to produce fuel. The ISO standard for LCA provides the basic template to capture the holistic environmental impacts related to food production and consumption. However, LCA practitioners and researchers need to further develop LCA tools so that they evolve dynamically to address the diverse environmental, economic and social impacts related specifically to food/feed and other bio-based products. Research is needed to develop an approach to integrate the entire suite of potential trade-offs in the decision making process as well as to elevate the consideration of food systems to the forefront in the current literature. A special issue in the *Journal of Cleaner Production* will be developed with selected papers from the lcafood 2010 conference and by invitation from other sources. This special issue will present new and novel solutions to sustainable food production regarding methodology, approaches, and data development.

Keywords: Life cycle assessment, food, bio-based materials, sustainable agriculture, GMOs, growth hormones, pesticides, terminator genes

1. Introduction

The increasingly severe threats to our eco-systems and to our global food security need to be given serious consideration. These threats stem from a diverse range of issues, including the development and widespread dissemination, globally, of genetically modified organisms (GMO's), global climate change, desertification, pesticide exposure, antibiotic-resistant strains of microorganisms, animal growth hormone residues in human food, etc. In addition, the increased production of bio-based materials and biofuels potentially increases risk of famine as valuable agricultural lands are diverted to produce bio-feedstocks, such as corn, to make fuel instead of human food or animal feed. Additionally these actions must be cast against the sea-level rising and spreading deserts due to climate changes that have already occurred and are projected to occur. Furthermore, all of this must be viewed in the context of the fact that the global population continues to increase at a rate of 75,000,000 per year.

* Corresponding Author. e-mail: Curran.MaryAnn@epa.gov; dhuising@utk.edu

Our current Life Cycle Assessment (LCA) systems are inadequate to properly address many of these factors singly or integratively. However, if we do not progress with LCA and LCA-like tools beyond those that are currently in use, we will not be able to provide value added to the scientific and non-scientific communities as we, together, strive to make the transition from risky, non-sustainable development patterns to those, which from ecological and human health, perspectives, are far less risky and can help us make the transition to sustainable societal patterns.

With terrestrial and aquatic-based food and feed production and consumption, one of the major driving forces behind environmental impact and resource consumption, it is increasingly urgent for researchers and policy-makers to look holistically at the entire chain including production, transportation, packaging, use, and end-of-life management. Walmart underscores this point in a video titled, "The Secret Life of Sour Cream," on their website (http://walmartstores.com/Video/). In addition, the increasing demand for biofuels and other bio-based materials has catapulted the issues related to bio-feedstock acquisition to the forefront. This is particularly important since agriculture is expected to comply with the principles of sustainability

LCA methodology provides the theoretical framework that is needed to evaluate the environmental impacts of products and production systems, whether it's to make a durable good, a disposable good, or an edible good. Although food LCA's are perhaps outnumbered by studies on other consumer products such as building materials, packaging, and energy sources (especially biofuels), it is important that we also pay equal attention to the short and long-term impacts of the foods/feeds we produce and use.

2. Findings

2.1 A Quick Review of the Literature for Published LCAs

A recent search in SCOPUS on the term "life cycle assessment" resulted in a return of 4,793 citations between 1991 and 2010. According to SCOPUS, the following five journals produced the most LCA-related papers: International Journal of Life Cycle Assessment (828), Journal of Cleaner Production (256), Journal of Industrial Ecology (159), Environmental Science & Technology (145), Resource Conservation and Recycling (109). Table 1 shows the increase in the number of citations per year since 1999; 2010 is on track to reach over 700 citations since there were already 350 citations by the middle of July 2010.

A similar search narrowed to food-related LCA's revealed approximately 41 such papers. Documents that addressed food LCAs also increased in recent years. Table 1 presents the breakdown of the number of LCA-related papers that are reported in SCOPUS between 1999 and July 2010.

Table 1: Food LCA and all LCA Publications Reported by SCOPUS, 1999 – July 2010

Year	Food LCAs	All LCAs
1999	0	144
2000	3	187
2001	0	182
2002	2	184
2003	2	253
2004	0	312
2005	3	420
2006	2	375
2007	2	448
2008	8	499
2009	12	649
1st half 2010	7	350
Total	41	4,793

2.2 Human Health and Environmental Issues related to Crop Production

LCAs on crops to provide food as well as industrial products such as biofuels have identified common environmental issues, such as greenhouse gas emissions, energy use, land use, water use (availability), soil quality, water quality, biodiversity, and human health (NAS 2010; von Blottnitz & Curran 2006). However, additional research is needed in these areas in order to bring the entire suite of potential trade-offs to the forefront to assist in decision-making to help reduce risks of implementing unsustainable societal patterns. In the following paragraphs, brief descriptions are given of some of the currently, less visible human health and environmental risk factors associated with bio-fuel feedstock and food/feed production.

Pesticide Exposure

While consumers worry about the chemical residues on or within their produce, farm workers are currently often unnecessarily exposed to pesticides, leading to harmful health effects (Ridley 2010). Although regulations exist to reduce the risk of pesticide poisonings and injuries among agricultural workers and pesticide handlers, such as the EPA's Worker Protection Standard for Agricultural Pesticides (WPS), more research is needed regarding exposure patterns among all types of farm workers. Furthermore, uniform & consistent enforcement of the safety precautions have been or will be developed as a result of better LCA tools to properly address the human and eco-system health risks of many of the current and potential practices.

Land Use Changes

Very few integrated, longitudinal studies of land use impacts driven by current crop production schemes have been done. Potential impacts in terms of indirect land use changes driven by increased bio-feedstock production and use have seldom, if ever, been adequately studied.

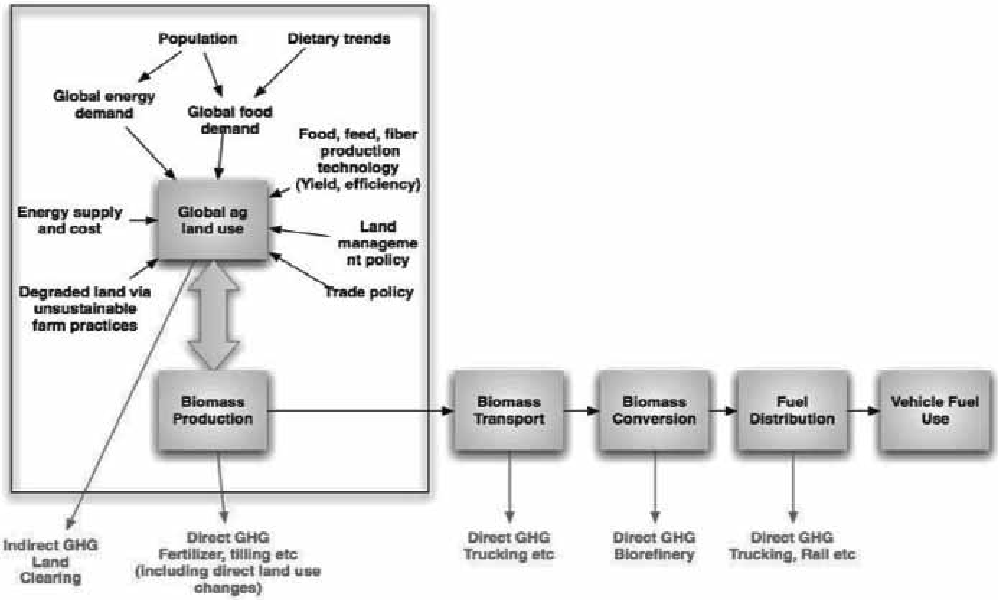

Figure 1. Expanding the life cycle boundaries of biofuels - from a presentation by John Sheehan, University of Minnesota, at a National Academics of Science workshop June 24, 2009 (NAS 2010).

Soil Function Impairment

Forms of soil degradation include soil erosion, soil compaction, low organic matter, loss of soil structure, poor internal drainage, salinization, and soil acidity problems. Typical tillage and cropping practices lower soil organic matter levels, cause poor soil structure, and result in compaction, which increases soil erodability. Carbon compounds in waste biomass left on the ground are consumed by microorganisms and degraded to produce valuable nutrients for future crops. When cellulosic ethanol is produced from bio-fuel feedstocks like switchgrass and sawgrass, the nutrients that are required to grow the lignocellulose, are removed and cannot be processed by microorganisms to replenish the soil nutrients. The soil is then of poorer quality. The widespread human use of biomass removes material, which would normally be returned to the soil as organic matter as the diverse organisms compost them. Annual removal of all or most of the biomass from the fields for biofuel feedstock production will result in decreased soil fertility and ultimately to unsustainable production systems, because the normal ecological systems that help to maintain healthy and fertile soils are not integrated into that type of management system (ETC 2008). Better models in LCA systems are needed to more adequately assess such short-term and long-term unsustainable practices.

Loss of Biodiversity

It has long been recognized that changing agricultural land use is a major cause of the decline of biodiversity. Although intensively farmed land supports a certain level of biodiversity, it generally lacks significant areas of 'high nature values,' which are essential for preserving biodiversity. Europe's more traditional, low-intensity farming systems with ‘high nature values’ are gradually disappearing, even when abandoned, agricultural land is replaced by less diverse vegetation or forests (EEA 2010).

Invasive Species

A recent study from Mexico documented extensive contamination of numerous wild forms of maize (corn) that were hundreds to thousands of kilometers from any genetically modified (GM) maize. Scientists found DNA from GM crops in wild maize growing on remote mountains in Mexico. The wild maize in question was growing around 100 kilometers (62 miles) from the nearest GM crops (Noble 2001).

On July 8, 2010, a coalition of environmental and agricultural technology groups sued the US Department of Agriculture for permitting open-air testing of genetically engineered eucalyptus trees across states, according to the Environmental News Service. The groups fear the eucalyptus could become invasive and claim the USDA has not conducted a thorough environmental impact analysis on the project. The USDA issued the permit to allow international biotech company Aborgen continue experimenting with cold-tolerant eucalyptus for harvesting pulp products and biomass (By: M.Ludwig, t r u t h o u t | News in Brief.).

3. Conclusions

The ISO 2006 standard provides the basic template to help producers capture the human health and environmental impacts related to food production & consumption in a holistic and long-term manner. Unfortunately, the current life cycle impact models and supporting databases are inadequate. Currently, LCA conceptual frameworks, tools and databases are not capable of coming close to assessing the comparative short and long-term risks and benefits of food, feed, and biofuel production systems. LCA practitioners and researchers need to further develop LCA tools so that they evolve dynamically to address the diverse, rapidly evolving issues related specifically to agricultural products, such as exposures to pesticides, soil function impairment, biodiversity losses, and invasive GM crops. Agri-medicines, animal growth hormones, antibiotics and other toxins, which have already been documented to be contaminating our food supply, need to be investigated. Furthermore, LCA researchers must investigate how to model species diversity challenges caused by GM crops and other 'selective pesticides' as well as the short and long-term consequences of usage of 'terminator genes.'

We need to push the envelope on the methodology and develop new and improved methods or models, as well as to develop the necessary supporting databases in order to achieve significant advances in the use of LCA concepts and life cycle-based tools, especially with regard to the numerous and wide ranging health and nutritional dimensions that are urgent problems that confront society.

4. Special Food LCA 2010 Issue in the Journal of Cleaner Production

As presented in the review of the published literature, a vast amount has been published in this and related fields. The *Journal of Cleaner Production* has been a key forum for publishing hundreds of relevant and related papers in its first 18 years of publication. The production of a special issue from the lcafood 2010 conference will continue this impressive publication record.

This conference, the 7th conference in a series on LCA of Food, continues to emphasize the importance of looking at the grand environmental and social challenges of food and the agricultural industry including the numerous issues pertaining to aquatic production. It is urgent and timely to address the interconnections between the terrestrial and aquatic systems as evidenced by the un-folding Gulf of Mexico oil spill disaster that is impacting numerous systems including the social, psychological, political, economic, human health and of course the short-and long-term ecological health of the interconnected systems. A focus on the life cycles of food products is important for several reasons: terrestrial and aquatic farming practices have a direct impact on global warming; problems need to be addressed at the regional, national & global levels; the same data issues occur in LCAs when we seek to address issues of the competition between the use of land for the production of human food, animal feed and bio-based fuels.

The special issue is intended to emphasize the need to work with entire production systems as parts of interconnecting production and consumption webs and networks in order to assess the risks and benefits; when we can do that in a transparent and reproducible manner, we will be able to provide real value added for decision-making that can help societies make the transition to truly sustainable patterns.

Notice: *The U.S. Environmental Protection Agency through its Office of Research and Development funded and collaborated in the research described here under. It has not been subject to Agency review; the views expressed by individual authors are their own, and do not necessarily reflect those of the Agency. No official endorsement should be inferred.*

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UNEP's activities on assessing environmental impacts and resource use from food in a life cycle perspective

Guido Sonnemann*, Sonia Valdivia, Sarah Tischhauser

UNEP, Division of Technology Industry and Economics (DTIE)

ABSTRACT

An overview of UNEP's activities in assessing environmental impacts and resource use from food is given. The Life Cycle Initiative pursues the goal to enhance Life Cycle Thinking worldwide by providing and promoting relevant data and methodologies. Furthermore, the Resource Panel provides independent, coherent and authoritative scientific assessments of policy relevance on the sustainable use of natural resources and their environmental impacts over the full life cycle, and contributes to a better understanding of how to decouple economic growth from environmental degradation. A recent Resource Panel publication identifies food and fossil fuels to be key areas of environmental impacts due to current consumption and production patterns worldwide. Therefore, both the Life Cycle Initiative and the Resource Panel consider food as a crucial topic. Further work needs to be done in this area. Ideas on what that could involve are elaborated.

Keywords: Life Cycle Initiative, Resource Panel, Life Cycle Assessment, Resource Efficiency, Food

1. The Life Cycle Initiative

After the publication of the ISO series on Life Cycle Assessment, a real need for supporting the dissemination and implementation of this approach in industrialized and non industrialized countries was identified. UNEP and SETAC, aware of this need, conjointly began to work on the articulation of existing efforts around Life Cycle Approaches resulting in the setting-up of the Life Cycle Initiative in 2002. Since 2007 the Initiative is now in its Phase 2. It aims at enhancing the global consensus and relevance of existing and emerging life cycle approaches methodology, facilitating the use of life cycle approaches worldwide by encouraging life cycle thinking in decision-making in business, government and the general public about natural resources, materials and products targeted at consumption clusters, and expanding capability worldwide to apply and to improve life cycle approaches.

SETAC commits to provide technical advice while UNEP facilitates the processes involving all kind of stakeholders and from different regions as well as communicates achievements in the role of the Secretariat of this Initiative.

Based on results achieved in Phase 1 and ongoing activities, the Initiative works towards the following results in Phase 2 (Fava, J. *et al.*, 2007): Increasing the global consensus on most relevant methodologies for Life Cycle approaches via Guidelines for Social Life Cycle Assessment launched in 2009 (Benoit, C. *et al.*, 2010), the UNEP/ SETAC LCA database registry as global reference good quality transparent and free Life Cycle databases, the USEtox model launched in 2010 as the global acknowledged Life Cycle toxicity impact assessment model, and coherent Life Cycle based footprints methodologies for example for carbon and water (Valdivia S. *et al.*, 2010) are jointly prepared with partners; Incorporating Life Cycle approaches in key international initiatives on sustainable consumption and production through joint efforts are currently ongoing with the Resource Panel, the

* Corresponding Author. e-mail guido.sonnemann@unep.org

Sustainable Building and Construction Initiative (SBCI), the Strategic Approach to International Chemicals Management (SAICM) and the World Business Council for Sustainable Development (WBCSD); And finally broadening capability to apply and improve life cycle approaches in key target groups through conferences, training and an award scheme, making the Life Cycle Initiative the one-stop-shop for knowledge (Sonnemann, G. *et al.*, 2006).

The work towards these goals and results is divided into five Work Areas: Life Cycle Approaches Methodology, Life Cycle Approaches for Resources and Materials, Life Cycle Approaches for Consumption Clusters including housing, mobility, food and other consumer products, Life Cycle Approaches for Capability Development and finally Life Cycle Management in Businesses and Industries. The governing body of the Life Cycle Initiative is the International Life Cycle Board (ILCB). The ILCB decides on the work plan and carries out the supervision of all work elements. The Coordinating Committee, appointed by the ILCB, coordinates the activities of each Work Area. Several Project Groups are active in each Work Area.

Interlinkages between the different Work Areas suggest that the impact of the Life Cycle Initiative will go beyond the work on methodologies and capacity building, on to practical applications that make a difference in the real world and thus contribute more effectively to the ongoing international efforts to change unsustainable patterns of consumption and production. The Work Area on LCA for Consumptions Clusters deals with housing, mobility, food, and consumer products. Following the Environmental Impacts of Products (EIPRO) study by the European Commission (Tukker *et al.*, 2006), these areas have been identified by the Life Cycle Initiative as key elements to be considered from a life cycle perspective.

2. The Resource Panel

Resources are crucial to the functioning of world economies and to our quality of life. Current patterns of consumption and production, with their associated environmental impacts, jeopardize the planet's capacity to provide adequate resources for people to live safely and sustainably. *"We need to break the links between economic growth and environmental degradation. Finding ways to achieve this 'decoupling' is what the new Resource Panel is all about."* says Achim Steiner, UNEP Executive Director. Therefore the International Panel for Sustainable Resource Management (short: Resource Panel) was launched in November 2007. Its members are leading experts in their field, that follow the vision of a transition process towards a "green economy" where patterns of consumption and production are sustainable and aim to enable all citizens to have access to resources while preserving the quality of the global commons. Its Steering Committee, consisting of representatives from governments, the EC, UNEP and other organizations, advises on annual work programmes, their outcomes and budgets.

Current rates of resource consumption are not only environmentally unsustainable, they are also inequitable. Therefore the Resource Panel recognizes the rapidly changing nature of the global economy. Developed economies, rapidly industrializing developing economies, and least developed economies that generally do not benefit from global economic growth all share common but differentiated challenges.

The work of the Resource Panel entails assessments of the literature and new syntheses and interpretations. All analyses of the Panel are peer reviewed. Comments of reviewers are addressed systematically before reports are publicly released.

2.1. Report on Environmental Impacts of Consumption and Production

The Resource Panel consists of five working areas, two of which are crosscutting ones: decoupling and environmental impacts; three of which are oriented towards specific resources: biofuels/land/soil, metals and water.

The recent launch of the Resource Panel's Report "*Environmental Impacts of Production and Consumption*" (UNEP, 2010) at the Green Week in Belgium in June 2010 identifies priorities amongst global consumption activities, industrial sectors and materials from primary industries in terms of their environmental impacts and their resource use from a global life cycle perspective, recognizing regional and local differences.

Global economic activity drives high levels of consumption and production. In order to maintain these, the global economy relies upon resources such as energy, materials and land. Economic activity also generates material residuals, which enter the environment as waste or pollution emissions. The Earth, being a finite planet, has a limited capability to supply resources and to absorb pollution.

The Environmental Impacts report addresses the fundamental question as of how different economic activities influence the use of natural resources and the generation of pollution in two main steps. The assessment is based on a broad review and comparison of existing studies and literature analyzing impacts of production, consumption, or resource use of countries, country groups, or the world as a whole. It reviews assessments of environmental impacts in order to identify environmental pressures that should be considered when assessing priority products and materials and also reviews work on scarcity of mineral, fossil and biotic resources.

Among the key findings are the identification of agriculture and food consumption as one of the most important drivers of environmental pressures, especially habitat change, climate change, fish depletion, water use and toxic emissions. *"We now know that food, mobility and housing must - as a priority - be made more sustainable if we are serious about tackling biodiversity loss and climate change. In most countries, household consumption, over the life cycle of the products and services, accounts for more than 60% of impacts of all consumption. We must start looking into our everyday activities if we truly want a green economy – for developed and developing countries"*, says Achim Steiner, UN Under-Secretary General and UNEP Executive Director.

The Environmental Impacts report reveals that the fossil fuel use and feeding the world in the current way cause the greatest environmental impacts. In other words, the way how the world is fed and fueled will in large part define development in the 21st century as one that is increasingly sustainable or a dead end for billions of people. It concludes that dramatically reforming, rethinking and redesigning two sectors - energy and agriculture - could generate significant environmental, social and economic returns.

2.2. Connection to the Life Cycle Initiative

The outcome of the Resource Panel report suggests that within the focus of the Life Cycle Initiative Work Area on Consumption Clusters, fossil fuels and food play the most crucial role. While the Resource Panel focuses on assessment reports at the meso- and macro-level covering specific industry sectors and the whole economy, the Life Cycle Initiative works on methodologies, tools and capability development and provides reports on relevant topics at the micro-level.

3. UN Activities on Food

Various UN organizations defined food – basic need, essential for human-well being, personal growth and the development of a society, but also the cause of environmental impacts and unsustainable use of resources – to be one of their core activities and mission.

The Food and Agriculture Organization's (FAO) mandate is to raise levels of nutrition, improve agricultural productivity, better the lives of rural populations and contribute to the growth of the world economy. The World Food Programme (WFP) of the United Nations, pursues the vision of a world in which every man, woman and child has access at all times to the food needed for an active and healthy life. The International Fund for Agriculture and Development (IFAD), a specialized agency of the United Nations has the goal is to empower poor rural women and men in developing countries to achieve higher incomes and improved food security. The World Bank Group set up the Global Food Crisis Response Program in May 2008 in response to the severity of the food crisis, to provide immediate relief to countries hard hit by food high prices.

4. Next Steps

Next steps in the work following the recent findings on food can be described in two focus areas.

4.1. Environmental Information Tools for Institutional and Individual Consumers

An activity at UNEP is the development of a Resource Use Intensity and Impact Assessment Indicator Framework which has the aims to propose a new benchmarking system using a number of indicators proposed, such as carbon and water footprint together with resource efficiency indicators dealing with water, energy and materials use/demand and environmental footprints. From the resource side it included the water footprint, energy demand, material intensity and land use. From the impact side it considers the carbon, (eco)toxicity and biodiversity footprints. This framework is being consulted with companies also coming from the food sector.

UNEP also is engaged in ecolabelling, certification standards, reporting, declaration and other forms of green or ethical claims that allow selecting products and services according to specific environmental and social criteria. For example, the UNEP Ecolabelling project is a capacity building project that works with SMEs in developing countries to meet the requirements of ISO type I labels and governments to create an enabling policy framework. A new project seeks to develop common principles among the existing standards, labels and reporting schemes.

4.2. Communicating Scientific Evidence to the Broad Public

There are a number of activities involving scientific assessment work related to food that however have not been adequately communicated to reach the broad public.

The current debate on climate change, carbon footprints and carbon tracking attracts full attention at the expense of other environmental impacts such as use of scarce water resources, human health effects due to pollution of water bodies or the potential threat to future generations caused by diminished biodiversity, toxic or high level radioactive wastes.

Therefore the Life Cycle Initiative has developed a project that aims at the publication of an argumentation, why a broad view is indispensable regarding environmental issues. This argumentation is illustrated with case studies where the focus on carbon footprints lead to substantially distorted conclusions. Potential case studies include food products and fuels based on agricultural products (agrofuels or biofuels).

The fastest growing entity today is information. Information is expanding exponentially and knowledge is experiencing a similar development. However, they are not reaching decision makers and limited information is finally used where it is needed. This challenge is taken up by a Life Cycle Initiative project "Lessons Learned from LCA Experiences" where relevant findings from crucial studies and life cycle assessments are identified and analyzed from a global perspective resulting in lessons learned for decision makers. So, for example, in case of food products too much attention has been given to impacts from packaging and less to the stage on agriculture where chemicals and water consumption are key. This compilation on lessons learned will elaborate on this type of cases from various angles and further discuss the impacts.

The "Assessing Biofuels" report of the Resource Panel (UNEP, 2009) provides an overview and perspectives towards sustainable production and use of biomass for energy purposes. The report points out biomass use for food and material purposes. It reveals that in particular food consumption is expected to induce an expansion of global cropland due to population growth, changing diets and various constraints for further increase of agricultural yields. Key findings of the report include that the long term sustainability of the bioenergy sector can only be achieved with sound policies and planning that take into consideration a range of global trends, including population growth, yield improvements, changing diet patterns and climate change.

In line with these findings new work of the Resource Panel will focus on land, soil and the need to feed 9 billion people by 2050.

5. Outlook to Other Relevant Ongoing Activities

More and more regional initiatives are currently developing on the topic of sustainable food consumption and production. Three examples are worth being highlighted.

A systematic analysis of what can be done to minimize the environmental degradation caused throughout the life cycle of products is given in the "Environmental improvement potential of meat and dairy products" (IMPRO) study (Weidema, B. P. *et al.*, 2008). Following these efforts, the European Commission set up the European Food Sustainable Consumption and Production (SCP) Round Table. It enables members to take a harmonized, life cycle approach and facilitates an open and results-driven dialogue among all players along the food chain. One of its key principles is that environmental information communicated along the food chain, including to consumers, shall be scientifically reliable and consistent, understandable and not misleading, so as to support informed choice.

In the US, Walmart has contributed to set up The Sustainability Consortium, an independent group of academics, retailers and manufacturing companies who work collaboratively towards the development of sustainability measurements and reporting standards to improve consumer product sustainability, particularly including food, through all stages of a product's life cycle. The group is developing a Sustainability Index, and therefore also working on understanding consumers and how to effectively communicate to them the sustainability attributes of a wide range of products such as different food sectors.

6. Conclusions

Scientific evaluation shows that changing food consumption and agricultural production is key for achieving sustainable consumption and production. More resource efficiency measures and policies are needed to move in that direction. Life Cycle Assessment is a crucial tool for highlighting the trade-offs of different ways towards sustainability. UNEP hopes to be able to work with the life cycle expert community on establishing critical metrics and bringing the scientific knowledge to decision makers in government and business as well as the general public for the sake of the environment.

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Greenhouse gas emissions from the global livestock sector – methodology for a Life Cycle Assessment

Theun Vellinga[1], Pierre Gerber[2,*], Carolyn Opio[2]

[1] Wageningen University and Research Centre
[2] Food and Agricultural Organisation of the UN, Rome, Italy

ABSTRACT

This paper presents a methodology developed for the estimation of greenhouse gas (GHG) emissions from the livestock sector. The methodology is based on the Life Cycle Assessment (LCA) approach and is illustrated for dairy cattle production, assessing the sector's emissions profile from cradle to retail. Three main methodological innovations have been made: the development of a herd model, a feed basket computation module linking locally available feed with animal numbers and productivity; and third, the use of geographic information system (GIS) to store data and compute emissions. These innovations permitted the computation of information required for the analysis, unavailable from statistical databases or literature as well as ensure spatial coherence. This paper also presents results on the dairy sector's contribution to GHG emissions and on the evaluation of the model. This new method is an important step towards a standardised approach to coherently assess the environmental implications of food systems.

Keywords: life cycle assessment, dairy cattle systems, climate change, greenhouse gas emissions

1. Introduction

This paper introduces a methodology developed for the assessment of greenhouse gas (GHG) emissions from the global livestock sector. This work seeks to refine and elaborate the initial estimates carried in FAO's 'Livestock's Long Shadow' by estimating GHG emissions for major dairy-related products and services--disaggregated by farming system and geographical region. The specific objective of the study was two-fold: to develop a methodology based on the Life Cycle Assessment (LCA) approach applicable to the global dairy sub-sector; and to apply this methodology to assess greenhouse gas emissions from the dairy cow sector and provide insight on the sector's contribution to GHG emissions.

2. Methodology

The methodology is based on standard guidelines regarding the use of Life Cycle Assessment such as ISO 14044 (ISO, 2006), PAS2050 (BSI, 2008) and IPCC Guidelines (IPCC, 2006). The functional unit in the animal production sector is a kg of animal protein, from milk and meat. This unconventional unit is used because the method reflects the primary function of the dairy sector, which is to provide humans with edible protein. The system boundary is defined by GHG emissions associated with milk production from 'cradle to retail' and encompasses the entire production chain of dairy cow milk production, from feed production through the final processing of milk and meat, including transport to the retailer.

Emissions of production are commonly allocated to meat and milk on an economic basis (Casey and Holden 2005; Thomassen *et al.*, 2008a), although physical allocation approaches have also been applied (Cederberg & Stadig, 2003). In this study, the protein production in the form of meat and milk is used for allocation. Cattle are not only important for milk and meat, but in certain regions also provide manure and draught. A detailed description of the

* Corresponding author: Dr. Pierre Gerber. e-mail: Pierre.gerber@fao.org

allocation rules is provided in FAO (2010). The assessment introduces three methodological innovations: a herd model, a feed balance module and the use of Geographic Information System.

The herd demography

Data on cattle herd structure are generally not available at national level. A specific "herd demography" module was thus developed to partition the total number of cattle into complete dairy and beef herds and to partition the animal numbers over adult, replacement and fattening animal categories. The module has a number of state variables and a number of rates. Rates used in the model include: the fertility rate, death rate of calves, replacement rate, growth rate of animal, and the bull to cow ratio. The six animal categories shown in Figure 1 are state variables. Calves are not counted *per se*, since they are immediately transferred to one of the replacement or meat categories. A detailed explanation is provided in FAO (2010).

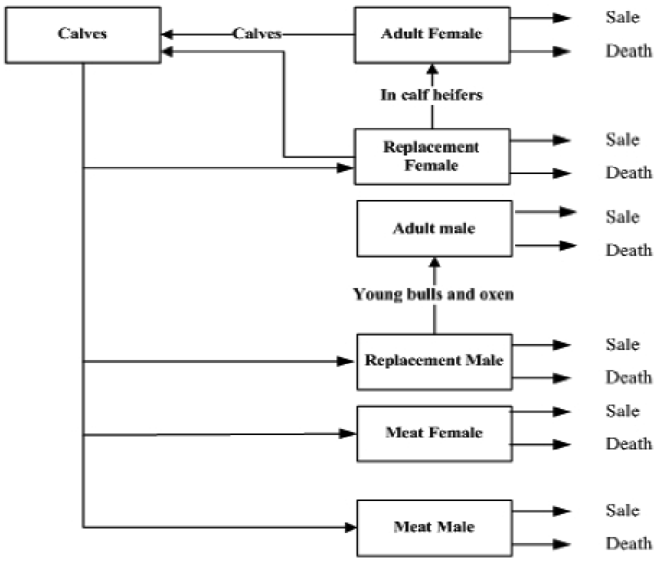

Figure 1: Structure of herd demography

To partition the total cattle numbers into complete dairy and beef herds, we perform two strings of calculations. The first sequence starts from the number of adult cows (input) and allows us to compute the numbers in the other five categories of the dairy herd. The total number of cattle in the dairy herd, deducted from the total number of cattle in the country, gives the number of animals in the pure beef herd. The number of animals in the six beef categories can then be computed.

Feed module

Feed plays a key role in any animal production system. High quality feed is necessary for optimal productivity and growth levels. In many livestock production systems, feed quality and quantity is a major limiting factor. In this assessment, all feed ingredients are identified by three key parameters: dry-matter yield per hectare, the digestible energy and the nitrogen content. Animal rations are generally a combination of different feed ingredients. Major feed ingredients include grass from natural pastures and roadsides to improved grasslands and leys; feed crops such as maize silage and grains; tree leaves, crop residues like straw and stover; agro-industrial by-products from the processing of non-feed crops such as oilseeds, cereals, sugarcane, and fruit and; concentrates.

The average digestibility and nitrogen content of the ration are based on the relative proportion of each ingredient. Emissions related to the production of feed are calculated according to the methods of Thomassen *et al.* (2008a, 2008b) and Cederberg *et al.* (2009).

Geographic Information System

The use of Geographic Information System (GIS) has proven to be essential in the calculations for two reasons. First, it has permitted the utilization of available geo-referenced data on animal densities (FAO, 2007), grassland area and production (GLC 2000 database, 2003) and area and yield of major arable crops (IFPRI, 2009) to calculate the feed balance which requires information on animal densities and feed availability on a local scale. Second, data on herd demography, feed availability, and land use are related to climatic and socio-economic conditions and are not bound to national boundaries. These data have to be combined with statistical data that are collected on a national scale.

To preserve and manage spatial heterogeneity, both at the level of data management and at the level of calculation, we relied on GIS to create the database and develop the calculation model. In this way, emissions are estimated at any location of the globe, using the most accurate information available, and then aggregated along the desired category, e.g. by farming systems, country grouping, commodity, or animal species.

3. Results

The amount of milk produced globally in 2007 was about 553 million tons (FAOSTAT, 2009). The total meat production related to the global dairy herd is calculated at 34 million tonnes (10 and 24 million tonnes from culled dairy cows and reproduction bulls and surplus calves fattened for beef production, respectively), contributing 57 percent of the global cattle meat production (60 million tons in 2007) (FAOSTAT, 2009).

The GHG emissions from the dairy herd, including emissions from deforestation and milk processing were estimated at 1,969 million tonnes CO_2 eq., of which 1,328 million tonnes are attributed to milk, 151 million tonnes to meat production from slaughtered animal and 490 million tonnes to meat production from fattened animals. The total emissions account for 4.0% of the total GHG anthropogenic emissions, of which milk production itself contributes 2.7%.

The average global emissions per kg of milk and kg of meat (from the culled dairy cows and bulls and surplus calves) are 2.4 kg of CO_2-eq. and 15.6 kg CO_2-eq., respectively. The regional variation of emissions per kg of fat and protein corrected milk (FPCM) is shown in Figure 2. The highest emissions are calculated for sub-Saharan Africa with an average of about 7.5 kg CO_2-eq. per kg FPCM. The lowest values are calculated for the industrialized regions of the world: 1 to 2 kg CO_2-eq. per kg FPCM. South Asia, West Asia & Northern Africa and Central & South America have intermediate levels of emissions (3 to 5 kg CO_2-eq. per kg FPCM). The highest proportion of emissions takes place at farm level. In North America, Western Europe and Oceania, 78 to 83 percent of emissions are generated by on-farm activities and in other parts of the world, these emissions contribute 90 to 99 percent to the total emissions. Regional variations in emissions per kg of milk are thus predominantly driven by differences in farming systems.

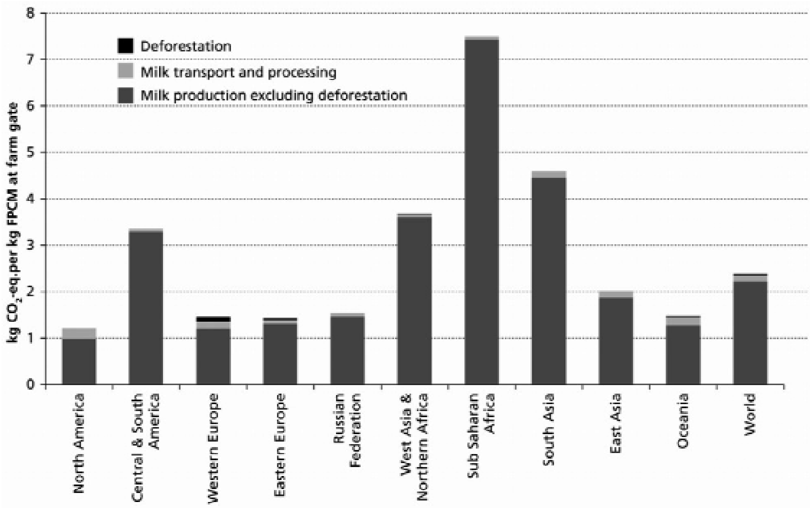

Figure 2: Average estimated GHG emissions per kg of FPCM at farm gate

Sensitivity analysis

The effect of herd parameters (fertility, replacement rate, death rates, age at first calving and milk yield per cow) and feed characteristics (digestibility and nitrogen content) was tested for extensive and intensive systems. The effect of these parameters on greenhouse gas emissions and milk and meat production are tested by changing one parameter by 10 percent at a time, holding others constant at the average level (Figure 3).

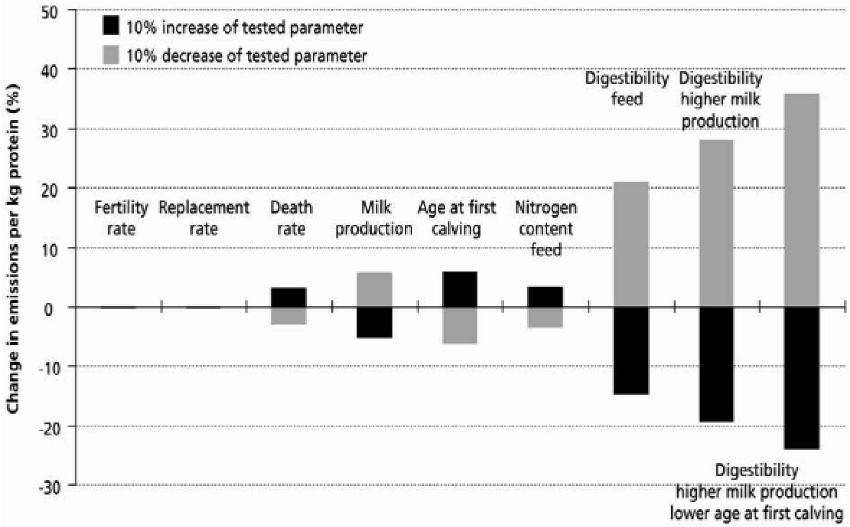

Figure 3: Sensitivity analysis: effect of a 10% change in key parameters on GHG emissions per kg of animal protein from a dairy system

The change in the herd reproduction parameters such as fertility, death and replacement rates affect the meat production proportionally, but the emissions per kg of animal protein (the sum of milk and meat protein) only change marginally. The changes in the milk production per cow and the age at first calving (in fact the growth rate) clearly have some effects on the emissions per kg of animal protein, but the effect is not as strong as the change in milk production or growth rate.

Increasing the nitrogen content of feed, without increasing milk production or growth rate causes a proportionally smaller increase in GHG emissions from both extensive and intensive systems. The digestibility of feed has a strong effect on the GHG emissions per kg of product; a 10 percent increase in feed digestibility (on an average digestibility of 56%) reduces GHG emissions by 14.8 percent and 10.1 percent in extensive and intensive systems, respectively. In practice, however, the quality of the feed is interrelated with milk production and growth, so looking at the combined effect of changes in feed quality, milk production and growth is more realistic. Assuming a 10% increase in milk production, parallel to the increased digestibility, GHG emissions are reduced by 19.2% and 15.4% in extensive and intensive systems, respectively. In a situation where the growth rate is also increased, GHG emissions are further reduced.

4. Discussion

Accuracy

The three main methodological innovations: the use of GIS, development of the herd model and feed basket described above has permitted the computation of information required for the assessment but not available in statistical databases and also ensured coherence between the production parameters (e.g. reproduction and herd size or feed intake and milk yields). Despite these methodological breakthroughs, the assessment relies on a substantial number of assumptions and simplifications, as well as on methodological choices that influence results. The sensitivity analysis has shown that the emissions per kg of milk and meat are mostly affected by digestibility, milk yield per cow and manure management.

Validation

The slaughtered animals and total meat production results calculated with the herd demography module were compared to FAO statistics (FAOSTAT, 2009) and found to be very similar for all countries, except for a few countries where live animals are traded in large numbers. Calculated GHG emissions were also compared to previous studies based on similar methodologies. Methane emissions per animal from this assessment are comparable to figures obtained by Schils *et al.* (2007), Cederberg *et al.* (2009) in OECD countries (ranging from 110 to 130 kg methane per cow per year) and by Herrero *et al.* (2008) in Africa, ranging between 21 and 40 kg methane per livestock unit per year. Emissions per kg of milk compare well with prior LCA studies for dairy production (Basset-Mens *et al.*, 2009; Block *et al.*, 2008; Capper *et al.*, 2008; Cederberg *et al.*, 2009; Foster *et al.*, 2007; Herrero *et al.*, 2008; Sevenster and DeJong, 2008; Thomassen *et al.*, 2008a; Vergé *et al.*, 2007).

Some of the results from prior analyses are lower than those presented in paper, which in part is caused by discrepancies in emission factors (e.g. Basset Mens *et al.*, 2009, Cederberg *et al.*, 2009) or allocation technique (Cederberg *et al.*, 2009). The choice to use the standard emissions factors of the IPCC at Tier 2 level may also result in discrepancies if compared to studies that utilise country-specific emissions factors.

5. Conclusions

The global average of emissions from milk production, processing and transport is estimated to be 2.4 CO_2eq. per kg of FPCM, which is 2.7 percent of the total anthropogenic emissions. The overall global emissions attributed to the dairy herd plus milk processing and transport activities are estimated to contribute between 4.0 percent of total anthropogenic emissions [±26 percent]. This includes the production of milk and milk products, the production of meat from dairy related animals (old stock and young fattened stock), as well as the provision of draught power. The method and database developed for this assessment effectively supported the calculation of GHG emissions related to dairy production on a global scale, and may be regarded as a step towards a harmonised methodology for the quantification of emission. In the same way, the global datasets collected for this assessment can serve as an initial data source, to be refined and updated by users over time.

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