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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POSTER SESSION A

Methodology and perspective of Food LCA

Fruits & vegetables supply chains specificities and stakes as element of discussion on Social-LCA

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ABSTRACT

Agri-food supply chains are at the heart of sustainable development concerns. In order to comprehend whole complex parameters and their global impacts, it appeared necessary to adopt a systemic approach, justifying a Life Cycle Assessment (LCA), not only from an environmental point of view but from a social and economic one too. Taking into account specificities and stakes of fruits and vegetables (F&V) supply chains in developing countries this paper focus on absences, deficiencies and methodological limits that LCA meets integrating social and economic aspects. The elements presented lead to an in-depth conceptual and theoretical discussion and suggest placing LCA in the perspective of development theory. The proposition is to endow LCA with an approach “by capitals”, which seems particularly adapted to express sustainable development and well-being.

Keywords: social LCA, fruit & vegetables, sustainability, multiple capital model,

1. Background

Agri-food supply chains are at the heart of sustainable development concerns. It’s particularly true from an environmental point of view due to off-season productions, remote localization away from consumption areas and culture intensification. These elements question productions models, in particular technologies of production and their localization, in terms of resource depletion, water, soil and air contamination, global warming, etc. Life Cycle Assessment (LCA) appeared particularly well adapted to consider whole complex parameters and their global impacts. Its initial goal was to assess a full range of potential environmental impacts related to products and services, in order to choose the best alternative or to improve its (Jolliet et al. 2004). Nevertheless, sustainability doesn’t end in environmental dimension, even if it’s a very important component. It includes (at least) social and economic dimensions (WCED 1987). To evaluate social and economic impacts presents similar interests as environmental-LCA, in terms of capacity of comparison of products or services and identification of hotspot and margin of improvement. In addition, this integration seems particularly important in a global sustainability assessment prospect, due to the strengthening of societal expectations towards agri-food products, tending to change the modes of governance of these supply chains as well as their organization, and to reinforce social standards. In this context, integrating socio-economic aspects in decision criteria is essential. To consider these aspects is all the more reason important for horticultural products which are source of significant social and economic impacts, in particular in developing countries where horticultural products greatly contribute to the GDP (Weinberger et al. 2005). To consider the specific case of F&V supply chains in these countries could enrich the discussion on Social LCA (S-LCA), highlighting through their specificities and stakes the important elements that need to be taken into account in a framework.

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2. Social and economic implications of F&V supply chains: specificities & stakes

Rising per capita income, urbanization, changes in consumer taste and globalization is changing consumption behaviour, consequently worldwide supply and international trade in F&V (Weiberger 2005, Temu et al. 2005). Many developing countries took advantage of these changes and have diversified into horticultural crop production and exports based on favourable climatic conditions and lower labour costs (Davis 2005). Effectively, horticultural products are considered as High Value Agricultural Products (HVAP), defined as a "product that return a higher gross margin per unit of available resources (land, labour, capital, human capacities) than other product within a given location and context" (GFAR 2005), offering an opportunity for rural poor to improve their livelihoods.

Horticultural products have some comparative advantages in comparison to others productions. They are source of high profitability for farmers in terms of net farm incomes and net returns on different input measures (McMulloch et al. 2002). For example, in Kenya net farm incomes were five times higher per family member compared to smallholder farmers who did not grow horticultural products (McCulloch et al. 2002). Furthermore, these products generate additional employment opportunities in rural areas because they are more labour intensive than the production of staple crops. For example, horticultural production requires nearly three times more labour than cereal crops (Weiberger et al. 2005). Requiring specialized inputs both upstream and downstream, the growth in HVAP induces a multiplier effect in terms of economic activities and employment potential generation. Horticultural sub-sector generates less tangible and indirect benefits. It contributes to the institutional environment development, in particular for access to credit and capital since the crops are more risky and costly than others (Weiberger et al. 2005). International markets need to comply with a range of legal and commercial standards (maximum residue level of pesticides, phytosanitary certificate, traceability, good agricultural practice) (Temu et al. 2005), which contributes to the determining of norms, labels, codes, etc. They encourage development of networks and market organizations (supply chains, market price information, etc.). It's a major factor in infrastructures investments like roads, rails, seaport, electrification, wastewater system, etc. Being sophisticated products, they require qualified employees, consequently high level of knowledge and skills reached thanks to training and formation.

In compensation, there are some negative impacts. International market development goes with pernicious effects. There aren't technical economies of scale (Temu et al. 2005), but legal and commercial requirements to access to these markets are very important. So that, only organized small-scale farmers or large-scale enterprises are able to comply with (Temu et al. 2005). It means that most private small-scale farmers are kept away from benefits of this developing sector and consequently from an opportunity of development. For example, in India, population still suffers from malnutrition whereas the country is one on the more important producer of basmati rice (Rahnema 2002). Moreover activities concentration and wealth appropriation by few actors is often synonym of capital flight for favourable taxation places. Attractive and lucrative character of HVAP (Dolan et al. 1999 could create a competition for land and resources with local production and food-producing. Accesses to international market and adaptations to satisfy developed countries expectations involve adoption of skills and technologies imported that could destroy knowledge and know-how (Rahnema 2002). These adaptations could change dramatically lifestyles and cause disruptions in local population habits, imitating northern functioning and rubbing local specificities. Working conditions, safety and workers rights are not always respected. Child labour is certainly the principal critical point, even if the perception of child labour is different depending on the place in the world. For example, in banana cropping, “deflowering” is a task entrusted to children after school in Latin America, allowing them to contribute to family incomes. It cannot be considered in West French Indies.

The stakes subtended by the development of horticultural productions in developing countries are poverty alleviation and economic development. It’s therefore important, not to say necessary, to be able to assess for example the difference between two organization modes, namely an integrated system (promoted by high accessing costs to international markets) and an atomized small-scale farmers system. Moreover, in a globalized world, where sustainable criteria will become access market barriers and criteria of decision for sourcing, it’s essential not only to discriminate alternatives thanks to environmental elements but also to include all the complex aspects presented previously. That is the whole issue of S-LCA development.

3. Ambiguities and absences in the scope of social and economic aspects integration

Social LCA no longer needs to be justified (Griebhammer et al. 2006). In terms of methodology, it was highlighted that there were evidently no fundamental problems even if considerable hurdles needed to be overcome in practice, especially in characterization modeling (Griebhammer et al. 2006). In spite of efforts to find an international consensus on the general principles (UNEP/ SETAC 2009), literature shows a wide range of frameworks with many differences (choice of indicators, impacts categories, characterization factors, etc.). Despite the Task Force preferred to put the emphasis on methodological hurdles, considering some absences, deficiencies or methodological limits, this article asks the question of the analysis and the evolution of LCA conceptual and theoretical framework in the view of a broader sustainable conception, integrating environmental, social and economic aspects.

3.1. A fuzzy conceptual framework

The first level of explication could concern the conceptual framework. Most of works deal with methodology rather than conceptual framework, whereas it appears essential and could explain a lot of deadlocks. Thus, a state of art of existing works on S-LCA highlighted some fuzzy and ambiguities on goals, extent, content and boundaries, and upstream on what is important to protect from a societal point of view (Areas of Protection). While the guidelines for S-LCA of UNEP/ SETAC (2009) declare that “social LCA will be used as a synonym for social and socio-economic LCA”, most of the authors make a clear distinction between economic impacts -assessed by Life Cycle Cost- and social impacts -the real object of S-LCA (Norris 2001, Klöpffer 2003, Dreyer 2006, Hunkeler 2006, Hutchins 2008), letting the real content of S-LCA vague. Yet, the will to integrate socio-economic aspects in LCA involves referring to human-being and the society in which he evolves, and its attributes (e.g. norms, rules, public utility, etc). Nevertheless, excepted in Jorgensen et al. (2010), the AoP relating to Human life as presented in the different framework do not differentiate clearly the individual dimension of human well-being from the societal dimension. In addition the position of “less tangible items of financial and cultural values” in the “man-made environment” AoP’s seems not so relevant, considering the original definition of the AoP, that is to say elements that change land surfaces for human purposes (Jolliet et al. 2004). Financial items don’t change land surface except indirectly through investment. Cultural values (e.g. languages or practices), with a broader conception than the “value of unique landscape and unique archaeological sites” (Weidema 2001), refer more to the societal dimension of Human life AoP than to the man-made environment.

3.2. Limited theoretical foundations

The second level of explication for methodological limits but also for conceptual ambiguities could refer to the subjacent theoretical model. LCA was originally an engineering counting method, "for evaluating the opportunities, risks, and trade-offs associated with products and services over their entire life cycle" (UNEP/SETAC 2009). By its empirical approach, it developed itself without clear theoretical foundations, apart from the fact that it was in line with sustainable development model like defined by WCED (1987). On time to integrate social and economic aspects, LCA confronted two hurdles. First, the discussions about S-LCA have concerned the categorization and classification of indicators. Nevertheless, social and economic aspects being particularly complex from one hand and the theoretical framework being not sufficiently explicit from another hand, this lead to draw up a large inventory of indicators without neither being able to produce a synthesis nor putting them into perspective. This limitation is in contradiction with the operational goal attribute to LCA which is "to evaluate trade-offs associated with products and services" (UNEP/SETAC 2009). In second point, S-LCA works give a partial view of social and economic aspects. The Life Cycle Initiative specified the main criticisms made to this method. In particular they could be seen "to be 'anti-development'-orientated because it provides only a picture of negative environmental consequences, but does not reflect any of the positive aspects of development; and to not address the developing countries most significant concerns" (UNEP/SETAC 2009). These critics reinforce the idea that the model of sustainable development which underlies S-LCA actual frameworks doesn't identify sufficiently human, social and institutional dimensions, as it was suggested previously as regards the consideration of the content of human AoP. This limitation is in contradiction with the conceptual goal attributed to LCA, which is "to achieve sustainable development" (UNEP/SETAC 2009).

3.3. Methodological limitations resulting

This double level of incompleteness and fuzziness results in absences and deficiencies at methodological level. The main deficiency concerns the distinction between well-being and sustainability from one hand, and between flow and stock from another hand. They aren't clearly expressed and developed, and yet they are crucial. According to Stiglitz et al. (2009) sustainability asks the question to know if it's possible to expect that actual well-being level could be at least maintained for future generations or periods. The notions of flow and stocks are required here, in the sense that future well-being will depend on their fluctuations, since sustainability needs a minimum and constant stock of "wealth". Wealth is understood in a broader sense which doesn't limit to natural resources but includes other forms of capital, in particular human, social and physical capital. To make the difference between well-being and sustainability - involving different temporal scales and different stakeholders with a specific reference to future generations – one needs to consider the assessment through a dynamic approach. Moreover, the difference between flow and stock involves the notion of depletion and irreversibility of "wealth/resources" consumption or destruction. Consequently, the depletion of all kind of capital by a productive process needs to be considered as a reduction of stock and not as an income. It's the case for productive capital considering depreciation mechanism, which immobilizes a value equivalent to the part of technical capital destroyed in the process of production in order to offset the loss of capital. But it's not the same thing for all capital forms. Others limitations concern the consideration of hidden costs (not only direct effects), positive impacts (not only damages), economic price (not only financial price). We will not develop these aspects in this communication.

4. Conclusion: a new theoretical framework

All elements presented previously involve to strike up a deep discussion on theoretical basis. To endow SLCA with a sound theoretical model would allow to structure the framework in a consistent whole. So it would allow not only to determine a set of indicators but also to refer to social impacts, thanks to the identification of logical and organized impact pathways. An approach "by capital" forms seems particularly well adapted. It consists in characterizing a process of growth and development as a production system in which multiple capitals are involved (natural, social, human, and produced/physical). It offers the advantage of placing LCA in a theory of development recognized as well adapted to assess sustainable development due to its perennial and exhaustive character (MDDEP 2009).

Many international organizations used this approach (United Nations, OECD, European Economic Comunity, World Bank, UNESCO, EuroStat). In LCA works, this approach has been proposed more or less explicitly. SEEbalance® (Schmidt et al. 2004) covers the four types of "societal" capital: social, human, produced/physical and natural capital. Labuschagne et al. (2006) mention human, productive and community capital. More recently Jorgensen et al. (2010b) suggest that SLCA has to assess changes in human, social and produced/physical capital. Nevertheless, none of these works fully developed this model (notion of flow and stock, positive impacts, pathways, etc.), it's the purpose of our proposition, according to the conclusion of Jorgensen et al. (2010a), confirming the validity of the impact pathways in SLCA. Moreover, until now, four forms of capital have been considered. We propose a broaden approach distinguishing a fifth form, the institutional capital (norms, rules). Actually it depends on social capital (networks) but it has an existence in itself distinct like demonstrated previously.

Until now, SLCA paid attention to characterize and organize social indicators, next step is to articulate them thanks the multiple capital model, in order to reflect social impact and damage or benefit to the AoPs. This would allow to clarify conceptual framework and methodology.

P. Feschet is member of the ELSA group (Environmental Life Cycle and Sustainability Assessment www.elsa-lca.org *); she thanks all the other members of ELSA for their advice.*

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Integration of environmental tools to support agro-food chain strategic decisions: a techno-management approach

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ABSTRACT

Analysing scientific research, it emerges that agriculture is the most dominant European-27 land use. Moreover, environmental quality management gains much attention in the agribusiness and food industry. From these considerations, it is important to increase environmental impact assessment related to the agro-food chain, but there is still a lack of analytical knowledge about aspects that determine certain types of impact, including one of the most important aspects of agribusiness: land use. The introduction of Technological Environmental Innovations may represent a best practice to tackle the problem, but it is important to integrate tools in order to broaden the social and economic dimensions of sustainable development in the food-chain. Life Cycle Assessment has become an environmental decision support tool that can be used in a techno-managerial approach. This paper explores several of the principal procedural and analytical methods and suggests a framework to broaden the environmental assessment of the agro-food supply-chain.

Keywords: Environmental tools , support decision tools, techno-managerial approach, agro-food chain land-use,

1. Introduction

The greater attention paid by policy makers and by the market to the theme of environmental sustainability has contributed to strengthening the use of a series of decision supporting instruments. In this context the LCA is an excellent tool if it is used to identify and quantify the environmental aspects and impacts of a product, process or activity. However, the multidisciplinary nature of environmental aspects, especially when seen from the decision-maker’s point of view, entails the need to expand this tool to other variables (economic and social). In scientific literature there are various examples of instruments correlated with the objective of developing a more uniform framework that over comes the gaps of single instruments. In this paper we consider the LCA as the main instrument for the evaluation of the impacts of the agro-food chain. In particular, we concentrate on the aspects connected to land use, where the tool shows some gaps in the evaluation of impact, and we propose a framework to support possible solutions in integration with other instruments, according to a techno-managerial approach.

2. LCA for land use management

The maintaining of biodiversity in land use plays an important role in European rural policy in order to improve the state of the environment (Lindeijer et al., 2002). In Europe agricultural activity directly affects the protection, preservation and biodiversity of 50% of endangered endemic species, making it a critical and highly significant activity. In 2007, agriculture utilised 172.5 mil hectares in EU-27 of which 60.5% were dedicated to arable crops, 33% to permanent pastures

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and 6.4% to permanent crops. Agriculture and forestry represent 78% of land use in the EU-27 (European Commission, 2009). This clearly shows how we need to concentrate on land consumption and its relative impacts when dealing with the topic of environmental sustainability in the agro-food chain (Renting et al., 2009).

The inclusion of the land use impact category in LCA studies has shown up a lot of gaps, mainly due to a lack of analytical knowledge of fundamental aspects, such as:
- heavy fragmentation of land use; about 30% of agricultural land in Europe consists of a mosaic of semi-natural landscapes and low intensity cultivations (Stoate et al., 2009);
- the varying impact of agriculture, which can essentially be traced to the intensification of production or the abandonment of land; in both cases it is the main threat for agricultural ecosystems, since it alters the state of the soil, water and air, causing the reduction of biodiversity in agricultural landscapes (Moonen et al., 2008).

A significant contribution to the expansion of the LCA, with relation to land use, is made by the improvement of data quality in the life cycle inventory (LCI) phase. Literature provides two approaches: consequential modelling, which uses marginal data and avoids co-product allocation by system expansion, and attributional modelling, which applies average or supplier-specific data and treats co-product allocation by applying allocation factors (Weidema, 2003; Schmidt, 2008). In Europe since 1985, through the CORINE programme (Coordinated Information on the European Environment), a process has been set up for the collection and hierarchization of data on the state of the environment. The system established, known as Corine Land Cover 2000, defines and divides the classification of the types of land cover and use into three principal levels of scale with different detail. This provides important support in terms of planning and sustainable development; however, the absence of a comparative matrix at a European level attributing a scale of weighted values, differentiated for land use, does not allow us to make comparative evaluations, typical of the LCA instrument. Certainly, greater homogenization of data, with increased detail, thanks to improved photo-interpretation technology, would allow for a more accurate analysis of land use and the way it changes. The central question remains that of defining impacts in relation to the functional unit, but one of the difficulties that emerges is the qualification of the characteristics of the functional unit in relation to the differences in the ecosystem, to native species and to genes (Koellner, 2000). Another critical aspect is the choice of indicators relating to the main types of impact: occupation, transformation and permanent impacts (Weidema et al., 2001). Biodiversity can be expressed through a set of mixed indicators and, in this sense, the EU has chosen a series aimed at monitoring the quality of the countryside in support of environmental management and improvement activities. Among all the various sets of indicators, the most important are those relating to biodiversity, highlighting the subject of the measurement (European Commission, 2009):

- population of farmland birds - trends of index of population of farmland birds;
- biodiversity: high nature value farmland/forestry - area of high nature value farmland (ha);
- biodiversity: tree species composition - area of forest and other wooded land classified by number of tree species occurring and by forest type;
- water quality: gross nutrient balances - surplus of nutrient in kg/ha;
- water quality: pollution by nitrates and pesticides - annual trends in concentrations;
- soil: areas at risk of soil erosion;
- soil: organic farming – utilised agricultural area under organic farming;
- climate change: production of renewable energy from agriculture and forestry;
- climate change: utilised agriculture area devoted to renewable energy - utilised agriculture area devoted to energy and biomass crops;
- climate change: agricultural emissions of GHG gases.

Moreover, although there is scientific literature on performance indicators in agro-food chains, they are mainly connected to cost aspects and there is a lack of uniformity relating to strategy, tactics and effectiveness (Beamon, 1998). The management aspect is not strongly correlated to the environmental impacts distributed among all the process and production activities. It seems clearer than ever, therefore, that we need a techno-management approach that can turn the environmental variable into a critical success factor, using the best technological innovations (Huber, 2008). The development of multi-criteria models of environmental performance management shows how the environmental dimension correlates results to process efficiency, both in project oriented and functional focused models. It is, nonetheless, complicated to analyse how and how much human activity, particularly agricultural activity, influences the level of wealth and specificity of an area, in relation to time, directly and/or indirectly, and which are the external factors (climate change, environmental anomalies, etc.) and their degree of correlation. Moreover, agriculture is more and more integrated with tourism and services and agricultural production influences the appearance of the countryside and quality of life, becoming a strong element of attraction and a factor of competitiveness. Consequently, a clear understanding of environmental impacts, using appropriate instruments, can help to orientate consumers and stimulate producers, promoting sustainable agricultural chains. The LCA is a data intensive methodology, giving results that may be different for the same product in relation to how it has been implemented, creating confusion among consumers; nonetheless, it allows us to introduce environmental aspects into the agro-food chain, highlighting the efficiency of the process/product in relation to impacts (Hagelaar et al., 2002). Aramyan et al., (2006) indicate the LCA as a useful instrument for developing guidelines for managers of supply chains from an environmental perspective; to relate a supply chain to its environmental performance and to assess the applicability of LCA as a tool for environmental supply-chain management and highlight how this managerial instrument is conditioned by factors external and internal to the chain such as competition, governmental laws, consumer preferences (external) and budget, knowledge, technology, cooperation (internal), etc. Besides, the LCA is able to respond to the growing demands of consumers on a broad range of quality aspects like food safety, production characteristics, sensory properties, shelf life, reliability, convenience, availability and quality/price ratio (Van der Spiegel, 2004).

3. Integration of environmental support decision tools: a system framework

An analysis of scientific literature shows that attention is paid to the theme of integration among the various environmental oriented instruments, in order to put forward a framework that shows up the overlaps and fills the gaps in the single instruments (Baumann & Cowell, 1999). In this sense, in order to consider the agro-food chain, we need a techno-management approach that explores several integrable LCA-related procedural and analytical methods and refers to the technological progress, through Technological Environmental Innovations (TEIs), including any kind of innovations, such as technical, economic, legal, institutional and organisational ones (Huber, 2008). This approach allows us to correlate management methods and instruments with other operational ones and, by balancing them, to rely on the ability to use the best technology available effectively and efficiently, also for communicating and orientating the market (Luninga & Marcelisb, 2006; Huber, 2008). A framework with these characteristics should be coherent and functional for governance actors (companies, government agencies, NGOs) and, in relation to the agro-food chain, it should allow us to choose the scale of intervention on which to make decisions (invalidated by the widening of markets). Moreover, given the complexity and uncertainness of the outcomes of decision making, this framework should deal with all the various activities and associated impacts, following an approach based on relational and interdependence processes, and setting out a significant time period (the effects of land use impacts show up over a long period of time) (Finnvedena & Moberg, 2005). Besides, the implementer/user has to position the framework among four possible approaches: land use approach, actor-oriented approach, marked oriented approach and Public regulation approach (Renting et al., 2009). Finally, as regards the instruments to be integrated, the framework, while remaining highly versatile, should allow a significant degree of diversification of instruments on the basis of the specific analysis requirements to be satisfied. The framework in figure 1., land use referenced, aims to simplify interpretation of information, making it more legible and including more aspects relating to the chain of production under examination and, thus, allowing us to widen both internal analysis and analysis in support of benchmarking.

		Approach	Land use approach	Actor-oriented approach	Marked oriented approach	Public regulation approach
TECHNO-MANAGERIAL APPROACH		Criteria	• Maintaining biodiversity • Landscape protection • Recovery of historical endogenous crops	• Creating value • Increasing profits • Reducing corporate environmental risks • Introducing innovation	• Increasing food quality • Guaranteeing food safety • Introducing new green products	• Land use planning • Legislation • Ownership • Responsibility • Cultural issues • Health and safety
STATE OF ENVIRONMENT		Indicators	• Loss of biodiversity, • Loss of soil quality, • Loss of biotic production potential	• Cost analysis • Environmental risk analysis • Performance indicators	• Customer satisfaction • Consumer-driver perspective • Hedonic scaling indicators	• Active planning instruments • Specific laws • Participation and negotiating processes
Aspects	**Criteria**	**Indicators**	Functional expectations for integration			
Environmental land use	Conservation of biodiversity – on-site	• Ecosystems identified • Flora species present • Fauna species present • Endangered species present • Native vegetation cleared • Remnant vegetation • Remnant vegetation condition • Weed species present	Measuring variations in biodiversity in relation, e.g., to the agricultural phase: • Land clearing • Levelling • Sealing • Ploughing • Draining • Irrigating • Sowing • Fertilizing • Suppress pests and diseases • Mowing • Harvesting	Analysing economic advantages in relation to environmental risk reduction, identifying and measuring land use costs, also in relation to the use of new technologies and processes.	Increasing consumer perception of the impacts of agricultural production and land use.	Identifying the best prospects for land use on the basis of concrete data and unequivocal results, through the development of easily accessible analytical reports.
	Rehabilitation	• Number of sites • Number of sites rehabilitated to 'sign off' • Number of sites closed • Number of abandoned, derelict/orphaned sites • Number of sites used for alternate land uses • Total area rehabilitated • Total area remaining • Proportion remaining	Measuring quantitative aspects in order to determine the availability of productive land withstanding land abandonment and consumption.	Analysing the best available areas for agricultural production in the light of direct and/or indirect economic gain.	Promoting a market orientated towards food choices that internalise the relationship between eco-friendly forms of agriculture and the vocation of agricultural areas.	Supporting government decision makers, on a quantitative basis, in determining optimal land use and change policies, in relation to environment, production and social requirements.
	Land condition	• Hazardous solid waste on site • Hazardous liquid waste on site • Tailings on site • Coarse rejects on site • Spontaneous combustion • Acid rock drainage • Physical assessment	Measuring qualitative aspects, evaluating pre-existing situations in order to promote agriculture as an environmental upgrading practice.	Identifying costs due to the effects of agriculture on land condition, in order to introduce product and/or process innovation.	Using easily readable labels and information instruments that increase consumers' level of environmental responsibility.	Having a significant set of parameters and evaluations in order to allow, e.g., the issuing of licences/permits.
	Off-site impacts	• Visual • Noise • Dust • Sediment yield • Water quality • Water discharge • Weed invasion	Correlating the direct impacts of agriculture with the indirect impacts of land use in neighbouring areas.	Evaluating environmental costs of choosing agricultural areas over areas exposed to indirect risks.	Providing information on indirect environmental aspects of other activities in order to create a global environmental market.	Having a tight-knit system for identification of correlations among environmental impacts of different activities over which government authority or control is needed.

Figure 1: Guideline expectations for functional integration among environmental instruments

This framework could help to choice the best environmental tool integration approach. In this light, we can mention some previous experiences of integration of the LCA tools:
- Jeswani et al. (2010) propose a distinction between two types of LCA-related instruments: procedural ones offering strategic-decisional support and analytical ones. Some of the procedural tools, aimed at defining sustainable policies and verifying the environmental compatibility of projects are: Environmental Impact Assessment (EIA), Strategic Environmental Assessment (SEA), Sustainability Assessment (SA) and Multi-Criteria Decision Analysis (MCDA). The operational instruments orientated towards environmental, economic and social aspects, also in an integrated way, include: Material Flow Analysis (MFA), Substance Flow Analysis (SFA), Energy/Exergy Analysis (EA), Environmental Input–Output Analysis (EIOA), Risk Assessment (RA), and, finally, relating to cost aspects: Life Cycle Costing (LCC), Cost Benefit Analysis (CBA) and Eco-Efficiency (EE);
- Hermann et al. (2007) propose integration among three tools: LCA, Multi-Criteria Analysis (MCA) and Environmental Performance Indicators (EPIs) in order to obtain an actor-oriented tool, designed for application to companies and sectors, and also to processes or products.

The fundamental aspect to be respected when constructing the framework is that of basing the various instruments, in relation to their specific characteristics, on the type of data/information available and in relation to the type of output expected. For this reason, the framework could be constructed by using the following procedure (Wrisberg et al., 2002): definition of decisive objectives, of time and space characteristics, of key questions (strategic planning, capital investments, design and development, communication and marketing and operational management, including purchasing), of improvement levels (from incremental improvements to system redesign), of the importance of sub-systems, identification of decision-makers' aspirations (defensive followers, continuous improvers or pro-active innovators), identification of chain control levers (the degree of control by an actor in a chain of processes), of key decisions (from regular and routine decisions to single, unique decisions), of decision steps (issue definition, criteria setting, option generation, option assessment and final decision) and, finally, of the cultural context in which the actor operates or sells. Finally, in relation to functional expectations, environmental instruments can be adopted and integrated in a coherent way.

4. Conclusion

The complexity and multidimensionality inherent in the agro-food chain is reflected in relative decision making, highlighting its multi-criteria nature. Policy makers, producers and consumers determine market choices and produce, directly and/or indirectly, serious effects on the change of land use. Scientific literature proposes interesting solutions in support of decision making, indicating possible integrations among tools that internalise environmental variables. However, the considerable fragmentation of agricultural businesses and the low cultural level of those working in them are a serious obstacle to the concrete adoption of these instruments. As a result, these instruments tend to be orientated towards profit because they are implemented by large companies, while governments use them for policy purposes, but sometimes on too high a scale. Certainly, great attention is paid to protection and preservation of natural heritage, supported by a widening of the supply of TEIs; however, despite an increase in land use protection policies, there is still an evident lack of responsibility among consumers and consequently of an effective market drive.

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Review of methodological choices in LCA literature

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ABSTRACT

This literature review analysis the methodological choices made within LCA literature. Most studies perform a cradle-to-farm gate analysis and base allocation on economic value. A large variation exists between the choice of the functional unit. It was concluded that in general papers do not or do poorly describe their computational models and tools. Also, little in-depth assessments are performed. More thorough descriptions on methodological choices and in-depth assessments can increase the learning factor for other researchers and enhance the reproducibility of the computations.

Keywords: Literature review, LCA tools, methodology, functional unit, system boundary

1. Introduction

The methodology of Life Cycle Assessment (LCA) has received increased attention over the last years. Especially since the start of this century, studies on the life cycle of agricultural products have appeared, both in scientific and non-scientific publications.

LCA studies show a large variety with respect to the methodology applied. The methodological steps are described in ISO (2006), which formulates guidelines for performing an LCA. Specific steps in the methodology are e.g. the definition of the system boundary and the functional unit. On a more practical level the researcher will have to make decisions regarding the use of tools and computational models. A clear description of the choices made in these methodological steps increases the learning factor for other researchers, helps them to interpret the results, and enhances the reproducibility of the computations. To our knowledge, no meta-analysis exists that depicts the distribution of papers over the methodological choices.

This literature review was performed with two main research goals. Firstly, our aim was to analyse the distribution of LCA literature over methodological choices. The second research goal was to explore the degree to which choices concerning these methodological steps are described and justified in LCA publications.

2. Method

In this study we considered the following methodological choices: system boundary, use of functional unit, allocation strategy, use of tools and data sources, and the performance of an in-depth assessment (table 1). Two methodological issues were considered which are not shown in the table, but are shortly discussed in the results. These are the number of farms on which the computations are based, and the degree to which computational models are described. In the table, papers are grouped based on their main research goals. The eight research goals we distinguished were: mitigation options, hotspot identification, measuring variation,

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temporal comparison, input comparison, process comparison, spatial comparison and product comparison. Our literature review is of a qualitative and explorative nature.

For this literature review LCA studies on animal products other then fish and written in English were included. We searched in Scopus and the Web of Science in the Wageningen UR Digital Library, and the book of Proceedings of the 6th International Conference on LCA in Zurich in 2008. Besides, the first order snowball effect was applied to include referenced LCA studies.

3. Results and Conclusions

The 47 selected papers were divided over the product categories dairy, poultry, pig and beef with respectively 16, 8, 7 and 7 papers. Nine papers performed an LCA on multiple products. ‘Hotspot identification’ and ‘process comparison’ were among the main goals of nearly half of the studies.

The majority of papers has chosen cradle-to-farm gate as system boundary, excluding steps such as product processing and waste management. Variation exists with regard to the starting point of the system, the cradle. For example, the cradle mostly excludes, but sometimes includes production of machinery (Basset-Mens and Van der Werf, 2005) and production of seeds (Cederberg and Mattson, 2000).

We found that many different functional units were defined, which makes it more difficult to compare products. Especially studies on meat show a large variation in functional unit, e.g. ‘fat-and-bone-free meat’, ‘consumable meat’ or ‘meat’, the latter two leaving room for interpretation.

Nearly 40 percent of the papers did not describe which tool was used. Around half of the studies explicitly mention the inclusion of data from other studies into their own computations, such as the inclusion of Life Cycle Inventories on feed ingredients for animal production. In general, little detail is provided on the validity of these data.

All papers provide descriptive results such as the computed emissions and proportional differences. Though, with a few exceptions, little in-depth analysis were performed. In general, little or no indication about the observed variance is provided. This makes it difficult to draw any finite conclusions on comparisons between systems or on mitigation options. It is common practice to poorly describe the details of the computational model used.

A substantial number of papers base computations on the average farm. It is often not well defined whether this should be interpreted as a typical farm or as average values over a group of farms.

4. Recommendations

In order to increase the learning factor and reproducability of LCA studies, we recommend a more thorough description of the tools and computational models used, the performance of an in-depth assessment and an indication about the observed variance.

Table 1: Framework for analysing LCA papers on the basis of methodological choices (numbers in the table refer to reference list underneath table)

	Mitigation options	**Within systems**		**Between systems**				
main objective ==>	Mitigation options	Hotspot identification	Measuring variation	Temporal comparison	Input comparison	Process comparison	Spatial comparison	Product comparison
System boundary								
cradle-farm gate	7,9,10,14,19,30,31	1,13,15,14,16,19,21, 24,26,28,32,40,43	4,26,37,44	21	1,2,4,8, 10,26	1,2,11,13,15,16,17,20,24, 30,32,33,35,34,38,40,47	1,26	7,9,26,36
cradle-industry		39			5	5,39		29
cradle-wholesale	18,41	18,41						27
cradle-retail		23				22		22
cradle-household	42	42,45,46				25		3,42
cradle-crave	12	6,12				6		
Functional unit								
unit of FPCM		32	37			32		36
unit of FCM		26	26		26	22	26	3,22,26
unit of ECM	19	15,16,19,40				15,16,40		
unit of raw milk			44			17,2		
unit of eggs		26	26				26	3,26
unit of SW						35,47		
unit of liveweight	31	1,13,39	4		1,2,4,5	1,2,5,13,39	1	
unit of protein						25		
unit of land		13,15,40				13,15,17,40		36
other	7,9,10,12,14,18, 30,41,42	6,12,14,18,21,23,24,26, 28,41,42,43,45,46	26,44	21	8,10,26	6,11,24,30,33,38,40	26	3,7,9,26,27,29,42
Allocation								
mass	7,41	6,16,26,41,46	4,26		4,8,26	6,16,22	26	7,22,26,27
economic	9,12,14,18,19	6,12,13,15,14,16,18, 19,28,32,40	37		8	6,13,15,16,20,25,32, 33,35,40		3,9,27,36
system expansion	12,31							
other/unknown	10,30,31	1,6,43,45	44	21	1,2,5,8,10	1,2,5,6,11,17,22,30,47	1	22

Continued Table 1: Framework for analyzing LCA papers on the basis of methodological choices (numbers in the table refer to reference list underneath table)

	Mitigation options	Within systems			Between systems			
main objective ==>	Mitigation options	Hotspot identification	Measuring variation	Temporal comparison	Input comparison	Process comparison	Spatial comparison	Product comparison
Tool								
SimaPro	10,30,31,41	13,41			10	13,20,30,38,47		27,29,36
Excel		26, 40	26		26		26	26,36
unknown	7,12,41	1,6,12,28,39,41,45,46			1,4,5,8	1,5,6,11,17,25,34,39	1	3,7
other	9,10,14,42	13,15,14,32,42,43	4,44		2,1	2,13,15,20,32,33,35,40		9,29,42
Data source								
EcoInvent	10,41	23,26,28,41	26		5,10,26	5,20,47	26	26,27,36
interview	41	13,28,41,43,45,46				11,13,17,20,22,35		3,22
empirical results	9,12,14,18,41	1,6,12,13,14,16,18,23, 32,39,40,41,43,46			1,2	1,2,6,13,16,32,33,35, 38,39,40,47	1	3,9
In-depth assessment								
descriptive	All	All	All	All	All	All	All	All
ANOVA		15,21,32		21		15,17,32,33		
OLS regression		26,45	26		26		26	26
PLS regression		40	37			40		
other	9,10,31,42	13,28,32,40,42	4,44		2,4,10	2,13,17,25,32,33,40		9,42

FPCM= Fat and Protein Corrected Milk; FCM= Fat Corrected Milk; ECM= Energy Corrected Milk; SW=Slaughtered weight; PLS= Partial Least Squares; OLS= Ordinary Least Squares. 1= Subak (1999); 2= Halberg et al., (2007); 3=Carlsson-Kanyama (2003); 4=Casey and Holden (2006); 5=Bennet et al., (2006); 6=Eide (2002); 7=Elferink and Nonhebel (2007); 8=Elferink et al., (2008); 9=Eriksson et al., (2005); 10=Nielsen et al., (2008); 11=Stern et al., (2005); 12=Berlin (2002); 13=Basset-Mens and Van der Werf (2005); 14Cederberg and Darelius (2002); 15=Cederberg and Flysjö (2004); 16=Cederberg and Mattsson (2000); 17=Haas et al., (2001); 18=Hospido et al., (2003); 19=Casey and Holden (2005); 20=Basset-Mens et al., (2009); 21=Meul et al., (2007); 22=Grönroos et al., (2006); 23=Usva et al., (2008); 24=Ogino et al., (2004); 25=Zhu and Van Ierland (2003); 26=Williams et al., 2006; 27=Ellingsen and Aanondsen (2006); 28=Dekker et al. (2008); 29=Núñez et al (2005); 30=Ogino et al.(2007); 31=Pelletier (2008); 32=Thomassen et al. (2008); 33=Mollenhorst et al. (2006); 34=Audsley and Williams (2008); 35=Alvarado-Ascencio et al. (2008); 36=Kanyarushoki et al. (2008); 37=De Boer et al. (2008); 38=Teixeira et al. (2008); 39=Prudêncio da Silva Júnior et al. (2008); 40=Corson and Van der Werf (2008); 41=Heller et al. (2008); 42=Weidema et al. (2008); 43=Cederberg et al. (2008); 44=Alig et al. (2008); 45=Schlich et al. (2008); 46=Garcia-Suarez et al. (2008); 47=Boggia et al. (2010)

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Social Life Cycle Assessment: looking for consensual indicators

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ABSTRACT

This paper aims to identify relevant social life cycle assessment (SLCA) indicators, based on the study and comparison of well-known and commonly used sustainability standards in the food sector (FLO, ESR, IMO, ETI, UTZ, Rainforest Alliance and Globalgap). The choice of relevant SLCA indicators is based on: (i) their realism and applicability (they must be easily verified by a third party); and (ii) existing consensus among the standards on “minimal requirements” to certify sustainable practices in the food sector. Our main contribution to the debate on the choice of significant and relevant SLCA indicators is to identify areas of consensus between the different standards studied and to question the definition of a socially sustainable product.

Keywords: Social LCA, Methodology, Social standards, indicators, Food sector

1. Introduction

Consumers are increasingly concerned by the conditions of production and trade of the goods they buy, and are ready to pay more for products with such desired attributes as food safety, environmental protection, respect of human and labour rights, animal welfare, etc. In the food industry, private firms have reacted to these new concerns by developing various strategies, including the development of certification systems and labelling.

Underlying such strategies, methodologies have been developed to assess and communicate the impacts of transnational production and trade flows “from the farm to the fork”. Among these methodologies, Life Cycle Assessment (LCA) has been enjoying growing popularity over the last decade. Based on a holistic and systemic approach, LCA is a relevant tool to collect information about potential and real impacts of a product over its entire life span (UNEP-SETAC, 2009). Traditionally designed to evaluate environmental impacts, LCA tools have only recently focused on social issues. Both the current development of ethical trade and the growing interweaving of social and environmental issues make it important to question LCAs ability to address social impacts. Several attempts to design a Social Life Cycle Assessment (SLCA) were made, but no consensus has yet been reached.

In a review of different SLCA approaches, Jorgensen *et al.* (2008) reveal two main approaches in the choice and formulation of indicators. In the *top-down* approach, indicators are selected based on international acceptance and representativeness of globally recognized societal values (Dreyer *et al.*, 2006; Kruse *et al.*, 2009). The formulation of these macro-level indicators is particularly helpful to avoid modelling too many insignificant impacts (Weidema, 2006). The main problem of this strategy is that the selected indicators are but loosely connected with the real world (Kruse *et al.*, 2009). In an attempt to better take into account local realities, the *bottom-up* approach identifies indicators at the micro-level (Kim and Hur, 2009; Kruse *et al.*, 2009), based on industry, stakeholder interests and/or data availability (Kruse *et al.*, 2009). The problems of this approach are a heavy reliance on *ad hoc* indicators and high site specificity.

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Another issue is related to the measure and aggregation of indicators across life cycles to allow a comparison of supply chains. Norris (2006) develops an approach to assess the social attributes of a supply chain – the Life Cycle Attribute Assessment (LCAA). LCAA is a quantitative methodology based on practical reporting and aggregation of attributes across a life cycle analysis. Instead of calculating quantitative impacts, LCAA provides performance in a relative way within the supply chain (Andrews *et al.*, 2009). According to Norris, process attributes can be whether or not a company is certified as following best management practices, as prohibiting child labour, etc. Andrews *et al.* (2009) apply this approach to the Quebec greenhouse tomato supply chain. The authors focus on local labour and select seven indicators, including: workplace insurance for employees, medical insurance for employees, wage above one or two times the minimum wage, annual health and safety incidence rate published by the company, etc. The authors consider these indicators as analogous to midpoint indicators in environmental LCA and consider them as good proxies of improved management of community impacts. However, Andrews *et al.*(2009) highlight the need of further research on the definition of indicators. Indeed, the choice of indicators has many implications for the analysis of the product system's performance. Academics in the field of LCAA underline the need to emphasize the connection with indicators in the field of certifications.

Drawing on this proposition, we contribute to the debate on the definition of relevant indicators by analyzing well-known food sector standards. To do so, we compare existing indicators belonging to: fair trade standards (FLO, ESR and IMO); private ethical standards (ETI); and ethical indicators from more general sustainability standards (Rain Forest Alliance and Utz) and one private standard (GlobalGap). Many of these standards are developed to regulate international trade flows of food products between developed and developing countries. As a result, many indicators bear the mark of this peculiar focus. Still, we think that the broad spectrum of indicators used by standards is little explored by the literature on LCA, and may be useful to define a socially sustainable product through consensual indicators.

This paper is organized as follows. First we describe the standards chosen and the method we use for comparison. We then present the results of our analysis. Finally we discuss the results by comparing them to the propositions found in the current literature.

2. Methods

Within the SLCA literature, there are two ways to qualify the hierarchical organization of indicators: (1) drawing on environmental LCA, some authors such as Weidema (2006) use the hierarchical organization based on *endpoint, midpoint and inventory indicators*; (2) UNEP SETAC (2009) identifies *impact categories, subcategories and inventory indicators*. A useful parallel is found at the international level where standards are negotiated: stakeholders express their codes of conduct in terms of *principles, criteria and indicators*. We assume that this hierarchical organization is comparable with that used in the LCA literature. This will facilitate our analysis and discussion within the debate on the definition of indicators. In addition, by using existing standards, we get rid of the problem of measure since the standards go together with checklists for certification bodies to assess stakeholder compliance. As a consequence, they already focus on easily available data that can be estimated at the inventory level and for which criteria may be relevant to assess.

In our analysis, we use seven sustainability standards that are currently used in the food sector. For the sake of comparability, we use the codes of conducts for the certification of coffee, which is a common product for all the selected standards. The Fairtrade labelling Organisation (FLO) is a group of international fair trade organizations created in 1997. FLO develops and reviews fair trade standards aimed at supporting small and vulnerable farmers in developing ountries. Ecocert is a French certification body that created its own fair trade standard in 2007, called *Echanges Equitables, Solidaires et Responsables (*referred to as ESR hereafter). IMO is a Swiss certification body that launched in 2006 its own social and fair-trade certification called *Fair for Life*. All three standards seek to improve the livelihoods of small producers and plantation wage workers. We use in this research the codes of conduct of plantations, since they give more indicators for wage workers. The Ethical Trading Initiative (ETI) is an alliance of companies, trade unions and voluntary organisations created in 1998. ETI works to improve the lives of workers across the globe. Global Good Agricultural Practices (GG) was created in 1997 by European retailers. This standard promotes good agricultural practices and improved farm management techniques. Rainforest Alliance (RA) is an international NGO created in 1987 to fight tropical deforestation. Its standard does not prohibit the use of agrochemicals but requires integrated pest management, the maintenance of shade cover and/or the restoration of native forest reserves. It also expresses concerns for the rights and welfare of workers and the interests of local communities. Utz certified is an independent multi-stakeholder initiative created in 1997 to promote responsible production and sourcing practices. Its standard covers good agricultural practices in coffee production and worker welfare, including access to healthcare and education. The last three standards are not socially oriented but have developed a social section in their codes of conducts. All the standards, analyzed here, claim to have all representative committee to negotiate and decide the certification design (including producer's organizations). The documents used are listed in the references.

Firstly, we identify the set of common criteria (equivalent to midpoints or categories) present in each standard according to a series of principles (equivalent to endpoints or categories) stated in their codes of conduct. We then compare these standards, based on their score for each criterion. The score is obtained by adding the number of compulsory indicators for a given criterion. It is equal to two if the indicator is compulsory and is null otherwise. The scores are then expressed as the percentage of the total score of the given standard. We show the comparison results in a table. Secondly, we identify areas of consensus among the indicators that we call *minimum social requirements to certify sustainable practices in the food sector*. To do so, we sum the number of standards where a given indicator is compulsory. Given that we selected seven standards and that the score of an indicator is equal to two when it is compulsory, the maximum total score obtained for an indicator (all standards included) is 14 and can be considered as a major consensual indicator. To represent these results, we use spider web graphs, where axes are the indicator scores.

3. Results

The three criteria with the largest number of indicator scores are *Health, Safety and Hygiene* (213), followed by *Prohibited labour Employment Practices* (197) and *Conditions of Employment* (106). The results show major differences on standard priorities in terms of social welfare (Table 1). Globalgap focuses only on the Health, Safety and Hygiene criteria. Rainforest Alliance clear focuses on Prohibited labour Employment Practices. The other standards are more diversified. The less used criteria are: Discrimination, Social Benefits and Right to Association.

Insofar the standards do not adopt all identified criteria (*e.g.* Globalgap only focuses on one criterion), there is no consensus about what indicators represent *a minimum social requirement* (Figure 1). Despite big differences between the studied standards that we will not detail here – *e.g.* in their objectives, scope, style, ownership, promoters, or in the way of ensuring compliance –, there are areas of agreement that we identify as minor consensual indicators.

Within the *Health, Safety and Hygiene* criterion, we identify three consensual indicators: "safety equipments" "risk management policy" and "access to drinking water". Concerning the *Conditions of Employment*, the only indicator retained is "compliance with the national legislation on minimum legal salary". Within the *Working Hours* criterion, the only indicator retained is "number of extra hours". The *Discrimination* criterion shows "no discrimination on salary level" as a consensus. Within the *Prohibited Labour Employment Practices*, we identify five nearly consensual indicators: "prohibition of child labour" "prohibition of forced labour" "no corporal punishment" "no retain legal document by the employer" and "young workers (in general between 15 years and 18 years) are not allowed to be engaged in inappropriate work (such as, hazardous work, night work…)". Finally, within the criteria *Right to Association* and *Social Benefit*, there are no consensuses at all.

The studied standards borrow several criteria and indicators to international agreements such as the *Universal Declaration of Human Rights* or the *International Labour Organization* as seen above. Nevertheless, some of these indicators – *e.g.* "freedom of association (conv. 138)" or "collective bargaining (conv. 98)" –, are not considered as priorities by the standards. As the UNEP guideline for SLCA (2009) highlights, international conventions often represent a minimum to attain. Although in many developed countries, the legislation already covers many principles of these international instruments and non-compliance represents a criminal offence, in developing countries this might not be the case. This explains why sustainability standards tend to focus on these minimum levels. Voluntary standards being designed "to avoid blame and shame", they focus on worker health and safety, on extreme labour practices (child labour, forced labour, corporal punishment) and on compliance with national legislation on minimum legal salaries. Although these standards as unsatisfactory for defining a socially sustainable product, they are certainly more appropriate in the context of developing countries. For instance, the indicators proposed by Andrews *et al.* (2009) – *e.g.* workplace insurance and basic medical insurance for employees – may be not relevant in many developing countries where this kind of insurance does not exist. Additional research is probably needed to include the perception of the main stakeholders, and therefore to use indicators that are meaningful for them in a specific context.

Table 1: Comparison of criteria scores among food standards

	Flo	**ESR**	**IMO**	**ETI**	**UTZ**	**RA**	**GG**	**∑**
Health, Safety & Hygiene	20	24	18	14	23	14	**100**	**213**
Conditions of employment	20	20	26	17	9	14	0	**106**
Working Hours	18	4	16	17	20	0	0	75
Social Benefits	5	0	5	3	11	0	0	26
Discrimination	10	8	5	10	6	0	0	39
Prohibited Labor Employment Practices	15	36	24	28	23	**71**	0	**197**
Right to Association	13	8	5	10	9	0	0	45
TOTAL	**100**	**100**	**100**	**100**	**100**	**100**	**100**	

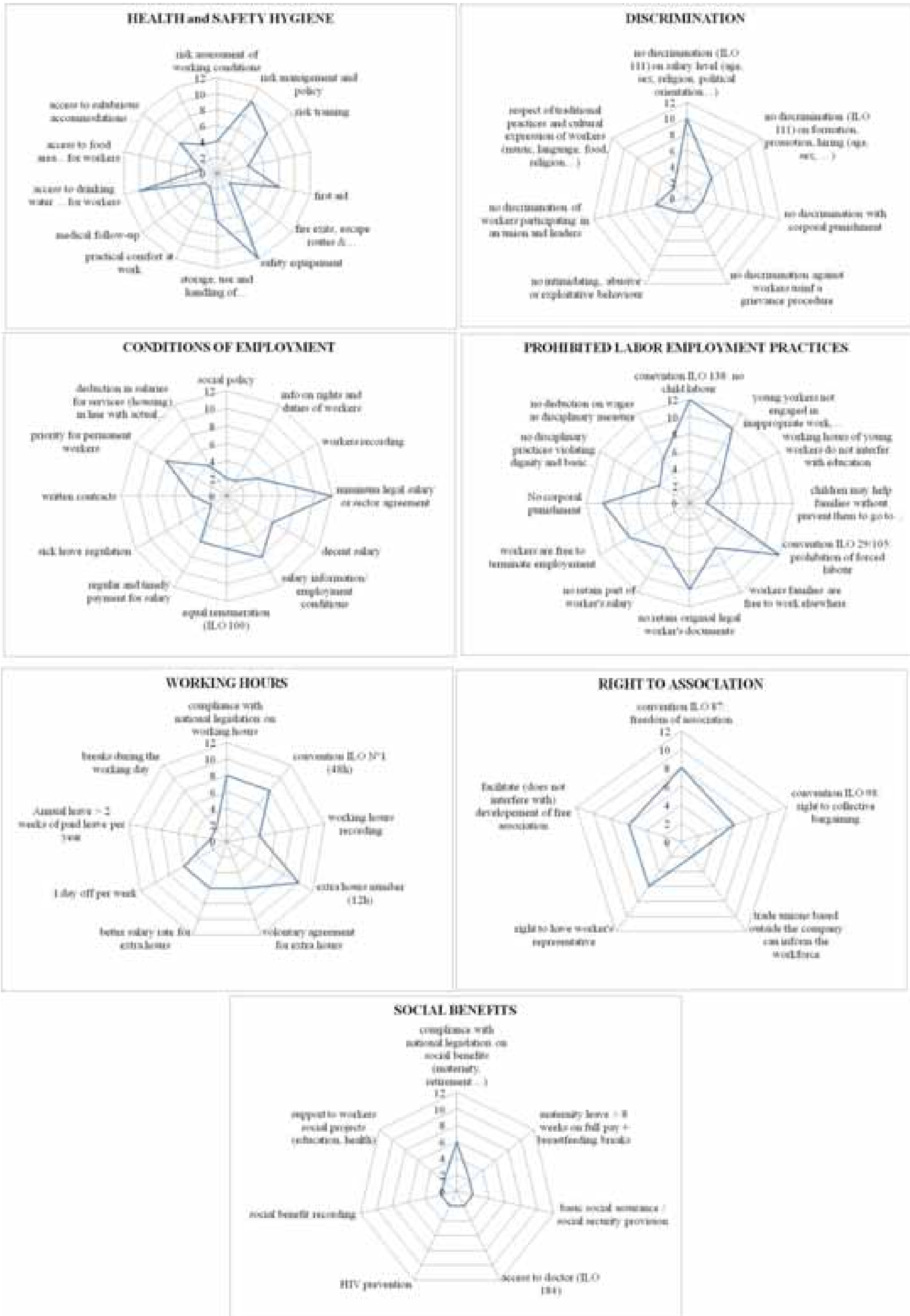

Figure 1: Identification of consensual social indicators among food standards

4. Conclusion

Despite growing consumer concerns about the social dimension of sustainable development, no consensus has yet been reached concerning the identification of appropriate indicators. This paper addresses this issue by studying the indicators used by seven sustainability standards from the food sector. Our hypothesis was that they may help us identify suitable social criteria. This method solves the problem of availability and measurability of the chosen criteria, since these standards are easily verified by third party certifiers. We analyse common criteria and investigate areas of consensus around indicators that we interpret as *minimal requirements* in the certified sustainable food sector. Results show that there is little consensus among the indicators and that the standards seem to be much more oriented towards "no blame no shame" strategies than towards social sustainability. Indeed, the criteria that encompass most consensual indicators are: *Health, Safety and Hygiene* (3) and *Prohibited Labour Employment Practices* (5). This may seem surprising since many of these standards claim to have been negotiated together with the stakeholders (namely producers and producer's organizations). In the end, our results question the ability of sustainability standards to be a basis for defining socially sustainable products. Nevertheless, these instruments have the advantage of focusing on indicators connected with local realities.

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A GIS-based biodiversity impact assessment method for LCA

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ABSTRACT

The authors propose a new impact assessment method for biodiversity in Life Cycle Assessment. It uses GIS-generated inventory data in the form of area of land use types in the study region. Characterization factors for each type of land use are calculated based on the species richness of the respective land use type and the abundance of each species. The impact is calculated by multiplying the characterization factor and the area difference between two states, so the basic principle of LCIA remains untouched. This enables a smooth integration of the new method into existing LCA tools.

Keywords: Land use, Biodiversity, GIS, Regionalization

1. Motivation

LCA methodology is supposed to yield a comprehensive environmental profile of products (Rebitzer *et al.* 2004). Standard LCA practice is just beginning to assess land use impacts. At this point, the UNEP/SETAC framework for land use in LCA (Milà i Canals *et al.* 2007) seems to achieve a high degree of consensus. Biodiversity is explicitly mentioned as one aspect of land quality in the framework. How to implement that part of the framework is the subject of scientific discussion around the world. The article at hand proposes a method for the assessment of the impact of land use on biodiversity. The starting point for the characterization model is inventory data which are generated in a GIS simulation, as described by Geyer *et al.,* (2010a). A broader range of biodiversity impact assessment methods are examined in a second paper by Geyer *et al.,* (2010b). Among them is the one proposed in this article, but in a general, rather open form. In order to throw a definite version into the discussion, it is presented here "as is" with all degrees of freedom fixed.

2. Proposed method

The method proposed in this work is called Rarity Rated Richness (R^3). It is a pure conservation value indicator, so it does not assess the ecologic function of species. Rare species are treated as more valuable than abundant species, which reflects the way conservation priority is defined e.g. by the WWF or similar organizations. Rarity is basically a lack of abundance, so abundance needs to be defined. The proposed method uses potential habitat area as a measure of abundance. The potential habitat area is the total area of all land use types which are suitable for a certain species. The California Wildlife Habitat Relationships database (CDFG, 2005) provides the link between species and land use types. It should be noted

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that in the context of this work, “land use” does not necessarily mean that the land is actually used by humans. The list of different land use types used for this work includes anthropogenic environments (e.g. “urban”, “irrigated row crops”) as well as natural environments (e.g. “wetlands”, “montane hardwood forest”).

The biodiversity impact of land use change is calculated as the difference between two states of a study area. The area of each land use type is used as an inventory flow. The characterization factors assigned to the inventory flows are a weighted sum of the species for which the respective land use types present potential habitat. The species are weighted by rarity (hence the name). Equation 1 shows the calculation of the land quality change.

$$\Delta Q = \sum_j CF_j \left(A_{j,1} - A_{j,0} \right) \qquad (1)$$

Q	land quality (biodiversity, conservation value) [m² USH]
CF_j	characterization factor for land cover type j [m² USH/m²]
$A_{j,t}$	area of land cover type j at time t [m²]
$t = 0$	before land use change
$t = 1$	after land use change
j	index referring to habitat types

The characterization factors CF_j are calculated as follows: Each species i is linked to a certain number of land cover types j and thus has a certain area of potential habitat A_i (equation 2).

$$A_i = \sum_j h_{ij} A_j \qquad (2)$$

A	area [m²]
h	elements of the habitat suitability matrix
i	index referring to species

The proportion of this area is defined as that species’ relative abundance a_i (equation 3).

$$a_i = \frac{A_i}{A_{tot}} \qquad (3)$$

a	relative abundance, based on habitat area [m²/m²]
tot	index referring to the total study area

The relative abundance values a_i for each species are transformed into rarity values R_i based on a logistic curve (equation 4).

$$R_i = \frac{1}{0.01 + a_i} \qquad (4)$$

R	rarity [ ]

The rarity values for each species for which the land cover type provides potential habitat are summed up and defined as that land cover type’s characterization factor CF_j (equation 5).

$$CF_j = \sum_i h_{ij} R_i \tag{5}$$

The rarity of species is a dimensionless index, but the characterization factor derived from it does have a unit (see equation 1). The unit is m² of ubiquitous species habitat (USH) per m² of the respective land cover type. It indicates the exchange rate of the land cover type to a hypothetical land cover type with only one ubiquitous species (rarity ≈ 1). For example, the characterization factor for irrigated grain crops (IGR) is 197, which means that the conservation value of all the species which may use IGR as habitat is 197 times higher than the conservation value of the hypothetical USH. Each m² of IGR is equal to 197 m² of USH.[1]

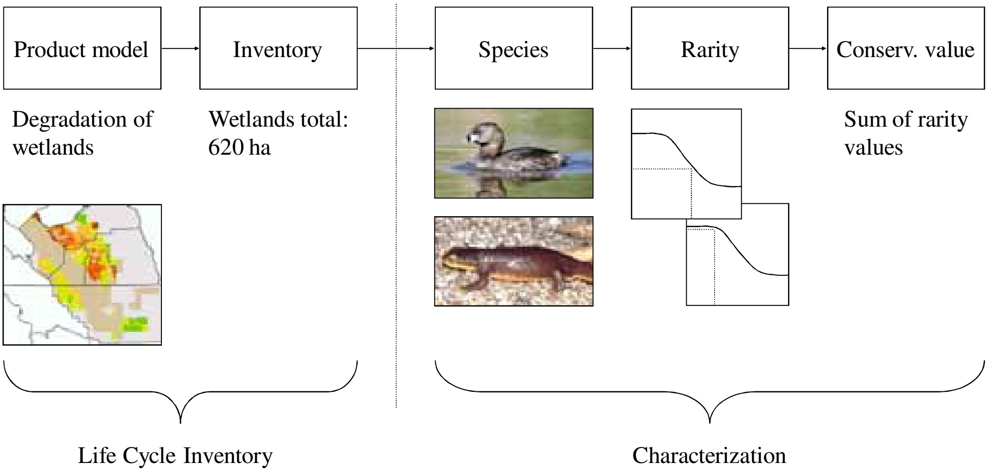

Figure 1: Life Cycle Impact Assessment using the R³ method, exemplified with wetlands

It has not been stated above at which time the CF_j shall be calculated. The landscape structure in t_0 and t_1 is obviously different, so the CF_j would also be different. For demonstration (Lindner, 2008; Geyer *et al.*, 2010a; Geyer *et al.,* 2010b) they have been calculated at t_0. If there was a defined reference state for land, the rarity values could as well be calculated from the reference state.

3. Rationale for the method

This section covers the rationale for the many choices that led to the definition of the R³ indicator/method as described above.

Land use type area as inventory/basis for impact assessment: By characterizing land use type areas, the R³ method is sensitive to the relevant changes in the system under investigation. The loss of habitat due to land use change has been identified as one of the top drivers of the loss of biodiversity (MEA, 2005). Land use data is relatively easy to obtain, contrary to e.g. species counts. In case few or little land cover data are available on a region, it is generally more feasible to obtain the missing data by remote sensing than by field sampling. Disturbance and succession are automatically accounted for, because the CWHR database integrates species ranges over the course of the year. It is possible that a habitat is classified

[1] Note that the method was developed in Californian context. The number 197 m² USH refers to a specific study region (see Lindner, 2008).

as suitable even if it is used only in winter. However, the disturbance mechanisms themselves are not recorded, so the R³ method relies on the assumption that the disturbance/succession dynamics are connected to the land use type, which is plausible though not always granted. There is no differentiation between natural and anthropogenic habitats. Even urban land is assigned a certain value because it provides potential habitat to a number of species (although these are usually fairly abundant).

Abundance measuring by habitat area: Species abundance can be measured in different units. The most common unit is the number of individuals, which is not appropriate because equal numbers of different animals is not what we want to preserve (e.g. mice and deer). Biomass can also be used as a measure of abundance, but conservation of equal biomass is not favoured in terms of conservation either. The R³ method uses potential habitat area as a measure of abundance. The advantage is that if certain species are naturally rare (e.g. apex predators) and others more abundant (e.g. rodents) the differences in numbers and biomass are automatically compensated. Using area as a basis for impact assessment is a very straightforward choice in the context of land use, which helps with acceptance among laypersons.

Logistic shape of the abundance-rarity curve: There are three characteristics of the curve that are known: It has a minimum value, it has a maximum value, and it decreases in a strictly monotonic manner. The existence of a lower and upper limit of rarity follows from the fact that every rarity classification system has a lowest and a highest rarity class, such as the classification defined by IUCN (2008). The strictly monotonic decrease represents the fact that any species that is less abundant than another is ascribed a higher contribution to the conservation value of biodiversity than the other. This means that it is considered a higher priority to protect the less abundant of the two species. In mathematical terms, for any two species A and B with A being more abundant than B, the rarity of A is smaller than the rarity of B. Thus, the abundance-rarity function is strictly monotonically decreasing.

There is a fourth characteristic of the curve: It has to be flat at the lowest and highest value and steep in the middle. Rarity has been defined as "lack of abundance" above, and the curve reflects the perception of rarity by people. The conservation value is a cultural value (see Lindner 2008 for theoretical background). It is assigned to biodiversity by people. The very concept of rarity is normative, because it implies that something should be there where it is not (or not in sufficient quantity). In this context, it makes sense to base the transformation function on human perception. A typical characteristic of human perception is that differentiation is greatest in the middle of the observable interval and smallest at the extreme values.

Finally, there is a very practical reason for the logistic shape of the abundance-rarity curve: Lack of abundance can be described in multiple ways. The two most straightforward approaches to define R_i as a lack of a_i are reciprocal ($1/a_i$) and complement ($1–a_i$). The interval of possible CF_j varies depending on their definition. The inverse-derived characterization factors range from 1 to infinity. This is undesirable because single species can achieve extremely high values and render the contribution of any other species negligible. The complement-derived characterization factors range from 0 to 1, which does not allow for enough distinction between very common and very rare species. The logistic transformation (equation 4) of the relative abundance produces values in the range of 1 to 100 (see figure 7). It allows the distinction of rare and common species but limits the possible over-valuing of super-rare species.

4. Improvement potential

The development of biodiversity assessment methods for LCA is ongoing. Although the authors believe the proposed R³ method is a good one, it is clearly not perfect. The method is, at this point, a compromise between accuracy and ease of application, so naturally some aspects which others may find more important have been omitted. This section covers the shortcomings of the R³ method that the authors have noticed themselves.

Habitat quality and land management practice: The resolution of the habitat quality measure is very low (binary by definition). Each land cover type either is or is not potential habitat for each species. Since there no gradient in habitat quality is considered, land management practices that would influence habitat quality are not recorded.

Reference to thresholds: The impact pathway for biodiversity loss due to habitat loss contains a threshold: If a habitat is too small to accommodate the minimum number of individuals for a stable and healthy population of a certain species, it is of practically no use to that species (only as a stepping stone or bridge habitat in some cases). This is not reflected in the cause-effect model behind the R³ method.

Tracking of structural diversity I: High structural diversity in a study region does not yield the highest possible score, because the characterization factors are fixed. The highest possible score is achieved by transforming the entire study area into the land cover type with the highest characterization factor. This is an obvious flaw because no single land cover type supports all species used to calculate the characterization factors.

Tracking of structural diversity II: A number of animals depend on a combination of landscape structures. Many bird species for example raise their young in the protective cover of hedgerows, but need meadows for hunting insects or rodents. Defining the habitat of such animals as neighbouring patches of two distinct land cover types would further refine the method. With this knowledge in mind, the important role of edge habitats (such as hedgerows between fields or wetland belts alongside rivers) becomes apparent. Consequently, it makes sense to either increase the resolution of the spatial analysis so as to identify these small scale habitats, or to include them as line objects with a buffer zone around them.

Reference to connectivity: No connectivity model is included in the R³ method. Because only the total area of each land cover type is recorded, no difference is made between continuous and scattered patches.

The logical response to many of the shortcomings described above is to improve the level of detail of the landscape structure analysis. Currently, only the total area of each land use class is recorded. Including the location and neighbours of each patch in the analysis could be the prerequisite to a number of improvement steps. However, it would also make the processing of data much more complex, and one of the main points for the acceptance of LCA as a whole is the simplicity and straightforwardness of the methodology.

Exotic species: Exotic species are not accounted for because the CWHR database encompasses only native species. This reflects a normative decision by US authorities to define certain species as exotic and consequently exclude them from conservation efforts.

Completeness of species inventory: The decision to base the R³ method on the CWHR database limits it to a few hundred species of terrestrial vertebrates. Invertebrate animals, plants, and microorganisms are completely omitted. This reflects a normative decision by US authorities to focus conservation efforts on these species. However, one could argue that there are more species worthy of conservation than only the classic "wildlife" critters.

Since the R³ method measures the conservation value of the species, it cannot be empirically validated by means of natural science. As stated above, the conservation value is a mere cultural/social value, which is not connected to the ecological role of the valued species. Validation of the definition of rarity (i.e. value of a species) can only be achieved by means of social science. This is extremely important because the transformation of abundance into rarity defines the exchange rates for species (and, consequently, for areas of habitat types). In order to achieve a more solid scientific basis for the curve, the parameters defining its shape should be based on quantitative studies of peoples' valuation of biodiversity. Consequently, more social scientists are needed in LCA development to collaborate with the engineers and natural scientists.

5. Conclusions

We propose a method for the quantification of the impact of land use on biodiversity that is suitable for use in LCA. The conservation value of species diversity is assessed as a weighted sum of species, each being weighted individually by its rarity in a given study area. The information needed for the assessment is obtained from remote sensing sources and a species habitat relationships database, so there is no need for field sampling in the application of the method. The basic principle of LCIA (flow quantity multiplied by characterization factor) remains untouched, so the LCA methodology as a whole is not altered by the addition of a new impact category. The proposed method certainly has shortcomings, but at this point we consider it a good compromise between meaningful results and ease of application. We hope to foster the discussion about how to assess biodiversity in LCA. Readers of this article should feel invited to share their thoughts about the proposed method with the authors.

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Sustainability of a food products: use of the LCA and its possible integration with economic and social assessment tools

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ABSTRACT

The agri-food industry is a significant resource for the European economy. However, the competitiveness of this industry seems to be at risk due to its many structural problems (i.e. extreme fragmentation, energy-related and service issues, low R&D investment levels). In order to boost the sector, European policy-makers have planned a number of actions aimed at promoting a research for a greater sustainability. One of the most significant actions is the use of Life Cycle Thinking tools, which allow for a quantification of the environmental and social impact, and cost of food production. To ensure the adoption of these tools, their application should be simplified, an integrated framework should be created for the measurement of social, economic and environmental impacts, and a vast dissemination of results should be developed. For this purpose, the Eco-label mark use has also been extended, with the last revision (EC Reg. no. 66/2010), to food products.

Keywords: food industry, Life Cycle Thinking, SLCA, LCA, integrated framework

1. Introduction

The agri-food industry is one of the most significant sectors of the European economy. In 2008, it reached a turnover of 917 billion euro for the EU-27, thus gaining the second position among top manufacturing corporations, and employed approximately 4.8 million persons, corresponding to 14% of the entire manufacturing industry. However, the European agri-food industry may soon be considerably resized due to some criticalities, most of which are linked with the structure of this industry. As a matter of fact, the agri-food industry is characterized by fragmentation, economically speaking: about 99% of all enterprises in the food sector are small and medium sized enterprises (SMEs). The reduced size of the businesses in this sector sets a limit to their competitiveness in the global market related to the scarcity of new investments in R&D which are primarily connected with the large size. On the demand side, we may observe that while the food expense is covering a progressively smaller portion of the global consumer expense, passing from 26.1% in 1983 to 17.7% in 2007, most of the demand is for high-innovation-content products, such as healthy or novel foods or high-investment food that ensures quality and safety. In particular, we point out that decisions regarding consumption are mostly based on 'credence' like properties, such as production processes, effects on animal wellbeing, the use of pesticides, the impact of agri-food productions on the environment and on labour conditions (Nelson, 1970; Darby *et al* 1973), which are all elements that can be developed only with huge efforts in research and innovation to obtain sustainable, high-quality, eco-compatible and economically acceptable production solutions. However, said characteristics cannot be checked by consumers either at the time of purchase of a product or after its consumption. Their authenticity is essentially based on the content of the communication conveyed by the producer to the consumer

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through the label, advertising and promotional activities in general. Although the European legislation regulates this kind of communications rather strictly with the specific purpose of protecting consumers, there are still some gaps concerning credence attributes. There are two critical areas: the first is linked to those characteristics that recall the notion of sustainability and the second is connected with the 'high innovation content food' already mentioned above. As regards the first issue, the lesser environmental and/or social impact associated with food often depends on the image that the manufacturer has succeeded in creating for its brand, for example through declarations of commitment in protecting the environment or the some particular social conditions, through cause related marketing actions or with the publication of their social balance. The second area of criticality refers to those food products that are modified in the recipe and that boast beneficial properties and are advertised through nutrition or health claims. These foods are not meant for persons with specific problems, and therefore they are not therapeutic products; however, if associated to a regular diet and taken for a long period of time, they may increase the probability to obtain those inferential benefits that consumers attribute to them on the basis of the abovementioned claim. A very clear example can be mentioned: 'light' products (Tarabella *et al*, 2009). All this leads us to think about what the players in the European agri-food market could do to prevent this industry from remaining dominated by a few businesses that, given the greater availability of resources, are capable of drawing continuous profits from the asymmetric information they often create and themselves, even though without violating the legislation. EU administrators have identified the direct support to research for innovation and for the identification of more sustainable manufacturing and marketing practices for food products as the most valuable strategy to foster the development of this industry. To this purpose, agriculture and food have been introduced in the planning of research prepared by the European Union for the VII Framework Programme (2007-2013). This programme is also backed by the European Technology Platform Food for Life, also established by the European Commission with the objective of promoting technological innovation in the Small and Medium Enterprise of the food industry and favour their development and competitiveness. The application of Life Cycle Thinking (LCT) to the agri-food industry, which consists in examining the entire life cycle of a product in order to prevent any transfer of polluting loads from a step to another, is one of the most interesting fields of research promoted by the abovementioned Platform and is related to a study approach that has been repeatedly promoted and backed by the European government, the Integrated Product Policy. Over the last few years, the basic method of the LCT approach, Life Cycle Assessment (LCA), has rapidly spread in the agri-food industry. This tool is capable of supporting the operators of the sector in making decisions concerning alternatives for production, industrial processes and farming, but also in the creation of the most sustainable recipes for the environment. In addition, this method is one of the founding principles of the Environmental Product Declaration, an ecological labelling standard of the ISO 14020 series that required information about the environmental impact of the food product to be provided on a label based on preset parameters. In this paper, we will express some considerations on new perspectives for a better use of the LCA tool in the agri-food industry, in order to resolve the critical issues mentioned above.

2. Life Cycle Thinking methodologies: perspectives of integration and improvement of the information potential

The standardization of the LCA method, as defined by ISO 14040, whose first edition dates back to 1997, allowed its rapid dissemination in a larger user base, which also included the small and medium size businesses (Frankl, Rubik, 1999) that had not been enabled to benefit from any such method until then due to a lack of specific knowledge. Some researchers (Welford, 1996) had made a further step forward when they stated that the underlying logic of this tool - breaking down and managing environmental problems and identifying the related impact responsibilities - could be definitely considered as a tool itself for daily use in the consumer's rational purchase choices. So, we may state that, over time, LCA has been transformed from an analysis system to be used to resolve (technical) problems to a model which may help, the different parties involved, in gaining awareness of the shared responsibility they have in generating an environmental impact with a given product or service. Within this framework, considering that this method emphasizes consumption, the consumers themselves should be among the main users of its results. The importance of this tool lies precisely in its capacity to make a quantitative and comparative assessment of the functions of a product for the consumer (Benoit, Norris *et al*, 2009). Therefore, while the identification of production strategies with a reduced environmental impact remains a primary purpose of LCA, today the even more important goal of this tool is to drive consumption choices towards globally more sustainable alternatives (De Leeuw, 2005). Only consumers, through appropriate information, can prevent the continued use of *unsustainable* production practices. Some of the proposal developments of LCA-based methods move towards this direction with the specific objective of simplifying and making the results of these analyses more easily intelligible by an average public (Nissinen *et al*, 2007). Furthermore, research on the product life cycle assessment method is also evolving towards some possible paths for integration with tools that are capable of detecting economic and social impacts as well (Finnveden *et al*, 2009). According to the Triple Bottom Line approach, an organization is defined as sustainable only when it manages to reconcile its profitability objectives with environment protection and social equity. Similarly, LCA-based models as well, precisely due to their repercussions on consumption choices, are expected to provide a complete picture of the sustainability of a product, and therefore also evaluate the economic and social issues of the product's life cycle. This is mentioned among the aims of the Society of Environmental Toxicology and Chemistry (SETAC) in the Workshop Report called "A Conceptual Framework for Life Cycle Impact Assessment" (Fava *et al*, 1993), the organization that has mostly contributed to the development and theory of LCA. As a matter of fact, SETAC has recently published the first guidelines on the Social LCA (SLCA) (Benoit *et al*, 2009) and an overview on the Life Cycle Costing (LCC) (Hunkeler *et al*, 2008). This latter method has been used recently in support of investment decisions, because it allows for a calculation of the total cost of a product, process or any other activity throughout its life cycle, including the costs connected with the demands that are not expressed in product price on the market as the cost of emission reduction. Companies' decision regarding demands for better environmental impacts are difficult because the demands differ and implementation is uncertain (Krozer, 2006). In many economic sector it's important to analyse the economic aspect as systematically as the environment is analysed with an LCA, then it may be important to analyze the integration between LCC and LCA. Moreover, it is a great advantage if the systems studied with the economic analysis and the LCA have the same system boundaries, in order for the two analyses to supplement each other in the decision process (Reich, 2005). The Kroser's analysis of ten cases of life-cycle management (environmental and also economic), for example, suggested that innovative and preventive environmental strategies can help companies to save costs of emission reduction in comparison with the compliance strategy and improve the product quality: three case studies were on agri-food products and agri-food industrial products. These results are concrete evidence of the usefulness, for companies and consumers, of an environmental management system based on life cycle. However, the integration of LCC into LCA can be hampered by the lack of a standardised LCC methodology and difficulties in defining some of the cost factors. Furthermore, it's hard to find reliable and adequate data (Jeswani *et al*, 2010). In particular LCC needs to define specific system boundaries, and functional units, compatible with LCA, and make a clear statement on externalities (Hunkler *et al*, 2005). With regard to the SLCA, to date there are few case studies on a concrete application of this method because it poses several problems including the definition of stakeholders, the need for qualitative assessments and the importance of localization (regional impact). The publication of guidelines has helped to identify a common methodology, based on LC tool; however, it must be fully implemented in practice to show its validity and usability. In spite the methodological difficulties about the application of LCC and SLCA, many authors have highlighted the need for integrated and harmonized methodology for assessing the environmental and economic impacts generated by a product throughout its life cycle with also the social ones (Hunkler *et al*, 2005, Gauthier, 2005, Schmidt et al, 2004). We address the case study analysed by Hunkler (2006) about the comparison between two detergents: he proposed a methodology of Social LCA (and also LCC) derived from life cycle inventory data; so, the analyses have identical system boundaries and functional units. The same European Commission has focused on the option to integrate the assessment of economic and social impacts in the LCA method (CALCAS, 2008; Patel, 2009). The similarity between the three models favours synergies, and consequently the construction of a single method to be used to interpret the level of sustainability of a product/service. However, creating an integrated model may worsen the present complexity of the LCA method. Some studies have already been started to simplify the LCA method, such as the spreading and use of existing databases to produce reliable data available in shorter times and at acceptable costs (Hur *et al*, 2005). Such an experience may be effectively repeated once a common framework for LCA, SLCA, and LCC has been created. The benefits that would be derived by a common framework for the three methods are multiple and easy to understand. First of all, the combined analysis of the environmental, social and economic hot spots of the product and of the related impacts in connection with the abovementioned three dimensions would allow useful results to be obtained in terms of global – i.e. economic, social and environmental - efficiency (Udo de Haes *et al*, 2004; Jeswani *et al*, 2010). The businessmen would be provided with a complete tool in support of their decision-making process and, similarly, policy-makers may also draw many benefits from this tool for a more effective planning of public policies and for the control of environmental and social regulations. On top of this, the results of these analyses, provided that they be adequately notified, as expected by the recent studies mentioned above, would be even more important for consumers, who would possess the necessary information to make more responsible and sustainable consumption choices. In particular, visualizing the global impacts generated by a given product on the label or the promotion claims (Otto H.E., 2003; Nissinen *et al*, 2007) would allow consumers to objectively see the image of sustainability proclaimed by a food producer, thus reducing information asymmetries in some credence attributes (Henson, Reardon, 2005) that often influence consumption choices. The three players – the industry, policy-makers and consumers – may activate a virtuous cycle towards sustainability in a co-makership logic. It is only through the external visibility, to the community and consumers, of the commitment undertaken by a business in fulfilling environmental sustainability that the spreading of increasingly sustainable practices can be fostered in the industry.

3. Conclusions

The LCA method has been identified, even by the same European governmental bodies, as one of the most effective tools to tackle the criticalities of this sector. However, the delicate balance between the availability of raw materials, transformation processes and, simultaneously, consumer protection, as well as environment, territory and landscape protection, that lie at the basis of the food industry, makes it necessary to identify an integrated approach in the triple bottom line assessment of sustainability and in the identification of the possible development and growth paths. Therefore, we have identified a need to further investigate the possibilities of using LCA in the agri-food industry with two perspectives: the first aims at refining the tool as regards the characteristics and requirements of this sector, also considering the scarce economic resources available to SMEs, and the second aims at creating a single tool capable of detecting globally the environmental, economic and social impacts of a food product during its life cycle. The latter perspective, in particular, shows many opportunities, but also some methodological issues. Indeed, the integration of LCA with LCC and Social LCA may worsen the present complexity of the LCA method, in consideration of some problems that regard, on the one side, the fact that SLCA is still going through an experimental stage bound by subjective judgement and, on the other side, the challenge of defining cost factors with LCC. However, these difficulties could be overcome through increased testing of the integrated model that takes into account of:

- the simplification of LCA method;
- the need for a LCC standard;
- the greater dissemination and application of SLCA to concrete case studies.

In addition, the results of an integrated LC method should be better reflected in the label to be stuck on the product, in view of eliminating or, at least, reducing the barriers between SMEs and the large corporations that can afford huge investments on building the image of sustainability of their products. In fact, the development of labelling systems for showing the results of an integrated LC method capable of providing information schematically and simply on the three levels of sustainability of the product, including the use of result benchmarking tools, can be certainly seen as tools to be provided to consumers in order to enable them to evaluate actual quality, and therefore the value of some innovative kinds of food, in order to make rational and conscious purchases.

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The importance of operational inputs in the environmental assessment of seafood. A case study with Galician fisheries (NW Spain)

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ABSTRACT

Environmental impacts related to seafood extraction are an increasing matter of concern. In this scenario, an environmental management tool (Life Cycle Assessment, LCA) is combined with an economic management tool (Data Envelopment Analysis, DEA) in order to jointly discuss the operational and environmental performances of a set of multiple vessels belonging to two different fishing fleets. By doing so, the use of average inventories is avoided and wider result interpretation is achieved when assessing the fleets. In particular, the "five-step LCA+DEA method" is applied to Galician coastal and deep-sea purse seiners. The link between operational efficiency and environmental impacts is revealed, operational inefficiencies detected, target performance values defined and environmental consequences of operational inefficiencies quantified. Results show an overwhelming dependence of environmental impacts on one major operational input: fuel consumption. Moreover, coastal seiners entail greater reduction potential for environmental impacts when compared to deep-sea seiners. This case study proves the appropriateness of the "five-step LCA+DEA method" as an eco-efficiency verification tool while highlighting the leading role of fuel demand from economic and environmental perspectives.

Keywords: Data Envelopment Analysis, eco-efficiency, fishery, Life Cycle Assessment, purse seiners.

1. Introduction

Life Cycle Assessment (LCA) is a standardized tool that is used worldwide for assessing environmental issues and potential impacts related to processes and products (ISO 2006a, 2006b). In this sense, in recent years numerous environmental analyses regarding fisheries and seafood products have been carried out (Pelletier *et al.*, 2007), due to increasing market demand for environmental related information. However, when applying LCA to fisheries, a series of methodological challenges still remain, relating mainly to more accurate impact categories for marine ecosystems and to the lack of social and economic issues (Vázquez-Rowe *et al.*, 2010a). In this context, the integration of LCA with Data Envelopment Analysis (DEA) has arisen as an attempt to link environmental and economic assessments of seafood products and fisheries (Lozano *et al.*, 2009, 2010; Iribarren, 2010; Vázquez-Rowe *et al.*, 2010a).

DEA is a linear programming methodology used for processes that involve multiple inputs and outputs, in order to measure the efficiency of a set of multiple similar entities, named decision making units (DMUs) (Cooper *et al.*, 2007). The main feature of this tool is to identify efficient DMUs of any selected sample provided that a certain number of inputs

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and outputs for a set of multiple homogenous units of assessment are available. Furthermore, efficiency scores and target operational values can be calculated for inefficient units.

In this study, the synergistic use of LCA and DEA is proposed as a methodological approach to link operational efficiency and environmental impacts for the assessment of two relevant Galician purse seining fleets. The first one comprises coastal purse seiners that capture low value pelagic species, such as European pilchard (*Sardina pilchardus*), horse mackerel (*Trachurus trachurus*) and Atlantic mackerel (*Scomber scombrus*). The second fleet involves deep-sea purse seiners that fish Yellowfin tuna (*Thunnus albacares*) and Skipjack tuna (*Katsuwonus pelamis*) in the Atlantic, Indian and Pacific oceans.

2. Framework

2.1. Motivation

Compared to the mere use of LCA, the joint usage of LCA and DEA provides a series of advantages including (i) avoidance of handling standard deviations, (ii) wider result interpretation through the inclusion of an operational/economic dimension in the LCA study, and (iii) eco-efficiency verification (Vázquez-Rowe *et al.*, 2010a). The purpose of this study is focused on the operational benchmarking and eco-efficiency verification of a set of vessels belonging to two different fishing fleets through their operational and environmental performance assessment according to LCA+DEA methodology. Furthermore, the link between fuel usage and potential environmental impacts as compared to other inputs is studied.

2.2. Methodology

The proposed LCA+DEA methodology is made up of five phases (Lozano *et al.*, 2009; Vázquez-Rowe *et al.*, 2010a):

1) Development of an individual Life Cycle Inventory (LCI) for each of the analyzed DMUs. Note that each vessel corresponds to a DMU.

2) Life Cycle Impact Assessment (LCIA) for each DMU, with the objective of characterizing the environmental performance of the current vessels.

3) Application of DEA for the calculation of operational efficiency scores for individual vessels. This step demands the prior establishment of a well-defined DEA matrix from the most relevant LCI data. Target vessels, i.e. virtual vessels that consume fewer inputs for the same or increased outputs, are then obtained. Efficiency scores and target consumption levels are calculated through the implementation of an optimization model that seeks the minimization of input levels while maintaining output production.

4) LCIA of target vessels with the projected LCIs calculated in step 3.

5) Comparison of the environmental performance of virtual and current vessels, revealing to what extent environmental impacts depend on operational efficiency. Eco-efficiency, understood as the delivery of competitive goods and services in order to satisfy human needs while reducing the corresponding environmental burdens (Schmidheiny, 1992), is then verified through the calculation of the environmental consequences of operational inefficiencies.

3. Case study: coastal and deep-sea Galician purse seiners

3.1. Introduction to the case study

The proposed example consists of a sample of coastal (F1) and deep-sea (F2) Galician purse seiners, which are shortly described in Table 1.

In order to focus on the performance of the individual vessels, rather than on the individual seafood products, the functional unit considered for LCA steps was 1 kg of landed fish.

LCIs include aspects regarding diesel, antifouling, lubricant oil and vessel construction, while DEA only deals with a sub-set of the relevant inputs and outputs used (Table 1).

Table 1: Main characteristics of the Galician fishing fleet samples selected and data included in the DEA matrix

	Coastal purse seining (F1)	Deep-sea purse seining (F2)
Sample size	15	9
Year of inventory	2008	2000-2004
Total landings (tons)	7,500	72,000
Catch value (€/year)	4,912,747	371,320,440
DEA input 1	Diesel	Diesel
DEA input 2	Hull material	Hull material
DEA input 3	Seine net	Anti-fouling
DEA output	Catch value	Catch value

3.2. Application of the five-step LCA+DEA method

Step 1: data acquisition and current LCIs

Data for the LCIs are based on primary data for each fleet as reported by Hospido and Tyedmers (2005) and Vázquez-Rowe *et al.* (2010b).

Step 2: environmental characterization of the selected fleets

LCIA was carried out using SimaPro 7 (Goedkoop *et al.*, 2008) and the CML baseline 2000 method (Guinée *et al.,* 2001). The impact categories assessed were: Acidification Potential (AP), Eutrophication Potential (EP), Global Warming Potential (GWP) and Marine aquatic Eco-Toxicity Potential (METP). Results for this phase are discussed together with target environmental characterization results in step 5.

Step 3: efficiency scores and target values for current selected vessels

DEA implementation reveals an efficiency score (Φ) for each assessed vessel and defines operational targets for the selected inputs and outputs of the vessels deemed inefficient (Table 2). Significant improvements were found feasible for all the inputs considered, but with important differences depending on the fleet and even between vessels belonging to the same fleet. Furthermore, the efficiency score for the average vessel of each fleet was also calculated and, again, an important difference was observed between fleets (76.17% for deep-sea versus 44.26% for coastal). Note that the average vessel for each fleet means an additional DMU that is defined through average inventory data in order to implement this hypothetical DMU as another unit of assessment into a new DEA.

When studying the different inputs separately, coastal purse seiners presented a diesel efficiency of the average vessel (45.08%) close to the global efficiency score obtained for the average vessel. Values for the other two inputs were only slightly lower (44.52% for I-2 and 43.17% for I-3). The average deep-sea vessel also showed a fuel efficiency value (78.27%) very similar to the efficiency score. However, efficiency values for inputs 2 and 3 were considerably different (67.1% for I-2 and 83.15% for I-3).

Step 4: environmental performance for target vessels

Target values calculated through DEA undergo a new LCIA that aims at calculating the potential environmental impacts for vessels if operated efficiently. Results for this phase are discussed together with current environmental characterization results in step 5.

Table 2: Efficiency of individual vessels and input minimization for target vessel definition (F1: coastal purse seining fleet; F2: deep-sea purse seining fleet)

DMU	Efficiency (Φ)	Input 1 (%)	Input 2 (%)	Input 3 (%)
F1-1	30.5	69.2	72.4	66.8
F1-2	29.7	75.2	67.7	68.1
F1-3	38.9	62.1	64.6	56.5
F1-4	36.8	64.0	66.4	59.3
F1-5	40.3	47.7	55.9	75.5
F1-6	67.1	26.4	20.9	51.3
F1-7	49.4	60.8	58.1	32.7
F1-8	48.5	52.5	40.7	61.3
F1-9	33.5	61.2	72.1	66.2
F1-10	34.2	60.6	71.5	65.4
F1-11	100.0	0.0	0.0	0.0
F1-12	100.0	0.0	0.0	0.0
F1-13	47.3	39.5	60.9	57.8
F1-14	44.6	65.5	48.5	52.3
F1-15	79.2	30.0	14.2	18.1
F2-1	78.5	15.0	31.8	17.7
F2-2	71.7	29.0	26.4	29.7
F2-3	70.3	31.6	43.2	14.3
F2-4	100.0	0.0	0.0	0.0
F2-5	100.0	0.0	0.0	0.0
F2-6	100.0	0.0	0.0	0.0
F2-7	66.2	35.3	48.6	17.5
F2-8	50.8	49.8	56.2	41.5
F2-9	81.2	12.6	35.6	8.2

Step 5: interpretation and eco-efficiency verification

Figure 1 shows the total percentage reduction in input consumption for both fleets, while Figure 2 represents the resulting total percentage reduction in potential environmental impacts. Furthermore, Figure 2 relates potential environmental improvements to operational minimization by including to what extent environmental improvement is linked to each of the inputs whose consumption is subject to optimization.

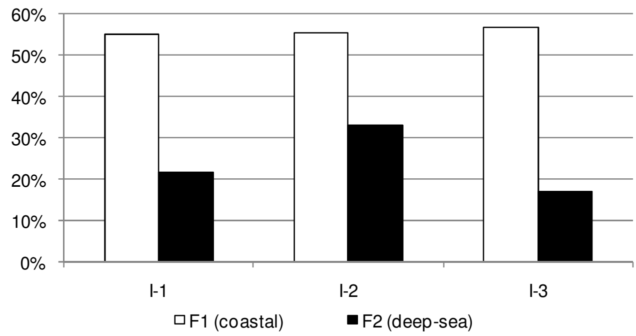

Figure 1: Total reduction in input consumption for the selected fleets

The fleet that presented higher potential for operational optimization was the coastal purse seining fleet (improvements over 50% for every input) while deep-sea seiners obtained advances that ranged from 17% (I3) to 33% (I2). As observed in Figure 2, this fact resulted in higher potential percentage reductions in the environmental impacts for coastal purse seining. Therefore, the five-step LCA+DEA method quantitatively demonstrated that operational inefficiencies highly determine potential environmental impacts. Moreover, Figure 2 reveals that potential environmental improvements are linked mainly to the minimization of fuel consumption levels since the great majority of the environmental reduction for each impact category was associated with the optimization of this input (I1).

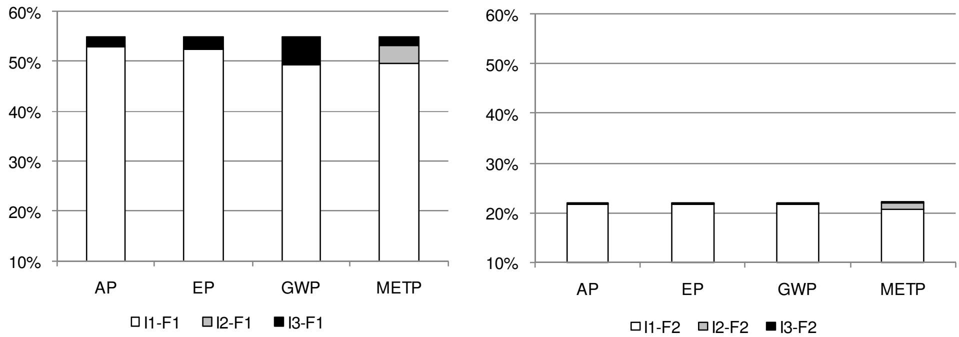

Figure 2: Total environmental impact reduction for both fleets and origin of the potential environmental improvement

4. Discussion

Not being new in seafood LCA studies (Thrane, 2004; Hospido and Tyedmers, 2005; Schau *et al.,* 2009), energy use is highlighted as the main environmental burden for both fleets assessed. However, operational benchmarking emphasizes this observation and leads to quantify the environmental consequences of inefficient vessel operations. On the other hand, inputs such as hull material or seine net and antifouling consumption, even though they do not show the high environmental relevance associated with fuel activities, can have increased significance when it comes to reducing economic costs. In this sense, the low efficiency scores obtained for the hull material input for deep-sea purse seiners suggest that this fleet is nowadays to some extent oversized.

When the two fleets are compared, deep-sea seiners have significantly higher operational efficiency than coastal seiners, while the latter present increased environmental impact reduction potentials. Thus, results prove the correlation of operational efficiency and environmental impacts. Nevertheless, it is important to stress that the potential environmental impacts associated with coastal vessels evaluated in this case study were – in absolute values – lower than those of the deep-sea fleet. Differences in operational efficiency are closely related to the different characteristics of each fleet (e.g. distance to fishing ground and hull dimensions).

Finally, it is important to point out that the environmental impact categories assessed correspond to a common set of environmental indicators. Even though a more comprehensive analysis should include a series of biological-related impact categories, these are currently underrepresented categories in seafood LCA.

5. Conclusions

Both fishing fleets assessed showed a high environmental dependence on one major operational input: fuel consumption. In this sense, optimization of diesel consumption levels would lead to the most significant environmental improvements. Additionally, minimization of other inputs, such as seine net consumption, can offer interesting reductions in operational costs, despite the reduced environmental impact that they entail.

Operational efficiencies of the average vessel for deep-sea seiners were considerably higher than for coastal seiners. Assessing whether low efficiencies are linked to overexploitation may be a topic of further research.

The five-step LCA+DEA method was proved to be a suitable methodology to quantify operational efficiency and potential environmental improvement on the basis of eco-efficiency criteria.

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Sustainable productivity of soil agricultural use and Jevons' Paradox. Past and future myths

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ABSTRACT
According to W.S. Jevons, the efficiency of a resource use tends to increase, rather than decrease, its consumption rate. This is particular true in the thermo-economics processes. In this note, the authors try to apply this proposition to explain the global trend of progressive impoverishment of the soil, especially in the western societies, and the rise of many environmental problems due to a high-inputs agriculture and to poor impact assessment and participatory methods. In fact, even a "technologically optimistic" scenario, using, for example, Georgesçu-Roegen's Promethean technologies (such as, in a more modern view, genetic engineering, biotechnologies and renewable energy supplies), for enhancing a better use of agriculture resources and factors, could lead to an increment of productivity in the short period, but, at the same time, to unsustainable practices in the middle-long period (such as biodiversity decrement and natural flow inversion of biosphere evolution, a non-renewable resources depletion, alterations of hydro-geological cycles and microclimate modifications).

Keywords: Sustainable agriculture; Ecological economics; Jevons' Paradox; Land use.

1. Introduction

More recently, economists and sociologists debate about the ecological degrading effects of capitalism and the actual economic growth paradigm.

Modern agricultural system of production, in particular, – with its high-intensity capital inputs, technological practices and non-renewable resources dependence – inevitably interacts with nature and affect the environment. Its most important negative side effects include: i) soil degradation (such as soil erosion and acidification, deforestation, desertification, etc.); ii) natural resources depletion (fossil fuels, water quality and quantity, habitat loss, reduction of biodiversity, etc.); iii) environmental degradation (eutrophication, atmospheric pollution, greenhouse warming, etc.); iv) increasing disparity between rich and poor nations, with examples of catastrophic degradation in developing countries.

Actual agro-ecosystems, mostly based on monocultured lands and large-scale land abuses, in order to obtain large effects on productivity, force land productivity (e.g. by a large use of fertilizers) and the natural ecological succession of cultivations. These environmental concerns have also been accompanied by social concerns: loss of economic viability – due, above all, to vertical integration of production, to high costs of production inputs, like chemicals and heavy machinery, and to highly specialized monocrop production (Nelson *et al.*, 2009) – of small to medium scale agriculture (rapidly increasing farm sizes), poor food quality, human health problems, steady exodus from rural to urban areas, and so on.

For example, Smil (1997) argues that, without the Haber-Bosh industrial nitrogen synthesis, the earth, with a vegetative nitrogen recycling process, could only carry three billion

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people rather than the current level of six billion people. But the same author also states that the indiscriminate use of exogenous industrial nitrogen fertilizers has enormous altered the natural cycles of agriculture.

Soil fertility, based on natural cycles, has been the basis of all past civilizations. In modern agriculture, besides massive supply of fertilizers, there is the need of intensive outside use of exogenic energy, external inputs, like genetic engineering, and harmful chemicals in order to fight insect pests, weeds, etc. All of this results in high risk of long-term land deterioration and high level of waste and pollutants production.

In this note, we'll examine some of the most important ecological economic key-ideas about environmental and social sustainability of modern agricultural production systems, quite all characterized by off-farm hi-inputs use, trying to point out that, as Jevons has shown, we must change rapidly growth paradigms.

2. Jevons' Paradox and agricultural productivity

In 1865, the British economist, William Stanley Jevons, first developed his contention, with reference to coal use and steam engines, that every energy-efficiency improvements will paradoxically increase rather than reduce energy consumption (Jevons, 1905). This concept was based on Lotka's idea that the tendency of individual economic behaviour was to maximize reproduction and growth (Weintraub, 1991). "Jevons' Paradox", even if it currently find important applications for energy and climate analysis and policy, could have, according to us, deep implications for sustainability of modern agriculture.

In fact, we could post: i) soil availability as a limited natural stock resource; ii) agricultural productivity of land use in the same way of energy efficiency; iii) and the best suitable use way of means of production as the technological improvements. In this note, we'll intend: i) "agricultural efficiency", simply, as the ratio of physical inputs to physical outputs; ii) technological means and changes higher other kinds of inputs, like time and human efforts (labour and organization); iii) environmental depletion and pollution as soil productivity capacity. We could also transpose some concepts of thermodynamics into the new paradigm: "energy savings" = "land savings"; "energy intensity" = "land productivity".

In this way, we can define, and apply, notion of *engineering savings* or energy/economic productivity (or efficiency) of a "factor" input to the agricultural activity. In Schipper and Grubb's formal presentation (Schipper *et al*., 2000), resumed recently by Sorrell and Dimitropoulos (Sorrell *et al*., 2007), this concept is defined as the difference between two ratios, the first stating energy/material "factor" input per unit of product *before*, the second *after*, a technologically achieved lowering of input per unit output. The growth rate of total economic output minus the weighted sum of the growth rate of the inputs – weighted for their own share to the value of output – gives the *total factor productivity* (TFP), improvements of which are always desirable. At the same time, we define *energy savings* as the product of a future activity level and the difference between the energy intensity at that time compared to the present level (Alcott, 2005).

A direct consequence of Jevons' Paradox is the associated phenomenon termed as "rebound effect" (or "take-back effect"), latter known as "Khazzoom-Brookes postulate" (Saunders, 1992), according to which any mechanism of resource saving, like, for example, an implementation of new more efficient methods of agriculture production, directly or indirectly, leads to an overall increased demand of soil, becoming economically viable, for many other non-agricultural new uses, such as civil and industrial ones, even more intensive and less renewable (Polimeni *et al*., 2007).

For better understanding the rebound postulate and Jevons' paradox of *land savings* and *land productivity*, we'll define the *land use* (L_u) of different agricultural activities as $L_u=A \cdot P_s$, where A is the level of activity and P_s the corresponding *productivity of the soil*. After a particular land saving technique is implemented, A changes to A' and P_s to P_s' and the new level of land use is $L'=A' \cdot P_s'$. (2) If P_s' is less than P_s, the area of land saved is $A'(P_s - P_s')$, while $A(P_s - P_s')$ would be the "engineering savings" of the specific land activity. But L_u', according to Jevons and Khazzoom-Brookes, will surely be larger than L_u because over the time that P_s fell to P_s', A grew by a greater relative amount to A'.

The consequence is that actually "more and more lands worldwide are being cultivated for food production while forests are disappearing at an unprecedented rate" (Zhang *et al.*, 2006): agricultural land expansion is widely recognized as one of the most significant human alterations to the global environment.

In contrast with many ecologists, economists, governments and NGOs, believing that an higher efficiency gains a lower consumption of natural resources, modern economic growth theory, in agreement with Jevons, considers technological improvement the main responsible of increased demand of consumption, higher production and environmental problems. Therefore, efficiency policies are economic and environmental counter-productive (Sorrell, 2009).

In the past, the efficiency paradox has been wrongly used as an argument against efforts to promote greater energy efficiency and conservation (Rubin, 2007). However, we want to underline that the efficient use of the resources could be always pursued, when it is possible, and that we had to disprove the myth of omnipotence of technology within a long-term sustainable development scenario.

3. Is "Sustainable agriculture" a myth?

Recent concern for "sustainability" of modern agriculture has attracted attention of many economists and ecologists. Among these, N. Georgesçu-Roegen too.

According Georgesçu-Roegen's definition, a Promethean technology is "just the spark of a match we can set on fire a whole forest" (Georgescu-Roegen, 1992); because "control of fire symbolises power over nature, the beginning of technology, science and art" (Small *et al.*, 2006). He identified three of these viable levers: husbandry, the mastery of fire and steam engine. Husbandry is to intend as agricultural practices and availability of *fertile land*, that is no longer an imperishable space or "Ricardian land" (as "indestructible powers of the soil"), according to David Ricardo, but a limited resource, like fossil fuels, the *fire* of the modern industry (Mayumi, 2009).

Another optimistic scenario designed by these tools, where any input not supplied by nature can be produced and substituted (except the cases of fixed coefficients and/or the existence of limitational factors) by one of the feasible recipes within the technologies (Neoclassical production theory or Solow's contention) (Solow, 1974), collides with actual natural resources depletion and environmental damage and pollution.

In fact, despite of Robert Solow's idea that "The world can, in effect, get along without natural resources" and that an increase in the input of any factor always yields an increase in output ("substitution assumption"), within the same factory process, it is quite impossible to compensate a decrease in output due to a decrease in a "fund element" (= agent transforming a given set of inflows into a given set of outflows, e.g. capital, labour and Ricardian land) by an increase in a "flow input" (= quantity of materials qualitatively transformed in the process, e.g. natural resources) (Gowdy *et al.*, 1997). Hence, concept of elasticity of factors substitution by technological improvements is, as David Pearce claiming too, an empirical meaning. Technology, however, can reduce, considerably, the amount of energy and materials inputs for the same level of agricultural production, as Robert Ayres' assessment on dematerialization (Ayres, 1997).

The whole process quickly fell into the "Malthusian instability trap", rapidly depleting the natural stocks associated with this forced development parameter (Mayumi, 2009). The Jevons' Paradox appears again! Besides, always on the basis of this statement, from a few years ago, increasing the agricultural efficiency of food production per hectare, mostly due to the "Green Revolution" (principally based on chemicals, fertilization and irrigation), did not solve problems of world hunger for the resulting increase in population (Giampietro, 1994).

Another question was that, in the past, there was the common political and economic idea that new technologies, developed by the future generations, will be able to solve our current problems (the other myth of "technological optimism") of environment safeguard and a granted sustainable economic growth (Costanza, 1989). For agriculture, e.g., there was the positive assumption that manufactured capital (technology) was a perfect substitute for natural capital (Daly, 1996). Now, we know that these visions are wrong, since we can finally see and foresee the detrimental effects of agricultural technologies and production practices on land hi-input productivity, soil erosion, deforestation, increasing salinity and water shortage, loss of nutrients and compression of soil, etc. (Geldermann *et al.*, 2002).

But what do we mean with the terms of "sustainable agriculture"?

Often it means different things to different people: some associate it with organic agriculture, some with the food sovereignty movement and some with the concept of state-funded multifunctional agriculture (Aerni *et al.*, 2009). Even if this is out of the aims of this note, very numerous are also the indicators and indicator sets, proposed in the past years and inspired by Life Cycle Assessment (LCA), for sustainable agriculture and sustainable land management (Walter, 2009).

Among many other, and many different, each others, definitions (see Harvey, 2006), the most adequate and now widely accepted by everyone seems to be this one, attributed to T. Gips: "Sustainable agriculture integrates three main goals: environmental health, economic profitability, and social and economic equity" (Appleby, 2005). In the social dimension, it must include food quality and food safety in order to protect human health.

This assessment has been adopted by FAO, arguing that "sustainable agriculture" must be a responsible system of production that consists of five major attributes: it conserves natural resources, it is environmentally non-degrading, technically appropriate, and economically and socially acceptable (FAO, 2010).

In practice, really sustainable agriculture, – requiring, like energy use, the handling of multi-dimensional and multi-scale analyses (Giampietro *et al.*, 2006) – uses fewer external off-farm inputs (see the *USDA Low Input Sustainable Agriculture* or *Sustainable Agriculture Research and Education Program,* LISA/SARE Program; Trevathan, 1991) such as purchased fertilizers and employs locally available natural resources, as well as purchased inputs, more efficiently (Kassie *et al.*, 2009).

4. Conclusions

Modern intensification of agricultural production is correlated with high cost pressures, sometimes, ignoring elementary rules of good and sustainable practices (Lee, 2005), like as rotation of crops, conservation of tillage and compost, permanent soil cover, minimal soil disturbance (that is zero-, minimum- or stubble tillage), natural carbon fertilization, etc.

Besides there is the need to invest in farm management formation and information, because farmers have different competence, education, knowledge, motivation, etc.; all of them are factors of strategic importance for a sustainability way of production. In this situation, environmental education, information and environmental monitoring have a significant capacity to decrease the negative impact of agriculture.

To maintain nutrition for an increasing world population and to safeguard natural resources and environment, other strategies could be the adoption of adequate systems for protecting crops against damage from weeds, pathogens and microbial diseases, developing high-yielding varieties, providing plants with nutrients, reduce losses caused by abiotic and climatic stresses, such as dryness and soil salinity (Geldermann, 2002).

Another question is the fact that the actual agricultural production system provides food at low market costs that have not adequately nor completely reflected environmental and social problems. In fact, very numerous are governmental interventions both directly, in the form of economic subsides and social programs, and indirectly, trough regulations, wrong market planning and so on. There is the need to drastically reduce those distortions adopting a more free-market approach tendencies, as Adam Smith suggested (Harvey, 2006).

Among all, however, future agriculture should maximize reliance on natural, renewable, and on-farm inputs and incorporate externalities of environmental amenities. More widely, sustainable agriculture should be both a philosophy and a system of farming that rooting in an adaptive set of values and principles reflecting awareness of local ecological, economic, and social realities, and balancing environmental conservation, agricultural production, farm profit, and family and community well-being.

Actually, the myths of Prometheus and Pandora, about the enormous potentiality of humanity, by the technological might of gods and the scientific knowledge, to harness and manipulate the forces of nature, led us to investigate if we have the capacity and the wisdom necessary to do so in an economically, environmental friendly and socially sustainable matter?

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A proposal for a LCA community knowledge management system

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ABSTRACT

Practitioners conducting life cycle assessments are uniquely dependent on data collected or published by their colleagues. To meet the LCA community's strong need for transparent, quality, regionally-relevant data, this paper proposes the development of an online LCA-community knowledge management system (KMS). An online LCA-community KMS could provide the means for the global LCA community to collaboratively create, store, review and compare LCI data. In conjunction with the LCI data store the KMS could provide for an online publication knowledgebase with the ability for authors to provide further clarification of the data collection and analysis methods used in their publications. Finally, an LCA-community KMS could adapt features of various social software applications to provide even more avenues for members to collaborate, to share and to learn from one another.

Keywords: online community, knowledgebase, LCA, LCI, knowledge management system

1. Introduction

Life Cycle Assessment (LCA) practitioners are uniquely dependent on data collected and published by their peers. An LCA of even a modest product supply chain can easily require data for hundreds or even thousands of unit processes. And in today's global economy the data requirements for upstream and downstream supply chain inputs can span the globe. This quantity and scope of data collection is beyond the budget and time allowances of almost all individual LCA projects. Consequently practitioners source data from wherever they can find it. Commercial databases with regionally based data will most likely have to be modified. Journal or conference publications have paper length restrictions that lead to insufficient descriptions of methodological choices. Sometimes processes are deemed to be insignificant, or at least unavailable, and their data are simply omitted (Suh, Lenzen et al. 2004; Gnansounou, Dauriat et al. 2009).

The LCA community has a strong need for transparent, quality, regionally relevant data. There is also a corresponding need for access to and a shared knowledge of community approved processes for conducting a life cycle assessment. The ISO 14040/44 standards provide the general framework for conducting an LCA. However the practitioner is still required to make many choices that can change the assessment's results and conclusions. In essence, LCA practitioners need to have access to community approved data, processes and best practices in order to ensure the quality and consistency of life cycle assessments conducted by the LCA community.

Knowledge of organisational processes and best practices has long been recognized by firms as a valuable resource and a key part of their competitive advantage (Wasko and Faraj 2000). In an attempt to "facilitate the sharing and integration of knowledge" (Alavi and Leidner 1999, p. 1) firms have employed information and communication technologies to build knowledge management systems (KMS). A knowledge management system refers to

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a system for managing knowledge in organizations. A KMS provides support for the creation, capture, storage and dissemination of information. The underlying design of these management systems is highly dependent on how knowledge is perceived.

Three perspectives of knowledge have emerged from research on organizational knowledge practices: knowledge as object, knowledge embedded in people, and knowledge embedded in a community. The first two perspectives view knowledge as a private good, a commodity that can be bought and sold like any other item. The third perspective, knowledge embedded in community, "views knowledge as a public good that is socially generated, maintained, and exchanged within emergent communities of practice" (Wasko and Faraj 2000, p. 156). It is this third perception of knowledge, knowledge embedded in community, which will form the basis for the underlying design of the proposed LCA community KMS.

2. Purpose of the research and research questions

2.1. Background

With today's Internet technologies, anyone with an Internet connection can easily publish knowledge and collaboratively create and share data (Shirky 2008). The free open source software (FOSS) movement were early adopters of this way of working together. A community of developers will typically 'meet' on special community web sites, such as SourceForge.net. Their knowledge creation and sharing is socially generated, maintained and exchanged via forums, mailing lists, wikis and blogs. The source code and applications are generally considered a public good and made available to the general public. Linux and Firefox are just two of many open source products created by the FOSS community. The open source software development model illustrates the scope and power of knowledge embedded in community. So does Wikipedia, the multi-lingual, web-based, free-content encyclopaedia project.

An example of a FOSS project within the LCA community is the openLCA project whose goal is to develop modular software for life cycle analysis and sustainability assessments. Like any other open source project, the openLCA project survives and thrives based on the contributions of its community.

The power to collaboratively generate, maintain and exchange knowledge can also be available to the global LCA community through an online community based KMS. An LCA community KMS could employ information and communication technologies to allow its practitioners to share and integrate the knowledge that is crucial to the LCA community. This crucial knowledge could include:

- access to and the ability to collaboratively generate and maintain transparent, quality, regionally relevant LCI data;
- guidelines for accepted processes and best practices in conducting a life cycle assessment; and
- a publication knowledgebase where authors could provide further clarification of the data collection and analysis methods used in their publications.

Some of this crucial information is already available to the community. Quality regionally relevant LCI data is available from several sources: the ELCD database for the European market, the US LCI database, and the AusLCI for Australia. The ILCD Handbook provides guidelines for accepted processes and best practices. The LCT forum provides a mailing list service where members can post and answer LCA related questions and gain access to global life cycle expertise.

However each of these exists as a separate isolated element, knowledge as object. If we accept the perception of knowledge embedded in community, than the true shape of an online LCA community KMS must allow for knowledge to be socially generated, maintained, and exchanged online. Not disparate elements existing in isolation online but one virtual 'meeting place' which has links to existing global LCA community information but also provides the means for any member of the global community to make a contribution.

The power of the open source software model, where knowledge is embedded in the community, means that each individual member's contribution added to the collective knowledge creates a richer knowledgebase of ideas and data than would be available to any one member working alone (Bell 2009).

2.2. Research questions and strategy

The proposed LCA community KMS is at its core an information system. Its development will therefore follow a typical Systems Development Life Cycle (SDLC): initiation and planning, requirements gathering and analysis, systems design, development, testing, implementation, and maintenance. This paper discusses the first two phases of the SDLC.

The initiation and planning phase of the SDLC defines a need and identifies the scope of the system to be developed to meet this need. The LCA communities need for transparent, quality, regionally relevant data, and access to community processes and best practices were discussed above.

The second phase, requirements gathering and analysis, involves communicating with key stakeholders to establish a group consensus on the system's requirements. To fulfil this phase, input will be sought from the LCA community to assist in identifying a list of system requirements based on the following research questions:

RQ1: What features must the KMS possess to motivate members to identify with and become active participants of their online community?

RQ2: What types of capabilities must the KMS provide to meet the LCA community's need for transparent, quality regionally relevant data?

RQ3: What types of activities must the KMS facilitate to enable members to collaborate with, to share and to learn from one another?

A requirement gathering typically uses an iterative feedback technique to obtain the most reliable group consensus. The process usually starts with a brainstorming/open-ended solicitation of ideas and ends with as close to a group consensus as is feasible.

In the interest of starting the brainstorming of ideas, the rest of this paper discusses the authors' personal opinions of some of the features, capabilities and activities that could be incorporated into the LCA community KMS.

3. An LCA Community KMS

Business and government policy makers increasingly base their decisions on published LCA reports. LCA practitioners themselves frequently use the published results of other papers for comparisons to their results or even as sources for missing data.

For LCA results to be transparent and comparable the reader needs all relevant information concerning the inventory data selected, the assumptions made to complement unavailable data and modelling choices about system definition and boundaries, functional units, reference systems and allocation methods. Unfortunately, whether due to lack of data or insufficient space to fully report all of the methodological choices made, many LCA publications provide insufficient information to make such quantitative comparisons with any confidence. And even if sufficient information is available, the supply chain modelled and its inputs can be unrepresentative of local regional inputs. For example, the differences between modelling a simplified piggery ration in an Australian pork supply chain compared to a European one (Wiedemann, McGahan et al. 2010).

The published values for a European pork LCA simplified piggery ration were based on a marginal grain (barley) and soybean meal imported from Argentina (Dalgaard, Halberg et al. 2007). But Australia is a major grain exporter. It does not in fact import any grain, only some grain by-products like soybean meal. A simplified Australian piggery ration has to model sorghum as the marginal grain. While the published energy inputs for milling of soybeans and canola (rapeseed) in Argentina were used, the soybeans had to be modelled based on a mix of imported (US) and Australian domestic production.

3.1. Publication Knowledgebase

An online LCA community KMS can provide a place for LCA practitioners to provide detailed information on the methodological choices made for their own publications and ask questions regarding other member's publications. All supplemental information provided for a publication could be linked to, and accessible with, that publication. Providing the means for further clarification in an online forum makes the knowledge available to all members. Members could make more informed decisions on which publications to use for comparison or as data sources. Business and government policy makers could have more confidence in their analysis of the publication's results.

Beyond this basic dissemination of information, an online KMS could allow LCA community members around the globe to collaboratively create and share their knowledge. A publications area of a KMS can serve as a repository for the community's general LCA references.

For example, each community member could upload their own EndNote reference libraries to the publication knowledgebase. The references uploaded would be available to the community as a whole. Community members could add their own reviews, citations and keywords for each publication in the knowledgebase. Also, each member could create and manage their own personal library based on selections from the entire publications knowledgebase. Member libraries could be downloaded, in whole or in part, as new EndNote reference library files. Where electronic versions are available and copyright permits, publications could be uploaded to and downloaded from the repository; otherwise links to online versions could be provided.

As more and more publications and their associated metadata are added to the knowledgebase, its value grows. The community's collective contributions create a richer knowledgebase available to the community as a whole than would have ever been available to any member through their own individual efforts.

A publication knowledgebase is one component of a LCA community KMS. Another key component for the LCA community is the facility to link publications with their LCI data.

3.2. LCI Data Store

The methodological choices made while defining the goal and scope step of a LCA greatly influence the gathering and selection of its LCI data. Since a LCA of even a modest supply chain can involve collecting data for hundreds of individual supply chain steps, i.e. unit processes, practitioners are uniquely dependent on data collected by their colleagues.

Given this dependency, the LCA community has a corresponding requirement for transparent, quality, regionally relevant data.

The publications knowledgebase can provide the means for clarifications on methodological choices made for a LCA publication. A LCI data store, in conjunction with a publications knowledgebase, would provide the means to make direct linkages between a publication's LCA results and the LCI data on which the results were based; thus increasing both the transparency of and the confidence in the publications results and in the usability of the LCI data for other life cycle assessments.

The LCI data store could consist of both complete unit process data files and unit process reference files. Unit process data files would provide complete data for a specific step in a supply chain, for example the input and output material and energy flows required to produce one tonne of sorghum on a farm in South East Queensland.

Unit process reference files could be used for data available in external databanks such as ELCD or Ecoinvent. A reference file could provide a link to where the unit process data and its meta-data describing functional units, included impact categories, etc could be accessed.

This form of an online data store could provide the means for community members to objectively review and compare data. It could also allow the means for community members to collaboratively create and share LCI data.

The KMS could provide the means for members to register their interest in specific types of data. Members with similar data requirements could form data interest groups who could collaboratively create and share data which follows a consistent protocol.

The KMS has the potential to allow LCA community members to gain access to valuable information they need to do their jobs and have their contributions open for peer review. LCA community members could therefore gain recognition for their areas of expertise and become more visible to the global LCA community.

3.3. Collaboration and More

Beyond the publications and data store sections of the KMS, other Internet technologies could provide ways for community knowledge to be socially generated, maintained and exchanged. Blogs, wikis and videos could be used to provide tutorials for conducting some of the more complicated LCA processes. Forums could be employed for community discussions on topics such as the adoption and appropriate use of a new impact category. Popular features of current social software applications could also be adapted.

One potential adaptation that could add value to the KMS is Amazon-style reviews for the publications. Amazon taps into the expertise and opinions of its customers by encouraging them to post reviews of their products. Undecided customers gain the advantage of the opinions of reviewers familiar with the product. The review system also allows customers to rank the usefulness of a reviewer's posting. Reviewers whose postings are consistently ranked as 'useful' have this higher level of confidence delineated next to their postings; providing an additional dimension of confidence in the reviewer's opinion.

This style of review system could be a very valuable addition to the publication knowledgebase. Publication authors get feedback, the reviewer gets feedback, good reviewers can establish a reputation for providing useful advice, and community members gain the advantage of other member's viewpoints regarding the value of a publication.

Another popular social software feature that could be adapted is iTunes Playlists. iTunes is a software application that allows users to organize their music. iTunes Playlists allow users to create song 'collections' based on artist, genre or use. Playlists can be shared with others by publishing them on the iTunes Store.

An iTunes-style Playlist for publications would allow members to create and share topical lists of publications. Unlike keywords which generally refer to the content of a publication, a Publist would provide a means to organize publications based on how they are used. A Publist for 'Australian Pork' could include publications on Australian grain production, regional farm processes, references to percentages of fertiliser imports, etc. Publists would provide a means of associating a publication with its relevant reference material, i.e. LCI data, allocation methods, etc. Creating such a project specific Publist would provide a way for experienced members to organize a project's reference material for easier documentation and retrieval. Sharing this type of Publist with the community would allow other members to gain insight into the standards and practices followed for the life cycle assessment. Transparency in methodological choices and data sources could increase the perceived value of and confidence in a publications result.

4. Conclusion and outlook

An online LCA community KMS provides the means for the global LCA community to collaboratively create, store, review and compare LCI data. In addition, a LCA-community KMS could provide the means for experienced LCA practitioners to share their knowledge and have their expertise recognised by the larger community. For newer members, a community based KMS could provide access to a collective knowledgebase of expertise and the opportunity to learn from and adopt the community's standards of practice.

With an online LCA community KMS, opportunities to collaborate, to learn, to share and to be recognized could all be viable and offer enormous potential. This paper proposes the development of an LCA community KMS, designed by and developed for the LCA community. Construction of the KMS will occur over the next few years. Its creation will require community input. Its success will require community participation, one member at a time.

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The application of EMAS regulation in the Italian food industry: a reliable data source for LCA

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ABSTRACT

The EMAS Regulation is a key voluntary tool amongst those proposed by the European Union for organizations to manage their environmental impacts. The link with Life Cycle Assessment (LCA) is quite evident since, apart from the focus on environmental impacts that these tools share, the correct implementation of the Environmental Management System (EMS) required to obtain EMAS registration allows gathering a great deal of information that can be used in an LCA. The survey presented in this paper focuses on Italian EMAS registered enterprises in the food sector, their view on this tool and in particular, the environmental impacts, the drivers to register, the difficulties encountered and the benefits achieved. Moreover, to identify the particularities of the food industry, the results from this sector are compared with those of all other registered organizations.

Keywords: Food industry, EMS (Environmental Management System), LCA, EMAS Regulation 761/2001 CE, environmental data

1. A brief introduction to LCA and EMAS

The Life Cycle Assessment (LCA) methodology was initially developed in the United States at the end of the 1960's as a tool to enable the evaluation of the impact of a product through the quantification of the environmental effects of all the processes the product is involved in during its entire lifetime.

Between 1997 and 2000, the LCA method was formalized in the ISO 14040-14043 standards that were reviewed in 2006, resulting in the ISO 14040:2006 and ISO 14044:2006 standards.

The structure of an LCA can be divided in four phases. In the first, the aim and scope of the study, the product, its function and the boundaries of its life cycle are defined. The impact categories, as well as the quality of data to be used, are evidenced. In the second phase, the so-called inventory, namely the quantitative data on inputs and outputs of each process are gathered. This phase is the most complicated but the availability of databanks on the technical characteristics of materials and manufacturing processes can be very helpful. In the third phase, an impact assessment is performed. Inputs and outputs of every impact category are classified, then these inputs, outputs and impact categories are characterised, and finally the categories are weighted. In the fourth and last phase, the results of all the preceding work are put together and interpreted (ISO, 2006a; ISO, 2006b).

EMAS is an environmental management system that was introduced for the first time by the European legislator in 1993 (Regulation No 1836/93). It was then revised in 2001 (Regulation (EC) No 761/2001), and recently the latest version of EMAS, the so-called EMAS III, came into force (Regulation (EC) No 1221/2009). The regulation establishes a voluntary scheme that allows organizations to evaluate their environmental performances, improve them, and report to the public on the progress made. From an operational point of view,

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EMAS implementation can be divided in seven phases (European Commission, 2001):

1) review of all the environmental aspects of the organisation
2) adoption of an environmental policy that contains appropriate environmental goals
3) development and implementation of a comprehensive EMS
4) internal environmental audit to identify any possible weaknesses
5) identification of adequate solutions for all the weaknesses found during the previous phase
6) preparation of an environmental statement that gives an account of all the relevant environmental impacts of the organization and how these were addressed and reduced
7) audit of the initial environmental review, the EMS, the audit procedure and its implementation by an accredited environmental verifier, that will also validate the environmental statement.

The final step involves the competent national body that is responsible for the registration of organizations.

2. The link between LCA and EMAS

It is quite evident that LCA and EMAS are two very different tools that share a number of similarities (Glumpak et al., 2009). In fact, environmental accounting, more specifically in the form of environmental indicators, has a primary role in both. In an LCA, an indicator is linked to each impact category whilst in EMAS, an indicator should be present for every relevant environmental impact and all indicators must be part of the environmental statement. The difference between the indicators used in these different tools is that in EMAS they are used to monitor the environmental improvements from one year to another while in an LCA they are used to compare a number of different products or production processes.

However, regardless of the tool under consideration, a strong quantitative approach must be used and the gathering of a huge amount of data is necessary. Although LCA focuses on the product, its production phase is so strongly linked to the organization's activity that a substantial part of the data gathered in the EMAS method could be useful when performing an LCA. In a certain way, the implementation of EMAS can be viewed as preliminary to carrying out an LCA as it can provide a comprehensive view of the enterprise and its environmental impacts.

3. The food processing industry and its environmental impacts

The Italian food industry generated 120 billion Euros of sales in 2008 (+5.7% on 2007) and represents the second largest national industrial sector after "mechanical and engineering". It accounts for 8.4% of the GNP and 12.6% of employees (Nomisma *et al.*, 2009; Rossi, 2009).

As pointed out by the EIPRO 2006 survey (European Commission *et al.*, 2006), the consumption of food products, and therefore the food industry, generates considerable environmental impacts with a very significant carbon footprint. This survey undertakes a review of several previous works in the field of impacts caused by the consumption of different products on the environment from a life cycle perspective. Within the EIPRO study, the CEDA EU-25 method to assess these same impacts was also developed.

Research has identified food and drink products as responsible for 20-30% of the various environmental impacts of total consumption considered in the study and for more than 50% of eutrophication.

Within food consumption, meat and meat products (including meat, poultry, sausages or similar) have the greatest environmental impact (Weidema *et al.*, 2008). The estimated contribution of this product grouping to global warming is in the range of 4-12 % of all products. Again, it must be noted that these results reflect the impact of the full production chain, including the different phases of agricultural production. Both the CEDA EU-25 analysis and the Nijdam and Wilting (2003) study support this conclusion.

Dairy products are the second most significant product grouping. In fact, in the Nijdam and Wilting study, the contribution of milk, cheese and butter to total global warming potential is estimated at 4%. In CEDA EU-25, this corresponds to fluid milk (2.4%), cheese (2.1%) and dry, condensed and other dairy products (0.6%). For these products, the contribution to eutrophication is also reportedly very high (10-13% of all products).

Following these two main groupings are a variety of others such as plant-based food products, soft drinks and alcoholic drinks that present lower levels of environmental impacts in most of the impact categories considered.

As previously shown, the food sector has the highest environmental impacts according to the EIPRO study. It therefore comes as no surprise that so many enterprises that operate in this industry have chosen to join EMAS, which expressly aims to help manage the environmental aspects of organizations and therefore also their environmental impacts. Even more important, among the registered enterprises of this industry, those that are active in the meat and dairy products segment account for over two thirds of the total.

4. Results of a survey on Italian EMAS registered enterprises in the food processing industry

To understand the opinions of Italian EMAS registered organizations on this tool and its capacity to help manage the company's environmental issues, a survey was carried out in the final application period (January – July 2009) of the second version of the EMAS regulation while the revision process carried out by the European Commission was in its concluding stage (Merli *et al.*, 2010). In this paper, we focus on the food processing industry and particularly on:

- the environmental issues that are considered most important within the sector
- the drivers that played a major role in convincing the managers of these enterprises to implement the scheme
- the benefits derived from EMAS registration

The survey tool used was a questionnaire submitted via e-mail containing 32 multiple-choice questions on several different aspects of the EMAS experience. All responses were statistically analyzed but in this paper, we concentrate solely on the three relevant responses that refer to environmental issues.

The survey population is composed of all Italian organizations adhering to EMAS at the end of 2008, totalling 962 registrations, of which 103 were from the food processing sector and identified with the NACE code no.10. NACE codes are used in the EU to standardize the definition of economic activities of Member States. Within the food industry there is a clear prevalence (67.3% of the total) of registrations referring to two subsectors: "Processing and preserving of meat" (identified by NACE code 10.11) and "Operation of dairies and cheese making" (identified by NACE code 10.51), which account for 50.5% and 16.8% respectively of the sector's registrations. This appears to be closely linked to the fact that these two industries, as previously observed, are among the most significant contributors to numerous environmental issues. The remaining registered food processing enterprises operate in sixteen different subsectors (EMAS Helpdesk, 2009; ISPRA, 2009).

From a geographical point of view, it is noteworthy that 84.5% of registrations refer to enterprises that have their head office in Northern Italy, the Emilia-Romagna region alone accounting for 78.6% of EMAS registrations in the food-processing sector. This region's registrations are also concentrated in the meat processing and preservation (60.2%) and in the dairy and cheese making (22.9%) industries.

This particular situation is driven by two factors (Provincia di Parma *et al.*, 2004):

- the environmental awareness of enterprises that produce world-famous products such as *Prosciutto di Parma* and *Parmigiano Reggiano* (a cured ham and a type of hard cheese respectively) within tightly regulated and excellence-oriented consortia
- the commitment of the Emilia-Romagna region and the Parma province to promote the diffusion of EMSs using different tools such as financing, training, publication of specific guidelines, etc., particularly addressed to companies that produce *Prosciutto di Parma DOP* ham and *Parmigiano Reggiano DOP* cheese (*DOP* stands for *Denominazione di Origine Protetta*, which means Protected *Designation of* Origin, a mark guaranteeing that a food product is produced in a specific area and in a particular way).

With regard to the size of the enterprises of the food sector, we found that they are amongst the smallest when compared to those of other sectors.

As to EMAS seniority, intended as the time elapsed since the first registration, enterprises in the food sector show higher mean values (36 months) than the remaining Italian registered organizations (31 months).

Out of 103 registrations in the food processing industry, 74 participated in the survey, which is a participation rate of 71.8%. To ensure that the results obtained are statistically significant, a minimum sample size was calculated, and the result, considering an error margin of 0.06, was 40. With 74 registrations in our sample, the results presented are therefore reliable from a statistical point of view.

As previously pointed out, the food processing industry has a major role in determining significant impacts in several environmental categories, particularly concerning water eutrophication. It is thus reasonable to expect water pollution to be a recurrent issue when analyzing the environment-related questions of our survey.

In fact, water issues are consistently at the top of the rankings in terms of importance of environmental issues *per se*, as drivers for EMAS registration and as benefits deriving from EMAS, as shown in Table 1.

Table 1: The most important environmental issues in the food sector

Environmental issues	**Mean values (relevance)**		
	Per se	As drivers for EMAS registration	As benefits deriving from EMAS
Water pollution	4.55	4.39	4.50
Soil pollution	3.47	3.65	4.20
Air pollution	3.88	3.64	3.47

When the participating organizations were asked to evaluate the importance of the main environmental issues on a scale ranging from 1 (meaning "not important") to 6 (meaning "very important"), we found that on average these issues rank as follows: first is water pollution (4.55), second is air pollution (3.88), and third is soil pollution (3.47).

In the second part of the survey regarding the environmental drivers to implement EMAS, the possibility to reduce water pollution is the most important, with an average importance of 4.39. The possibility to reduce waste production and soil pollution is ranked second, while the possibility to reduce air pollution is ranked third.

The same ranking can be found in terms of the benefits associated with the reduction of environmental impacts. In fact, the most important benefits obtained from the implementation of EMAS are reduced water, soil, and air pollution with average importance scores of

4.50, 4.20, and 3.47 respectively.

Moreover, it appears that EMAS is a valuable tool for these organizations to improve their environmental performance as is also confirmed by the high registration renewal rate. In fact, 84% of respondents from the food sector expressed the will to also participate in the scheme in the future and only 2.7% were against this option. The remaining 13.3% were unsure whether to renew their registration.

As far as the comparison between the food sector and all other sectors in our sample is concerned, a number of interesting differences can be observed with reference to the drivers, benefits and difficulties linked to EMAS implementation.

In the part of the survey that investigates the importance of the drivers, the items are the same as those that concern the benefits. In particular, four issues are considered consistently more important in the food sector than in others, as shown in Table 2 and Table 3. These issues are reduction of water pollution (confirming the importance of this issue once again), reduction of energy consumption, reduction of raw materials used, and improved access to public funding and competitive bids. If we consider the small size of the participating enterprises that operate in the food sector, as previously pointed out, as well as the fact that SMEs are very often underfunded, the greater importance of this last issue, especially in terms of public funding opportunities, comes as no surprise. Further evidence of the importance of financial support from the public sector for SMEs has come to light in the part of our survey on the improvements that organizations were expecting from public decision makers as a consequence of the revision of EMAS II.

Table 2: Comparison between the most important drivers for EMAS registration

Drivers	**Mean importance of drivers**		
	NACE 10	Other NACE codes	Difference
Access to public funding and competitive bids	4.77	3.87	0.91
Reduction of water pollution	4.37	3.56	0.81
Reduction of energy consumption	4.35	3.54	0.80
Reduction of raw materials used	4.00	3.25	0.75
Improvement of internal organization	4.68	4.51	0.17

Table 3: Comparison between the most important benefits of the EMAS registration

Benefits	**Mean importance of benefits**		
	NACE 10	Other NACE codes	Difference
Reduction of water pollution	4.48	3.35	1.13
Reduction of raw materials used	4.11	3.11	1.00
Access to public funding and competitive bids	4.21	3.42	0.79
Reduction of energy consumption	3.95	3.32	0.63
Improvement of legislative compliance	5.01	4.58	0.43

Another area of the survey from which interesting evidence can be drawn, is that pertaining to the difficulties linked to the implementation process of EMAS. In fact, it clearly emerges that enterprises from the food sector encountered significantly more obstacles than other organizations. This is most evident with reference to the environmental review (the identification of direct and indirect environmental aspects was a major problem here), the economical aspects (such as consulting costs and costs sustained to adjust production processes), and setting up an EMS (in this case, EMS documentation, document control, and operational control were major issues).

Finally, although EMAS is an effective tool to cope with the main environmental challenges of companies in the food sector, there are some significant problems during the implementation of the scheme. The complexity and the high costs involved affect the food sector more than other sectors due to the small size of the majority of the enterprises in this industry.

5. Conclusions

As we have pointed out in this paper, EMAS and LCA share a similar focus on the improvement of the environmental performance of enterprises as well as the need to collect a huge amount of data to produce meaningful indicators. Therefore, it appears necessary to further investigate the relationships that exist between these tools so that possible synergies in terms of reduced costs and minimization of harmful impacts on the environment can be clearly identified. Due to the importance of the environmental impacts of the food sector, we suggest that any research effort should start with the analysis of this industry.

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