

# Towards the use of LCA as an approach to evaluate contribution of agriculture to sustainable development

Thévenot A. <sup>1,\*</sup>, Vayssières J. <sup>1</sup>

<sup>1</sup> CIRAD, UR Livestock Systems, Saint-Pierre, Réunion, France

\* alexandre.thevenot@cirad.fr

**Abstract** Development of sustainable agriculture is essential for maintaining ecosystem services and human well-being facing significant human population growth. Decision-makers must now take into account not only economic performance but also environmental compliance and social responsibility of supply chains. Agriculture differs from other sectors such as industry in the sense that it provides numerous ecosystem services such as landscape maintenance, social cohesion, and rural exodus limitation. Life Cycle Analysis (LCA) is largely presented as a standardized method for environmental impact assessment of a product or a process. Implementation of LCA generally points out only the negative impact of agricultural activities. In this paper we suggest that LCA should be considered not as a standardized method - with the risk of limiting its implementation domain - but as an approach offering the possibility to integrate the three dimensions of sustainable development. LCA can use numerous impact assessment methodologies produced by various disciplines (agronomy, social sciences, economy, etc.). Particular attention is needed on methodological problems encountered on allocation, assessment scale and system boundaries in order to build an integrated view of products and processes.

## 1 Introduction

Sustainable development returns to the concepts of environmental, economic and social durability [1]. Assessment in agriculture has always been complicated by multiple links between ecosystems and humans. It is one of the anthropic activities that has the strongest link with environment. Through it, ecosystem provides many services to humans. They are known as ecosystemic services (food, aesthetics, leisure activities, etc.). On the other hand, humans generate via agricultural activities negative externalities on the environment (pollution, loss of biodiversity)

and unlike the majority of other industry branches, produced externalities can also be positive (ex: carbon sequestration, biodiversity conservation) [2].

Sustainability assessment often focuses on negative externalities. In the last decades, the increase of impacts frequency became a big concern, which makes environmental dimension unavoidable in decision-making process. Tools for decision-making were thus elaborated. Life Cycle Analysis became a privileged approach because of its holistic and systemic vision of the system. However, classic tools (Attributional LCA, carbon accounting) based on this approach only focus on potential environmental impacts. In 2006, a FAO report estimates that livestock sector is responsible for 18% of the total entropic gas emissions [3]. Other reports [4] showed only the negative impact of agriculture on environment. The published global results do not evaluate neither positive nor economic and social performance of the whole product. Consideration of those externalities and dimensions through LCA approach becomes necessary for a coherent decision making. In this paper we present a review of several methods used in environmental, economic and social field that could be useful in the research field of sustainable LCA. We will try also to point out how those methods could improve assessment of a sustainable agriculture.

## **2 Environmental assessment perspectives in agriculture**

Crops and animal productions have been widely evaluated [5]. Most of these assessments were carried out in order to establish environmental impact references for the agricultural sector [6-8]. Classical Attributional Life Cycle Assessment (ALCA) allows system quantification of pollution and resource flows attributed to a functional unit [9]. Allocation is the standard procedure (ISO 14041) applied in order to allocate pollution and resource flows of a multi-functional process [10]. However, it is one of the most controversial issues of LCA because of its arbitrary appliance [11], particularly in agriculture that is highly multi-functional and where co-products can have significant roles in the main product system and in adjacent product systems. For instance, manure produced by livestock systems is reused by plant production systems, which avoids mineral fertilizer consumption. The relatively tight system boundaries of classic LCA do not consider the consequences resulting from the co-product use in other product systems. That should allow a more accurate durability assessment.

By expanding the system to include alternative production ways using co-products, the system expansion method is an alternative within the use of consequential LCA. Table 1 provides an overview of several differences between

CLCA and ALCA. CLCA development is currently on going. A few studies exist in agricultural field but some cases of avoided co-product allocation are shown. For instance, Thrane [12] expands the system boundaries in flat fish filet assessment from Danish fisheries to avoid by-catch, fish mince and fish offal allocation. Those co-products substitute respectively catch in other Danish fisheries that target these species, pork meat and soy-protein. The principles of the system expansion that were followed here, and in most cases studied in consequential LCA field, are described by Ekvall and Weidema [13]. In another study, Thommassen [14] showed results from an attributional LCA and a consequential LCA on a dairy farm production system. System expansion is applied on co-products of milk life cycle: soybean and beef meat impacts that are converted into palm oil, pork and beef meat avoided impacts. The conclusions were that it is possible to perform both LCA types, however, the choice of ALCA or CLCA must be done according to the study goals. CLCA should be used to assess a change in demand whereas ALCA to assess environmental burdens of a product. According to Dalgaard [15] it might be easier to handle CLCA if more effort is put into the development of marginal data. Indeed, this approach requires the existence of alternative systems to substitute co-products [16]. The use of system expansion and marginal data still induces some important limitations concerning completeness, accuracy and relevance [17]. The use of CLCA in agriculture assessment could allow to avoid allocation problems. This way, positive impacts for each indicator are quantified and displayed [12].

### **3 Extension to economic and social aspects**

In addition to these interactions with the environment, agriculture can have many social and economic impacts and can also return economic and social services that can be evaluated at very different levels. Focusing only on environmental impacts limits the use of LCA in the decision making process. To be sustainable a company must be economically sustainable and able to keep competing for advantages on its products. Figure 1 shows a set of three indicators that could be relevant for supply chain assessment in agriculture. The actual issue is to point out methodologies available in literature and to compare assessment scales, system boundaries, and purpose of application.

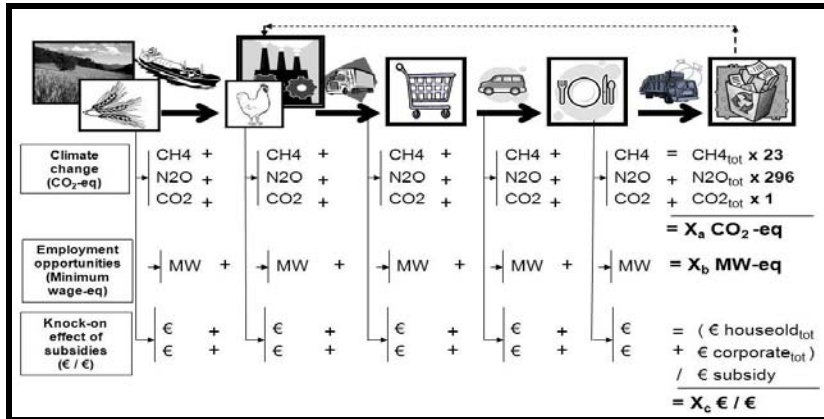


Figure 1. Example of economic and social aspects integration in LCA of a livestock supply chain.

### 3.1 Guidelines for economic dimension

Many methods and their applications can be found in the economic evaluation field but few share ideas with life cycle thinking. Among the attempts to carry out economic and environmental assessment, the most integrated approach is Environmental Life Cycle Costing (ELCC) [18]. It estimates, at product scale, the economic performance of a product and allows multiple points of view. The costs evaluated are linked to real monetary flows and include use, end-of-life, and hidden costs. It allows to evaluate whether or not a product developed in a sustainable way will be profitable and has a reasonable price for consumers. At another level, Cost Benefit Analysis (CBA) allows to assess direct and indirect economic costs and benefits of a project. It was developed separately from LCA but shares the same objective to provide holistic assessment of human activities. Weidema [19] emphasizes that much can be gained from both, however, his approach was quite taken up in literature. Other approach known as Input-Output Life-Cycle Assessment (IOA - LCA) [20] combines Input- Output Analysis with LCA. IOA is used to analyze the flows of goods and services between sectors within an economy. Efforts are being made in this field by the IOA-LCA community [21] because it can bring improvement in various areas of LCA. The economic dimension of sustainability can also be evaluated at a regional or national scale with Social Accounting Matrix (SAM). SAM has the advantage to measure aggregated impacts along the supply chain, taking into consideration all stakeholders [22, 23]. Another recent work carried out by Binder and al. [24] combines environmental and socio-economic indicators in a Sustainability

Solution Space. This approach provides a multi criteria decision analysis based on stakeholder participation and allows benchmarking.

All presented approaches bring relevant elements to economic LCA construction. Further work might be necessary to highlight connections that exist between them and LCA approach.

### 3.2 Guidelines for social dimension

Several studies have been trying to integrate the social aspect in LCA but SLCA is still in its infancy [9, 25, 26]. Different ways have been explored with different scales, functional units, and indicators (see Table 1). A lot of methodological problems remain unsolved, but those studies point out interesting leads for further research. The use of midpoint or endpoint indicators is, for example, still discussed within scientist’s community. Dreyer and Flysjö [27] argued that midpoint indicators should be used because they are easier to comprehend for the decision makers. Weidema [19] suggests the use of a procedure that converts all impacts into a QALY (Quality Adjusted Life Years) as a measure of human well-being. Kloepffer [11] suggests that impacts have to be quantitatively linked to a functional unit. Hunkeler [26] refers to a single impact category based on working hours and evaluates social impacts from the labor income. Franze [28] presents the first case study based on « Guidelines for Social Life Cycle Assessment of products » elaborated by the UNEP/SETAC working group [29]. A conclusion of this study shows that there is a strong difficulty to find appropriate indicators. These results confirm several problems identified concerning social integration in LCA. According to Hunkeler [26] “More than 200 societal midpoint impact indicators exist, which may lower probability of obtaining agreement on their selection and valuation in actual use”. Moreover “Data needs are greatly increased with non-environmental, company-specific data or region-specific data”, according to Dreyer [25].

**Tab.1: Table 1. Overview of potential methods that can be integrated in LCA for agriculture sustainability assessment**

Method	System boundaries	Data inventory	Scale	e.g. of indicators	Study
Environmental dimension					
ALCA	Supply Chain	Resources and processes directly used in life cycle of the	Global	Climate change, Energy use, Acidification	Cedeberg [7]

		product			
CLCA	Supply Chain	Resources and processes directly and indirectly affected by a change in the output of a product	Global	Climate change, Energy use, Acidification	Thomassen [14]
Economic dimension					
ELCC	Supply Chain	All internal and external costs associated with a product	Product	Climate change, Energy use, Acidification	Hunkeler [18]
I-OA	Industry	All monetary values of an industry's inputs and output	Regional /National	-	Lenzen [20]
C-BA	Project	All costs and benefits of a project	Regional /National	Economic costs and benefits to different agents, changes in capital stocks	Weidema [19]
SAM	Part of Supply Chain	Income and economic flows between different institutional units	Regional /National	Total Value Added, Employee Comp VA; Profits VA	Basquin [22]
Social dimension					
S-LCA	Supply Chain	Global burden of well-being	Regional /National	Child labor, Trafficking, Excessive work, Crime victim compensation	Weidema [19]
S-LCA	Supply Chain	The most important companies in the product chain	Regional /National	Wages, Stability of employment, Job creation	Dreyer [25]
S-LCA	Supply Chain	Employment hours of life-cycle stages	Regional /National	Housing, Health care, Education, Necessities	Hunkeler [26]
S-LCA	Supply Chain	Social Hot Spot and classic environmental system boundaries	Regional /National	Forced labor, Fair competition	Franze [28]

#### 4 Discussion and conclusions

All methods presented in Table 1 provide several interesting indicators and results. For environmental dimension, CLCA allows construction of avoided impact

indicators. It implies making hypothesis on which alternative product impact could replace the co-product impact. However this seems more relevant in agriculture assessment than allocation because of the high value added of co-products. Economic field brings several indicators for assessing economic contribution of agriculture. Value added distribution among stakeholders and contribution to GDP (Gross Domestic Product) assessed with IOA methods are particularly relevant in this way. Advances in social LCA show a large panel of indicators, from employee well being to job creation.

Nevertheless, this multiplicity of indicators leads to some methodological problems. One of them is the presence of various assessment scales. For economic dimension, assessment can focus whether on the economic product performance or the added value created along the supply chain. At product scale, ELCC is the most relevant approach for sustainable company assessment, but there is no relevance when it comes to assess world society [30]. At regional scale, IOA or SAM can be useful because it takes all stakeholders into account. This problem is also founded in SLCA, which is highly site-specific. Decision-makers goals can be to evaluate the respect of workers' rights or about how many jobs are created at each step of the product chain at regional scale.

Another issue is about the delimitation of system boundaries. The system boundary defines the start and the end of the material flows which are accounted. Setting those boundaries is a persistent problem in ELCA [31] as it can be noticed regarding the criticisms towards the lack of objectivity allowed by ISO standards [32]. It is confirmed for agricultural system assessment, where contrarily to other sectors as industry, multiplicity of biological processes involved complicates the identification of all flows between processes and the environment. Although it seems to focus on supply chain for most of the methods seen in Table 1, conjunction of system boundaries might be harder when it comes to integrate economic and social aspects in LCA. Indeed, most impacts on people are independent of the physical processes [25].

There is a significant variety of methods that could be used to develop social and economic indicators. However, it requires more research before leading to a standardized and generic tool as environmental LCA. In the short term, methodological connections highlighted between current methods in economic and social sciences field and LCA must be applied on real case studies in order to prospect a various set of scenarios. Learning those bases will allow to develop appropriate sets of indicators. Researches in this field should give priority focus on agricultural case study. It is the anthropic activity that will provide the biggest part of human basic needs and will feed the nine billion people tomorrow.

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