The potential contribution of Life Cycle Assessment to analyzing the environmental impacts and the sustainability of irrigation and drainage systems

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1. Introduction

Sustainable production and consumption have become key policy priorities, and environmental and socio-economic challenges in recent years.

According to the IPCC (2006), there is no well-established approach that is able to, simultaneously and in an integrated manner, take account of the whole set of indicators that characterize the environmental, social and economic performances of agri-food systems, with regard to current global and regional sustainable development challenges.

In this context, Life Cycle Analysis (LCA) has been promoted and increasingly used as a comprehensive, integrated methodology for analyzing the environmental impacts of products, goods and services.

This volume has been prepared to provide insights onto the LCA methodology and its application in irrigation and drainage systems, in order to inform the ICID community and to promote LCA use.

To that aim, the ICID working group on Environment (WG-ENV) formed a task team in 2011, including Dr. SR Perret, Dr. M Van der Laan, and Prof. N Hatcho, Chair, Secretary and Vice-Chair of WG-ENV, respectively.

This contribution first presents briefly what is LCA, its principles, outcomes, and main methodological features. It then proposes case studies of LCA application in irrigated agriculture, as illustrations of the potential contribution of the approach.

2. What is Life Cycle Analysis ?

LCA stands for Life Cycle Analysis or Life Cycle Assessment. It proposes a systematic and efficient methodology to assess the environmental impacts of goods, products, processes or services.

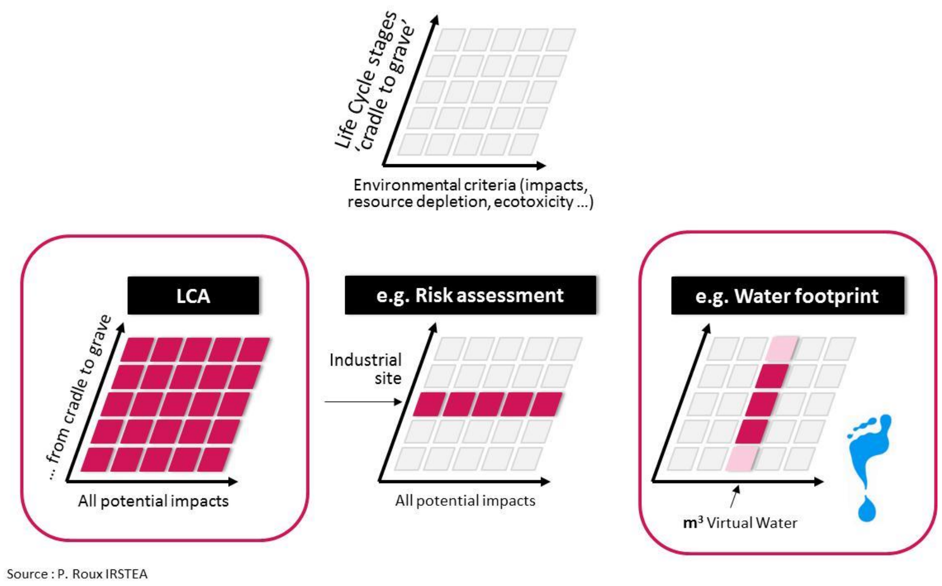

Figure 1. LCA and other environmental impact assessment approaches

LCA was first developed in the industry for assessing and comparing the environmental impacts of products, technological processes and options throughout their life, and for ultimately reducing the pressure onto the environment. The concept of product “life cycle” means that a product is followed from its origin (“cradle”) where raw materials are extracted from natural resources through production and use, to its “grave”, the disposal (see figure 1). The following case studies show that, in fact, many LCA-related studies in the agricultural sector do not cover products from “cradle” to “grave”, but rather stops at the farm gate, and sometimes at the processing stages. The consumption and disposal stages are seldom addressed.

LCA designates at the same time the whole assessment procedure (i.e. a set of standardized methods and stages) and a set of models or algorithms that translate input and output flows into environmental impacts. In LCA, natural resource use and pollutant emissions are described in quantitative terms. Also, LCA does not always focus onto the product or service itself (e.g. irrigation technology used, or mass of rice produced), but rather onto the functions attached to it (through the concept of functional unit; e.g. volume of water delivered at crop level, or amount of calorie-equivalent). This allows for comparing different products or services with similar functional units.

LCA may be used for comparing products or services, for characterizing one given product (e.g. towards eco-labeling), or to investigate possible changes in a given production processes towards lower environmental impact.

LCA methodology is standardized (ISO 14040-41-42-43-48); as shown in figure 2, its main stages are:

- Goal and scope definition, where the objectives and expected outcomes are defined as clearly as possible (i.e. definition of the product, good or service to study, definition of the functional unit thereof, system boundaries, allocation rules, data required, purpose and expected role of the analysis, etc.);
- Inventory analysis, where all resource uses, emissions to air, soil and water are listed, documented, quantified (i.e. a detailed input-output flow analysis), and referred to one functional unit (e.g. as per mass unit of good produced, or per unit of service rendered); this step supposes much fieldwork, observations and primary data, in order to best reflect and document the flows at play;
- Impact analysis itself, or characterization (see figure 2), where input and output flows are translated into environmental impacts through appropriate models and algorithms; existing databases and models are mobilized for that purpose; also specific platforms (e.g. Simapro, Gabi, etc.) are commonly used to ease up calculations and provide access to databases (e.g. Ecoinvent).

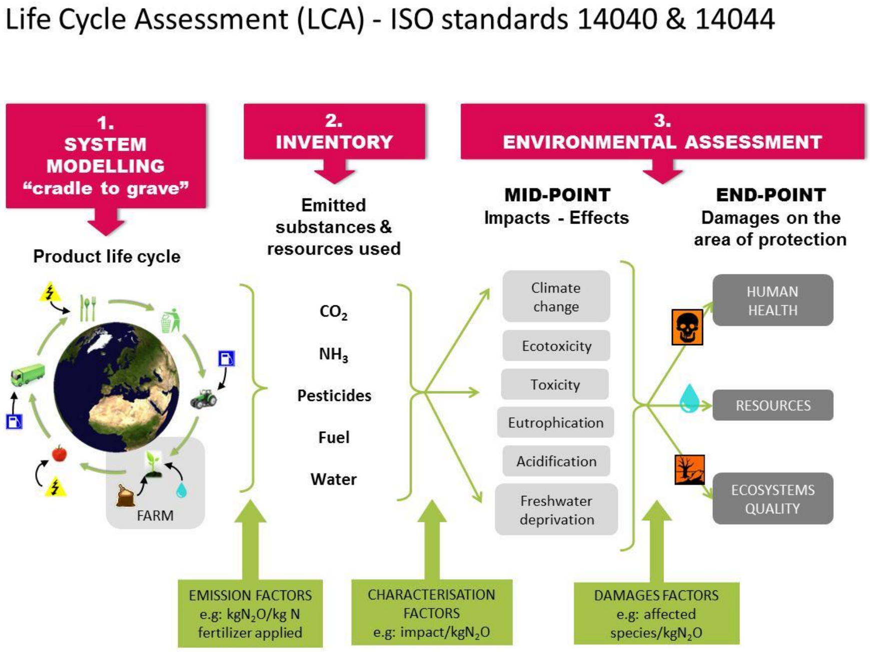

Figure 2. The main stages of LCA (source S. Payen, CIRAD)

Our purpose here is not to elaborate in detail on the methodology itself but rather to introduce case studies and applications. Readers may find additional information in the following references:

Baumann, H., and Tillman, A. 2004. The Hitchhiker's Guide to LCA: An orientation in Life Cycle Assessment Methodology and Application. Studentlitteratur, Lund, Sweden.

Mila i Canals, L. et al., 2009. Assessing freshwater use impacts in LCA: Part I—inventory modelling and characterisation factors for the main impact pathways. *International Journal Life Cycle Assessment*, (42), 28-42.

Pfister, S., Koehler, A. & Hellweg , S., 2009. Assessing the Environmental Impacts of Freshwater Consumption in LCA. *Environmental Sciences and Technology*, 43(11), 4098-4104.

Basset-Mens, C., Benoist, A., Bessou, C., Tran, T., Perret, S., 2010. Is LCA-based eco-labelling reasonable? The issue of tropical food productions, International conference on Life Cycle Assessment in the agri-food sector (Vll), pp. 46-466.

It must be noted that LCA application to agricultural systems is recent, fraught with many challenges, especially in developing conditions (Basset-Mens et al., 2010). To date, applications in irrigation and drainage systems remain rare. As shown in the reference list above, there are still vivid debates about the special status of water in LCA, which require specific approaches: water is both a resource that is susceptible to be depleted and a compartment that is susceptible to be polluted. Also, the resource ultimately interacts with the three areas of protection that are defined in LCA, i.e. ecosystems, humans, and resources (see figure 2).

3. Presentation of the case studies

The following case studies demonstrate the significant potential contribution of LCA to irrigation agriculture. They show that LCA may not be used as a single methodology but rather combined with other methodologies.

Thanawong et al. combine the environmental impacts of various rice cropping systems (assessed with LCA) with techno-economic performances in Thailand, leading to defining so-called eco-efficiency indicators, as proxys to sustainability indicators. They show that systems under controlled irrigation, especially during the dry season, are more impacting and less eco-efficient than rainfed ones.

Van der Laan et al. combine the LCA of irrigated sugarcane with water balance and crop growth models in South Africa, in order to investigate the potential benefits of alternative, improved management of water and fertilizer. They show that improved management leads to lesser environmental impacts and sustained yields.

Hatcho et al. used LCA to assess the environmental impacts of environment-friendly rice systems in Japan. They show that such systems, while using fewer inputs, are not necessarily more environment-friendly than traditional ones.

Assessment of Environment-friendly Rice Farming Through Life Cycle Assessment (LCA)

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Abstract

To reduce the negative impacts of farming, both national and local governments in Japan are promoting environmentally friendly farming. Similarly sustainable agriculture practices are pursued in different parts of the world. Shiga prefecture (135° 52′ E, 35° 00′ N), Japan is promoting such environmentally friendly farming by providing subsidies to farmers who reduce the level of chemical fertilizer application to control water pollution and eutrophication in Lake Biwa basin.

Environmental impacts of rice farming, particularly the emission of global warming gas (CO2, N2O, and CH4), eutrophication (T-N and T-P and COD to water) and energy consumption, were analyzed by applying life cycle assessment (LCA), which is a method to analyze environmental impacts associated with whole process of certain product from raw material extraction, processing/production, distribution, use, and disposal. Cultivation practices and inputs (labor, materials, and chemicals) of farmers who adopt environmentally friendly and conventional practices were collected through interviews with local farmers in the basin of Nishinoko area in Shiga prefecture. The system boundary includes all processes of paddy production from seeding to harvest/drying and machinery/materials used for production, but does not include construction of facilities and buildings/land consolidation and waste disposal, distribution of products, and consumption processes. The process of making compost is also included in the analysis where compost is applied. Results show that environmentally friendly farming does not necessarily have lesser impacts when compared to conventional farming in different categories of assessment, which largely depends on the estimation of methane emission and total-P/total-nitrogen from paddy fields.

Full paper has been published by Chiang Mai University's Journal of Natural Sciences, Special Issue on Agricultural & Natural Resources (2012) 11(1): 403-408

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