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Modelling of food loss within life cycle assessment: From current practice towards a systematisation

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ABSTRACT

Food loss is a major concern from both environmental and social point of view. Life Cycle Assessment (LCA) has been largely applied to quantify the environmental impact of food and to identify pros and cons of different options for optimisation of food systems management, including the recovery of potential waste occurring along the supply chain. However, within LCA case studies, there is still a general lack of proper accounting of food losses. A discrepancy both in food loss definition and in the approaches adopted to model the environmental burden of food loss has been observed. These aspects can lead to misleading and, sometimes, contrasting results, limiting the reliability of LCA as a decision support tool for assessing food production systems. This article aims, firstly, at providing a preliminary analysis on how the modelling of food loss has been conducted so far in LCA studies. Secondly, it suggests a definition for food loss to be adopted. Finally, the article investigates the consequence of using such definition and it proposes potential paths for the development of a common methodological framework to increase the robustness and comparability of the LCA studies. It discusses the strengths and weaknesses of the different approaches adopted to account for food loss along the food supply chain: primary production, transport and storage, food processing, distribution, consumption and end of life. It is also proposed to account separately between avoidable, possibly avoidable and unavoidable food loss by means of specific indicators. Finally, some recommendations for LCA practitioners are provided on how to deal with food loss in LCA studies focused on food products. The most relevant recommendations concern: i) the systematic accounting of food loss generated along the food supply chain; ii) the modelling of waste treatments according to the specific characteristics of food; iii) the sensitivity analysis on the modelling approaches adopted to model multi-functionality; and iv) the need of transparency in describing the modelling of food loss generation and management.

1. Introduction

The Food and Agriculture Organization of the United Nations (FAO) has estimated that each year approximately 1.3 billion tons of edible food are wasted throughout global food supply chains (FSCs), corresponding roughly to one-third of all food produced for human consumption (FAO, 2011a). Food loss (FL) represents a major concern from both an environmental and social point of view. On the one hand, by tackling FL in FSC, there is a great opportunity to reduce major environmental burdens related to FL generation and management, especially in developed countries; while on the other hand, about 800 million people on the planet are suffering from chronic undernourishment (FAO, 2014a). Wasting food means wasting all the inputs consumed along the entire food supply chain (energy, natural resources, human labour, etc.) and contributes directly to the depletion of some already scarce resources, such as phosphorous used to produce fertilisers, or land and water. FAO (2013) has estimated that the total water used to produce the food currently lost within global food supply chains is equivalent to 3 times the size of the lake of Geneva (about 80,000 m^3) whereas the land use needed accounts for 1.4 billion of hectare. Food produced and not eaten at global level is responsible for the emissions of 3.3 $GtCO_{2eq}$ equal to more than 30 times the greenhouse gas emissions associated to domestic final demand in Switzerland in 2005 (Jungbluth et al., 2011).

Moreover, food production is expected to increase in order to satisfy the needs of the raising world population, which may reach

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9.5 billion by 2050 (United Nation - Department of Economic and Social Affairs (2015)). Reducing FL can play an important role in addressing this challenge, since - together with closing yield gaps, increasing cropping efficiency, and changing diets - it is one of the key actions to increase the availability of food for human consumption while reducing the environmental impact per unit of product (Foley et al., 2011). In the European context, tackling FL is one of the objectives of the European Commission. The Roadmap to Resource Efficient Europe (EC, 2011) has identified food production and FL as key areas where resource efficiency can be improved. Two interventions are foreseen: setting targets for FL reduction for each EU member state and improving industrial symbiosis practices recovering waste and by-products (EC, 2014). Furthermore, the recent communication on circular economy, a system where the products, materials and resources value is maintained in the economy for as long as possible and waste production is minimised, has identified food waste (FW) as one of the priority areas of intervention (EC, 2015; UNEP, 2006).

To achieve these objectives at international as well as at lower scale of intervention, integrated assessment methodologies and a full supply chain perspective are needed. Indeed, it is crucial that the envisaged actions for a reduction of FL and its better management are assessed through a life cycle perspective to avoid the shifting of burdens amongst different life cycle stages along the supply chain or different environmental compartments (EC-JRC, 2011). Given that FL occurs all along the supply chains, Life Cycle Assessment (LCA) represents a valuable tool for assessing: i) the environmental burdens associated to FL, ii) the benefits associated to FL reduction as well as iii) the preference among the possible recovery options.

The available scientific literature on LCA and food is rather wide (Arvanitoyannis et al., 2014; Chen et al., 2016). Currently, the most remarkable study estimating the impact of FL at global level, applying LCA, is a recent report from FAO (2013). In this report FL has been estimated in all regions of the world for both developing and developed countries.

Within the published LCA studies on food, the assessment of FL along the supply chain is often performed partially or inconsistently (Cerutti et al., 2014), limiting the effectiveness of LCA as a decision support tool in this context.

In order to contribute to the current debate on FW assessment and accounting, the present article has a triple purpose. Firstly, it aims to summarise the terms related to FL currently used to address the topic and to enhance their harmonised use in the LCA context. The use of shared terminology is, indeed, fundamental to achieve a harmonised approach (FAO, 2014b; Ostergren et al., 2014; Williams et al., 2015). Secondly, it aims to analyse and classify the different approaches observed in the scientific literature to assess the environmental burdens of FL, highlighting strengths, criticalities and possible inconsistencies. While conducting this analysis, the article discusses some relevant studies in the literature which can be considered as “exemplary” of different modelling approaches used by LCA practitioners. Finally, recommendations for the harmonisation of these approaches within LCA studies have been provided, fostering the effectiveness of LCA as a decision support tool to achieve FL reduction.

2. Materials and methods

A selection of recent scientific articles, reviews and reports was analysed in order to shed light on the terminology currently adopted when referring to FL as well as to depict a classification of approaches to account for FL.

The assessment of FL was performed only from an environmental perspective, whereas the economic and the social dimension of sustainability were not taken into consideration. Relevant documents have been identified through search engines (e.g. Scopus and Google Scholar) using the key words “food loss”, “food waste”, “food wastage”, “food + LCA”, “vegetables + LCA”, “fish + LCA”, “meat + LCA”.

Furthermore, the reference list of these articles was analysed and additional references considered relevant were included in the survey.

In particular, 82 articles published in peer review journals, 1 published in conference proceedings and 17 scientific reports have been analysed. All the documents are written in English and published starting from 1998. Among these, more than 70% of the documents have been published after 2010. The selected documents cover different themes: production of vegetables food origins (25 documents), production of meat, dairy and eggs (7 documents), fish production (7 documents), the assessment of the environmental burden of dietary choices and meals (10 documents), waste treatments (5 documents), industrial ecology (14 documents), methodological aspects related to the application of LCA (14 documents) and other themes related to the topic (18 documents).

The present work investigated the use of the terms “food loss” and “food waste” and the definitions provided. These were compared and, when necessary, combined in order to provide some recommendations about their clear application within the LCA.

Furthermore, the documents were reviewed in order to analyse the approaches adopted to account for FL in LCA studies focused on food products. In order to support such analysis, some articles were taken as example. However, since the present article is not intended as an extensive literature review, the list of mentioned articles should not be considered as exhaustive.

Accordingly to FAO (2011), five stages of the FSC were considered: (1) primary production, (2) transport and storage, (3) food processing, (4) distribution and (5) consumption. Furthermore, the end of life of FL generated within all the FSC stages was also considered. Food items were classified according to their origin as: (1) fruit and vegetables; (2) meat, dairy and eggs; and (3) fish.

“Primary production” includes the agricultural stage for fruit and vegetables, breeding, aquaculture or fishing for animals and animal products and, when pertinent in case of fishing, it includes also first processing on fishing boat (Vázquez-Rowe et al., 2012). “Transport and storage” includes the activities between the primary production and the processing of the food. “Processing” includes a variety of options and treatments according to the food output. The “distribution” stage refers to both wholesale and retail distribution and it involves transport and storage activities. “Consumption” represents the last stage of the FSC and it includes household consumption or consumption in restaurants or canteens. Finally, the analysis covers the “end of life” stage. This includes the treatments performed in dedicated plants for the disposal or recovery of the waste derived from FL generated along the FSC. As an alternative to waste treatments for FL, it was discussed the recovery of FL in industrial ecology (IE) applications, in which FL are used as raw materials in downstream production processes.

As results of the analysis performed, some recommendations for LCA practitioners were derived to foster the systematic inclusion of FL within their studies.

3. Results

The establishment of a possible common framework to account for FL in LCA should consider, among others, relevant elements, as: i) the definitions to be used; ii) accounting of FL in LCA; and iii) the modelling of FL recovery processes. An overview of these elements