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In quest of reducing the environmental impacts of food production and consumption

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A B S T R A C T

Food supply chains are increasingly associated with environmental and socio-economic impacts. An increasing global population, an evolution in consumers' needs, and changes in consumption models pose serious challenges to the overall sustainability of food production and consumption. Life cycle thinking (LCT) and assessment (LCA) are key elements in identifying more sustainable solutions for global food challenges. In defining solutions to major global challenges, it is fundamentally important to avoid burden shifting amongst supply chain stages and amongst typologies of impacts, and LCA should, therefore, be regarded as a reference method for the assessment of agri-food supply chains. Hence, this special volume has been prepared to present the role of life cycle thinking and life cycle assessment in: i) the identification of hotspots of impacts along food supply chains with a focus on major global challenges; ii) food supply chain optimisation (e.g. productivity increase, food loss reduction, etc.) that delivers sustainable solutions; and iii) assessment of future scenarios arising from both technological improvements and behavioural changes, and under different environmental conditions (e.g. climate change). This special volume consists of a collection of papers from a conference organized within the last Universal Exposition (EXPO2015) “LCA for Feeding the planet and energy for life” in Milan (Italy) in 2015 as well as other contributions that were submitted in the year after the conference that addressed the same key challenges presented at the conference. The papers in the special volume address some of the key challenges for optimizing food-related supply chains by using LCA as a reference method for environmental impact assessment. Beyond specific methodological improvements to better tailor LCA studies to food systems, there is a clear need for the LCA community to “think outside the box”, exploring complementarity with other methods and domains. The concepts and the case studies presented in this special volume demonstrate how cross-fertilization among difference science domains (such as environmental, technological, social and economic ones) may be key elements of a sustainable “today and tomorrow” for feeding the planet.

1. Introduction

Food systems are at the heart of the 2030 Agenda for Sustainable Development (UN, 2015), a global commitment to eradicate poverty and hunger while ensuring reduction of environmental and socio-economic impacts. Amongst the United Nations Sustainable Development Goals, Goal 2 (“end hunger, achieve food security and improved nutrition and promote sustainable agriculture”) and Goal 12 (“ensure sustainable consumption and production patterns”) are the focus of this special volume.

Ensuring sustainable human development means being able to feed a planet with increasing population, decoupling the socio-economic development from environmental impact, and addressing the evolving food and energy demand (UN, 2015). Food and energy supply chains are associated with complex and intertwined

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environmental and socio-economic impacts (Ericksen, 2008), as an evolution in consumers' needs and the changes in consumption models pose serious threats to the overall sustainability of food production and consumption.

The identification of sustainable solutions in the food and energy sectors needs to rely on integrated appraisal methods for comparing possible alternatives, and avoiding burden shifting geographically, temporally and along supply chains (FAO, 2012). Due to the variety of challenges and perspectives related to food systems, several methods are needed to answer different sustainability questions. This requires a transition towards systemic thinking, where impacts of global production and consumption patterns remain within the carrying capacity of the planet, namely the sustainability thresholds identified as planetary boundaries (recently updated by Steffen et al., 2015). This systemic thinking entails the identification of complementarity amongst methods and the critical analysis of their pros and cons for supporting decision making (Sala et al., 2013a,b).

Food systems entail the overall supply chain from agriculture to production, trade, distribution, consumption and the waste production. With an increasing global population, the need of 'resource-smart' food systems is of uppermost importance (UNEP, 2016). Life Cycle Thinking (LCT) and the different life cycle-based methods, such as Life Cycle Assessment (LCA) (ISO, 2006a, b), Life Cycle Costing (LCC), Social Life Cycle Assessment (sLCA) and the overall Life Cycle Sustainability Assessment (LCSA) may support a transition toward increasing the sustainability of current patterns of production and consumption. Specifically, Life cycle assessment (LCA) represents a reference method that helps in analysing supply chains with the aim of achieving environmental sustainability objectives, including improved agriculture, food production and consumption as well as more efficient energy conversion and use, supporting the identification of sustainable solutions for global food challenges (Notarnicola et al. 2016a). However, the complexity of food systems and supply chains requires food systems-tailored approaches in LCA, and the aim of this volume is, therefore, to gather together studies on LCA, and on the integration of LCA and other domains and disciplines, in order to assess agricultural supply chains.

In defining solutions to major global challenges, life cycle thinking and life cycle assessment are applied for: i) the identification of hotspots of impacts along food supply chain with a focus on major global challenges; ii) the comparison of options related to food supply chain optimizations (such as increase of productivity, and reduction of food losses) towards sustainable solutions; and iii) assessment of future scenarios both related to technological improvement, behavioural changes and under different environmental conditions (e.g. climate change); iv) assessment of social impacts associated to consumption patterns.

Analyzing these challenges from a global/continental perspective, major improvements are needed in all step of the LCA method. For example, life cycle inventories should cope with data availability, data quality and representativeness, whereas life cycle impact assessment needs the enhancement of impact modelling of water, land use, resource and toxicity for robust assessment of alternatives.

These topics were discussed during a conference organized by the European Commission- Joint Research Centre jointly with the Italian Association of Life Cycle Assessment. The conference "LCA for Feeding the Planet and Energy for Life" (6–8 October 2015) was held during the Universal exposition EXPO 2015 in Milan. The volume includes selected papers from the conference (proceedings available ENEA, 2015) as well as other contributions submitted to the journal that addressed the key challenges presented at the conference.

This special volume builds specifically on the theme proposed by (EXPO 2015) held in Italy in 2015, entitled "Feeding the Planet, Energy for Life". The key topics were related to the issue of the sustainability of agricultural intensification for answering the food needs of a growing population, the competition between land use for energy and for food, and the maximization of societal benefits whilst reducing environmental and socio-economics burdens (Fig. 1).

The special volume welcomed submission of papers focusing on: 1) analysing these challenges from a global/continental perspectives and proposing potential solutions; 2) case studies presenting comparison of results adopting different approaches leading to environmental improvements and optimizations; 3) reviewing methods and tools for sustainability assessment of food supply chains, focusing on food waste and resource recovery; and 4) Thinking outside the box: LCA and its complementarity with other methods and domains.

Contributions to this special volume were selected in order to cover these topics which are major challenges, proposing methodological improvements and specific case studies towards better assessment of agri-food supply chains. To set the context and the need for the improvement of life cycle based assessment of food supply chains, the volume opens with an overview of challenges for improving the robustness of current LCA method, identifying the research needs at the modelling, inventory and impact assessment level (Notarnicola et al., 2016a). The volume is then structured in four main parts: i) improving the current LCA methodologies for responding to Food LCA challenges; ii) how to better assess intensive, extensive and organic farming with LCA; iii) resource-smart food systems: LCA supporting the assessment of food waste and nutrient recovery; and iv) LCA supporting consumers and stakeholder's choices.

2. Improving current LCA methods for responding to food system challenges

Current Life Cycle Assessment applied to single food products and to food systems faces a number of methodological challenges. A review of them has been recently performed and opens the special volume (Notarnicola et al., 2016a). These challenges affect all steps of the method: from goal and scope definition, to life cycle inventory (LCI), life cycle impact assessment (LCIA) and interpretation of LCA results.

2.1. System boundaries and functional unit

When dealing with the assessment of the impacts/benefits due to agricultural intensification, one of the fundamental elements to be taken into account is the functional unit selected for the assessment. In the majority of LCA studies, mass is the only functional unit used to report LCA results of food product.

Recently, the number of LCA studies of whole diets has increased and Pernollet et al. (2016) investigated a number of studies on choices of systems boundaries and impact categories and how that affected the results. The results showed that many studies still include the agricultural phase only and most often included one or a few impact categories (e.g. climate change and land use), which significantly reduced the potential to make general conclusions. Similarly, Baldini et al. (2016) performed a review and analysed 44 studies on dairy production. The main conclusion was that there is a need for harmonization of approaches. Some areas for further development include broader range of impact categories, functional units, transparency, system boundaries, and sensitivity analysis.

Figueiredo et al. (2016) assess the production of sunflower in

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