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Hotspots analysis and critical interpretation of food life cycle assessment studies for selecting eco-innovation options and for policy support

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A B S T R A C T

Food production and consumption have been identified among the human interventions generating huge pressures and impacts on the environment. Policies aiming at sustainable production and consumption need to identify hotspots in order to decide where and how to act to steer eco-innovation and to reduce impacts. This could be achieved by applying a life cycle perspective and having a thorough and systematic interpretation of the results of the assessment within and beyond LCA (life cycle assessment) results. The present study aims at presenting a life cycle based method for hotspots analysis focussing on the life cycle impact assessment steps (characterization, normalization and weighting). These steps, which support a correct interpretation of the results, are often performed superficially and not in a systematic way. Hence, in this study, we propose a procedure for supporting the interpretation of LCA results, complementing the assessment with an analysis of hotspots of impact beyond those identified by LCA, to avoid excluding potential hotspots only because they are not fully captured by the current LCIA (life cycle impact assessment) methods. A case study on hotspot analysis and interpretation of results is presented, building on the results of a previous study, which assessed the impact of EU (European Union) food consumption based on the LCA of 17 representative food products. The present study includes: i) a hotspots analysis on characterized and normalized results, ii) the check of un-characterized elementary flows, iii) a sensitivity analysis of the results applying several LCIA methods, normalization references and weighting factors. For all the analyses, product group contribution and impact category relevance are assessed. The results of the hotspot analyses are generally convergent in identifying the most impacting product groups (meat and dairy), whereas they are sometimes diverging in identifying the most relevant impact categories. In this case study, the identification of the most relevant impact categories is mainly influenced by the selection of the set of normalization references compared to that of the weighting sets.

1. Introduction

Food production and consumption have been identified among the human interventions generating huge pressures and impacts on the environment. For example, the EIPRO study (EC-JRC, 2006) and the Report on impact of consumption by the European Environmental Agency (EEA, 2012) clearly identified the food sector as leading the overall environmental impacts of EU consumption with mobility and housing. According to EEA (2012), these three broad consumption areas are estimated to have contributed 74% of GHG emissions, 74% of acidifying emissions, 72% of tropospheric ozone precursor emissions and 70% of the direct and indirect material input caused globally by private consumption in 2007 (in the EU-27 Member States). As the impacts occur all along the food supply chain (agriculture, manufacturing, distribution and retail, consumption and end of life) (Notarnicola et al., 2016), life cycle assessment (LCA) method may support the identification of the hotspots of impacts and the comparison of alternative options for impacts' reduction. Indeed, the major challenge for businesses, policy-makers, academic researchers and consumers is to decide where and how to act to have the maximum reduction of impacts, especially acting on hotspots (UNEP-DTIE, 2014). More and more, policies aiming at sustainable production and consumption may need and may benefit from the results of LCA studies to steer eco-

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innovation and reduce impacts. This requires a thorough and systematic interpretation of the results of the assessment as well as of the associated uncertainties.

LCA method (ISO, 2006 a,b) can support the analysis of the impacts associated to food supply chains, covering several categories of impacts and embracing life cycle stages of production and consumption, from extraction of raw materials to end of life. A detailed inventory (life cycle inventory, LCI) is characterized using several models to assess the impacts associated to emissions and resource used in a product (life cycle impact assessment, LCIA). According to ISO 14040 (2006a), interpretation is the phase of LCA in which the findings from the inventory analysis and the impact assessment are considered together; it should deliver results that are consistent with the defined goal and scope and which reach conclusions, explain limitations and provide recommendations. ISO 14044 (2006b) further specifies that interpretation comprises the following elements: i) identification of the significant issues based on the results of the LCI and LCIA phases of LCA; ii) an evaluation that considers completeness, sensitivity and consistency checks; iii) conclusions, limitations, and recommendations. Indeed, interpretation may involve several steps of analysis, both at inventory and impact assessment scale. Previous studies (e.g. Corrado et al., 2016a) have explored the importance of better understanding the assumptions underpinning widely used inventory databases. Interpretation is then crucial and driven by different purposes. For example, the Product Environmental Footprint (PEF) Guide (EC, 2013) explains that interpretation of the results of a PEF study serves two purposes: i) to ensure that the performance of the PEF model corresponds to the goals and quality requirements of the study; in this sense, PEF interpretation may inform iterative improvements of the PEF model until all goals and requirements are met; and ii) to derive robust conclusions and recommendations from the analysis, for example in support of environmental improvements.

Besides, a recent report of UNEP (UNEP DPTIE, 2014) is giving guidance on hotspot analysis, recognising that the identification of major sources of impact requires a systematic approach to the interpretation of the results.

Several studies, e.g. Gaudreault et al. (2009), pointed out that LCA has become an important method for more sustainable process design. However, they observed that LCA application in a decision-making context has been limited by a poor understanding of methodological choices and assumptions. Therefore, they recommend careful interpretation of results to improve the quality of the outcome (i.e. improve the decision-making process). Similarly, Prado-Lopez et al. (2014) have identified the lack of robust methods of interpretation to support decision makers, hence, they provide a novel approach based on a multi-criteria decision analytic method, which in their view should support both interpretation of results and decision making. Along these lines for supporting decision-making, van Hoof et al. (2013) explained how normalization helps maintaining a multi-indicator approach while keeping the most relevant indicators. In order to draw conclusions to support sector specific interventions, Cellura et al. (2011) and Huang et al. (2013) performed LCA of specific products (tiles and road pavements) and they pointed out the relevance of sensitivity analysis to strengthen the reliability of the results obtained.

Regarding the food sector, over time, the number of LCA case studies focussing on food products is increased (Notarnicola et al., 2015). However, the presentation of the results lacks sometimes a thorough interpretation.

Moreover, there is the need of a so-called “beyond LCA” view of hotspots (e.g. Roy et al., 2009). This may help “users to overcome some of the limitations associated with traditional LCA (e.g. the assessment of multiple, cumulative impacts from different activities in the same geographical location; a more explicit way of understanding wasted resources in a sector of product system; the inclusion of ethical and governance issues in the analysis)” (UNEP DTIE, 2014, p.29).

Hence, LCA results could be complemented by the results of specific studies done in the field of each impact category, which, in turn, given their more focused approach (e.g., on a single sector or on specific impacts), may benefit from the broader perspective of LCA.

The present study aims at illustrating how to conduct the interpretation of LCA results, focussing on the impact assessment steps (characterization, normalization and weighting). This is fundamental when there is the need of using LCA results for policy support, i.e. when the identification of the hotspots is expected to support the definition of possible policy options for impacts reduction. A case study is presented, building on the results of Notarnicola et al. (2016), which assessed the impact of EU food consumption based on the LCA of 17 representative products.

The paper is organized as follows: Section 2 illustrates the method for supporting the assessment of hotspots using LCA (and beyond); Section 3 presents and discusses the results of the method applied to a case study on EU food consumption; Section 4 concludes providing a set of recommendations for the use of the LCA results for policy support.

2. Method

This paper proposes a method adopting LCA for the identification of hotspots of environmental impact as basis for steering eco-innovation and supporting policies. The method could be applied to any economic sector. However, the present work aims at illustrating how to improve environmental sustainability of food supply chains and support the identification of policy targets in this sector.

In assessing supply chains, LCA can be applied with different aims: both for the hotspots analysis (namely, the identification of the most relevant environmental impacts) and for the evaluation of the benefits associated to possible improvements aimed at reducing the impacts.

In designing sector-specific and product group-specific policies, there is the need to better understand which are the key elements of the production and consumption chain in terms of environmental impacts (namely, the “hotspots”) and how to act on these hotspots to improve the environmental performance of the whole system, avoiding burden shifting among the life cycle stages or among impact categories. The method is designed to answer these needs, by:

i. providing guidance on how to improve interpretation of the results, in order to identify key issues of concern within the production and consumption chain (step 2);
ii. fostering the understanding of what happens at the system-scale and at the macro scale with reference to current situation and to different policy goals, complementing LCA results with the hotspots identified from other disciplines and domains (“beyond LCA” perspective) (step 3);
iii. adopting eco-design and sustainability principles as check list for improvement, towards the identification of a set of policy options and targets (step 4);
iv. assessing potential benefits of improvement options, with regards to the overall environmental performance of the whole system (step 5).

The LCA-based method steps for defining targets are presented in a flowchart (Fig. 1), as follows:

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