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How to define future LCA scenarios addressing the effect of climate change in crop production

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1. Introduction

The inclusion of Life Cycle Assessment (LCA) as a support tool in the decision-making process at policy level has been increasing over the past years. When LCA is intended to be used to affect more strategic long term decisions, it faces the challenge to describe scenarios of the future in which the environmental impacts will occur. But the definition of future systems is inherently controversial, as many uncertain and unknown aspects need to be addressed. This poses many challenges on how to better exploit the possibilities of forecasting scenarios for LCA. One important contribution is provided by scenario analysis. Scenario analysis is a defined technique in the LCA context, which deals with three aspects: definition of alternative future circumstances, path from the present to the future and inclusion of uncertainty about the future [1].

Despite the broad available literature on scenario analysis in LCA, e.g. [1], as pointed out by Zamagni et al. [2], further research is needed in this area. Research, both at methodological and practical level, with the aim to find a balance between the feasibility and the uncertainty related to scenario development in LCA.

This paper elaborates on this issue, addressing the three aspects of scenario analysis in LCA with regard to one of the most pressing environmental issues at international level, i.e. climate change. We focus on agriculture, i.e. one of the most contributing sectors to the global greenhouse gas emissions [3]. Considering the case study of future barley production in a changing climate we aim to address the following question: how can future scenarios be performed in LCA when addressing climate change effects on crop production?

2. Materials and methods

In order to answer the abovementioned question we performed a cradle to farm gate study of 1 kg dry matter spring barley for malting in Denmark, considering a change of climate according to the IPCC A1FI scenario, expected to happen in the second half of this century [4]. We focused on the definition of scenarios at the life cycle inventory level [1]. The proposed approach for defining consistent future circumstances using scenario analysis consists of the following steps:

1. Define the baseline scenario at the inventory level for the selected crop, i.e. in the specific case study the current spring barley production, and perform the impact assessment in order to identify the hot-spots through contribution analysis;
2. Identify the main deviations from the current production addressing the path from the present to the future based on the best available data and knowledge;
3. Suggest adaptive measures to compensate for possible deviations from current production, with the aim to limit the number of scenarios to the more realistic and relevant ones.

3. Results and discussion

The definition of the baseline scenario included the main agricultural operations, i.e. soil preparation operations (ploughing, harrowing, fertilizer application), sowing, external agents (weed-, disease-, and pest animal control), harvesting, drying and storage and the field emissions (N_2O , NO_x , NH_3 , nitrate, P, Cu, Zn). The identified hot spots are fertilizer application and field emissions, both being dependent on the amount of fertilizer applied and crop yield. The identification of the main deviations from the current situation is the key point, as it deals with predicting future conditions. Table 1 presents the main deviations expected for future spring barley production, the source of data, the main issues to consider in the definition of the future scenarios including adaptive measures, and the indication of the level of uncertainty connected with the predicted deviation.

Inventory data	Source of data	Issue to deepen for defining adaptive measures	Level of uncertainty
Grain yield	Experimental data from cultivation in simulated future climates in climate phytotron RERAF (Risø Environmental Risk Assessment Facility) [5]	Cultivars selection (low vs. high productivity, low vs. high environmental stability)	Low
Pesticide treatment index	Prediction based on literature [6]	Disease, insect and weed management strategies	High -
N leaching from fertilizer application	Prediction based on literature, assuming same fertilization rate as today [7]	Crop management strategies	High

Table 1: Outcome from the implementation of step 2 of the proposed approach

Data on crop yields come from cultivation experiment where the performance of the crop is investigated under the predicted climatic conditions. These data are therefore associated with relatively small uncertainty. In contrast, the estimation of the pesticide treatment index and leaching from fertilizer application is less straightforward, as it is affected by many unknown factors, the influence of which should be assessed with sensitivity analysis. The definition of the range of variability of sensitive parameters should be based on best estimate from expert judgements from breeders and farmers. Furthermore, when presenting the results of a multiple scenario study focusing on different adaptive measures, the issue of uncertainties included in each of the scenarios becomes extremely important and is addressed by parameter uncertainty analysis. The decision-maker has to be made fully aware of the uncertainties underlying each scenario in order to be able to make decisions based on comparisons between them.

4. Conclusions

One way to reduce the uncertainty in the definition of future scenarios in LCA of crop production addressing the effects of climate change is to rely on primary data coming from field experiments and involving experts in the definition of changes in central parameters for the cultivation system. This approach can be implemented using the tools already included in the interpretation step, i.e contribution analysis to identify the hotspots; sensitivity analysis to determine the most influencing parameters, and uncertainty analysis to account for different levels of confidence in these parameters and other input data.

The output of long term scenarios based on LCA results is only effective in informing policy makers, if criteria to detect sensible aspects are taken into account, then the risk of defining unrealistic scenarios is minimized.

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