Improving resource efficiency of low-input farming systems through integrative design – two case studies from France

Michal Kulak[1,2], Thomas Nemecek[1], Emmanuel Frossard[2] and Gérard Gaillard[1]

[1] *Life Cycle Assessment, Institute for Sustainability Sciences, Agroscope, Reckenholzstrasse 191, 8046 Zurich, Switzerland; michal.kulak@agroscope.admin.ch*

[2] *Institute of Agricultural Sciences, ETH Zurich, 8315 Lindau, Switzerland*

Abstract: Whole system design (integrative design) is an approach embedding social, economic and environmental phenomena into a design solution. The concept is based on the need for the integration of techniques such as system thinking, the development of partnerships and the use of trans-disciplinary skills to develop more sustainable and innovative solutions. This study aimed at testing the hypothesis, if resource-efficient cropping systems can be created by applying principles of integrative design to agriculture. Data were collected from two farmers in France cultivating ancient wheat varieties, processing grains on farm and distributing products through local markets. Life Cycle Assessment was used to track environmental impacts of their products along the whole value chain. Opportunities for improvements were mapped out in an interdisciplinary design workshop and results were consulted with farmers on a feedback-loop basis. Potential improvements reached 47 % reduction in the global warming potential at one farm and 40 % in eutrophication potential at another. Solutions for improving resource efficiency included i.e. switching to higher yielding crops and cultivars, optimising crop rotations, optimising the timing and type of applied fertilizers or installing anaerobic digestion (AD) plants. Resource efficiency of agricultural systems is often limited by the lack of innovation, suboptimal management and the lack of access to reliable environmental information. Integrative approaches coupled with systematic assessment tools such as LCA show to be effective in overcoming these barriers.

Keywords: Integrative design, bread, Life Cycle Assessment, low-input agriculture

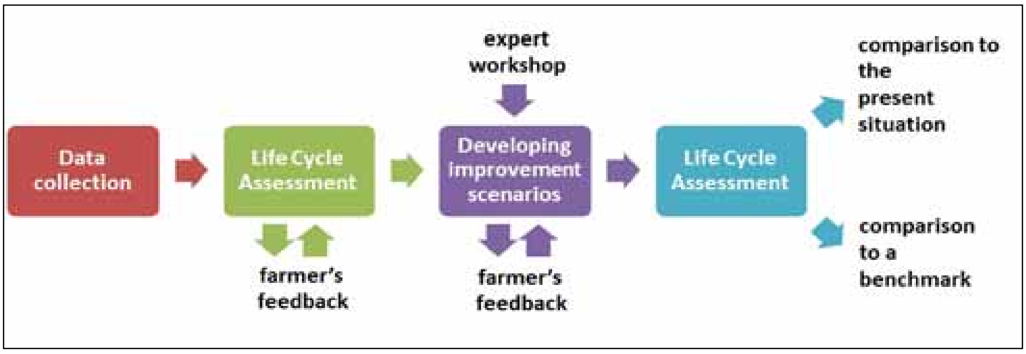
Introduction

Modern socio-technical systems evolved when fossil fuels, land and useful minerals were in a relatively abundant supply, but in the future, natural resources will have to be utilised more efficiently. Eco-innovation can be defined as any activity of an actor that leads to the development of new products, behaviours or processes contributing to some specific sustainability targets or reducing anthropogenic environmental burdens (Klemmer et al., 1999). Many past eco-innovations in food supply chains were aimed at partial optimisations. This resulted in only incremental improvements or failures to contribute to sustainability targets. Organic farming systems that were promoted by the European Common Agricultural Policy present one example. Developments in environmental impact assessment methods in recent years revealed that the switch from synthetic, water soluble fertilisers to manure and slurry and avoiding pesticides does not guarantee reduction of environmental impacts, particularly not when results are expressed per product unit (Tuomisto et al., 2012). This is due to the fact that in systems aiming at partial optimisations some inputs, like synthetic fertilisers and pesticides are substituted by others, like land and diesel. To achieve the absolute reduction of environmental impacts, more holistic approaches to farming systems design are needed. Whole system design (integrative design) is an approach embedding social, economic and environmental phenomena into a design solution (Charnley et al., 2011). The concept is based on the need for the integration of techniques such as system thinking, the development of partnerships and the use of trans-disciplinary skills to develop more sustainable and innovative solutions. This study aimed at testing the hypothesis, if resource-efficient low-input cropping systems can be created by applying principles of integrative design to agriculture.

Methodology

The study was based on a case study of bread production and supply in low-input farming systems in France. Fig. 1. Illustrates the conceptual framework of the applied methodology. Primary data were collected from farmers who cultivate cereals under organic and low-input conditions, process grains locally and sell products directly to the consumers. Environmental impacts of their products were compared to equivalents from supermarkets (reference) with the use of environmental Life Cycle Assessment (LCA). Reference systems for comparison were characterised by higher rates of applied agricultural inputs at the agricultural stage and more complex supply chains. The scope of LCA was from cradle to the consumer. In the next step of the study, a structured procedure of integrative design was followed. Results of LCA were disclosed to producers. To map out opportunities for improvements, a workshop was organised with stakeholders. Participants included breeders, agronomists, representatives of seed companies and farmer's associations Results were consulted with farmers on a feedback-loop basis. To increase the probability of adoption, only solutions that were approved by farmers were considered in further LCA simulations. Redesigned farms were compared to the business-as-usual scenarios as well as generic references.

Figure 1. Generic framework of the applied design methodology



Results

Results of the initial cross-sectional LCA study revealed a high variability from year to year and between different impact categories. At the agricultural stage, one farm showed similar or better performance per kg of bread to high-input agriculture. The other one showed higher environmental burdens. Decentralised processing and distribution had similar environmental impacts to conventional supply chains in France. Baking with wood reduced resource use and global warming potential, but increased human toxicity. Neither low-input farming nor on-farm processing showed to guarantee overall reductions in the environmental impacts of food. The workshop gave rise to a range of improvement options. Management suggestions included i.e. switching varieties, optimising rotations or installing anaerobic digestion units. Farmers rejected some but were able to develop other scenarios, such as increasing the proportion of rye in the bread recipe. Conservative modelling of improved systems demonstrated potential reduction of at least 47% in the global warming potential at one farm and 40% for aquatic eutrophication at the other one.

Discussion

The study has shown that switching to alternative bread supply chains based on low-input farming and local processing and distribution does not guarantee reductions in the environmental impacts. Depending on the specific system and the impact category, analysed breads were characterised by higher or lower environmental impacts than standard supply chains. However, the structured design procedure revealed opportunities for reductions in all analysed environmental impacts. There is a number of reasons for this discrepancy of the potential eco-efficiency and the actual practice. The methodology applied in this study allowed to link various types of knowledge: the tacit knowledge supplied through the farmer feedback (Fig. 1.), explicit know-how of interdisciplinary group of scientists and the environmental information as supplied through LCA models. The availability of knowledge is one of the limiting factors for a successful environmental management. In addition to the knowledge, the involvement of multiple actors brings in their creativity. (Mouron et al., 2006) suggested that eco-efficient orchard management requires cognitive skills and non-linear thinking. The same principles can be applied to cereal-based low-input cropping systems.

Conclusions

Resource efficiency in food supply chains is often limited by the lack of innovation, suboptimal management and the lack of access to reliable environmental information. Integrative approaches coupled with systematic assessment tools such as LCA can be very effective in overcoming these barriers. The difficulty lays in their large-scale facilitation, as these are resource and knowledge-intensive methodologies. However, stakeholder preconceptions of where the environmental impacts come from can be very different to the picture shown by quantification of resource flows. The case of bread demonstrated that measuring and communication of environmental information from the earliest stages of the design process is crucial for developing more sustainable systems.

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