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Comparing the environmental performance of mixed and specialised dairy farms: the role of the system level analysed

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ABSTRACT

Mixed crop–livestock systems are often considered more environmental friendly compared to specialised systems, but due to the interactions between different farming activities, it is not trivial to quantify possible benefits. Using life cycle assessment (LCA), we tested different allocation procedures and system expansion through avoided burden to compare the environmental impact of milk from either specialised or mixed dairy production systems (product level). In a second approach, we compared the whole farming systems with additive system expansion, where the functional unit comprised milk, live animals sold for meat production and crops (farm level). On the product level, milk from the mixed farm had higher non-renewable cumulative energy demand, terrestrial ecotoxicity and phosphorus use, but lower aquatic eutrophication N, independently of the allocation method. For all other impact categories, differences were not significant. On the farm level, results were partially reversed. The mixed system had a lower energy demand and potassium use, while phosphorus use was higher. All other differences were not significant on farm level. The different rankings on product and on farm level were caused by the way manure was attributed to the farming activities. In order to avoid allocation, manure management was sub-divided into storage and application processes. Storage was attributed to dairy production, application to dairy production only if applied on grassland or feed crops, and to cash crops when applied to produce these crops. Manure applied on cash crop areas was thus out of the scope of the product approach, and mineral fertilisers that could be saved within the cash crop production were thus not attributed to milk production. We conclude that only system expansion was able to cope with the complexity of mixed farming systems in LCA. Based on our results with modelled farms, mixed farming showed the potential to reduce environmental impacts compared to specialised farming. Nevertheless, due to the complexity of the system regarding farm management and interactions between cropping and livestock activities, only an assessment with real farm data could reveal the actual benefits of such systems.

1. Introduction

Mixed farming systems combine cash crop and livestock production on the same farm. Such systems were very common in the past, but in industrialised countries increasingly specialised agricultural systems emerged (Ryschawy et al., 2012). With a rising concern about the environmental effects of agriculture, mixed farms are currently reconsidered, as they are assumed to be more efficient in nutrient cycling and to foster ecosystem services through an enhanced biodiversity (Lemaire et al., 2014). However, it is not evident to which extent these theoretical advantages are translated into effective environmental benefits. In a life cycle

Abbreviations: aqEN, Aquatic eutrophication N; FADN, Farm Accountancy Data Network; FE, Farm enterprise; FPCM, Fat and protein corrected milk; GWP100, Global warming potential over 100 years; IG, Input group; K use, Potassium use from mineral sources; nrCED, Cumulative energy demand from fossil and nuclear sources; LCA, Life cycle assessment; LCI, Life cycle inventory; LU, Livestock unit; P use, Phosphorus use from mineral sources; terrET, Terrestrial ecotoxicity; SE, System expansion.

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assessment (LCA) of Swiss dairy production, Alig et al. (2011) found no significant differences between specialised and mixed farms per kilogram of milk. Veysset et al. (2014) even calculated a higher N surplus per hectare and higher greenhouse gas emissions on mixed beef and crop farms compared to specialised beef farms in France. Both studies focussed on the livestock product, and did not compare the crop products from the mixed systems to those from specialised crop farms. However, the interactions between crops and livestock have benefits and drawbacks (Bell and Moore, 2012), and thus a focus on just one product category might not reflect the overall effect of mixed farming. For LCA studies, processes with co-products are challenging, as there are different approaches on how to allocate emissions to different outputs. Dairy production is a multi-output process per-se, with the outputs being milk and live animals sold for meat production. Various studies therefore used dairy production to illustrate the influence of different co-product handling methods on LCA results and interpretation (Bartl et al., 2011; Cederberg and Stadig, 2003; Flysjö et al., 2011; Thomassen et al., 2008). They showed that the choice of the co-product handling method has a significant influence on the absolute results, and some even showed that the ranking between production alternatives can change depending on the method chosen (Flysjö et al., 2012; Zehetmeier et al., 2011). All these studies were based on specialised dairy production systems, i.e. systems that only produced milk and meat. If the dairy production happens on a mixed crop–livestock farm, this adds further complexity to the system. The livestock system provides manure for the cropping system, and part of the cropping system produces feed for the livestock system. These interactions might have an influence on the environmental performance of the different products on the farm and the whole farming system. In order to identify the most suitable method to compare mixed and specialised farming systems in LCA, we therefore analysed the effect of different co-product handling methods as well as different system boundaries when comparing specialised and mixed dairy production systems.

2. Methods

In the present study, a specialised and a mixed dairy system were modelled. The LCA was performed on both product and farm level. On the product level, we focussed on milk as the primary product and tested different co-product handling methods between milk and its co-product meat. On the farm level, we considered all products of the farming systems, i.e. milk, meat and crops. The latter approach was more holistic and aimed at including all possible effects of mixed farming systems compared to specialised ones. The focus was put on the ranking of the different systems and not primarily on the absolute results.

2.1. Dairy production systems

Our analysis focussed on dairy production in the Swiss lowlands, where both specialised and mixed dairy farms can be found. In order to get representative farms for the two systems, we modelled the farms based on the average specialised and the average mixed dairy farms as obtained from the Swiss Farm Accountancy Data Network (FADN; Mouron and Schmid, 2011). Table 1 gives an overview about the main characteristics of the simulated farms. The average specialised lowland dairy farm kept 33.1 livestock units (LU) and had an agricultural area of 20.3 ha. Thereof 17.7 ha were grassland, 1.1 ha silage maize and the remaining part was used for other crops. The average mixed lowland dairy farm kept 29.9 LU and had an agricultural area of 26.8 ha, thereof 12.3 ha grassland. The cropping area was used for both, cash and feed crop production. On both farms, the LU consisted mainly of dairy cows and young stock, with some minor quantities of other animal categories, like fattening pigs. For the simulated farms, we presumed that the farms only kept dairy cattle, i.e. dairy cows and young stock. In order to cover the full dairy production cycle, i.e. from the birth of a female dairy calf until the end of the productive life of a dairy cow, we attributed the LU on the farms to the two animal categories young stock and dairy cows, based on a restocking rate of 0.29 cows per year and an age at first calving of 30 months (Boessinger et al., 2013). The mixed farm was assumed to produce less meat per kilogram milk, because the total milk production per cow was higher on this farm type (Mouron and Schmid, 2011). This higher milk yield on mixed farms was achieved with a higher amount of concentrate fed to the cows, which was produced in part on the farm.

2.2. Life cycle assessment

In order to identify a suitable method to compare crop–livestock systems, two different LCA approaches were tested. These were a product approach and a farm approach. The product approach focussed on milk production, while the farm approach integrated all products obtained from the activities in the entire farming system, i.e. milk, live animals for meat production and cash crops.

2.2.1. Goal and scope

The goal of the product approach was to compare the environmental impact of milk production, while the farm approach aimed at comparing the impact of a basket of products generated by the farms. Both, the product and the farm approach, included all environmental impacts from cradle to farm gate. All inputs and outputs of the farm were considered and no cut-off criteria were applied. The farming system itself was sub-divided into two farm enterprises (FE), both with their own system boundaries: dairy and cash crops. The FE dairy produced milk and the co-product meat from culled animals and surplus calves. It included all processes related to the husbandry of dairy cows and young stock, such as direct emissions generated by the animals or the storage of its manure, forage and concentrate feed production on the farm including direct emissions of applied fertilisers and manure, external inputs and infrastructure for keeping the animals. The FE cash crops included all processes related to the production of sold crops, such as external inputs, machinery, and direct emissions from the application of fertilisers and manure (Fig. 1). The system boundaries of the product approach were limited to the FE dairy, while the farm approach included all FE on the farm. Both approaches had their own definition of the functional unit and different methods to cope with multiple outputs from the production systems.

Product approach: The functional unit was 1 kg FPCM at farm gate. As the dairy system had two outputs, milk and live animals for meat production, the environmental impact of the dairy system needed to be allocated between the two products. Previous studies have shown that different allocation methods may influence the results (e.g. Flysjö et al., 2012; Zehetmeier et al., 2011). Therefore, four different co-product handling methods were applied in the present study to evaluate their influence on the result: physical causality allocation, economic allocation, and two system expansion alternatives. We performed physical causality allocation based on the guidelines from the IDF (2010) and economic allocation based on price information from Boessinger et al. (2013). For system expansion, we assumed that the meat derived from the dairy system replaced an equal amount of meat from an alternative production system. The impact of the replaced meat was thus credited to the dairy system (system expansion through avoided burden). As

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