Life cycle assessment of grassland-based dairy production systems in Switzerland

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Abstract

The feeding system of dairy cows can strongly influence their environmental impacts. We compared three grassland-based production systems: (A) full-grazing with seasonal calving, and indoor feeding of fresh herbage with (B) reduced concentrate (< 500 kg cow^{-1} yr^{-1}), and (C) standard concentrate (800 - 1,200 kg cow^{-1} yr^{-1}) supplementation. The three systems were analysed on 12 pilot farms (PF) (four per strategy) in 2014 as well as on the experimental farm (EF) of the centre for Nature and Nutrition in Hohenrain (2014 - 16) with the life cycle assessment (LCA) method Swiss Agricultural LCA (SALCA). In terms of environmental impacts, higher concentrate inputs (C) resulted in higher P and K resource use, deforestation and ecotoxicity per kilogram of energy corrected milk (kg ECM). Full grazing tended to a higher global warming potential per kg ECM. However, the differences in environmental impacts per kg ECM were often larger between the single PF and the years than between the three systems. Four main factors influencing the environmental impacts were identified: (1) composition of the feed ration, (2) performance of the system (feed conversion ratio), (3) grazing and manure management, (4) purchase of animals.

Keywords: LCA, environment, dairy, production, grass, feed

Introduction

The choice of the feeding system in dairy production (i.e. grazing vs indoor, grassland vs maize/concentrate based feeding) can strongly influence environmental impacts. Different life cycle assessment (LCA) studies have investigated this topic; however, due to the multitude of the influencing factors, they came to partly contradictory conclusions (Nemecek and Alig, 2016; Nemecek *et al.,* 2014). In a previous system comparison, the full-grazing system tended to perform better per kg ECM in terms of eutrophication, acidification, ecotoxicity, resource use (K and P) and deforestation than the maize/concentrate based system, which itself reached more favourable values categories land-use, global warming potential and ozone formation (Sutter *et al.*, 2013). In Switzerland, however, most dairy farms practice a combination of partial grazing with indoor feeding of fresh herbage and concentrate supplementation, the environmental impacts of which have not been examined in detail by LCA so far. This study aimed to analyse the environmental performance of partial grazing with indoor feeding of fresh herbage with two levels of concentrate supplementation (< 500 vs 800 - 1,500 kg cow^{-1} yr^{-1} as vs a full-grazing system (242 - 265 d) with seasonal calving.

Materials and methods

The systems were analysed on 12 PF in 2014 (four farms per system) as well as on the EF of the vocational education and training Centre for Nature and Nutrition in Hohenrain (2014-16). Data were collected from a farm network system comparison described by Reidy *et al.* (2017). Missing data – such as the detailed building and machinery data used at each PF – was extrapolated from model farms and scaled to fit the farm that was analysed. Environmental impacts were calculated per kg of energy corrected milk (ECM) ((0.038 × raw fat content (g kg^{-1} milk) + 0.024 × raw protein content (g kg^{-1} milk) + 0.816) /

3.14) × milk (kg)) at farm gate, as the goal of the analysis was to compare the environmental impacts of the milk produced in the different systems. The system boundary included the cattle husbandry, feeding and manure management, production of feedstuffs, energy carriers, fertilisers, buildings and equipment. Breeding and fattening of cattle were included and physical allocation based on the net energy needed for the production of 1 kg of ECM (3.1 MJ) and 1 kg of bodyweight (14.1 MJ) was used to allocate the environmental impacts to the outputs milk and live weight. Other agricultural or land enterprises, such as crop production or livestock other than cattle, were deducted from the total inputs. On the EF, the cattle was split into three groups for the duration of the experiment. The inputs and outputs of the three systems were recorded separately for the three groups (number of animals, animal weight, milk produced, concentrated feed use, mineral fertiliser use, etc.) or split between the three groups (differently done for different aspects, e.g. gasoline was split by the total harvested area for each system, diesel by estimates by the person in charge of the experiment at Hohenrain). The direct emissions were calculated with the SALCA farm tool, which was especially adapted for taking into account specific characteristics of grassland and grazing based milk production (Nemecek and Ledgard, 2016). For instance, it was considered that N excretion in urine and dung on pasture lead to different N emissions. The impact assessment was calculated in Simapro by applying the SALCA impact assessment method. Carbon sequestration was not accounted for in permanent grassland in the global warming potential impact category, due to lack of experimental evidence. Inventories were from the ecoinvent V3 database.

Results and discussion

Due to the small sample size, no statistical tests were carried out. In the following, we only discuss differences if the range of data in one system did not overlap with that in the compared system. We only speak about tendencies if the minimum value of one system overlapped with the maximum of another. The following differences were found between the three systems kg^{-1} of ECM produced (some shown in Figure 1): Higher concentrate inputs (C) result in higher P and K (not depicted) resource use, deforestation (not depicted, compared to A) and ecotoxicity. For the other impact categories, the single farm results show a large spread and overlap between the feeding systems, especially for the PF

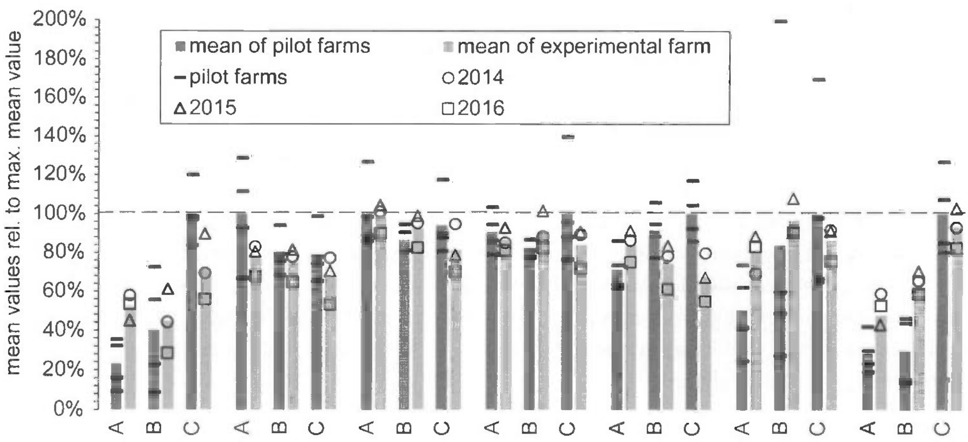

Figure 1. Selected LCA results per kg of ECM for three production systems, values relative to the maximum mean value of the respective impact category (A: full-grazing; fresh grass feeding in barn with B:, reduced concentrate; C: standard concentrate; PF: mean result of the four PF per system, EF: mean over the three years of the EF. Categories from left to right: mining of P resources [kg P], land-use [m^2a], global warming potential [kg CO_2-eq], non-renewable energy use [MJ], acidification potential [mol H + -eq.], aquatic N eutrophication [kg N], aquatic ecotoxicity [kg DB^{-1}, 4-eq.].

and for aquatic N eutrophication. However, system C tends to lead to lower global warming potential (only for EF) compared to the two others. Regarding the biodiversity indicator and the newly developed indicator on landscape-aesthetics, only relatively small differences were found between the three systems, with a tendency to better scores for the system with higher concentrate inputs (C) regarding landscape aesthetics, but a tendency to worse scores regarding biodiversity (results not shown).

Generally, the environmental impacts kg^{-1} ECM from the PF and from the EF are in agreement with each other, except for acidification. As expected, the results from the single PF are more widely spread than the results for the three years for each system from the EF. The purchase of animals – often ignored in studies of dairy production – is an important factor for almost all impact categories (12 to 37% of total impact over all the impact categories). Further important factors are – depending on the impact category husbandry, fertilisation and feed import (not depicted on figure).

Conclusion

The higher concentrate inputs resulted in higher P and K resource use, deforestation and ecotoxicity, whereas the systems with no or less concentrate tended to higher global warming potential per kg ECM (only for EF). However, other aspects in the management of each farm next to the feeding system influence the environmental impacts: the differences in environmental impacts per kg ECM were often larger between the single PF and the years than between the three systems. Four main factors influencing the environmental impacts were identified: (1) the composition of the feed ration, (2) the performance of the system (feed conversion ratio), (3) grazing and manure management, and (4) the purchase of animals.

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