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Environmental and socioeconomic benefits of a division of labour between lowland and mountain farms in milk production systems

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ABSTRACT

Swiss mountains and lowlands feature different climatic and topographic conditions for agricultural production. Thus, farmers developed a collaborative dairy production scheme, where they take advantage of the specific environment of the two regions. In this contract rearing system, the young stock is reared on a mountain farm and the more intensive milk production is performed in the lowlands. This system is an example for the principle of comparative advantage, where each region focuses on the activity where it has the lowest opportunity costs. We hypothesised that the same principle can also be applied in an environmental context, to reduce the environmental impacts of agricultural production. Based on the life cycle assessments of average dairy farms, we could show that the absolute environmental impact was higher on mountain farms for both, the production of one heifer for restocking and the production of one kg milk. However, they had a comparative environmental advantage for rearing, as the young stock was better suitable for their local conditions than the dairy cows. Therefore, milk produced in collaboration between lowland and mountain farms had an up to 4.5% lower non-renewable energy demand and used up to 30.9% less potassium and up to 5.2% less phosphorus resources compared to non-collaborative production. Further consequences of collaboration were a reduced workload and income on mountain farms, and a potentially increased income on lowland farms. We conclude that the principle of comparative environmental advantage is appropriate as a screening method to identify suitable production systems for less favoured regions. However, the total effects of a possible division of labour among regions need to be assessed in a more holistic way where possible side-effects on other aspects are considered as well.

1. Introduction

Some agricultural production regions are confronted with constraints that influence both the environmental and economic performance of farming systems. Such constraints can be the result of man-made factors such as the political environment and market conditions, but in many cases they are due to natural factors such as climate, topography, or soil quality. Factors such as the latter cannot be changed easily, which results in disadvantages for certain regions. Farmers in such regions can either use technical solutions, e.g. irrigation in dry regions, or try to identify production systems that are most suitable within their given environment. Life cycle assessments (LCA) could help to identify such systems. However, in LCA studies comparing the environmental impact of production in different regions or countries, the aim is often set at identifying the production region with the lowest impact (Bystricky et al., 2014; Edwards-Jones, 2010). Therefore, classical comparative LCA fails to identify any product that should be optimally produced in regions that are less favoured because nothing can be produced there more efficiently than in other regions. It is tempting to conclude that such regions should not be involved in agricultural production at all. However, Switzerland already has a rather low self-sufficiency rate of 50% in food production (Rossi, 2015), and in a global context the demand for both food and agricultural area are increasing (Brunelle et al., 2014). Thus, the abandonment of less favoured but productive agricultural land would be short-sighted.

The environmental optimisation problem outlined is comparable to the theory of trade in classical economics. Therefore, principles typically applied in economics might be applicable to the environmental context in order to identify environmentally suitable production systems for less favoured regions. The concept of comparative advantage developed by Ricardo (1817) is still used to explain trade between countries (e.g. Deardorff, 2014) or the spatial distribution of production systems (Rajsic and Fox, 2015). Compared to an absolute advantage, the comparative advantage focuses on opportunity costs. If a favoured and a

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less favoured region collaborate and each region focuses on the activities where it has lower opportunity costs, the overal costs of production are reduced.

In Switzerland, agricultural land is classified according to its suitability for agricultural production, which is highly influenced by topography, distinguishing between lowland and mountain regions (Landwirtschaftliche Zonen-Verordnung, 1998). The lowlands offer broad possibilities for different farming activities, whilst the mountains are less favoured due to a shorter vegetation period and steeper slopes, both factors impeding competitive crop production. Even for dairy production, which is still performed by many mountain farms, the disadvantage compared to lowland farms is large, which is reflected by the corresponding differences in income (Hoop and Schmid, 2014). Due to the natural constraints in the mountains, production is often more extensive and mountain farms thus have lower environmental impacts on a per hectare basis. However, as a consequence of the lower productivity, the environmental impacts of their agricultural outputs (per kg product) are higher (Alig et al., 2011; Bystricky et al., 2014).

The idea of collaboration between lowland and mountainous areas in dairy production originates from the 1960s. At that time, lowland farmers from the Swiss Canton of Thurgau recognised that the high quality forage available would be better invested completely in milk producing animals, as the young stock did not require forage of such high quality. However, the farmers preferred breeding their own animals for creating high genetic merit cows instead of purchasing restocking animals from the market. The result was a collaboration with mountain farmers from the Canton of Grisons for contract rearing, where the lowland farms sold dairy calves to mountain farms and purchased them back when they were close to calving. In this system, the less intensive phase in the life cycle of a dairy cow was shifted to the less favoured mountain region, while the productive phase was maintained in the favoured lowlands. Although rearing heifers on mountain farms was more expensive than on lowland farms, these extra costs were more than compensated by additional milk sales on lowland farms (M. Tanner, son of one of the founders of the system, 20 October 2015, personal communication). The benefits of the system are founded in the comparative advantage of lowland farms in the productive phase of the dairy cow, and the mountain farms' comparative advantage in rearing the young stock. As this model for collaboration became more popular, it was formalised by a standardised contract between the two parties. Once a year, a delegation of mountain and lowland farmers meets to negotiate the details of their partnership and the prices (Honegger et al., 1977). In addition to the comparative advantage, both profit from a rationalisation through specialisation while reducing market risks due to the contract (Agridea, 2013). Nowadays, the system is rather popular in the eastern part of Switzerland, but it has not made its way to other regions (F. Sutter, personal communication, 18 January 2013). The advantages and disadvantages are not well enough known for this system to be more widespread in Switzerland.

Our first hypothesis is that mountain farms have a comparative advantage for rearing the young stock also in environmental respect, as the forage quality on farm is sufficient for these animals. For productive dairy cows, on the other side, a comparative disadvantage is expected, as higher imports of concentrates are needed in order to cover the nutrient requirements of higher-yielding dairy cows. If this is true, the collaboration between mountain farms and lowland farms has the potential to reduce the environmental impact of dairy production. However, farming systems are complex, and a change within the dairy production might also influence other farming activities. Our second hypothesis is, therefore, that the environmental impact, and thus the success of the collaboration, also depends on the extent and kind of changes in other activities. This could be e.g. through a changed availability or quality of manure. In addition, lowland farms that opt for a collaboration with a mountain farm will free land that would have been used by the young stock. They could use this land either to increase dairy production, which was the original motivation for the farmers who started the collaboration back in the 1960s (M. Tanner, 20 October 2015, personal communication). Another option would be to increase crop production, as the land in the lowlands would be well suitable for this activity. To test the first hypothesis, we performed an LCA for both phases in the life cycle of a dairy cow, i.e. the rearing of a heifer from the day of birth up to the first calving, and the productive phase. For testing the second hypothesis, we expanded our LCA to the farm level. In addition to the LCA, we also evaluated the effect of such forms of collaboration on farm income and workload.

2. Methods

We compared three dairy production systems, a non-collaborative baseline, and two collaborative systems, one with increased specialisation in dairy production and one with increased diversification. The comparison is based on simulated farms. The systems were analysed for their environmental performance as well as their effects on economics and labour.

2.1. Farm types considered and simulation

Specialised dairy farms that rear their own young stock were defined as the baseline, with a baseline farm in the lowlands (BaseLow) and one in the mountains (BaseMount). Under collaboration, the mountain farm (ColMount) was assumed to specialise in the rearing of young stock and to quit milk production. The ColMount farm purchased weaned female dairy calves from the collaborating lowland farms and sold the heifers back 1 month before calving. As the collaborating lowland farm outsourced its young stock, it freed land and resources formerly used by the young stock for other activities. This farm could have either used those resources to increase dairy production or crop production. The former corresponds to a situation where the farm remained specialised, hereafter referred to as the collaborative specialised lowland farm (ColSpLow), the latter corresponds to a situation with more diversification, hereafter referred to as the collaborative diversified lowland farm (ColDiLow).

The starting point of the farm simulations were the different restocking strategies of the dairy farms. The restocking was modelled according to Boessinger et al. (2013), with a restocking rate of 0.29, and an age at first calving of 30 months, both for mountain and lowland farms. Only female calves required and designated for restocking were kept, surplus and male calves were sold to a fattening farm a few days after birth. The dairy herd of the BaseLow and BaseMount farms therefore consisted of dairy cows and the respective amount of young stock needed for restocking, from the day of birth up to an age of 30 months. On the collaborative lowland farms (ColSpLow and ColDiLow) the dairy herds consisted of dairy cows, female calves up to the age of 4 months and the heifers close to calving, with an age of 29 to 30 months. The ColMount farm kept the young stock of an age between 4 and 29 months.

In order to simulate representative Swiss dairy farms the average land use, stocking densities and milk yields for specialised dairy farms were taken from the Swiss farm accounting data network (FADN; Mouron and Schmid, 2011). The BaseLow, BaseMount, ColSpLow, and ColMount farms were modelled to have the land use and total livestock units as the average farm from the respective region. The livestock units were composed by animals from the different age categories corresponding to the restocking strategies of the respective farms. For the ColDiLow farm, we modelled a farm with the same number of cows as the BaseLow farm and thus the same milk yield. Due to the outsourced young stock, the total livestock units of this farm were lower, thus less land was needed for forage production (grassland and silage maize). The freed land was used for increased crop production, with a relative increase of the area of all crops that were already grown under the BaseLow scenario. Table 1 shows the main characteristics of the simulated farms. The diet of the animals was modelled combining data