An LCA-based analysis of the factors affecting the economic and environmental performance of Swiss dairy farms in the alpine area

P. Jan, D. Dux, M. Lips und M. Alig[1]

***Abstract* - Promoting both the economic and the environmental performance of Swiss farms is one of the core objectives of Swiss agricultural policy. In this paper we combine Life Cycle Assessments and Farm Accountancy Data to analyse the factors affecting the economic and environmental performance of Swiss dairy farms in the alpine area. The results of the analysis reveal the existence of synergies in the promotion of farm economic and environmental performance. Unfavourable natural production conditions and part-time farming have a negative impact on both the economic and environmental performance of the farms studied. Conversely, farm size and a higher agricultural education have a positive effect on these two dimensions of the sustainable performance of a farm.**

INTRODUCTION

The promotion of an economically viable and environmentally friendly agricultural sector is a major objective of Swiss agricultural policy. This objective is enshrined in Article 104 of the Swiss Federal Constitution. Before we can promote farm economic and environmental performance we need to establish their respective determinants. Having done so, we can then build on the determinants analysis in order to identify synergies and trade-offs in the enhancement of these two dimensions of the sustainable performance of a farm. Despite the omnipresence of the sustainability issue in the debate on Swiss agriculture, no such study based on precise and comprehensive farm environmental data has yet been conducted at micro-level for Swiss agriculture. The present work aims at performing such an analysis for the Swiss dairy farms in the hill and mountain regions by making use of Life Cycle Assessments (LCA) in combination with Farm Accountancy Data.

MATERIAL AND METHODS

The study is based on a sample of 56 Swiss dairy farms located in the hill and mountain regions from the Swiss Farm Accountancy Data Network. For each farm, a comprehensive environmental impact assessment using the SALCA (Swiss Agricultural Life Cycle Assessment) approach has been performed. Life Cycle Assessment is a methodological framework for assessing the environmental impacts of a product throughout its entire life cycle (Rebitzer et al., 2004). The first stage of an LCA consists in defining the boundaries of the system investigated. In the present case, the spatial boundary is set at the farm gate. The system under consideration consists of the agricultural production system defined in a narrower sense, i.e. without any forestry or para-agricultural activity. The second step of an LCA, the Life Cycle Inventory, is aimed at estimating the quantities of resources used and waste flows and emissions generated by the system under investigation. This inventory is carried out on the basis of the production inventory of the farm under investigation and a life cycle inventory database, the Ecoinvent database version 2.0, with specific complementary models to assess the direct emissions released at field and farm level. Based on the life cycle inventory, the environmental inputs and outputs of the system investigated are converted into environmental impacts. For our investigation, the following five environmental impact categories are considered: the demand for non-renewable energy resources, eutrophication potential, terrestrial ecotoxicity potential, human toxicity potential and land use. For further details on the environmental impact assessment performed using the SALCA approach, please refer to Jan et al. (2012).

The environmental performance of a farm is assessed by means of several eco-efficiency indicators. For each environmental impact category considered, we assess, for each farm investigated, its eco-efficiency as regards this issue. Eco-efficiency is defined as the amount of farm digestible energy output (in MJ) per unit of environmental impact generated. In a subsequent step, we estimate for each farm an aggregate eco-efficiency indicator using the approach based on Data Envelopment Analysis as proposed by Kuosmanen and Kortelainen (2005). The major advantage of this approach is that it makes it possible to aggregate the environmental impacts in an objective manner as the weights are determined endogenously within the framework of a maximisation problem.

To measure farm economic performance, a traditional profitability indicator, work income per family work unit, is used. This is defined as the amount of added value available per family worker after all production factors (equity capital included) have been remunerated. In that sense, it reflects the

[1] Pierrick Jan*, Dunja Dux and Markus Lips from the Farm Economics Research Group, Agroscope Reckenholz-Tänikon Research Station, Tänikon 1, CH-8356 Ettenhausen.
Martina Alig is from the Life Cycle Assessment Research Group, Agroscope Reckenholz-Tänikon Research Station, Reckenholzstrasse 191, CH-8046 Zürich.
Contact author: pierrick.jan@art.admin.ch

ability of the farm to remunerate all its production factors to an adequate extent.

Once the performance indicators have been defined and estimated, we analyse the effect of the following selected factors on farm economic and environmental performance: natural production conditions (farm location), farm size, farming type (full- *vs.* part-time) and agricultural education. Due to the limited sample size and taking into account the number of potential determinants, we cannot use a multivariate approach for our purpose. Instead, we use bivariate approaches and analyse separately the relationship between each performance indicator considered and each potential determinant taken into account. Owing to the limited size of our sample and due to the fact that the assumptions required to perform parametric tests for the analysis of the relationship between two variables are not met, the tests we conduct are non-parametric. If the determinant investigated is interval-scaled, then we use the non-parametric Spearman's rank correlation analysis. In the case of a nominal scaled determinant, we make use of the Mann and Whitney U-Test if the factor in question has two categories or of the Kruskal-Wallis Test if the factor considered has more than two categories.

Based on this analysis, we can identify the factors presenting synergies (i.e. influencing both dimensions in the same direction) and those showing trade-offs (i.e. affecting the two dimensions in an opposite direction) in the promotion of farm economic and environmental performance.

RESULTS

The results of the analysis of the factors affecting farm economic and environmental performance are shown in Table 1.

Table 1. Effect of selected factors on farm economic and environmental performance.

	Environmental performance						Economic performance
	Eco-efficiency non-renewable energy	Eco-efficiency eutrophication	Eco-efficiency terrestrial eco-toxicity	Eco-efficiency human toxicity	Eco-efficiency land use	Aggregate eco-efficiency	Work income per family work unit
Unfavourable natural production conditions	–***	–***	–*	–***	–***	–***	–*
Part-time farming	–*	–**	n.s.	–***	n.s.	n.s.	–***
Farm size	+***	+***	+***	+***	+***	+***	+***
Higher agricultural education	+***	+***	+***	+***	+***	+***	+*

Legend:

- : significant negative effect ; + : significant positive effect; n.s.: non-significant effect

Significance levels: ***: $p \leq 0.01$; **: $p \leq 0.05$; *: $p \leq 0.1$;

Unfavourable natural production conditions are shown to have a negative impact on all eco-efficiency indicators defined and also the economic performance indicator. By comparison with full-time farms, part-time farms demonstrate a lower level of eco-efficiency as regards the use of non-renewable energy, eutrophication and human toxicity. Part-time farming is, furthermore, associated with a lower level of economic performance than full-time farming. Farm size turns out to exert a strongly positive impact on both environmental and economic performance. The positive impact of farm size on environmental performance applies to all environmental issues considered. Having a higher agricultural education is associated both with better environmental performance (with respect to all environmental impacts considered) and improved economic performance.

DISCUSSION AND CONCLUSIONS

The results of our work provide initial evidence that the promotion of an economically viable agricultural system as well as the enhancement of one with a high eco-efficiency are not antinomic but synergetic. By increasing farm size, i.e. through scale effects, by promoting full-time farming and by raising the level of agricultural education among future farm managers, major enhancements in terms of economic and environmental performance could be achieved.

A major limitation of the present study lies in the fact that the sample has not been selected at random, with the associated possible consequences in terms of representativeness. The second limitation of our work is that the analysis considers only the global and not the local dimension of environmental performance. Whereas global environmental performance measures the productivity of the environmental impacts generation over the whole production chain, local environmental performance assesses the level of environmental pressure on the local ecosystem and compares it to the carrying capacity of this ecosystem.

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REFERENCES

Jan, P., Dux, D., Lips, M., Alig, M. and Dumondel, M. (2012). On the link between economic and environmental performance of Swiss dairy farms of the alpine area. The International Journal of Life Cycle Assessment. DOI: 10.1007/s11367-012-0405-z

Kuosmanen, T. and Kortelainen, M. (2005). Measuring eco-efficiency of production with data envelopment analysis. Journal of Industrial Ecology, 9(4), 59-72.

Rebitzer, G., Ekvall, T., Frischknecht, R., Hunkeler, D., Norris, G., Rydberg, T., Schmidt, W.-P., Suh, S., Weidema, B.P. and Pennington, D.W. (2004). Life cycle assessments – Part 1: Framework, goal and scope definition, inventory analysis and applications. Environment International, 30, 701-720.