Synergies and trade-offs between farm local and global environmental performance: a case study of Swiss alpine dairy farms

N. Repar, P. Jan, T. Nemecek and D. Dux[1]

***Abstract* - Improving the environmental sustainability of agriculture requires a better understanding of the link between the local and global dimension of the environmental performance of a farm. The aim of our research is therefore to investigate the possible synergies and trade-offs between farm local and global environmental performance using the example of Swiss dairy farms in the alpine region. The analysis relies on a sample of 56 dairy farms. For each of them, a detailed and comprehensive cradle-to-farm gate LCA (life cycle assessment) has been estimated using the SALCA (Swiss Agricultural Life Cycle Assessment) approach. Spearman's rank correlation analysis between the global and local environmental performance indicators reveals a complex picture. Depending on the environmental impact categories considered, both trade-offs as well as synergies can be observed. Our findings imply that the improvement of the environmental sustainability of dairy farming is a highly complex endeavour, one for which no one size fits all solutions may exist. Our results furthermore suggest that existing farm-level agri-environmental policy measures that focus on the local dimension of environmental performance may lead to a deterioration of global environmental performance of farming.**

Introduction

Assessing and improving the sustainability of farming is an issue of growing importance, especially when considering that farms, and, more precisely, the cradle-to-farm gate link of the food chain, play a major role in the environmental impact generation of the entire chain (see e.g. Thoma et al., 2013; Bystricky et al., 2014). Complying with the carrying capacity of the local and global ecosystem is a prerequisite to ensure environmental sustainability (Repar et al., 2016). In terms of environmental performance assessment at farm level, this implies, as proposed in the framework developed by Repar et al. (2016), separate implementation of local and global farm environmental performance indicators. Farm global environmental performance is defined as the environmental intensity of agricultural production. Environmental intensity is measured by the farm environmental impact generation in the cradle-to-farm gate link of the food chain per unit of farm biophysical output, enabling us to indirectly link global-ecosystem carrying capacity with the farm unit. The cradle-to-farm gate impacts encompass the environmental impacts generated both on-farm and in the upstream stages of farm inputs production. Farm local environmental performance refers to the environmental impact generation at local farm level, i.e. at the level of the local ecosystem underlying the local area on which the farm is operating. Farm local environmental performance is measured by means of the local environmental impact generation per unit farm area, enabling us to assess the intensity of the farm's environmental impact generation on its local ecosystem (Repar et al., 2016).

In order to improve the environmental sustainability of farming, a better understanding of the link between these two dimensions of farm environmental performance is necessary. The aim of our work is therefore to investigate the possible synergies and trade-offs between farm local and global environmental performance using the example of dairy farms in the Swiss alpine region.

Materials and methods

Our analysis relies on a sample of 56 dairy farms in the Swiss alpine region for which detailed and comprehensive cradle-to-farm gate LCAs were estimated using the SALCA approach (Jan et al., 2012). The LCA estimated in Jan et al. (2012) are recalculated using the updated version of the SALCA approach described in Alig et al. (2015). The quantified environmental impacts are then decomposed into their on- and off-farm parts. We measure global environmental performance as the on- and off-farm environmental impacts generated in the cradle-to-farm gate link per MJ digestible energy for humans produced by the farm. We calculate global environmental performance indicator for each of the 16 environmental impact categories of global concern. We assess local environmental performance for nine local environmental impact categories by dividing the on-farm environmental impact generation for each category by the usable agricultural area.

Results

As shown in Table 1, the results of the Spearman's rank correlation analysis between the global and local environmental performance indicators show a

[1] Nina Repar, Pierrick Jan and Dunja Dux work for the Farm Economics Research Group of Agroscope, Tänikon 1, 8356 Ettenhausen, Switzerland (nina.repar@agroscope.admin.ch).

Thomas Nemecek works for the Life Cycle Assessment Research Group of Agroscope, Reckenholzstrasse 191, 8046 Zurich, Switzerland.

quite complex picture. Overall, depending on the environmental impact categories considered, no significant relationships, trade-offs as well as synergies can be observed. Nevertheless trade-offs predominate over synergies.

Table 1. Spearman's correlation analysis between the global and local farm environmental performance indicators (Significant Spearman's rhos are given in the table; Statistical significance level: *= p<0.1; **=p<0.01; ***=p<0.001; n.s. = not significant).

		Farm global environmental performance (on- and off-farm environmental impact / MJ digestible energy for humans)															
		Demand for non-renewable energy	Ozone depletion	P-resources demand	K-resources demand	Deforestation	Global warming potential	Land competition	Human toxicity	Aquatic ecotoxicity	Terrestrial ecotoxicity	Ozone formation	Acidification	Eutrophication terrestrial	Eutrophication aquatic N	Eutrophication aquatic P	Water deprivation
Farm local environmental performance (on-farm environmental impact / ha farm usable agricultural area)	Human toxicity	+ 0.25 *	n.s.	+ 0.36 **	+ 0.39 **	+ 0.24 *	n.s.	n.s.	+ 0.60 ***	n.s.	+ 0.30 *	n.s.	n.s.	n.s.	n.s.	n.s.	+ 0.27 *
	Aquatic ecotoxicity	- 0.39 **	- 0.31 *	n.s.	n.s.	n.s.	- 0.45 ***	- 0.40 **	- 0.28 *	+ 0.34 *	+ 0.32 *	- 0.49 ***	- 0.46 ***	- 0.46 ***	n.s.	n.s.	- 0.50 ***
	Terrestrial ecotoxicity	- 0.26 *	n.s.	n.s.	+ 0.27 *	n.s.	- 0.39 **	- 0.42 **	n.s.	+ 0.30 *	+ 0.47 ***	- 0.42 **	- 0.44 ***	- 0.44 ***	n.s.	- 0.31 *	- 0.37 **
	Ozone formation	- 0.26 *	- 0.25 *	n.s.	n.s.	n.s.	- 0.25 *	- 0.40 **	- 0.28 *	n.s.	n.s.	- 0.26 *	n.s.	n.s.	- 0.23 *	- 0.30 *	- 0.24 *
	Acidification	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	- 0.25 *	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Eutrophication terrestrial	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	- 0.25 *	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Eutrophication aquatic N	- 0.39 **	- 0.31 *	n.s.	n.s.	n.s.	- 0.39 **	- 0.36 **	- 0.30 *	n.s.	n.s.	- 0.38 **	- 0.40 **	- 0.39 **	n.s.	- 0.23 *	- 0.39 **
	Eutrophication aquatic P	n.s.	n.s.	n.s.	n.s.	+ 0.23 *	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	+ 0.24 *	n.s.	+ 0.49 ***	n.s.
	Water deprivation	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	- 0.24 *	n.s.	n.s.	n.s.	n.s.	n.s.

Conclusions

Our findings imply that the improvement of the environmental sustainability of dairy farming in the mountain region of Switzerland is a highly complex endeavor, for which no one size fits all solutions may exist. To avoid that any improvement in one dimension of environmental performance happens at the expense of the other, both local and global performance dimensions have to be accounted for.

These findings have implications for policy-makers. Existing farm-level agri-environmental policy measures/instruments tend in Switzerland, as in many other countries, to focus exclusively on the local dimension of farm environmental performance. Due to the negative correlations that were found between local and global environmental performance, these instruments may lead to a deterioration of farm global environmental performance. Hence, clear definition of the objectives of environmental policy measures, consideration of both local and global aspects of environmental performance and use of LCAs in policy-making are indispensable if we wish to prevent problem shifting between the local and global ecosystems and reach real improvements in terms of environmental sustainability.

Acknowledgement

The research presented has been carried out within the ECON'ENTAL project of the National Research Programme 69 of the Swiss National Science Foundation (SNSF). Financial support from the Swiss National Science Foundation is gratefully acknowledged.

References

Alig, M., Preschl, U., Schwitter, K., Waldvogel, T., Wolff, V., Wunderlich, A., Zorn, A. und Gaillard, G. (2015). Ökologische und ökonomische Bewertung von Klimaschutzmassnahmen zur Umsetzung auf landwirtschaftlichen Betrieben in der Schweiz. Agroscope Science, 29.

Bystricky M., Alig M., Nemecek T. und Gaillard G. (2014). Ökobilanz ausgewählter Schweizer Landwirtschaftsprodukte im Vergleich zum Import. Zurich: Agroscope, Institut für Nachhaltigkeitswissenschaften INH.

Jan, P., Dux, D., Lips, M., Alig, N. 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* 17(6):706-719.

Repar, N., Jan, P., Dux, D., Nemecek, T. and Doluschitz, R. (2016). Implementing farm-level environmental sustainability in environmental performance indicators: a combined global-local approach. In press. *Journal of Cleaner Production* (in press).

Thoma, G., Popp, J., Nutter, D., Shonnard, D., Ulrich, R., Matlock, M., Kim, D. S., Neiderman, Z., Kemper, N. and East, C. (2013). Greenhouse gas emissions from milk production and consumption in the United States: a cradle-to-grave life cycle assessment circa 2008. *International Dairy Journal* 31: 3-14.