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Analysis of the determinants of the economic and environmental performance of Swiss dairy farms in the alpine area

Pierrick Jan, Dunja Dux, Markus Lips, Martina Alig and Daniel U. Baumgartner

9 October 2014, 9th International Conference LCA of Food, San Francisco, USA

Introduction

- Dairy products of high relevance in terms of environmental sustainability of final consumption
  - EU-25: dairy products are – within the food and drink consumption area – the second highest contributors to the environmental impact of final consumption by private households and the public sector (Tukker et al., 2006)
- "Cradle-to-farm gate" link of the milk life cycle as major contributor to the environmental impact of the full chain for most environmental impact categories (see for example Bystricky et al., 2014; Thoma et al., 2013; Hospido et al., 2003; Eide, 2002)
- Improving the environmental sustainability of the dairy food chain pre-requisites thus a better understanding of the factors affecting the environmental impact generation in this link.
- Objective

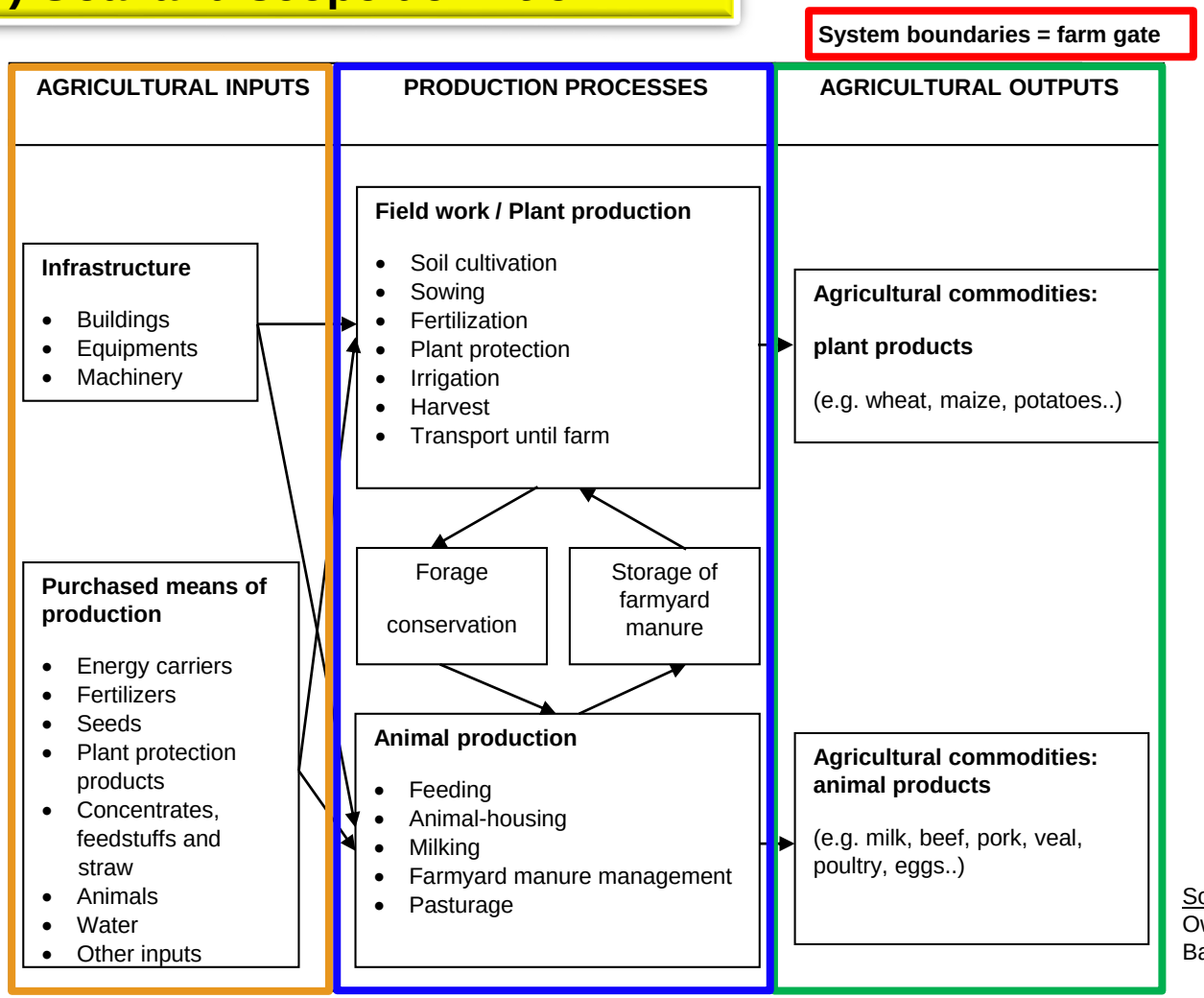
  Using life cycle assessment in combination with farm accountancy data: identification of the factors influencing the environmental and economic performance of Swiss dairy farms located in the hill and mountain region.

Sample of farms

- Present work relies on the data collected within the LCA-FADN (Life Cycle Assessment – Farm Accountancy Data Network) project (Hersener et al., 2011).
- Pooled sample of specialized dairy farms located in the hill and mountain region (56 farm observations of a three-year period from 2006 to 2008)
- Specialized dairy farm = farm whose revenues from dairying generate at least 60% of total farm agricultural revenues without any direct payments
- To ensure homogeneity between observations in terms of production activities:
  - Exclusion of farms with revenues from para-agricultural activities > 20% of total farm revenues
  - Exclusion of farms with revenues from forestry activities > 10% of total farm revenues
- Analysis at whole-farm level and not at the level of the product milk
  - High degree of specialization in dairying of the farms investigated and associated product mix homogeneity
  - It enables to circumvent the typical allocation problem met in LCA (see for example Feitz et al., 2007).

Environmental impact assessment using SALCA (1/3)

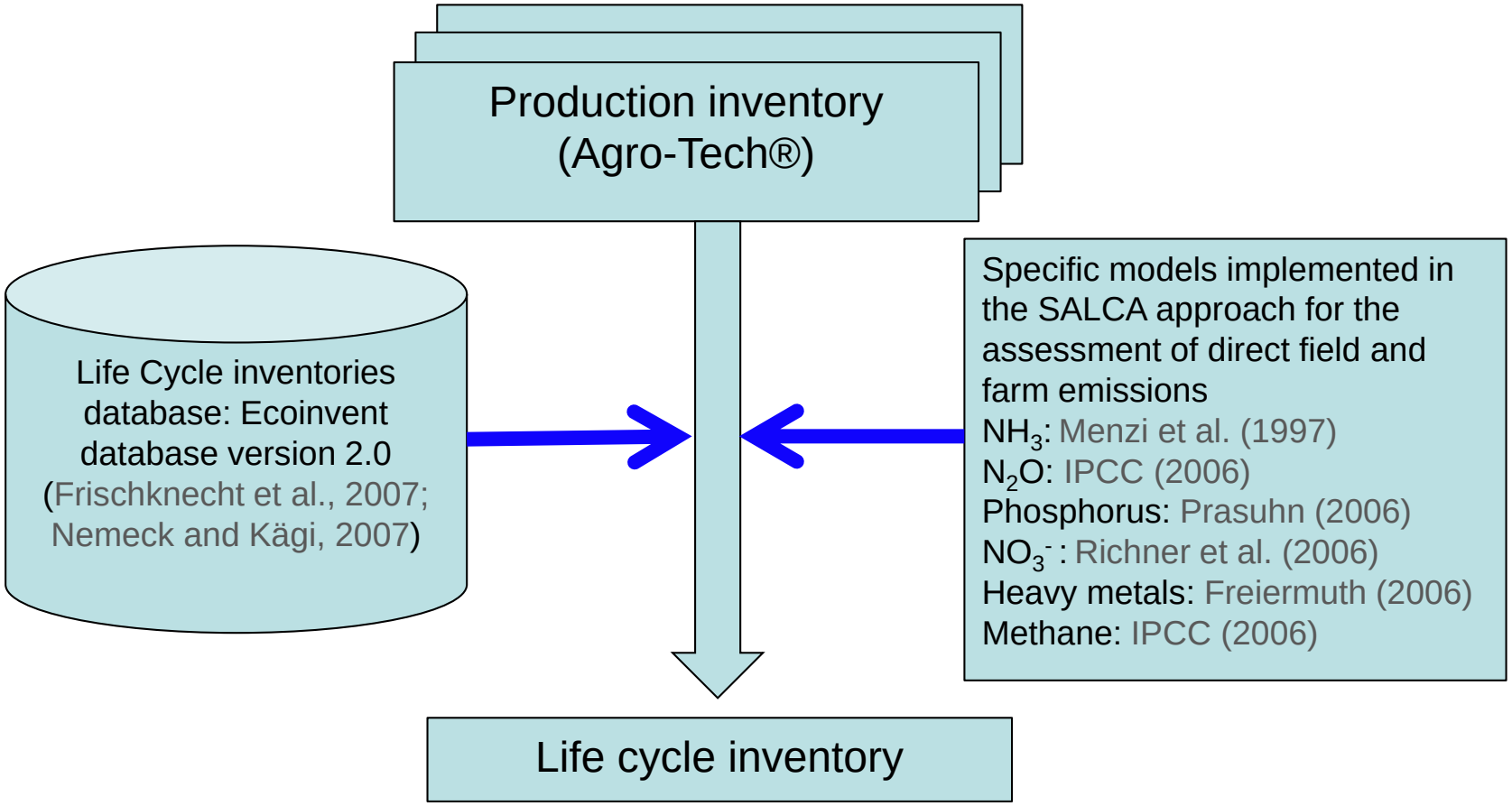
(i) Goal and scope definition



Source:
Own representation adapted from Baumgartner et al. (2011)

Environmental impact assessment using SALCA (2/3)

(ii) Life Cycle Inventory



Environmental impact assessment using SALCA (3/3)

(iii) Environmental impacts assessment

8 environmental impact categories considered

Environmental impact category	Reference of the impact assessment method used
Demand for non-renewable energy resources	Ecoinvent method (Frischknecht et al., 2004)
Global warming potential over 100 years	IPCC method (IPCC, 2007)
Eutrophication potential	EDIP97 method (Hauschild and Wenzel, 1998)
Acidification potential	EDIP97 method (Hauschild and Wenzel, 1998)
Aquatic ecotoxicity	CML01 method (Guinée et al., 2001)
Terrestrial toxicity	CML01 method (Guinée et al., 2001)
Human toxicity	CML01 method (Guinée et al., 2001)
Land use	CML01 method (Guinée et al., 2001)

Defining and measuring environmental performance at farm level: the local vs. global perspective

- Based on Halberg et al. (2005): distinction between the local and global environmental performance of a farm (Jan et al., 2012)
- **Local environmental performance**
  - Environmental issues that are primarily of relevance at the level of the local ecosystem of the farm
  - Environmental performance measured using a so-called area-based indicator: amount of environmental impacts generated by the farm at local [i.e. farm] level per unit of local farm area.
- **Global environmental performance**
  - Eco-efficiency of food production in the “cradle-to-farm gate” link of the food chain
  - Eco-efficiency = output (in physical terms) of the farm per unit of environmental impact generated
  - Eco-efficiency = inverse of the environmental intensity (also referred to as product-based indicator by Halberg et al. [2005])

Indicators used to assess farm global environmental and economic performance

- **Global environmental performance**
  - Eco-efficiency = amount of digestible energy (in MJ) produced by the dairy farm per unit of environmental impact
  - One eco-efficiency indicator for each environmental impact category (partial eco-efficiency indicator)
  - Aggregate eco-efficiency estimated using the Data Envelopment Analysis-based approach described in Jan et al. (2012) and originally proposed by Kuosmanen and Kortelainen (2005)
- **Economic performance**
  - Profitability indicator: work income per family work unit
  - Work income per family work unit = farm income available per unpaid full-time family labor force after deduction of the costs of equity capital (valued at its opportunity cost)

Analysis of the determinants of environmental and economic performance

DETERMINANTS CONSIDERED	
Category	**Variables**
Natural environment of the farm	**Agricultural production area (unfavorableness of the natural production conditions)**: 1: hill region; 2: mountain zones I & II; 3: mountain zones III & IV
Structural characteristics of the farm	**Farm size**: digestible energy output in MJ (quantity of food produced by the farm)
	Farming type 0: full-time farming; 1: part-time farming
	Production form 0: conventional farming; 1: organic farming
Sociologic characteristics of the farm manager	**Agricultural education** 0: apprenticeship or lower agricultural education level; 1: higher agricultural education

- As a consequence of the limited sample size: impossibility of performing a multiple linear regression
- Effect of each factor on each performance indicator is investigated separately by means of non-parametric statistical tools (normal distribution assumption not fulfilled)
  - Interval-scaled determinant: Spearman's rank correlation
  - Categorical determinant: Mann-Whitney U-Test or Kruskal-Wallis test

Effect of selected factors on the environmental and economic performance

	Environmental performance							Economic performance
	Partial eco-efficiency						Aggregate eco-efficiency	Work income per family labour unit
	Energy	Global warming	Eutrophication	Terrestrial ecotoxicity	Human toxicity	Land use		
Unfavorable natural production conditions	-	-	-	-	-	-	-	-
Farm size	+	+	+	+	+	+	+	+
Part-time farming	-	-	-	n.s.	-	n.s.	n.s.	-
Organic farming	+	+	+	+	+	n.s.	+	+
Higher agricultural education	+	+	+	+	+	+	+	+

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

Effect of selected factors on the environmental and economic performance

- Negative impact of unfavorable natural production conditions on eco-efficiency not due to a specific input group
- Positive impact of farm size on eco-efficiency not attributable to a specific input group
- Negative effect of part-time farming on eco-efficiency results primarily from an inefficient use of purchased feed, of buildings and equipments as well as, in some cases, of fertilizers and energy carriers.
- Higher eco-efficiency of organic farming attributable to the input groups purchased animal feed, fertilizers and nutrients as well as purchased animals
- All input groups involved in the higher eco-efficiency of better educated farm managers

Main findings (1/2)

- Systematic environmental and economic competitive disadvantage of milk production under unfavorable natural production conditions
- Farm size positively affects both dimensions of the sustainable performance of a farm: existence of a substantial productivity increase potential both in economic and environmental terms due to scale effects
- Compared to full-time farms, part-time farms show not only a lower economic performance but also a lower eco-efficiency for some environmental issues.

Main findings (2/2)

- Organic farming associated with a higher eco-efficiency for almost all impact categories considered and with a higher economic performance
  - Better environmental performance of organic farming attributable to the feeding and fertilization strategies and practices of organic farming
  - Organic farming as a more appropriate/competitive production technology than conventional farming under the natural production conditions of the alpine area
- A high agricultural education implies both high eco-efficiency and high economic performance
  - Better educated managers seem to have better management capacities for the use of economic and environmental resources.

Limits of the study

- No random sample and limited size of the sample: representativeness?
- Focus only on the global dimension of the environmental performance of a farm; local dimension not considered.
- Qualitative environmental issues (biodiversity, soil quality and erosion) not taken into account
- Social issues not considered: critical as improvement in both economic and environmental performance might present a trade-off regarding social issues

Conclusions

- Initial evidence that the promotion of an economically viable alpine dairy farming sector as well as the enhancement of one with a high eco-efficiency are not antinomic but synergetic.

- Increasing farm size, promoting organic and full-time farming as well as raising the level of agricultural education among future farm managers as possible ways to enhance farm economic performance and eco-efficiency

- Datasets combining economic and LCA data at micro (i.e. farm) level are highly valuable to get a better insight into the relationship between these two dimensions of sustainability.

Thank you for your attention

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References (1/3)

- Baumgartner DU, Alig M, Dux D, Schmid D, Blaser S (2011) Material und Methoden. In: Hersener JL, Baumgartner DU, Dux D (eds) Zentrale Auswertung von Ökobilanzen landwirtschaftlicher Betriebe (ZA-ÖB) – Schlussbericht. Agroscope Reckenholz-Tänikon Research Station ART, Zurich/Ettenhausen
- Bystricky M, Alig M, Nemecek T, Gaillard G (2014) Ökobilanz ausgewählter Schweizer Landwirtschaftsprodukte im Vergleich zum Import. Agroscope, Institut für Nachhaltigkeitswissenschaften INH, Zurich
- Eide MH (2002) Life cycle assessment (LCA) of industrial milk production. Int J Life Cycle Assess 7(2): 115-126
- Feitz AJ, Lundie S, Dennien G, Morain M, Jones M (2007) Generation of an industry-specific physico-chemical allocation matrix. Application in the dairy industry and implications for systems analysis. Int J Life Cycle Assess 12(2): 109-117
- Freiermuth R (2006) Modell zur Berechnung der Schwermetallflüsse in der landwirtschaftlichen Ökobilanz. Agroscope FAL Reckenholz, Zürich. http://www.agroscope.admin.ch/oekobilanzen/01194/. Accessed 15. April 2011
- Frischknecht R, Jungbluth N, Althaus HJ, Doka G, Hellweg S, Hischier R, Nemecek T, Margni M, Spielmann M (2004) Implementation of life cycle assessment methods—ecoinvent data v1.1. Ecoinvent report. Swiss Centre for Life Cycle Inventories (Ecoinvent), Dübendorf
- Frischknecht R, Jungbluth N, Althaus HJ, Doka G, Dones G, Heck T, Hellweg S, Hischier R, Nemecek T, Rebitzer G, Spielmann M, Wernet G (2007) Overview and methodology. Data v2.0 (2007) Ecoinvent report, N°1. Swiss Centre for Life Cycle Inventories, Dübendorf
- Guinée JB, Gorrée M, Heijungs R, Huppes G, Kleijn R, de Koning A, van Oers L, Wegener Sleeswijk A, Suh S, Udo de Haes HA, de Bruijn H, van Duin R, Huijbregts MAJ, Lindeijer E, Roorda AAH, Weidema BP (2001) Life cycle assessment—an operational guide to the ISO standards. Ministry of Housing, Spatial Planning and Environment (VROM) and Centre of Environmental Sciences (CML), Den Haag and Leiden, the Netherlands.
- Halberg N, van der Werf HMG, Basset-Mens C, Dalgaard R, de Boer IJM (2005) Environmental assessment tools for the evaluation and improvement of European livestock production systems. Livest Prod Sci 96: 33-50

References (2/3)

- Hauschild M, Wenzel H (1998) Environmental assessment of products. Vol. 2: Scientific background. Chapman, London
- Hersener JL, Baumgartner DU, Dux D (eds) (2011) Zentrale Auswertung von Ökobilanzen landwirtschaftlicher Betriebe (ZA-ÖB). Agroscope Reckenholz-Tänikon Research Station ART, Zurich/Ettenhausen
- Hospido A, Moreira MT, Feijoo G (2003) Simplified life cycle assessment of Galician milk production. Int Dairy J 13(10): 783-796
- IPCC (Intergovernmental Panel on Climate Change) (2006) IPCC guidelines for national greenhouse gas inventories. Volume 4: Agriculture, forestry, and other land use. Institute for Global Environmental Strategies (IGES) on behalf of the IPCC, Hayama
- IPCC (Intergovernmental Panel on Climate Change) (2007) Contribution of working group I to the fourth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge
- Jan P, Dux D, Lips M, Alig M, Dumondel M (2012a). On the link between economic and environmental performance of Swiss dairy farms of the alpine area. Int J Life Cycle Assess 17(6): 706-719
- Kuosmanen T, Kortelainen M (2005) Measuring eco-efficiency of production with data envelopment analysis. J Ind Ecol 9(4):59–72
- Menzi H, Frick R, Kaufmann R (1997) Ammoniak-Emissionen in der Schweiz: Ausmass und technische Beurteilung des Reduktionspotenzials. Schriftenreihe der FAL Nr. 26. Eidgenössische Forschungsanstalt für Agrarökologie und Landbau, Zürich-Reckenholz
- Nemecek T, Kägi T (2007) Life cycle inventories of Swiss and European agricultural production systems. Final report ecoinvent V2.0 N°15a. Agroscope Reckenholz-Tänikon Research Station ART, Zurich
- Prasuhn V (2006) Erfassung der PO4-Austräge für die Ökobilanzierung-SALCA-Phosphor. Agroscope FAL (Eidgenössische Forschungsanstalt für Agrarökologie und Landbau), Zürich. http://www.agroscope.admin.ch/oekobilanzen/01194/. Accessed 14 April 2011

References (3/3)

- Richner W, Oberholzer HR, Freiermuth R, Huguenin O, Walther U (2006) Modell zur Beurteilung des Nitratauswaschungspotenzials in Ökobilanzen-SALCA-Nitrat—Unter Berücksichtigung der Bewirtschaftung (Fruchtfolge, Bodenbearbeitung, N-Düngung), der mikrobiellen Nitratbildung im Boden, der Stickstoffaufnahme durch die Pflanzen und verschiedener Bodeneigenschaften. FAL (Eidgenössische Forschungsanstalt für Agrarökologie und Landbau), Zürich-Reckenholz, http://www.agroscope.admin.ch/oekobilanzen/01194/. Accessed 14 April 2011
- Thoma G, Popp J, Nutter D, Shonnard D, Ulrich R, Matlock M, Kim DS, Neiderman Z, Kemper N, East C, Adom F (2013) Greenhouse gas emissions from milk production and consumption in the United States: a cradle-to-grave life cycle assessment circa 2008. Int Dairy J 31(1): S3-S14
- Tukker A, Huppes G, Guinée JB, Heijungs R, de Koning A, van Oers L, Suh S, Geerken T, van Holderbeke M, Jansen B, Nielsen P (2006) Environmental Impact of Products (EIPRO)—analysis of the life cycle environmental impacts related to the final consumption of the EU-25. Main report. IPTS/ESTO project. European Commission. Directorate-General. Joint Research Centre, Brussels

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