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Life cycle assessment of Swiss farming systems: I. Integrated and organic farming

Thomas Nemecek *, David Dubois, Olivier Huguenin-Elie, Gérard Gaillard

Agroscope Reckenholz-Tänikon Research Station ART, Reckenholzstrasse 191, CH-8046 Zurich, Switzerland

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ABSTRACT

Organic farming (OF) is considered a promising solution for reducing environmental burdens related to intensive agricultural management practices. The question arises whether OF really reduces the environmental impacts once lower yields and all the changes in farming methods are taken into consideration. This question is addressed in a comprehensive study of Swiss arable cropping and forage production systems comparing OF to integrated production (IP) systems by means of the life cycle assessment (LCA) method.

The LCA study investigated the environmental impacts of two long-term farming system experiments: the DOC experiment comparing bio-dynamic, bio-organic and conventional/integrated farming and the "Burgrain" experiment encompassing integrated intensive, integrated extensive and organic production. All treatments received similar amounts of farmyard manure. The system boundary encompasses the plant production system; storage and application of farmyard manure is included in the system boundary, the animal husbandry is not included. The Swiss Agricultural Life Cycle Assessment method (SALCA) was used to analyse the environmental impacts.

In the overall assessment OF was revealed to be either superior or similar to IP in environmental terms. OF has its main strengths in better resource conservation, since the farming system relies mainly on farm-internal resources and limits the input of external auxiliary materials. This results in less fossil and mineral resources being consumed. Moreover the greatly restricted use of pesticides makes it possible to markedly reduce ecotoxicity potentials on the one hand, and to achieve a higher biodiversity potential on the other. This overall positive assessment is not valid for all organic products: some products such as potatoes had higher environmental burdens than their counterparts from IP.

The main drawbacks identified for Swiss OF systems are lower yields. As a consequence some production factors are used less efficiently, thus partly negating the advantages of OF. Furthermore, the different manure management strategy leads to relatively high nutrient losses in relation to yield. These two points were shown to be the main priorities for the environmental optimisation of OF systems. The differences between the bio-organic and the bio-dynamic farming systems consisted in a slightly higher input of organic matter, a few applications of mineral fertilisers and copper applications in the former.

The eco-efficiency analysis led to the conclusion that the optimisation of OF is mainly output-driven, i.e. that higher yields of good quality should be achieved with the available (limited) resources. On the contrary, optimisation of IP was found to be input-driven; the inputs should be used in a quantity and manner which minimise the environmental burdens per unit produced. The study showed that despite the efforts of recent years, there is still considerable room for the environmental optimisation of Swiss farming systems.

1. Introduction

Agricultural production in Switzerland, as in other industrialised countries, has experienced rapid intensification in recent decades. Ensuring a high degree of self-sufficiency in food was the main goal of agricultural policy until the early 1990s (BLW, 1992). The increase in yields was achieved thanks to technical progress, breeding, and also to a large extent to a sharp increase in the use of auxiliaries like mineral fertilisers and pesticides and a rise in livestock density. These changes in agricultural practices led to numerous environmental problems like high consumption of non-renewable energy resources, loss of biodiversity, pollution of the aquatic environment by the nutrients nitrogen and phosphorus as well as by pesticides (Flury, 2005).

Single measures can only partially solve such problems, since they target only a small part of the farming system. There is, moreover, a risk of shifting problems either along the production process chain or from one environmental aspect to the other. On the

* Corresponding author. Tel.: +41 44 377 7254; fax: +41 44 377 7201.
E-mail address: thomas.nemecek@art.admin.ch (T. Nemecek).

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one hand, for example, the dilution of slurry reduces ammonia emissions and toxicity to earthworms, on the other hand this measure requires more intensive machine operations, resulting in higher energy demand and more emissions from tractor use. Two basic options exist to solve the above-mentioned problems: (i) to move from conventional to integrated production, or from integrated production to organic farming (OF) as an alternative (conversion of farming system) including the use of alternative farming techniques or inputs, (ii) to optimise a given farming system, e.g. by reducing the management intensity. The first option is investigated in this paper; the second one is the subject of a related paper (Nemecek et al., 2011).

We need to know the consequences for the environment of both the conversion of the farming system as well as its extensification, which may have various direct and indirect effects on the environment. Changes in the management of one crop (e.g. fertiliser application or plant protection) may affect product yield or quality of other crops in the crop rotation. Furthermore, techniques to reduce some environmental impacts may increase others (replacement of mineral by organic fertilisers reduces the use of resources but increases nutrient losses, (Gaillard and Nemecek, 2006). We need therefore an evaluation covering all relevant environmental impacts, the whole life cycle (to avoid the shift of environmental burdens from one activity to another), the entire farming system and the different goals of agriculture and society. Life cycle assessment allows the consideration of the most relevant environmental impacts and all phases of a product life cycle (Guinée et al., 2001; ISO, 2006a).

The main characteristics of life cycle assessment are a comprehensive assessment of all relevant environmental impacts, the consideration of the whole life cycle of a product, beginning with extraction of the resources, production of infrastructure and primary materials, processing, transport, storage and ending with disposal of the waste ("from cradle to grave"). In agriculture the system boundaries often analyse from cradle to farm gate, since the focus is on the farm management and the post-farm processes are less affected by agricultural practices. The impacts are calculated by models and not directly measured in most cases. LCA relates the driving forces to the environmental pressures and environmental impacts. This can allow recognition of environmental problems before damage occurs. The environmental impacts are related to system function. This enables the analysis of eco-efficiency and the optimisation of farming systems. The LCA method is therefore well suited to analysing the environmental impacts of farming systems.

1.1. Integrated and organic farming in Switzerland

Since the 1950s the intensive mode of agricultural production provoked a number of problems such as water pollution by pesticides, phosphorus or nitrate, and overproduction. To remedy these problems Swiss agricultural policy turned towards more environmentally friendly production during the early 1990s (BLW, 1992), with the introduction of direct payments and standards for ecological performance. Two farming systems were promoted: integrated production and organic farming.

Integrated production (IP) emerged from integrated pest management, but includes all areas of the production system. The goal is to achieve an optimal result from an economic and environmental perspective in the long run (Manhoudt et al., 2002; Niklaus et al., 1992). Since 1998 most of the IP principles have been declared as the required standard for ecological performance (REP, according to DZV, 1998) with the key elements equilibrated nutrient balance, ecological compensation areas (ECA) on at least 7% of the farm area, diversified crop rotation, soil protection during winter to reduce the risk of erosion and nitrate leaching, and targeted and restricted application of pesticides. In this paper the term IP is used for a kind of farming respecting REP but not following the rules for organic farming. This kind of production was practised on 87% of the agricultural area in Switzerland (year 2003, Flury, 2005).

According to IFOAM (2010) *Organic farming* (OF) "should sustain the health of soil, plant animal, human and planet". It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved. It relies on the four principles of health, ecology, fairness and care. The characteristics relevant for this study are in particular, the fostering of biological activity, a ban of chemical-synthetic pesticides (preventive measures, mechanical, thermal, biological treatments and some inorganic chemicals like copper or sulphur are used instead). Fertiliser use is based mainly on farmyard manure and compost. If required, the nutrient demand can also be covered by other organic fertilisers, and some selected low-solubility mineral fertilisers are allowed. In 2003 OF was practised on 10.4% of the agricultural area in Switzerland (Flury, 2005). IP and OF are farming systems defined at the farm level, i.e. the whole farm must be managed according to these criteria.

Conventional farming is defined in this study as a mode of production not respecting the rules of REP for the Swiss context. The main goal is to achieve high yields and a high economic output. This mode of production has almost disappeared in Switzerland over recent years (Flury, 2005).

1.2. Overview of selected studies

Various studies have compared the environmental impacts of conventional, integrated and organic farming. The following short review concentrates mainly on LCA studies. Most of the publications cited came to the conclusion that the environmental impacts per cultivated area are reduced in organic farming systems as compared to conventional agriculture. In an evaluation per product unit, the authors found lower, similar or higher impacts of organic farming, depending on the production system, site effects and differences in management intensity. Therefore the following overview concentrates on the evaluation per kg of product.

Many studies report a lower *energy demand* per product unit, e.g. Refsgaard et al. (1998) and Cederberg and Mattsson (1998) for milk production, Mattsson (1999) for baby food, but the energy demand can also be similar (Bailey et al., 2003) or higher (Kramer et al., 2000) than for conventional farming. A conversion to OF would increase energy efficiency of Danish agriculture (Dalgaard et al., 2001). Lötjönen (2003) showed that machinery operations can use up to twice as much energy on organic than on conventional farms. For the global warming potential, the results are less clear: e.g. organic Irish suckler-beef production had lower emissions of *greenhouse gases* than conventional production per area and per product unit (Casey and Holden, 2006). Also organic apples had a lower global warming potential (Milà i Canals et al., 2001), while organic baby food (Mattsson, 1999) or organic milk (De Boer, 2003) and various other products (Williams et al., 2006) showed higher emissions per product unit. Some studies (Geier et al., 2001, 1998; Milà i Canals et al., 2001) report the *loss of nutrients* and related impact categories like acidification and eutrophication to be lower in organic farming, while other authors came to the opposite conclusion (Alföldi et al., 1999; Gaillard and Hausheer, 1999; Hansen et al., 2001; Mattsson, 1999; Spruit-Verkerke et al., 2004). The latter result was often related to the higher use of farmyard manure in the organic system. A clear difference in favour of organic farming was often found for the impact categories