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# The effect of feed demand on greenhouse gas emissions and farm profitability for organic and conventional dairy farms

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## ABSTRACT

Because of the significant effect of ruminants on climate change, the reduction of product-related greenhouse gas (GHG) emissions in milk production appears to be necessary. The reduction of emissions on an individual farm might be highly accepted by farm owners if it were accompanied by an increase in profitability. Using life cycle assessments to determine the product carbon footprints (PCF) and farm-level evaluations to record profitability, we explored opportunities for optimization based on analysis of 81 organic and conventional pasture-based dairy farms in southern Germany. The objective of the present study was to detect common determining factors for low PCF and high management incomes (MI) to achieve GHG reductions at the lowest possible operational cost. In our sample, organic farms, which performed economically better than conventional farms, produced PCF that were significantly higher than those produced by conventional farms [1.61 ± 0.29 vs. 1.45 ± 0.28 kg of $CO_2$ equivalents ($CO_2$eq) per kg of milk; means ± SD)]. A multiple linear regression analysis of the sample demonstrated that low feed demand per kilogram of milk, high grassland yield, and low forage area requirements per cow are the main factors that decrease PCF. These factors are also useful for improving a farm's profitability in principle. For organic farms, a reduction of feed demand of 100 g/kg of milk resulted in a PCF reduction of 105 g of $CO_2$eq/kg of milk and an increase in MI of approximately 2.1 euro cents (c)/kg of milk. For conventional farms, a decrease of feed demand of 100 g/kg of milk corresponded to a reduction in PCF of 117 g of $CO_2$eq/kg of milk and an increase in MI of approximately 3.1 c/kg of milk. Accordingly, farmers could achieve higher profits while reducing GHG emissions. Improved education and training of farmers and consultants regarding GHG mitigation and farm profitability appear to be the best methods of improving efficiency under traditional and organic farming practices.

**Key words:** dairy, greenhouse gas, farm profitability, carbon footprint

## INTRODUCTION

From a global perspective, agriculture is the fourth largest greenhouse gas (**GHG**) emission source (IPCC, 2007) and accounts for 10.1% of the overall emissions in the European Union (EEA, 2013). The dairy sector alone is thought to contribute 4% of global GHG emissions (FAO, 2010). Because emissions due to agriculture are expected to sharply increase quantities of global GHG in the future (Smith et al., 2007), a reduction potential of 5.5 to 6 Gt of $CO_2$ equivalents (**$CO_2$eq**; Neufeldt et al., 2006) per year until 2030 deserves special attention. Much of agricultural emissions derive from methane emissions of ruminants.

Because pasture accounts for approximately 70% of the areas used for agriculture globally (FAO, 2013) and can be used for food production by ruminants, pasture makes a considerable contribution to global food security in the framework of milk production (Gill et al., 2010). Compared with increasingly expensive concentrate-based milk production in the recent past, grazing on grassland is a low-cost milk production approach that has attracted increasing interest in Germany (Thomet et al., 2011; Reijs et al., 2013; Kiefer et al., 2014). Investigations into the effects of pasture-based milk production systems on GHG emissions arrive at different results: Lewis et al. (2011) reported pasture to produce less methane emissions than permanent housing. Similarly, Flysjö et al. (2011) observed slightly lower GHG emissions from the pasture systems of New Zealand compared with permanent housing and higher milk yields in Sweden. However, according to Sutter et al. (2013), the weakest aspect of pasture feeding is the high methane emission per kilogram of ECM. To improve the GHG balance in milk production, Brade and Flachowsky (2007), Yan et al. (2010), and Havlik et al. (2014) advocate for increased productivity with higher performance in individual cows, which is usually not found with pasture feeding. Their proposal aims to decrease enteric methane emissions and would necessitate a greater portion of concentrate in the ration (see also Hindrichsen et al., 2006; Christie et al., 2012).

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It is important to note that emissions are influenced by numerous factors, and complex interactions exist between individual sources of emission (Schils et al., 2005; Amon et al., 2006). However, increased efficiency actually appears to be a feasible approach to reducing GHG emissions on the individual farm (Pirlo, 2012). One important factor influencing efficiency and GHG emissions is the amount of feed (forage plus concentrates) that each cow needs to produce 1 L of milk (Waghorn and Hegarty, 2011).

Against this background, 81 dairy farms in southern Germany with pasture feeding frequently situated in the uplands (a practice that is not representative of the overall milk production in southern Germany) were analyzed economically and for their GHG emissions over 3 economic years (2008-2009 to 2010-2011). To create a high level of acceptance by producers, not only should GHG emissions be reduced, but profitability of milk production should be increased simultaneously (Lovett et al., 2006). Various variables of milk production that can influence GHG emissions and simultaneously influence profitability of the farms were examined as a basis for discussing the following hypotheses: (1) a production-related optimization potential in milk production exists that enables the realization of climate protection with low financial costs of reducing GHG; and (2) specifically, reduced feed demand (forage plus concentrates) per kilogram of milk is a preferable measure to improve GHG balances and increase farm profitability simultaneously.

In this analysis, production by organic and conventional enterprises was considered separately to evaluate the potential differences in production techniques and profitability of the systems.

## MATERIALS AND METHODS

This section describes the method of ascertaining profitability as well as GHG emissions. All of the relevant operational data were collected in cooperation with the farm managers during multiple farm visits.

### Sample Description

The nonrepresentative 81 farms in this study were randomly requested to participate and had to meet the following basic conditions: (1) frequent usage of pasture for dairy cows, (2) location in southern Germany (Baden-Wuerttemberg, Bavaria, and Hesse), (3) a minimum of 25 cows, (4) keeping in loose housing stable indoor systems, and (5) mandatory accounting. On average, these farms were characterized by maintaining a herd of 43 cows. Fleckvieh (34%), Holstein (31%), Vorderwälder and Hinterwälder (24%), Brown Swiss (9%), and other (2%) breeds were found. In total, 44% of the farms operated according to the criteria of organic farming under Council Regulation (EC) No. 834/2007 or under the guidelines of the Naturland and Bioland farming associations (Bioland, 2013;Naturland, 2014). Most cows calved throughout the whole year and only one-third of farmers practiced seasonal calving in spring. The forage ration consisted mainly of pasture grass in summer and grass silage in winter. The land for mowing and pasture was improved grassland and the feed budget per cow and year totaled approximately 5 t (DM). The average concentrate portion in the ration is approximately 20%. Additional production-related features of the farms are shown in Table 2.

### Data Acquisition and Determination of Selected Efficiency Criteria of Farms

All material flows (inputs and outputs) relevant to the framework of the present study were quantified during data acquisition of the 81 practicing enterprises and subject to mandatory accounting. Accounting is defined as the complete recording of all of the business transactions based on documents; it provides information to the entrepreneur and is used as a basis for calculating tax liability.

Livestock and any entries and withdrawals or losses of animals were centrally recorded in the animal identification and information database, conducted by the Bavarian State Ministry for Food, Agriculture and Forests. Animal performance data (e.g. milk yield, age at first calving, replacement rate) were taken from reports by state inspection associations for individual farms as well as milk processing plants.

The quantities and ingredients of the purchased feed were recorded based on the bills of feed suppliers. For feed production, necessary input quantities (e.g., diesel, electricity, mineral fertilizers, and pesticides) and their specific emissions were allocated and related to kilograms of $CO_2$eq/decitonne (**dt**) through the cultivation area and yield. The quality of homegrown feed could only be partly verified based on feed analyses. Therefore, the feed ingredient data were partially adopted from data sets of the Agricultural Centre of Baden-Wuerttemberg (LAZBW, 2009–2011) and Bavarian State Research Centre for Agriculture (LFL, 2012) for the relevant region and respective economic year. Farmland yields were estimated based on information provided by the farm managers and verified through records of nutrient comparisons according to §5 Fertilizer Ordinance (BMELV, 2012b) and, again, data sets of the Agricultural Center of Baden-Wuerttemberg (LAZBW, 2009–2011) and the Bavarian State Research Center for Agriculture (LFL, 2012). Yields were a function of