



Effect of production system and farming strategy on greenhouse gas emissions from commercial dairy farms in a life cycle approach

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ABSTRACT

This paper documents and illustrates a model to estimate the greenhouse gas (GHG) emissions and land use on commercial dairy farms. Furthermore, a method of allocating total farm emissions into meat and milk products was developed and, finally, potential mitigation options at farm scale were identified. The GHG emission at farm gate using a Life Cycle Approach (LCA) was estimated based on data from 35 conventional dairy farms with an average 122 cows and 127 ha, and 32 organic dairy farms with an average 115 cows and 178 ha. There was a significant ($p < 0.05$) higher emission in kg CO₂-eq. per kg energy corrected milk (ECM) in the organic system (1.27) compared to conventional (1.20) before allocation into milk and meat. In the conventional system 88% was on-farm emission vs. 98% in the organic production system. Based on a mathematical model, an average of 15% of total farm GHG emissions was allocated to meat. This level was low compared with four other methods traditionally used to allocate between milk and meat, with the amounts allocated to meat ranging from 13% for economic value, 18% for protein mass, 23% for system expansion and up to 26% for biological allocation. The allocation method highly influenced the GHG emission per kg meat (3.41 to 7.33 kg CO₂-eq. per kg meat), while the effect on the GHG emission per kg milk was lower (0.90 to 1.10 kg CO₂-eq. per kg ECM). After allocation there was no significant effect of production system on GHG emission per kg ECM. Land requirement, including imported feed, was highest in the organic system at 2.37 m² per kg ECM against 1.78 m² in the conventional system. Farming strategies based on low stocking rate or with focus on high efficiency in the herd were identified as the most promising for reducing GHG emissions per kg milk at farm gate after allocation between meat and milk. It was concluded that the model can estimate relevant variation in GHG emissions between commercial farms without intensive data registration.

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1. Introduction

Agriculture is an important contributor to global emissions of greenhouse gases (GHG), in particular of methane (CH₄) and nitrous oxide (N₂O). Agriculture contributes 10–12% to overall global emissions. Of this, livestock is assumed to be responsible for the largest part at nearly 80% of global agricultural GHG emissions (FAO, 2006). This is particularly due to CH₄ emissions from enteric fermentation in ruminants and manure handling, and due to the intensive nitrogen (N) cycle on livestock farms

leading to direct and indirect N₂O emissions (Olesen et al., 2006). With the global demand for animal-sourced foods set to double by 2050, the implications for GHG emissions are profound (FAO, 2006). The already large contribution from agriculture to global GHG emissions will therefore increase in importance unless more effective and climate-friendly systems are adopted. Furthermore, the agricultural contribution to CO₂ emissions from deforestation can only be reduced if the productivity of existing agricultural land is improved. The future challenge within agriculture is therefore three-fold: to adapt to a changing and more variable climate, to increase production and, at the same time, to reduce GHG emissions (Basse et al., 2009).

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This paper will address the last part in relation to dairy production. Olesen et al. (2006) modelled GHG emissions from European dairy production systems and concluded that the GHG emission per kg product was more closely related to N efficiency than to production system, while Schils et al. (2006) found that a reduction in N surplus effectively reduced GHG emissions from Dutch dairy farms. In a model study of different US production systems, Rotz et al. (2010) found that milk yield per cow and the feeding and manure handling strategies were the main factors explaining the variation in emissions between systems. Casey and Holden (2005) in an Irish study found that a combination of high-yielding cows and elimination of non-milking animals was the most effective mitigation strategy. In a Swedish study, Cederberg and Mattsson (2000) found a difference in GHG emissions between organic and conventional milk production based on data from two farms, while Cederberg and Flysjö (2004) in a larger study based on 23 farms in a Swedish region and Thomassen et al. (2008a) based on data from 21 Dutch farms concluded that there was no difference between organic and conventional production systems in terms of GHG emission per kg milk. Within organic farming Müller-Lindenlauf et al. (2010) found that grassland-based farms combined with high milk yield per cow resulted in the lowest emission per kg milk, which is in line with the overall conclusion by FAO (2010), that intensification of farming, in terms of milk yield per cow, creates the lowest GHG emission per kg product. However, no studies have yet set out to verify these suggestions based on empirical farm data, as the very complex structure of the farming system might be an obstacle to identifying the effect of partial changes in a whole-farm perspective (Del Prado et al., 2010).

The purpose of this study was to develop a method based on available data from commercial farms to estimate the impact of dairy farming on GHG emissions at farm gate divided into on-farm (direct or primary) and off-farm (indirect or secondary) emissions and types of GHG, including a method to allocate between milk and meat. Another purpose was to obtain benchmark figures for important parts of total GHG emissions and to highlight areas that have significant impact on these figures and thereby identify possible mitigation options.

2. Materials and methods

Annual data of the production performance, economic turnover and the N budget of specialized dairy farms from the period 2001–2003 were analyzed. The results were expressed either per cow with 365 feeding days, per livestock unit (LSU) equal to 0.75 cow (annual yield 9200 kg ECM with correction for milk yield) or 2.4 heifers of the Holstein Friesian type (Anonymous, 2009a), or per ha of agricultural land, equal to the farmed area including permanent grass and set-aside. These data had been collected as part of other activities in relation to dairy production and N emission to the environment by Nielsen and Kristensen (2005), who also give a more detailed description of the methods used for registration and data collection. We included only farms with (a) at least 90% of the income from dairy activities, (b) registrations of the yearly turnover of animals, feedstuff and manure balanced with the change in on-farm stock, and (c) consistent data on forage

production and feed use. Based on these criteria a total of 67 farms, representing both organic ($n=32$) and conventional ($n=35$) farms were analyzed. The herds on all organic farms were Holstein Friesian (HF), while on conventional farms nine of the 35 herds were Jersey and the remaining HF. The most dominant manure handling system was slurry, used on 86% of the conventional farms, but only on 53% of the organic farms.

The environmental performance in a cradle-to-farm-gate perspective was evaluated using life cycle assessment (LCA) with focus on the global warming impact category. The LCA was made by the attributional method, where the environmental impact of the production is quantified in a status quo situation (Thomassen et al., 2008b). The global warming potential was estimated for a 100-year time period by converting all GHG to CO₂ equivalents (CO₂-eq.), which on a weight basis gives 1 kg CH₄ = 25 and 1 kg N₂O-N = 298 CO₂-eq. (IPCC, 2006).

2.1. System boundary definition

Traditionally the physical farm defines the dairy production system, but in this case the system boundary was extended in order to include also the emissions related to the imported resources such as feed and fertilizer. These latter resources are referred to as off-farm or secondary emissions and the former as direct or primary emissions.

2.2. Production data

We have as far as possible used data from the farm-gate turnover, as also argued by van der Werf et al. (2009), which means that only few data from the internal turnover at the farm are needed. This type of data is often difficult to get and the uncertainty attached to the figures often larger than for the data related to the farm-gate (Kristensen, 2004).

The products from the farms were amounts of milk and meat sold, with meat adjusted for the difference in herd live weight at the start and end of the year and imported animals. The typical Danish dairy farm is a mixed farm based on feed production from its own arable area, where roughage is produced in a rotation with cereals. Often the cereals are used both directly as feed and in exchange for concentrates at the feed manufacturers. This means that the grain production is not a separate enterprise in order to produce a cash crop, but is an integral part of the dairy production system. The amount of cereals produced and its exchange for other types of concentrate at the feed manufacturers is part of the process of giving the herd a balanced diet in terms of energy and crude protein. Therefore we have calculated the net amount of imported feed as the actual import minus exported crops expressed in MJ net energy to lactation (NE) and kg nitrogen (N) based on the amount in kg from the farm accounts, and the nutrient content from either analyses of the feed, information from the feed manufacturer or standard values from feed tables.

The net amount of imported manure was also calculated as the difference between exported and imported manure expressed in kg N. These net calculated sources were treated as input, as they only in a few observations were negative. By calculating the manure and feed sources as net inputs, we did

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