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A dominance analysis of greenhouse gas emissions, beef output and land use of German dairy farms

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ABSTRACT

The goal of this study was to firstly compare greenhouse gas (GHG) emissions, land use and beef output per kg of fat and protein corrected milk (FPCM) of German dairy farms using a life cycle approach and secondly determine the relative importance of parameters explaining variation of GHG emissions, beef and land use outcomes. In total, 27 dairy farms from south Germany with dual purpose Fleckvieh cows (South-FV) and 26 dairy farms from west Germany with Holstein–Friesian cows (West-HF) both feeding total mixed rations were assessed. Modelling of GHG emissions was based on international LCA guidelines and included all emissions up to the moment milk is sold from the farm. Beef output was calculated as actual (beef from culled cows) and potential beef output (includes beef from culled cows and from fattening of surplus calves outside the farm). Stepwise multiple linear regression and dominance analysis was used to identify parameters that have the highest impact on variation of GHG emissions, beef output and land use. The results showed that South-FV dairy farms emitted greater GHG emissions/kg of FPCM ($P < 0.01$) than higher yielding West-HF dairy farms. A wide range in GHG emissions within region was found from 0.90–1.25 kg CO_2-eq/kg of FPCM for South-FV German farms and 0.79–1.20 kg CO_2-eq/kg of FPCM for West-HF German farms. Average beef output/kg of FPCM of West-HF dairy farms was significantly lower compared to South-FV dairy farms. Outcomes of variable importance analysis showed that milk yield and replacement rate had a high impact on variation of GHG emissions and beef output of both dairy farm groups. A trade off between GHG emissions/kg of FPCM and beef output/kg FPCM was shown in the case of increasing milk yield and reducing replacement rate. However, the impact of replacement rate on potential beef output/kg of FPCM was sensitive to assumptions made to estimate potential beef output. No difference between the regions and breeds was found in case of land use/kg of FPCM. The analysis is a first approach identifying the parameters of commercial dairy farms that are key contributors to GHG emissions/kg of FPCM and are also highly variable between farms. It was also shown that it is important to identify those parameters that have a negative impact on beef output to avoid shifting GHG emissions between production systems.

1. Introduction

While achieving a viable income is the basic goal of most farmers from industrialized countries, there is now an increasing focus on dairy farmers, by consumers and policy makers, to minimise the effects dairy farming has on the environment and in particular climate change. On average livestock production emits about 9% of total EU-27 GHG emissions. The contribution of dairy farming to total livestock GHG emissions of individual EU-27 nations ranges from 22% in Spain to 70% in Latvia (Lesschen et al., 2011).

In order to identify GHG mitigation potential on commercial farms it is important to investigate variability of emission sources between farms and to address the risk of carbon leakage attributed to single on-farm mitigation options. Carbon leakage occurs when GHG emissions are reduced on a farm or in a country by reducing production but replacing the production shortfall with increased output from another farm or imports from other countries that emit greater GHG emissions/unit of output (Franks and Hadingham, 2012; Lee et al., 2004; Webb et al., 2013). Most studies

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comparing GHG emissions of different dairy cow production systems are based on model approaches and sensitivity analysis of case studies or single research farms (Flysjö et al., 2011b; Nguyen et al., 2013; O'Brien et al., 2012; Zehetmeier et al., 2012). A major advantage of these studies is that they refer to detailed data from literature or measurements. However, the potential from these studies are limited as these experiments are expensive and limited to only small numbers for each region.

Furthermore, these studies do not give insight into variability of investigated outcomes between farms and identification of those parameters that have the highest impact on variability of investigated farm outcomes. Assessing the parameters that influence variability between GHG emissions from dairy farms is important to identify mitigation potential. For instance, if parameters that contribute to GHG emissions per kg of milk have a low variability between farms there is little room for improvement within the investigated group of farms assuming a certain system/technology. However, where a parameter significantly contributes to sensitivity of GHG emission outcomes and also shows a large variability between farms it has a high potential to mitigate GHG emissions (Fig. 1). Parameters or variables that are important contributors to GHG emissions and show a high degree of variability are defined as "important parameters/variables" (Azen and Budescu, 2003).

Relatively few studies give insight into variability of emission sources and parameters between farms by modelling GHG emissions of commercial dairy farms due to the high amounts of data required (Cederberg and Flysjö, 2004; Christie et al., 2012; Haas et al., 2001; Thomassen et al., 2008; van der Werf et al., 2009). Apart from Christie et al. (2012) these studies mainly focus on inter-system comparison of different dairy farming systems. A comparison of single farms within one system gives insight into variability between farms of one system.

Previous modelling and case studies (Capper and Cady, 2012; Flysjö et al., 2011b; O'Brien et al., 2010) have reported that the breed or type of cow has an important effect on total farm GHG emissions when comparing different dairy farm systems. This is mainly due to differences in production traits (e.g. milk yield). Generally, the effect of dairy breeds on GHG emissions is assessed by comparing breeds specifically selected for milk production such as Holstein–Friesian (HF) and Jersey cows. One of the main reasons for this is the dominance of HF dairy cows in most developed countries (e.g. over 90% of total dairy cows are estimated to be HF breed in Canada, USA and UK; WHFF, 2011). However, in some European countries dual purpose breeds, such as Fleckvieh (FV) dairy cows still play an important role. The contribution of dual purpose FV dairy cows to national dairy cow populations is 80% in Austria and Serbia, 50% in Slovenia and Czech-Republic, 16% in France and Switzerland. In Germany about 30% of the dairy cow population are dual purpose FV breed mainly located in the south of Germany (ESF, 2013). The FV breed is mainly characterised by a lower milk yield per cow, a higher live weight per dairy cow and better fattening characteristics of surplus female and bull calves (Geuder et al., 2012; Haiger and Knaus, 2010).

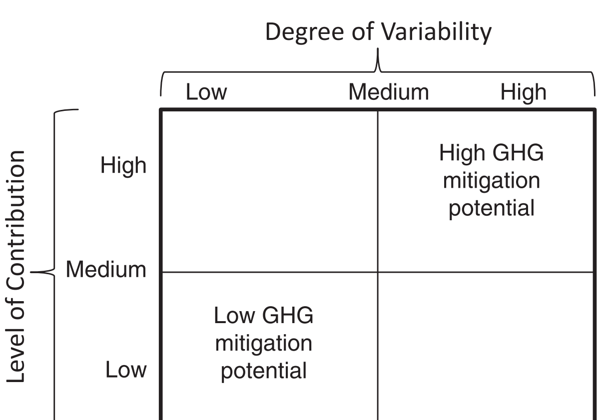

Fig. 1. A matrix of variability of parameters versus contribution of parameters on greenhouse gas (GHG) emissions (Makinson et al., 2012; Heijungs, 1996).

The overall aim of this study was to investigate GHG emissions/kg of fat and protein corrected milk (FPCM) of commercial dairy farms from two regions in Germany with different breeds using a life cycle approach. We further investigated beef output and land use/kg of FPCM. These are important indicators that need to be considered when comparing GHG emission of dairy farms as changes in beef output or land use of dairy farming could result in carbon leakage (Smith et al., 2013).

We specifically aimed to identify:

(i) The impact of different parameters on GHG emissions, beef output and land use.
(ii) The relative importance of these parameters explaining variability of investigated farm outputs.

2. Material and methods

2.1. BZA-Milk database

Data from BZA (economic performance of milk production branch within a farm)-Milk network (Dorfner and Hofmann, 2012) were taken to calculate GHG emissions, beef output and land use of commercial dairy farms. The BZA-Milk database was used as it has several advantages:

- Contrary to other farm accounting tools (e.g. European Commission, 2011) BZA-Milk provides several physical and supplementary data besides economic data which are reported by farm advisors e.g. production and fertility traits such as calving interval and replacement rate, feed intake of dairy cows, calf and heifer mortality, type and amount of mineral fertilizer application, yield of forage and concentrates produced on-farm and type of feed purchased.
- Inputs and outputs of other enterprises on the dairy farm that are not connected to milk production are excluded (e.g. production of cash crops).

Further information on the source of the BZA-Milk data and how it is collected is given in Table A1 in the supplementary materials.

2.2. Farm selection

We used the group of dairy farms out of the BZA-Milk database that are defined as high-performing-dairy farms. These farms have a better economic performance, and higher production trait performance compared to the average of farms reported in BZA-Milk. They are also expected to be the most competitive under future market conditions. Four groups of high-performing-dairy farms, representing south, west, north and east Germany are defined each year to compare economic and production trait performance of dairy production systems (Dorfner, 2013). The group of west and south high-performing-dairy farms was chosen for this study to represent two different dairy breeds. Holstein–Friesian is the dominant breed of west dairy farms (87% of farms) and FV is the most important breed for south dairy farms (57% of farms; Dorfner, 2013). Farms with breeds other than FV or HF were excluded from the study. Furthermore, farms that fed a total mixed ration (TMR) were only selected. This was to guarantee homogeneity in feeding