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Emissions of greenhouse gases from dairy farms – a case study using the German agricultural emission model GAS-EM

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Abstract

The model GAS-EM was used to calculate the greenhouse gas (GHG) emissions from the dairy cattle husbandry of four organic and two conventional farms in northern and southern Germany. Emissions from enteric fermentation, manure management and grazing were included. Results lie between 3779 and 5060 kg $CO_{2\text{-}eq}$ cow^{-1} a^{-1} or 0.54 and 0.96 kg $CO_{2\text{-}eq}$ kg ECM^{-1}. GAS-EM can be used to calculate GHG-emissions of single farms, but a refined methodology would be desirable so that all data available at the farm level (e.g., share of concentrates) could be included. At the moment the algorithms of GAS-EM cause in some cases substantial differences between the survey and model in the share of concentrates. The adequate modeling of feed flows and qualities is fundamental for a realistic calculation of dairy farm GHG-balances. The modular structure of GAS-EM, due to the aims of the model and the specifications of the IPCC (1996), makes it difficult to calculate a comprehensive GHG-balance of a dairy farm.

Key words: GHG-emissions, dairy farms, farm comparison, model, GAS-EM

Introduction

GHG-emissions associated with dairy cows form a large part of agricultural GHG-emissions. By modeling the GHG-emissions of single farms, farm-specific potentials for the reduction of emissions can be explored. The model GAS-EM was developed to calculate agricultural GHG-emissions at the national and regional level for the German National Emission Inventory. The aim of our study was to examine the suitability of GAS-EM for the calculation of GHG-emissions from single dairy farms and to investigate farm differences in GHG-emissions.

Material and methodology

In the project „Climate effects and sustainability of organic and conventional farming systems" 20 conventional and 25 organic dairy farms in four different regions of Germany were studied in the years 2008 to 2010. On each farm samples of feed stuffs and manure were collected and analysed. Extensive data on feeding, housing, herd management and manure management were collected in interviews with the farmers. Milk production data were taken from the monthly milk recording. Six farms were chosen from the 45 project farms: two extensive and two intensive organic farms and two intensive conventional dairy farms. The GHG-emissions were calculated for the years 2009 and 2010 for these farms with the dairy module of GAS-EM, so the emission sources enteric fermentation, housing, grazing and manure management could be included. Additionally the mean GHG-emission values of the respective districts for the year 2009 were compared with the farm values. Characteristics of the six farms are given in Table 1. The main manure on all farms, apart from Farm 11, was slurry, which was stored mainly in open tanks and spread by broadcasting.

Table 1. Characteristics of the six studied farms

Farm System region[1]	10 Org B	11 Org B	13 Org B	20 Conv B	73 Org N	85 Conv N
Farm size [ha]	43	55	36	59	1299	153
Herd size [cows]	42	18	44	57	234	77
Breed[2]	Si	HF	Si	Si	HF	RH
Milk yield [kg ECM a^{-1}]	4243	5156	6937	8000	8598	8610
Prod. herd life [a]	3.33	4.90	3.26	1.69	2.26	2.35
Grazing summer	half-day	half-day	night	none	whole day	half-day
Share of concentrates [% in DM]	12	5	16	27	34	30
Housing[3]	FS	DL	FS	FS	FS	FS

[1] B: Bavaria, N: Northern Germany (Baltic Sea) [2] Si: Simmental, HF: Holstein Friesian, RH: Red Holstein [3] FS: Free stall with slatted floor, DL: Deep litter

The model GAS-EM has a modular structure. Emissions are calculated in defined categories in compliance with the specifications of the IPCC (1996), that is according to animal groups (e.g., dairy cows, other cattle) and not as per farm branch or product. A detailed description of the calculation procedures is given in Haenel et al. (2010) and Roesemann et al. (2011). The amounts of feed consumed are calculated based on animal performance and energy contents of the feedstuffs. Due to the design of the model for national calculations (and the limited data availability at this level), data on amounts of feed or share of concentrates that are collected on farm can not be included directly; these values are modeled by GAS-EM.

Results

The modeled amount of concentrates lies in most cases below the input data (Table 2). In half of the farm years the difference is no more than 0.5 kg DM cow^{-1} d^{-1}, in the other cases it amounts to up to 2.4 kg DM cow^{-1} d^{-1}. The modeled amount of forage is usually lower than the input value, up to 5.9 kg DM cow^{-1} d^{-1}.

Table 2. Mean energy content and daily amount of feed, comparison of the input and output data of the model GAS-EM

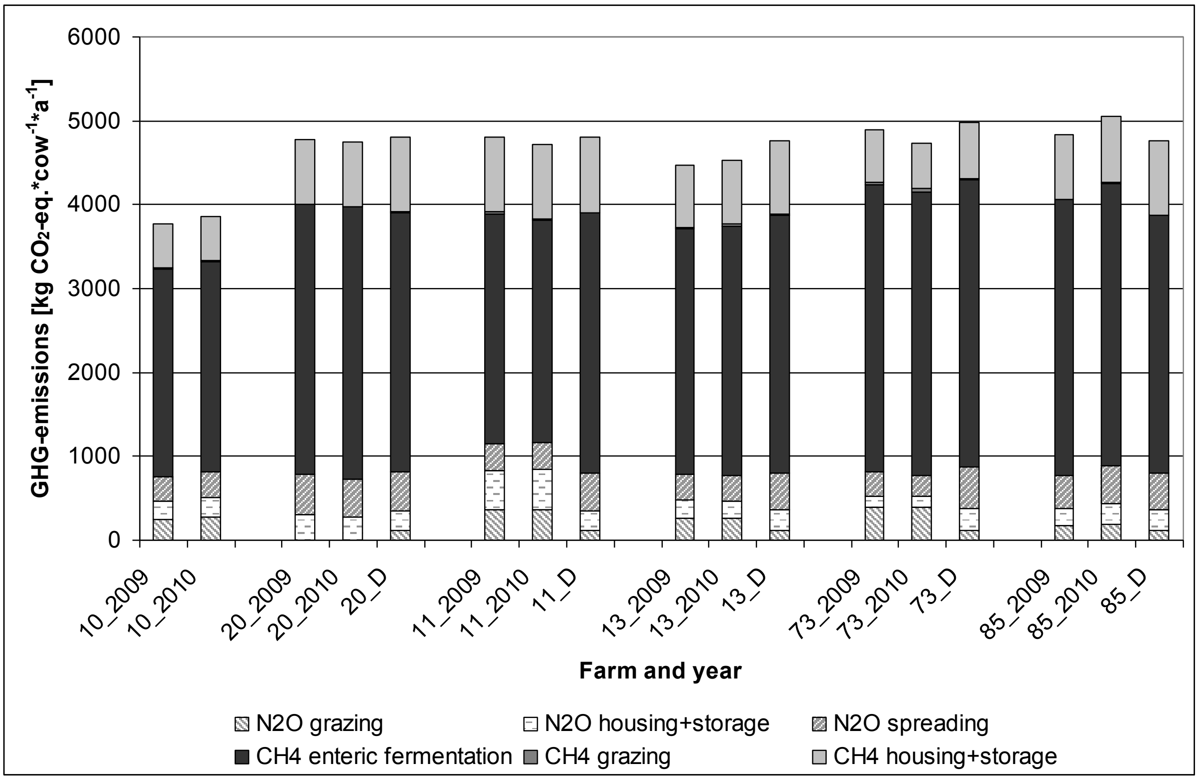
	Energy content[1] [MJ NEL kg DM^{-1}]		Amount[1] [kg DM cow^{-1} d^{-1}] of concentrates		forage		Share [% DM] concentrates	
Farm_year	conc.	forage	I[2]	G[3]	I[2]	G[3]	I[2]	G[3]
10_2009: org	8.1	6.4	0.7	0.2	14.2	13.6	4.9	1.4
10_2010: org	8.1	6.4	2.5	0.4	12.5	13.5	16.7	3.0
11_2009: org	8.5	6.1	1.1	1.1	17.2	14.0	5.8	7.1
11_2010: org	8.8	6.1	0.8	0.4	17.4	14.1	4.4	2.5
13_2009: org	8.5	6.3	2.8	2.9	19.4	13.5	12.5	17.8
13_2010: org	8.5	6.6	3.1	2.2	19.1	14.4	14.0	13.3
20_2009: conv	7.9	6.3	6.1	5.0	14.5	12.7	29.5	28.4
20_2010: conv	8.1	6.3	5.8	5.0	12.9	12.8	30.9	28.0
73_2009: org	7.8	6.5	5.7	4.6	14.1	13.9	28.7	24.9
73_2010: org	8.1	6.6	7.0	4.6	10.4	14.0	40.2	24.8
85_2009: conv	7.9	6.5	5.4	5.1	14.2	12.7	27.5	28.4
85_2010: conv	7.6	6.5	5.3	5.6	13.4	12.8	28.3	30.5

[1] NEL: Net Energy Lactation, DM: dry matter [2] I: Input data for GAS-EM [3] G: Output data of GAS-EM

This reduction of feed amounts by the model can be explained by the more precise inclusion of animal requirements in GAS-EM than was possible during the plausibility check (comparison of feed ration and milk yield), which was conducted after the on-farm data collection. The changes in the feed amounts modeled in GAS-EM lead sometimes to conside-rable differences between input and model values in the share of concentrates.

The per cow GHG-emissions of the Intensive Dairy Farms 13 to 85 and the Extensive Deep Litter Farm 11 are on the same level, between 4531 (13_2009) and 5060 (85_2009) kg $CO_{2\text{-eq}}$ cow^{-1} a^{-1}, and differ by no more than 13 % (Figure 1).

The other extensive farm (Farm 10) shows clearly lower per-cow GHG-emissions. Reason for the higher values of the Extensive Farm 11 are the higher GHG-emissions from its deep litter system compared to the slurry systems of the other five farms. GHG-emissions in relation to milk yield range from 0.54 (73_2010) to 0.96 kg (11_2010) $CO_{2\text{-eq}}$ kg ECM^{-1}. These results agree with the findings of other studies (de Vries et al., 2010), but are on a lower level, as some emission sources are not included in the dairy module of GAS-EM. The farms with higher milk yields have lower GHG-emissions per kg ECM than low yielding farms when regarding solely the emissions from manure and enteric fermentation.



D: mean value for the respective district for the year 2009; the farms 10 and 20 are located in the same district, so the district value is given only once

Figure 1. GHG-emissions from selected sources of six dairy farms calculated with the model GAS-EM

Discussion

GAS-EM can be used to calculate GHG-emissions of single dairy farms. But to do so the model should be refined, so data (e.g., share of concentrates) which are available on farm can be incorpo-rated directly into the model. The sometimes large deviance in the share of concentrates between model and survey is problematic when detailed equations based on feed properties are used to cal-culate emissions from enteric fermentation.

Besides, the modular design of GAS-EM makes it difficult to calculate a comprehensive GHG-balance of a dairy farm. Important emission sources belonging to dairy cows indirectly (e.g., replacement animals, feed production on- and off-farm) are not part of the dairy module and can be included only with difficulty or not at all.

A comparison of the studied farms shows the importance of the level of milk yield, as the basis for the calculation of feed intake, and thus emissions from enteric fermentation and the amount of manure produced, for the GHG-emissions per cow.

Suggestions to tackle the future challenges of organic animal husbandry

To realistically and comprehensively estimate GHG-emissions from dairy farms, models should incorporate all relevant emission sources, including feed production off-farm, land use change and carbon sequestration. This is of special importance for organic farms, as they might have advantages in these areas. The adequate modeling of feed flows and qualities is fundamental for a realistic calculation of dairy farm GHG-balances. Calculation procedures with smaller uncertainties are desirable.

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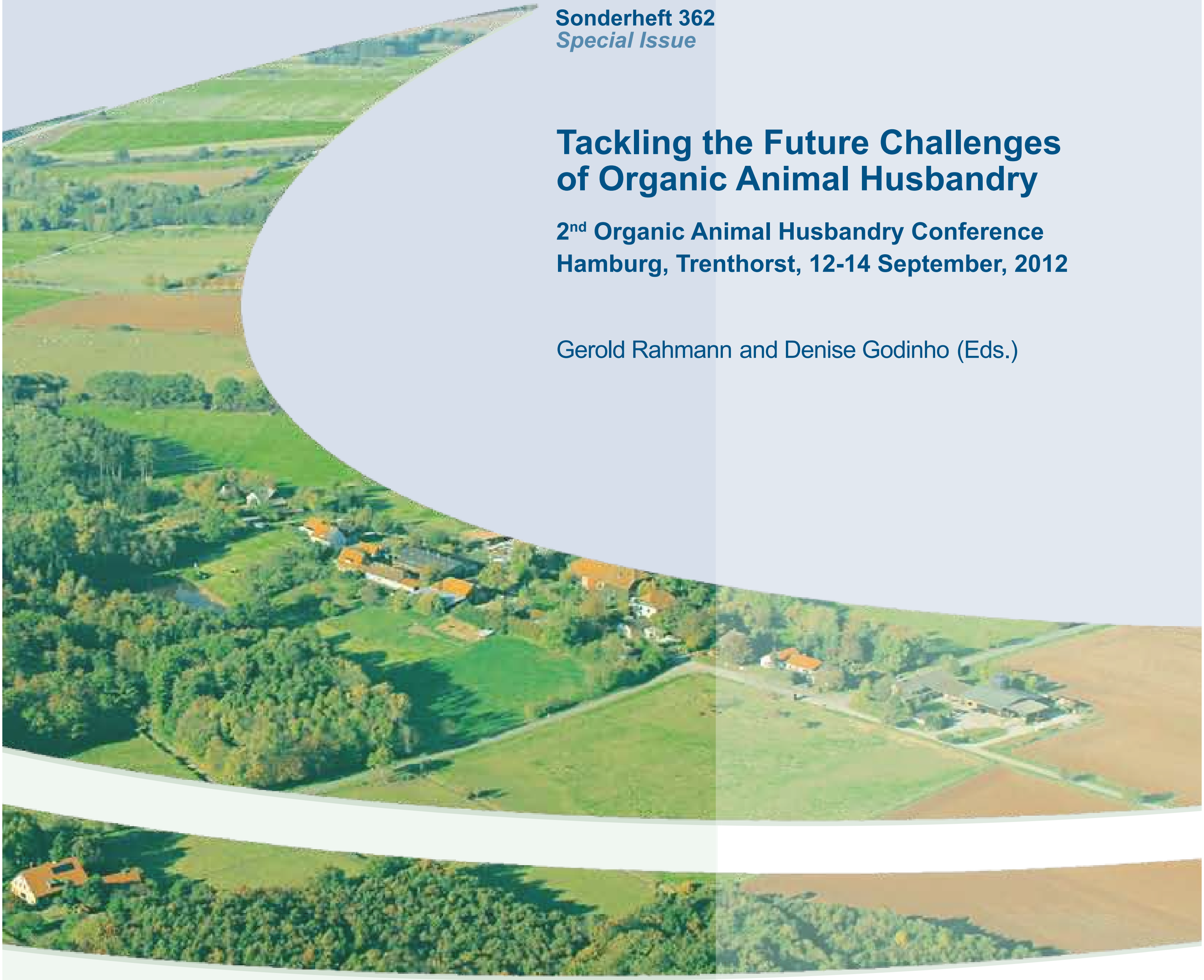

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