Estimating greenhouse gas and ammonia emissions of dairy farms participating in the CCCfarming project

Project: CCCfarming

Deliverable Work package 1.4 'Implementation of NPC tools'

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Summary

The use of accounting tools for estimating greenhouse gas (GHG) and ammonia (NH_3) emissions from dairy farms is of increasing importance for monitoring environmental performance and effects of mitigation strategies. In the EU project Climate Care Cattle Farming Systems ('CCCfarming') three GHG accounting tools were used for estimating environmental impacts of dairy farms participating in the project: a tool from the Netherlands (ANCA), United Kingdom (Agrecalc), and France (CAP'2ER). The aim of this report was to estimate baseline GHG and NH_3 emissions of dairy farms participating in the CCCfarming project, using the three accounting tools.

Activity data was collected from 54 dairy farms in 8 countries participating in the CCCfarming project. Farms were not randomly selected, but selected based on predefined criteria for project participation (hence, results were not representative of the national dairy farm population of the countries). A common data recording sheet was developed for the 3 tools to ensure similarity of activity data used in the tools. Local researchers were trained by the project and collected activity data for the reference year 2020 in a farm visit between January and March 2021. After the farm visit the activity data was entered in the tools by the local researcher (ANCA and AgreCalc) or by the research institute (CAP'2ER). All tools used a life cycle assessment (LCA) approach for calculation of GHG emission intensity. Ammonia emissions were calculated in the ANCA tool only.

GHG emission intensity ranged from 1.12-2.24 kg CO_2-eq/kg FPCM among farms based on ANCA, 0.70-3.39 kg CO_2-eq/kg FPCM based on Agrecalc, and 0.79-3.93 kg CO_2-eq/L milk based on CAP'2ER. On average across countries, NH_3 emissions ranged from 22 to 90 kg NH_3 per ha. The three tools showed large differences in calculated GHG emission per farm, although rankings showed a reasonably strong correlation. Besides differences in farm characteristics and management, differences in outcomes were expected to be due to methodological differences between models, background data, and quality and completeness of the activity data. In particular, it is stressed that ignoring of changes in feed stocks had a large influence on tool outcomes. Further research is recommended for better understanding of methodological differences between models, while further harmonization of background data should reduce differences in outcomes between tools.

Introduction

The use of accounting tools for estimating greenhouse gas (GHG) and ammonia (NH_3) emissions from dairy farms is of increasing importance for monitoring environmental performance and identifying effective mitigation strategies.

In the EU project Climate Care Cattle Farming Systems ('CCCfarming') three GHG accounting tools were used for the estimation of environmental impacts of dairy farms participating in the project:

- **ANCA**: the Annual Nutrient Cycling Assessment tool, developed in the Netherlands for dairy production systems (link to website; 'KringloopWijzer' in Dutch). The ANCA tool is used for farm-specific assessment of nutrient cycles in dairy farms and emissions to air, water and soil, including: N and P surplus, NH_3 emission, and GHG emissions. The tool is mandatory for nearly all Dutch dairy farms (industry requirement). Besides its use as management tool, ANCA is increasingly used for rewarding farm environmental performance by the Dutch dairy industry. The input data of Dutch dairy farms, therefore, needs to be of high quality, complete, standardized and verifiable; and is collectively organized and stored in a central database ('Central Database KringloopWijzer').
- **Agrecalc**: a carbon footprint tool developed in the United Kingdom for agricultural production systems (www.agrecalc.com) designed to identify the main sources of GHG emissions and benchmark key performance indicators. Agrecalc is a tool for a variety of farming systems including livestock (pigs, sheep, dairy and beef) and mixed farming with a focus on farm efficiency. Agecalc calculates the final C footprint of the farm based on three main GHG emissions CO_2, produced by burning fossil fuels; CH_4, produced as a natural by-product of animal digestion and; N_2O which is released from soils following the application of nitrogen fertiliser (manufactured and organic) and soil disturbance.
- **CAP'2ER**: The objective of the tool "Automated Calculation of Environmental Performances for Responsible Operations" ("Calcul Automatisé des Performances Environnementales pour des Exploitations Responsables") developed in France is to provide advisors and farmers with a multicriteria environmental assessment tool at the farm, unit and product levels (https://cap2er.eu/). Ruminants and non-ruminants production sectors can be evaluated. Two levels of calculations are available. The first one has been used in the present assessments.

The three tools were applied in dairy farms participating in this project to estimate farm-specific baseline GHG emissions. The baseline outcomes were then used by partners to draft farm plans for GHG mitigation, taking into account potential trade-offs/synergies with NH_3 emissions.

The aim of this report was to estimate baseline GHG and NH_3 emissions of dairy farms participating in the CCCfarming project, based on the three accounting tools.

Materials and methods

Farm sample

Activity data was collected for the reference year 2020 (1 jan – 31 dec) on 4 to 8 dairy farms per country (Table 1). Farms were selected for participation in the CCCfarming project based on the following criteria:

- Representing a country-wide variety of housing systems, management practices, breeds, feeding, land use, etc. With regard to housing systems, at least cubicle housing and bedded pack/freewalk or deep litter should be present.
- Two farms are 'representative' farms, i.e. representing the locally most common system(s).
- Six farms have innovative features.
- Farmer is willing to share data and ideas, and is motivated to cooperate.

In total 54 farms were entered in at least one tool. Six out of the 8 partner countries in the project chose to analyze their farms with all tools, whereas the German partner chose to use AgreCalc only. The French partner chose to have only 2 French farms analyzed, with AgreCalc and CAP'2ER only (Table 1). Partner country representatives indicated which farms could be considered 'representative farms' and 'farms with innovative features' (Table 1; more details are provided in the Results section).

Seven farms were excluded from further analysis (see explanation in footnote below Table 1), mostly because of outliers in the results. Outliers in ANCA results are further discussed in the Discussion section.

Table 1. Number of farms in the study per tool and farm ID's of representative farms and farms with innovative features.

	ANCA[1]	Agrecalc[2]	CAP'2ER	Representative	Innovative features
France (FR)	-	2	2	FR1, FR3, FR4, FR8	FR2, FR5, FR6, FR7
Germany (GE)	-	12	-	DE2	DE3, DE4, DE7
Italy (IT)	5	5	5	IT2, IT5	IT1, IT3
Latvia (LV)	8	8	8	(N/A)	LV5, LV7, LV8
Lithuania (LT)	4	4	4	(N/A)	LT2
Netherlands (NL)	7	7	1	NL1, NL3, NL5	NL2, NL4, NL6, NL7
Poland (PL)	8	8	8	PL1, PL5	PL6
Scotland (UK)	8	8	8	UK2, UK3	UK6

[1] Three of the 8 Scottish farms were excluded from further analysis due to outliers in ANCA results: UK1 (extremely high crude protein level feed ration of 287 g/kg DM), UK4 (extremely high N application rate of 888 kg N/ha) and UK7 (extremely high GHG emission intensity due to a very low milk yield (2089 kg/cow; concerns a very small herd only milked during the summer, once a day). Details of the 3 farms can be found in Annex 1.

[2] Two of the German farms and one French farm were excluded from further analysis due to outliers in Agrecalc results: GE9 (extremely high GHG EI), GE12 (no result), FR1 (negative GHG EI).

[3] One Polish farm was excluded from analysis of emissions with CAP'2ER because of a corrupt file (PL1).

Data collection

To enhance similarity of data in tools, a protocol and common data recording sheet was developed by Wageningen Livestock Research (WLR), Scotland's Rural College (SRUC) and Institute de L'Elevage (IDELE). The common data recording sheet combined the input data requirements of the three tools, consisting of 1 common data entry sheet and 1 sheet per tool with tool-specific data automatically filled (using links to the input sheet and conversion rules where needed). The common recording sheet was not used for the Dutch farms, as nearly required data was already present in ANCA reports of these farms, which could be entered directly into AgreCalc (a separate questionnaire was developed for the data that were not present on these farms).

Local researchers of the project's participating countries were first trained in multiple online sessions, including testing of the tools on 1-2 farms in 2020 in order get acquainted with tools and to assess the feasibility of applying the tools each country.

The local researchers collected the activity data for the reference year 2020 in a farm visit between January-March 2021. Data was directly entered in the recording sheets during the farm visit. The type of activity collected included:

- Herd demographics (animal categories and numbers)
- Technical performance (milk yield, fat and protein content, reproduction, growth, etc.)
- Manure management (type of housing, storage, etc.)
- Feeding and nutrition (feed ration composition, amounts and nutritional values)
- Grazing practices (animal categories, duration)
- Pasture and crop production (practices, rotation, fertilizers, etc.)
- Energy use and production

Primary farm data were preferred over secondary data. In case were not available on the farm, secondary data were used, either from literature or a farmer's or advisor's estimate.

For the Dutch dairy farms, readily available ANCA analyses were used (obligatory for Dutch farms since 2016; using the Dutch version of ANCA (Kringloopwijzer), version 2019).

Data gaps

Part of the activity data required for ANCA was not collected on (non-Dutch) farms due to budget and time limitations:

- Initial and final feed stocks (on January 1 and December 31 of the reference year, resp.)[1]
- Initial and final manure stocks
- Initial and final artificial fertilizer stocks

In ANCA, stock changes in livestock, feed, fertilizer and manure are required as model input data to calculate annual material and nutrient flows on a farm (including e.g. feed intake). For example, when livestock on the farm consume more roughage than is harvested (e.g. due to drought), stocks will decrease. When a farm does not purchase artificial fertilizer but uses the amount in stock (purchased last year), stocks will decrease. Hence, correcting for stock changes is important for the accuracy of model estimates of emissions[2]. In Dutch farms, collecting information about feed, manure and fertilizer stocks is a standard procedure for using ANCA.

In the common recording sheets, information about feed, manure and fertilizer was recorded as follows:

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[1] Data of Polish was corrected for final feed stocks

[2] This is why ANCA reports 3-y average results, flattening the influence of larges stock changes, e.g. due to extreme weather conditions such as a very dry or wet year.

- Feed: amount of feed purchased, amount (and DM%) harvested (or forage yield), amount fed to livestock, and share per type of livestock.
- Manure: type and amount of organic fertilizer applied on fields, application method, type and amount of manure imported, and type and amount exported in the reference year.
- Artificial fertilizer: type and amount applied on the field in the reference year, per forage or crop.

In ANCA, initial and final stocks were assumed to be zero for farms that lacked stock data. This may have consequences for the accuracy of the results of this study, which is further discussed in the Discussion section.

Data processing

After the farm visit the activity data was entered in tools by the local researcher:

- For Agrecalc, data was entered in an online tool http://www.agrecalc.com/;
- For ANCA, data was entered in a software programme installed by the local researchers (http://webapplicaties.wur.nl/software/ancadairy);
- For CAP'2ER, local researchers sent the data to IDELE researchers for modelling in CAP'2ER.

The quality of activity data from farms was verified by the local researchers. For data entry in Agrecalc and ANCA local researchers were supported remotely by WLR and SRUC. Also, the ANCA tool contained an automatic data quality screening, and the user receives a warning in case of possibly biased input or output data.

NPC tools

Tool versions used for this study were ANCA version 2019.19-plus[3], the Agrecalc version using the default coefficients for 2021, and CAP'2ER Level 1 Version 11.01.04 - 07/2023.

Calculation of GHG emissions

For calculation of GHG emissions all tools use a life cycle assessment (LCA) approach with cradle-to-farm gate system boundaries, based on IPCC guidelines (2006). In an LCA, GHG emissions are calculated from all processes in the dairy production chain up, including so-called 'upstream' emissions from production and transport of inputs to the farm (e.g. feed, fuel, fertilizers) and 'on-farm' emissions due to activities taking place on the farm. The tools in this study do not include 'downstream emissions', i.e. emissions that take place after products left the farm (milk transport, milk processing, etc.). Types of greenhouse gases included in the LCA are methane (CH4), nitrous oxide (N2O) and carbon dioxide (CO_2). In order to sum the different gases, amounts are expressed in the same metric 'CO_2 equivalents' (CO_2-eq) on the basis of the global-warming potential (GWP) of gases, to an equivalent amount of CO_2.

Calculation rules for the LCA used in the three tools are largely similar as they are primarily based on IPCC guidelines (2006). Part of the calculation rules and emission factors differ between tools because they rely on different standards (e.g. EMEP 2013 in CAP'2ER, Product Environmental Category Rules (PEFCR) in ANCA) and sometimes national emission factors are used.

[3] Calculation rules of ANCA version 2019.19-plus are similar to calculation rules of the Kringloopwijzer version 2019.12, but the interface of the software was adjusted to accommodate international application. In addition, the option of an outdoor manure storage with no cover was added, with an emission factor for NH_3 based on Van Bruggen et al. 2022).

Main characteristics of the accounting tools are shown in Table 2. However a comprehensive analysis was beyond the scope of the present study, some important differences are found between the models:

- The global warming potential (GWP) characterization factor used for methane in ANCA differs from CAP'2ER and Agrecalc, distinguishing biogenic methane (34 kg CO_2) and fossil methane (36.75 kg CO_2; PEFCR, 2018).
- Enteric methane emissions in Agrecalc are calculated using the Tier 2 methodology, in which the gross energy intake of animals is calculated and a fixed percentage of the gross energy intake is assumed to be lost as methane (IPCC, 2006). In ANCA and CAP'2ER the Tier 3 methodology for calculating enteric methane emissions is used (Bannink et al., 2018; Šebek et al., 2020), in which not only the level of feed intake but also the effect of specific feed ingredients and feed ration composition on methane emission is included in the equation (see calculation rules and emission factor per feed ingredient in Šebek et al., 2020).
- For N_2O emissions from soils, all tools use the Tier 1 methodology (IPCC, 2006), which assumes the N_2O emissions from the soil is a standard fraction of the N input to soils. In ANCA, some of the IPCC emission factors were replaced by specific Dutch emission factors for land use and soil type based on Velthof & Mosquera (2011).
- The feed database used in CAP'2ER differs from ANCA and Agrecalc, and an older version of the FeedPrint database was used in Agrecalc than in ANCA (2015 vs. 2020). In ANCA, following PEFCR guidelines, emissions from land use change are based on the PAS2050:2011 standard (BSI 2011, 2012).

There are also similarities, e.g. system boundaries. Further details of the calculation methods used in the tools can be found in:

- ANCA: https://edepot.wur.nl/533905 (De Vries et al., 2019);
- AgreCalc: https://www.agrecalc.com/home/about/information-on-ipcc-methodologies/ ;
- CAP'2ER: https://idele.fr/detail-article/cap2er-guide-simplifie-de-la-methodologie-devaluation-environnementale-dune-exploitation-agricole .

Table 2. Methods used for calculation of GHG emissions in Agrecalc, ANCA and CAP'2ER.

	Standards	System boundaries	GWP characterization (CO_2:CH_4:N_2O)	Allocation method milk/LW	Feed database used	Tier level
Agrecalc	IPCC 2006 PAS2050:2011	Cradle-farm gate	1:25:298	Economic	FeedPrint v2015	Enteric: Tier 2 Soil: Tier 1
CAP'2ER	IPCC 2006 EMEP 2013	Cradle-farm gate	1:25:298	Biophysical[1]	Ecoalim V7/ Agribalyse 3.0	Enteric: Tier 3 Soil: Tier 1
ANCA	IPCC 2006 PAS2050:2011 PEFCR 2018	Cradle-farm gate	1:34/36.75:298	Biophysical[2]	GFLI/ FeedPrint v2020	Enteric: Tier 3 Soil: Tier 1/ Tier 2

[1] Equation based on IPCC (2006): AFmilk = [NElact + (NEmaintenance + NEactivity)x(1-(NEgestation/NElact))] / (NEtotal -NEgrowth)

[2] Equation based on IDF (2015): AFmilk = 1 − 6.04 ∗ Mmeat / Mmilk

Calculation of NH_3 emissions

Ammonia (NH_3) emissions were calculated by ANCA only (not by Agrecalc and CAP'2ER). The calculation methods used in ANCA are summarized below (details of methods used in ANCA can be found in De Vries et al., 2020).

In ANCA farm-specific NH_3 emission is calculated released from stables, manure storages, feces and urine excreted during grazing, machine-spreading of animal manure on grassland and arable land, some types of synthetic fertilizers, and some other sources (e.g. standing, grazed and harvested crops). This is done in two steps: 1) calculation of the amount of N excreted in manure by the dairy herd, 2) calculation of NH_3 emissions from housing and manure storage, and from manure application. As step 1 is also used for calculation of soil N and P surplus (see next paragraph), the method for calculating P excretion is also included in the explanation below.

Step 1 - To calculate the farm-specific amount of N and P excreted in manure by the dairy cattle, N and P intake of the dairy herd[4] is calculated based on N and P contents of the feed ration fed to the dairy herd, with the assumed level of feed intake estimated based on net energy (VEM) requirement of herd.

The intake per feed ingredient is estimated as follows:

- For purchased feed ingredients (concentrates, milk products, wet by-products, other roughage), intake is calculated as the amount purchased minus a change in stock. Information is available from suppliers' invoices.
- For homegrown roughage, estimating intake of roughage (per type) is more difficult especially because it lacks reliable data on the share of fresh pasture grass in the roughage supply. First, total energy (VEM) intake from all roughage (maize silage, grass products, fresh grass) is estimated by deducing energy (VEM) intake from purchased feed ingredients (see above) from the total calculated energy (VEM) intake of the herd (corrected for feed losses). In a next step energy (VEM) intake is allocated to maize silage, grass products and fresh grass based on the ratio of the calculated fresh grass intake (based on grazing hours) and stock changes[5] of grassland products and maize silage products.

Step 2 – Ammonia emissions are calculated (based on the National Emission Model for Ammonia (NEMA); Van Bruggen et al., 2017/2018) based on farm-specific N flows in manure, i.e.: herd excretion, housing (barn floor and manure storage under the barn), storage outside the barn and manure application. The share of NH_3-N in the total amount of nitrogen in manure is the % total ammoniacal nitrogen (TAN). In each step in the N flow, emission factors (EF) are used to calculate how much TAN volatilizes as ammonia (NH_3 -N) and other gaseous N compounds.

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[4] Excretion by the dairy herd (dairy cows and young stock) is calculated on a farm-specific basis, whereas the excretion of 'other ruminants' (breeding bulls, beef cattle, sheep, etc.) is calculated using standard excretion values (N and P excretions in manure from non-ruminants are not calculated).

[5] Because of time and budget limitations, non-Dutch farms in this project did not collect data of initial and final stock volumes (feed, organic manure, artificial fertilizer). See explanation in the paragraph 'data collection' and discussion about implications of this limitation in the discussion section.

Results ANCA

Farms characteristics and technical performance

Farm characteristics

Farm characteristics are shown in Table 3[6,7] (country averages and ranges; details per farm can be found in Annex 1). Average herd size was largest in the Polish and Scottish farms. For Poland one very large farm was included (PL4, 1437 cows) but also smaller farms (<100). In Scotland two very large farms were included (UK6 and UK8; 1025 and 905 cows, resp.) as well as 4 other farms with more than 200 cows. Less variation in herd size was present in farms in Latvia, Lithuania, Italy and the Netherlands, with herd size ranging from 35 to 218 dairy cows.

Average area of agricultural land was largest in Polish farms, with four farms occupying more than 800 ha, but also small Polish farms (<50 ha) are included. Average land area was smaller in farms in Latvia, Lithuania, and Scotland (between 76 and 732 ha), and smallest in Italy and the Netherlands (<100 ha). Most farms in Lithuania were mixed arable-dairy farms (3 out of 4 farms). In Latvia and Poland some farms were mixed farms (3 out of 8, and 2 out of 8 farms, resp.). In Italy, the Netherlands and Scotland most farms were specialist dairy farms. In one Polish farm (PL7) a significant number of beef cattle and sheep were kept besides dairy cattle.

In most countries farms concerned slurry-based systems, except for Poland, Lithuania and Latvia; in these countries farms were included producing solid manure. In the Netherlands and Scotland most farms were grazed farms, whereas in Poland and Italy most were zero-grazing farms.

Farms were not randomly selected in this study, but were selected based on specific features. Therefore, results are not representative of the country average farm population. Below is a short description of some features on the farms (more details can be found in the report 'CCCfarming: study farms overview'):

- French farms: FR2 has a deep straw area. FR7 is a compost bedded-pack barn. FR5 and FR6 have waterbed mattresses.
- German farms: DE3, DE4 and DE7 are compost bedded-pack barns. DE1, DE5, DE6 and DE7 are organic farms (DE5 with deep straw). DE2 is a conventional farm with a cow shower, feed robot and rubber floor in the walking area.
- Italian farms: IT1 and IT3 are compost bedded-pack barns. IT1, IT2 and IT5 use milking robots. IT2 transfers slurry to a nearby farm with a biogas plant. IT4, IT5 and IT6 apply manure separation.
- Latvian farms: LV5, LV7 and LV8 have a robotic milking system. Farms LV7 and LV8 have feed robots. Four farms have tie stalls and 4 farms have cubicle housing.
- Lithuanian farms: LT1 and LT2 are loose housing systems (cubicles), LT3 and LT4 are tie-stalls. LT2 applies manure separation.
- Dutch farms: NL2 and NL7 are compost bedded-back barns. NL4 has a freewalk system with a permeable artificial floor separating feces and urine. NL6 applies manure separation and thermal oxidation of methane (flaming). NL1 is the experimental farm of WUR.

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[6] German farms are not included in the general description because they were not modelled in ANCA.
[7] It should be noted that farms were not randomly selected in this study. Hence, results are not representative of the average dairy farm population of countries.

- Polish farms: PL6 is a bedded-pack farm. PL2 has the highest average milk yield in Poland (15 464 kg in 2020). PL3 is a very modern robotic barn. PL4 is a large industrial farm with 1200 cows in one barn, and slurry used for biogas plant. PL7 is the experimental farm of the Poznan University of Life Sciences, with a strong focus on ecology. PL8 is an ecological, versatile and modern farm.
- Scottish farms: UK1 cattle are housed year round with pedigree selection line for milk yield, butterfat and protein. UK3 uses rumen monitors. UK5 is a low input organic farm with dairy product processing and selling direct to the public. UK6 applies paddock grazing (New Zealand system). UK7 has cheese making from rare breed cows. UK8 has beef calf production.

Milk production

Average milk production per cow was highest in farms in Italy (10570 kg/cow), the Netherlands (9285) and Poland (9241). Average milk production per hectare was highest in Italian farms, followed by Dutch and Scottish farms (see Figure 1). Three farms in Poland had a relatively high milk production per ha, comparable to the Dutch average.

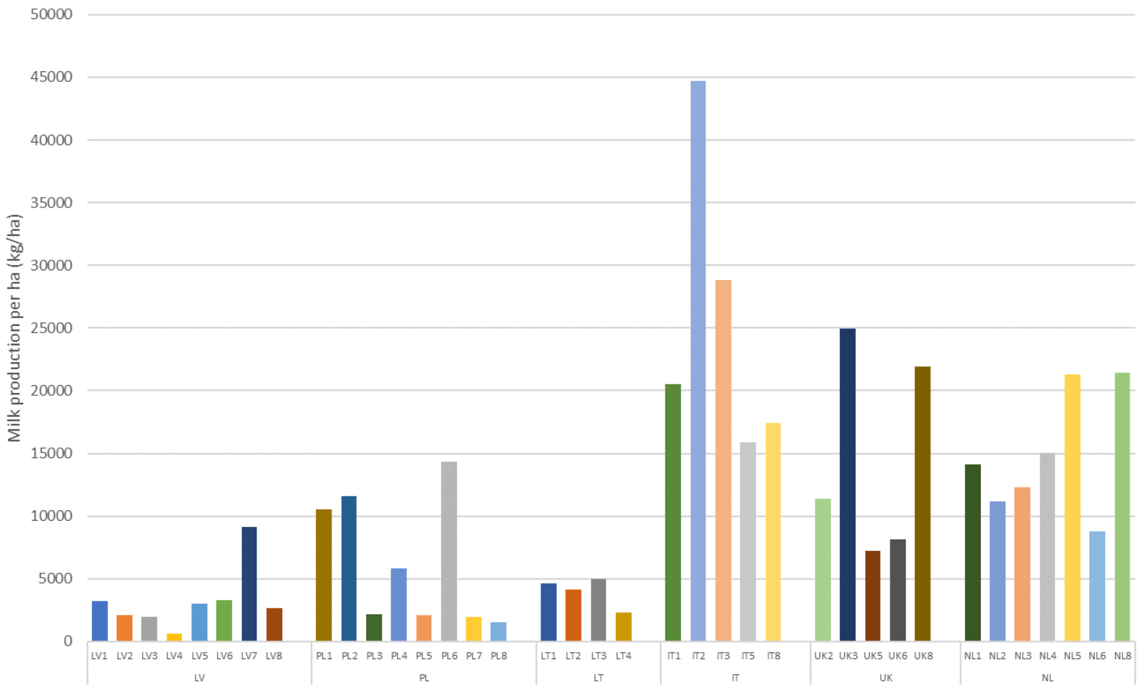

Figure 1. Milk production per hectare (kg/ha).

Feed ration

Feed ration composition differed substantially among countries. Rations on farms in Scotland, the Netherlands, Lithuania and Latvia were largely grass-based (fresh or conserved; Figure 2 and Table 3). Most Scottish and Dutch farms showed a relatively large part of fresh grazed grass. In Poland and Italy a relatively large share of the ration is 'other forage', wet by-products, and concentrate feeds. For example, in Poland other forage and by-products fed on farms included alfalfa silage, wholecrop cereals, straw (wheat, rye, triticale, barley), beet pulp, brewers grains, and sugar beet. In Italy other forage and by-products include e.g. lucerne hay, whole crop cereals, and red clover silage.

Average calculated crude protein in the feed ration was highest in farms in Scotland, the Netherlands (both 164 g/kg DM) and Italy (161 g), and lowest in Lithuanian farms (142 g). Except for the Dutch farms, the estimated crude protein content of the rations may be biased, however, due to lacking activity data (initial and feed stocks were not registered). This is further discussed in the Discussion section.

With regard to feed protein import, average nitrogen from own land (% of ration) is lowest in Italy, Scotland, Poland and the Netherlands, which implies more feed protein is imported to these farms. There is a large variation within countries, however, and it should be re-emphasized that farms are not representative of the country average farm population. Also the source of protein is unknown (e.g. regional or overseas).

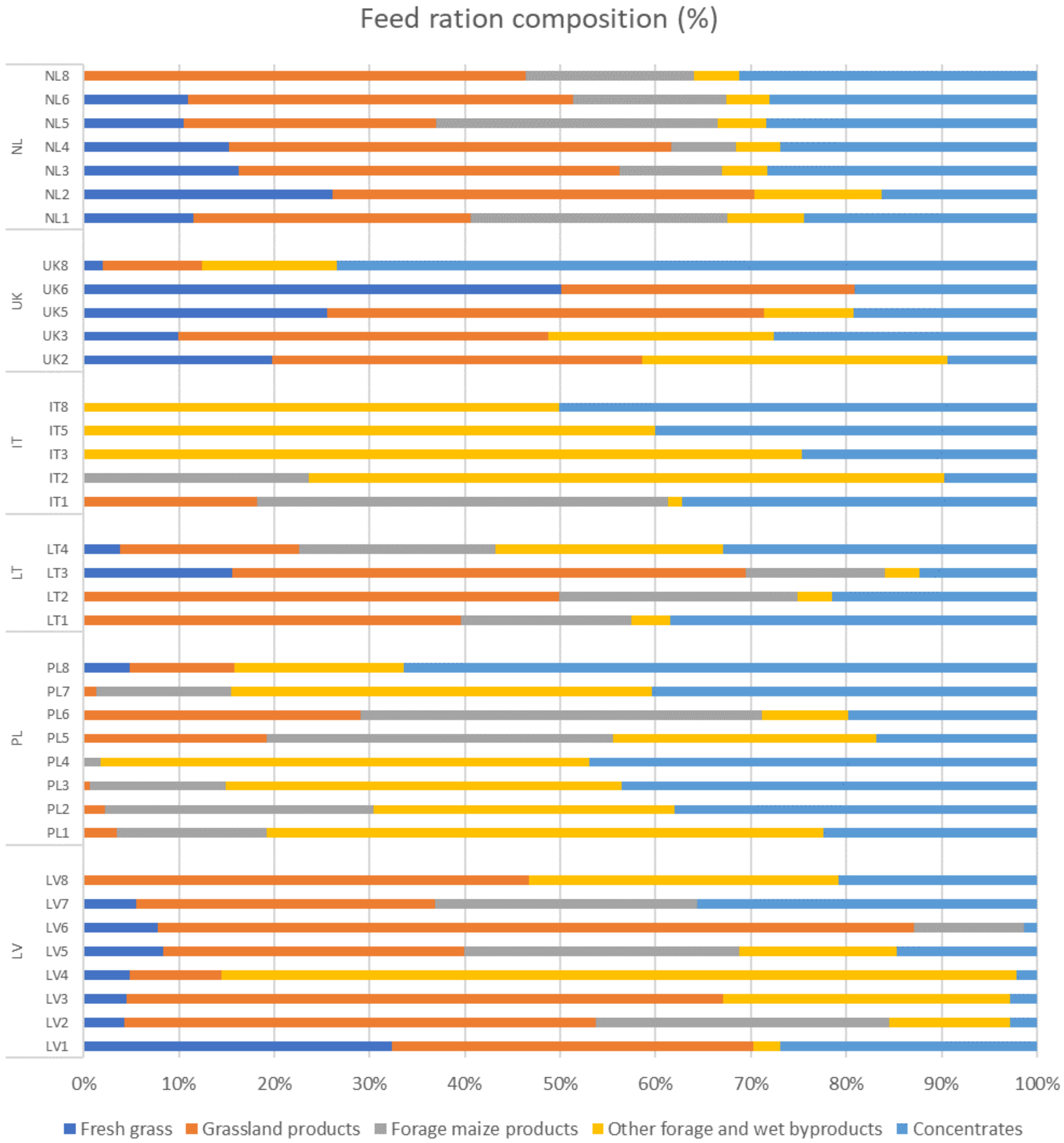

Figure 2. Feed ration composition (%) per farm.

Table 3. General farm characteristics (average (min, max) per country).

	Latvia (n=8)		*Poland (n=8)*		*Lithuania (n=4)*		*Italy (n=4)*		*Scotland (n=5)*		*Netherlands (n=7)*	
Herd size (n heads)												
Cows	88	(35, 130)	307	(10, 1437)	126	(38, 218)	125	(80, 210)	578	(143,1025)	113	(70, 211)
Young stock	75	(44, 112)	284	(5, 1259)	129	(32, 270)	104	(70, 190)	389	(80,700)	50	(16, 79)
YS per 10 cows	9	(7, 13)	10	(5, 14)	10	(7, 12)	8	(6, 10)	7	(5,8)	5	(1, 7)
Agricultural area (ha)												
Total area	324	(116, 732)	749	(28, 2428)	319	(76, 685)	53	(42, 61)	341	(150,660)	71	(55, 95)
Grassland	162	(98, 273)	137	(6, 637)	101	(51, 199)	5	(0, 13)	284	(118,660)	58	(38, 82)
Forage maize	12	(0, 35)	114	(0, 430)	41	(9, 97)	17	(0, 48)	11	(0,55)	9	(0, 17)
Arable land	150	(0, 518)	498	(15, 1878)	177	(17, 390)	31	(9, 54)	45	(0,120)	3	(0, 10)
Percentage slurry (vs solid)	51	(0, 87)	34	(7, 88)	66	(4, 96)	67	(37, 93)	95	(92,97)	86	(31, 100)
Grazing days per year (cows)	68	(0, 180)	23	(0, 180)	90	(0, 180)	40	(0, 200)	109	(0,270)	134	(0, 210)
Milk production												
per farm (tons)	754	(377, 1280)	2884	(59, 14147)	1048	(376, 1559)	1350	(858, 2539)	4877	(1086,9230)	1064	(587, 2030)
per ha (kg)	3252	(591, 9161)	6268	(1567, 14343)	4006	(2275, 4982)	25471	(15893, 44696)	14717	(7220,24934)	14877	(8754, 21469)
per cow (kg)	8779	(6077, 11965)	9241	(5205, 12789)	8813	(7152, 9913)	10570	(8900, 12089)	8789	(5230,11008)	9285	(7652, 10750)
Fat content (%)	4.0	(3.5, 4.5)	4.0	(3.7, 4.5)	4.5	(3.9, 5.0)	3.9	(3.6, 4.3)	4.4	(4.2,5.0)	4.4	(4.2, 4.7)
Protein content (%)	3.4	(3.3, 3.5)	3.4	(3.2, 3.7)	3.4	(3.4, 3.4)	3.5	(3.4, 3.6)	3.2	(2.0,4.1)	3.6	(3.3, 3.7)
Feed ration composition (%)												
Fresh grass	8	(0, 32)	1	(0, 5)	5	(0, 16)	0	(0, 0)	21	(2,50)	13	(0, 26)
Grass products	44	(10, 79)	8	(0, 29)	41	(19, 54)	4	(0, 18)	33	(10,46)	39	(26, 46)
Forage maize	12	(0, 31)	19	(0, 42)	20	(15, 25)	13	(0, 43)	0	(0,0)	15	(0, 29)
Other forage, wet byproducts	22	(0, 83)	35	(9, 58)	9	(4, 24)	51	(1, 75)	16	(0,32)	6	(5, 13)
Concentrates	13	(1, 36)	37	(17, 66)	26	(12, 38)	32	(10, 50)	30	(9,73)	26	(16, 31)
Dairy products	0	(0, 0)	0	(0, 0)	0	(0, 0)	0	(0, 1)	0	(0,0)	0	(0, 0)

GHG emissions

Greenhouse gas emission intensity from milk production is shown in Figure 3. On average, GHG emission intensity for milk production was lowest for farms in the Netherlands (1182 g CO_2-eq/kg FPCM), and highest in farms in Latvia (1658 g) and Poland (1575 g). The fraction of GHG emissions allocated to milk varied between 61 and 99%, and this fraction was not associated with the emission intensity. The high allocation factor for milk in some farms was due to little or no culling, in some cases due to herd expansion. Relatively little variation in carbon footprint is shown among farms in the Netherlands, Latvia and Lithuania compared to other countries.

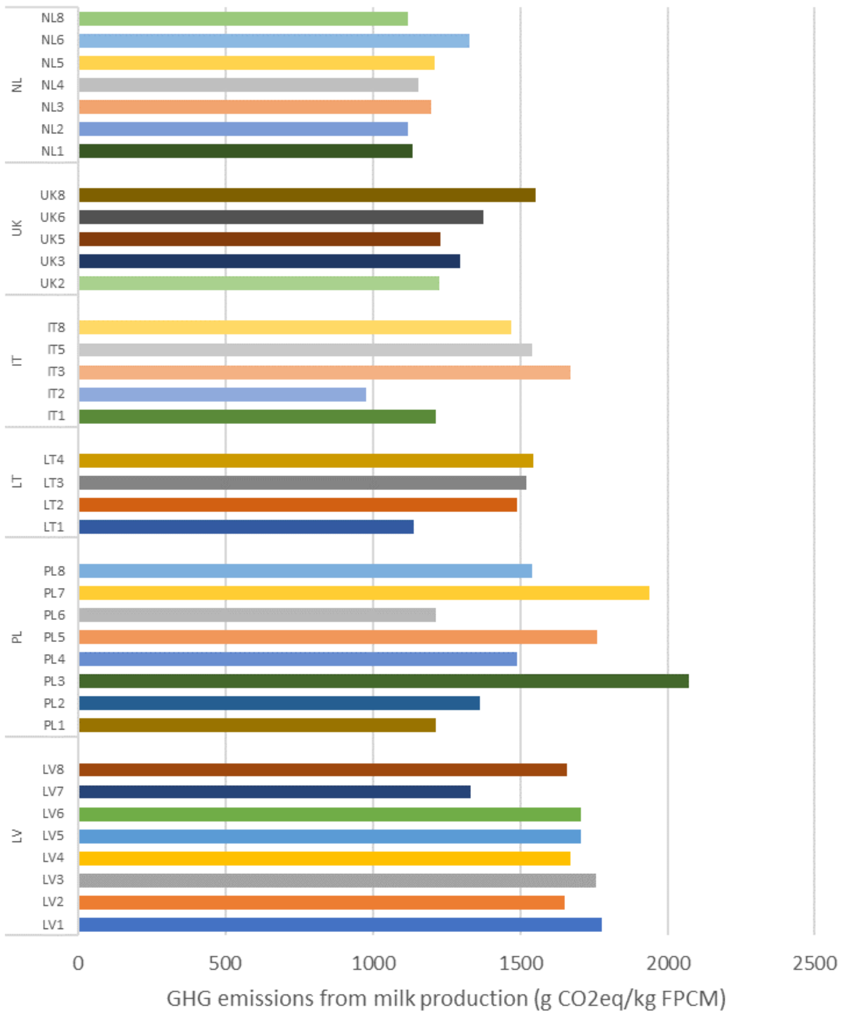

Figure 3. Greenhouse gas emission intensity from milk production per farm, based on ANCA calculation (g CO_2 equivalents per kg fat and protein corrected milk (FPCM)).

Sources of GHG emissions are shown in Figure 4. In most farms methane from enteric fermentation was the largest source of GHG. In some farms, feed production (LV5, PL5, PL7) or imports to the farm was the largest source (PL2, PL3, IT3, UK3, UK8). On average across all farms, emissions from enteric fermentation contributed 39% to total emissions, farm inputs 27%, feed production 16%, stable and manure storage 10%, and energy use 8%. Average GHG emissions (per kg FPCM) from stable and manure storage were relatively high in Italy, likely due to the large share of zero-grazing farms (larger amounts of manure stored). GHG emissions from farm inputs were relatively low in Latvian and

Lithuanian farms, whereas emissions from feed production and energy use were relatively high on various farms in Latvia.

Farms with the highest GHG emission intensity are PL3 (2073 g CO_2-eq/kg FPCM) and PL7 (1939 g; Figure 3). GHG emissions from imports to the farm are relatively high in PL3 (859 g CO_2-eq/kg FPCM; Figure 4). In PL7, emissions from feed production are relatively high (656 g), as well as emissions from imports to the farm (542 g).

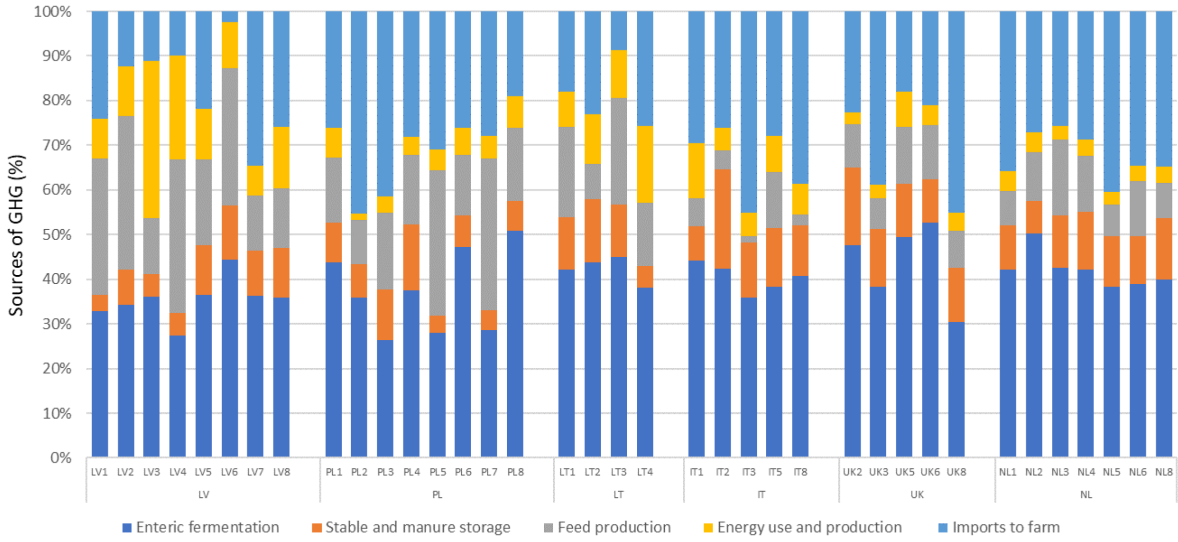

Figure 4. Sources of greenhouse gas emissions per farm, based on ANCA calculation (%).

NH_3 emissions

Total NH_3 emissions per ha are shown in Figure 5. On average, total NH_3 emissions were highest for farms in Italy and Scotland (90 and 85 kg NH_3/ha), mainly caused by a few farms with very high emissions (UK3, UK8, IT3). As shown in Figure 6, both emissions from the stable/manure storage and from the field were high in UK8 and IT3. The main cause of the high NH_3 emissions in these farms is a high (calculated) crude protein content of the feed ration, ranging from 175 (IT2) to 181 g/kg DM (UK8). In UK3 especially the NH_3 emissions from the field were very high (Figure 6), due to a very high (calculated) manure application rate on grassland in this farm (518 kg N/ha). It should be noted that both the crude protein content of the diet and the application rate calculated for farms may be biased due to lacking activity data (initial and final feed and manure stocks were not registered), which can cause less accurate estimates of NH_3 emissions. This is further discussed in the Discussion section.

Average NH_3 emissions were lowest in Latvia, Lithuania and Poland (22, 30 and 36 kg NH_3/ha, resp.). Crude protein content of feed rations were relatively low in these farms (159, 142, and 153 g/kg DM, resp.). Especially in Latvia and Lithuania the amount of N applied on grassland was relatively low (134 and 208 kg N / ha, resp.).

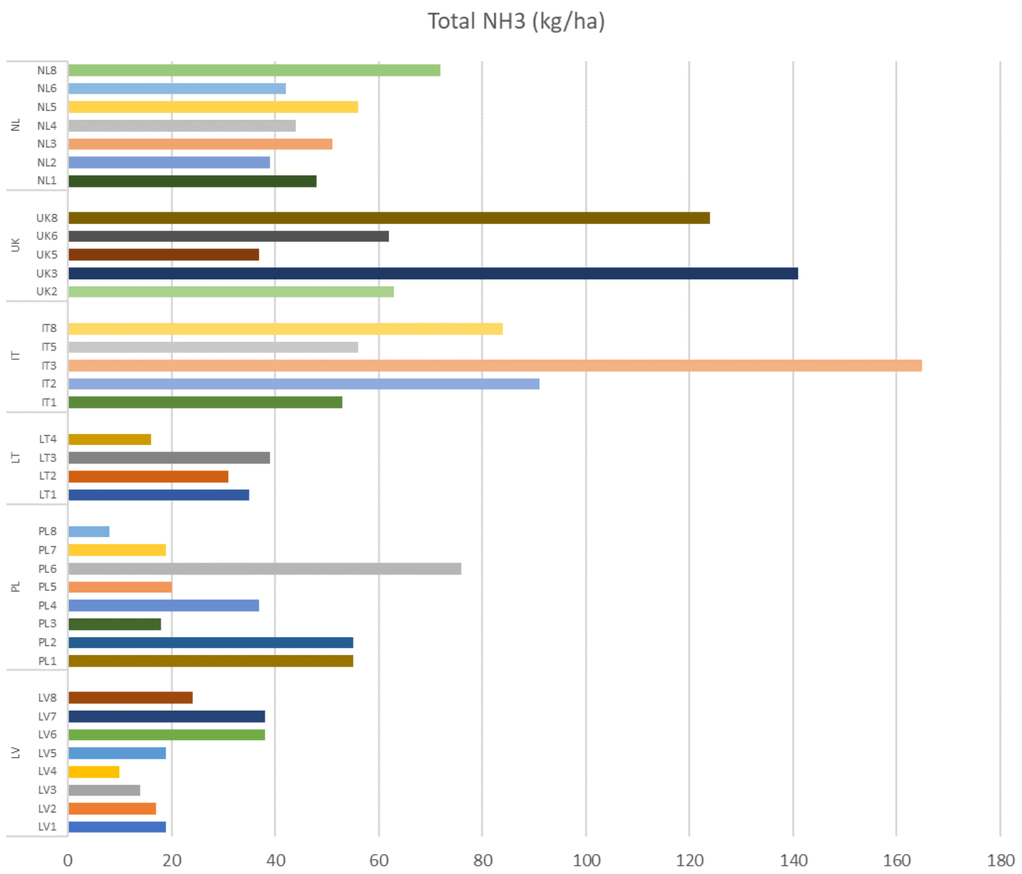

Figure 5. Total ammonia emissions (kg NH_3/ha), based on ANCA calculation.

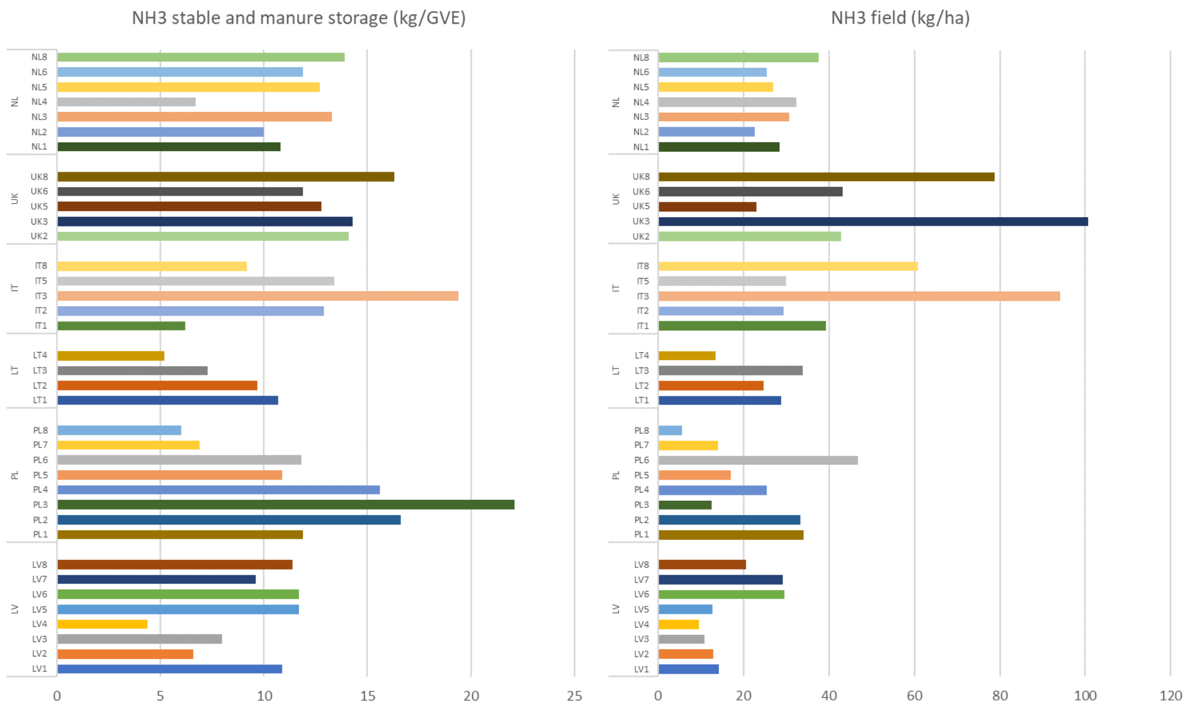

Figure 6. Ammonia emissions from a) stable and manure storage (kg NH_3/livestock unit) and b) grazing and fertilization (kg NH_3/ha), based on ANCA calculation.

Results Agrecalc

Greenhouse gas emissions from milk production are shown in Figure 7 (gross emissions, excl. soil carbon storage). On average, GHG emission intensity is lowest in the French farms (0.94 kg CO_2-eq/kg FPCM), followed by farms in the Netherlands and Germany (1.01 and 1.08 kg). Emission intensity is highest in farms in Scotland, Poland and Latvia (1.45, 1.44 and 1.41 kg). The high emission intensity of the Scottish farm UK 7 is due to a very low milk production on this farm (2089 kg/cow; Annex 1). The high emission intensity of the Polish farm PL7 is due to high CO_2 emissions from purchased inputs (Figure 8 and 9).

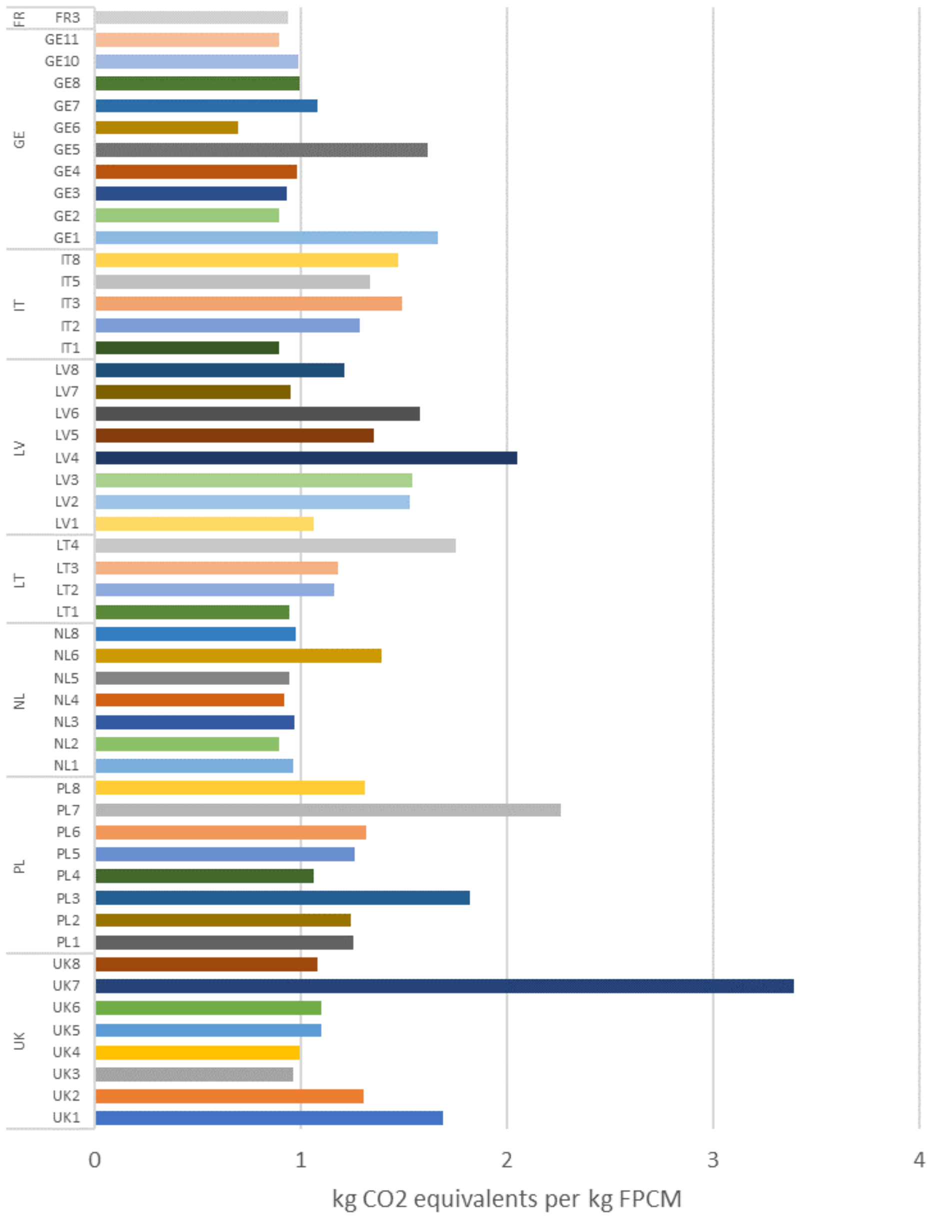

Figure 7. Greenhouse gas emissions from milk production per farm, based on Agrecalc calculation (kg CO_2 equivalents per kg fat and protein corrected milk (FPCM).

Types of GHG emissions per farm are shown in Figure 8. In nearly all farms methane (from enteric fermentation and manure) is the largest source of GHG, except for six farms (UK1, PL2, PL7, IT2, IT3, GE1), where CO_2 is the largest source. On average across all farms, methane contributed 52% to total emissions, carbon dioxide 29%, and nitrous oxide 19%. Nitrous oxide emissions were relatively high in Germany, France, Lithuania and Latvia (20-23%), and relatively low in Italy and the Netherlands (11 and 16%).

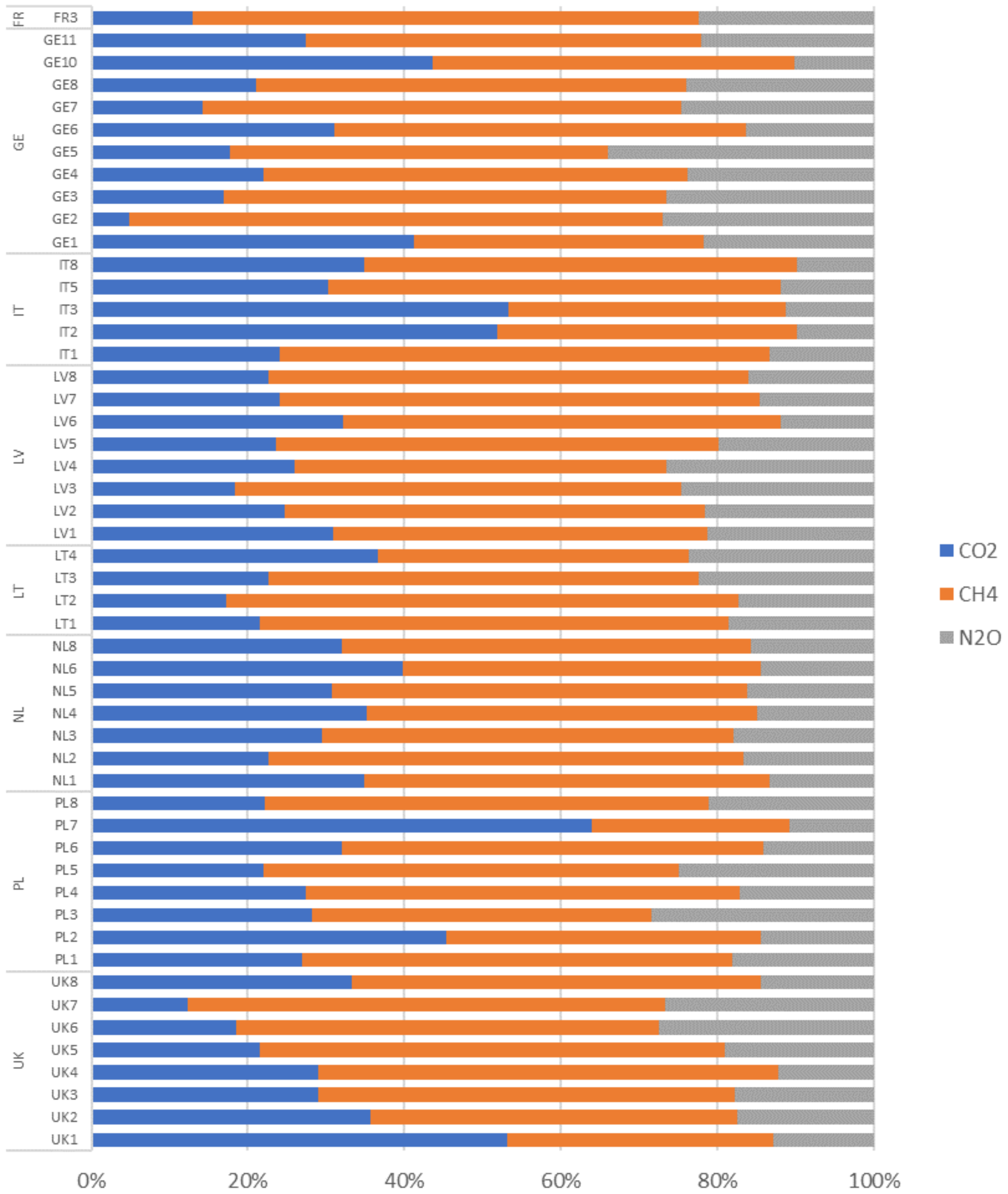

Figure 8. Types of greenhouse gas emissions per farm, based on Agrecalc calculation (%; carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) expressed in CO_2 equivalents).

Sources of GHG emissions per farm are shown in Figure X. On average across all farms, CH_4 from enteric fermentation contributed 43% to total emissions, CO_2 from purchased inputs 24%, N_2O from manure inputs to soil 12%, CH_4 from manure management 9%, and other sources 12%. CO_2 emissions from purchased inputs were relatively high in Italy, Poland and the Netherlands (35, 31 and 28%) and relatively low in Lithuania, Latvia, Germany and the French farm (15, 17, 18, and 6%). CH_4 emissions from manure management are low in most grazing farms.

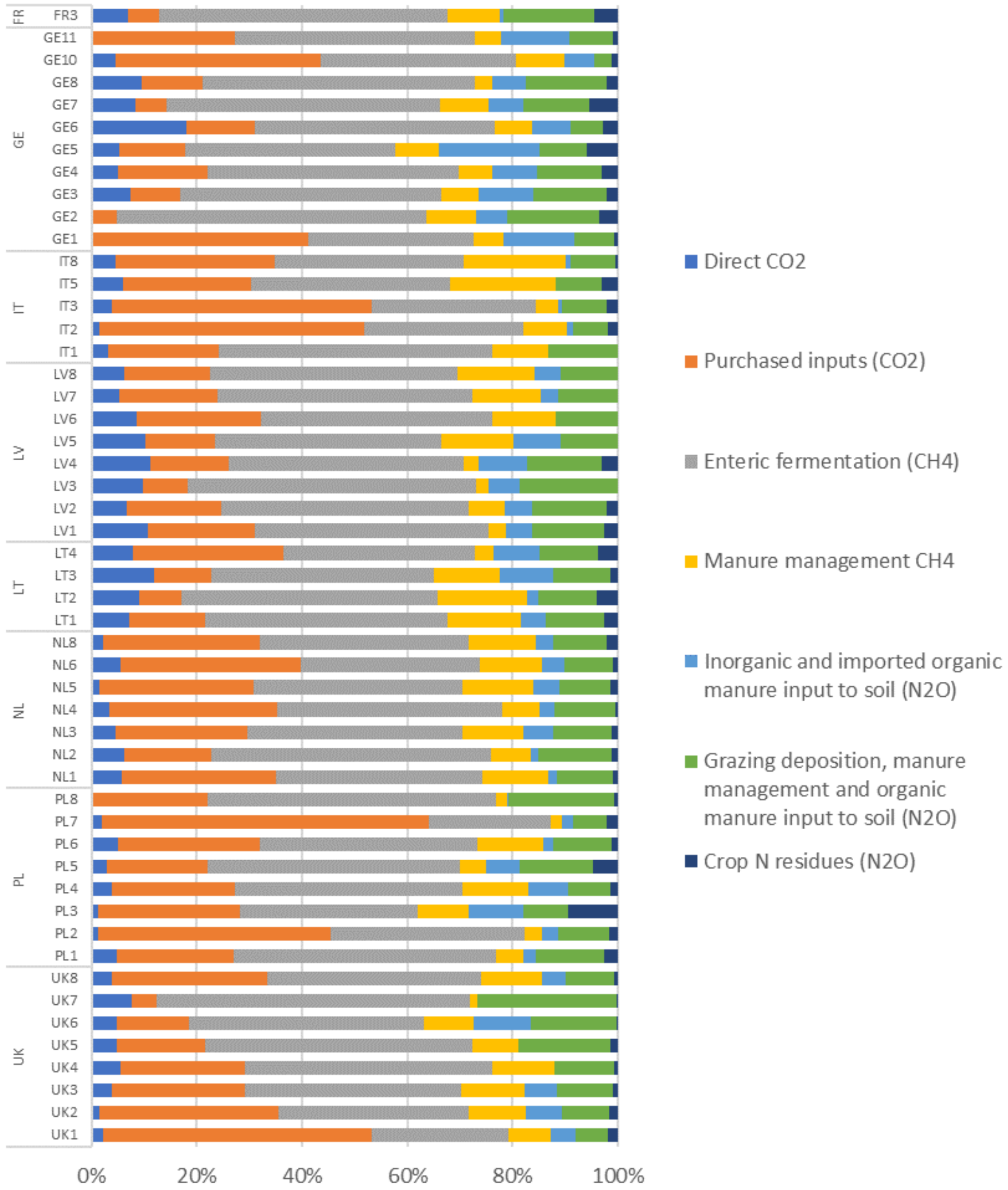

Figure 9. Sources of greenhouse gas emissions per farm, based on Agrecalc calculation (%; carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) expressed in CO_2 equivalents).

Results CAP’2ER

Greenhouse gas emissions from milk production are shown in Figure 10 (gross emissions, excl. soil carbon storage). On average, GHG emission intensity is lowest in the French and Dutch farms (0.88 and 0.91 kg CO_2-eq/kg FPCM), followed by farms in the Italy and Scotland (1.05 and 1.12 kg). Emission intensity is highest in farms in Latvia and Poland (2.46 and 1.51 kg).

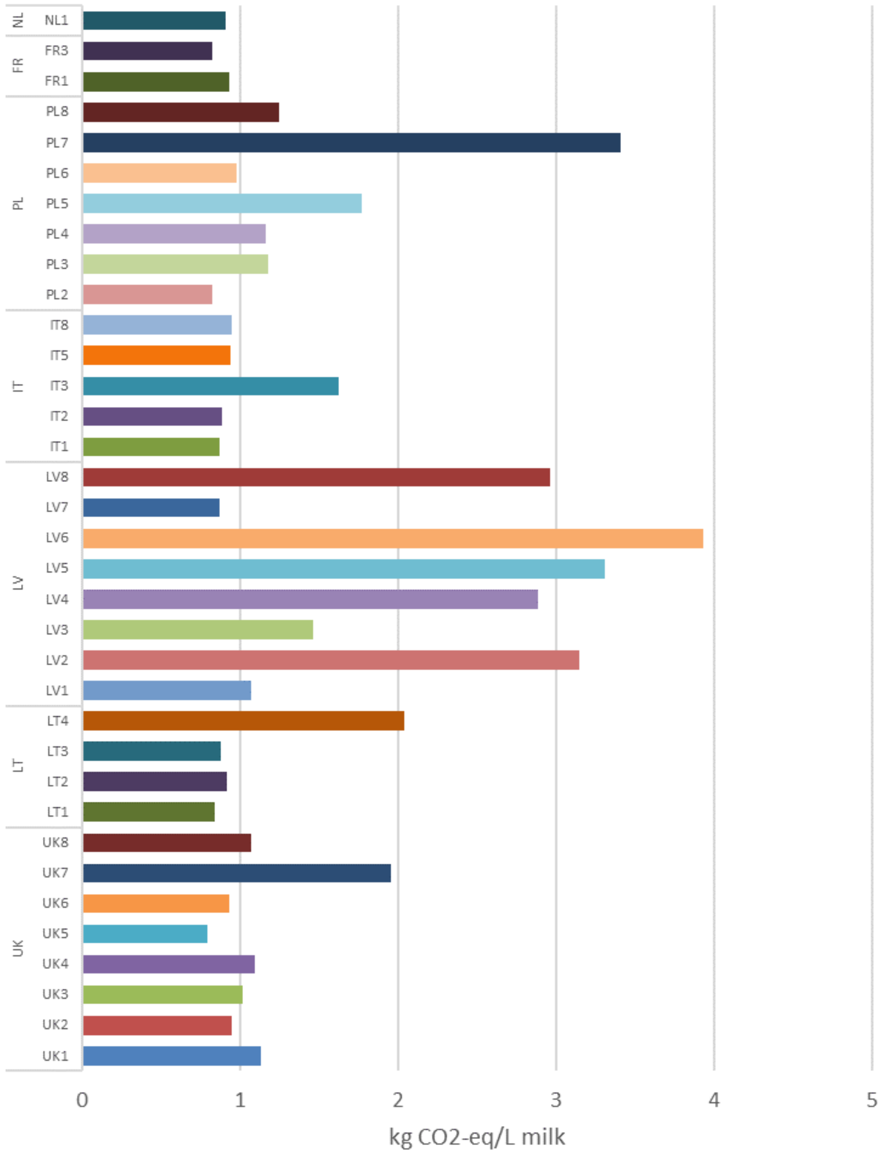

Figure 10. Greenhouse gas emissions from milk production per farm, based on CAP’2ER calculation (kg CO_2 equivalents per liter milk).

Types of GHG emissions per farm are shown in Figure 11. In nearly all farms methane (from enteric fermentation and manure) is the largest source of GHG, except for 3 farms (PL7, IT3, LT4), where CO_2 is the largest source. On average across all farms, methane contributed 49% to total emissions, carbon dioxide 32%, and nitrous oxide 19%. Carbon dioxide emissions were relatively high in Italy and Poland (40 and 43%), and relatively low in Latvia and France (15 and 20%). Nitrous oxide emissions were relatively high in Lithuania and Scotland (21 and 22%), and relatively low in Italy, the Netherlands and France (14-16%).

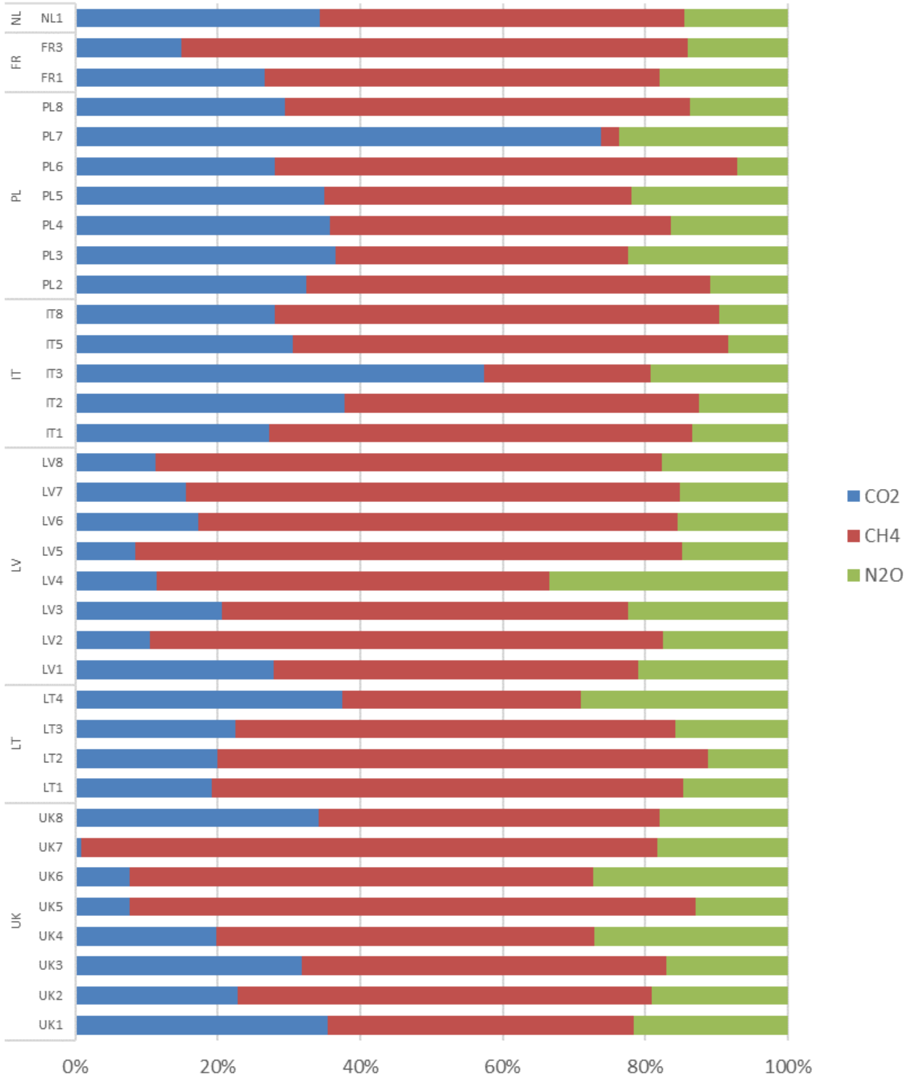

Figure 11. Types of greenhouse gas emissions per farm, based on CAP'2ER calculation (%; carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) expressed in CO_2 equivalents).

Sources of GHG emissions per farm are shown in Figure 12. On average across all farms, CH_4 from enteric fermentation contributed 39% to total emissions, CO_2 from purchased inputs 29%, CH_4 from manure management 10%, N_2O from manure and mineral fertilizer inputs to soil 8%, and other sources 13%.

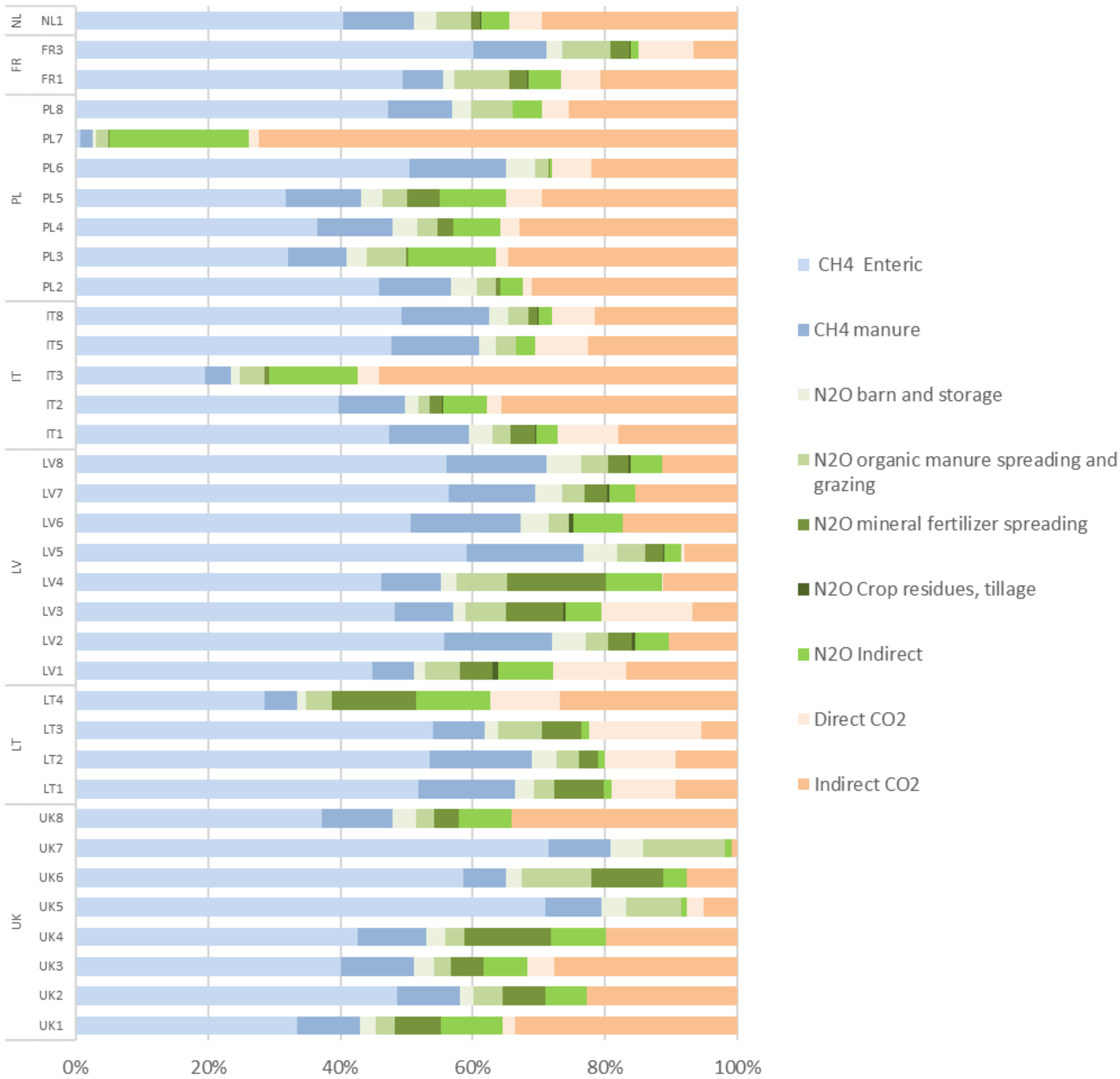

Figure 12. Sources of greenhouse gas emissions per farm, based on CAP'2ER calculation (%; carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) expressed in CO_2 equivalents).

Discussion and conclusions

We estimated baseline GHG and NH_3 emissions of 54 dairy farms in 8 partners countries participating in the CCCfarming project, based on 3 accounting tools: ANCA, Agrecalc and CAP'2ER. This report shows results of using the 3 tools with regard to GHG emission intensity from milk production (excl. carbon sequestration). In addition, based on the ANCA tool, NH_3 emissions were estimated. Importantly, data collection was a challenging and time-consuming task, and it was found that complete data collection was not feasible in this project, which may have led to inaccurate results.

Methodological limitations

There are two types of methodological limitations that are relevant for a correct interpretation of the results in this study: quality and completeness of the activity data and use of country-specific emission factors in models.

Firstly, with regard to activity data, ANCA and (to a lesser extent) Agrecalc required much activity data, whereas availability and quality of farm data are common issues in many countries. Like in any survey, the quality of the activity data may be affected by self-reporting bias by farmers, which can affect the accuracy of results. Activity data was the same for all tools, however, hence any quality issue affected all tool results to the same extend.

Regarding data availability, information was lacking about stocks of feed, manure and fertilizer, as this was considered too laborious and costly in the present study. Collecting data about the amounts of feed stocks, for example, is time consuming as it is done by measuring storage dimensions of stocks (length x width x height, e.g. silage heap) and has to be done twice (start and end of reference period). This had several implications for the calculations:

- For feed, the calculated composition and quality of the feed ration was based on feeds and forages harvested or purchased in the reference year only, ignoring changes in feed stocks. In practice, stocks of forage and crops harvested or feed purchased in previous year may be fed, or harvested or purchased feed may be saved for next year. For example, a farm purchases 1 t of a specific feed in the reference year, but only 0.5 t is fed in that year and the other 0.5 t is saved for next year. Without correcting for stocks, the assumed amount fed is overestimated. In a similar vein, the farm may harvest less forage due to drought, and the farmer used conserved forage in stock from last year – in this case the assumed amount of that forage fed is underestimated.
- For manure, only amounts applied on the field, amounts imported and amounts exported in the reference year were reported. As a consequence, amounts (and emissions) of stored manure were ignored, as well as the (emissions related to the) composition of stored manure applied in the reference year.
- For artificial fertilizers, only the type and amount applied on the field was reported. As emissions are related to applied fertilizer only, the lack of stock information was expected to have resulted in little bias (whereas self-reporting bias of amounts applied may be high).

We expect that especially for feed the ignorance of changes in stocks had a large influence on model results, whereas ignoring stocks of manure and artificial fertilizer had less impact. In all tools, feed intake is based on the IPCC Tier 2 methodology to estimate animal-specific gross energy intake. Ignoring stock changes, therefore, implies the assumed *relative* share of feed ingredients in the feed ration can be biased. Bias is more likely in case of major stock changes on a farm, and less likely in case of minor stock changes. Not only amounts of feed, but also the assumed quality of feed ingredients can be affected by this bias. Intermediate indicators such as feed ration crude protein level or dry matter intake are useful to detect bias. For example, an Italian feed consultant indicated that the crude protein content of the calculated feed ration in farm IT2 should be 160 g/DM rather than 175 g/kg DM calculated by ANCA (likely caused by the lack of feed stock information).

Feed stock information was demanded by ANCA only in this study. The potential bias caused by the lack of feed stock information, however, is an issue for any GHG accounting tool that uses farm feed data to estimate the feed ration composition and related emissions. It is important, therefore, to ensure appropriate data collection for accurate estimation of feed ration compositions in tools. Alternative solutions should be created for countries with limited data availability.

Second, different country specific factors were used in models. For example, in ANCA country specific emission factors (Tier 3 approach) are used for direct N2O emission (in % of N applied) rather than IPCC default emission factors (Tier 1 and Tier 2 approach). The emission factors are derived from field experiments in the Netherlands (Velthof and Mosquera, 2011). As N2O emissions contribute only a small part of total greenhouse gas emissions (about 6%; Olivier et al., 2017), we do not expect a large impact on our results. Adjusting emission factors could be considered in future use of tools in other countries. If Tier 3 emission factors are not available, Tier 1 or Tier 2 approaches could be considered (Hercoualc'h et al., 2021).

GHG emissions

GHG emission intensity ranged from 1.12-2.24 kg CO_2-eq/kg FPCM based on ANCA, 0.70-3.39 kg CO_2-eq/kg FPCM based on Agrecalc, and 0.79-3.93 kg CO_2-eq/L milk based on CAP'2ER. Across countries, Dutch and French farms showed lowest emissions (on average 0.91 – 1.18 kg CO_2-eq/kg FPCM or L milk, depending on the tool; Figure 13). German farms were also among the farms with lowest emissions in Agrecalc. Highest emissions were found for farms in Latvia and Poland (on average 1.41 – 2.46 kg CO_2-eq/kg FPCM or L milk, depending on the tool). It should be emphasized that farms in this study were not randomly selected, and hence results are not representative of the national dairy farm population of the countries.

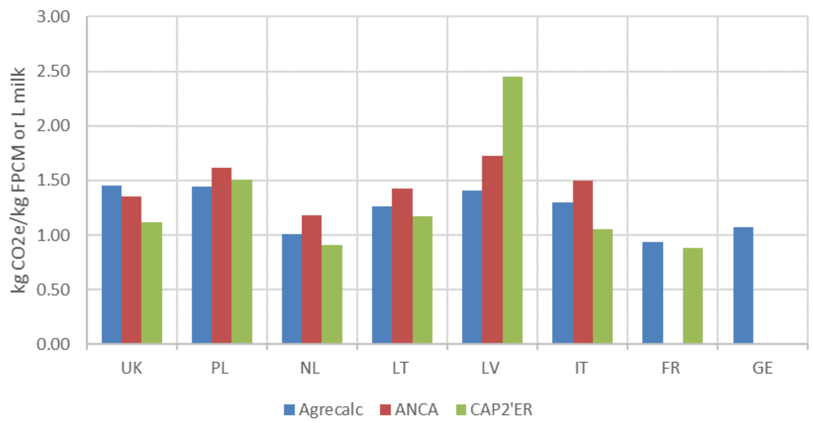

Figure 13. Average GHG emission intensity per country, based on 3 tools (expressed in kg CO_2 equivalents per kg FPCM for ANCA and Agrecalc, and per liter milk for CAP'2ER).

Across all farms there were three major sources of GHG emissions (enteric fermentation, purchased farm inputs, and feed production; consistent across tools), but the variation in contribution of sources per farm is large. For instance, in two farms with the highest emissions, this was due to very high emissions from farm inputs comprising 37-45% of their total emissions, vs. 24% on average across all farms. These farm-specific hotspots are clear entry points for GHG mitigation.

For some farms, farm management influenced GHG emissions. For example, a higher share of forage maize in the feed ration was (weakly) associated with lower GHG emission intensity (R^2 = 0.38). In farms applying grazing, emissions from stable and manure storage were 27 g lower, emissions from feed production were 31 g lower, and emissions from farm inputs were 27 g lower per kg FPCM than in zero-grazing farms (total GHG emission intensity was 59 g lower). Interestingly, whereas the relation between milk yield and GHG emission intensity is well known (Gerber *et al.*, 2011), in the present study milk yield per cow did not show an association with GHG emission intensity. Number of youngstock per 10 cows showed a (weak) positive association with GHG emission intensity (R^2 = 0.25). In addition, the farm type played a role in sources of GHG emissions. For example, extensive, mixed livestock-arable farms (e.g. Latvia, Lithuania) showed high emissions from feed production and energy/fuel use and low emissions from farm inputs; whereas intensive, specialized farms (e.g. Italy, Poland and the Netherlands) showed high emissions from farm inputs.

NH_3 emissions

On average across countries, NH_3 emissions ranged from 22 to 90 kg NH_3 per ha. Across countries, NH_3 emissions per ha appeared to be lower in the 3 countries located in the east of Europe (Latvia, Lithuania and Poland) compared to the 3 countries in the northwest and south (Scotland, Netherlands, Italy). This was mainly due to the intensity of dairy farming (milk production per ha), which was much lower in the countries in the east (on average 4609 kg milk/ha) compared to those in northwest/south (17946 kg milk/ha). The crude protein content of the feed ration and the N application rate on land are among the major determinants of the NH_3 emission per ha. The crude protein content was lower in countries in the east compared to the northwest/south (153 vs. 163 g/kg DM, resp.), as well as lower N application rates.

Differences between tools

Comparison of tools was not an aim of this study and requires a different approach. However, results of this study undoubtedly showed large differences between tools, despite using the same input data by means of a common data recording sheet, and despite a certain level of harmonization of models based on international standards for GHG accounting (e.g. IPCC). This raises the question what caused these differences.

Recently a more detailed comparison of the models behind the tools used in the present study was done by De Vries et al. (2022), based on 3 farms in the present study (LT, UK, and NL). The comparison showed large absolute differences in GHG emission intensity between the 3 farms, with ANCA yielding higher a carbon footprint than Agrecalc and CAP2ER in 2 farms, and a lower carbon footprint than CAP'2ER emissions in 1 farm. According to De Vries et al. (2022) differences between tools were mainly caused by differences in upstream emissions from imported feed (feed LCA database used, feed ingredients listed in the tool) and differences in enteric methane emissions (GWP characterization factor for biogenic methane; calculated herd feed intake and composition, feed stock information). Other aspects were the calculations methods for feed intake and feed ration composition; animal registration; allocation factor for milk and live weight; allocation of emissions to dairy production and arable crops; emission factors of fertilizers; and country-specific background data (e.g. electricity-mix, soil N_2O).

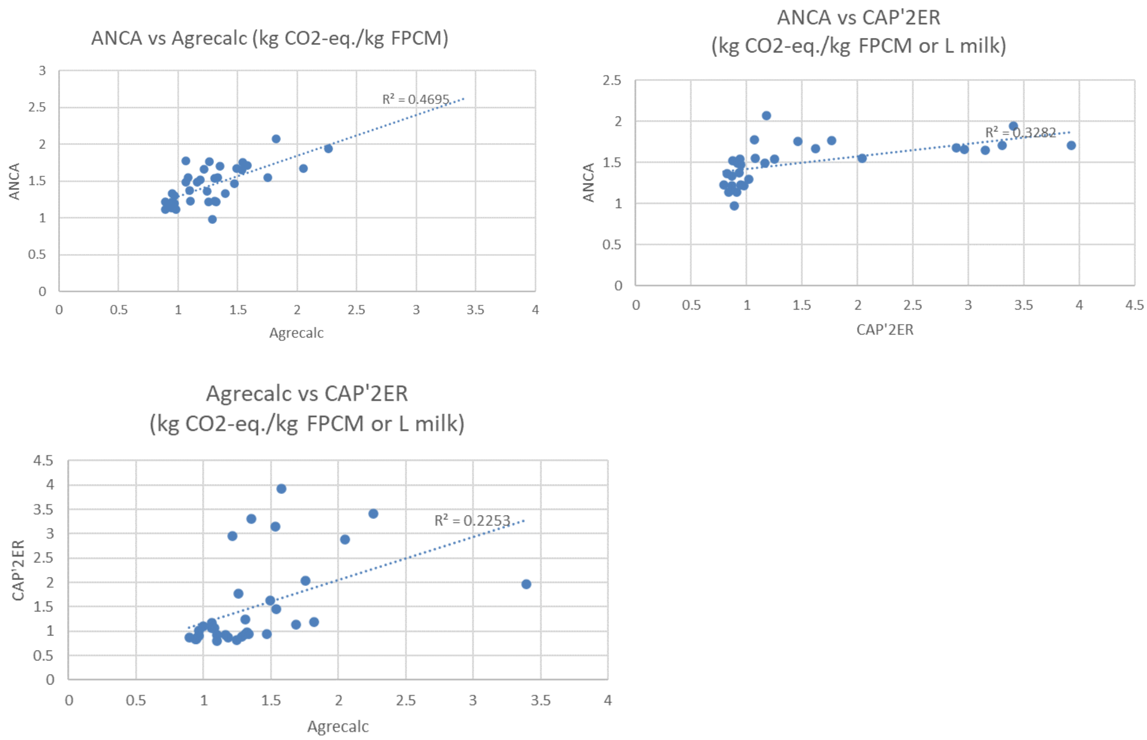

Figure 14. Comparison of outcomes of the 3 tools (GHG emissions from milk production, expressed in kg CO_2 equivalents per kg FPCM for ANCA and Agrecalc, and per liter milk for CAP'2ER; each dot represents a farm). Note graphs include only farms analyzed by both tools; not all farms were analyzed with all tools.

Results of the present study with a larger group of farms (incl. the 3 farms analyzed in De Vries et al., 2022) confirmed the large differences in outcomes between the tools, the largest difference in outcomes between CAP'2ER and the two other tools, and smaller differences between ANCA and Agrecalc (Figure 14). The large difference with CAP'2ER is possibly due to the use of CAP'2ER Level 1, which is a simplified analysis with limited activity data[8]. When farms were ranked, however, the rankings showed a 'strong' correlation (Spearman rank; R_s) between ANCA and Agrecalc (R_s=0.68), Agrecalc and CAP'2ER (R_s=0.69), and ANCA and CAP'2ER (R_s=0.78).

Further research is recommended for a better understanding of the differences between the tools, in particular the calculation methods for feed ration composition and feed intake. In addition, further harmonization should be realized in methods and background data to reduce differences in outcomes between tools, in order to enhance a level playing field for GHG monitoring in European dairy farms.

[8] In CAP'2ER Level 2 a more complete analysis is available with 5 times more activity data, but also more time needed to collect data. It is likely that a comparison with CAP'2ER Level 2 would have produced more similar results.

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ANNEX 1. Detailed farm characteristics

Farm	Herd size (n heads)			Agricultural area (ha)				Type of barn	Grazing dairy cows
	Cows	*Young stock*	*YS per 10 cows*	*Total area*	*Grass land*	*Forage maize*	*Arable land*	*(% slurry)*	*(days/year)*
LV1	35	46	13	116	116	0	0	22	180
LV2	95	124	13	368	273	35	60	22	0
LV3	125	101	8	392	187	0	206	0	180
LV4	48	64	13	732	214	0	518	22	180
LV5	96	68	7	213	98	21	94	86	0
LV6	65	61	9	155	140	15	0	85	0
LV7	107	87	8	140	116	24	0	87	0
LV8	130	162	13	475	156	0	319	75	0
PL1	54	87	16	51	20	15	16	18	0
PL2	118	194	16	130	10	65	55	18	0
PL3	198	579	29	1152	40	320	792	80	0
PL4	1437	2070	14	2428	120	430	1878	80	0
PL5	10	14	14	28	6	2	21	20	0
PL6	77	118	15	42	13	15	15	9	0
PL7	175	260	15	862	247	65	550	19	0
PL8	390	437	11	1296	637	0	658	19	180
LT1	126	83	7	265	66	26	173	74	0
LT2	122	131	11	250	91	32	127	91	0
LT3	38	32	8	76	51	9	17	96	180
LT4	218	270	12	685	199	97	390	4	180
IT1	112	70	6	61	1	25	35	37	0
IT2	210	190	9	57	0	48	9	92	0
IT3	120	95	8	42	13	14	14	37	200
IT5	80	117	15	54	0	0	54	94	0
IT8	102	84	8	52	10	0	42	76	0
UK1	205	303	15	301	191	45	65	86	0
UK2	258	196	8	225	170	55	0	92	55
UK3	559	412	7	247	172	0	75	93	0
UK4	370	40	1	131	70	0	61	100	30
UK5	143	80	6	150	118	0	32	97	200
UK6	1025	600	6	660	660	0	0	97	270
UK7	28	40	14	175	175	0	0	65	234
UK8	905	700	8	421	301	0	120	97	22
NL1	85	47	6	55	38	17	0	100	132
NL2	87	37	4	60	50	0	10	31	210
NL3	121	66	6	94	82	8	4	92	175
NL4	103	51	5	68	58	6	3	95	182
NL5	211	16	1	95	77	15	4	96	120
NL6	70	52	7	67	57	10	1	93	120
NL8	112	79	7	56	46	10	0	93	0

Farm	Milk production			Fat content	Protein content	Other production
	(kg/farm)	(kg/ha)	(kg/cow)	(%)	(%)	
LV1	377141	3253	10775	4.2	3.4	
LV2	781830	2125	8230	4.1	3.5	Beef
LV3	759654	1937	6077	4.5	3.5	Arable crops
LV4	432091	591	9002	4.0	3.4	Arable crops
LV5	648634	3042	6757	3.9	3.3	
LV6	508212	3279	7819	4.2	3.4	
LV7	1280275	9161	11965	3.5	3.3	
LV8	1249247	2630	9610	3.7	3.4	Arable crops
PL1	541125	10569	10021	4.0	3.7	
PL2	1509100	11608	12789	4.1	3.6	
PL3	2480000	2153	12525	3.7	3.3	
PL4	14147817	5827	9845	3.9	3.4	Arable crops
PL5	59375	2103	5938	3.8	3.2	
PL6	608000	14343	7896	4.2	3.5	
PL7	1698868	1971	9708	4.0	3.6	Beef, sheep
PL8	2029979	1567	5205	4.5	3.3	Arable crops, beef
LT1	1224984	4627	9722	5.0	3.4	Arable crops
LT2	1032705	4138	8465	4.5	3.4	Arable crops
LT3	376680	4982	9913	4.5	3.4	
LT4	1559224	2275	7152	3.9	3.4	Arable crops, beef
IT1	1251300	20513	11172	3.6	3.6	Arable crops
IT2	2538720	44696	12089	3.9	3.4	
IT3	1195056	28797	9959	4.3	3.5	
IT5	858209	15893	10728	3.8	3.4	
IT8	907815	17458	8900	3.8	3.4	
UK1	1970290	6553	9611	4.3	3.5	
UK2	2557501	11383	9913	4.3	3.3	
UK3	6153292	24934	11008	4.2	3.4	
UK4	3680000	28092	9946	3.9	3.4	
UK5	1086100	7220	7595	4.2	2.0	
UK6	5360804	8122	5230	5.0	4.1	
UK7	58500	335	2089	3.7	3.4	
UK8	9229913	21924	10199	4.3	3.5	Fattening calves
NL1	776220	14121	9186	4.7	3.6	
NL2	668760	11163	7652	4.3	3.7	
NL3	1160982	12325	9571	4.2	3.5	
NL4	1020724	15017	9881	4.3	3.5	
NL5	2029622	21293	9619	4.3	3.6	
NL6	586722	8754	8334	4.5	3.7	
NL8	1204000	21469	10750	4.3	3.3	Arable crops

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