Proportion, type and utilization of grassland affects the environmental impact of dairy farming

Troels Kristensen[1)] *& Ib Sillebak Kristensen*
Aarhus University, Department of Agroecology
Blichers Alle 20, P.O. Box 50, DK-8830 Tjele, Denmark
Tel.: +45 87158014; E-mail: troels.kristensen@agro.au.dk

Introduction

Dairy farming across the world relay to various degree on utilization of grass as either pasture, hay or silage. Several studies has shown that proportion of grassland has an impact on the environmental performance. Flysjo et al. (2011), O'Brien et al. (2012) and O'Brien et al. (2014) showing a lower green house gas (GHG) emission from grass-based dairy compared to confinement dairy, while Belflower et al. (2012) showed the lowest emission from a high intensive confinement type of dairy compared to a grass-based system. Guerci et al. (2013) comparing twelve different farming system observed that proportion of grassland of the farmed area was negatively correlated to the emission of GHG per kg milk, and that the three farms with the lowest emission also were the farms with the highest proportion of grazing. This could indicate that not only the proportion of grassland, but also the way of utilization of the grass growth has an impact on the emission. In addition Aguirre-Villegas et al. (2017) showed that the environmental impact was reduced from farm types that supplemented grazing at a level that increased milk yield, while maintaining pasture intake.

These inconsistencies in effect on GHG of different systems may partly be due to differences in the models used for calculation (Flysjo et al., 2011) as well as the type of farms chosen as representative for the systems. Permanent grassland compared to temporary grassland, being part of an arable crop rotation system is one factor. Permanent grassland reducing the energy cost and emission from cultivation being positive for a low emission, while a lower productivity might counteract these effect (Belflower et al., 2012). Several studies have shown that soil carbon sequestration is different from these type of grassland system, with an expected higher annually sequestration in grassland in rotation compared to permanent pasture, but also a high release of carbon when grassland in rotation is turned into annual crops like maize or grain (Soussana et al., 2009). These effects might have an importance even at the emission at farm level as the ranking of three system differing in type and proportion of grass change due to how grassland sequestration was modelled (O'Brien et al., 2014).

---

1) Corresponding author.

This report was made as part of ***Life14 CCM/BE/001187 LIFE-Dairyclim***

In general is higher milk yield associated with lower emission per kg milk (Kristensen et al., 2011), which is an obstacle for pasture based system having lower yield than confinement system. Some emission might be reduce though, like methane emission from storage of slurry compared to emission from deposition during grazing, while on the other hand emission of N_2O from manure deposited is much higher than from manure applied to land after storage (IPPC, 2006). Even the enteric methane emission might be different as content of starch and fat in the feed is related to a reduced methane production, and in pasture based diet the level of these two nutrient is often lower than in economical optimal ration fed indoor (Knapp et al., 2014).

All together is not obvious how systems differing in proportion, type and utilization of grassland affects the environmental impact of dairy farming. The aim with this paper is to add additional knowledge to understand how farming differing in these aspects perform in relation to release of greenhouse gasses, land use and biodiversity.

2. Materials and Methods

This study use a combination of farm data and modelling of the farm production to estimate the environmental impact of dairy production at farm and product scale.

2.1 Data

Information from questioner send to dairy farmer and published by (XX, 2017), together with additional national statistical information and other literature sources (Kristensen et al., 2015a) was used to define two system, either conventional (DK-con) or organic (DK-org) typically for Denmark and two system both with conventional farming, typical for Luxemburg (LUX) and Belgium (BEL). These systems represent a large variation in grassland utilization (silage vs. grazing), proportion of grass in the feeding and the type of grassland (temporary vs. permanent) and grassland management.

All farm data is annually data based on year 2015. Crop productivity, taken from statistic and farm information, were reduced by 15% for pasture, 10% for silage and 5% for maize to give figures for amount of roughage identical to the herd demand, as there will be several pathways for losses in the chain from field to animal intake (Kristensen, 2015).

Information about soil type and soil carbon content was from Denmark average soil on dairy farms from national database (Kristensen, 2014). For Belgium and Luxemburg the values used are based on Wesemael et al. (2010) and Lettens et al. (2005) assuming same C-content in 0-30 cm and 30-100 cm layer: in total 0-100 cm soil depth 19% clay, 195 ton soil-C per ha in permanent grassland and 148 ton C per ha on arable and maize area.

Grass/clover N-input from fixation in Denmark is estimated from Kristensen et al. (1995) adjusted to the actual level in these systems 21 % clover DK-con and on DK-org 34 % (Kristensen & Søndergaard, 2017). In BEL and LUX there is no direct data on legumes so the fixation was based on 20 % clover found as average of conventional dairy in Denmark by Kristensen et al. (1995).

Annually climate data was from United Nations (2017), with climate from the Jutland climate station Års for DK and for BEL and LUX the climate from respectively Uccle and Luxembourg. With around 850 mm precipitation all places, no irrigation need is simulated.

N in precipitation is measured 13 kg per ha in DK (Ellermann et al., 2017), and is assumed 25 kg N per ha in BEL and LUX.

2.2 System boundary definition

In order to have possibilities for comparing different types of dairy systems and products directly the model farm area represent only the area needed for producing the home grown feed for the dairy herd – cows and young stock. To include a product approach was the system boundary extended in order to include also the emissions related to the imported resources such as feed and fertilizer. These latter resources are refered to as off-farm or secondary emissions and the former as direct or primary emissions.

2.3 Functional unit and allocation

The functional unit in the study was one kg energy corrected milk (ECM) from kg milk sold at the farm gate and one kg of live weight gain, including both cows and heifers, but not bull calves. The method used to divide total farm GHG emissions into meat and milk has significant impact on the estimated emission of the products. In the present study, we used first a system expansion to subtract emission related to cash crops, with emission equivalent to the one used for imported grain, and a biological allocation, based on feed energy required to produce the amount of milk and meat at the farm developed by IDF (2010) to allocate the remaining emission to milk and meat.

2.4 Modelling

Calculations was made using a farm model FarmAC (www.FarmAC.dk), combined with methodologies for estimating of climate emission at farm level as given by Hutchings & Kristensen (2016), Kristensen et al. (2011) and emission at crop level by Mogensen et al. (2014). The FarmAC is a whole farm model, which consists of static, annual modules to describe ruminant livestock, animal housing and manure storage. A dynamic, multi-year module to describe crop production, including effect of the crop sequences present and how each crop is managed and effect on nutrient flow and soil change, including C sequestration and N mineralisation (Hutchings & Kristensen, 2016). The farm is characterised in terms of the numbers of different livestock categories present (e.g. dairy cattle, heifers) and their feed ration, where each livestock category is housed, the manure storage associated with each housed, including pasture.

During the calibration of the model was the assumption that the proportion between the three types of roughage - permanent and arable grassland and maize for silage - had to be identical with the known proportion from each location (xx, 2017). The actual area at farm level was estimated with focus on balance between roughage net production and herd demand (DMI, net energy and protein) as well as between manure excretion and use of fertilizer – which has to evaluated and corrected as part of initiation of the model. If necessary in order to established realistic crop rotation some minor areas with grain as cash crops was included. This was an important part of the work going from farm data to model as the some of the farms (LUX and BEL 49% and DK 15%) from the questioner had beef and crop production together with dairy (xx, 2017). Simulation of each scenario was done by running the model for at a period of 10 year with average annually climate data for each location.

The environmental performance in a cradle-to-farm-gate perspective was evaluated using life cycle assessment (LCA) with focus on the impact category global warming. The global warming potential was estimated for a 100- year time horizon by converting all GHG emissions to CO_2 equivalents (CO_2 eq.), with on weight basis 1 kg CH_4=25 and 1 kg N_2O=298 kg CO_2 eq. (IPCC, 2006).

2. 5 Emission factors

Table A1 gives the EF used for calculating the primary emissions of CH_4 and N_2O for each pollutant. Enteric methane emission was estimated using an EF of 6% (Nielsen et al., 2016) and GE gross energy per kg dry matter (DM) for each feedstuff in combination with the herd-specific annual dry matter intake (DMI).

Emission from manure was calculated with specific EF for the two types of manure, slurry (0.1) and pasture (0.01). The amount of organic matter in manure was estimated from the herd-specific DMI and standard digestion coefficient (72%) and ash content in DM (8%) with a methane formation capacity of 0.22 m^3 CH_4 per kg organic matter (Nielsen et al., 2016). The proportion of DMI intake from pasture was used to allocate the total amount of manure excreted between pasture and indoors.

The direct and indirect N_2O emissions via NH_3 and NO_3 were calculated from the N flow. N excreted ex animal was calculated as the difference between N in feed intake and N in produced milk and live weight change. The content of crude protein in feed was converted to nitrogen by dividing by 6.25. The N content in milk was converted to N by dividing by 6.38 and nitrogen in live weight gain was set to 26 g N per kg live weight (Poulsen & Kristensen, 1998). Table A1 gives EF in the different steps from stable to crop residues. The emissions of NH_3 in the chain from animal to soil were estimated using site specific EF (Table A1). NH_3 emission was based on temperature effect combined with application method, injection in DK and broadspread in BEL and LUX, calculated with Alfam (Hutchings, 2002), included in the used FarmAC-model.

The indirect N_2O emission was calculated from the sum of all pathways for NH_3 emission using a common EF of 0.01 (IPCC, 2006), while the proportion from leaching was 0.0075 in all cases.

The annual crop residues was estimated at farm level by multiplying the area of each type of crop with an amount of drymatter in residues (sum of above and below-ground level) per ha for each type of crop estimated from drymatter yield and the method given by Taghizadeh-Toosi et al. (2014). All straw from grain was included as residues. Besides crops residues was the effect of manure added at farm level based on the estimated excretion of N ab animal and a standard C/N content of 8.23.

Carbon sequestration from crop residues and manure was estimate based on 10% annual net accumulation (Petersen et al., 2013) and 45% carbon of drymatter, combined with land use and tillage factors (IPCC, 2006) and the method for scaling documented by Mogensen et al. (2017).

The N_2O emission from mineralization was estimated from the calculated net carbon sequestration, assuming a C/N ratio of 10 (IPPC, 2006).

The N-surplus at farm gate was divided into losses as shown by Nielsen & Kristensen (2005). The N_2 emission is calculated from N_2O-emission with a factor 3.5 kg N_2-N per kg N_2O-N emitted in DK (5% clay) and 7.5 kg in LUX and BEL due to 16 % clay (Vinther, 2005). Leaching is calculated as the difference between N surplus minus the estimated losses by NH_3, N_2 and N_2O.

Use of energy was estimate based on Arla (2017) with average 855 kwh per cow and 197 l diesel (incl. oil) per ha in conventional Danish farms. The proportion of diesel related to crop production was estimated from Mogensen et al. (2017) in systems without pasture, which was used to scale diesel to proportion of pasture

$$\text{Diesel per ha} = 197 - \text{Proportion of DMI from pasture} * 0.8$$

Energy was converted to CO_2 eq. with 1 liter diesel = 3.309 kg CO_2 eq. and 1 kwh = 0.655 kg CO_2 eq.

The secondary emission from import of feed and fertilizer is only given in CO_2 eq., but in some cases estimated from CH_4 and N_2O emissions. The secondary emission from imported fertilizer with an emission of 4.37 kg CO_2 per kg N (Mogensen et al., 2015).

The import of feed was simplified by use of a combination of barley and respectively, soybean meal in the three conventional systems and organic rape cake in the organic system with impact as given in Table 1, based Mogensen et al. (2015).

Table 1. Impact factor for imported feed (from Mogensen et al., 2017)

Production system	Organic		Conventional	
Fed item	Barley	Rapecake	Barley	soy
Production, g CO_2 eq per kg DM	473	513	496	577
C-seq, g CO_2 eq per kg DM	-130	-9	-109	-116
GHG total, g CO_2 eq per kg DM	603	522	605	693
Area, m^2 per kg DM	2.73	2.28	2.31	1.75

Table 2 . Characterization factor for potential biodiversity loses, per m^2 (from Knudsen et al., 2017).

Country	Luxemburg	Belgium	Denmark	
System	Conventional	Conventional	Organic	Conventional
Maize	0.68	0.68	0.29	0.68
Cereals	0.68	0.68	0.29	0.68
Temporary grassland	0.09	0.09	-0.12	0.09
Permanent grassland 1)	-0.07	-0.07	-0.34	-0.23
Grain - import	0.68	0.68	0.29	0.68
Rape and Soy import	0.68	0.68	0.29	0.68

1) *LUX & BEL is high input type of permanent – CF is calculated as average of permanent low input and arable grassland from Knudsen et al (2017).*

Biodiversity impact was calculated based on characterization factor for potential biodiversity loses for each crop (Table 2) and the method given by Knudsen et al. (2017).

Emissions from other production inputs like pesticides, seeds, liming and medicine were not included, as information was missing, and neither were emissions associated with the construction of machinery and buildings or the potential emission from managed organic soil.

3. Results

Main characteristics for the four systems showed in Table 3, as area given for each farm is a result of the simulation. The soil type is identical in LUX and BEL with higher clay content than in the Danish soil. The size of the dairy herd was fixed to data from (xx, 2017), while the milk yield was an output based on the feeding defined. Stocking rate was lowest 1.26 LSU per ha in DK-org increasing to almost two LSU per ha in LUX and DK-con, and looking at milk production per ha there was the same trend from DK-org with 6,641 kg ECM per ha to almost the double in DK-con, 11,103 kg ECM per ha.

Table 3. Basic information – results from modelling of dairy farms.

Country	Luxemburg	Belgium	Denmark	
System	Conventional	Conventional	Organic	Conventional
Farm land, ha total	65	71	234	151
Soil, clay %	19	19	5	5
Rainfall, mm annully	865	821	842	842
Precipitation, mm annully	653	530	547	535
Herd, dairy cows no	74	70	169	168
Milk yield, kg per cow	8,389	8,254	9,199	9,980
Live weight gain (herd), kg per cow	217	248	204	208
Stocking rate, LSU per ha	1.99	1.73	1.26	1.95
Milk, kg ECM per ha farm land	9,519	8,102	6,641	11,103

Landuse (Table 4) was very different between the four cases, with high proportion of permanent grassland in LUX and BEL and a high proportion of temporary in DK-org and a bit lower in DK-con. In total was grassland the most dominating landuse in all case from 39 % in DK-con to 68 % in LUX. In DK-con and LUX was maize the second most dominating crop, while grain was the second in BEL and DK-org. Average yield was highest in DK-con, due to a the high proportion of maize being the crop with the highest yield in all cases. Lowest production was in DK-org, due to a general lower yield in the organic crops compared to the three conventional systems. Between the conventional systems in the yield in permanent grass land much higher in LUX and BEL compared to DK-con, while the temporary grassland yield highest in DK-con.

Feeding was an input to the model based on detailed feeding plans for 4 groups of animals and two seasons, all made to fulfill the demand for energy, intake capacity and protein. Total drymatter intakevaried from 8,559 kg DM in LUX to 9,958 kg DM in DK-con (Table 5) with the difference being due to higher milk yield, some variation in live weight growth (Table 1) and energy concentration of the feed ration. In systems

Table 4. Landuse and production

Country	Luxemburg	Belgium	Denmark	
System	Conventional	Conventional	Organic	Conventional
Croptype, % of farmland				
-Permanent grassland	57%	55%	9%	7%
-Temporary grassland	11%	11%	48%	32%
-Maize	18%	5%	3%	31%
-Cereals	15%	29%	40%	29%
Net yield, kg DM per ha				
-Permanent grassland	6,925	8,237	2,333	2,508
-Temporary grassland	8,300	10,574	7,884	10,986
-Maize	13,384	13,480	8,232	12,307
-Cereals	6,180	6,170	3,976	5,593
-Average of farm land	8,705	9,565	6,422	10,158
Protein content, % of DM	14.4%	14.5%	16.7%	12.2%

Table 5. Annually herd feed intake in kg drymatter and content of protein, per dairy cow

	Luxemburg	Belgium	Denmark	
	Conventional	Conventional	Organic	Conventional
Feedintake, kg DM				
-pasture	2,355	2,956	2,161	550
-grass silage/hay	1,898	2,838	3,358	2,792
-maize / whole crop silage[1)]	2,225	693	925	3,525
-grain –on farm	793	1,853	1,816	1,605
-grain -import	611	54	500	500
-protein -import	722	322	573	1,077

with high proportion of pasture is the protein content highest due to a higher content in pasture than the demand. Looking at the amount of each type of feedstuff, pasture is only supporting 6 % in DK-con, but up to 34 % in BEL of total DMI. In addition, the total proportion of grassland products (pasture, silage and hay) was much lower in DK-con compared to the three other cases.

The next tables' gives data related to the environmental impact of the systems. The N flow at farm level in Table 6 shows the largest input per ha farm land in DK-con, 218 kg N followed by 200 kg in LUX and 190 kg BEL, while the input was lowest 134 kg N per ha in DK-org, where the contribution from fixation is 2/3 of total input. In the three conventional systems is commercial fertilizer the most dominating input, with up to 72% of total N in BEL. Fixation in LUX and BEL is lower than in DK-con despite the larger proportion of grassland due to a reduction of fixation with increasing application of nitrogen from manure and fertilizer.

Nitrogen in milk is by far the most dominating output with 78 % in BEL to 88 % in LUX. Some minor amount from crop and manure is a result of small deviations between production and herd use. The farm gate

Table 6. N farm balance and estimated losses, kg N per ha

	Luxemburg	Belgium	Denmark	
	Conventional	Conventional	Organic	Conventional
N input				
-fertilizer	92	136	0	71
-fix	3	0	89	26
-feed	81	29	32	109
-deposition	25	25	13	13
Sum	200	190	134	218
N output				
-milk	53	45	37	62
-meat	6	6	4	6
-crop+manure	0	7 + 0	3 + 3	2 + 3
Sum	59	58	47	73
Farm balance	**141**	**132**	**87**	**146**
Estimated losses				
-NH_3	35	32	20	52
-N_2	53	50	16	25
-N_2O	7	6	4	6
-Soil N	16	27	8	15
-Leaching (Difference)	33	17	39	48

balance is lowest in DK-org with 87 kg N per ha, while the level is almost identical between the three conventional systems, with up to 146 kg N per ha in DK-con.

The losses were estimated based on the input of manure, fertilizer and fixation, which was from 219 kg N per ha in DK-org to 296 to 313 kg N per ha in the three conventional systems. Variation in loss as NH_3 is an effect of these amount of input in combination with an effect of system as loss during application was highest in LUX and BEL. The losses as N_2 from denitrification is double in LUX and BEL compared to DK-org, which is due to the higher clay content in LUX and BEL. Together with a higher soil sequestration this leads to the lowest leaching in BEL of 17 kg N per ha compared to DK where the estimate leaching is 39 kg N per ha in DK-org and 48 kg N per ha in DK-con.

Green house gas emission is calculated using the life cycle approach so the figures in Table 7 shows the impact through the chain until leaving the farm gate, expressed as total emission per kg of milk, while figures in Table 8 shows the impact allocated to milk and meat. Emission due to import of feed is the most dominating indirect contribution, except in BEL where the import of feed is lower than of fertilizer. In all systems is the contribution of indirect sources less than 11% of the total emission. The major source to direct emission is enteric methane, followed by N_2O in all systems. In DK-con, explains the high proportion of slurry, the high contribution from manure compared to the three other systems. The relative high emission from energy in DK-org is due to the area bases estimation of diesel. In total, before allocation is the highest emission per kg milk in BEL, 1,187 g CO_2 per kg, and 10 % lower emission in the lowest DK-org.

Table 7. LCA – GHG emission, g CO_2 eq., per kg milk before allocation

	Luxemburg	Belgium	Denmark	
	Conventional	Conventional	Organic	Conventional
GHG emisson				
Indirect				
-fertilizer	42	73	0	28
-feed import	86	26	58	87
-crop + manure	0	0	-1	-1
Direct				
-Methane - enteric	524	537	517	515
-Methane - manure	81	76	84	101
-N_20	327	360	262	234
-Energy (Feed production + stable)	128	137	150	113
Total GHG	1,187	1,209	1,070	1,078
% on farm	89%	92%	95%	89%

Table 8. Product environmental impact for milk and meat – after allocation

	Luxemburg	Belgium	Denmark	
	Conventional	Conventional	Organic	Conventional
Proportion to milk. %	85%	83%	87%	88%
Per kg milk				
GHG, g CO_2 eq.	1,010	999	933	949
Soil carbon sequestration, g CO_2 eq.	44	82	38	37
Land use, m^2	1.12	0.94	1.47	1.00
Biodiversity damage index	0.36	0.26	0.12	0.52
Per kg live weight gain				
GHG, g CO_2 eq.	6,850	6,976	6,174	6,223
Soil carbon sequestration, g CO_2 eq.	301	569	252	240
Land use, m^2	7.59	6.58	9.75	6.58
Biodiversity damage index	2.41	1.79	0.81	3.39

The product environmental footprint given for milk and meat in Table 8, are based on an allocation of 83 to 88% of total emission to milk. Looking at GHG emission this change the ranking of the systems compared to Table 7, as the highest emission from milk after allocation is in LUX followed by BEL, DK-con and DK-org being still the lowest with 934 g CO_2 eq. per kg milk or 8% lower than LUX. If soil carbon sequestration was added to emission of GHG this would reduce the impact of all systems, but not change the ranking (Figure 1). Indirect landuse emission, based on Audsley et al (2009) with 143 g CO_2 per m^2 of total landuse, cources that the DK-org system has an relatively higher emission due to the high land use 1.47 m^2 compared to 0.94 to 1.12 in the conventional systems. The biodiversity damage index (BDI) is highest in DK-con, due to the

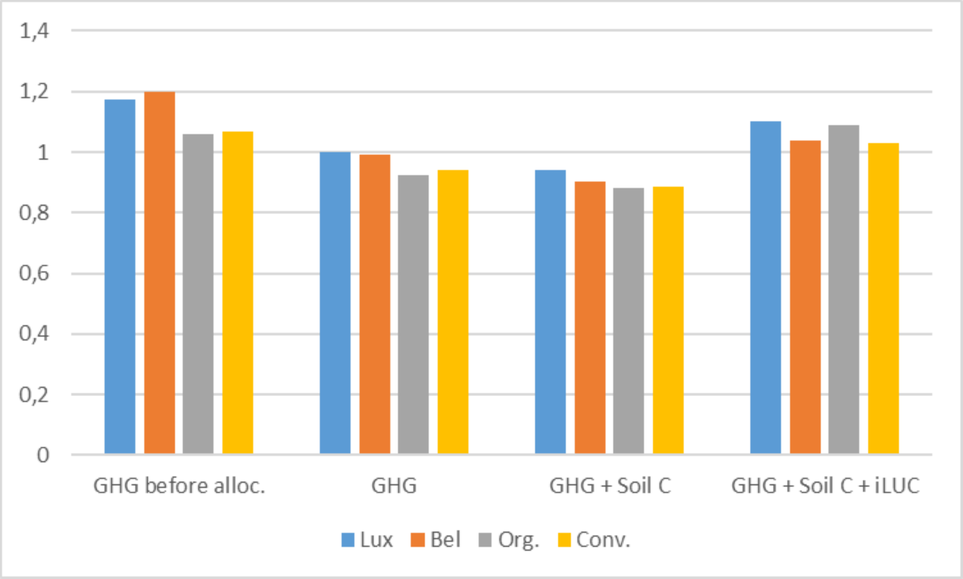

Figure 1. Emission of GHG in four systems and four approaches for estimation of GHG, relative to LUX GHG after allocation but without soil C and ILUC.

high proportion of annual crops, while the low damage index in DK-org compared to LUX and BEL is due to lower BDC factors in all type of organic crop compared to the same types grown conventional.

4. Discussion

The farming system evaluated is systems where the actual farm system has been reduced to include only the land and animals of interest for milk production. Other ways would have been to include the entire farm and the allocate the emission to more than milk and directly from dairy, as beef cattle and cash crops (Marton et al., 2016). Especially for manure management and benefit of crop rotation is the system reducing problematic, but using the whole system would introduce choice in either methods of allocation or system expansion. Both know to have a potential major effect on the impact from the major product (Kristensen et al., 2011).

The aim with this paper is to add additional knowledge to understand how farming differing in proportion, type and utilization of grassland affects the environmental impact of dairy farming in relation to release of greenhouse gasses, land use and biodiversity. In Table 9 is some of the result summarized with focus on this aim.

The farms clearly differs in proportion of grassland at farm and herd level as well as in type of grassland and way of utilization. The DK-con system relying on temporary grassland for cutting together with maize, the DK-org system with high proportion of temporary grassland and the two other systems with even higher proportion of grassland, but primarily as permanent. Each farm is unique, so these four systems can only give some ideas to which part of the farm contributes to reduced impact, this will be highlighted in the following.

Table 9. Summary – impact of grassland

	Luxemburg	Belgium	Denmark	
	Conventional	Conventional	Organic	Conventional
Land				
Grassland, % of farm	68	66	57	39
Permanent grassland, % of farm	57	55	9	7
Grazed area, % of grassland	55	51	39	18
Production grassland, kg DM per ha	7,144	8,635	7,006	9,421
Herd				
Pasture, % of DMI	28	34	23	6
Grass silage, % of DMI	22	33	36	28
Farm				
Intensity, kg ECM per ha	9,514	8,102	6,641	11,103
Fertilizer, kg N per ha	92	136	0	71
On farm produced, % of DMI	85%	96%	89%	85%
Environment – farm area				
N surplus, kg N pr ha	141	132	87	146
GHG, kg CO_2 eq per ha	10,083	8,993	6,728	10,704
Soil sequestration, kg CO_2 per ha	569	980	286	551
Environment – product (LCA)				
GHG, g CO_2 eq per kg ECM	1,010	999	933	949
Biodiversity damage index, per kg milk	0.36	0.26	0.12	0.52

4.1 Emission of GHG

The model applied to estimate the GHG emission, defined by type of pollutant included, methods of quantification, the EF and the FU, is important when comparing with the results of other studies (Kristensen et al., 2011; De Vries & De Boer, 2010; Van der Werf et al., 2009). With this in mind, our results for kg CO_2 eq. per kg milk is comparable to the level found by Cederberg & Flysjo (2004) and van der Welf et al. (2009) using economic allocation between milk and meat, but lower than that in Dutch systems (Thomassen et al., 2008a). The difference between the systems app. 8% in CO_2 eq. per kg milk is small, compared to both uncertainty in data (Oenema et al., 2003) and EF, like 100% on EF for N_2O (IPCC, 2006) and to variation between farms within systems (Kristensen et al., 2011).

The main contribution to GHG was enteric methane, emission related to N turn over from manure and fertilizer together with fossil energy used in crop production and stable, which are in accordance with (Kristensen et al., 2011). Increased efficiency in the herd (EKM per kg DMI) is therefore an import parameter for reducing farm product emission. In the four system was the efficiency from 0.95 kg ECM per kg DMI in BEL to 1.00 kg ECM per kg DMI in DK-con, which is in line with results from Flysjo et al (2011). Lowering feed to milk can be done either by dilution of maintenance by increased milk yield (Bava et al., 2014) or by reducing the number of offspring (Lehmann et al., 2017).

Systems

In pasture based system intensification defined as higher milk production per cow and ha due to higher input of fertilizer and concentrate lead to higher GHG emission per area and product, while improved pasture management lead to lower emission (Chobtang et al., 2017). In the three systems with a high proportion of pasture would an increased efficiency reduce the import of protein by 200 – 300 kg drymatter per cow annually.

In confinement type of dairy system Bava et al. (2014) and Kristensen et al. (2011) found that GHG emission per kg milk was reduced by increased milk production per cow as this was followed by higher dairy efficiency, kg milk per kg DMI at herd level. Kristensen et al. (2011) identified low stocking rate as the second most important strategy as a mitigation options looking at emission in the total chain, due to a lower impact from on farm fed production than imported fed per kg DM, together with a higher N utilization on these farm. The systems in this case already has a low import of feed – which is part of the systems definition – so the systems might already has taken this advantage.

Hay, silage or pasture

Enteric methane from either silage or pasture of same digestibility is identical (Knapp et al., 2014), while Patra (2012) found a reduction in methane in ration high in legumes, which would be in favor of the organic system compared to the conventional systems. Maize silage, on the other hand, compared to grass silage might reduce methane production (Knapp et al., 2014). These effects was not included in the method used to estimate methane as this only included DMI and gross energy. As enteric methane counted for almost 50% of the total GHG would even small effect could have a significant impact on total emission.

Energy for hay drying counts for up to 30 % of total emission to feedproduction (Kristensen et al., 2015b) while fossil energy used to silage production – either grass or silage - is only about 10 % and for pasture almost zero (Mogensen et al., 2017). All though these effects relatively are large would the numerical effect on the total GHG not be significant as energy used in feed production only accounts for less than 10% in our systems.

FU – per kg milk or per ha

The ranking of the three conventional systems in relation to GHG emission changed according to FU. With the typical unit, per kg milk, was DK-con lowest, while this system had the highest emission per ha of farm compared to LUX and BEL, which could be due the differences in proportion of maize and grassland, as Salou et al. (2017) found a high emission per ha in systems with high proportion of maize as in DK-con. The low emission per ha in the organic system is in agreement with Kristensen et al. (2011), while the low emission per kg milk compared to conventional is unusual (Toumistro et al., 2012), but might be a result of the high milk production in DK-org compared to the difference between organic and conventional in other studies.

Soil carbon sequestration

Grassland has potential to mitigate GHG emission from dairy through carbon sequestration (Soussana et al., 2009) with huge effect of management, like grazing being superior to cutting. On farm level we estimated an annual sequestration up to 980 kg CO_2 eq. or 210 kg C per ha, while the contribution from temporary grassland by its own was up to 400 kg C per ha. This is lower than the net carbon balance for mixed (grazing and cutting) grassland of 500 kg C per ha, but within the range of uncertainty in of carbon balance estimation (Sousana et al., 2009). Even in systems with a high proportion of grassland, this amount of sequestration will not counteract the other source by more than up to 11 % (BEL) so net emission from dairy is still high.

The way of estimating the sequestration favour systems with high net yield as the total dry matter production was directly related to net yield within crop type, so in systems with poor management leading lower utilization of the growth this could underestimate the actual sequestration.

4.2 Landuse

On a global scale is land a limited factor for development of the agriculture production for food, but also other matters like bioenergy. The org-DK system had the highest land use 1.47 m^2 per kg milk compared to 1.02 m^2 in average of the three conventional systems, in agreement with the effect of organic found by Kristensen et al. (2011) and Guerci et al. (2013). Of the landuse was arable cropping most pronounced in the two Danish systems, while it only was 45% in the two other systems of this type of land use.

4.3 Biodiversity

The results showed a range from 0.12 to 0.56 in BDI per kg ECM with the conventional Danish system having the highest biodiversity loss, as this is highly correlated to area of annual crops. Guerci et al. (2013) found similar importance of grassland on BDI per kg milk. The current method do not take into account factors related to the landscape, like lakes or rivers along the field, nor a potential effect of the way of utilization of the grassland or size of each field (Knudsen et al., 2017). Grazing compared to intensive cutting systems has been document to increase biodiversity (Tuomisto et al., 2012), but also different ways of grazing might have an impact.

5. Conclusion – grassland

DK-con was the most intensive system of the four systems, with a high production both at land and herd level, which gave the highest GHG emission per area of farm land, but of most importance also the lowest emission per kg of product. This despite the higher proportion of grassland in combination with more permanent grassland and a higher proportion of pasture in the two other conventional systems, LUX and BEL.

The contribution from grassland to carbon sequestration was positive, but the effect of inclusion of straw from the grain area and the high input of from manure diminished the difference in total sequestration between the systems. It also is very important to underline that the calculation is based on stable systems, as the carbon loss will be much higher in situation where permanent grassland is converted to arable land (Sousana et al., 2009). The results can there for not be used as an argument for that converting a permanent grassland system to an arable system will not affect the emission of GHG.

Both this study and other studies support the positive influence of grassland on the biodiversity of the farmed area, but as shown here it is too simple when comparing organic and conventional dairy.

Acknowlegdements

This work was supported by funding from the Life project LIFE14 CCM/BE/001187 with the aconym “Life-Dairyclim”. Besides the authors has project participants from University of Liege and CONVIS – farm advicory services in Luxemburg – supported with documentation of the dairy systems.

5. References

Aguirre-Villegas, H.A., Passos-Fonseca, T.H., Reinemann, D.J., Larson, R. 2017. Grazing intensity affects the environmental impact of dairy systems. J. Dairy Sci., 100, 6804-6821

Arla. 2017. Personal information in relation to climate impact from dairy farmers.

Audsley, E., Brander, M., Chatterton, J., Murphy-Bokern, D., Webster, C., and Williams, A. 2009. How low can we go? An assessment of greenhouse gas emissions from the UK food system and the scope for to reduction them by 2050. How low can we go? WWF- UK.

Bava, L., Sandrucci, A., Zucali, M., Guerci, M., Tamburini. 2014. How can farming intensification affect the environmental impact of milk production. J. Dairy Sci., 97: 4579-4593.

Belflower, J.B., Bernard, J.K., Gattie, D.K., Hnacock, D.W., Risse, L.M., Rotz, C.A. 2012. A case study of the potential environmental impacts of different dairy production systems in Georgia. Agric. Syst., 108, 84-923.

Cederberg, C., Flysjø, A. 2004. Life cycle inventory of 23 dairy farms in southwestern Sweden. SIK-rapport 728, 1-57.

Chobtang, J., Ledgaard, S.F., Mclaren, S.J., Donaghy, D.J. 2017. Life cycle environmental impacts of high and low intensification pasture-based milk production systems: :a case study of the Waikato region, New Zealand. J. Cleaner Prod., 140, 664-674.

Ellermann, T., Nygaard, J., Nøjgaard, J.K., Nordstrøm, C., Brandt, J., Christensen, J., Ketzel, M., Massling, A. & Jensen, S.S. 2016. The Danish Air Quality Monitoring Programme. Annual Summary for 2015. Aarhus University, DCE. Scientific Report from DCE – Danish Centre for Environment

Hutchings, N. J. 2002. Ammonia Loss from Field-applied Animal Manure, ALFAM FAIT-PL 98-457. http://alfam.dk/alfam/Results/Interactive_results.xls: 1-110.

Hutchings, N. J., Kristensen, I.S. 2016. Measures to reduce the greenhouse gas emissions from dairy farming and their effect on nitrogen flows. Poster presented at 19th N workshop in Skara, Sweden, 27-29. June 2016. http://akkonferens.slu.se/nitrogenworkshop/wp-content/uploads/sites/18/2014/05/Nitrogen-Absracts-USB_ny.pdf.

de Vries, M., de Boer, I.J.M., 2010. Comparing environmental impacts for livestock products: A review of life cycle assessments. Livest. Sci. 128, 1-11.

Flysjø, A., Henriksson, M., Cederberg, C., Ledgaard, S. & Englund, J-E. 2011. The impact of various paramenters on the carbon footprint of milk production in New Zealand and Sweden. Agric. Syst., 104, 459-469.

Guerci, M., Knudsen, M.T., Bava, L., Zucali, M. Schonbach, P., Kristensen, T. 2013. Parameters affecting the environmental impact of a range of dairy farming systems in Denmark, Germany and Italy. J. Cleaner Prod. 54, 133-141.

IDF, 2010. A common carbon footprint approach for dairy. Bulletin of the International Dairy Federation 445, 40 pp. ISSN 0250-5118.

IPCC, 2006. IPCC Guidelines for national greenhouse gas inventories. http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

Knapp, J.R., Laur, G.L., Vadas, P.A., Weiss, W.P., Tricarico, J.M. 2014. Invited review: Enteric methane in dairy cattle production: Quantifying the opportunities and impact of reducing emissions. J. Dairy Sci., 97, 3231-3261

Knudsen, M. T., Hermansen, J.E., Cederberg, C., Herzog, F., Vale, J., Jeanneret, P., Sarthou, J.P., Friedel, J.K., Balazs, K., Fjellstad, W., Kainz, M., Wolfrum, S., Dennis, P. 2017. Characterization factors for land use impact on biodiversity in life cycle assessment based on direct measures of plant species richness in European farmland in the temperate broadleaf and mixed forest biome. Science of the total environment, 580, 358-366.

Kristensen, E. S., H. Høgh-Jensen and I. S. Kristensen. 1995. A simple model for estimation of atmospherically-derived nitrogen in grass-clover systems. Biological Agriculture and Horticulture 12(3): 263-276.

Kristensen, I. T. 2014. Arealfordeling, dyrehold og gødskning på konventionelle og økologiske brug i 2011, efter gødningsregnskaber, DFFE's Centrale LandbrugsRegister (CLR), Det Central HusdyrRegister (CHR), Kort- og Matrikelstyrelsens adressekoordinater og Plantedirektoratets økologi- og gødningskontrol.

Kristensen, T. 2015. Beregning af grovfoderudbytte på kvægbrug ud fra regnskabstal. DCA rapport 57, 27 pp.

Kristensen, T., Mogensen, L., Knudsen, M.T., Hermansen, J.E., 2011. Effect of production system and farming strategy on greenhouse gas emissions from commercial dairy farms in a life cycle approach. Livest. Sci. 140, 136–148.

Kristensen, T., Jensen, C., Weisbjerg, M.R., Aaes, O., Nielsen, N.I. 2015a. Feeding, production and efficiency of Holstein-Friesian, Jersey and mixed-breed lactating dairy cows in commercial Danish herds. J. Dairy Sci. 98, 1-12.

Kristensen, T., Søegaard, K., Eriksen, J., Mogensen, L. 2015b. Carbon footprint of cheese produced on milk from Holstein and Jersey cows fed hay differing in proportion of herb content. J. Cleaner Prod., 101 (4), 229-237

Kristensen, T., Søndergaard, L.S. 2017. Grovfoderproduktion på danske malkekvægbedrifter. http://anis.au.dk/aktuelt/nyheder/vis/artikel/grovfoderproduktionen-paa-danske-malkekvaegbedrifter/

Lehmann, J., Mogensen, L., Kristensen, T. 2017. Economic, productivity and climate impact of managing cows in a dairy herd for extended lactation. In prep.

Lettens, S., J. O. S. Van Orshoven, B. A. S. Van Wesemael, B. Muys and D. Perrin. 2005. Soil organic carbon changes in landscape units of Belgium between 1960 and 2000 with reference to 1990. Global Change Biology 11(12), 2128-2140.

Marton, S. M. R. R., Zimmermann, A., Kreuzer, M., Gaillard, G. 2016. Comparing the environmental performance of mixed and specialized dairy farms: the role of system level analyzed. J. Cleaner Prod., 124, 73-84.

Mogensen, L., Kristensen, T., Nguyen, T. L. T., Knudsen, M. T., Hermansen, J.E. 2014. Method for calculating carbon footprint of cattle feeds – including contribution from soil carbon change and use of manure. J. Cleaner Prod. 73, 40-51.

Mogensen, L., Hermansen, J.E., Nguyen, L., Preda, T. 2015. Environmental impact of beef. DCA rapport, 61, 81 pp.

Mogensen, L., Kristensen, T., Knudsen, M. T., Preda, T. 2017. Sustainability values for feedstuff –In prep.

Nielsen, A.H., Kristensen, I.S. 2005. Nitrogen and phosphorus surpluses on Danish dairy and pig farms in relation to farm characteristics. Livest. Prod. Sci. 96, 97-107.

Nielsen, O. K., M. S. Plejdrup, M. Winther, M. Nielsen, S. Gyldenkærne, M. H. Mikkelsen, R. Albrektsen, M. Thomsen, K. Hjelgaard, P. Fauser, H. G. Bruun, V. K. Johannsen, T. Nord-Larsen, L. Vesterdal, O. H. Caspersen, E. Schou, K. Suadicani, E. Rasmussen, S. B. Petersen, L. Baunbæk and M. G. Hansen. 2016. "Denmark's National Inventory Report 2015 and 2016. Emission Inventories 1990-2014 - Submitted under the United Nations Framework Convention on Climate Change and the Kyoto Protocol. Aarhus University, DCE – Danish Centre for Environment and Energy. Report from DCE – Danish Centre for Environment and Energy 189: 1-947.

O'Brien, D., Shalloo, L., Patton, J., Buckley, F., Grainger, C., Wallance, M. 2012. A life cycle assessment of seasonal grass-based and confinement dairy farms. Agric. Syst., 107, 33-46

O'Brien, D., Capper, J.L., Garnsworthy, P.C., Grainger, C., Shalloo, L. 2014. A case study of carbon footprint of milk from high-performing confiment and grass-based dairy farms. J. Dairy Sci., 97, 1835-1851

Oenema, O., Kros, H., de Vries, W., 2003. Approaches and uncertainties in nutrient budgets: implications for nutrient management and environmental policies. Europ. J. Agronomy 20, 3-16.

Patra A.K., 2012. Enteric methane mitigation technologies for ruminant livestock: a synthesis of current research and future directions. Environmental Monitoring and Assessment 184, 1929-1952.

Poulsen, H.D., Kristensen, V.F. 1998. Standard values for farm manure. DIAS report no 7, Danish Institute of agricultural sciences, 166 pp.

xx. 2017. Survey on grasslands loss and proportion of grazed areas. Report DairyClim

Salou, T., Mouel, C.L., Werf, H.M.G. 2017. Environmental impacts of dairy system intensification: the functional units matters. J. Cleaner Prod., 140, 445.454

Soussana, J.F., Tallec, T., Blanfort, V. 2009. Mitigating the greenhouse gas balance of ruminant production systems through carbon sequestration in grasslands. Animal, 4:3, 334-350

Taghizadeh-Toosi, A., Christensen, B.T., Hutchings, N.J., Vejlin, J., Kätterer, T., Glendining, M., Olesen, J.E. 2014. C-TOOL – A soil carbon model and its parameterization. Ecological Modelling 292: 11-25.

Thomassen, M.A., van Calker, K.J., Smits, M.C.J., Lepema, G.L., de Boer, I.J.M. 2008. Life cycle assessment of conventional and organic milk production in the Netherlands. Agr. Syst. 96, 95-107.

Tuomisto, H.L., Hodge, I.D., Riordan, P., Macdonald, D.W. 2012. Comparing energy balances, greenhouse gas balances and biodiversity impacts of contrasting farming systems with alternative land uses. Agri. Syst., 108, 42-49.

Van der Welf, H.M.G., Kanyarushoki, C., Corson, M-S. 2009. An operational method for evaluation of resource use and environmental Impacts of dairy farms by life cycle assessment. J. Environ. Manage., 90 (11), 3643-3653.

Wesemael, B van., Paustian, K., Meersmans, J., Goidts, E., Barancikova, G., Easter, M. 2010. Agricultural management explains historic changes in regional soil carbon stocks. Proceedings of the National Academy of Sciences of the United States of America 107(33): 14926-14930.

Vinther, F. P. 2005. SimDen - A simple model for quantifying denitrification and N2O emission. In: Stensberg, M., Nilsson, H., Brynjolfsson, R., Kapuinen, P., Morken, J. & Birkmose, T.S. (eds.). Manure - an agronomic and environmental challenge. Proceedings from NJF seminar **372**: 41-44.

United Nations. 2017. ClimWat. Food and Agriculture Organization of the United Nations. Land & Water. http://www.fao.org/land-water/databases-and-software/climwat-for-cropwat/en/.