KU LEUVEN

DEPARTMENT OF BIOSYSTEMS, MEBIOS,
SUSTAINABILITY IN THE AGRI-FOOD CHAIN

Carbon Footprint Flemish Milk

Reference year 2019

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Content

1 Introduction

In this study, the carbon footprint of Flemish milk was assessed for the reference year 2019. The approach for this assessment is mostly based on the carbon footprint methodology for livestock products developed by Bracquené et al. during a study for the Flemish government (Bracquené et al., 2011). In this original study, the carbon footprint of Flemish milk was assessed for the reference year 2009. In 2015, the carbon footprint of Flemish milk was assessed for the year 2014 and compared with reference years 2000 and 2009. The results of the different reference years (2000 – 2009 – 2014 – 2019) are compared in this study to map the evolution in the carbon footprint of Belgian milk. Although the methodology of the original study is mostly followed, some adaptations were required:

- Since 2011, more accurate emission factors (EFs) for animal feed ingredients have been published in literature (Blonk Consultants, 2019). These new EFs were integrated in the new calculations for this study and, in order to allow a fair comparison, the 2009 results have been re-calculated taking into account these new EFs.
- Milk powder is consumed by calves and has a high emission factor. Unlike the studies of previous reference years, this study included the impact of milk powder, and in order to allow a fair comparison, the results of the previous reference years have been re-calculated taking into account the consumption of milk powder.
- In this study, the most recent guide to standard life cycle assessment methodology of the International Dairy Federation (IDF) was considered (International Dairy Federation, 2015), while the studies of previous reference years considered earlier versions of this guide (International Dairy Federation, 2010). The most recent guide includes a slightly different formula to calculate the allocation factor for milk than the previous version.

2 Materials and methods

The carbon footprint calculation method developed by Bracquené et al. (2011) was applied using the collected data for the 2019 reference year. The most recent guide to standard life cycle assessment methodology of the International Dairy Federation (IDF) was considered (International Dairy Federation, 2015). The system boundary of this study starts at the production of raw materials (“cradle”) to the point the milk leaves the farm (“farm gate”) and does not include any further processing (as shown in Figure 1). The functional unit is one kg of fat- and protein-corrected milk (FPCM, raw milk with 4% fat and 3.3% protein) at the moment the milk leaves the farm.

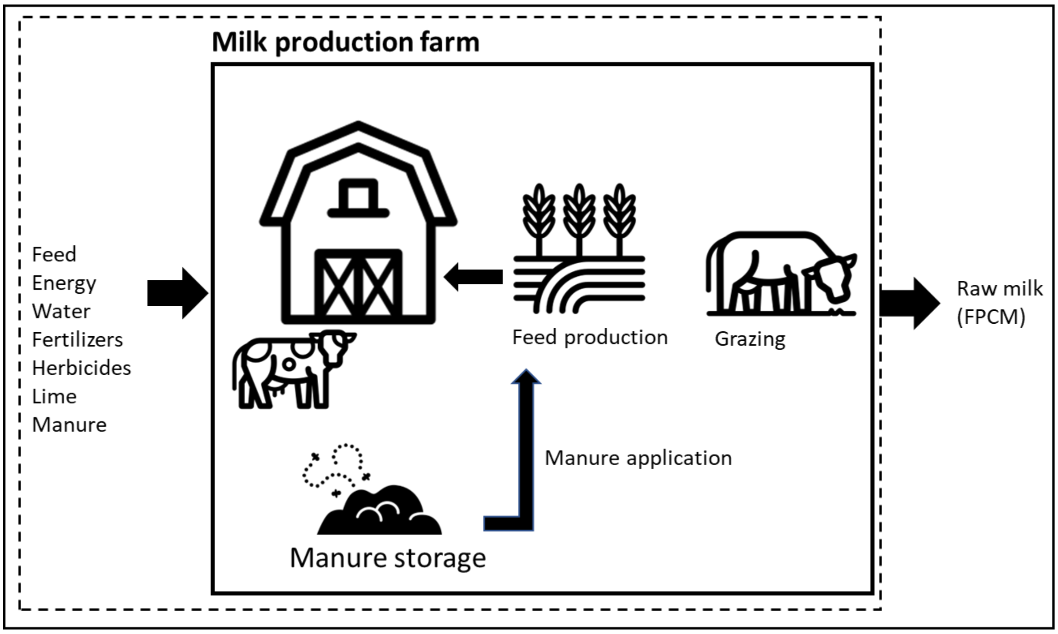

Figure 1. System boundaries of the carbon footprint calculations of milk.

Data concerning the milk farms were delivered by Boerenbond and represent the average of 138 specialized milk production farms in Flanders. Data concerning feed composition were delivered by the Belgian Feed Association (BFA), data on feed type shares by AVEVE and data concerning water use were retrieved from a technical report (Departement Landbouw en Visserij, 2018). As explained in the introduction, wherever possible, advancements in data availability and/or modeling accuracy are included. Table 1 compares data used for the carbon footprint assessment for reference years 2000, 2009, 2014 and 2019. The values are hidden due to confidentiality reasons, but are used in the calculations.

Table 1. Activity data for the reference years 2000, 2009, 2014 and 2019 for the average farm, used for the carbon footprint calculations. The data are delivered by Boerenbond in 2020 or calculated based on the delivered values. For the reference years 2000, 2009 and 2014, they are not always identical to values used in calculations. Due to confidentiality reasons, the values are hidden in this table.

Reference year	**2000**	**2009**	**2014**	**2019**
Number of farms	x	x	x	x
Milk production (liters raw milk /(cow year))	x	x	x	x
Total milk available at farm gate (kg raw milk / year)	x	x	x	x
Total FPCM available at farm gate (kg FPCM / year)	x	x	x	x
Animals sold for beef (kg)	x	x	x	x
Farm population				
# milk cows (average)	x	x	x	x
# calves <3 months	x	x	x	x
# heifer 3 – 12 months	x	x	x	x
# heifer 1 – 2 years	x	x	x	x
# heifer > 2 year	x	x	x	x
# calves <1y sold from farm	x	x	x	x
Time between calving (days)	x	x	x	x
Final live weights of cows – Inventory BB				
Weight of milk cow (kg)	x	x	x	x
Weight of heifer > 1 year (kg)	x	x	x	x
Weight of heifer < 1 year (kg)	x	x	x	x
Weight of unproductive cow sold (kg)	x	x	x	x
Live weights of cows – average values (used in calculations)				
Weight of mature dairy cows (kg)	x	x	x	x
Weight of Heifers calve <3 months (kg)	x	x	x	x
Weight of Heifers 3-12 months (kg)				x
Weight of Heifers 1-2 years (kg)	x	x	x	x
Weight of Heifers >2 years (kg)	x	x	x	x
Purchased feed – concentrates (kg per cow per year)				
Balanced concentrates	x	x	x	x
Protein rich (soy, turnip meal, rapeseed,...)	x	x	x	x
Minerals	x	x	x	x
Grains (own production + purchased)	x	x	x	x
Dry pulp	x	x	x	x
Press pulp	x	x	x	x

Wet by-products (own production + purchased)	x	x	x	x
CCM (own production + purchased)	x	x	x	x
Other (own production + purchased)	x	x	x	x
Heifer flakes	x	x	x	x
Milk powder	x	x	x	x
Produced feed – roughages – field areas (ha)				
Pasture	x	x	x	x
Corn	x	x	x	x
Wheat	x	x	x	x
Ryegrass + green manure	x	x	x	x
Protein rich roughages	x	x	x	x
Produced feed – roughages – total production (kg/year)				
Pasture	x	x	x	x
Corn	x	x	x	x
Wheat	x	x	x	x
Ryegrass + green manure	x	x	x	x
Protein rich roughages	x	x	x	x
Produced feed – roughages – consumption per cow (kg per cow per year)				
Pasture	x	x	x	x
Corn	x	x	x	x
Wheat	x	x	x	x
Ryegrass + green manure	x	x	x	x
Protein rich roughages	x	x	x	x
Digestible energy feed	x	x	x	x
Produced feed – applied fertilizer (N/ha)				
Pasture	x	x	x	x
Corn	x	x	x	x
Wheat	x	x	x	x
Ryegrass + green manure	x	x	x	x
Protein rich roughages	x	x	x	x
Produced feed – applied lime (kg/ha)				
Pasture	x	x	x	x
Corn	x	x	x	x
Wheat	x	x	x	x
Ryegrass + green manure	x	x	x	x
Protein rich roughages	x	x	x	x
Manure management				
Grazing days mature cows	x	x	x	x
Grazing days heifers >1y	x	x	x	x
Grazing days heifers <1y	x	x	x	x
% spread on pasture	x	x	x	x
% pit storage	x	x	x	x
% solid storage	x	x	x	x

Energy and water use				
Grid electricity (kWh/year)	x	x	x	x
Own production electricity (kWh/year)	x	x	x	x
Gas oil (litres/year)	x	x	x	x
Diesel (litres/year)	x	x	x	x
Gasoline (litres/year)	x	x	x	x
Propane (litres/year)	x	x	x	x
Total water use (m3/year)	x	x	x	x

2.1 Farm population

The average livestock population on the modeled farm consists of 118 milk cows, 12 calves younger than 3 months, 31 heifers between 3 and 12 months, 38 heifers between 1 and 2 years and 6 heifers older than 2 years. One mature cow produces 0.91 calves per year on average. The milk production per milk cow is 9170 liters per cow per year. A clear increase in total milk production on the farm can be observed from 2000 to 2019, due to an increase in milk productivity (from 6757 to 9170 liters per year per cow) and the average amount of milk cows on the farm (from 57 to 118).

The live weight of the cows are estimated for each growing phase. The bookkeeping of Boerenbond provides the weights of the final inventory. However, in the calculations the average weight of each growing phase are used, as they are more accurate estimations of the live weights. Both the final (from the database) and average (used in the CF calculations) live weights are provided in Table 1.

2.2 Feed

Feed is partly produced on the farm (roughages) and partly purchased (concentrates).

2.2.1 Concentrates

As shown in Table 1, the total use of purchased feed (concentrates) per cow has increased compared to previous years. The composition of the "balanced" concentrate feed and the “protein rich” feed fluctuates between years. Table 2 shows the ingredients of the feed in 2000, 2009, 2014 and 2019. The content of the ingredients in the feed products are hidden due to confidentiality reasons. In 2019, the composition of the calve feed (heifer flakes) was taken into account separately, while in the previous calculations it was considered together with the cow feed. The consumed amounts of balanced and protein rich feed include different composed feeds: “milk cows 20 110” (56%), “milk cows 38 185” (24%) and “VLOG” (20%). The feed compositions are provided by BFA and the shares of the different feeds are provided by AVEVE. For 2014, a division of 75% for “milk cows 20110” and 25% for “milk cows 38185” was assumed. For 2000 and 2009, only one feed product was considered; “milk cows 26130”.

Table 2 also shows the emission factors of the feed products. In previous years, the EFs of the feed ingredients were retrieved from a preliminary database provided by Blonk Consultants. The project was still in development at that time and was recently finalized (in 2019). This resulted in a new updated database named the ‘Global Feed Lifecycle Institute (GFLI)’ (Blonk Consultants, 2019). The EFs of the feed ingredients in the currently available database differ from the values retrieved from the preliminary database in 2011. The authors of the GFLI database were consulted in order to understand the large differences in terms of specific greenhouse gas emissions for some feed ingredients (Mike van Paassen, Blonk Consultants, personal communication, 14/08/2020). The difference in EFs can be explained by the fact that more aspects (use of manure, lime and pesticides) were considered in the GFLI database.

The GLFI database is used in the carbon footprint calculation of this study because it represents the most recent, complete and accurate data. However, an important goal of the current study is to map the carbon footprint evolution for Flemish milk production at farm level between 2000, 2009, 2014 and 2019. Therefore, in order to compare the carbon footprint of milk calculated for 2019 with the carbon footprint results of previous years, the feed EFs were also adjusted in the carbon footprint calculation of the previous years. For the previous years, Table 2 shows both the emission factors used in the original study and the updated values based on the GLFI. In the previous calculations, the consumption of milk powder was not considered, while the consumption of milk powder is recorded in the bookkeeping of Boerenbond. In the results with the updated EF’s from the GLFI database, the impact of milk powder is included.

Table 2. Feed compositions and emission factors of purchased feed and emission factors of feed components. The crosses indicate that the feed product contains the ingredient, however, the amounts are hidden due to confidentiality reasons.

	Emission factor (CO_2 eq. /kg)	**Feed composition (%)**						
		2000/ 2009	2014		2019			
		Milk cows 26130	Milk cows 20110	Milk cows 38185	Milk cows 20110	Milk cows 38185	Milk cows VLOG	Calve feed
% consumed per stage		100%	75%	25%	56%	24%	20%	100%
Barley	0.42				x			x
Soy meal AR	2.69	x	x	x	x	x		x
Palm kernel	3.41	x	x	x	x	x		x
Wheat	0.47	x	x		x			x
Protifeed (wheat)	0.47	x		x				
Soy hulls	1.35	x	x	x	x			x
Maize	0.47				x	x		x
Rapeseed meal	0.66	x		x	x	x	x	
Maize gluten feed	1.72							
Sugarbeet pulp	0.00				x		x	x
Linseed flakes	3.44							x
Rapeseed flakes	1.02							
Amyplus	0.27							
Maize germ meal	0.48		x					
Wheat gluten feed	0.66		x					x
Minerals and vitamins	1.18				x	x	x	x
Soy meal BR (non-GMO)	2.69						x	
Sugar beet molasses	0.21				x	x	x	x
Vinasse	0.75				x	x	x	x
Proticorn (maize distillers grais)	1.02					x	x	
Sunflower seed meal	0.86							x
Palm oil	9.26							x
Total emission factor (original (CO_2 eq. / kg)		**1.29**	**1.12**					
Total emission factor (updated) (CO_2 eq. / kg)		**1.67**	**1.32**		**0.96**	**2.16**	**1.49**	**1.32**

2.2.2 Roughages

Table 1 shows the field areas, the total production and the consumption amounts of roughages produced on the farm. The yield of the feed produced on the farm in 2019 is assumed to remain equal to the yields in 2014. The field areas and therewith the total feed production on the farm in 2019 have increased slightly compared with the previous years, and for protein rich roughages the field area and production have increased considerably to 2.8 ha or 84 000 kg/year. Because of the larger average number of dairy cows on the farm, the amount of roughage per cow has decreased, except for protein rich feed. It should be noted that in reality, the consumed amount of roughages per cow has not decreased, because roughages are bought from other farms to meet the demand. In 2019 specifically, in which the harvest of corn was very low, more corn and grass was purchased compared to the years before. These purchased roughages are however not accounted for in the calculations.

For the reference year 2019, the following amount of artificial fertilizer are recorded:

- 733 kg artificial fertilizer (203 units N) and 101 kg lime per ha pasture;
- 693 kg artificial fertilizer (192 units N) and 209 kg lime per ha ryegrass;
- 123 kg artificial fertilizer (34 units N) and 210 kg lime per ha corn;
- 530 kg artificial fertilizer (147 units N) and 543 kg lime per ha protein rich roughages;
- 589 kg artificial fertilizer (163 units N) and 119 kg lime per ha wheat.

As can be seen in Table 1, the amount of applied N is comparable with the amounts applied in previous years, whereas the amounts of lime applied differ significantly from the amounts applied in previous years.

Additionally, applications of 100m^3 pig manure and 65 kg herbicide in total are assumed, divided over the different crops according to field areas.

2.3 Manure management

It is assumed that mature cows graze 8 hours per day during 6 months, corresponding with approximately 61 grazing days per year, slightly higher than the amount in 2014 but lower than the amounts in 2000 and 2009. Comparable to previous years, 183 grazing days are considered for heifers older than 1 year and 30 days are considered for calves younger than 1 year. This results in 18% of the manure directly deposed on the pasture. Pit storage represents 62% and the solid storage represents 20%.

2.4 Energy and water use

The average farm uses on average 44708 kWh purchased electricity and 7347 kWh electricity that is produced on the farm. Further, 12921 liter of gas oil, 74 liter of diesel, 4 liters of gasoline and 1 liter of propane per year. The total water use per year is 4791 liters per year. The energy and water use in 2019 was higher compared to previous years.

2.5 Allocation

Allocation between milk and meat was based on the most recent IDF guidelines (International Dairy Federation, 2015), in which a physical allocation method is recommended and the following formula is proposed to calculate the allocation factor for milk:

$$AF_{milk} = 1 - 6.04 \times BMR$$

in which BMR represents the beef to milk ratio: the sum of live weight of animals sold divided by the sum of fat- and protein- corrected milk (FPCM) sold per farm per year (as shown in table 1). This leads to an allocation of 89.2% to milk and of 10.8% to meat.

For the previous years, the previous version of the IDF guidelines were followed (International Dairy Federation, 2010), which proposed a slightly different version of the formula to determine the allocation factor for milk:

$$AF_{milk} = 1 - 5.7717 \times BMR$$

In 2000, this led to an allocation of 83.9% to milk and of 16.1% to meat, in 2009 to an allocation of 88.2% to milk and of 11.8% to meat and in 2014 to an allocation of 87.6% to milk and 12.4% to meat. The higher allocation factor for milk in 2019 is caused by an increase in milk production per cow compared to the previous years, and is not affected considerably by the updated formula to calculate the allocation factor for milk.

3 Results

The carbon footprint of 1 kg of FPCM on the modelled farm in 2019 is 0.93 kg CO_2 eq. As shown in Figure 2, the average carbon footprint in 2019 is lower than the carbon footprints in 2000, 2009 and 2014, which were 1.32, 1.10 and 0.98 respectively. Figure 1 also shows the results of the previous years without updating the emission factors of the feed components. As discussed in previous chapters, only the results with updated EF’s can be compared directly with the results of 2019.

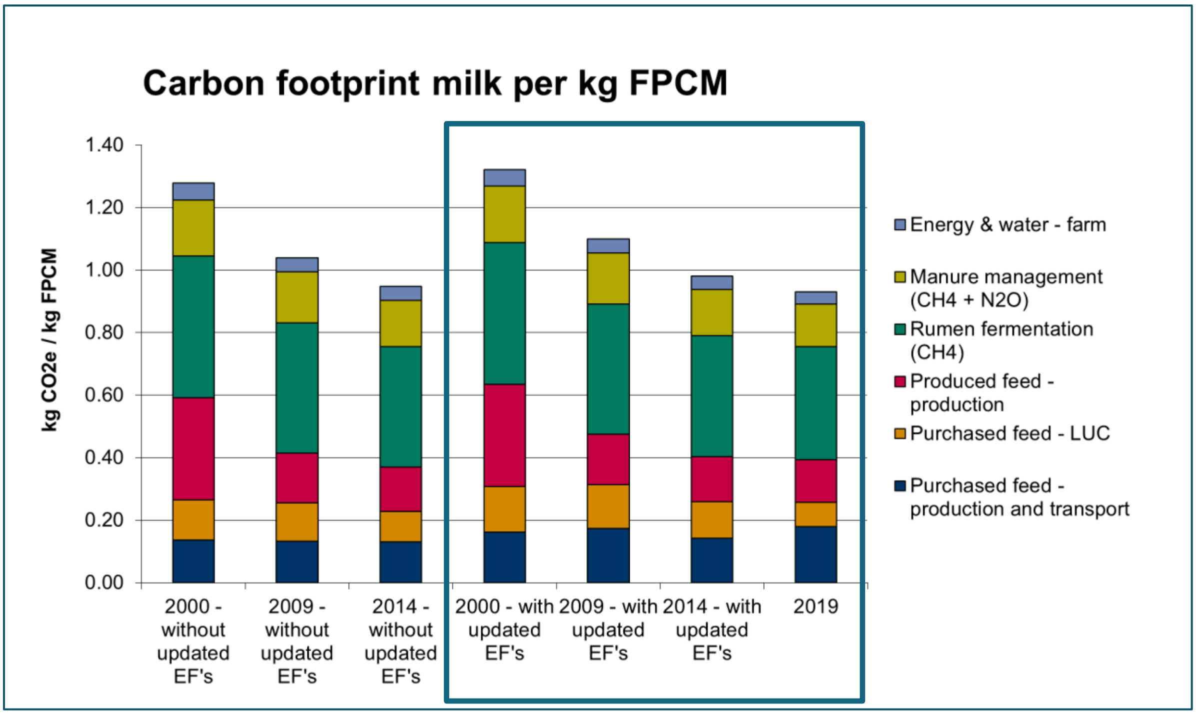

Figure 2. Carbon footprint of 1 kg of FPCM in 2000, 2009, 2014 and contributing processes (with and without update feed EF’s) and in 2019.LUC= Land Use Change.

Table 3 shows the contribution of the different emissions sources to the total carbon footprint of milk. The main contributor to the carbon footprint is the enteric fermentation, which is responsible for 38.9%. The impact of enteric fermentation has decreased compared to the previous years, mainly due to the higher total milk production. The impacts of the other emission sources have decreased as well, except for the purchased feed. This is due to an increase in the consumption of concentrates and due to feed ingredients with high emissions factors such as palm oil and milk powder.

Table 3. Carbon footprint of 1 kg of FPCM in 2000, 2009, 2014 and contributing processes (with and without update feed EF's) and in 2019.

Emission source	**2000 - without updated EF's**		**2009 - without updated EF's**		**2014 - without updated EF's**		**2000 - with updated EF's**		**2009 - with updated EF's**		**2014 - with updated EF's**		**2019**	
	kg CO_2 eq./ kg FPCM	**%**	**kg CO_2 eq./ kg FPCM**	**%**	**kg CO_2 eq./ kg FPCM**	**%**	**kg CO_2 eq./ kg FPCM**	**%**	**kg CO_2 eq./ kg FPCM**	**%**	**kg CO_2 eq./ kg FPCM**	**%**	**kg CO_2 eq./ kg FPCM**	**%**
Purchased feed - production and transport	0.14	**10.7 %**	0.13	**12.8 %**	0.13	**13.7 %**	0.16	**12.2 %**	0.17	**15.8 %**	0.14	**14.6 %**	0.18	**19.2 %**
Purchased feed - LUC	0.13	**9.9 %**	0.12	**11.7 %**	0.10	**10.4 %**	0.15	**11.1 %**	0.14	**12.8 %**	0.12	**12.0 %**	0.08	**8.5 %**
Produced feed - production	0.33	**25.6 %**	0.16	**15.4 %**	0.14	**14.9 %**	0.33	**24.8 %**	0.16	**14.5 %**	0.14	**14.4 %**	0.14	**14.4 %**
Enteric fermentation (CH4)	0.45	**35.4 %**	0.42	**40.1 %**	0.39	**40.8 %**	0.45	**34.3 %**	0.42	**37.9 %**	0.39	**39.5 %**	0.36	**38.9 %**
Manure management (CH4 + N2O)	0.18	**14.0 %**	0.16	**15.7 %**	0.15	**15.6 %**	0.18	**13.6 %**	0.16	**14.9 %**	0.15	**15.1 %**	0.14	**14.7 %**
Energy & water - farm	0.05	**4.2 %**	0.05	**4.4 %**	0.04	**4.6 %**	0.05	**4.1 %**	0.05	**4.1 %**	0.04	**4.5 %**	0.04	**4.3 %**
Total	1.28		1.04		0.95		1.32		1.10		0.98		0.93	

Due to an increase in farm scale and milk productivity, the impact per kg FPCM has decreased for each emissions source except for purchased feed. The different factors that influence the results are discussed in detail below.

3.1 Farm population

The number of animals on the farm and the productivity of the milk cows has increased. This results in a higher amount of FPCM per farm per year, which balances out the increase in used resources and emissions.

The beef to milk ratio (BMR) in 2019 has decreased compared to previous years, leading to a larger allocation of the impact to milk production in 2019 (89.2% compared to 83.9% in 2000, 88.2% in 2009 and 87.6% in 2014).

3.2 Feed

The impact of the purchased feed has increased compared to previous years, while the impact of land use change has decreased. This is due to an increase in concentrate consumption per cow, as well as feed ingredients with a high emission factor, such as palm oil and milk powder. Note that the impact of milk powder was not taken into account in the non-updated calculations (despite it now, for the sake of completeness, being reported in Table 1 for all years).

Since 2006, Belgian feed producers endorse the Amazone Soy Moratorium (BFA, 2019), an agreement which aims to ensure soy production only on non-deforested areas in the Amazons. This could decrease the impact of land use change of the soy within the purchased feed. More specifically, after 20 years, the usual period considered for the impact of land use change (IPCC, 2006b), the land use change impact of soy from the Amazons could diminish. However, land use changes related with the cultivation phase of other products that have occurred in the last 20 years should be taken into account (IDF, 2015).

3.3 Enteric fermentation

The total emissions on the farm from enteric fermentation in 2019 were higher than the previous years because of the higher weight of the animals and therewith the total energy requirements. This is balanced out by the higher total milk production, and, to a lower extend, the higher digestible energy of the feed, leading to lower emissions per kg produced milk.

3.4 Manure management

The total methane emissions on the farm from manure management in 2019 were higher than the previous years because of the higher number of animals and the higher energy requirement. This is however balanced out by the higher total milk production, leading to lower methane emissions per kg produced milk. The total nitrous oxide emissions on the farm were higher than previous years, because of the higher number of animals and higher nitrogen excretion rates. The higher proportion of manure directly deposed on pasture in 2019 led to higher direct nitrous oxide emissions but lower indirect nitrous oxide emissions. The higher total nitrous emissions of the farm are balanced out by the higher total milk production in 2019.

3.5 Energy and water use

Although the total energy use per farm in 2019 is considerably higher than in the previous years, the energy use per kg milk in 2019 is lower due to increased milk production. Even though the water use per kg live weight has increased, this has a negligible effect on the overall carbon footprint results.

3.6 Carbon uptake in soil – pasture

According to the most recent IDF guidelines, carbon sequestration should not be taken into account in carbon footprint calculations of dairy systems, due to the large uncertainty and the lack of global data. However, soil carbon sequestration could have a mitigation potential for climate change. Therefore, the IDF recommends to calculate the net fluxes of carbon storage / emission and report them separately (IDF, 2015). Therefore, a rough, preliminary estimation was made of the potential carbon uptake by the pasture of the modeled farm.

In 2017, the research institute for agriculture, fisheries and food (ILVO) published a study about the possibilities of carbon storage under pasture and arable land (ILVO, 2017). According to this report, if 1 ton of stable carbon is stored in the soil, 3.7 tons of CO_2 are taken up from the air. It further states that permanent pasture can take up in between 0.5 and 1.0 ton of carbon per hectare per year, after being transformed from arable land. After a certain amount of time (some studies indicate > 40 years), the carbon stock is however stable and does not take up additional carbon anymore. When analyzing this stable carbon stock under pasture for different soil types, namely clay, loam and sand, results indicate a carbon stock of 163, 109 and 132 ton C/ha under grassland which is intensively grazed (ILVO, 2017).

Based on data delivered by Boerenbond, it can be assumed that an average Flemish milk production farm has 28.55 hectares of pasture, of which approximately 19.03 hectares are permanent and 9.52 hectares are temporarily. The average milk production farm further has 23.64 hectares of arable land.

Based on above mentioned information, an estimation of the potential carbon uptake by pasture on the average farm was made. It was assumed that the carbon stock under the arable land and the temporarily grassland stays constant (if grassland is converted to arable land, carbon is lost again). The carbon uptake was calculated by considering the hectares of permanent pasture, the amount of milk produced on the farm and the average carbon uptake per hectare. Based on the information mentioned above, it is assumed that the pasture is converted from arable land and that the carbon stock is not stable yet.

$$CO_2\ uptake = \frac{3.7\,\frac{ton\ CO_2}{ton\ C} * 0.75\,\frac{ton\ C}{ha.year} * 19.03\ ha}{1173196\,\frac{kg\ FPCM}{year}} = 0.000045\ \frac{ton\ CO_2}{kg\ FPCM} = 0.045\ \frac{kg\ CO_2}{kg\ FPCM}$$

Considering the carbon footprint of 0.93 kg CO2 eq. per kg FPCM, carbon uptake by permanent pasture with a non-stable carbon stock has an estimated potential of about 5% to lower the total carbon footprint of Flemish milk.

4 Conclusion

The carbon footprint of 1 kg Flemish fat- and protein- corrected raw at farmgate in 2019 is 0.93 kg CO_2 eq. The carbon footprint has decreased with respectively 29.7%, 15.51% and 5.1% compared to 2000, 2009 and 2014. This decrease is mainly due to an increase in farm scale and milk productivity. It is relevant to note that the carbon footprint is a *global* environmental impact indicator, and does not take into account the potential local rural and environmental impact of farm holdings.

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