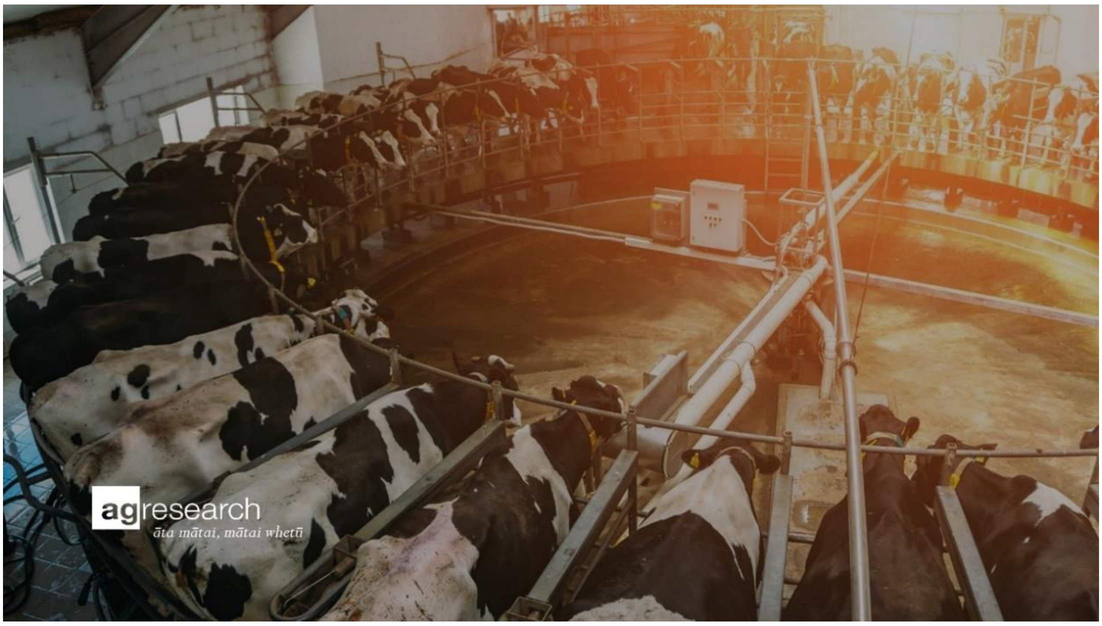
Carbon footprint of milk production at Lincoln University Dairy Farm (LUDF)

Andre Mazzetto

May 2020



Report for LUDF

RE450/2020/033

agresearch
āta mātai, mātai whetū

Contents

1. Executive Summary

This carbon footprint study covers cradle-to-farm-gate milk production at Lincoln University Dairy Farm. Data from farm-level was collected and used to calculate the total greenhouse gas emissions (in carbon-dioxide equivalents, CO_2-eq), for milk to the farm gate using internationally-agreed life cycle assessment (LCA) methodology. It accounted for emissions from the milking platform and all other land associated with milk production (e.g. areas for grazing replacements, cow wintering-off and production of brought-in feeds), as well as emissions from the production, transport and use of all farm inputs (including fertilisers, agrichemicals, brought-in feeds, fuel and electricity).

The carbon footprint for 1 kg of fat-and-protein-correct milk (FPCM) was 0.68 kg CO_2-eq/kg FPCM. The carbon footprint for 1 kg of milk solids (MS) was 8.52 kg CO_2-eq/kg MS.

The relative contributions from methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2) were 76%, 16% and 9%, respectively. The main contributor to the carbon footprint of milk was the enteric fermentation associated with animal rumen digestion of feed (73% of total). The second main sources were the CO_2 emissions from pasture production (for the main dairy farm, support block and wintering off areas) and CO_2 emissions from fertiliser (production and use of urea), both accounting for 5% of total CO_2e emission. The carbon footprint for milk production calculated in this study for the LUDF is lower than the most recent published study in NZ for an average dairy farm (0.78 kg CO_2e / kg FPCM for 2017/2018 – Ledgard et al., 2020).

2. Introduction

Recently, consumers have been concerned about the environmental impacts associated with the production of food. Milk is an important product for human nutrition, and the greenhouse gas (GHG) emissions from dairy production have been a common way to evaluate the efficiency of milk production. The carbon footprint (total GHG emissions divided by total milk production) is calculated using a life cycle assessment (LCA) approach and aims to capture all GHG emissions, including those from extraction of raw materials used through all stages of the life cycle.

Lincoln University Dairy Farm (LUDF) is interested in assessing the carbon footprint of milk produced from its demonstration farm. The objective of this study was to determine the carbon footprint of milk produced by LUDF from a cradle-to-farm-gate LCA perspective.

3. Materials and Methods

The scope of the carbon footprint study covers the cradle-to-farm-gate for one kg of fat-and-protein-corrected-milk (FPCM) or one kg of milk solids (MS). An LCA methodology was used (e.g. International Dairy Federation (IDF), IDF (2015) and Chobtang et al. (2016)), that complies with international standards (ISO 2006), and has a system boundary for milk production from the “cradle-to-farm-gate”. The calculated GHG emissions were allocated between the co-products milk and live-weight sold for meat based on the physiological feed requirements of the animal to produce milk and meat (surplus calves, culled cows) using the IDF (2015) methodology.

The boundaries of the study were expanded to account for all the relevant activities for milk production, including the wintering of cows off farm and the support blocks used for grazing replacement animals. Figure 1 summarises key elements of the system boundary for the LUDF farm. All stages of transportation and the associated GHG emissions from production and combustion of fuel within the system boundary were fully accounted for. It included transportation of feeds and chemicals (including fertilisers) to the farm and the fuel use within the farm system. It also included the transportation of the animals to/from the wintering-off farm and to/from the support block used to graze replacement animals. It did not include transport of surplus animals from the farm-gate to the meat processor or transport of milk from the farm gate to the dairy factory. Other areas of fuel use that were accounted for were in transportation of chemicals to farms. The GHG emission factor for electricity use was based on the NZ average grid mix from Ecoinvent 3.5. Minor agri-chemicals such as treatments for intestinal parasites, mastitis and shed cleaning chemicals were not accounted for in the carbon footprint assessment, but will have had a negligible contribution.

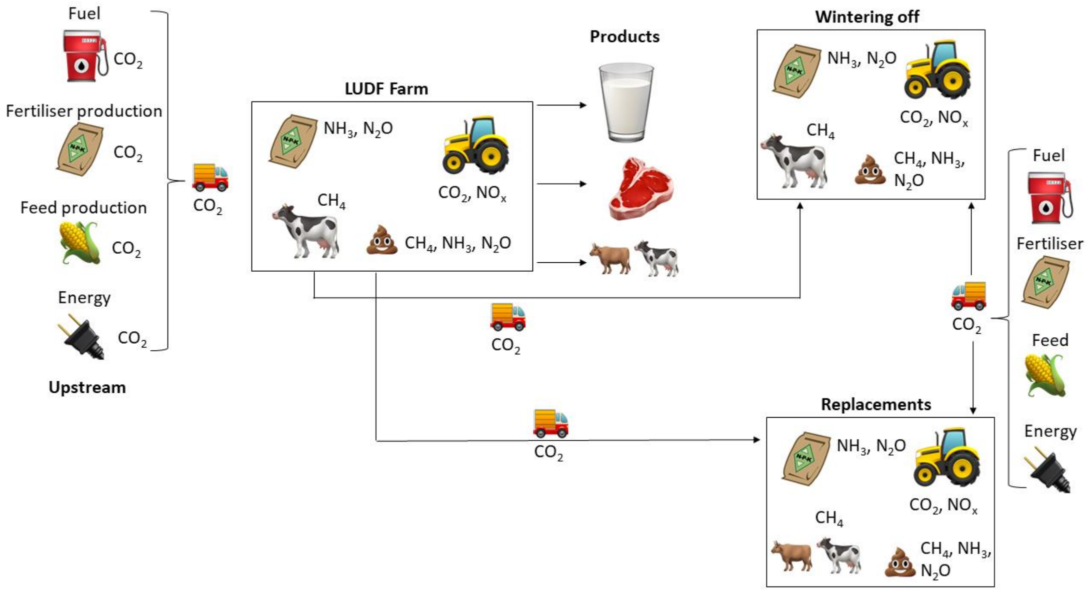


Figure 1 – Cradle-to-farm-gate life cycle assessment (LCA) of milk production from the Lincoln University Dairy Farm (LUDF), including the wintering of cows off-farm and the grazing of replacement animals on a support block.

A dairy cattle population summary was provided by LUDF farm staff for a 12-month period (2018/19), which included milking cows and all replacements. Table 1 gives a summary of milk production and animal numbers. Data provided by LUDF on animal numbers, their average liveweights and sales of surplus animals was used to define the total live-weight of surplus cattle sold from the farm (cull cows, cull heifers and surplus calves) over the 12 months.

Table 1. Summary of annual milk production, and animal data for the LUDF farm in 2018/2019.

	Units	LUDF
Milk production	kg FPCM	3,556,426
Milk production	kg MS	285,670
Milk fat concentration	% by kg	4.99
Milk protein concentration	% by kg	4.02
Milking cows	number	550
Surplus cattle sold	kg LW	72,160
Number of replacements (R1s)	number	185
Number of replacements (R2s)	number	158

Replacement rate	%	25
Allocation to milk*	%	88

*based on relative feed requirements for milk production to milk plus meat

LUDF also provided data on the quantities (dry weight) of the range of feeds fed to all animal classes (such as pasture silage). Simple carbon footprint models were developed for each of the feeds. These covered all life cycle emissions to the point of harvested/stored product or processed product (for concentrates), including all background emissions associated with the production and use of inputs such as fertilisers, fuel and pesticides (e.g. Figure 1).

Enteric methane (CH_4) emissions (from animal rumen digestion of feed) from all cattle were calculated using the dry matter intake from the different animal classes (based on NZ GHG Inventory) and an NZ-specific emission factor

Nitrous oxide emissions from cattle excreta were calculated assuming that the amount of N in excreta was the difference between the N in feed intake minus the N in the milk and meat using IPCC (2006) methodology. Methane and N_2O emissions from cattle excreta were also calculated, based on CH_4 and N_2O emission factors from the NZ GHG Inventory. The NZ GHG Inventory and default equations from IPCC (2006) were used for calculating all N_2O emission calculations for fertiliser and crop residues, respectively.

LUDF provided primary data on the fuel and electricity use associated with the dairy farm. Fuel use for all aspects of the production of crops and transportation of crops to the farm was calculated as part of the carbon footprint of feeds, as described previously. Electricity use for pumping water for irrigation was assumed to be included in the electricity data provided by LUDF.

The carbon footprint (equivalent to Global Warming Potential (GWP)) for a 100 year time horizon (GWP100) was calculated according to the IPCC 2013 method (IPCC 2006) in kg CO_2-equivalent (subsequently expressed as kg CO_2-eq). This has multiplication factors of carbon dioxide (CO_2) = 1, nitrous oxide (N_2O) = 265 and biogenic methane (CH_4) = 27.75.

4. Results and Discussion

The estimate of the carbon footprint (cradle-to-farm-gate) of milk production for the LUDF in 2018/19 was 0.68 kg CO_2-eq/kg FPCM, and 8.52 kg CO_2-eq/kg MS (Table 2). The main contributor to the carbon footprint of milk was enteric fermentation (73% of total). The emission from carbon dioxide CO_2 from other activities (production of pasture for the dairy farm, wintering off and replacements area) and the CO_2 emissions from fertiliser (production and application of urea) contributed both with 5% of the carbon footprint of milk. Other sources with much smaller contribution to the carbon footprint were urine, dung and farm dairy effluent (FDE) N_2O, CO_2 from fuel and electricity, CH_4 from dung and FDE, CO_2 from supplementary feeds and on-farm crop residues, all accounting for less than 5% of the total emission.

Table 2. Carbon footprint and percentage contribution from different sources to the carbon footprint of milk.

	kg CO_2-eq/kg FPCM	kg CO_2-eq/kg MS	%
Enteric CH_4	0.50	6.23	73%
CO_2 from other activities	0.04	0.47	5%
CO_2 from fertiliser application and production	0.03	0.44	5%
Urine, Dung and FDE N_2O	0.03	0.38	4%
Nitrogen fertiliser N_2O	0.03	0.37	4%
CO_2 from fuel and electricity	0.03	0.34	4%
Dung and FDE CH_4	0.02	0.23	3%
CO_2 from supplementary feed production	0.00	0.06	2%
N_2O from on farm crop residues	0.00	0.00	0%
Total	**0.68**	**8.52**	**100%**

FDE: Farm Dairy effluent

Other activities: pasture production on wintering off and replacements area

For the carbon footprint of milk production from LUDF, the relative contributions from CH_4, N_2O and CO_2 were 76%, 15% and 9%, respectively (Table 3). For CH_4, enteric fermentation dominated the emissions, accounting for 96% of total CH_4 emission. For N_2O, 50% were from excreta deposited on pasture (urine and dung), while 48% of N_2O emissions were from application of N fertiliser on pasture (Table 3). For CO_2, the largest contributing source was the pasture production, considering the wintering off and replacements area at 32%. The next largest sources of CO_2 were fertilisers and electricity, representing 28% and 21%, respectively (Table 3).

Table 3. Percentage contribution from various gases and sources to the carbon footprint of milk.

Source	LUDF
Methane (CH_4)	76%
Nitrous oxide (N_2O)	15%
Carbon dioxide (CO_2)	9%
Sources of CH_4:	
Enteric fermentation	96%
Manure/FDE/dung	4%
Sources of N_2O:	
Excreta on pasture	50%
N fertiliser on pasture	48%
Other	2%
Sources of CO_2:	
Production of pasture*	32%
N fertiliser production	28%
Electricity	21%
Other	19%

FDE: Farm Dairy Effluent
*Includes wintering off and replacements area

The result obtained (0.68 kg CO_2-eq / kg FPCM) is lower than the NZ average carbon footprint of milk calculated between 2010/2011 and 2017/2018 (0.75-0.81 kg CO_2-eq / kg FPCM) (Ledgard et al., 2020) and the average Canterbury carbon footprint (0.76 kg CO_2-eq / kg FPCM) (Ledgard et al., 2020). This conforms with a recent review of international dairy carbon footprint studies showing a lower carbon footprint with increased reliance on grazed pastures (Lorenz et al. 2017).

Among the main factors that influence the low value for the LUDF is the minimal use of brought-in feed and the pasture-based management on the farm. Dairy farms that rely on grazing of pasture usually show a proportionally high contribution of enteric methane in the total footprint (73% of total emission in this study is attribuited to enteric CH_4) which is also seen in this farm.

5. Acknowledgements

I thank Clare Buchanan and the LUDF team for her help in data collection and Stewart Ledgard and Shelley Falconer for their help building the LCA model.

6. References

Chobtang, J.; Ledgard, S. F.; McLaren, S. J.; Zonderland-Thomassen, M. and Donaghy, D. J. (2016). Appraisal of environmental profiles of pasture-based milk production: a case study of dairy farms in the Waikato region, New Zealand. *The International Journal of Life Cycle Assessment 21*. 311-325.

IDF (2015). A common carbon footprint approach for the dairy sector: The IDF guide to standard life cycle assessment methodology. Bulletin of the International Dairy Federation 479. Available at http://www.fil-idf.org/wp-content/uploads/2016/09/Bulletin479-2015_A-common-carbon-footprint-approach-for-the-dairy-sector.CAT.pdf. Accessed on 26 February 2020.

ISO (2006). Environmental management - Life cycle assessment - Requirements and guidelines, no. 14044. International Organization for Standardization. European Committee for Standardization, Brussels, Belgium.

IPCC (2006). IPCC Guidelines for National Greenhouse Gas Inventories: Volume 4: Agriculture, Forestry and Other Land Use Intergovernmental Panel on Climate Change, Paris, France (2006)

Ledgard, S.F.; Falconer, S.J.; Abercombie, R.; Phillip, G.; Hil, J.P (2020). Temporal, spatial and management variability in the carbon footprint of New Zealand milk. *Journal of Dairy Science* 103, 1031-1046.

Lorenz, H.; T. Reinsch; S. Hess; F. Taube (2019). Is low-input dairy farming more climate friendly? A meta-analysis of the carbon footprints of different production systems. Journal of Cleaner Production 211: 161-170.