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LIFE CYCLE ASSESSMENT OF DAIRY PRODUCTION SYSTEMS IN WAIKATO, NEW ZEALAND

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Abstract

Life Cycle Assessment (LCA) is a standardised approach to evaluate resource use and environmental emissions of a production system or product. It covers multiple stages, including raw material extraction, production of farm inputs and farm emissions (i.e. cradle-to-farm-gate stages), and can extend to milk processing, transport, consumer use and waste.

LCA has been applied in agriculture over the past decade to examine the total greenhouse gas (GHG) emissions associated with products such as milk. More recently it has been applied in assessing a range of environmental emissions. For example, the current European Product Environmental Footprinting initiative covers multiple environmental impact categories.

This paper reports on studies using LCA to evaluate effects of dairy intensification in the Waikato region of New Zealand (NZ; using DairyNZ DairyBase farm survey data) covering cradle-to-farm-gate stages. Initial focus was on the carbon footprint of milk (total GHG emissions) and the effects of intensification using different brought-in supplementary feeds. While GHG emissions per on-farm hectare increased with dairy intensification, there was little difference in GHG emissions per kg milk. However, the results depended on the type of feed used, with highest emissions from use of palm kernel expeller.

Recent research extended the use of LCA to evaluate a wider range of environmental impact indicators (up to 12). This evaluation showed an increase in emissions per kg milk for the high intensification level compared to the low intensification level of 5-32%, depending on the impact indicator, with the highest increase for Freshwater Ecotoxicity. Sensitivity analysis revealed the importance of using NZ-specific data, rather than relying in global default values, for Product Environmental Footprinting of NZ milk products. Across many environmental impact indicators, the off-farm stages of agrichemical (fertilisers and pesticides) production and production of off-farm feeds were significant contributors to total environmental emissions. This has implications for practices to reduce the environmental impacts from NZ agricultural products.

Introduction

Life Cycle Assessment (LCA) is a standardised approach to evaluation of resource use and environmental emissions of a production system or product and its application is based on ISO standards (ISO14040 series). It covers multiple stages, including raw material extraction, production of farm inputs and farm emissions (i.e. cradle-to-farm-gate stages), and can extend to processing, transport, consumer use and waste.

LCA can be used to examine a range of different resource use and environmental emission impact categories (e.g. resource depletion, climate change, acidification, eutrophication, eco-toxicity). An advantage of evaluating multiple environmental impact categories is that any 'pollution swapping' can be identified. Despite this, over the past decade most applications of LCA in agriculture, including dairying, have focused on the total greenhouse gas (GHG) emissions associated with products such as milk. For example, Flysjö et al. (2011) compared average New Zealand (NZ) and Swedish dairy systems and estimated their total GHG emissions (or carbon footprint) of milk to the farm-gate to be 1.0 and 1.2 kg CO_2-equivalents/kg fat-and-protein-corrected-milk (FPCM), respectively. This emphasis on the carbon footprint of products had been driven initially by its use for product labelling by some large United Kingdom supermarket chains and later extended to interest at a government policy level. More recently, there is increasing interest in the use of LCA for assessing a range of environmental emissions. For example, the European Commission (2013) currently has a major international programme on developing methodology for Product Environmental Footprinting (PEF) of products for European markets and beyond. This PEF programme, which includes agricultural products, is based on LCA and includes up to16 environmental impact and resource use categories relating to the broad areas of human health, ecosystem health (covering water and air quality indicators, including greenhouse gases) and resource depletion (e.g. EC-JRC-IES 2011). The European Commission has identified that PEF should be used by all member countries in the area of public procurement in future. It is likely that these methods will also be used by countries such as France that have been working on a requirement for environmental labelling of products in their supermarkets. Thus, it has important implications for all suppliers of products to European countries and beyond, including NZ suppliers of agricultural products.

This paper reports on recent research on the application of LCA to dairying in NZ, with emphasis on evaluation of effects of dairy intensification, particularly based on use of brought-in supplementary feeds. The two main areas covered are i. effects of different feed types on carbon footprint of milk from Waikato low, medium and high feed input farms, and ii. evaluation of multiple environmental impact categories using low, medium and high intensity Waikato farms.

Methods

An outline of the LCA system boundary illustrating the range of stages that contribute to resource use and environmental emissions on dairy farms covered by research presented in subsequent sections is given in Figure 1. The underlying LCA methodology used was based on methods described in LEAP (2014a) and IDF (2010). The LCA approach that was applied in estimating the GHG emissions associated with production of a range of brought-in feeds was based on use of NZ GHG Inventory methods (MfE 2014). Where the feed was a co-product (e.g. palm kernel expeller (PKE) and palm oil), the total emissions were allocated between the co-products based on their relative economic value (LEAP 2014b). Allocation of emissions between milk and meat co-products was based on relative energy requirements for the production of meat and milk using the method outlined in IDF (2010). For a wider range of 12 environmental impact categories, internationally published methods (EC-JRC-IES 2011; Hauschild et al. 2013) were used, as recommended for food and drink products by the European Food Sustainable Consumption and Production Round Table (European Food SCP Roundtable 2013).

Primary data for Waikato farms was derived from DairyNZ DairyBase for 2010/2011, and covered farms across DairyNZ farm classes 1-5, ranging from system 1 with no brought-in feed through to system 5 with about 20-40% of the total feed derived from brought-in supplementary feeds (Hedley and Bird 2006). In these studies the farms were grouped into low, medium and high intensity farms, whereby 'low' covered dairy systems 1 and 2, 'medium' was system 3 and 'high' covered systems 4 and 5.

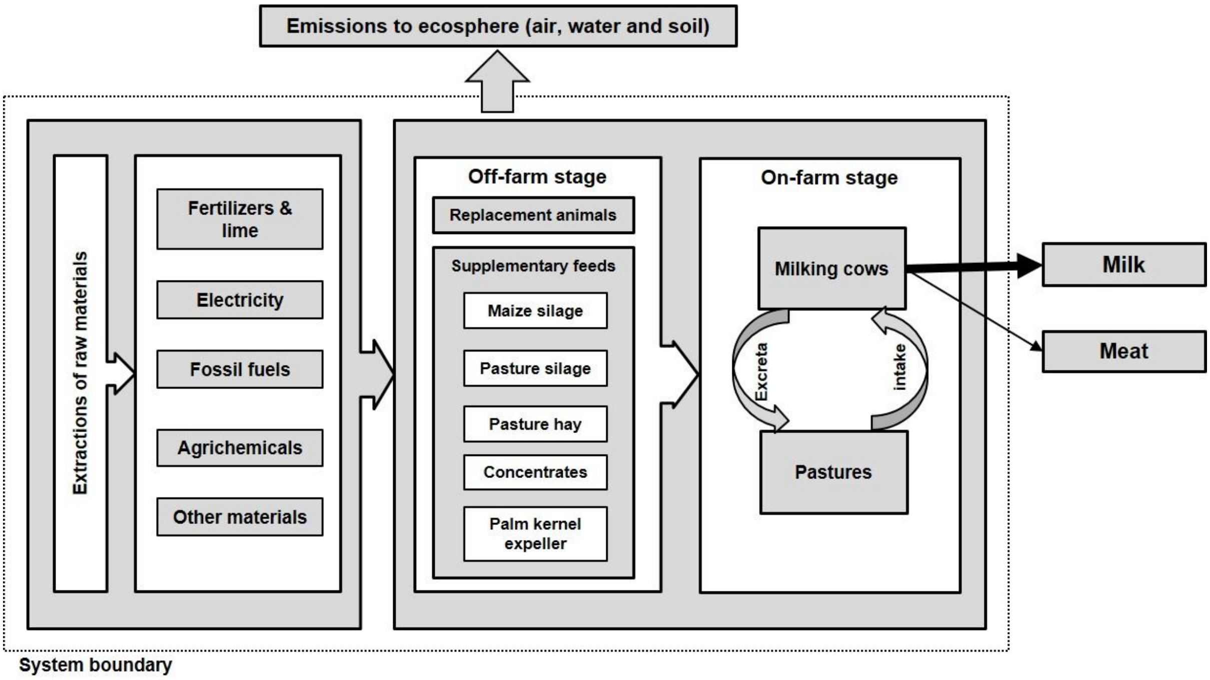

Figure 1. Diagrammatic representation of the system boundary for production of milk and live-weight for meat from dairy farms, covered by research presented in this paper.

Results and Discussion

Carbon footprint of milk and effect of brought-in feeds

The milksolids production per on-farm hectare for the average Waikato dairy farm (from DairyBase survey data) increased by 29% between the low and high levels of intensification (Table 1). This was associated with a similar relative increase in N fertiliser use and a small increase in stocking rate, whereas there was a four-fold increase in brought-in feed.

Table 1. Average annual farm data for Waikato farms (2010/2011; from DairyNZ DairyBase) that had low, medium or high levels of intensification based on level of brought-in feed and DairyNZ farm class (Hedley and Bird 2006).

	Low	**Medium**	**High**
DairyNZ farm class	1+2	3	4+5
Cows/ha (live-weight adjusted)	2.8	2.9	3.1
kg milksolids/ha	915	1083	1184
kg fat and protein corrected milk/ha	12230	14485	15830
kg fertiliser-N/ha	121	151	164
kg brought-in feed/ha	1030	2180	4030
Percentage of brought-in feeds from:			
Palm kernel expeller (PKE)	49%	41%	51%
Maize silage	27%	31%	29%
Other feeds	24%	28%	20%

The total GHG emissions expressed on a per on-farm hectare basis (i.e. the ‘milking platform”) were 10,950, 12,660 and 14,570 kg CO_2-equivalents/ha for low, medium and high intensity farms, respectively. These GHG emissions were calculated using an LCA approach and therefore included emissions for production of all off-farm inputs, as well as from dairy replacement animals and all off-farm land including that used in production of brought-in feeds (Figure 1). However, when GHG emissions were expressed on a per unit of milk production basis (i.e. the carbon footprint of milk) there was little difference between the low, medium and high intensity farms (Figure 2). The GHG emissions were dominated by enteric methane from animals, while nitrous oxide (N_2O) from animal excreta and emissions from N fertiliser (after application and from manufacturing) were also important contributors. The contribution from the production, transport and feeding of brought-in feeds increased considerably from low to high intensity farms.

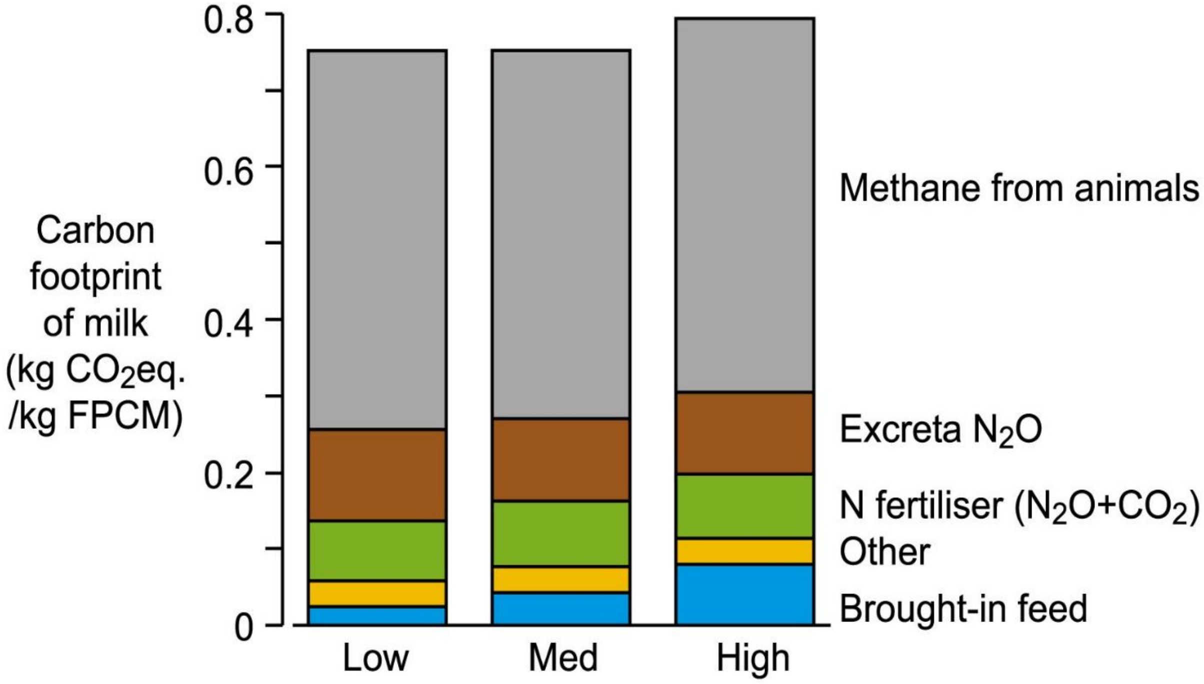

Figure 2. Carbon footprint of milk (fat and protein corrected milk; FPCM) and contributing factors from Waikato farms (2010/2011; from DairyNZ DairyBase) that had low, medium or high levels of intensification based on level of brought-in feed (see Table 1).

The carbon footprint for the production of a range of different feed types was estimated using an LCA approach (accounting for all inputs and emissions) based on average published or industry data on crop yields and inputs for crop production. Results showed a large variation between feed types (Table 2). PKE was the main feed type used on farms and had the highest carbon footprint. In contrast, waste fruit and vegetables had the lowest carbon footprint since they had no emissions attributed to their production because they are a waste product of no economic value.

Table 2. Carbon footprint for the production of various supplementary feeds used on farm (excluding transport to the farm and feeding out on the farm).

Supplementary feed	kg CO_2-equivalent/kg DM[1]
Palm kernel expeller (PKE)	0.506[2]
Barley grain	0.355
Pasture Silage (baled)	0.201
Kale	0.192
Maize silage - contract grower	0.188
Molasses	0.079[3]
Brewers grain	0.004[4]
Waste fruit and vegetables	0.000

[1] After allocation to main products of palm oil[2], sugar[3], or beer[4].

A sensitivity analysis was carried out to examine the effects of choice of brought-in feed type on the carbon footprint of milk (Figure 3). Where all brought-in feed was PKE, the carbon footprint of milk increased compared to that for the current mix of brought-in feed types and was 6% higher for the high intensity farm than for the low intensity farm. In contrast, where all brought-in feed was assumed to be from Brewers grain the carbon footprint of milk was decreased and was 15% lower for the high intensity farm than for the low intensity farm. An important factor associated with the high intensity farm was that the brought-in feed was used to extend the lactation period so that the milk production per cow increased by about 30%. This resulted in increased efficiency due to proportionately less feed intake and emissions going to animal maintenance compared to milk production (e.g. Gerber et al. 2013). This is a key factor explaining the limited difference in carbon footprint of milk between high and low intensity farms.

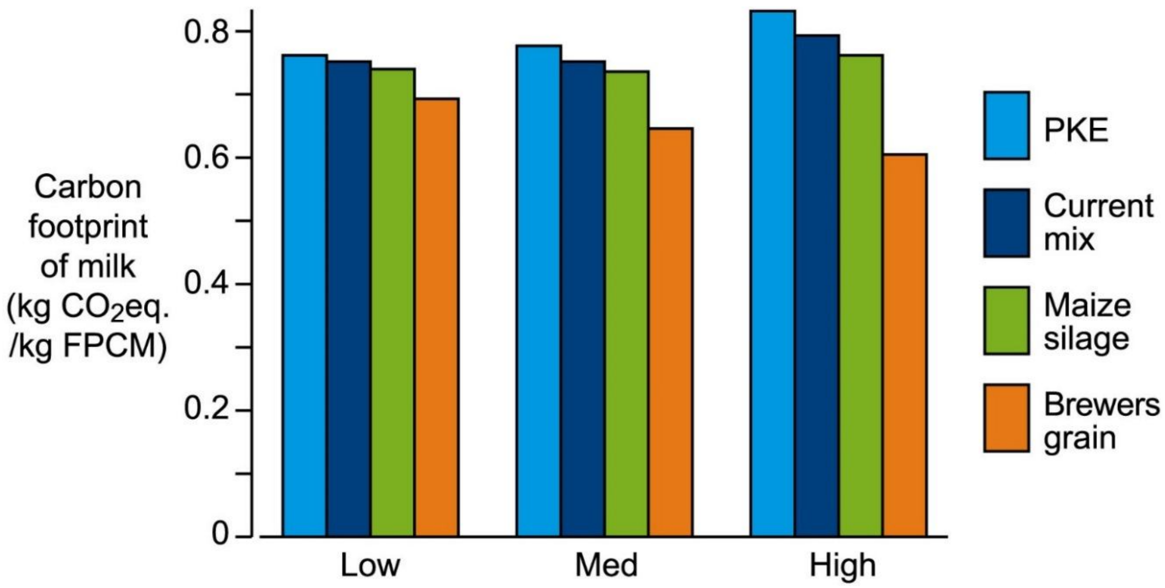

Figure 3. Carbon footprint of milk (fat and protein corrected milk; FPCM) and the effects of type of brought-in feed, for Waikato farms (2010/2011; from DairyNZ DairyBase) that had low, medium or high levels of intensification based on level of brought-in feed (see Table 1). The ‘current mix’ refers to the actual mix of different brought-in feed types used, while the other feed types were based on an assumption of them as the sole brought-in feed type.

Evaluation of a range of environmental impact categories

The effects of dairy intensification on a wider range of environmental impact categories was evaluated per kg milk production (Figure 4). For most impact categories there was a small increase (7-19%) in emissions between the low and high levels of dairy intensification, whereas for Freshwater Ecotoxicity this increase was 33%. The main drivers for these increases were the production of brought-in feeds, manufacturing of agrichemicals and transportation of off-farm inputs for use on dairy farms. For example, for the Freshwater Ecotoxicity indicator approximately 25% of emissions were associated with manufacturing (including extraction of raw materials) of agrichemicals (fertilisers and pesticides), while 9% and 20% were from production of off-farm feeds for the low and high intensity farms, respectively. The main contributors to the Freshwater Ecotoxicity indicator were heavy metals (largely associated with fertilisers) and pesticides (mainly from the production of off-farm feeds).

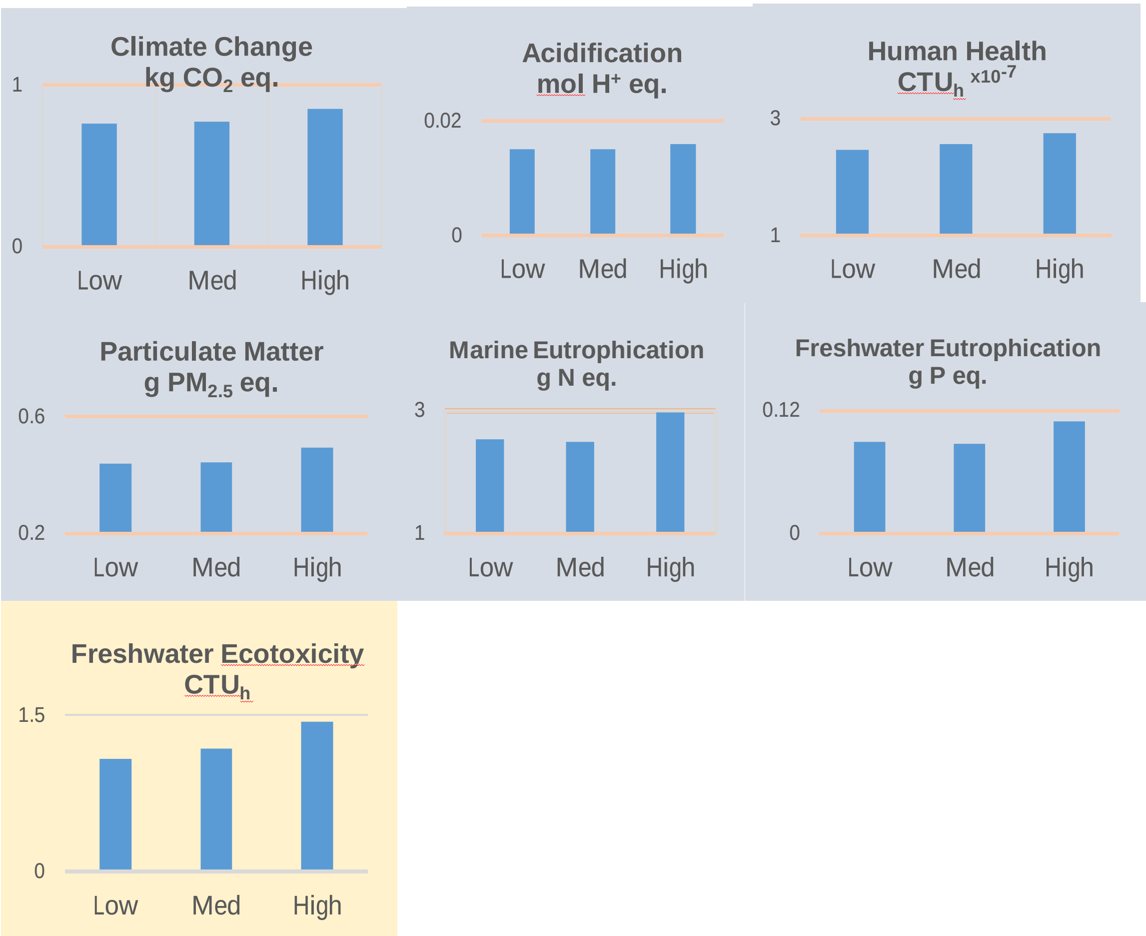

Figure 4. Effect of level of dairy farm intensification (low, medium or high) in Waikato (2010/2011; from DairyNZ DairyBase) on potential environmental impacts calculated for a range of different environmental impact categories. Impacts were calculated according to EC-JRC-IES (2011), and are expressed per kg of FPCM.

For many other environmental impact categories, the off-farm contributors were also significant. The production of off-farm feeds (i.e. those brought-in to the dairy farm) contributed 12-25% of total emissions per kg FPCM for the Eutrophication Potential (freshwater and marine), Human Health (non-cancer) and Freshwater Ecotoxicity indicators

(Chobtang et al. 2016). Similarly, the production of agrichemicals (fertilisers and pesticides) contributed 19-42% of total emissions for Freshwater Eutrophication Potential, Ozone Depletion Potential, Particulate Matter, Human Health (cancer) and Freshwater Ecotoxicity. The transportation of off-farm inputs for use on the dairy farms contributed 11-15% for Ozone Depletion Potential and Photochemical Ozone Formation Potential.

Sensitivity analysis on different aspects of the multiple environmental impact categories showed the importance of using NZ-specific data for LCA rather than using international default data. For example, heavy metal concentrations in NZ superphosphate are markedly lower than those given for international default values and this can have a large effect on environmental impact categories for Human Health and Freshwater Ecotoxicity (Chobtang et al. 2016). Similarly, when LCA is being used in evaluation of the effects of NZ-produced agricultural products or in the comparison with those from other countries, it is important that relevant NZ-specific data is used. This is particularly important in current international work on evaluation of the European PEF methodology, where key NZ sector groups (Beef+LambNZ, Fonterra and MPI) are being proactive. Future research in this area needs to be extended to evaluate key NZ agricultural products for multiple environmental impact categories using the PEF methodology and also to evaluate potential options for reducing environmental impacts while avoiding trade-offs between different environmental impact categories.

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