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Short Communication

Reducing greenhouse gas emissions of New Zealand beef through better integration of dairy and beef production

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ABSTRACT

Integrating dairy and beef production offers opportunities to reduce greenhouse gas (GHG) emissions of beef production, which is dominated by emissions related to maintenance of the breeding cow. This study aims to quantify the GHG reduction potential of the New Zealand (NZ) beef sector when replacing beef breeding cows and their calves with dairy beef animals. To this end, we combined a cattle herd model of NZ beef and dairy production with GHG emission calculations of beef production. We computed GHG emissions (to farm-gate stage) of the current amount of beef produced, while increasing the number of dairy beef calves at the expense of the number of suckler-beef calves. GHG emissions were 29% lower per kg carcass weight for dairy beef animals compared to suckler-beef animals. The average emission intensity decreased from 21.3 to 16.7 kg CO_2e per kg carcass weight (−22%) as the number of suckler-beef animals declined to zero and dairy beef animals increased. Integrating dairy and beef production would enable the NZ beef sector to reduce annual GHG emissions by nearly 2000 kt CO_2e (i.e. 22% of the total sector's emissions), while the dairy sector would improve their social licence to operate by reducing the number of surplus dairy calves slaughtered from 4-days old.

1. Introduction

The beef sector in New Zealand (NZ) has an annual production volume of 677 kilotonne (kt) of carcass weight (CW) (1st of July 2017-30th of June 2018), of which 83% is exported. It is NZ's third most important agricultural industry in terms of export revenues (Ministry for Primary Industries, 2018, 2019; Beef + Lamb New Zealand Economic Service, 2018b). At the same time, the sector has an important share (9%) of the country's gross greenhouse gas (GHG) emissions (i.e. excluding emissions related to land use and land use change), being responsible for an annual emission of 7128 kt of carbon dioxide equivalents (CO_2e) (Ministry for the Environment, 2018). To maintain its central role as an export country and limit the effects of climate change, the government has set a target to reduce all GHG emissions (excluding biogenic methane) to net zero by 2050 and to reduce biogenic methane emissions (largely from animal enteric methane) by 24 to 47% relative to 2017 before 2050 (Ministry for the Environment, 2019). The beef sector has not set a target yet, however mitigating GHG emissions of beef production will play an important role in meeting national targets, while ensuring the long-term survival of the beef sector.

Around 60% of beef produced in NZ originates from the traditional beef sector, while the other 40% comes from culled cows and slaughtered surplus calves (from 4-days old) from the dairy industry (Ministry for Primary Industries, 2018). The origin of calves used to produce beef has an important impact on the level of GHGs emitted. Per kg beef, beef calves of dairy origin have a significantly lower emission intensity (kg CO_2 equivalent) compared to their suckler-beef counterparts, because emissions from suckler-beef are dominated by the maintenance of the breeding cow, while in the case of dairy-based beef, those emissions are mainly attributed to milk (de Vries et al., 2015).

Previous studies found 0.95 million calves of dairy origin were destined for beef production while the majority (1.4 million) were slaughtered from 4-days old (for veal, hides and by-products) (Flysjö et al., 2011a). More recent statistics found the number of slaughtered calves could be as high as 1.8 million (Ministry for Primary Industries, 2018). Generally these calves are Jersey, or Jersey crossbred. Jersey calves have a lower birthweight and average daily gain making them undesirable for beef production (Barton and Pleasants, 1997; Hickson et al., 2015). Crossing Jersey cows (whose calves are not wanted for dairy replacements) with a beef breed sire would make these surplus calves more desirable for beef production. No national study thus far has explored GHG mitigation opportunities through better integration of the dairy and beef sectors.

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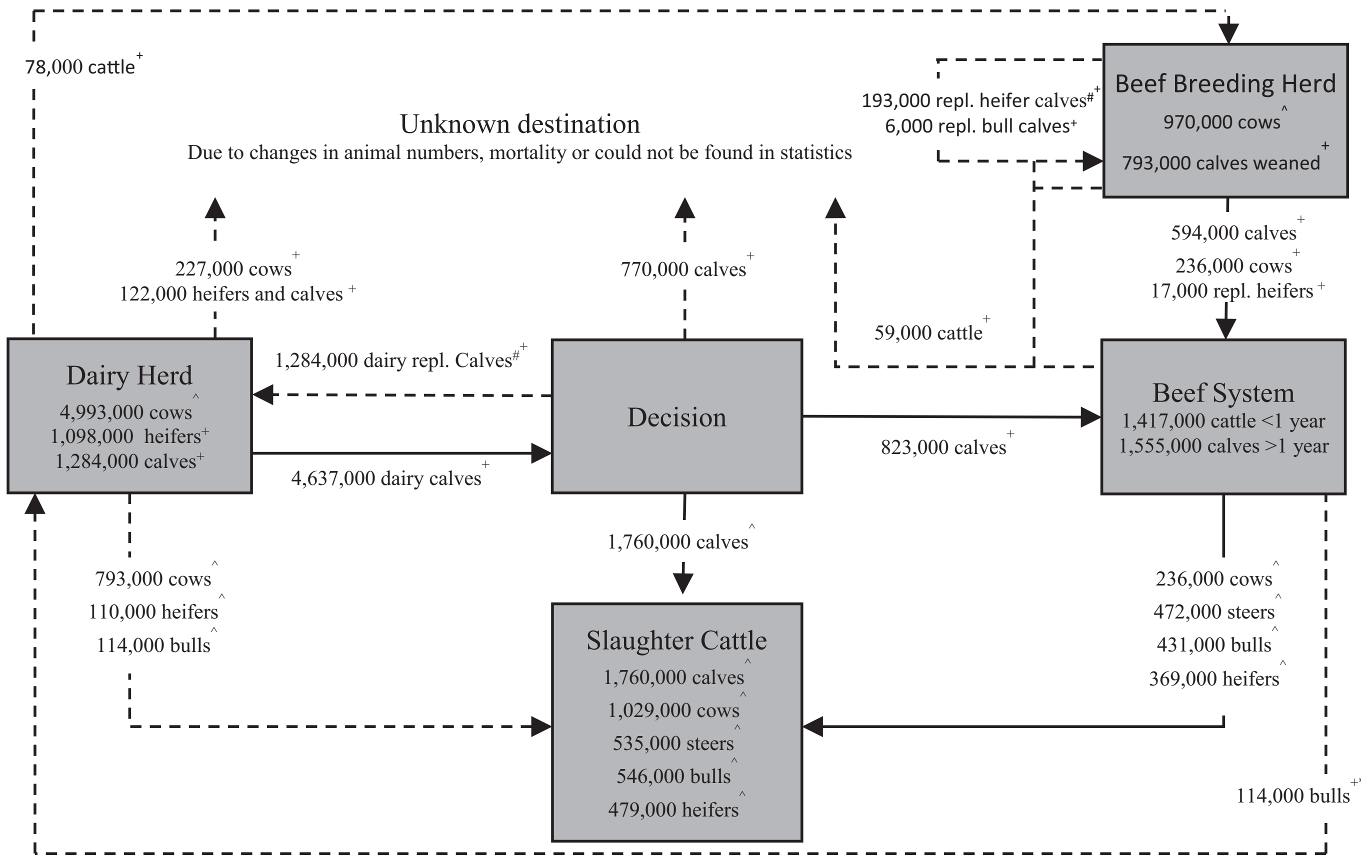

Fig. 1. Population dynamics of the NZ beef and dairy sectors (Beef + Lamb New Zealand Economic Service, 2018b; Dairy, 2018a; Ministry for Primary Industries, 2018) (Numbers may not add up due to rounding).
^ values based on statistics, + values based on calculations, * bulls were of dairy and/or beef origin, # a portion of these animals don't enter the beef/dairy herd due to mortality/failure to get in-calf.

This study aims to quantify the GHG reduction potential of the NZ beef sector when replacing beef breeding cows and calves with dairy beef animals. To this end, we created a model of the NZ cattle population and computed the GHG emissions per kg of suckler-beef and dairy beef. Subsequently, GHG emission results were combined with the cattle population model to quantify the reduction potential in terms of GHG emissions when increasing the use of dairy beef animals at the expense of suckler-beef animals.

2. Methods

2.1. New Zealand cattle population

Fig. 1 shows the number of slaughter cattle and their origin from 1st July 2017-30th June 2018. The size of the national beef breeding herd and dairy herd was collected from industry statistics (Beef + Lamb New Zealand Economic Service, 2018b; Dairy, 2018a). The number of cattle leaving the sectors for slaughter was based on Ministry of Primary Industry (MPI) slaughter statistics (Ministry for Primary Industries, 2018). Flows of cattle numbers within and between sectors were calculated. Details of those calculations can be found in Supplement 1.

Fifty percent of calves born were assumed to be male. Annual replacement rate of the dairy herd was 22% and 18% for the beef (Dairy, 2018b; Flysjö et al., 2011a). Animal mortality rates ranged from 1 to 4.1%, depending on age and origin of the animal (Beef + Lamb New Zealand Economic Service, 2018a; Cuttance et al., 2017). A number of dairy calves (i.e. 0.77 million) could not be accounted for due to a lack of detailed statistics.

2.2. Greenhouse gas emissions of beef production

To determine GHG emissions of NZ beef production, seven animal classes were created based on origin, breed and sex (beef breeding cows, bulls, steers, heifers, dairy bulls and dairy x beef steers, heifers). These classes represent average animals in NZ beef production. Data on the growth rates of animals per class was collected in a literature review (Supplement 2). MPI slaughter statistics were used to estimate the average CW (Ministry for Primary Industries, 2018). Subsequently, we estimated slaughter age based on average daily gain, CW and dressing out percentage (i.e. to determine live weight at slaughter). If parameters were missing (e.g. dressing out percentage) they were estimated using other data (e.g. Muir et al. (2008) for beef bulls) (Supplement 2).

For each class, GHG emissions per kg CW were determined based on a life cycle assessment, including all stages up to the farm gate. Processes included are the extraction of raw materials to produce farm inputs (e.g. fertilisers), the manufacturing and distribution of these inputs, and all on-farm processes (e.g. the keeping of livestock and pasture production). GHG calculations were performed in Microsoft Excel 2016 using NZ GHG Inventory methodologies, which are based on IPCC methods (Ministry for the Environment, 2018).

The amount of feed required by an animal in each class was calculated based on its energy requirements, according to Pickering et al. (2016). The diet of all animals consisted of fresh pasture only (10.21 M joules of metabolisable energy per kilogram (kg) of dry matter (DM) and 18.5% crude protein (CP) (Bown et al., 2013)). Annual pasture production was 9000 kg of DM per hectare (Thomas et al., 2014). Supplement feed (e.g. hay and silage) only made up a small proportion of total DM intake (DMI) and had little effect on average energy and protein content per kg DM and was therefore excluded.

On-farm emissions included those from enteric fermentation, manure deposited during grazing, and pasture production. Emission of enteric methane (CH_4) was based on the IPCC Tier 2 method, using NZ specific emission factors (EF) (21.6 kg CH_4 / kg DM) (Clark et al., 2003; IPCC, 2006a; Pickering et al., 2016). Emissions of CH_4 from manure deposition on pasture were based on Saggar et al. (2003) at 0.98 g CH_4 / kg faecal DM, with the latter being determined based on DM intake and digestibility. Nitrous oxide (N_2O) emissions from manure deposition were calculated by multiplying the respective nitrogen (N) input from urine or dung by the appropriate EF (Supplement 3). N intake of animals was calculated using CP% and DMI. A proportion of N was retained for live weight gain and the remaining was excreted (Pickering et al., 2016). N excretion was proportioned between dung and urine using NZ specific calculations (Luo and Kelliher, 2010). Direct and indirect N_2O emissions (the latter resulting from the volatilisation of ammonia and nitrogen (di)oxide and the leaching of nitrate) from the deposition of manure, application of fertiliser N and cultivation (i.e. pasture renewal, 1.3% per year, Beef + Lamb New Zealand Economic Service, 2018a) were based on inventory reports and IPCC Tier 2 methods (IPCC, 2006b; Ministry for the Environment, 2018) (Supplement 3). Further on-farm emissions included carbon dioxide (CO_2) emitted from the application of lime and combustion of fossil fuels (to run farm machinery) (IPCC, 2006b; Ministry for the Environment, 2015).

Off-farm emissions included those related to the production of farm inputs (Supplement 3), including that from production of dairy beef calves. Emissions were calculated by multiplying the respective inputs by the appropriate EF (Supplement 3). To sustain pasture production, fertiliser inputs of 13.7 kg of N, 10.9 kg of phosphorus and 4.7 kg of potassium per hectare were applied (Beef + Lamb New Zealand Economic Service, 2018a). Emissions from the production and types of synthetic fertilisers were based on Ledgard et al. (2011b). For dairy beef animals, an additional 20 kg of calf milk replacer and 70 kg of calf meal per head was assumed to be used for artificial rearing (Muir et al., 2000). Emissions related to the production of calf milk replacer and calf meal were based on data for NZ production of cereals and milk powder (Ledgard and Falconer, 2014). Emissions from the production of petrol and diesel required to run farm machinery (i.e. tractor) were based on Ministry for the Environment (2015).

Calves from dairy origin were allocated 242 kg CO_2e per calf, which equals 5.7% of the emissions related to dairy farming based on a physical causality allocation (Flysjö et al., 2011b; IDF, 2015). All emissions of breeding-cows prior to first mating (i.e. birth to first mating) were allocated to the meat produced by the breeding cows when culled. Not all beef breeding cows produced a calf annually, successive annual emissions from breeding cows from first mating until culling were increased by 21% based on reproduction rates (only 82.6 calves were born alive annually per 100 cows; Beef + Lamb New Zealand Economic Service, 2018a). To account for animal mortality, emissions were increased by half the mortality rate as it was assumed the animal died halfway through the phase (Supplement 1).

Emissions of the different GHGs were summed based on their equivalence factor in terms of CO_2 equivalents (CO_2e; 100-yr time horizon): 1 for CO_2, 28 for biogenic CH_4, 30 for non-biogenic CH_4 and 265 for N_2O (IPCC, 2013). Emissions were divided by the total amount of CW (i.e. the animal minus the head, hide, organs, blood, and feet) and expressed in kg of CO_2e per kg of CW.

2.3. Changes in beef cattle population and related GHG emissions

We calculated changes in GHG emissions associated with beef production, as the number of beef breeding cows (and calves) declined and dairy beef calves entering the beef sector increased. The beef breeding herd was reduced in 10% increments (i.e. 97,000 beef breeding cows) until it reached zero. To calculate potential emission reduction based on current production volumes, beef CW production by the total beef sector (Fig. 1: beef herd to slaughter cattle) was kept constant as the suckler beef herd reduced. Reduction in beef production by beef breeding cows was compensated for by an increase in beef production derived from dairy beef calves as the beef herd declined. It was assumed that pasture suitable for finishing suckler-beef animals would also be suitable for finishing dairy-beef animals and no changes in management were considered. A proportion of pastures currently used by breeding cows would also be required to finish dairy-beef animals, however not all of this land would be required (due to a reduction in total breeding cows, and cattle numbers). The ratio of bulls:steers:heifers slaughtered was kept constant as beef breeding cows and suckler-beef calves declined.

3. Results & discussion

Per kg beef, GHG emissions were 29% lower for dairy beef animals (16.6 kg CO_2e per kg CW) compared to suckler-beef animals (23.4 kg CO_2e per kg CW). Differences are explained by the variation in emissions per phase (e.g. mother, birth to weaning, weaning to slaughter). On average, the weaning to slaughter phase of suckler-beef animals contributed 11.1 kg CO_2e per kg CW (47%) to total emissions, while the mothers (i.e. beef breeding cows) contributed 11.1 kg CO_2e per kg CW (47%). The remaining 1.3 kg CO_2e per kg CW (6%) was emitted during the birth to pre-wean phase of the calf. In comparison, the weaning to slaughter phase of dairy beef animals contributed 14.8 kg CO_2e per kg CW (89%) to the total emissions, while the dairy cow contributed 0.8 kg CO_2e per kg CW (5%). The remaining 1.0 kg CO_2e per kg CW (6%) was emitted during the birth to pre-weaning phase of the calf.

Differences in weaning to slaughter phase emissions between dairy beef and suckler beef animals were explained by differences in growth rates. On average, dairy beef animals weaned earlier and took 4 months longer to reach target slaughter weight (Supplement 2). The mothers of the respective animals had the largest influence on results (Supplement 3). Dairy-beef mothers produced meat, milk and calves, which enabled annual emissions to be allocated among these three products, with the largest proportion being allocated to milk. In comparison beef breeding cows only produced meat and calves, with all emissions after first mating being allocated to calves.

Birth to weaning emissions were similar, due to a combination of an earlier weaning age of dairy beef animals (i.e. 3 vs. 8 months) and more GHG emissions from system inputs (e.g. calf milk replacer and calf meal). The methodologies used to determine average GHG emissions were similar to Wiedemann et al. (2016). Results are in line with other studies that have calculated GHG emissions related to beef production in NZ (Ledgard et al., 2011a).

Fig. 2 shows the effect of reducing the beef breeding herd to nil on total sector GHG emissions. Total emissions of the beef sector decreased from 8860 to 6913 kt CO_2e (22%) while the average emission factor per kg CW decreased from 21.3to 16.7 kg CO_2e (22%). The number of dairy beef calves flowing from the dairy sector to the beef sector increased from 0.82 to 1.51 million as the number of beef breeding cows declined from 0.97 million to 0.

3.1. General discussion

Results show that integrating dairy and beef production using dairy beef animals can reduce annual GHG emissions from NZ beef production by 1947 kt CO_2e, i.e., 22% of the total sector emissions (if the suckler-beef herd was reduced by 100%), based on current ratios of bulls:steers:heifers. Changing the ratio to favour more bulls could result in even greater reductions in GHG emissions (due to rapid growth rates of beef bulls). Although in practice, a 100% reduction in beef breeding cow numbers is unrealistic because some beef bulls are required to inseminate the dairy herd, results show that integrating dairy and beef production offers great opportunities to reduce GHG emissions.

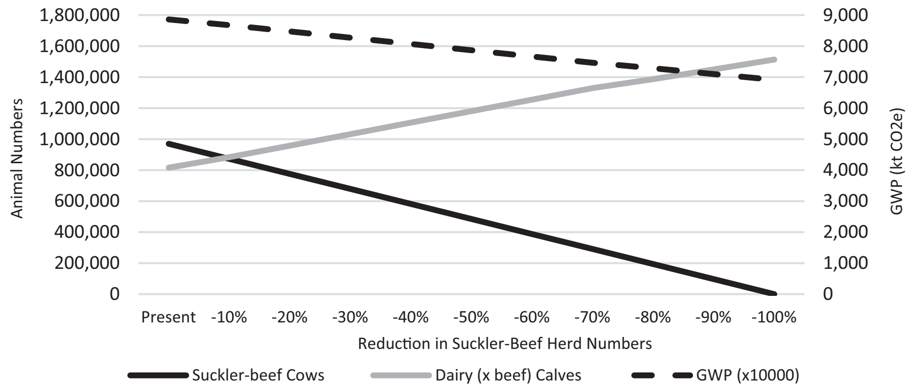

Fig. 2. Consequences of decreasing beef breeding cows and calves on GHG emissions and dairy beef calves entering the beef sector when CW beef output remains constant. GWP: global warming potential.

Reductions in beef breeding herd numbers could be optimized by artificially inseminating dairy cattle with beef semen to reduce the need for sires of suckler-beef origin and to optimize the growth capacity of dairy x beef animals (Hietala et al., 2014).

The nature of this study will always lead to uncertainty, e.g., annual and regional variations will occur in pasture quality and affect average daily growth (ADG) and GHG emissions. In the literature review, ADG varied up to 160 g within a livestock class (Supplement 2). To gain further insight into the likely range in results, it would be beneficial to compare ADG and system inputs of suckler-beef and dairy beef animals raised under the same conditions and the resulting GHG emissions. The overall conclusion that integration of beef and dairy production will benefit GHG reduction targets, however, is not expected to change.

The first step to better integration of dairy and beef production would be changing sire breed and stimulating collaboration between dairy and beef farmers (Oliver and McDermott, 2005). Dairy beef animals often receive criticism for their perceived inferior meat quality. Under similar growing conditions, however, there is little difference in meat quality (Bown et al., 2016). The use of beef sires in the dairy sector is further criticised for their relative calving difficulty compared to dairy breeds such as Jersey (Oliver and McDermott, 2005). However, selective breeding for easy-calving offers opportunities to overcome this issue (Burggraaf and Lineham, 2016).

Although some groups in NZ have integrated dairy and beef production (e.g. Pamu Farms, Firstlight Foods), further expanding the integration would be beneficial for both sectors. Slaughtering surplus dairy calves from 4 days old is controversial, and therefore reducing the number slaughtered while creating a higher value calf suitable for beef production can give economic and social benefits (i.e. industry image) to the dairy sector. The net effect is that the beef sector can produce a product with less GHG emissions.

4. Conclusions

Integrating dairy and beef production through dairy beef calves would enable the NZ beef sector to reduce annual GHG emissions from beef production by nearly 2000 kt kg CO_2e, i.e., 22% (based on 2017/2018 statistics) of the total sector's emissions. Furthermore, the number of surplus dairy calves slaughtered from 4-days old could be reduced creating economic and social benefits for both sectors.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.agsy.2020.102936.

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