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Sheep and Cattle Birth and Slaughter Dates

Greenhouse Gas Inventory Research Fund – Final Report

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Prepared for Ministry for Primary Industries
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Greenhouse Gas Inventory Research Fund – Final Report

Agreement Number: 406622

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Report for the Ministry for Primary Industries

Client Report Number RE450/2022/048

ata mātai, mātai whetū

Contents

1. Executive Summary

Sheep and beef cattle are one of New Zealand's largest sources of agricultural GHG emissions. To calculate their contribution to methane and nitrous oxide production, the New Zealand Agricultural GHG Inventory Model (AIM) calculates emissions based on animal gender, age and whether they are used for breeding or finishing. The purpose of this project is to review and revise current methods and assumptions in AIM for birth and slaughter dates for individual classes of sheep and beef cattle grown for finishing. This process considers changes that have occurred from 1990 to present, provided enough data are available. The proposed process will determine if changes are required for the sheep and beef stock classes modelled, based on industry datasets, and where data are lacking, sector expert opinion can be used.

The analysis of B+LNZ's data was used to build a baseline that more accurately reflects New Zealand agricultural GHG emissions from sheep and beef farming. Despite a few variables examined having negligible effects, the current analysis suggests that a few birth and slaughter variables and assumptions in AIM will need additional consideration (i.e., having potential to be adopted by AIM).

1.1 Sheep

The analysis indicates that there has been no significant change in sheep mating date over the 30-year time frame examined. Translated into a median lambing date, this equated to 10 September, which is similar to the currently used date in the inventory (11 September). When B+LNZ's dataset was weighted for regional sheep population (ewes to ram), the median lambing date shifted from 10 September to 13 September. Similarly, this trend would have relatively little impact on current inventory outcomes. However, this may provide the opportunity to increase the accuracy of the inventory, using the Beef + Lamb NZ dataset, particularly as flock numbers and contributions from different regions may change over time. But these changes would only be relevant if a decision was made to regionalise sheep inventory calculations.

Recommendation 1: No change to lambing date needed at this time.

Since the introduction of split slaughter dates for lambs, the percentage of lambs killed at the first and second slaughter dates has remained fixed at 84 and 16% respectively, and this value has been used for estimating GHG emissions ever since. A trend towards an increased % of lambs carried through to the second slaughter date (from the first lamb slaughter date) was seen (i.e., more and heavier lambs carried through winter to the second slaughter date). While the increase in methane emissions is likely to be small (i.e., the impact on total emissions is likely to be negligible), incorporating these results into the AIM methodology would help improve the model's accuracy, with a solid dataset to support greater feed requirements, but without a significant change in emissions.

Recommendation 2: Increase the proportion of lambs held over to a second slaughter date from 16% to 22% from 2010 onwards.

1.2 Beef cattle

The analysis indicates that there is a significant trend towards a later beef cattle mating date over the 30-year time frame. The mating dates examined translate into calving dates of 20 September for the 1990-2000 period, and 25 September for the 2010-2019 period. The current inventory

calving date is 20 September. A difference was seen between mating dates in Northland and Southland, but mating dates in other regions were similar, and trends towards later mating dates were evident in most regional datasets (the extent of the shift, however, varied little between regions). Again, these changes would only be relevant if a decision was made to regionalise beef cattle inventory calculations.

Recommendation 3. Change the national calving date to 25 September.

In the process of examining the data, some anomalies were identified in the AIM methodology. All slaughter bulls, steers and heifers are assigned the same birth date in AIM. But most slaughter bulls are sourced from the dairy industry, which has an inventory birth date of 01 August. Dairy bulls enter the inventory with a gap in record (difference between dairy cattle weaning date and beef cattle weaning date) of 140 days. This creates a potentially significant gap in emissions resulting in an artificially lower GHG output for bulls sourced from the dairy industry than equivalent beef animals.

Recommendation 4. Review calving date, rearing policy and weaning date allocated to bull beef.

Slaughter dates for all classes of beef across the recorded period (1993-2019) show little variation in average slaughter date within stock classes. The age of bulls at slaughter appears to be relatively stable, whereas the age at slaughter of both 1-2 year-old heifers and steers has declined slightly over the 27-year period considered. This equates to 1-2 year-old heifers now being slaughtered approximately 24 days younger in 2019 than in 1993 (528 vs 552 days of age respectively). Steers of 1-2 years of age are now being slaughtered approximately 35 days earlier in 2019 than in 1993 (520 vs 555 days of age respectively). These days of age are supported by growth rates that align with industry best practice and expert knowledge.

Recommendation 5. Apply distinct, new, slaughter dates to slaughter bulls, 1-2 and 2-3 year-old heifers, and 1-2 and 2-3 year old steers. These dates are specified in the Recommendations section. An analysis to determine if a relationship between age at slaughter and genetic gain may be warranted.

Creating separate categories for 1-2 year-old cattle increased the level of precision. To create relativities to the inventory, relative proportions of young and older cattle were calculated. Weighed days of age were greater in all categories when comparing the B+LNZ data set to the inventory guidelines.

Recommendation 6. Consider the practicality of splitting heifers and steers into age classes to further increase the precision of the inventory calculations. Review the relative proportions of animals slaughtered as 1-2 or 2-3 year-olds as genetic improvement continues (related to recommendation 5).

Overall, the current inventory calculations may underrepresent the methane emissions from beef cattle. Steers were the exception in intake and daily emissions; however, when calculated over their lifetime, the relative underprediction of the inventory remained. Bull beef were the furthest group from current calculations with inventory numbers representing only 75% of the emissions calculated from the B+LNZ dataset. This was due both to higher growth rates of bulls as well as later slaughter dates.

The summarised data could be used to build a baseline that more accurately reflects New Zealand agricultural GHG emissions from sheep and beef farming. This baseline could then be used to test scenarios aimed at improving profitability and environmental performance including GHG emissions.

2. Background

2.1 Project background

Sheep and beef cattle are one of New Zealand's largest sources of agricultural GHG emissions. To calculate their contribution to methane and nitrous oxide production, the New Zealand Agricultural GHG Inventory Model (AIM) calculates emissions separately based on 7 sheep and 11 beef cattle livestock classes (Appendix 1), based on gender, age and whether they are used for breeding or finishing (MPI 2021). Within each animal species, these classes are coupled as livestock move from one age group to the next.

On commercial farms, birth and slaughter timing varies across years, regions and farm classes, and is affected by meat schedule prices and feed availability. It is imperative that the AIM methodology and current and historical data are reviewed to ensure that the model accurately reflects past, current and future sheep and beef cattle populations, and hence emissions. These assumptions were last reviewed by Thompson et al. (2010). With more data now available, it is important that all available data is reviewed again, considering any changes from 1990 to present.

The purpose of this project is to review and revise current methods and assumptions in AIM for birth and slaughter dates for individual classes of sheep and beef cattle grown for finishing. This process considers changes that have occurred from 1990 to present, provided enough data are available. Outcomes can be used by MPI to ensure a) a more robust sheep and beef cattle population methodology, and b) a more accurate representation of animal energy requirements, and thus feed intake, in the model. Feed intake is a critical variable for estimating agricultural methane and nitrous oxide emissions.

The proposed process will determine if changes are required for the sheep and beef stock classes modelled, based on industry datasets, and where data are lacking, sector expert opinion can be used. The project is divided into three objectives:

- Clarifying the current assumptions for birth and slaughter dates for each age class,
- Summarising relevant available industry data, and
- Making recommendations on whether and how to change the current assumptions in AIM for sheep and beef cattle birth and slaughter dates.

The summarised data could be used to build a baseline that more accurately reflects New Zealand agricultural GHG emissions from sheep and beef farming. This baseline could then be used to test scenarios aimed at improving profitability and environmental performance including GHG emissions.

2.2 Current AIM methodology relevant to this report (M03)

Calculations in AIM are undertaken on a monthly timestep based on energy requirements per head, and upscaled with monthly population estimates to provide total national emission estimates (Clark 2008; MPI 2021). AIM currently uses publicly available livestock population data from MPI and provided by Statistics New Zealand (StatsNZ) via Infoshare (https://infoshare.stats.govt.nz/).

2.2.1 Sheep birth and slaughter dates in AIM

The average carcass weights for non-breeding sheep classes can be accessed (using InfoShare) under Industry Sectors – Livestock Slaughtering – Total NZ kill by animal type (annual – June). Data on the total graded number (of lambs for example) and total graded weight can be downloaded. The average weight for lamb slaughter can be calculated by dividing the total graded weight by the total graded number of lambs, and is an input (activity data) to AIM.

For the lamb category, the current methodology assumes that all lambs are born on the 1st of September (MPI 2021). For the months of October to February and for May to August, the population of lambs is reduced according to the following formula:

$$\begin{aligned} &Population\ of\ lambs\ in\ month\ m \\ &\qquad = Population\ of\ lambs\ in\ (m-1) \\ &\qquad \times \left(1 - \frac{0.045\ \times number\ of\ days\ in\ (m-1)}{number\ of\ days\ in\ year}\right) \end{aligned}$$

where $m - 1$ is the previous month and 0.045 is the current annual lamb death rate (expressed as a proportion) assumed by AIM (MPI 2021).

In March, the population of lambs is assumed to be equal to the preceding July sum of the four growing, non-breeding sheep categories (breeding ewe hoggets, dry ewe hoggets, ram hoggets and wether hoggets), with an adjustment for deaths that occurred between July and March. Every March, 84% of lambs in AIM are sold to slaughter, with the remainder (accounting for deaths) maturing into the hogget category. Therefore, the population of lambs in April is calculated according to the following formula:

$$Population\ of\ lambs\ in\ April = Population\ of\ lambs\ in\ March\ \times (1 - 0.84)$$

where 0.84 is the proportion of lambs sold to slaughter in March (MPI 2021).

This last assumption dates back to work conducted in 2010 for the implementation and results of the 2012 submission. The following recommendation was from the 2011 Agricultural Inventory Advisory Panel report (Pickering 2011), referring in particular to a panel paper titled "Review of population models within the national methane inventory" (Thompson et al. 2010).

"One slaughter date for lambs in February – change to two slaughter dates with 84 percent of lambs slaughtered 28 February and the remainder 31 August using the average carcass weight for each month as input values." Thompson et al. (2010) provide details on the basis for the change to two lamb slaughter dates cited above, including justification for the value of 84%.

2.2.2 Beef cattle birth and slaughter dates in AIM

The average carcass weights for non-breeding beef classes can be accessed (using InfoShare) under Industry Sectors / Livestock Slaughtering / Total NZ kill by animal type (annual – June). Data on the total graded number (of heifers for example) and total graded weight can be downloaded. The average weight for slaughter cattle can be calculated for 1- to 2- and 2- to 3-year-old heifers, steers and bulls, and is an input (activity data) to AIM.

For the beef category, the current methodology assumes that all cattle are born on the 1st of September (MPI 2021). As the animals age, the proportion of heifers retained as replacements is assumed to be 17% of the population of mature breeding cows.

Slaughter heifers are removed from the population in September at either 365 or 730 days of age, while slaughter steers are removed in February at 498 days of age. The proportions of each, at each date, are unspecified in the AIM methodology (MPI 2021).

Beef cattle classed as growing (either for slaughter or as breeding replacements) have a liveweight which increases linearly from their assigned birth date to the date at which the model deems that they have reached maturity or are slaughtered. Calves are presumed to be weaned at 150 days-of-age (5 months) and be on milk only until then (MPI 2021).

To calculate liveweight, information on mature and slaughter weights are required, along with information or assumptions on the animal birth weight. Results are reported for a southern hemisphere growing season, from July to June. Calculations are always made on the physiological year of the animal (i.e., from birth). The physiological year is then mapped to the July-June reporting year. So, the September R2 population will have just received the R1s that have turned 12 months of age, and they keep going through to June, so their population does not go to zero. As a result of this movement to a new class on birth date, any July R2 beef animals are nearly two years old. These results (reported for the July to June growing year) are then mapped to a calendar year (January to December) for final reporting in the agricultural sector of the national GHG inventory.

3. Method

3.1 Data source

Data was provided by Beef and Lamb New Zealand (B+LNZ). The Economic Service of B+LNZ has been providing reliable, independent information and analysis of the sheep and beef sector since 1950. A core part of this process is B+LNZ's Sheep and Beef Farm Survey that has been running continuously since 1950. The Sheep and Beef Farm Survey is a sample assessment in which the sample is randomly selected from the business frame used in the country's census of agricultural producers to reflect New Zealand's livestock base. Over 2,000 annual data points are captured to describe each Sheep and Beef Farm business. Information collected by the survey that may be relevant to the birth and slaughter date information required here include a diary of stock transactions, including date, livestock class/category and carcass or liveweight.

Two datasets were provided that include data from the whole survey: a) "Summary of Sales Transactions: 1990-2019 Survey", and b) "Breeding information: 1990-2019 Survey", a period of

30 years. The first dataset contains 'transaction' data; every transaction is in a row comprising farm class (1 – 8), region (1 - 11) (**Table 1**), livestock class, weighted date (from 01 Jul 1990 to 30 Jun 2020), average carcass weight per head, average liveweight per head and number of head. The second dataset contains 'breeding' data. In a similar structure, every row has a farm class (1 - 8), region (1 - 11), and mating date, dam to sire, and birth rate percent (per dam mated), for both sheep and cattle.

On the transaction dataset, the first step was to separate sheep from beef classes, followed by a separation of 'intermixed' sales (i.e., prime vs store sales, determined by the weight numerical value; prime sales have a carcass weight whereas store sales have a liveweight numerical value). We extracted information about sheep and cattle birth dates and slaughter dates and carcass weights. We also extracted ewe and cow slaughter weights and numbers (B+LNZ 1990-2019). A simple comparison of relative intake, using the CSIRO equations upon which the AIM methodology is based, was made to identify the potential for differences between data of actual slaughter dates provided by B+LNZ and the current assumptions in AIM.

***Table 1**. Beef and lamb New Zealand (B+LNZ) regional classes.*

1.	Northland
2.	Waikato – Bay of Plenty
3.	Gisborne
4.	Hawkes Bay
5.	Wairarapa
6.	Taranaki – Manawatu
7.	Nelson – West Coast
8.	Marlborough
9.	Canterbury
10.	Otago
11.	Southland

3.2 Anomalies in the Agricultural Inventory Methodology

In attempting to identify comparative ages at slaughter for comparison between the B+LNZ dataset and the AIM methodology, some anomalies were identified in the documentation (MPI 2021).

3.2.1 Milk in early life

The AIM methodology section 4.4.1. paragraph 2, states that ‘Beef calves do not begin grazing until their sixth month of life. Until that time, they are milk fed’.

But in section 4.4.6 paragraph 1, it states that ‘For the first 8 months of life it is assumed that they (beef animals) are fed either suckled milk or milk derived from powder…’ and in Paragraph 2 ‘For the first two months of life, the inventory model assumes that a calf bred as beef livestock does not produce any methane as they are strictly fed milk. In Paragraph 3 ‘for the third to eight month of a beef calf’s life, equation 4.25 is used to calculate the amount of energy from milk.’

These statements are in conflict, meaning that a weaning date is difficult to determine. Calculations for comparison were based on the statement in section 4.4.1, discounting 5 months of intake when calculating methane emissions.

Further statements in section 4.4.6 regarding the use of milk powder, while technically accurate regarding the rearing of bull beef sourced from the dairy industry, are misleading if applied to the whole beef industry. Considering that those bulls are most likely born well before the standard beef animal, and weaned at 60 days of age, then this indicates a potential problem with the accuracy of the AIM methodology.

3.2.2 Age at slaughter

It is difficult to determine true age at slaughter due to some contradictions in statements throughout the inventory. Section 4.7, Table 4.6 in the AIM methodology has the clearest definition, stating that all beef animals are slaughtered at 730 days-of-age, two years from a birth date of 20 September. However, this is at odds with other statements in the population section of the methodology. Here we have several statements that conflict.

In section 3.2.5 (Slaughter heifers 0-1) it states that ‘During September it is assumed that new heifers for the year are born, while 12-month-old heifers are either slaughtered or moved to the next age class’. This implies that some heifers are slaughtered at 12 months of age and so are 365 days old. This is also the case for section 3.2.7 (Slaughter steers 1-0)

In section 3.2.6 (Slaughter heifers 1-2) it states that ‘During September it is assumed that 12-month-old heifers are moved to the next age class and some heifers aged 1-2 are slaughtered.’ This implies these animals are at the end of their second year of life and so are 760 days old.

In Section 3.2.8 (Slaughter steers 1-2) it states that ‘During February it is assumed that 1–2-year-old steers are slaughtered. These changes are seen in the February population figure.’ This makes these animals 497 days of age, if slaughtered between the ages of 1 and 2, or 862 days old if 2-3 years old.

It has been assumed in this report that a slaughter age of 730 days old has been used.

4. Results and Discussion

4.1 Birth dates

Birth dates have been calculated from joining date for both sheep and beef cattle. Gestation length, and adjustments for median birth date have been applied. Slaughter bulls are most often sourced from the dairy industry. The current inventory methodology states a birth date of 01 August being applied.

4.1.1 Sheep birth dates

An examination of sheep mating dates (available from the data) was made to determine average birth date of lambs. Start of mating was used as a starting point. A gestation length of 152 days was added to attain potential start of lambing. A median lambing date of 17 days after planned start of lambing was chosen, based on Knight et al. (1980). Data was summarised as the average for each year of the dataset (1990-2019) and for each geographic region (from Northland to Southland; Table 1).

In terms of national trends over time, data indicates that there has been no significant change in mating date over the 30-year time frame (**Figure 1**). When translated into median lambing date, this equates to 10 September. This is similar to the currently used date in the inventory (11 September), and this analysis *provides no reason to suggest changing the sheep birth date*.

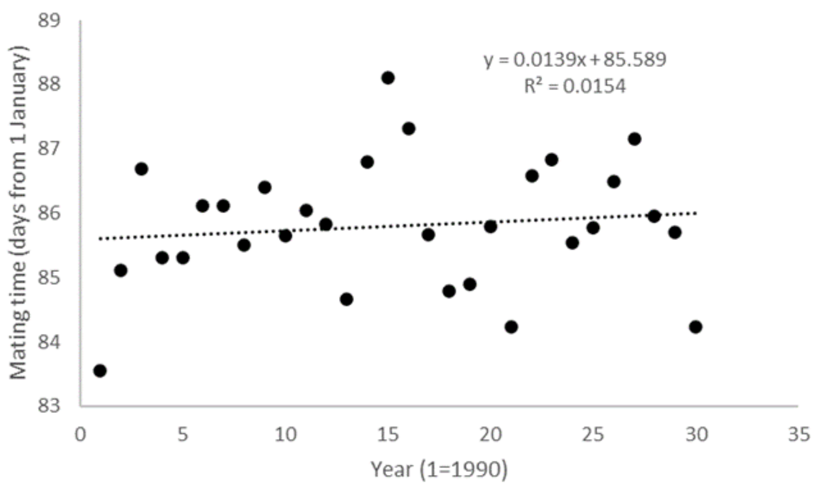


***Figure 1**. Mean breeding ewe mating dates (days after 01 January) over the period 1990 – 2019. The range of days after 01 January in the y-axis represent the following dates: 83 = 24-March, 89 = 31-March.*

In terms of regional differences, a significant trend towards later mating dates as we move south (1 = Northland, 11 = Southland) is shown in **Figure 2**. Sheep populations vary across this geographic range. When weighted for sheep population (ewes to ram), the median lambing date shifts from 10 September (see previous section) to 13 September (Figure 2). Again, this trend would have relatively little impact on current inventory outcomes. However, this may provide the opportunity to increase the accuracy of the inventory, particularly as flock numbers and contributions from different regions may change over time. *This would only be relevant if a decision was made to regionalise the sheep inventory calculations*.

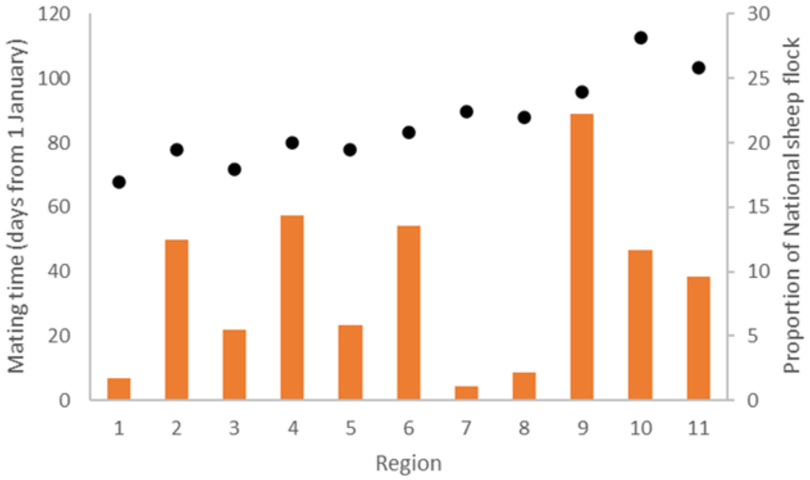


Figure 2. *Regional differences in mean mating dates (dots) and proportions of the national sheep flock (columns) in each region (1 = Northland, 11 = Southland). The range of days after 01 January in the y-axis represent the following dates: 0 = 01-January, 120 = 30-April.*

4.1.2 Beef cattle birth dates

An examination of beef mating date (available from the data) was made to determine average birth date of calves. Start of mating was used as with the current default gestation length (282 days) added to attain potential start of calving date. The methodology documented by Thompson et al. (2011) was used to determine mean birth date, in brief, a 21 day cycle, equal number of cows cycling each day, a 70% conception success in each cycle, for three mating cycles. Data was summarised as the average for each year of the dataset (1990-2019) and for each geographic region (1 = Northland, 11 = Southland).

In terms of national trends over time, data indicates that there is a significant trend towards a later beef cattle mating date over the 30-year time frame (**Figure 3**). This is described in equation 1 ($r^2 = 0.94$). The shape of the curve represents a stable mating date from 1990 until 2000, then a steady trend towards a later mating date until approximately 2010 and a more stable mating date between 2011 and 2019. These mating dates translate into calving dates of 10 September for 1990-2000, and 25 September for 2010-2019. The inventory date of 20 September was calculated by Thompson et al. (2011) based on mating data from 2006/2007. The mean birth date weighted for population distribution across all years is 17 September and is consistent with the data presented here.

$$f = y0 + \frac{a}{\left(1+\exp\left(-\frac{x-x0}{b}\right)\right)^{c}} \qquad \text{(Equation 1)}$$

where f = mean mating date (days after 01 January), a = 14.0517; b = 3.5273, c = 4.7491, and x0 = 10.6242.

All slaughter bulls, steers and heifers are assigned the same birth date. Most slaughter bulls are sourced from the dairy industry, which has an inventory birth date of 01 August. Dairy calves are weaned to grass at two months of age (as per the AIM methodology, section 4.3.1 on pg. 62) entering the inventory in month three, while animals assumed to be in the beef supply chain are weaned to grass at five months of age (section 4.4.1), entering the inventory in month six (though this appears to be confounded with statements in section 4.4.6 which states beef animals are gradually weaned from milk from months 3 to 8). Therefore, dairy bulls enter the inventory with a gap in record (difference between dairy cattle weaning date and beef cattle weaning date) of 140 days. This creates a potentially significant gap in emissions resulting in an artificially lower GHG output than equivalent beef animals.

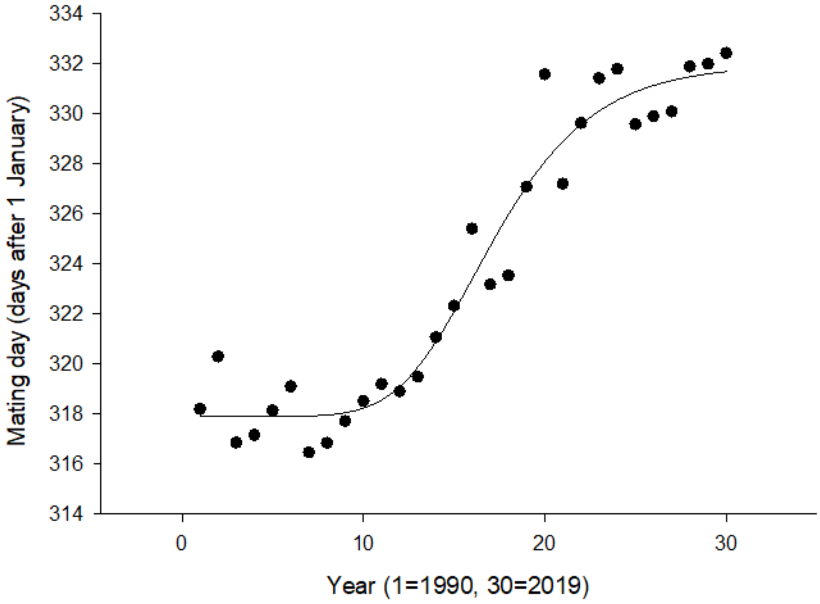


Figure 3*. Mean breeding beef cow mating dates (days after 01 January) over the period 1990 – 2019. The range of days after 01 January in the y-axis represent the following dates: 314 = 10-November, 334 = 30-November.*

In terms of regional differences, data indicates a difference between mating dates in Northland and Southland, although mating dates in other regions were similar (**Figure 4**). Trends towards later mating dates were evident in most regional datasets, although the extent of the shift varied a little between regions. These shifts during the 2000-2010 era were most likely a response to the need to provide more feed at lambing time to the sheep flock, by manipulating the timing of beef cattle feed requirements.

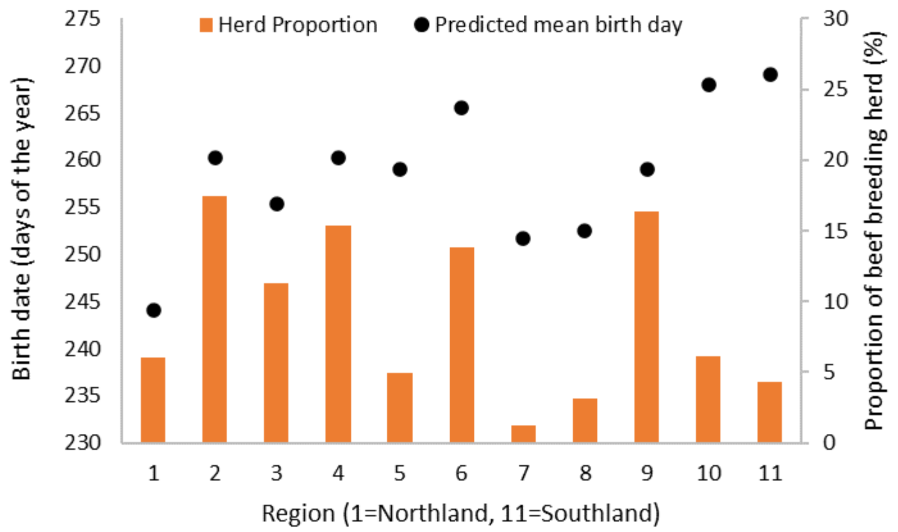


Figure 4. *Regional differences in mean breeding beef cow birth date (1 = Northland, 11 = Southland). The range of days of the year in the y-axis represent the following dates: 230 = 19-August, 275 = 2-October.*

4.2 Slaughter dates

Slaughter dates were calculated from the dataset for both region and year. To estimate age at slaughter, these dates were then adjusted for birth date, and then compared to expert advice to ensure that relevant ages were determined.

4.2.1 Sheep slaughter dates

Since the introduction of split slaughter dates for lambs (see above Thompson et al. 2011), the percentage of lambs killed at the first slaughter date has remained fixed at 84%, and this value has been used for estimating GHG emissions since. All lambs are slaughtered, and the class is self-contained with no lactation or gestation involved when calculating their metabolisable energy (ME) requirements. Logic then suggests that if more lambs are slaughtered at the first slaughter date, emissions (from sheep and grand total) would decrease due to the smaller number of heavier animals kept through to the second slaughter date. These heavier animals would have higher ME requirements (due to higher liveweights) resulting in higher emissions.

As a first step, we extracted information about lamb slaughter dates, and the percentage slaughtered at the first slaughter date, approximately 78% (with 22% carried through to the second slaughter date) from a sample dataset (B+LNZ 2019-2020). Based on this, an initial sensitivity analysis (using AIM methodology) was made investigating the effect of the % lambs slaughtered at the first slaughter date. The results are consistent with the logic described, with emissions [grand total (**Figure 5a**) and from sheep only (**Figure 5b**)] decreasing as the % slaughtered at the first slaughter date increases.

a) b)

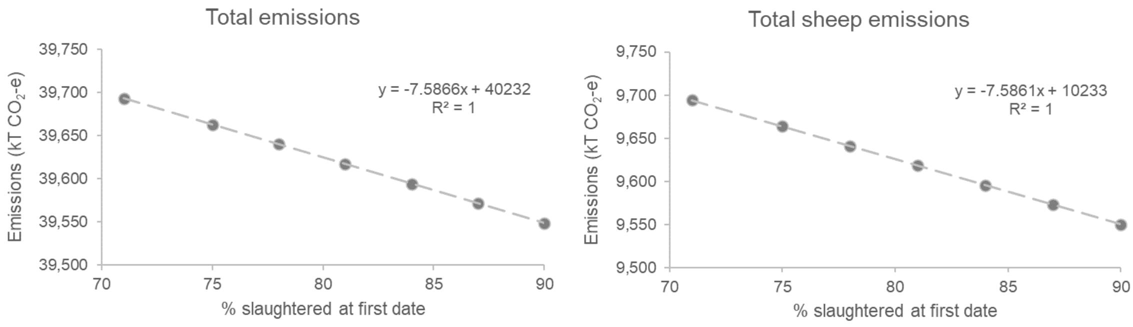


***Figure 5**. a) Total and b) Sheep GHG emissions (in kT CO_2-e) from varying the percent of lambs slaughtered at the first slaughter date, ranging from 71 to 90%. For this analysis, the existing default slaughter dates in AIM were retained.*

The initial analysis was extended to the full range of years available in the B+LNZ dataset. An examination of lamb slaughter dates (available from the data) was made to determine average slaughter dates of lambs. A clear trend for the % carried through to the second slaughter date (from the first lamb slaughter date) was seen, ranging from 14% (1997) to 24% (2013) (**Figure 6**). The trend to an increasing proportion of lambs being held to a second slaughter date appears to have stabilised in the period 2010-2019 averaging approximately 22% carried through. While the data only goes back to 1993, there is a clear case for using 84% (the current default in AIM) back to 1990, though a revised value of 22% should be considered from 2010 onwards.

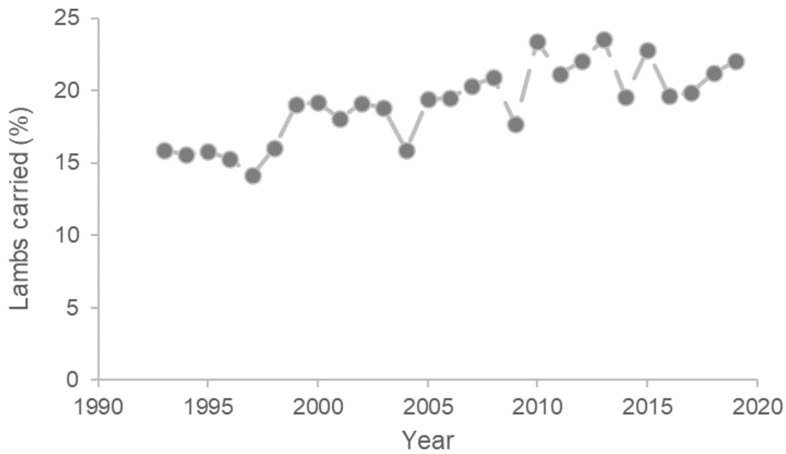


***Figure 6**. Percent of lambs carried beyond the first lamb slaughter date (as currently described in the AIM methodology) over the period 1993 – 2019.*

4.2.2 Beef cattle slaughter dates

Slaughter dates for all classes of beef across the recorded period (1993-2019) demonstrate little variation in average slaughter date within stock classes (**Table 2**). This variation appears to be related to feeding conditions during summer. The current dates when sales animals are removed from the inventory (sold to slaughter) are also presented in Table 2.

Table 2*. Beef cattle slaughter dates from Beef + Lamb NZ Economic service data from 1993 to 2019. LSD = Least significant difference; CV = Coefficient of variation. YO: year-old.*

Year	Average Slaughter date					
	Bulls	Cows	1-2 YO Heifers	2-3 YO Heifers	1-2 YO Steers	2-3 YO Steers
1993	3-Feb	27-Feb	6-Mar	3-Jan	25-Mar	4-Jan
1994	29-Jan	15-Mar	19-Mar	18-Jan	1-Mar	27-Jan
1995	21-Jan	25-Feb	21-Mar	15-Dec	20-Mar	4-Jan
1996	13-Feb	26-Feb	30-Mar	5-Jan	3-Apr	4-Jan
1997	27-Jan	28-Feb	13-Feb	11-Dec	26-Feb	21-Dec
1998	4-Feb	24-Feb	30-Mar	16-Dec	23-Mar	5-Jan
1999	9-Feb	22-Feb	24-Mar	17-Dec	3-Apr	8-Jan
2000	11-Feb	21-Feb	3-Apr	24-Dec	24-Mar	7-Jan
2001	23-Jan	21-Feb	2-Apr	27-Dec	18-Apr	12-Jan
2002	30-Jan	14-Mar	10-Apr	9-Jan	12-Apr	22-Jan
2003	2-Feb	11-Mar	18-Mar	14-Jan	6-Apr	14-Jan
2004	5-Feb	27-Feb	23-Mar	3-Jan	16-Apr	24-Jan
2005	27-Jan	24-Feb	23-Mar	30-Dec	7-Apr	20-Jan
2006	11-Feb	26-Feb	20-Mar	29-Dec	26-Mar	25-Jan
2007	30-Jan	9-Mar	5-Apr	15-Jan	18-Mar	23-Jan
2008	31-Jan	2-Mar	4-Apr	13-Jan	15-Mar	24-Jan
2009	8-Feb	1-Mar	6-Mar	19-Jan	28-Mar	3-Feb
2010	22-Feb	5-Mar	22-Feb	1-Feb	3-Mar	23-Jan
2011	10-Feb	21-Feb	16-Mar	12-Jan	8-Apr	19-Jan
2012	19-Feb	24-Feb	13-Mar	20-Jan	2-Mar	24-Jan
2013	8-Feb	4-Mar	2-Apr	15-Jan	22-Mar	10-Jan
2014	12-Feb	24-Feb	13-Feb	15-Jan	3-Feb	16-Jan
2015	2-Feb	23-Feb	19-Mar	1-Jan	27-Mar	8-Jan
2016	16-Feb	7-Mar	3-Mar	19-Jan	3-Feb	17-Jan
2017	2-Feb	1-Mar	16-Apr	10-Jan	26-Mar	9-Jan
2018	17-Jan	7-Mar	17-Mar	7-Jan	6-Mar	14-Jan
2019	26-Dec	21-Feb	14-Mar	8-Jan	26-Mar	29-Dec
Mean	3-Feb	28-Feb	19-Mar	6-Jan	21-Mar	14-Jan
LSD (days)	20.9	18.2	35.8	24.9	39.9	18.8
CV%	2.6	2.1	4.0	3.4	4.5	2.5

Inventory Dates	**1-Oct**	**1-Jul**	**1-Oct**	**1-Oct**	**1-Oct**	**1-Feb**

Slaughter dates can be translated into days of age. Days of age at slaughter of beef bulls (**Figure 7**), heifers (**Figure 8**) and steers (**Figure 9**) are presented below. The age of bulls at slaughter (Figure 7) appears to be relatively stable, except for 2018 and 2019. This aligns with significant drought conditions during these years. The average days to slaughter for 2-3-year-old cattle remains unchanged over the 27-year period (Figures 8 and 9).

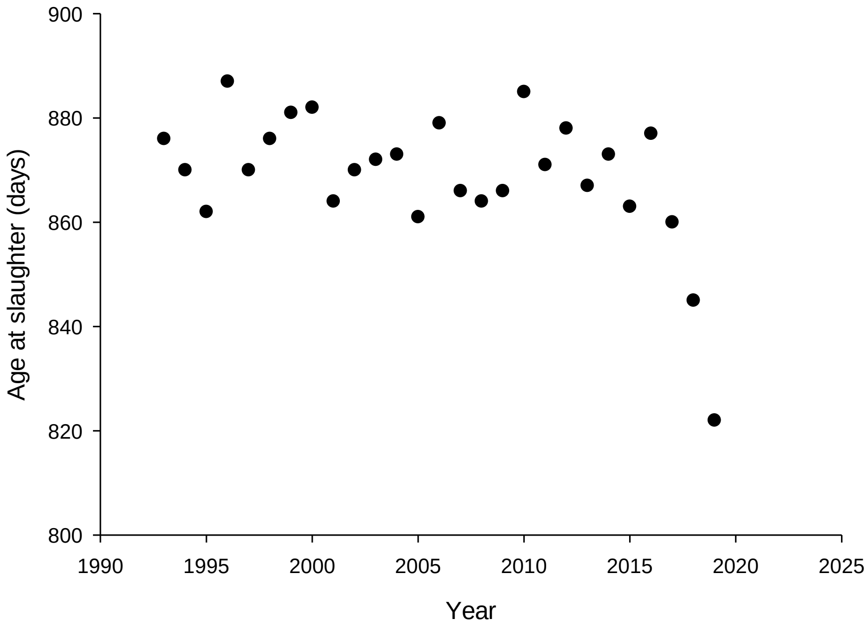


Figure 7*. Age of bulls at slaughter from the B+LNZ Economic Service dataset from 1993 to 2019.*

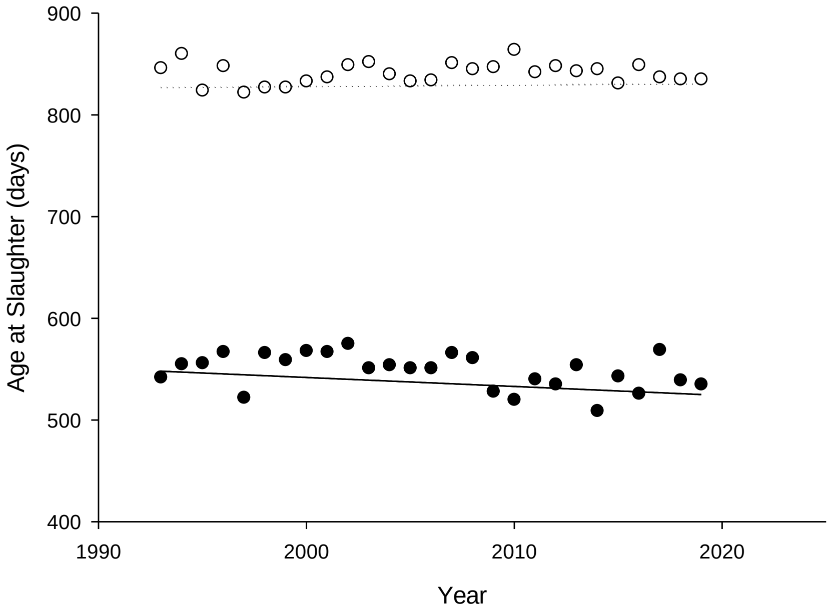


Figure 8*. Age of heifers at slaughter (closed symbols = 1-2 year-old heifers, open symbols = 2-3 year-old heifers) from the B+LNZ Economic Service dataset from 1993 to 2019.*

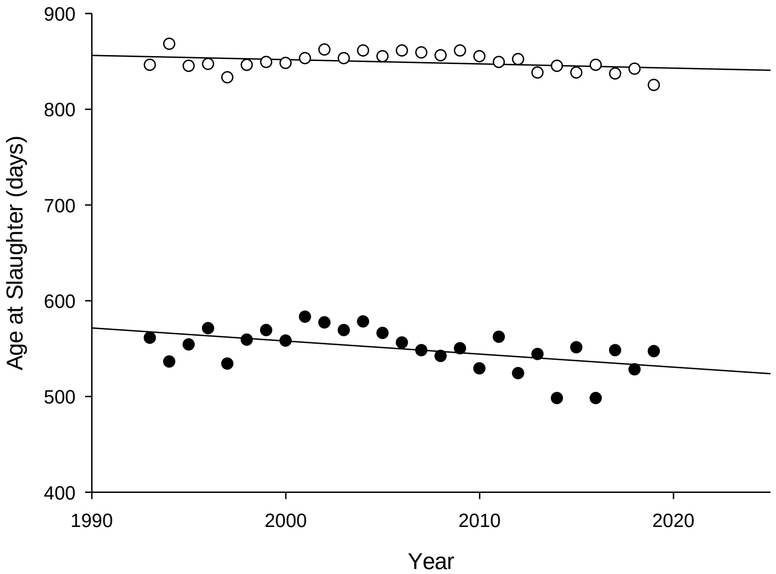


Figure 9*. Age of steers at slaughter (closed symbols = 1-2 year-old steers, open symbols = 2-3 year-old steers) from the B+LNZ Economic Service dataset from 1993 to 2019.*

The age at slaughter of both 1-2 year-old heifers (Figure 8) and steers (Figure 9) has declined slightly over the past 27 years. The decline in age is approximately 0.9 and 1.3 days per year of record ($P < 0.05$) over the 27 years. This equates to 1-2 year-old heifers now being slaughtered approximately 24 days younger in 2019 than in 1993 (528 vs 552 days of age respectively).

Steers of 1-2 years of age are now being slaughtered approximately 35 days earlier in 2019 than in 1993 (520 vs 555 days of age respectively). These changes may reflect genetic gain in the beef herd. Calf weaning weight has seen significant genetic improvement over the past 30 years, and this may have translated into earlier slaughter of younger animals. These days of age calculations are supported by the growth rates (**Table 3**) which aligns with industry best practice and expert knowledge (Bob Thompson personal communication).

***Table 3**. Beef growth rates (kg/d) from 2006 to 2019 from the Beef + Lamb NZ Economic Service data. YO: year-old.*

	Growth rate (kg/day)				
Year	Bulls	1-2 YO Heifers	2-3 YO Heifers	1-2 YO Steers	2-3 YO Steers
2006	0.794	0.751	0.580	0.849	0.627
2007	0.709	0.712	0.516	0.850	0.611
2008	0.734	0.747	0.537	0.883	0.622
2009	0.744	0.786	0.531	0.870	0.637
2010	0.723	0.770	0.516	0.907	0.632
2011	0.773	0.784	0.545	0.876	0.644
2012	0.735	0.765	0.541	0.890	0.631
2013	0.761	0.769	0.528	0.848	0.643
2014	0.716	0.836	0.534	0.939	0.632
2015	0.757	0.772	0.547	0.860	0.631
2016	0.740	0.787	0.549	0.943	0.657
2017	0.733	0.725	0.560	0.890	0.661
2018	0.752	0.793	0.569	0.873	0.663
2019	0.773	0.804	0.562	0.841	0.662
Mean	0.746	0.772	0.544	0.880	0.639
SD	0.024	0.032	0.019	0.032	0.016
CV%	3.2	4.1	3.5	3.6	2.5

Regional differences in slaughter dates for cattle from the B+LNZ Economic Service data (1993-2019) are presented in **Table 4** and **Figure 10**.

***Table 4**. Beef cattle slaughter dates from regions across New Zealand (from the B+LNZ Economic Service data 1993-2019). YO: year-old.*

	Slaughter day of year					
Region	Bulls	Cows	1-2 YO Heifers	2-3 YO Heifers	1-2 YO Steers	2-3 YO Steers
Northland	4-Jan	6-Feb	18-Feb	23-Nov	21-Feb	26-Dec
Waikato/Bay of Plenty	25-Jan	16-Feb	10-Mar	11-Dec	10-Mar	13-Jan
Gisborne	8-Feb	20-Feb	14-Apr	11-Jan	21-Apr	15-Jan
Hawkes Bay	3-Feb	27-Feb	6-Apr	24-Jan	28-Mar	18-Jan
Wairarapa	25-Jan	3-Mar	6-Apr	31-Dec	14-Mar	5-Jan
Taranaki/Manawatu	11-Feb	6-Mar	22-Mar	14-Jan	31-Mar	5-Feb
Nelson/West Coast	28-Jan	2-Mar	28-Mar	9-Feb	14-Mar	25-Jan
Marlborough	19-Jan	22-Feb	21-Feb	19-Dec	26-Feb	25-Dec
Canterbury	30-Jan	7-Mar	3-Mar	26-Dec	10-Mar	26-Dec

Otago	19-Feb	11-Mar	20-Mar	8-Feb	24-Mar	29-Jan
Southland	14-Mar	28-Mar	3-Apr	11-Feb	10-Apr	7-Feb
LSD (days)	13.5	11.7	23.3	16.1	26.3	12.2
CV%	3.4	2.8	5.3	4.3	5.9	3.2

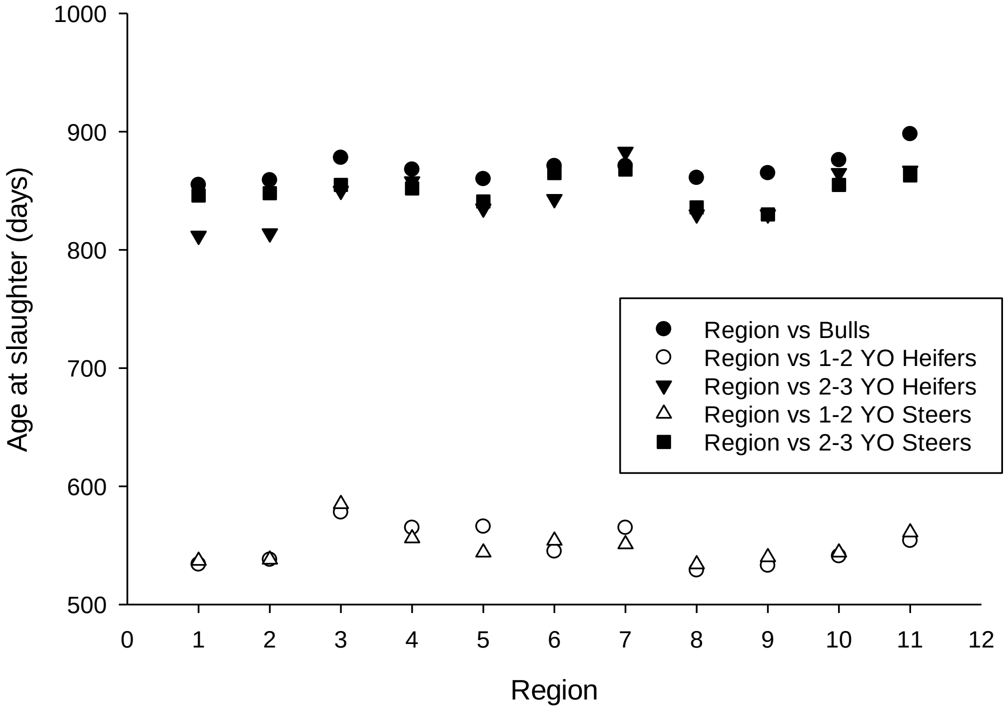


***Figure 10**. Regional differences in bulls, heifers and steers age at slaughter (in days).*

When compared within region, age at slaughter was relatively similar for both 1-2 year-old heifers and steers. The average age at slaughter varied significantly between regions, most likely based on feed supply.

4.3 Comparison with inventory stats and comparative impacts

4.3.1 Sheep

The initial sheep sensitivity analysis (Figures 5a and 5b) examined the effect of varying the percentage of lambs killed at the first slaughter date. A lower proportion of lambs slaughtered at the first slaughter date is equivalent to a higher proportion of lambs being retained through to their second slaughter date. This means that there will be more lambs being carried through winter to the second slaughter date. These animals will also be heavier, and as a result have higher intake requirements and therefore higher emissions. However, *the increase in emissions is likely to be small as they are small animals, and the time period is short (i.e., a few months)*.

Analysis of the full B+LNZ dataset (1993 to 2019) showed a clear trend towards an increase of the percentage of lambs retained for the second slaughter (Figure 6; a reduction over time in the percentage killed at the first slaughter date). Comparisons were made using AIM methodology, for the total emissions from sheep and grand total emissions using the current inventory default value (84% of lambs slaughtered at the first slaughter date), and then using the results from the analysis of the B+LNZ dataset. The B+LNZ dataset indicated that using a value of 84% from 1990 to 1992 was reasonable, as the values for 1993 to 1996 averaged 84.4% killed at the first slaughter date.

For both total methane emissions from sheep (**Figure S1** in Appendix 2) and total methane emissions (**Figure S2** in Appendix 2), it was difficult to distinguish differences by inspecting the chart lines, so the difference was plotted on a secondary axis for sheep total and grand total emissions. The percentage differences (for 2019) were small at 0.48% for sheep and 0.12% for grand total emissions. *The B+LNZ dataset provides evidence of a trend towards increasing retention of lambs to the second slaughter date, though the impact on emissions (sheep and grand totals) is likely to be negligible*. Incorporating these results into the AIM methodology would help improve the model's accuracy, with a solid dataset to support a greater feed requirement, but without a significant change in emissions.

4.3.2 Beef cattle

While the methodology (MPI 2021) has potential conflicts in dates, **Table 5** was used to illustrate potential impacts of using the B+LNZ dataset when determining beef cattle birth and slaughter dates. Days of age were calculated either from 20 September for the Inventory or from 25 September, as per the Birth date section conclusions.

Creating separate categories for 1-2 year-old cattle increased the level of precision. To create relativities to the inventory, relative proportions of young and older cattle were calculated. Weighed days of age were greater in all categories when comparing the B+LNZ data set to the inventory standards.

Carcass weights are also presented. Inventory carcass weights (2015-2019) were calculated from total carcass weight recorded divided by the number of animals slaughtered for each category. Heifer carcass weights (when weighted for population), and bull carcass weights were higher, while steer carcass weights were lower (Table 5).

***Table 5**. Comparison of AIM and B+LNZ birth date, slaughter date, days of age at slaughter and carcass weight using data for the 2015-2019 period. YO: year-old.*

Item		AIM	B+LNZ		
Birth date		20-Sep	25-Sep	Relative numbers	Weighted value
Slaughter date	Bulls	1-Oct	3-Feb		
	1-2 YO Heifers	1-Oct	19-Mar		
	2-3 YO Heifers	1-Oct	6-Jan		
	1-2 YO Steers	1-Feb	21-Mar		
	2-3 YO Steers	1-Feb	14-Jan		
Age (days)	Bulls	730	865	100	
	1-2 YO Heifers		544	29.8	
	2-3 YO Heifers	730	837	70.2	750
	1-2 YO Steers		546	14.3	
	2-3 YO Steers	730	845	85.7	802
Carcass weight (kg)	Bulls	301.5	356		
	1-2 YO Heifers		231		
	2-3 YO Heifers	236.5	256		249
	1-2 YO Steers		261		
	2-3 YO Steers	306.5	305		299

Methane emissions from current inventory values were compared with those calculated from the B+LNZ dataset. Again, the contribution of 1-2- and 2-3- year-old animals was calculated based on relative slaughter numbers. *Overall, the current inventory calculations may underrepresent the methane emissions from beef cattle* (**Table 6**). Relativity values that are <1 indicate that the inventory is underestimating the factor represented in the table. Steers were the exception in intake and daily emissions; however, when calculated over their lifetime, the relative underprediction of the inventory remained.

Bull beef were the furthest group from current calculations with inventory numbers representing only 75% of the emissions calculated from the B+LNZ dataset. This was due both to higher growth rates of bulls as well as later slaughter dates.

Although out of scope, the overall mean lambing percentage has increased throughout the 29-year period (from 99.3% in 1990 to 129.8% in 2019) (Figure S3 in Appendix 2), whereas the calving percentage has remained relatively unchanged (or even slightly declined) during the same period (Figure S4 in Appendix 2).

Table 6*. Growth rates, feed intake and daily and lifetime methane emissions, calculated using the AIM methodology (MPI 2021) and AR6 emissions factors. Relativities are calculated using the AIM value as the base, hence numbers below 1 represent an underestimate using the current inventory birth and slaughter data. YO: year-old.*

Item		AIM	B+LNZ	Weighted value	Relativity
Growth rates (kg/d)	Bulls	0.752	0.766		0.981
	1-2 YO Heifers		0.767		
	2-3 YO Heifers	0.579	0.558	0.620	0.934
	1-2 YO Steers		0.866		
	2-3 YO Steers	0.766	0.664	0.693	1.105
Intake (kg DM/d)	Bulls	9.032	9.95		0.907
	1-2 YO Heifers		8.30		
	2-3 YO Heifers	7.22	7.43	7.69	0.972
	1-2 YO Steers		9.09		
	2-3 YO Steers	9.19	8.59	8.66	1.07
Daily methane emissions (kg/d)	Bulls	0.195	0.215		0.907
	1-2 YO Heifers		0.179		
	2-3 YO Heifers	0.156	0.160	0.166	0.972
	1-2 YO Steers		0.196		
	2-3 YO Steers	0.199	0.186	0.187	1.07
Lifetime methane emissions (kg/head)	Bulls	113.2	153.7		0.736
	1-2 YO Heifers		70.6		
	2-3 YO Heifers	90.4	110.2	98.4	0.919
	1-2 YO Steers		77.7		
	2-3 YO Steers	115.1	128.9	121.6	0.947

4.4 The Beef + Lamb NZ Economic Survey

4.4.1 Background to the Economic Survey

The Sheep and Beef Farm Survey is extremely consistent by design, within years and between Survey years as an accurate record of Sheep and Beef Sector activity. The Sheep and Beef Farm Survey has been in operation and development for over 70 years. By design, the Sheep and Beef Farm Survey measures and reports a complex set of Sheep and Beef Farm data with 6 Revenue streams and their associated expenditure, financial structure and physical inputs and land management systems. The Survey is categorised into 8 Farm Classes along with a weighted All Classes average of the 8 Farm Classes. Farm Classes are defined by altitude, climate and contour, which broadly determine their management systems. There are multiple Land Use Capability (LUC) classes within each farm and each Farm Class.

The Survey is about the whole farm business and its operating environment, covering land, labour and capital.

The Survey captures, for example:

1. Up to 2,200 annual data points for each farm – from livestock numbers to revenue, expenditure and capital, fertiliser, forage and grain crops, exotic forest areas

2. Actual livestock sales and purchases are recorded and collected annually from around 30,000 invoices

3. Other within-season on-farm supporting data

4. Fertiliser applications for each farm, and the NPKS elemental content of the fertiliser and applied areas

5. Fertiliser purchases for each farm, and the NPKS elemental content of fertiliser that is purchased

The Survey data are consistent, and each farm case is validated by 1,729 compound edit checks. e.g., if a farm sells wool, it must have shorn sheep during the year, if no sheep were shorn then there has to be an inventory of wool on hand to sell that is less than, or equal to, the amount sold. If not, then an error is reported that has to be fixed for the farm to enter the Survey as completed.

The Sheep and Beef Farm Survey sample is based on the so-called Business Frame (BF) for New Zealand. The BF is a database of the individual economic units that make up the New Zealand economy. It includes private businesses ranging from self-employed individuals, farms and small stores to large corporations. The BF records details such as business names and addresses, predominant type of industrial activity performed, institutional sector, employment levels, and the degree of overseas ownership. The primary purpose of the BF is as a statistical register or frame for the statistical outputs produced by StatsNZ. Using the BF, which is a single centralised and conformed set of information, ensures overall alignment and consistency within New Zealand.

The sample is based on the distribution of Sheep and Beef stock units on farms that operate commercially. The commercial farm definition includes:

1. the farm has 750 or more sheep and beef stock units.

2. 70% or more of farm revenue must be derived from sheep and beef with an exception for mixed cropping farms, which are mainly in Canterbury that farm livestock within crop rotations.

3. At least 80% of the stock units must be sheep and/or beef cattle stock units.

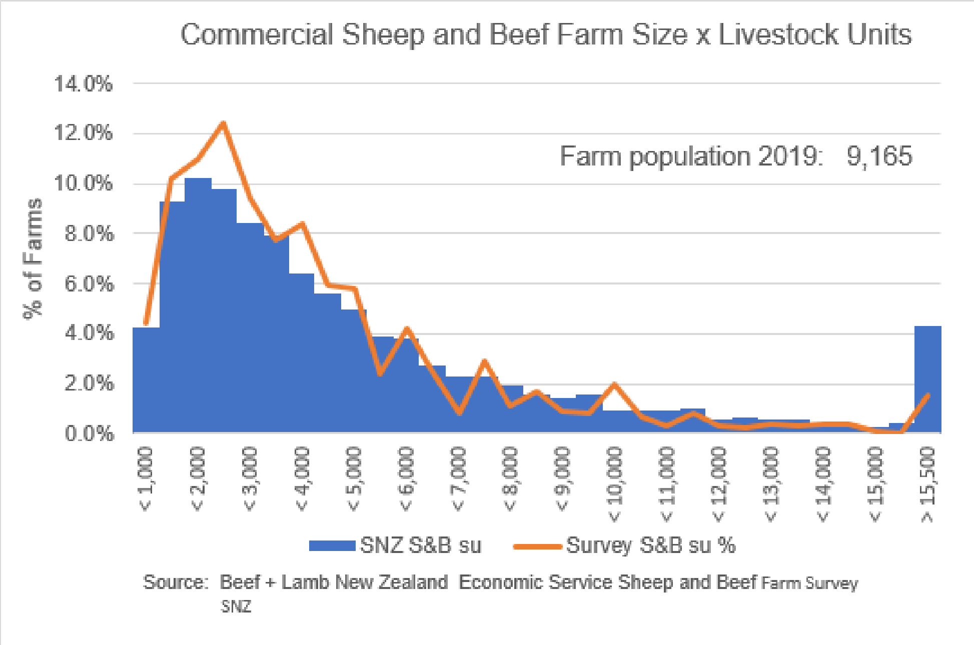
4. The farm must be run as a commercial sheep and beef farm.

Given this, the number of commercial sheep and beef farms is currently estimated at 9,165 (compared with 19,600 in 1990-91).

The number of commercial sheep and beef farms will be revised following the results of the next five-yearly StatsNZ Census, which is for the year ending 30 June 2022, to be published in May 2023.

The Sheep and Beef Farm Survey is a sample survey that uses a sample that is around 5.6% of the commercial Sheep and Beef Farm population. By design, it is a random proportional sample so there are approximately 5.6% of sheep and beef farms within each size interval (with size measured by stock units).

The chart below illustrates the Sheep and Beef Farm Survey sample distribution compared with StatsNZ distribution of holdings ranked by sheep and beef stock units. This proportional sample reduces sample variability because the sample distribution conforms to the population distribution of Sheep and Beef stock units on commercial Sheep and Beef Farms.



By design, the Sheep and Beef Farm Survey is to report on annual outcomes and trends through time. To measure trends and reduce variability, around 15% of the sample is refreshed each year, which means 85% of the farms in the Survey are the same between adjoining years.

The Sheep and Beef Farm Survey is not an end in itself but is a means to:

1. Provide a base of actual data to meet research and policy demands. The Survey has been in operation since 1950 – so for over 70 years.

2. Supply farm benchmark data and distributions.

3. Provide a framework for two within-season surveys:

    a. The Stock Number Survey that is used to estimate livestock numbers at 30 June in the current year. The results are published at the end of July whereas StatsNZ data are published in the following May. This provides a sound estimate of livestock for forecasting wool, lamb, mutton and beef production, which among other things is used extensively in the industry when marketing plans are being developed (because over 90% of New Zealand's meat production is exported) and shipping programmes.

b. The Lamb Crop Survey, the report for which is published in early November for the current year to confirm/update lamb crop forecasts. New Zealand's official lamb crop data come from the Ag Production Census, which is for the year ending 30 June, so the lamb crop data released in May 2023 for example will relate to the spring of 2021.

4. Provide a consistent base of authoritative, credible data to support forecasts of farm outcomes, profitability and to provide input to whole-sector forecasts of export meat production and wool production at the regional and New Zealand levels.

4.4.2 Comparison of the Economic Survey with StatsNZ Agricultural Production Statistics

In May 2022, StatsNZ released the results of the Agricultural Production Statistics (APS) Survey that was conducted in 2021. A comparison with the results of B+LNZ's 2020-21 Sheep and Beef Farm Survey is in Appendix 3.

This shows the official New Zealand "Pastoral Area" and "Other Land use areas" for "Sheep, Beef", "Grain-crop" and "Deer" enterprises. Note 30% to 40% of the deer herd is farmed on commercial sheep and beef farms.

In the spreadsheet (Appendix 3):

a. Row 12 shows the pastoral <u>grazing and crop</u> areas assigned by StatsNZ to "Sheep Beef Crop Deer" – a total of 7.519 m ha [Col F]

b. Row 25 shows these areas <u>as a percentage</u> of the total "Sheep, Beef", "Grain-crop" and "Deer" area of 8.888 m ha [Col N]

c. Row 35 shows the All Classes weighted average areas from the Sheep and Beef Farm Survey <u>on a percentage</u> basis aligns closely with the StatsNZ data (Row 25), which reflects the proportional sampling design.

d. Row 34 shows the aggregate area estimated from the results of the Sheep and Beef Farm Survey.

e. Row 35 shows the aggregate area estimated from the results of the Sheep and Beef Farm Survey as a percentage of the aggregate area from the corresponding areas according to StatsNZ.

   i. Col F, the aggregate grazed area on <u>commercial</u> sheep and beef farms is 85% of grazed area published by StatsNZ [Row 12]. Large stations like Molesworth in the StatsNZ data need to be considered in their total. The remainder will be small holding-lifestyle block areas.

   ii. Col H, the aggregate area of "Horticulture" estimated from the Sheep and Beef Farm Survey is double that published by StatsNZ, but the areas are small in the overall picture.

   iii. Col J, the aggregate area of "Forestry" estimated from the Sheep and Beef Farm Survey is 89% of the area of "Sheep, Beef", "Grain-crop", "Deer" and forestry published by StatsNZ. It is reasonable that the majority afforestation is on commercial Sheep and Beef Farms.

iv. Col M, the aggregate area of “Other” estimated from the Sheep and Beef Farm Survey is 82% of the area of “Other Land use areas” published by StatsNZ. The remainder is on small holdings and other land areas not assigned to commercial sheep and beef farming.

5. Recommendations

The analysis of B+LNZ’s data was used to build a baseline that more accurately reflects New Zealand agricultural GHG emissions from sheep and beef farming. Despite a few variables examined having negligible effects, the current analysis suggests that a few birth and slaughter variables and assumptions in AIM will need additional consideration (i.e., having potential to be adopted by AIM).

5.1 Sheep

In terms of national trends over time, the analysis indicates that there has been no significant change in sheep mating date over the 30-year time frame examined. When data was translated into a median lambing date, this equated to 10 September, which is similar to the currently used date in the inventory (11 September), and the analysis provides no reason to suggest that sheep birth dates need to be changed. When B+LNZ’s dataset was weighted for regional sheep population (ewes to ram), the median lambing date shifted from 10 September to 13 September. Similarly, this trend would have relatively little impact on current inventory outcomes. However, this may provide the opportunity to increase the accuracy of the inventory, particularly as flock numbers and contributions from different regions may change over time. But these changes would only be relevant if a decision was made to regionalise sheep inventory calculations.

1. No change to lambing date at this time.

Since the introduction of split slaughter dates for lambs, the percentage of lambs killed at the first slaughter date has remained fixed at 84%, and this value has been used for estimating GHG emissions ever since. Although a trend towards an increased % of lambs carried through to the second slaughter date (from the first lamb slaughter date) was seen (i.e., more and heavier lambs carried through winter to the second slaughter date), the increase in methane emissions is likely to be small (i.e., the impact on total emissions is likely to be negligible). Incorporating these results into the AIM methodology would help improve the model’s accuracy, with a solid dataset to support greater feed requirements, but without a significant change in emissions.

2. Increase the proportion of lambs held over to a second slaughter date to 22% from 2010 onwards.

5.2 Beef cattle

In terms of national trends over time, the analysis indicates that there is a significant trend towards a later beef cattle mating date over the 30-year time frame. The mating dates examined translate into calving dates of 20 September for the 1990-2000 period, and 25 September for the 2010-2019 period. The current inventory calving date is 20 September. In terms of regional differences, data indicates a difference between mating dates in Northland and Southland, although mating dates in other regions were similar, and trends towards later mating dates were evident in most regional datasets (the extent of the shift, however, varied little between regions). Again, these changes would only be relevant if a decision was made to regionalise beef cattle inventory calculations.

3. Change the national calving date to 25 September

In attempting to identify comparative ages at slaughter for comparison between the B+LNZ dataset and AIM, some anomalies were identified in the AIM methodology. All slaughter bulls, steers and heifers are assigned the same birth date in AIM. But most slaughter bulls are sourced from the dairy industry, which has an inventory birth date of 01 August. Dairy bulls enter the inventory with a gap in record (difference between dairy cattle weaning date and beef cattle weaning date) of 140 days. This creates a potentially significant gap in emissions resulting in an artificially lower GHG output than equivalent beef animals.

4. Review calving date, rearing policy and weaning date allocated to bull beef

Slaughter dates for all classes of beef across the recorded period (1993-2019) show little variation in average slaughter date within stock classes.

With a couple of recent exceptions, the age of bulls at slaughter appears to be relatively stable, whereas the age at slaughter of both 1-2 year-old heifers and steers has declined slightly over the 27-year period considered. This equates to 1-2 year-old heifers now being slaughtered approximately 24 days younger in 2019 than in 1993 (528 vs 552 days of age respectively). Steers of 1-2 years of age are now being slaughtered approximately 35 days earlier in 2019 than in 1993 (520 vs 555 days of age respectively). These days of age are supported by growth rates that align with industry best practice and expert knowledge.

5. Apply slaughter dates of:

    a. 3 February to slaughter bulls (865 days-of-age)

    b. 19 March to 1-2 year-old heifers (544 days-of-age)

    c. 6 January to 2-3 year-old heifers (837 days-of-age)

    d. 21 March to 1-2 year-old steers (546 days-of-age)

    e. 14 January to 2-3 year old steers (845 days-of-age)

6. Review potential changes to slaughter date over time with respect to the potentially earlier dates as genetic improvement continues. An analysis to determine if a relationship between age at slaughter and genetic gain may be warranted.

Creating separate categories for 1-2 year-old cattle increased the level of precision. To create relativities to the inventory, relative proportions of young and older cattle were calculated. Weighed days of age were greater in all categories when comparing the B+LNZ data set to the inventory guidelines.

7. Consider the practicality of splitting heifers and steers into age classes to further increase the precision of the inventory calculations

    a. Heifers – estimates are 30% 1-2 year-old; 70% 2-3 year-old

    b. Steers – estimates are 14% 1-2 year-old; 86% 2-3 year old

8. Review the relative proportions of animals slaughtered as 1-2 or 2-3 year-olds as genetic improvement continues (related to recommendation 6).

Overall, the current inventory calculations may underrepresent the methane emissions from beef cattle. Steers were the exception in intake and daily emissions; however, when calculated over their lifetime, the relative underprediction of the inventory remained. Bull beef were the furthest group from current calculations with inventory numbers representing only 75% of the emissions calculated from the B+LNZ dataset. This was due both to higher growth rates of bulls as well as later slaughter dates.

6. Acknowledgements

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8. Appendices

8.1 Appendix 1.

To calculate their contribution to methane and nitrous oxide production, the New Zealand Agricultural GHG Inventory model (AIM) calculates emissions separately based on 7 sheep and 11 beef cattle livestock classes, based on gender, age and whether they are used for breeding or finishing (MPI 2021). The 7 sheep classes include lambs, wethers, growing non-breeding sheep, growing breeding sheep, mature breeding ewes, dry ewes, and rams. The 11 beef classes include growing 'cows' (calves or heifers; 0 - 1 year), growing 'cows' (heifers; 1 - 2 years), breeding growing cows (2 - 3 years), breeding mature cows, breeding bulls (mixed age), slaughter 'heifers' in two different age groups (calves and yearlings, 0 - 1 and 1 - 2 years, respectively), slaughter 'steers' (same age groups as heifers), and slaughter 'bulls' (same age groups as slaughter heifers and steers) (MPI 2021).

8.2 Appendix 2.

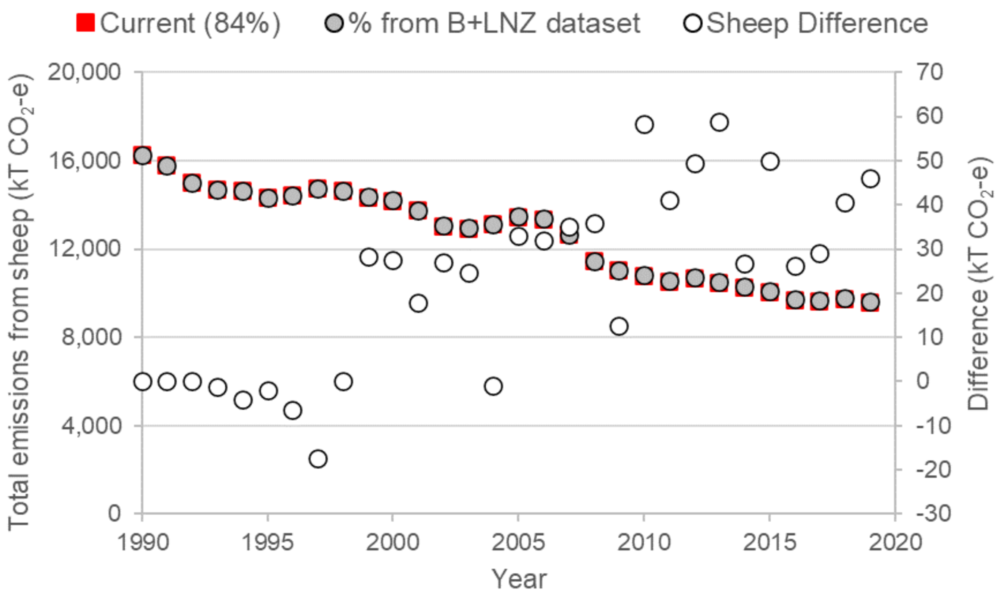

***Figure S1**. Total sheep emissions (kT CO_2-e) comparing percentage lambs slaughtered at first slaughter date (current default is 84% for all years) with results from analysis of B+LNZ datasets (trend of decreasing percentage slaughtered at first slaughter date; Figure 6).*

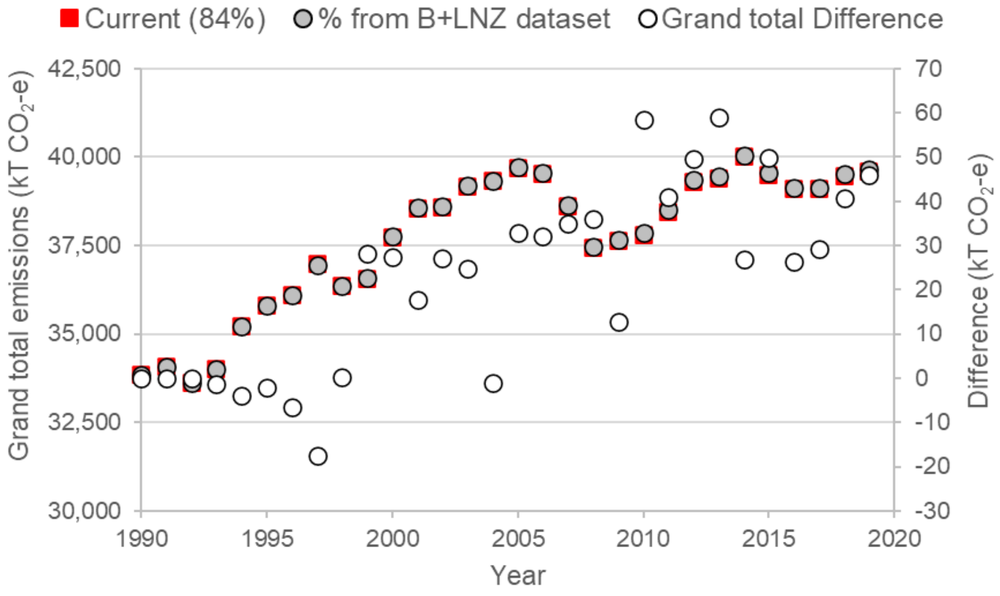

Figure S2*. Total emissions (kT CO_2-e) comparing percentage lambs slaughtered at first slaughter date (current default is 84% for all years) with results from analysis of B+LNZ datasets (trend of decreasing percentage slaughtered at first slaughter date; Figure 6).*

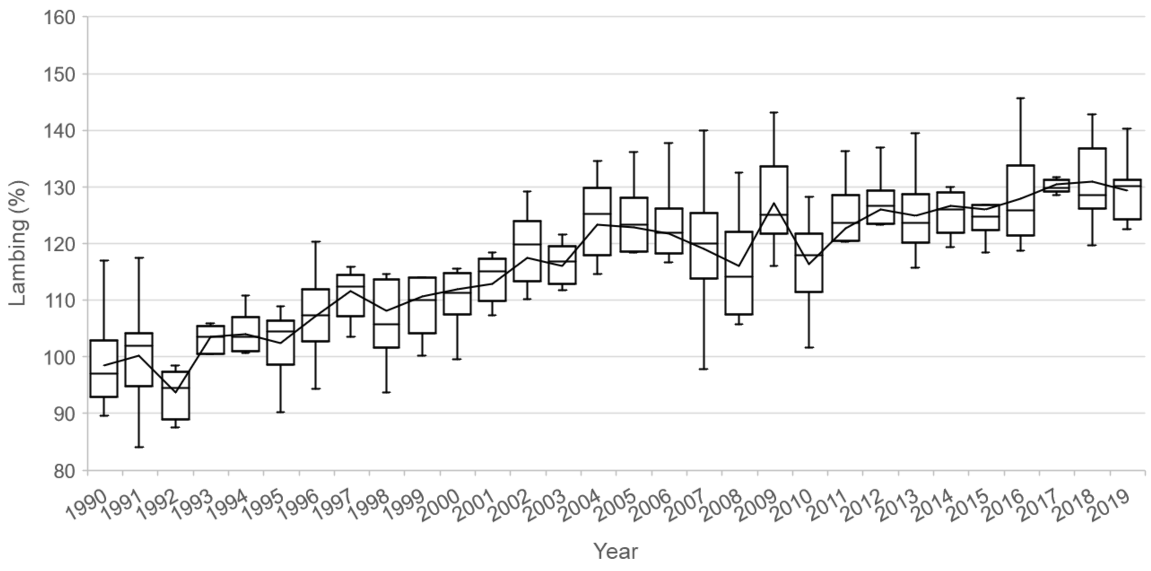

Figure S3. *Mean lambing percentage from 1990 to 2019 (Source: B+LNZ's Sheep and Beef Farm Survey data).*

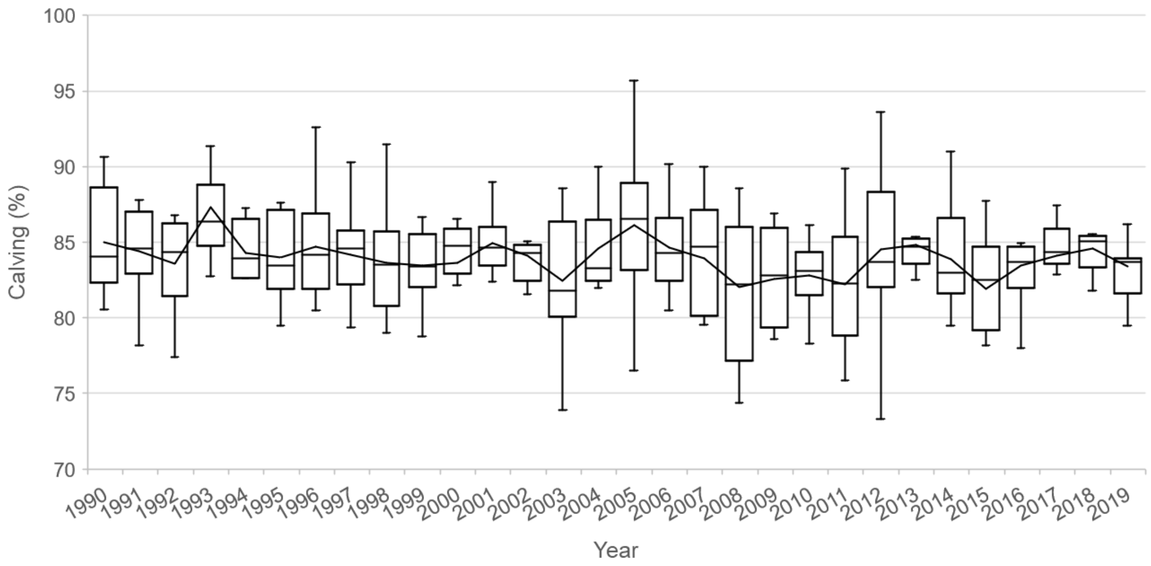

Figure S4. *Mean calving percentage from 1990 to 2019 (Source: B+LNZ's Sheep and Beef Farm Survey data).*

8.3 Appendix 3.

A comparison of the Agricultural Production Statistics (APS) Survey conducted in 2021 with B+LNZ's 2020-21 Sheep and Beef Farm Survey.

RMD 21 Sep 2022

SORTX SURV.TS WITH CLASS.REG "9800" AND WITH SEASON "202021"BY SEASON CLASS.NAME SEASON CLASS.WEIGHT AREA.GRAZEDTOTAL AREA.HORTICULTURE AREA.FOREST AREA.OTHER AREA.TOTAL2 HEADING "%%ES%%'L'Sheep & beef Farm Surve

SNZ APS survey 30 June 2021

Summary Table	**2021 Pastoral Area ha**					**2021 Other Land use areas ha**						
	Grassland	**Tussock grazed**	**Grain, seed, Cropped**	**Total ha**	**% allocation**	**Horticulture**	**Plantations Exotic**	**Exotic to restock**	**Mature Bush**	**Native Scrub & Regenerating**	**All Other (shelter belts, tracks, yards)**	**Total Occupied**
SNZ ref	Ic6002	Ic6003	Ic6012			Ic6007	Ic6009	Ic6019	Ic6015	Ic6016	Ic6018	Ic6013
Sheep, Beef	4,754,861	1,971,519	266,102	6,992,482	70.1%	5,841	158,685	7,842	362,283	513,638	246,454	8,287,225
Grain-crop (assumed stocked too)	155,430	65,149	96,705	317,284	3.2%	2,838	1,645	102	4,585	4,436	10,462	341,352
Deer	145,624	52,674	10,978	209,276	2.1%	140	6,264	524	17,406	16,915	9,289	259,814
Sheep Beef Crop Deer	**5,055,915**	**2,089,342**	**373,785**	**7,519,042**	**75.4%**	**8,819**	**166,594**	**8,468**	**384,274**	**534,989**	**266,205**	**8,888,391**
Dairy	2,070,873	29,997	87,591	2,188,461	22.0%	1,626	36,500	2,590	45,392	39,991	99,551	2,414,111
Pastoral	**7,126,788**	**2,119,339**	**461,376**	**9,707,503**	**97.4%**	**10,445**	**203,094**	**11,058**	**429,666**	**574,980**	**365,756**	**11,302,502**
Forestry	68,585	-	100	68,685	0.7%	900	1,349,444	55,294	54,683	92,454	44,491	1,665,951
Other, nurseries, orchards, hort etc	156,568	13,606	23,196	193,370	1.9%	117,820	14,280	273	2,467	3,279	16,462	347,951
Total	**7,351,941**	**2,132,945**	**484,672**	**9,969,558**	**100.0%**	**129,165**	**1,566,818**	**66,625**	**486,816**	**670,713**	**426,709**	**13,316,404**
Source: Beef + Lamb New Zealand Economic Service & Insights Statistics New Zealand												
SNZ Sheep Beef Crop Deer as % total area				**85%**		**0%**	**1.9%**	**0.1%**	**4%**	**6%**	**3%**	**100%**

Beef + Lamb New Zealand Economic Service
Sheep & beef Farm Survey All Classes Land Use
21 Sep 2022.

Class		**Season**	**Class Weight**	**Area Grazed**	**Area Horticulture**	**Area Forestry**	**Area Other**	**Area Total ha**
All Classes		2020-21	9,165	698	1	17	106	822
				85%	**0.1%**	**2%**	**13%**	**100%**
Survey Weighted Aggregate data (commercial farms)				6,397,170	9,165	155,805	971,490	7,533,630
as % of SNZ Sheep, Beef, Deer Crop ha				85%	104%	89%	82%	85%
Blue =								
Grazing area including flat rolling								
that could be planted in forestry	**4,969,070**							
	50%							
Afforested ha est by 20235	400,000							
% of avail grazing ha	8.0%							

Sheet1