

# Modelling the cost of ewe mortality in New Zealand sheep flocks

Anne L Ridler<sup>a,\*</sup>, Rene A Corner-Thomas<sup>b</sup>, Peter Tozer<sup>b,c</sup>

<sup>a</sup> Tāwharau Ora – School of Veterinary Science, Massey University, Private Bag 11-222, Palmerston North, New Zealand

<sup>b</sup> School of Agriculture and Environment, Massey University, Private Bag 11-222, Palmerston North, New Zealand

<sup>c</sup> PRT Consulting, 9 Helen St, Cunderdin, Australia

## HIGHLIGHTS

- Ewe deaths reduce farm profit; most occur during lambing and are preventable.
- Bioeconomic model links ewe mortality to cash surplus in NZ sheep flocks.
- Reducing ewe deaths by 50 % boosts cash surplus by up to NZ\$6.67 per ewe.
- Mortality cost estimates help farmers assess value of prevention strategies.

## ARTICLE INFO

### Keywords:

Sheep farming  
Ewe mortality  
Bio-economic modelling  
Wastage  
Animal health economics  
Pasture-based systems

## ABSTRACT

**CONTEXT:** Reported ewe mortality rates in extensively farmed sheep flocks range from 2.9–12.8%. Most deaths occur over the lambing period, and many are potentially preventable or treatable. An understanding of the costs of ewe mortality would allow farmers to determine which interventions are most cost-effective.

**OBJECTIVE:** Use a dynamic bioeconomic model to investigate the impacts of ewe mortality on cash operating surplus for New Zealand sheep flocks.

**METHODS:** An existing dataset of 23 flocks was used which comprised data on ewe numbers throughout the year, ewe deaths, reproductive data and farm demographic data (location, size, topography and stock numbers). Each flock was modelled using economic data for the 2023 financial year. Cash operating surplus per ewe (COS/ewe) was generated for each flock using their actual death rates. For flocks with death rates >4%, the effects on COS/ewe were also modelled based on a reduction in ewe deaths by 20% or 50%.

**RESULTS AND CONCLUSIONS:** Flocks with higher ewe death rates had lower COS/ewe, with an overall correlation of 0.58. Reducing deaths by 20% and 50% resulted in an increased COS/ewe of NZ\$1.12 to \$2.66/ewe and NZ\$2.89 to \$6.67/ewe, respectively. Multiplying these numbers by the total number of ewes in their flock provides guidance to producers on how much they could spend to reduce the death rate of their ewes.

**SIGNIFICANCE:** Producers can use the results, along with their flock-specific ewe mortality data, to determine cost-effective strategies to reduce ewe mortality.

## 1. Introduction

In a majority of New Zealand sheep flocks ewes are culled at the end of their expected productive life, usually at or around 6 years of age (Ridler et al., 2024). However, many ewes are culled or die before they reach this age, which is often described as ewe wastage (Flay et al. 2021; 2022; Robertson and Friend 2023). Farrell et al. (2019) used a bio-economic model to examine the effects of ewe wastage (ewes culled up to 6 ewes of age, and ewe deaths) for a self-replacing flock based on a representative North Island of New Zealand hill country sheep and beef

cattle farm. Wastage rates of 5 to 21 % were modelled and, for example, for a flock with 15 % wastage a 10 % reduction could increase cash profit by 17 %. They identified that greater wastage meant that more young ewes were kept which resulted in a corresponding decrease in lamb weaning rates and hence fewer lambs sold. Additionally, the requirement to keep proportionally more replacements, and hence breed more ewes to maternal breed sires, reduced the proportion of ewes that could be bred to terminal sires which also reduces cash operating surplus (Farrell et al. 2020).

The potential economic consequences of culling ewes before they

\* Corresponding author.

E-mail address: [A.L.Ridler@massey.ac.nz](mailto:A.L.Ridler@massey.ac.nz) (A.L. Ridler).

<https://doi.org/10.1016/j.livsci.2025.105877>

Received 19 October 2025; Received in revised form 4 December 2025; Accepted 19 December 2025

Available online 20 December 2025

1871-1413/© 2026 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

reach the end of their productive life, sometimes described as premature culling, are likely to vary depending on various factors such as the price for cull ewes and lambs. Additionally, ewes are often prematurely culled for physical defects that reduce their productivity, such as teeth or udder defects (Ridler et al. 2024; 2025). The causes of these conditions, and hence their effective prevention, are poorly understood (McGregor 2011; Flay et al. 2022). Culling affected ewes, therefore, is the most rational approach for their management.

On-farm ewe deaths, however, mean that the cull value for the ewe cannot be recouped. Mean annual ewe mortality rates reported from various studies across New Zealand, Australia and the United Kingdom ranged from 2.9 – 12.8 % (Flay et al. 2022) but there is considerable variation between flocks (Ridler et al. 2025). In New Zealand, on average two thirds of ewe deaths are reported to occur during the lambing period (Flay et al. 2021; 2023; Ridler et al. 2025) and death during this time means that potential value of the lamb/s is also lost. The most frequently reported causes of death during the lambing period are dystocia and septicaemia (McQuillan et al. 2024) and casting (Capdevila-Ospina et al. 2021). These conditions are potentially preventable and/or treatable, and therefore a clear understanding of the economic losses associated with ewe deaths would facilitate farmers to determine cost-effective interventions to reduce mortality.

Dynamic bioeconomic models allow researchers to study the interactions between biological systems and management changes and their impact on the economic outcomes from the system. These types of models also can take into account feedback loops or the impact of simultaneous multiple changes in the system due to either biological factors, such as changes in birth or death rates or feed production, or economic/management changes, such as producers seeking to increase sale weight of progeny (Moloney et al. 2023) or adopting land management changes (Wangui et al. 2021). These types of models also can be used to study inter-temporal changes to the system and how the system adapts to the types of changes mentioned previously.

The aim of this study was to use a dynamic bioeconomic model and utilize an existing dataset on ewe flocks from the North and South Islands of New Zealand, to investigate the impacts of ewe mortality on cash operating surplus.

## 2. Materials and methods

### 2.1. Flocks

In 2021, 36 mainly Romney-based flocks were studied to investigate ewe culling and mortality in New Zealand sheep flocks (Ridler et al. 2024; 2025). Initially, flock owners provided basic demographic data on their sheep enterprise including farm location, size and contour, livestock numbers for all stock classes and approximate sheep to cattle ratio (in stock units). Over an approximately 9–10-month period in 2021, they provided the number of ewes at some, or all, of the following five management events: 1. Start of breeding (autumn); 2. pregnancy diagnosis (winter); 3. pre-lambing (early spring); 4. lamb marking (late spring); 5. weaning (early summer). Flock owners also provided details on the number and timing of ewes being culled, and reproductive data, specifically flock scanning percentage (number of fetuses scanned divided by number of ewes present at scanning) and number of non-pregnant ewes. Data on ewe deaths were determined by a combination of those reported by flock owners and by calculating ewes missing from tallies that were not accounted for by culling or recorded death (Ridler et al. 2025). Flock replacement rates were calculated by dividing the number of two-tooth ewes present in the flock at the start of breeding over the total number of ewes in the flock (two-tooth plus mixed age) at the start of breeding.

Data from 23 of the 36 flocks were selected for modelling in the present study, based on completeness of data and location across a wide geographic range. The dataset comprised 15 North Island and 8 South Island flocks with a mean flock size of 5407 ewes (range 920 – 17,461).

### 2.2. Model

A dynamic simulation model was utilized to measure the impact of ewe death rates on cash operating surplus (COS) on the 23 flocks identified above. COS does not make assumptions about farm financial structure and is measured as gross cash income minus farm cash operating expenses, excluding rates, interest, rent, and depreciation (Shadbolt and Martin, 2005). The model of Farrell et al. (2019), and as adapted by Wangui et al. (2021) and Moloney et al. (2023), to capture topography and differing lamb management options, was used as the basis for this research. The model has seven modules that interact to generate the desired output. The seven modules were: flock dynamics; feed supply; feed demand; feed balance; wool production; beef herd dynamics; and economics. The beef herd dynamics module was assumed to be fixed in this research and interacted only with the feed supply and feed balance modules, meaning that there were no changes in the beef herd or management of the beef herd in the context of the reported research.

#### 2.2.1. Flock dynamics

In the flock dynamics module, the size of the ewe flock ( $Y$ ) was the sum of six age groups ( $Y_i$ ) ( $i$  = age class 1 to 6) with  $i$  ranging from 1, maiden ewes (one-year-old) ( $Y_1$ ) to 6 = six-year-old ewes ( $Y_6$ ) Eq. (1). All ewes from  $Y_2$  to  $Y_6$  were presented for breeding. Each year, the ewes from the previous age group ( $Y_{i-1}$ ) aside from the culls ( $C_i$ ) and deaths ( $D_i$ ) were aged up to the next age bracket (Eq. (2)). The numbers of culls ( $C_i$ ) and deaths ( $D_i$ ) were a product of the number of ewes in that age group ( $Y_i$ ) and the age-specific culling ( $c_i$ ) and death rates ( $d_i$ ) (Eqs. (3) and (4)).

$$Y = \sum_{i=1}^6 Y_i \quad (1)$$

Where:

$$Y_i = Y_{i-1} - D_{i-1} - C_{i-1} \quad (2)$$

And

$$D_i = Y_i * d_i \quad (3)$$

$$C_i = Y_i * c_i \quad (4)$$

A constant culling rate across age classes,  $c_i$ , of 20 % was used for all  $i = 2$  to 6 ewes. The death rates for ewes  $d_i$  was constant across age classes but varied between farms as reported by the producers. Ewes were also culled at the end of their breeding age, and this varied across farms, with some farms culling at 5 years of age and some at 6 years of age. Several farms reported that they didn't cull for age and in these cases it was assumed in the model that ewes were culled at 6 years of age. The majority of ewe deaths were assumed to have occurred at lambing due to the greatest proportion of ewe deaths occurring during dystocia births or other lambing difficulties. Death rates for each farm are shown in Table 1.  $Y_{0.5}$  represented lambs on farm post-weaning, from which replacements were kept and aged into  $Y_1$  ewes, with all other lambs, male and excess females, sold.

Lambs born ( $LB$ ) was a function of the ewe flock ( $Y_{1-6}$ ), the pregnancy scanning rate ( $PSR$ ), as a percentage, and the foetal/lamb loss rate ( $F$ ). Some of farms in the study reported mating ewe lambs (7–9 months of age) ( $Y_1$ ), however not all farms reported mating ewe lambs. For those farms that did mate ewe lambs, not all of the farm's ewe lambs were mated due to some not reaching the "ideal" mating weight before the breeding season commenced. The proportion of lambs born in each age class depended on the flock lambing percentage, and the relative age reproduction rates which varied with age ( $RR_i$ ), where  $RR_2=0.85$ ,  $RR_3=0.97$ ,  $RR_4=1.04$ ,  $RR_5=1.09$  and  $RR_6=1.06$  (Farrell et al., 2019). An average foetal/lamb loss rate of 25 % between mid-pregnancy

**Table 1**

Flock ID, location (NI = North Island, SI = South Island), number of ewes at the beginning of the breeding year, ewe death rate<sup>1</sup>, and lamb weaning rate<sup>2</sup> for each of 23 New Zealand sheep flocks modelled using a bioeconomic model to determine the cost of ewe mortality.

Flock ID	Flock Location	No. Ewes	Ewe Death rate <sup>1</sup>	Lamb weaning rate <sup>2</sup>
1	NI	7616	2.10 %	154 %
2	NI	3782	2.38 %	143 %
3	NI	1932	4.71 %	146 %
4	NI	920	3.26 %	135 %
5	NI	7051	3.63 %	129 %
6	NI	7377	5.88 %	120 %
7	NI	4770	4.91 %	120 %
8	NI	10,735	11.58 %	121 %
9	NI	6057	5.88 %	138 %
10	NI	6682	5.22 %	109 %
11	NI	5025	5.69 %	134 %
12	NI	2737	3.84 %	123 %
13	NI	5020	2.23 %	124 %
14	NI	5149	6.06 %	139 %
15	NI	12,712	5.51 %	132 %
16	SI	2384	7.59 %	113 %
17	SI	2200	6.82 %	131 %
18	SI	1950	5.28 %	114 %
19	SI	2238	3.62 %	124 %
20	SI	3879	2.32 %	132 %
21	SI	2724	2.97 %	132 %
22	SI	17,461	8.84 %	149 %
23	SI	3981	2.64 %	143 %

<sup>1</sup> Number of ewes recorded dead or calculated to be missing between the start of breeding and mid-lactation, as a percentage of the number of ewes present at breeding.

<sup>2</sup> Calculated based on the number of fetuses present at pregnancy scanning (mid-pregnancy) minus 25 % (assumed losses to weaning), as a percentage of the number of ewes present at breeding.

(scanning) and weaning was assumed and calculated weaning rates are shown in Table 1.

$$LB = \sum_{i=1}^6 (Y_i * S * RR_i) * (1 - F) \quad (5)$$

The number of replacements (R) required to maintain the flock at a relatively steady state was the sum of the number of dead (D<sub>i</sub>) and culled (C<sub>i</sub>) ewes in each age class.

$$R = \sum_{i=1}^6 (D_i + C_i) \quad (6)$$

### 2.2.2. Feed demand

Energy demand, in MJ of metabolizable energy (ME), was driven by the physiological state of sheep in each age and sex class, i.e. pregnancy, lactation, weight gain or loss, and male or female lambs. Also, energy for wool growth was included for completeness. The equations for energy requirements were derived from Nicol and Brookes (2017) and CSIRO (2007). Maintenance energy (ME<sub>m</sub>) was estimated using Eq. (7), derived from Nicol and Brookes (2007):

$$ME_m = \left[ 0.28 * \frac{LW^{0.75} * e^{-0.03i}}{0.02 * Q + 0.5} \right] \quad (7)$$

Where LW = animal liveweight (kg/hd), *i* was defined as previously, and Q = pasture quality in MJ ME/kg dry matter (DM) and assumed to be 10 MJ ME/kg DM (Bown et al. 2012; Litherland et al. 2002). The liveweight of ewes was as supplied by each farm, and ranged from 55–70 kg/hd at the start of breeding, and the weight of ewes just prior to entering the main ewe flock (at approximately 15 months of age) was assumed to be 80 % of mature liveweight.

The maintenance energy requirement of lambs prior to weaning was captured in the ewe energy requirements. Post-weaning maintenance

energy requirements for lambs was estimated using Eq. (7), given a weaning weight of 30kg/hd and 25 kg/hd for single and multiple born lambs, respectively.

Total energy demand for lactation, ME<sub>l</sub>, for a ewe was calculated using Eq. (8), and was based on the lamb weaning weight(s) (LWW) and age of lamb(s) reared by the ewe up to weaning (*α*). Weaning weights were as previously defined, and the weaning age was assumed to be 12 weeks.

$$ME_m = 1,088 + 51.4LWW + 134.7\alpha \quad (8)$$

Energy requirements for gestation, ME<sub>g</sub>, was estimated based on the number of foetuses and expected lamb birthweights (*W<sub>l</sub>*) of 5 kg hd for singles and 4.5 kg/hd for twins. The number of higher multiple births, i.e. triplets or quads was very low, hence birthweights are not assumed for these.

$$ME_g = 0.25 W_l \frac{0.07372E_t \exp^{-0.00643d_g}}{k_c} \quad (9)$$

And

$$E_t = 10^{(3.322 - 4.979 * \exp^{-0.00643d})} \quad (10)$$

Where *d<sub>g</sub>* = day of gestation = 1–147, *E<sub>t</sub>* = the energy content of the gravid foetus, and *k<sub>c</sub>* = the efficiency of ME utilization for conception = 0.13 (MPI 2022). Given this information, the total energy demand for gestation was 277.5 MJ ME for single born lambs, and 227.5 MJ ME for each multiple born lamb.

Energy for, or from, weight gain, or weight loss was 55 MJ ME/kg of gain or 35 MJ ME/kg of loss. It was assumed ewes gained 2 kg of LW at approximately 50 g/d for 6 weeks prior to mating. Ewes also lost 2 kg of LW in the first month of lactation.

Demand for energy by lambs post-weaning was based on their LWW and the post-weaning LW gain assumed to be 200 g/d and 100 g/d for single and multiple born lambs, respectively. Within the model we assumed that all single-born lambs were sold to slaughter 28 d post-weaning, and multiple-born males and females were sold to other farmers for finishing, 77 d and 91 d post weaning, respectively, regardless of LW (Farrell et al., 2020).

The energy required for wool production, ME<sub>w</sub>, was estimated from the growth rate of wool (*G*), assumed to be 13.15 g/d, to generate an average fleece weight of 4.8 kg/hd. At this growth rate, the daily energy requirements for wool were:

$$ME_w = 0.13(G - 6) = 0.13(7.5) = 0.9295 \text{ ME MJ/d} \quad (11)$$

As lambs were sold earlier, as described previously, the total energy for wool growth for these animals was 26.026, 73.882, and 84.585 MJ ME, for single-born males and females, multiple-born, males, and females, respectively. For ewe lambs kept as replacements the ME<sub>w</sub> is 261 MJ ME, was part of their annual energy requirements were included in the maternal energy pre-weaning.

The total wool production (WP) was a function of average wool yield (*W*) adjusted for an age effect, *w<sub>i</sub>*. The age effect was *w<sub>1</sub>* = −1.8, *w<sub>2</sub>* = −0.09, *w<sub>3</sub>* = 0.42, *w<sub>4</sub>* = 0.28, *w<sub>5</sub>* = 0.05, and *w<sub>6</sub>* = −0.4.

$$WP = \sum_{i=2}^6 Y_i(W * w_i) \quad (12)$$

### 2.2.3. Feed supply

The supply of nutrients to satisfy the requirements above was assumed, within the model, to be sourced entirely from pasture, with allowance made for feed transfers between periods of high pasture growth to periods with low production, in the form of hay. Pasture growth rates for each region were derived from Trafford and Trafford (2011). The model was designed to adjust pasture growth rates based on topography of the farm by slope class: flat (0–5° slope), low slope (5° - <15° slope), and steep (>15° slope). These growth rate adjustment

factors were: 100 %, 52.1 %, and 38.1 %, respectively, for flat, low, and steep slope classes (Wangui et al., 2021). Topography data for each of the farms modelled was derived from information provided by each producer. Therefore, the feed supply profile for each farm was unique due to topographical variation across farms.

As the sheep enterprise only utilises a portion of the pasture produced on farm, other enterprises such as beef cattle or deer consume the rest. The amount of pasture feed available to the sheep enterprises was a fixed ratio of sheep stock units (SU<sup>1</sup>) to the beef and deer SU.

The model construct was such that all, or approximately all, feed was consumed either by the sheep, beef, and or deer enterprises. There were also a number of feedback loops within the model to adjust flock size to ensure that under or overgrazing did not occur.

#### 2.2.4. Costs and revenue data

Cost data for use within the model was derived from the Beef and Lamb Survey data for the 2023 financial year (Beef and Lamb NZ, 2024). The survey was collected by Beef and Lamb New Zealand and disaggregated by region. The range of locations modelled was covered by the survey data. The survey measures all cash costs and depreciation to measure economic farm surplus, or net farm profit. Because cash costs such as interest, drawings, and taxation payments and non-cash costs such as depreciation are unique to each farm, and for some of these costs they are not included in the data, cash only costs were utilised to calculate COS/ewe. Using COS/ewe allowed comparison between farms of different sizes. In the survey, cash operating costs were provided on a total or per SU basis, in the current study the SU-level data were utilised except for shearing costs which were number specific. Shearing costs were estimated based on the number of adult sheep shorn once per year and lambs for sale at a cost of \$6.68/hd. Lamb and adult sheep sale prices were also sourced from the survey data to ensure consistency between costs and returns.

### 3. Results and discussion

Cash operating surplus per ewe was calculated for each farm as shown in Table 2. Also, the relationship between COS/ewe and ewe death rate is presented in Fig. 1. From Table 2 and Fig. 1 it is evident that increasing the ewe death rate resulted in lower COS/ewe with overall correlation  $\rho = -0.58$ , and for the North Island (NI) and South Island (SI),  $\rho = -0.66$  and  $\rho = -0.46$ , respectively. The variation in the relationship between COS/ewe and ewe death rate was likely due to differences in management of stock, and differences in input usage, or potentially climate factors, such as rain or snow at critical times, which was not reported in the data.

Some variations may have also been related to differences in farm systems and farm goals and objectives, particularly differences in systems between the NI and the SI farms. Typically, the NI systems were purely livestock operations, with mostly sheep and beef enterprises, with some deer included. However, many of the farming systems in the SI data set incorporated cropping, and in some cases, significant areas of cropping, requiring these systems be integrated into the overall farming system.

Table 2 also indicates the impact of these activities on the COS/ewe if ewe death rates for some systems were reduced. In the analysis, for the 13 farms with ewe death rates greater than 4 %, the change in COS/ewe was modelled if the death rate was reduced by 20 % and 50 %. These results indicate that if ewe death rates were reduced by 20 %, whilst holding all other variables constant, COS/ewe would increase by between \$1.12 to \$2.66/ewe (3.3–14.7 %). If death rates were reduced by 50 % then COS/ewe would increase by \$2.89 to \$6.67/ewe (8.4–36.8 %). Multiplying these numbers by the total number of ewes in their flock

provides guidance to a producer on how much they could spend to reduce the death rate of ewes in their flock. The death rate of 4 % was taken arbitrarily as a measure of a “reasonable” death rate within a ewe flock, as it is not possible to reduce the ewe death rate to zero.

Ridler et al. (2025) analysed a dataset which included the flocks included in the present study and did not identify any association between ewe mortality rate and broad farm demographics such as farm location, farm size, flock size, number of ewes per labour unit and ewe lamb breeding policy. This suggests that the major factors affecting ewe mortality rates are farm-specific and it should be possible therefore for all farms to have rates of less than approximately 5 % per annum. Known risk factors for increased ewe mortality include poor body condition (Flay et al. 2022; 2023), older aged ewes (McQuillan et al. 2024), and death from preventable conditions during the lambing period (Capdevila-Ospina et al. 2021; Flay et al. 2022; McQuillan et al. 2024). The present study demonstrates that, based on prices from the 2023 financial year, New Zealand sheep farmers could afford to allocate \$2.89–6.67 per ewe on farm specific strategies to reduce mortality and likely have an economic return on that investment. Examples of such strategies include whole flock body condition scoring to identify ewes in poor body condition (BCS) and improve their management to increase their BCS, keeping older ewes separate from the main flock and assessing their condition and health more frequently, or allocation of labour to observe ewes daily in the pre-lambing period to rescue cast ewes. Ideally before embarking on intervention strategies, farmers would firstly identify the main timing and causes of ewe deaths in their flock so that interventions can be targeted.

In the present study, ewe mortality data were based on data from an approximately 9–10-month (pre-breeding to weaning) period, rather than a full year. It would have been preferable to have had data for an entire year. However, previous studies conducted in commercially farmed New Zealand sheep flocks indicate that, typically, relatively few ewes die in the weaning to pre-breeding period (Capdevila-Ospina et al. 2021; Flay et al. 2021) so the data used were likely to be a reasonable approximation of flocks’ annual mortality rates. The mortality data was primarily based on farmer-reported ewe tallies and ewe culling data, which were used to determine the number of ewes which were missing and thus presumed dead (Ridler et al. 2025). It is possible that some farmers may have miscounted ewes or not correctly recorded all culls, which may have reduced the accuracy of some of the calculated ewe mortality rates.

The objective of this research was to estimate the cost of ewe mortality in New Zealand sheep flocks; this objective was achieved utilising a dynamic bioeconomic model. As with all models, the resultant information is based on the assumptions made in model development and the data used as the basis for the model. In this research we utilised prices and costs for 2023; in this year lamb and mutton prices were amongst the lowest recorded over the period 2019 to 2025 (Beef and Lamb New Zealand 2025). Input cost inflation also would have affected COS for each farm, however, cost inflation in the year studied impacted costs outside COS, such as interest on borrowings (Beef and Lamb New Zealand 2023). To address this effect the models could have been run using data from different years or averages across a range of years, however, the key to understanding the results reported is that the differences across sheep farms with differences in ewe mortality rates may have changed in absolute values, but the relativity between farms would have remained. Therefore, the overall conclusion that ewe mortality has a significant impact on farm COS is still valid.

#### Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors did not use generative AI or AI-assisted technologies.

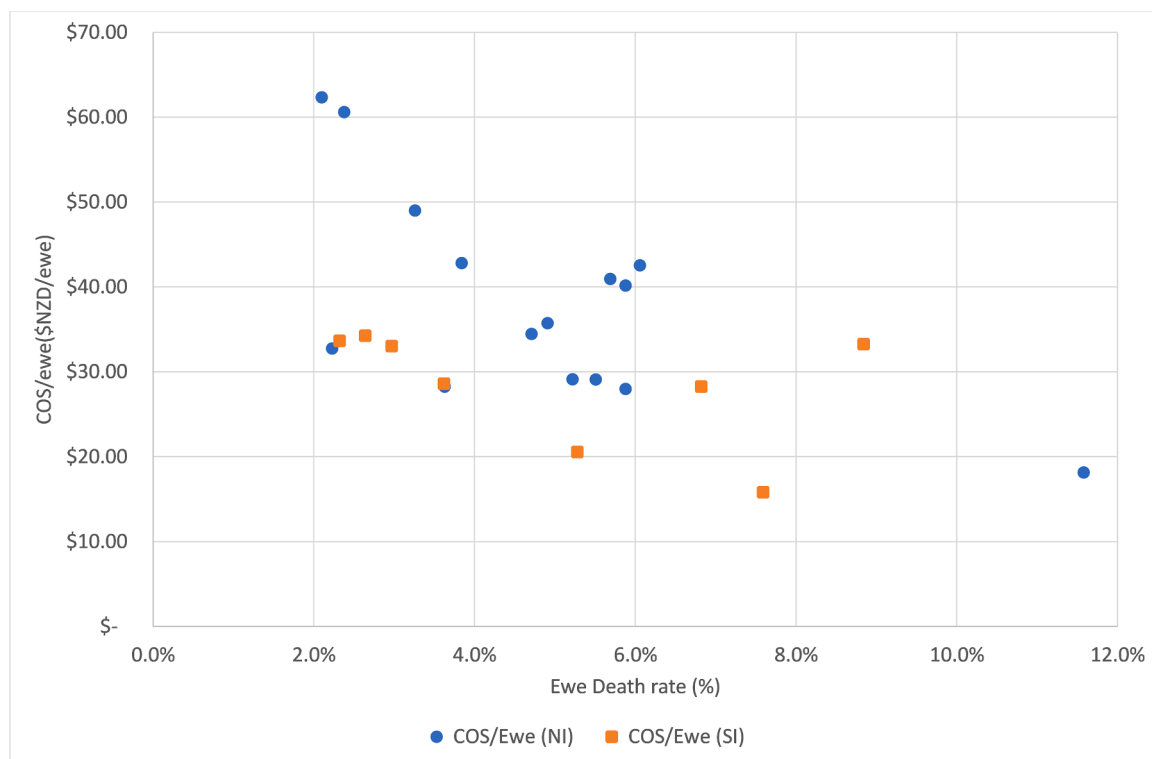
<sup>1</sup> A stock unit (SU) is equivalent to 550 kg of DM consumed by a 60 kg ewe raising one lamb. A mature cow is 6 SU, and a mature hind is 1.9 SU.

**Table 2**

Cash operating surplus per ewe (COS<sup>1</sup>/ewe) modelled for 23 sheep flocks located in the North Island (NI) and South Island (SI) of New Zealand based on actual ewe death rates over 9–10 months and modelled for when the death rates were reduced by 20 % and by 50 %. Dollar values are in New Zealand \$ using economic data from the 2023 financial year. (na: modelling of death rate reduction was not undertaken for flocks with an actual death rate <4 %).

Flock ID	Flock Location	Actual death rate	COS/Ewe	Death rate reduced by 20 %			Death rate reduced by 50 %		
				Death rate	COS/Ewe	\$ difference from actual (and %)	Death rate	COS/Ewe	\$ difference from actual (and %)
1	NI	2.1 %	\$62.33	na	na	na	na	na	na
2	NI	2.4 %	\$60.60	na	na	na	na	na	na
3	NI	4.7 %	\$34.46	3.8 %	\$35.58	\$1.12 (3.3 %)	2.4 %	\$37.35	\$2.89 (8.4 %)
4	NI	3.3 %	\$48.98	na	na	na	na	na	na
5	NI	3.6 %	\$28.24	na	na	na	na	na	na
6	NI	5.9 %	\$27.97	4.7 %	\$30.14	\$2.17 (7.8 %)	2.9 %	\$33.46	\$5.49 (19.6 %)
7	NI	4.9 %	\$35.72	3.9 %	\$37.64	\$1.92 (5.5 %)	2.5 %	\$39.57	\$3.85 (10.8 %)
8	NI	11.6 %	\$18.13	9.3 %	\$20.79	\$2.66 (14.7 %)	5.8 %	\$24.80	\$6.67 (36.8 %)
9	NI	5.9 %	\$40.16	4.7 %	\$42.44	\$2.28 (5.7 %)	2.9 %	\$45.87	\$5.71 (14.2 %)
10	NI	5.2 %	\$29.10	4.2 %	\$30.97	\$1.87 (6.4 %)	2.6 %	\$33.89	\$4.79 (16.5 %)
11	NI	5.7 %	\$40.94	4.6 %	\$43.12	\$2.18 (5.3 %)	2.9 %	\$46.37	\$5.43 (13.3 %)
12	NI	3.8 %	\$42.81	na	na	na	na	na	na
13	NI	2.2 %	\$32.73	na	na	na	na	na	na
14	NI	6.1 %	\$42.53	4.9 %	\$44.87	\$2.34 (5.5 %)	3.0 %	\$48.40	\$5.87 (13.8 %)
15	NI	5.5 %	\$29.09	4.4 %	\$30.43	\$1.34 (4.6 %)	2.8 %	\$32.48	\$3.39 (11.7 %)
16	SI	7.6 %	\$15.82	6.1 %	\$17.51	\$1.69 (10.7 %)	3.8 %	\$20.01	\$4.19 (26.5 %)
17	SI	6.8 %	\$28.27	5.5 %	\$29.81	\$1.54 (5.4 %)	3.4 %	\$32.10	\$3.85 (13.6 %)
18	SI	5.3 %	\$20.55	4.2 %	\$21.74	\$1.19 (5.8 %)	2.6 %	\$23.48	\$2.93 (14.3 %)
19	SI	3.6 %	\$28.59	na	na	na	na	na	na
20	SI	2.3 %	\$33.64	na	na	na	na	na	na
21	SI	3.0 %	\$33.02	na	na	na	na	na	na
22	SI	8.8 %	\$33.27	7.1 %	\$35.40	2.13 (6.4 %)	4.4 %	\$38.62	\$5.35 (16.1 %)
23	SI	2.6 %	\$34.25	na	na	na	na	na	na

<sup>1</sup> COS = Gross farm cash income – Cash farm operating costs.



**Fig. 1.** Relationship of ewe death rate to Cash Operating Surplus per ewe (COS<sup>1</sup>/ewe) for 23 New Zealand sheep flocks modelled using a bioeconomic model. NI = North Island flocks (blue circles); SI = South Island flock (orange squares)

<sup>1</sup> COS = Cash operating surplus = gross farm cash income – cash farm operating costs.

**CRedit authorship contribution statement**

**Anne L Ridler:** Writing – review & editing, Writing – original draft, Validation, Project administration, Investigation, Funding acquisition,

Data curation, Conceptualization. **Rene A Corner-Thomas:** Writing – review & editing, Investigation, Conceptualization. **Peter Tozer:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation,

Conceptualization.

## Declaration of competing interest

The authors have no competing interests to declare.

## Acknowledgements

**Funding:** This work was supported by Beef + Lamb New Zealand Ltd [grant number 21139\_MU]. Thanks to the flock owners whose flocks were modelled and Sarah Morgan, Catriona Jenkinson, Andy Greer and Chris Logan for assistance with data collection.

## References

- Beef and Lamb New Zealand Economic Service, 2023. Sheep and Beef On-Farm Inflation 2023-24. Retrieved 30 November 2025 from <https://beeflambnz.com/knowledge-hub/PDF/sheep-and-beef-farm-inflation-report-2023-24.pdf>.
- Beef and Lamb New Zealand Ltd, 2024. Benchmark your farm. Retrieved 11 August 2025 from <https://beeflambnz.com/industry-data/farm-data-and-industry-production/benchmark-your-farm>.
- Beef and Lamb New Zealand Economic Service, 2025. New Season Outlook 2025-26. Retrieved 30 November 2025 from <https://beeflambnz.com/knowledge-hub/PDF/new-season-outlook-2025-26.pdf>.
- Bown, M., Thomson, B., Cruickshank, G., Muir, P., 2012. Evaluation of the energy equations used by the National Enteric Methane Inventory. *Minis. Prim. Ind.* Retrieved 11 August 2025 from <https://www.mpi.govt.nz/dmsdocument/2961/direct>.
- Capdevila-Ospina, K., Corner-Thomas, R.A., Flay, K.J., Kenyon, P.R., Ridler, A.L., 2021. Factors associated with ewe death and casting in an extensively farmed sheep flock in New Zealand. *Ruminants* 1, 87–99. <https://doi.org/10.3390/ruminants1020007>.
- CSIRO, 2007. *Nutrient Requirements of Domesticated Ruminants*. CSIRO Publishing: Collingwood, Vic., Australia.
- Farrell, L.J., Tozer, P.R., Kenyon, P.R., Ramilan, T., Cranston, L.M., 2019. The effect of ewe wastage in New Zealand sheep and beef farms on flock productivity and farm profitability. *Agric. Systems* 174, 125–132. <https://doi.org/10.1016/j.agsy.2019.04.013>.
- Farrell, L.J., Kenyon, P.R., Tozer, P.R., Ramilan, T., Cranston, L.M., 2020. Quantifying sheep enterprise profitability with varying flock replacement rates, lambing rates, and breeding strategies in New Zealand. *Agric. Syst.* 184, 102888. <https://doi.org/10.1016/j.agsy.2020.102888>.
- Flay, K.J., Kenyon, P.R., Corner-Thomas, R.A., Ridler, A.L., 2022. Ewe wastage in commercial flocks: a review of current knowledge. *N. Z. Vet. J.* 70, 187–197. <https://doi.org/10.1080/00480169.2022.2032446>.
- Flay, K.J., Ridler, A.L., Compton, C.W.R., Kenyon, P.R., 2021. Ewe wastage in New Zealand commercial flocks: extent, timing, association with hogget reproductive outcomes and BCS. *Animals* 11, 1–19. <https://doi.org/10.3390/ani11030779>.
- Flay, K.J., Chen, A.S., Yang, D.A., Kenyon, P.R., Ridler, A.L., 2023. Identification of risk factors for ewe mortality during the pregnancy and lambing period in extensively managed flocks. *BMC Vet. Res.* 19, 257. <https://doi.org/10.1186/s12917-023-03822-x>.
- Litherland, A., Woodward, S., Stevens, D., McDougal, D., Boom, C., Knight, T., Lambert, M., 2002. Seasonal variations in pasture quality on New Zealand sheep and beef farms. *Proc. N.Z. Soc. Anim. Prod.* 62, 138–142.
- McGregor, B.A., 2011. Incisor development, wear and loss in sheep and their impact on ewe production, longevity and economics: a review. *Small Rumin. Res.* 95, 79–87. <https://doi.org/10.1016/j.smallrumres.2010.11.012>.
- McQuillan, M.C., Glanville, E., Jacobsen, C., Sherriff, L., McGill, D.M., Whale, A., Allworth, M.B., 2024. Peri-parturient ewe mortality in commercial, southern Australian, non-Merino ewe flocks: establishing the frequency and investigating causes. *Aust. Vet. J.* 102, 605–615. <https://doi.org/10.1111/avj.13380>.
- MPI (Ministry for Primary Industries), 2022. Methodology for calculation of New Zealand's agricultural greenhouse gas emissions. Retrieved 11 August 2025 from <https://www.mpi.govt.nz/dmsdocument/13906-detailed-methodologies-for-agricultural-greenhouse-gas-emission-calculation>.
- Moloney, A.J., Tozer, P.R., Morris, S.T., Kenyon, P.R., 2023. Bigger lambs or more lambs: the conundrum for New Zealand lamb producers. *Livest. Sci.* 270, 105204. <https://doi.org/10.1016/j.livsci.2023.105204>.
- Nicol, A.M., Brookes, I.M., 2017. The metabolisable energy requirements of grazing livestock. In: Rattray, P.V., Brooks, I.M., Nicol, A.M. (Eds.), *In: Pasture and supplements for grazing animals*. A.M. N.Z. Soc. Anim. Prod., Occasional Publication No. 14 151–172.
- Ridler, A.L., Kenyon, P.R., Greer, A.W., Logan, C., Morgan, S., Corner-Thomas, R.A., 2024. Ewe culling in New Zealand: an interview study of 38 farmers. *N. Z. J. Agric. Res.* 67, 361–371. <https://doi.org/10.1080/00288233.2023.2280624>.
- Ridler, A.L., Corner-Thomas, R.A., Mote, S., Morgan, S., Kenyon, P.R., Flay, K.J., 2025. Where do all the ewes go? Ewe culling and mortality in 34 sheep flocks in New Zealand. *N. Z. Vet. J.* 73, 112–123. <https://doi.org/10.1080/00480169.2024.2409216>.
- Roberston, S.M., Friend, M.A., 2023. Longitudinal assessment of the impact of aging on wastage, productivity and welfare of ewes. *Aust. Vet. J.* 101, 248–253. <https://doi.org/10.1111/avj.13240>.
- Shadbolt, N., Martin, S., 2005. *Farm Management in New Zealand*. Oxford University Press, Australia.
- Trafford, G., Trafford, S., 2011. *Farm Technical Manual*. Lincoln University, Christchurch, New Zealand.
- Wangui, J.C., Kenyon, P.R., Tozer, P.R., Millner, J.P., Pain, S.J., 2021. Bioeconomic modelling to assess the impacts of using native shrubs on the marginal portions of the sheep and beef hill country farms in New Zealand. *Agriculture* 11, 1019. <https://doi.org/10.3390/agriculture11101019>.