Fecundity and ewe liveweight affect ewe wastage, productivity and greenhouse gas emissions

David R. STEVENS[1*]

[1]*Bioeconomy Science Institute, Invermay Research Centre, Mosgiel, New Zealand*
*Corresponding author: David.stevens@agresearch.co.nz

Abstract

Ewe wastage, defined as ewe death and failure to rear lambs, reduces productivity, profitability and ecoefficiency in New Zealand sheep systems. National survey data identified ewe fecundity and ewe liveweight as significant drivers of wastage, but their whole-farm impacts are poorly quantified. This study modelled the effects of changes in ewe liveweight (−10 to +10 kg) and fecundity (−20% to +20% scanning percentage) on flock dynamics, production, gross margins and greenhouse gas (GHG) emissions, assuming a constant annual feed supply. National average performance was represented by a fecundity of 184%, ewe liveweight of 66.4 kg, ewe mortality of 5.5% and 14.2% of ewes rearing no lambs. Increasing ewe liveweight from 56.4 to 76.4 kg reduced ewe mortality from 6.4% to 4.6% and failure to rear lambs from 18.6% to 9.8%, increasing weaning rate from 131% to 150%. Increasing fecundity from 164% to 204% reduced ewe mortality from 6.1% to 4.9%, reduced ewes rearing no lambs from 17.8% to 10.6% and increased weaning rate from 117% to 166%. Under constant feed supply, higher ewe liveweight resulted in little change in lambs sold (≤20 head), whereas higher fecundity increased lambs sold by approximately 480 head per farm. Gross margin per ewe increased from $102 to $125 with increasing liveweight and from $86 to $145 with increasing fecundity. Total GHG emissions declined by 5–6%, with emissions intensity reduced by up to 18% per unit of product. Reducing ewe wastage through improved fecundity delivers larger system-level gains than increasing liveweight alone, although both pathways improve productivity, profitability and emissions efficiency.

Keywords: Ewe wastage, fecundity, greenhouse gas emissions, liveweight, productivity, profitability

Background

Wastage in breeding ewes can be defined as ewes not reaching the end of their productive life (Flay et al. 2022). However, culling due to not weaning a lamb is applied less vigorously than other culling practices, often because of the limited number of ewes available to cull after accounting for deaths, non-pregnancy, poor condition and structural defects (Flay et al. 2022). Wastage is most often represented by ewe deaths and the failure of ewes to rear the lambs born (Ridler et al. 2025) and can contribute significantly to overall productivity and profitability of farming systems in New Zealand (Ridler et al. 2026, Taylor et al. 2024). Collection of wastage data at regional and national scales has been hampered by lack of individual identification, scale, topography, farm management structure, low labour inputs and the perceived likelihood of wastage (Trompf et al. 2011, Doughty et al. 2019, Munoz et al. 2019). A recent survey of 34 farms around New Zealand identified significant rates of ewe loss and wastage which varied from region to region (Ridler et al. 2025). While ewe deaths have often been estimated, this study provided a definitive assessment of the impacts of ewe wastage beyond just mortality.

Culling, studied in 34 farms nationally, defined as the removal of a ewe from the flock before the end of their productive life (thus contributing to wastage), almost always included failure to become pregnant and vaginal prolapse (Ridler et al. 2025). Farmers also generally had a defined age for end-of-life at between 6 and 7 years-of-age. Beyond this the reasons for culling and rationale were diverse. Culling for failure to rear any lambs (wet-dry) was a regular practice in 58% and 29% of mixed-age and 2 Tooth ewe flocks respectively (Ridler et al. 2025).

Analysis of the data revealed two potential factors influencing ewe wastage. These were ewe fecundity, represented as scanning percentage, and ewe liveweight (Ridler et al. 2025). Bio-economic modelling of fecundity using field data (Farrell et al. 2022) indicated that increasing fecundity (scanning percentage) continued to increase farm profit beyond current industry performance levels. Farmer observations are that increasing the number of triplets, which is closely associated with increasing scanning percentage beyond approximately 170% (Davis et al. 1983), result in increases in ewe deaths and lamb losses. This is borne out by the literature, though the relative change in productivity is not well understood at the whole farm level.

Griffiths et al. (2016) identified liveweight change in winter as important to ewe wastage caused by not rearing lambs. Many others have also found relationships with lamb survival, often noted as retaining or improving BCS over that time (e.g. Everitt-Hincks et al. 2013;

Table 1 Estimates of the effects of changing ewe liveweight or ewe fecundity on ewe death rate, ewes rearing zero lambs, lamb weaning weight and 2TH liveweight, as predicted from New Zealand national survey data presented in Ridler et al. (2025).

			Liveweight change (kg)		
	-10	-5	National Average	+5	+10
Replacement rate (%)	30.0	29.6	29.2	28.7	28.3
Average age (y)	4.33	4.38	4.43	4.48	4.53
Lamb death via ewe failure (%)	25.0	22.3	19.7	17.1	14.4
Weaning rate (%)	131	136	140	145	150
Lambs sold (%)	77	78	79	80	81
Lamb sale date	27-Apr	8-Apr	21-Mar	2-Mar	11-Feb
			Fecundity change (%)		
	-20	-10	National average	+10	+20
Replacement rate (%)	30.8	30.0	29.2	28.4	27.6
Average age (y)	4.25	4.34	4.43	4.52	4.62
Lamb death via ewe failure (%)	23.9	21.8	19.7	17.6	15.5
Weaning rate (%)	117	128	140	153	166
Lambs sold (%)	73	76	79	81	83
Lamb sale date	1-Apr	26-Mar	21-Mar	15-Mar	9-Mar

McCoard et al. 2020). However, common farmer interpretation of this phenomenon is that heavy ewes at lambing will cause lambing problems such as dystocia, casting, vaginal prolapse and metabolic issues, thus reducing lamb survival. The data collected by Ridler et al. (2025) provides evidence to the contrary with both increasing liveweight and increasing fecundity resulting in lower ewe mortality and increased ability to rear lambs.

This paper used the Ridler et al. (2025) data to demonstrate the outcomes at farm level when answering the following question. How do changes in fecundity and liveweight impact on failure to rear a lamb by the ewe? How do these changes affect lamb losses, feed requirements, ecoefficiency and profitability of sheep farming enterprises?

Approach

General approach

The impacts of ewe mortality and failure to rear lambs at national and regional scales were investigated using national and regional data from 34 farms (Ridler et al. 2025). Analysis showed that there were relationships between ewe fecundity and ewe liveweight which independently affected ewe mortality and reproductive success. These relationships were applied to farm scale data to assess how changes in fecundity and liveweight affect lamb losses, feed requirements, meat sales, replacement rates, profitability and greenhouse gas emissions.

Potential implications of ewe liveweight and fecundity

Ridler et al. (2025) identified ewe liveweight and fecundity, measured as scanning percentage, as key drivers of ewe mortality and failure to rear lambs. Reported fecundity was underestimated because triplet and greater pregnancies were commonly recorded as twins. Therefore, to estimate the true lamb losses based on the actual fecundity of the ewe flock, the reported fecundity of 171% was adjusted to 184%, using the relationships reported by Davis et al. (1983) which was then used as the baseline fecundity in all analyses.

National average parameters (Table 1) were adjusted to reflect increasing or decreasing live weight and increasing or decreasing ewe fecundity (Table 1) according to the relationships reported by Ridler et al. (2024), as below.

For liveweight change:

Ewe death rate = -0.087% x ΔLW (kg)

Failure to rear lambs = -0.442% x ΔLW

For ewe fecundity change:

Ewe death rate = -0.032% x ΔScan%[1]

Failure to rear lambs = -0.179% x ΔScan%

Ewes not pregnant = -0.07% x ΔScan%

Ewe liveweight = + 0.15kg x ΔScan%

[1] per 1% change in scanning percentage

These relationships (Table 1; Ridler et al. 2025) were

incorporated into the calculations where appropriate, for example to calculate feed requirements, replacement rates and lamb and ewe sales.

Predicting lamb loss

Potential lamb loss was calculated from fecundity applied to all pregnant ewes (96.7%; Ridler et al. 2025). Non-pregnant ewes (Table 1) were assumed culled in mid-July after pregnancy diagnosis and late winter culls (1.7%) were also removed before lambing. The proportion of non-pregnant ewes was affected by fecundity but not liveweight. Ewe mortality included all animals reported dead or missing, while failure to rear lambs was assigned to ewes recorded with no lambs at mid-lactation. Lambs at weaning were calculated after accounting for ewe mortality and failure to rear lambs using the following steps:

Ewes lambing = (Total ewes – (non-pregnant ewes[1] + late winter culls)

Lambs at weaning = (Ewes lambing – (Dead or missing ewes + Ewes not rearing lambs)) * fecundity rate

Lamb loss = ((Dead or missing ewes% + Ewes not rearing lambs%)

Where non-pregnant ewes varied with fecundity changes by 0.07% per 1% change in fecundity (Ridler et al. 2025)

Variations to lamb loss calculations were applied using the range of performance (Table 1) recorded by Ridler et al. (2025) for changing liveweight and fecundity rate respectively.

Predicting ewe replacement rate

Ewe replacement rate was estimated from non-pregnancy, mortality, non-reproductive and culling data (Ridler et al. 2025), assuming age of culling at 6 years-of-age. Ewes rearing no lambs were not specifically culled. Removals were applied annually by age cohort to maintain flock size, with replacement rates adjusted for a 2% hogget death rate.

Estimating numbers sold and carcase weights

The number of lambs weaned, and replacement ewe lambs required were calculated, with the difference being sold. Lamb weaning weight at 100 days-of-age was assumed to be 44% of mature ewe live weight based published literature (Cocks et al. 2002; Fraser and Saville 2000; Haslin et al. 2021; Johns et al. 2016) across all litter sizes. Using the national average ewe liveweight of 66.4 kg (Ridler et al. 2025), this resulted in a weaning weight of 29.2 kg.

Changes in liveweight or fecundity modified this baseline (Table 1). A standard post-weaning growth profile was used to attain a carcase weight of 18.5 kg, with slaughter date adjusted according to weaning weight while maintaining a constant growth rate of 120 g/d, aligned with current estimates from the National GHG Inventory calculations (Ministry for Primary Industries 2025), and industry slaughter statistics (Stats NZ 2025).

Ewe carcase weight was calculated as 40% of mixed age ewe liveweight (Ministry for Primary Industries 2025) and varied by scenario. All ewes sold achieved the same carcase weight regardless of culling reasons. Hogget mating was not included.

Estimating feed requirements and greenhouse gas emissions

A spreadsheet model was used to estimate energy requirements using equations published in the New Zealand Agricultural Inventory Model, version 11 (AIM; Ministry for Primary Industries 2025) including maintenance and pregnancy requirements dependant on litter size. Milk production was calculated separately. Lambs were assumed to rely on milk until 21 days-of-age, with ewes able to meet this demand. Milk production then declined at 1% of peak lamb demand per day until weaning, after Muir et al. (2000), and energy requirements for milk production were calculated (AFRC 1993). Energy requirements for lambs after 21 days of age were calculated to meet the proscribed weaning weight and was supplied by forage demand. Energy intake was calculated weekly for ewes, hoggets and finishing lambs. Lambs were weaned at 100 days of age at weaning weights described in , then finished to a carcase weight of 18.5 kg using a common liveweight gain profile. Hoggets were unmated and grown to 90% of mixed age ewe liveweight by mating at 18-months (Stevens and Young 2013) (Table 1). Non-pregnant ewes were removed from the feed budget when they were culled after pregnancy diagnosis. No allowance was made for liveweight changes throughout the year. Dry matter intake (DMI) was derived from energy intake using monthly feed quality data (Giltrap and McNeill 2020).

Greenhouse gas emissions were calculated (Ministry for Primary Industries 2025). Specifically, methane emissions were calculated at the daily level and summed for the number of days that the animal was in the flock. For sheep under 1 year-of-age

Methane (g/d) = $11.705/1000 \times \exp^{(0.05*\text{Energy concentration})} \times \text{DMI}^{0.734}$

Where Energy concentration is expressed as MJME/kg DMI

For sheep over 1 year-of-age

Methane (g/d) = 21.977/1000* $DMI^{0.765}$

Nitrous oxide emissions were also calculated at the daily level. The amount of N captured in the developing foetus is not calculated.

N intake (g/d) = N_{feed} x DMI
Where N_{feed}= N in the diet expressed as a proportion of DMI (MPI 2025)

Nitrogen captured in production

$N_{wool} = N_w \times W_g$
Where N_w = nitrogen content of wool = 0.134g/g

And W_g = wool growth = 0.012 g/d for sheep <1 year -of-age or 0.015 g/d for sheep >1 year=of-age

$N_{lwg} = LWG/1000*(N_{bt}/100)$
Where N_{bt} = Nitrogen concentration in body tissue = 0.026%

$N_{milk} = (GE_t/GE_{conc})*(N\%/6.25)$

Where GE_t = total gross energy in milk (MJGE/d)
And GE_{conc} = Gross energy concentration in milk (4.82 MJGE/kg). GE_{conc} has been calculated for New Zealand sheep milk based on milk composition (Day et al. 2017) and energy content prediction (Sebek and Everts 1993).

And N% = 6% CP in sheep milk

Nitrogen in excreta

Faeces N = $(2.23+(N\ intake*0.299)+N_{feed}^2)*0.001$
Urine N = N intake - N_{wool} - N_{lwg} - N_{milk} - Faeces N

Nitrous oxide calculations

N_2O from faeces = 44/28*Faeces N*0.0012

N_2O from urine = 44/28 *((Urine N*0.56*0.005) + (Urine N*0.44*0.0008))

The deposition of urine is split between flat and sloping land (greater than 12º) in the proportions 56:44 as per the National Inventory with appropriate emissions factors being applied.
Final emissions were summed from daily records and presented as the sum of the flock per annum.

Financial analysis

Gross margins were calculated using Beef + Lamb New Zealand Economic Survey data (Beef + Lamb NZ 2025) representing regional farm systems and then averaged national. Gross margin was defined as the difference between direct costs and total returns for the ewe flock on an average farm.

Direct costs included animal health, shearing and feed related costs (including purchased feed, fertiliser and lime and seed and cultivation) (Beef + Lamb NZ 2025), with costs (except shearing) assumed to be attributed to the sheep and cattle enterprises on a per stock unit basis.

Lambs for slaughter were assumed finished on the property and all cull ewes sold for slaughter. Returns were derived from lamb and ewe meat sales and wool income. Meat values used 5-year average prices (2020-2025; $7.18/kg for lamb; $3.33/kg for ewes). Wool income of 4.84 kg wool per sheep stock unit was based on five-year averages (2019-2024; Beef + Lamb NZ 2025). No changes to input costs were assumed when analysing liveweight and fecundity effects, as many factors may influence this and the feed supply, the major source of cost changes is left unaltered.

Reporting

Data for liveweight and fecundity changes are presented for an average New Zealand sheep farm to enable productivity comparisons. The average flock size was calculated as 1690 ewes (See Stevens 2026 for details), though this may underrepresent total sheep numbers by excluding flocks with fewer than 250 ewes. Average farm size is 707 ha (Beef + Lamb New Zealand 2025) with sheep representing 58% of total stock units. Mean stocking rate was 6.4 SU/ha, equivalent to a sheep stocking rate of 3.72 SSU/ha (Beef + Lamb New Zealand 2025). The sheep flock is reported, excluding other livestock or cropping enterprises.

Changes in liveweight and scanning percentage altered flock feed demand. To allow meaningful comparison across scenarios, flock size was scaled to utilise equal amounts of feed across scenarios. The average flock consumed 2227 kg DM/ha under baseline conditions. Lower ewe liveweight or scanning scenarios resulted in larger ewe numbers while higher values resulted in smaller flocks reflecting differences in per-head feed demand. Results are presented for these balanced feeding scenarios.

Lamb loss due to ewe mortality and failure to rear lambs was used to estimate lambs available for slaughter. Losses from other causes were not included and therefore financial returns may be overstated. Ewe deaths were removed from the ewe tally, and all culling categories were combined and reported as total number of ewes slaughtered.

Results and Discussion

Ridler et al. (2025) provides the most comprehensive dataset on New Zealand flock reproductive performance across regions and farm systems. Variation in ewe

Table 2 Changes in flock dynamics when changing ewe liveweight or fecundity (expressed as scanning percentage) when applying the findings of Ridler et al. (2025) regarding ewe death and failure to rear lambs.

	Liveweight change (kg)				
	-10	-5	National Average	+5	+10
Replacement rate (%)	30.0	29.6	29.2	28.7	28.3
Average age (y)	4.33	4.38	4.43	4.48	4.53
Lamb death via ewe failure (%)	25.0	22.3	19.7	17.1	14.4
Weaning rate (%)	131	136	140	145	150
Lambs sold (%)	77	78	79	80	81
Lamb sale date	27-Apr	8-Apr	21-Mar	2-Mar	11-Feb
	Fecundity change (%)				
	-20	-10	National average	+10	+20
Replacement rate (%)	30.8	30.0	29.2	28.4	27.6
Average age (y)	4.25	4.34	4.43	4.52	4.62
Lamb death via ewe failure (%)	23.9	21.8	19.7	17.6	15.5
Weaning rate (%)	117	128	140	153	166
Lambs sold (%)	73	76	79	81	83
Lamb sale date	1-Apr	26-Mar	21-Mar	15-Mar	9-Mar

liveweight and fecundity may reflect differences in breed and feed supply. These effects were unable to be isolated within the original data (Ridler et al. 2025). However, the changes in ewe liveweight and fecundity were both independently associated with changes in the productive outcomes related to ewe mortality and lamb rearing success. Increases in fecundity were accompanied by only minor increases in liveweight suggesting a primarily genetic basis. Modelling these relationships (Ridler et al. 2025) under a constant feed supply enabled direct comparisons of potential productivity, economics, and GHG outcomes.

Changes in flock dynamics

Increasing ewe liveweight or fecundity altered flock structure by reduced replacement rate and lamb losses, and increased ewe age, weaning rate and the proportion of lambs sold (Table 2). Changes associated with increasing liveweight were smaller than changes due to increased scanning percentage. Weaning rate increased disproportionally as scanning percentage increased due to reduced ewe mortality and death rate and fewer ewes failing to rear a lamb, along with a small decrease in the percentage of non-pregnant ewes. This response has been noted by Johns et al. (2016) when improving the overall reproductive success of a commercial flock.

Although higher scanning percentages are often expected to increase losses, the national data suggest that flocks with higher fecundity may also engage in improved feeding practices which enhance ewe survival and lamb rearing. Reallocating feed, particularly in late pregnancy, can increase lamb numbers and weaning weights, enable earlier slaughter, and reduce autumn feed demand, allowing greater feed carryover for winter (Johns et al. 2016).

Changes in feed consumption

Changing flock structure then flowed on to alter feed consumption. Increasing ewe liveweight or fecundity increased feed demand by ewes and hoggets (Table 3) despite lower replacement rates. Changes in liveweight were a feature of both scenarios (Table 1), though lower in the fecundity scenario (Table 1). Increases in both liveweight and lamb survival resulted in greater feed consumption by the ewe. In contrast lamb feed consumption declined as higher weaning weights shortened time to slaughter, particularly when ewe liveweight increased. Given that the weaning weight was calculated as a proportion of ewe liveweight, this is a logical outcome. At the farm scale Anderson et al. (2024) documented increases in both ewe liveweight and lamb weaning weight over 16 years. Mathias-Davis et al. (2013) also noted a significant relationship between ewe liveweight and lamb growth rate from birth to weaning in data from over 2500 ewes lambing over 3 years across four flocks. Schreurs et al. (2012) noted in a meta-analysis of research data that the effect of ewe liveweight on lamb weaning weight was small (50 to 100 g/kg increase in ewe liveweight) but significant.

Total intake per ewe mated rose in both scenarios leading to approximately +/-10% changes in stocking rate (Table 3) and subsequent flock size adjustments (Table 3) to utilise equal amounts of feed on-farm for each scenario.

Table 3 Changes in feed intake, relative stocking rate and potential ewe flock size when changing ewe liveweight or fecundity (expressed as scanning percentage) when applying the findings of Ridler et al. (2025) regarding ewe death and failure to rear lambs.

	Liveweight change (kg)				
	-10	-5	National Average	+5	+10
Ewe intake (kg DM/annum)	540	585	638	692	762
Hogget intake (kg DM/annum)	417	465	494	527	561
Lamb intake (kg DM/annum)	191	168	144	128	98
Total intake (kg DM/annum)	860	902	944	994	1042
Relative stocking rate[1]	0.91	0.96	1.00	1.05	1.10
Ewe flock (n)[2]	1855	1768	1690	1605	1531
	Fecundity change (%)				
	-20	-10	National average	+10	+20
Ewe intake (kg DM/annum)	549	586	638	671	713
Hogget intake (kg DM/annum)	469	482	494	504	511
Lamb intake (kg DM/annum)	172	163	144	146	137
Total intake (kg DM/annum)	843	893	944	999	1046
Relative stocking rate[1]	0.89	0.95	1.00	1.06	1.11
Ewe flock (n)[2]	1900	1791	1690	1597	1523

[1] Stocking rate relative to the current national average
[2] Ewe flock number when scaled to consume an amount equal to the national average

Table 4 Changes in numbers of lambs weaned, replacements retained, lambs sold and categories of ewe wastage changing ewe liveweight or fecundity (expressed as scanning percentage) when applying the findings of Ridler et al. (2025) regarding ewe death and failure to rear lambs.

	Liveweight change (kg)				
	-10	-5	National Average	+5	+10
Lambs weaned (n)	2432	2400	2372	2328	2291
Replacements retained (n)	568	534	503	470	442
Lambs sold (n)	1864	1866	1869	1858	1849
Non-pregnant ewes sold (n)	61	58	56	53	51
Cull ewes sold (n)[1]	221	210	201	191	182
Ewes aged out (n)[2]	157	149	143	136	130
Ewe deaths (n)	118	105	93	81	71
	Fecundity change (%)				
	-20	-10	National average	+10	+20
Lambs weaned (n)	2219	2298	2372	2444	2531
Replacements retained (n)	597	547	503	462	429
Lambs sold (n)	1622	1751	1869	1982	2102
Non-pregnant ewes sold (n)	89	72	56	42	29
Cull ewes sold (n)[1]	226	213	201	190	181
Ewes aged out (n)[2]	153	148	143	139	137
Ewe deaths (n)	117	104	93	83	74

[1] Includes all ewes sold due to culling reasons
[2] Ewes sold at 6 years-of-age

Table 5 Changes in the annual flock meat and wool production when changing ewe liveweight or fecundity (expressed as scanning percentage) when applying the findings of Ridler et al. (2025) regarding ewe death and failure to rear lambs.

			Liveweight change (kg)		
	-10	-5	National Average	+5	+10
Lamb meat (kg)	34484	34521	34577	34373	34207
Ewe meat (kg)	9903	10271	10620	10850	11082
Wool (kg)	14862	13901	12986	12130	11146
Total product (kg/ewe)	32	33	34	36	37
			Fecundity change (%)		
	-20	-10	National average	+10	+20
Lamb meat (kg)	30007	32394	34577	36667	38887
Ewe meat (kg)	11874	11223	10620	10064	9628
Wool (kg)	14535	13832	12986	12521	11976
Total product (kg/ewe)	30	32	34	37	40

Table 6 Changes in income, expenses gross margin when changing ewe liveweight or fecundity (expressed as scanning percentage) when applying the findings of Ridler et al. (2025) regarding ewe death and failure to rear lambs.

			Liveweight change (kg)		
	-10	-5	National Average	+5	+10
Lamb sales ($)	$247,595	$247,861	$248,259	$246,798	$245,603
Ewe sales ($)	$30,609	$31,746	$32,824	$33,535	$34,254
Sheep flock income[1] ($)	$313,242	$314,730	$316,290	$315,597	$315,173
Sheep flock expenses[2] ($)	$123,741	$123,727	$123,731	$123,740	$123,735
Sheep flock gross margin[3] ($)	$189,501	$191,003	$192,559	$191,857	$191,439
Gross margin ($/ewe mated)	$102	$108	$114	$120	$125
			Fecundity change (%)		
	-20	-10	National average	+10	+20
Lamb sales ($)	$215,450	$232,585	$248,259	$263,269	$279,209
Ewe sales ($)	$36,812	$36,812	$32,824	$31,058	$29,670
Sheep flock income[1] ($)	$287,774	$302,703	$316,290	$329,438	$343,881
Sheep flock expenses[2] ($)	$124,179	$124,026	$123,731	$123,687	$123,515
Sheep flock gross margin[3] ($)	$163,596	$178,678	$192,559	$205,751	$220,366
Gross margin ($/ewe mated)	$86	$100	$114	$129	$145

[1] Includes wool revenue of $11.42

[2] Direct expenses include animal health ($6.74), shearing ($11.89), fertiliser ($14.20), Lime ($1.03), seed ($2.57), feed ($4.77), and cultivation ($2.08) to total $42.65 per sheep stock unit,

[3] Sheep flock income – sheep flock expenses

Changes in sheep numbers

Adjusting flock size to utilise equal amounts for feed in each scenario reduced the number of lambs weaned as liveweight increased but increased the number of lambs weaned as fecundity increased (Table 4). Replacements requirements declined in both scenarios, resulting in little change in lambs sold (n= -15) with higher liveweight and a substantial gain (n= +480) with higher fecundity (Table 4). There were fewer non-pregnant ewes, cull ewes, ewes aged out and ewe deaths as liveweight or fecundity increased.

Production

Changes in flock size, and ewe liveweight influenced production outcomes (Table 5). Increasing ewe liveweight had little effect on lamb meat production. While the number of ewes sold declined, the increase in ewe liveweight resulted in a greater weight of ewe meat to be sold. Wool production also declined as the number of sheep declined with increasing ewe liveweight (Table 5). In contrast, higher fecundity substantially increased

lamb meat production, with slight declines in ewe meat and wool production (Table 5).

In both scenarios, product per ewe increased, ranging from 32 to 37kg/ewe when liveweight increased, and 30 to 40 kg/ewe when fecundity increased, highlighting the value of per-ewe metrics for assessing the impact of heavier or more fecund ewes. Often, data reported from farming situations entails changes in both feed supply and ewe performance. Stevens et al. (2021) analysed ten case studies across New Zealand and concluded that managing the resources of the systems to optimise the fitting of feed demand to feed supply was of greater importance than overall feed production to systems resilience. However, the results presented as outputs per ewe in this research give the practitioner the opportunity to evaluate the potential impacts of making changes that may entail increasing feed supply to meet demands of heavier or more fecund ewes.

Economics

Flock production influenced profitability, with expenses calculated per stock unit remaining similar across scenarios (Table 6), resulting in a higher cost per ewe mated. While this may reflect higher individual performance, it may overstate costs compared with a per head approach. Shorter finishing times, for example will require less anthelmintic treatment of lambs, reducing their cost of production.

Increasing ewe liveweight caused little change in whole-flock gross margin (Table 6) as efficiency gains and reduced wastage (Table 2) were offset by smaller flock size (Table 4) in response to increased feed demand (Table 3). However, the gross margin per ewe increased significantly from $102 to $125 as liveweight increased (Table 6). Given potential opportunities to achieve this increase in liveweight through changing seasonal feed demand (Johns et al. 2016) the inclusion of a gross margin per ewe may provide practitioners with information regarding potential to change practice.

Previous studies have shown strong profitability gains from reducing ewe wastage and increasing fecundity. Farrell et al. (2022) reported linear increases in profit up to 200% fecundity. Farrell et al. (2020) also reported greater profitability with reducing ewe replacement rates. Farrell et al. (2019) reported an increased cash operating surplus of 17% when ewe wastage declined by 10%. In the present study, similar reductions in wastage (~10%) produced markedly different outcomes depending on the mechanism. Increasing ewe liveweight lifted gross margin per ewe by ~25% but had little effect at flock level. Increasing fecundity from ~120 to ~165% increased gross margin per ewe by ~$60 per ewe (75%) and by ~35% at the flock level (Table 6).

Moloney et al. (2023) calculated that increasing lamb weaning weight was more cost effective than increasing lambing percentage, due to changes in potential to finish lambs to economic weights within the productive season. They highlighted the need to increase the feed supply in spring to achieve this, proposing that savings of feed during autumn, with earlier finished may offset later feed requirements. The current study assigned the post-weaning growth rate as a constant, while altering weaning weight based on ewe liveweight. This may have some impact on the outcome of changing lambing percentage, as increasing lambing percentage will increase the number of multiple born lambs with potentially slower growth rates. However, practical examples exist in the literature which demonstrate increasing lamb performance alongside increasing lambing percentage (Johns et al. 2016; Moot et al. 2024). These examples highlight the complex interactions between liveweight, fecundity and seasonal feed supply.

Greenhouse gas emissions

With equal feed intake across scenarios, total greenhouse gas (GHG) emissions varied little. However, an efficiency advantage at the whole flock level and per hectare, related to higher per animal intake, led to slightly lower GHG emissions as both liveweight (6%) and fecundity (5%) increased (Table 9). This results from the use of a power function (see Methods) to calculate methane emissions at the individual animal scale (Swainson et al. 2016), which results in lower emissions of methane as DMI per head increases (Ministry for Primary Industries 2025).

Efficiency measures of GHG per unit of product and per $GM improved by 7.6% and 6.7% respectively when liveweight increased (Table 9). When fecundity increased efficiency measures of GHG per unit of product and per $GM improved by 17.8% and 29.4% respectively (Table 9).

Reductions in flock and per hectare scale GHG emissions can be achieved while maintaining feed intake reinforcing the scope for productivity-driven efficiency gains within current farm systems. Changes in efficiency measures have been documented when productivity and profitability increase (e.g. Taylor et al. 2021; Hutchinson et al. 2021; Taylor et al. 2025) while noting an overall increase in feed consumption. Previous whole farm studies show that GHG emissions can vary even at similar feed intakes (Vibart et al. 2021), though often do not isolate the sheep flock. Flock specific studies (Taylor et al. 2025; Adjabui et al. 2026) that maintained feed consumption while improving fecundity found that economic farm surplus increased with a small decrease in overall GHG production. The present study extends this work by isolating the sheep flock and quantifying the effects of changes in either ewe live weight or fecundity that are currently being achieved.

Conclusions

This study demonstrated that reductions in ewe wastage achieved through increases in ewe fecundity or ewe liveweight generated clear gains in productivity, profitability and greenhouse gas (GHG) efficiency in New Zealand sheep farming systems. By applying nationally derived relationships within a constant feed supply framework, the analysis isolated the effects of biological performance from changes in total feed availability, enabling direct comparison of alternative management pathways.

Increasing either ewe liveweight or scanning percentage reduced ewe mortality and the proportion of ewes failing to rear lambs, leading to lower replacement rates, increased average flock age and higher weaning rates. These changes improved output per ewe and system efficiency. However, the magnitude of benefits differed markedly between pathways. Increasing ewe liveweight improved lamb weaning weight, shortened finishing time and increased gross margin per ewe, but resulted in little change in total lambs sold once flock size was adjusted to maintain feed balance. In contrast, increasing fecundity substantially increased lamb numbers sold, driving large improvements in whole-flock production and gross margin.

Across the ranges modelled, improvements in fecundity delivered the greatest system-level gains, including higher whole-farm profitability and substantial reductions in emissions intensity per unit of product and per dollar of gross margin. Despite higher feed intake per animal, total flock GHG emissions declined slightly due to reduced wastage, faster turnover of sale stock and improved biological efficiency. These findings reinforce the principle that productivity gains achieved through better reproductive performance can align economic and environmental objectives.

From a practical perspective, minimising ewe wastage remains critical for farm performance. Strategies that lift scanning percentage or maintain adequate ewe liveweight provide opportunities to improve outcomes without increasing total feed supply, provided seasonal feed allocation supports higher reproductive demand. Improving fecundity is not necessarily related to increased ewe loss. Feeding and management need to meet the feed requirements of the ewe and need to acknowledge the under-prediction of scanning percentage when triplet bearing ewes are amalgamated with twins in reporting. While gains from increasing liveweight alone are smaller at the wholefarm level, this pathway remains relevant where reproductive change is constrained or weaning weight is a priority. Overall, prioritising reproductive performance offered the greatest opportunity to enhance productivity, profitability and ecoefficiency within existing farm systems.

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