Impacts of winter crop choice and ewe body condition score change on whole farm profitability and production

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Abstract
Variations in body condition score (BCS) in ewes influences lamb survival, ewe survival and ewe lactation performance. Feeding a low protein diet can further decrease sheep production and affect farm profitability. Whole farm modelling was used to test the effects of winter crop choice (brassica and fodder beet) and BCS (maintaining and reducing by –0.5) on whole-farm production and profitability in wet or dry environments and tested the use of a supplement to increase the protein concentration of the fodder beet diet to 18% from 9%. Maintaining ewe BCS in late winter increased farm productivity of approximately 10% and economic farm surplus by approximately 6% compared with a loss of –0.5 BCS in farms in both wet and dry environments. Feeding fodder beet of a protein concentration of 9% to ewes in late pregnancy resulted a further reduction in production of 15% and economic farm surplus of 25%. Restoring the protein concentration of the diet to 18% using a supplement restored overall farm profitability even when the cost of the supplement was accounted for. Outcomes from this type of analysis in two contrasting environments provides a robust demonstration of potential impacts of both BCS change and winter forage choice.

Keywords: fecundity, forage, lamb survival, nutrition

Introduction
Since 1990 sheep flock performance in New Zealand has markedly increased as farmers have adopted cross breeding, composite breeding and the introduction of new breeds (Fennessey et al. 2016). At the same time farmers have added other technologies such as pregnancy scanning to aid improved nutritional management and feeding (Johns et al. 2016). Flock scanning levels have increased by 120–125% in the two decades preceding 2015, to the extent that many flocks consistently achieve pregnancy rates greater than 180% (Stevens and Young 2013).

Body condition score (BCS) in mid-to-late pregnancy impacts on the reproductive performance of sheep, including ewe mortality (Morgan-Davies et al. 2008; Flay et al. 2021), lamb mortality (Everett-Hincks et al. 2004; McCoard et al. 2020) and lamb liveweight gain to weaning (Stevens et al. 2011; Mathias et al. 2013; Everett-Hincks et al. 2013). While these factors have been noted, actual whole-flock performance in response to BCS change has not been well documented. McCoard et al. (2020) noted that avoiding BCS loss may be more important than pre-winter BCS.

Many New Zealand cool-temperate sheep and beef farm systems use winter crops to feed ewes in mid-late pregnancy, including forage brassicas (*Brassica* spp.) and fodder beet (*Beta vulgaris* L.). Under both winter crop and pasture feeding regimes, ensuring adequate allocation to prevent BCS loss is crucial to prevent any negatively associated reproductive performance. Any nutritional limitations of the feed can amplify this even more (Everett-Hincks et al. 2004). Crops such as fodder beet, with protein concentrations of between 7% and 9% (Chakwizira et al. 2013), have been shown to reduce the lamb birth weight and consequent lamb survival when fed as sole diets (Hammond et al. 2021).

In a previous examination of feeding fodder beet to pregnant ewes without additional protein, we documented a reduction in overall production and ecoefficiency per unit of product which was greater than just lower BCS (Taylor et al. 2021). In that study, we also reported that whole farm nitrogen and phosphorus losses were low and were reduced when feeding fodder beet, and use of a balanced supplement to mitigate low protein in the diet was able to restore whole farm productivity and ecoefficiency without increasing nitrogen losses. The objective of the present paper is to build on our prior study and report on the effects of ewe winter crop choice (brassica or fodder beet) and BCS (maintaining or reducing through targeted supplementation) on whole-farm production and profitability.

Materials and Methods
The impact of feeding winter crops and BCS on the reproductive performance of ewe flocks and subsequent productivity and profitability of mixed livestock farms was investigated. The experimental design was a two-by-two factorial with four replicates, represented by individual farms, repeated in two geo-climatic

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environments. The two factors were BCS change in mid-to-late pregnancy (0 and –0.5) and protein diet of 18% or 9% (control and fodder beet). The 1–5 BCS scale of Jefferies (1961) was used. The BSC change of –0.5 was chosen as consistent with reported experimental (Hammond et al. 2021) and on-farm results (Stevens et al. 2011).

Farm selection and base modelling

Eight farms (replicates) were anonymously selected from an existing database to represent two environments, 'high rainfall' (four farms, 1090 mm/annum) representing Class 6 (Beef + Lamb NZ 2021a) South Island Finishing Breeding farms, and 'low rainfall' (four farms, 590 mm/annum) representing Class 2 (Beef + Lamb NZ 2021b) South Island Hill Country with a cool temperate climate in southern New Zealand (Table 1). These farms and their selection are described in detail in Taylor et al. (2021). Briefly, they represent a balance of topography, winter crop use and size (Beef + Lamb NZ 2021a,b). Each farm was represented in a Farmax simulation (Marshall et al. 1991) Red Meat (version 8.0.1.34 Science Edition), based on current production metrics. Farmax was then used to determine the impacts of BCS change and winter forage choice on whole-farm productivity and profitability.

Body condition score and reproductive parameters

Ewe BCS change during the mid-to-late-pregnancy period was calculated from liveweight change estimates from the Farmax files for each farm. A relationship of 1 BCS = 10% of true liveweight (Kenyon et al. 2014) was used. Subsequent BCS change values and production records for each farm were then adjusted to match the test conditions of either –0.5 or 0 BCS change during pregnancy, with feeding levels altered to reflect this within each model.

A model representing the effects of BCS change on ewe mortality, lamb loss and lamb growth from birth to weaning was developed using data from Johns et al. (2016). The equations for ewe mortality, lamb loss and lamb liveweight gain to weaning are presented in Taylor et al. (2021). These equations were validated with data from Morgan-Davies et al. (2008) and Flay et al. (2021) (ewe mortality), Everett-Hincks et al. (2013) and McCoard et al. (2020) (lamb mortality) and Stevens et al. (2011), Mathais-Davis et al. (2013) and Everett-Hincks et al. (2013) (lamb growth to weaning). Further adjustment for the effects of feeding fodder beet without supplementation were made using data from Hammond et al. (2021), which effectively doubles potential losses calculated in the control conditions.

Original conditions on each farm were reported in Taylor et al. (2021). Briefly the pregnancy scanning percentage ranged from 144% to 202%, ewe liveweight from 61 to 76 kg, ewe BCS change from –0.17 to –0.4 and lamb weaning weight from 26.2 to 33.0 kg.

Outcomes from the modelling of BCS change and winter feed type (Taylor et al. 2021) were then transferred into the Farmax models for prediction of production and profitability parameters. The effects of BCS change resulted in average ewe liveweights of 64.0 and 67.4 kg and average ewe death rates of 6.4 and 3.5% for –0.5 and 0 BCS change, respectively.

Predicting crop growth and late pregnancy nutrition

Control scenarios used either kale (*Brassica oleracea* L.) or swede (*Brassica napus* var. *napobrassica* L.) as the winter crop. The area of crop in the Control 0 and Control –0.5 scenarios was taken from the area on the base farms (Taylor et al. 2021) and ranged from 4.1% to 10.5% of effective farm area. Winter crop yields were not available for each farm and so were predicted from growing degree days and effective rainfall data from the National Institute of Air and Water Virtual Climate Network. The process for these representative farms is described in Stevens and Taylor (2022). Yields were calculated using the growth relationship of 20 kg DM/mm of rainfall for brassicas (de Ruiter et al. 2009) and 50 kg DM/mm rainfall for fodder beet (Chakwizara et al. 2014). Both calculations assumed that 50% of the annual rainfall was available during the growing period of the crop. Brassica and fodder beet yields (Taylor et al. 2021) averaged 10.9 and 27.4 t DM/ha in the high rainfall environment and 5.9 and 14.7 t DM/ha in the dry environment, respectively.

The area of fodder beet required was adjusted to match the total yield previously grown by the brassica crop on each farm to maintain a consistent amount of feed available from winter crops. To maintain BCS when fodder beet was fed required the addition of a targeted protein-based supplement (Knol et al. 2019). For the BCS 0/fodder beet scenario, a supplement of 0.5 kg DM/day was included. This resulted in a further reduction in the area required for winter crop. The supplement to achieve 0 BCS change on fodder beet was formulated as 30% lucerne (*Medicago sativa* L.) hay, 13% soy meal, 1% urea and 56% fodder beet, following Knol et al. (2019) to create a diet of 18% crude protein, compared with the fodder beet alone diet estimated to be 9% crude protein (Knol et al. 2019).

Farm modelling criteria

Changing flock performance and area cropped resulted in variations in whole-farm seasonal feed supply and demand. Therefore, alterations were made to ensure that pasture covers at the beginning (1 July) and end (30 June) of the modelling cycle were representative of mid-winter. General adjustments made to ensure

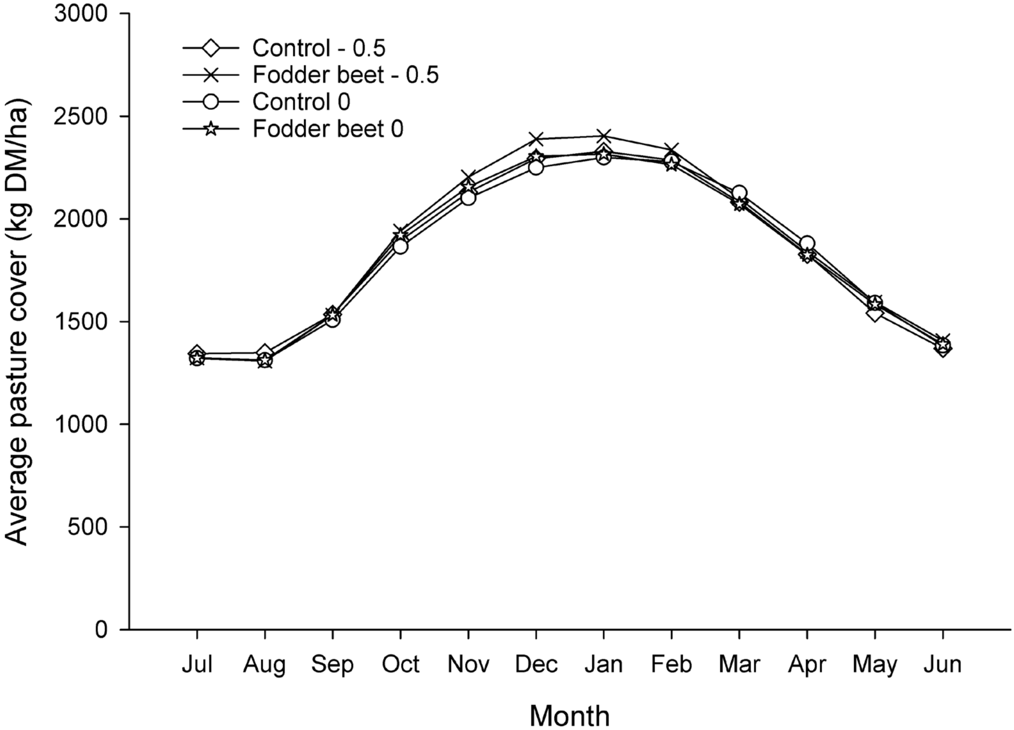

Figure 1 Average pasture cover of dry matter (DM) throughout the year from farms using either brassicas or fodder beet as a winter forage, and either maintaining or losing 0.5 BCS on sheep and beef farms, when modelled in cool, temperate southern New Zealand.

pasture utilisation was similar to the original farms included adjusting lamb sale date, pasture conservation, stocking rate and autumn nitrogen use (Taylor et al. 2021). Seasonal fluctuations in average farm pasture cover (Figure 1) were maintained using this approach.

Data analysis

The effect of high and low rainfall was analysed using each farm as a replicate to provide a description of the two environments representing Class 2 and 6 farm types (Beef + Lamb NZ 2021a,b). Variables included pasture and supplement (including crop) consumed, proportion of area cropped, sheep:beef ratios and stocking rate. Production factors analysed included lamb survival, weaning weight, lamb sales store and prime and the distribution and price of lamb sales. Results of the two-by-two factorial with BCS change (0 and –0.5) and winter crop (brassica and fodder beet) as main factors were analysed using rainfall (high and low) as a blocking factor and individual farms as replicates. A number of covariates were explored, including stocking rate, initial productivity (kg product/ha), farm size and beef enterprise (% stock units as beef). Only the proportion of beef explained any further variation and this was retained in all analyses. All analyses used the restricted maximum likelihood (REML) function of the statistical package Genstat (version 18, 2017) and applied a Fisher's Least Significant Difference (LSD) to test multiple means.

Results

Analysis of the results found no interactions between farm environments and feeding regimes. Therefore, the results for the environmental effects of rainfall are presented separately for completion. Some interactions between winter forage crop and BCS change were detected, and interaction tables are presented.

Comparing high and low rainfall environments

High and low rainfall resulted in differences between many of the variables analysed, including higher pasture and supplement consumption and higher stocking rate in the high rainfall environments ($P<0.05$; Table 1). Reproductive parameters were unaffected by environment (Table 1). Sheep returns were greater ($P<0.05$) in the high rainfall environment, while beef returns were greater ($P<0.05$) in the low rainfall environment (Table 1). The return from sales of conserved feed was greater ($P<0.05$) in the low rainfall environment. Overall gross returns were

Table 1 Production parameters, reproductive outcomes, financial returns and variable costs associated with forage cropping choice from sheep and beef farms in high and low rainfall environments, when modelled in cool, temperate southern New Zealand.

Parameters		High Rainfall	Low Rainfall	P Value
Rainfall	(mm/annum)	1,090	590	na
Topography	(Flat:Rolling:Steep)	5:75:20	17:45:38	na
Pasture consumed	(t DM[1]/ha)	5.25	3.47	0.001
Supplement consumed	(t DM/ha)	0.75	0.55	0.001
Proportion of area cropped (%)		6.1	5.4	0.008
Sheep:beef ratio		83:17	74:26	na
Stocking rate	(Stock units/ha)	10.9	7.3	
Lambs weaned	(% weaned)	126.9	130.3	0.569
Lambs sold prime	(per ewe mated)	0.75	0.69	0.647
Lambs sold	(per ewe mated)	1.02	1.07	0.578
Returns ($/ha)	Sheep	784.30	452.10	0.001
	Beef	190.00	306.80	0.001
	Conserved feed	10.30	139.50	0.001
	Total	984.60	859.40	0.022
Expenditure ($/ha)	Forage establishment	71.92	82.24	0.215
	Purchased feed	33.11	16.44	0.349
	Conservation	25.46	94.34	0.001
	Pasture renewal	23.79	33.61	0.078
	Nitrogen fertiliser	18.04	13.68	0.475
	Total fertiliser	28.49	17.89	0.160
	Total farm working expenses	529.90	504.00	0.580
Net income ($/ha)	Economic farm surplus[2]	388.60	333.10	0.05

[1] Dry matter (DM)

[2] Economic farm surplus includes depreciation but not interest payments.

Table 2 Sheep flock productivity parameters and outcomes.

Winter crop	Brassica		Fodder Beet			
BCS Change in mid-late pregnancy	0	–0.5	0	–0.5	P Value	LSD
Ewe death rate (%)[1]	3.5	6.4	3.5	6.4		na
Lamb survival to weaning (%)	141.3[a2]	129.6[b]	141.3[a]	102.1[c]	0.029	17.2
Lamb weaning weight (kg)	29.79[a]	28.29[b]	29.79[a]	28.29[b]	0.027	1.31
Lambs sold (per ewe mated)	1.17	1.06	1.17	0.78	0.085	0.22
Lambs sold prime (per ewe mated)	0.750	0.714	0.824	0.584	0.354	na
Lamb sales value ($)	88.29	86.41	92.16	90.55	0.953	na

[1] Input to modelling.

[2] Means with different letters within rows are significantly different (P<0.05) based on Fisher's Least Significant Difference (LSD) test.

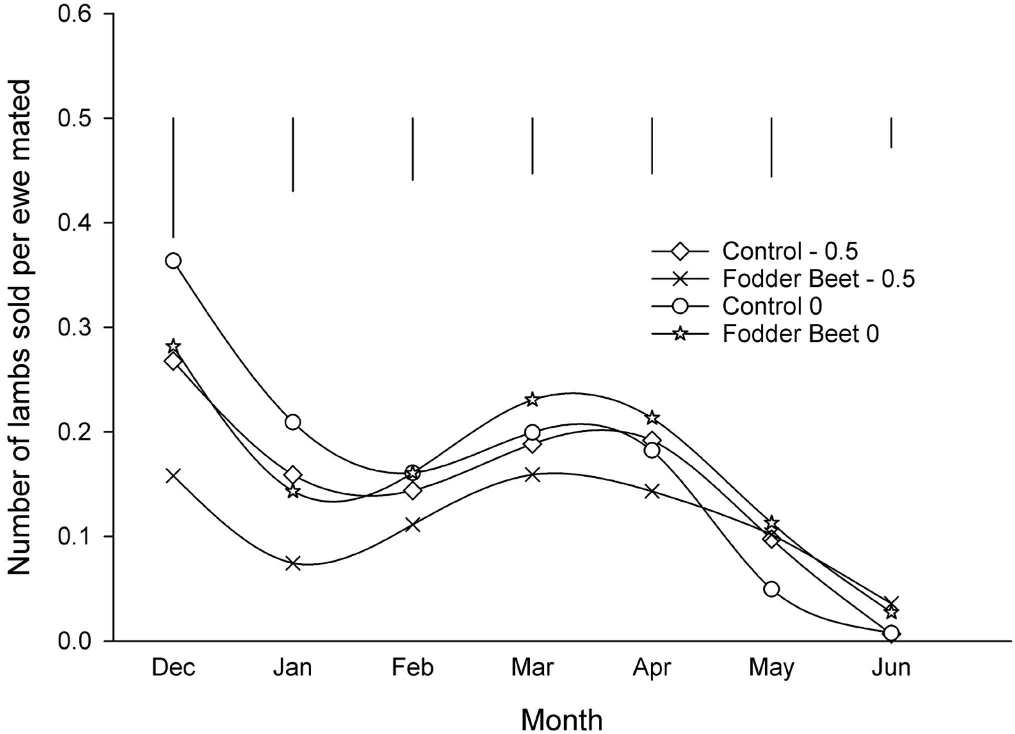

Figure 2 Effects of ewe body condition score change in mid-late pregnancy and winter fodder crop choice on the distribution of number of lambs sold per ewe mated. Vertical bars represent Fisher's Least Significant Difference between means (P<0.05).

greater (P<0.05) in the high rainfall environment (Table 1). Costs associated with feeding were similar in both environments, except harvesting of conserved feed, which was greater (P<0.05) in the low rainfall environment (Table 1). Total farm working expenses were similar, resulting in a greater (P<0.05) effective farm surplus in the high rainfall environment (Table 1).

Comparing BCS change and winter crop choice

Sheep flock productivity parameters

Reproductive outcomes changed in line with the parameters set in the modelling. Lamb survival to weaning (Table 2) was lowest when fodder beet was used as a winter forage, with no alteration to prevent BCS loss. Using brassicas, when body condition was lost, resulted in an intermediate rate of lamb survival to weaning, while ensuring no body condition was lost in ewes in mid-late gestation through targeted use of a balanced supplementary diet resulted in the greatest lamb survival, regardless of winter forage choice (Table 2). This also translated into lower weaning liveweights when BCS declined in winter.

There was a trend for lambs sold per ewe mated to be reduced (P=0.085) when fodder beet was used as a winter forage and body condition of ewes was reduced (Table 2). Using brassicas, and fodder beet without condition score change through targeted use of a balanced supplementary diet for the later, were not significantly different. Lambs sold prime per ewe mated also followed this trend (Table 2).

The numerically lower number of lamb sales when fodder beet was fed, and ewe condition score declined, translated into a different (P<0.05) lamb sales profile throughout the summer and autumn (Figure 2). The extra area of the farm in crop when using a traditional cropping approach with brassicas resulted in lower feed availability during the late spring leading to early store lamb sales (Figure 2). Lambs sold per ewe mated were greater early in the season when brassicas were the winter forage and BCS was maintained. Either losing condition on brassicas or using fodder beet while maintaining BCS through targeted supplement use were intermediate, while losing condition when feeding fodder beet produced the lowest number of lambs for sale in December and January (Figure 2). Conversely, using brassicas as a winter forage, while maintaining BCS saw the lowest number of lamb sales in May and June, compared to other options (Figure 2). This shift to later sales on the farms using fodder beet also led to a trend towards higher value of lambs sold (Table 2; P=0.088) than on farms using brassicas.

Financial outcomes due to BCS change and winter crop choice

Productivity, previously reported in Taylor et al. (2021), of the farm system and financial returns of both the sheep flock and the farm system were lowest (P=0.005) when fodder beet was fed and BCS change was –0.5 during late pregnancy (Table 3). Sheep flock productivity was intermediate when BCS change was –0.5 and brassica-based crops were fed. However, if BCS loss was eliminated through improved feeding and for the fodder beet included targeted use of a balanced supplementary diet, there was no difference in production associated with winter crop choice.

Costs of forage establishment were reduced (P=0.001) when fodder beet was used, and condition score was maintained through targeted supplement use. However, purchased feed increased (P=0.001) under this scenario (Table 3). Feed conservation costs were increased when fodder beet was used (P=0.066), while pasture renewal costs were lower (P<0.001), when compared with using brassica crops for winter forage.

Overall, total farm working expenses were not different between the scenarios. Economic farm surplus (EFS) was lower when BCS change was –0.5 during mid-late pregnancy (P=0.017) compared with maintaining BCS (Table 3).

Discussion

A previous paper documented results from farm practice to quantify the potential impacts of changes in BCS of the ewe flock and winter-feeding practices on greenhouse gas emissions and nitrogen and phosphorus loss, as well as production of meat and fibre (Taylor et al. 2021). The key to ensuring that BCS could be maintained when feeding fodder beet was supplementation to achieve a diet of 18% crude protein, compared with an unsupplemented diet of approximately 9% crude protein (Knol et al. 2019).

This paper continues the documentation of these case study farms to include further productivity and profitability metrics. The outcomes in profitability in this study reflect the complex interactions and trade-offs present in matching seasonal forage supplies to an equally seasonal value chain. They also represent the potential for buffering in sheep and beef systems through multiple potential income streams, including the sale of surplus feed. Further complicating the outcomes are the variety of input states, such as ewe liveweight, BCS change, scanning percentage and lamb weaning weight. These reflect the management decisions of the farmer, such as breed selection and feed allocation. To ensure some consistency of comparison, the modelling done here adjusted current states to reflect the desired experimental conditions to gauge the impact of changing feeding criteria and BCS change.

Overall, the productivity of the using brassicas as winter forage increased by approximately 10% when BCS was maintained compared to a change of –0.5 BCS. This translated into an increase in EFS of approximately 6%, if the option of sale of conserved feed was used. However, if fodder beet was used as a winter feed without supplementation, production was reduced by a further 15%with a loss of 0.5 BCS. The use of a supplement to increase dietary protein concentration from 9% to 18% when feeding fodder beet restored production and EFS.

The impacts of feeding fodder beet were seen in both positive and negative outcomes. Without a targeted supplement to overcome the protein deficiency, lamb numbers per ewe mated were reduced by approximately 40%. While this reduces the number for sale, it also reduces the requirement for feed in summer, which in these case studies, increased the proportion of prime lamb sales by 5–10%, while increasing sales price by 5% (Table 2). When fodder beet was supplemented, income increased by approximately \$50/ha, offsetting the extra costs of feed (Table 3).

The overall use of fodder beet with supplementation meant that the area required for crop was reduced from approximately 7.4% to 4.5%. This resulted in an increase in available pasture area of approximately 3% throughout the year providing more feed and resulting in the increases in lambs sold prime and sold later (Table 2).

The number of lambs weaned per ewe mated were approximately 135 per 100 ewes in the brassica systems compared with 120 lambs per ewe mated in the fodder beet systems. This required a strategy of early store lamb sales, diluting the value of the extra lambs born. Predicted fodder beet and brassica yields of approximately 21 and 8.4 t DM/ha were similar to the range of reported yields (e.g., Wheadon et al. 2023). The higher yield of fodder beet required approximately 3% less farm area for cropping, resulting in the opportunity to conserve summer surplus feed. Farmers may choose to use this feed in a number of ways. In this exercise, baleage was conserved (cost \$0.14/kg DM) and sold at market rates (\$0.38/kg DM). This may not be the case for farmers who are balancing feed supply and demand in variable climates. They may not want to decide around conservation and sale of surplus feed. The modelling used an average year, with the foresight of future feed supply. Farmers may decide to retain the feed on-farm, either as standing feed, or as conserved feed, rather than selling it especially in dryland environments (Gray et al. 2011). Keeping the feed standing may potentially cause a decline in future feed quality (Devantier et al. 2017) which may further impact on animal carrying capacity and performance. These decisions would also vary depending on cattle

Table 3 Interactions between ewe body condition score (BCS) change in mid-late pregnancy and winter fodder crops on the productivity, financial returns and variable expenditure related to forage crop choice.

	Winter Crop	Brassica		Fodder Beet		P Value			
Parameters	**BCS Change in Mid-Late Pregnancy**	**0**	**–0.5**	**0**	**–0.5**	**BCS change**	**Winter crop**	**Interaction**	**LSD (interaction, P<0.05)**
Area cropped (%)		7.3	7.5	4.5	5.7	0.320	0.003	0.473	na
Productivity (kg product/ha/year)		190[a]	173[b]	194[a]	160[c]	0.001	0.123	0.005	9
Returns ($/ha)	Sheep	[1]679.30[ab]	630.80[b]	710.70[a]	539.70[c]	0.001	0.052	0.001	42.97
	Beef	240.10	240.10	240.10	240.10	na	na	na	na
	Conserved feed	31.97	56.26	59.67	97.52	0.063	0.041	0.673	na
	Total	950.90[b]	926.70[b]	1009.40[a]	876.90[c]	0.001	0.789	0.003	46.97
Expenditure ($/ha)	Forage establishment	83.84[a]	83.84[a]	60.24[b]	82.8[a]	0.001	0.001	0.001	7.70
	Purchased feed	2.91[b]	2.91[b]	90.54[a]	2.91[b]	0.001	0.001	0.001	34.58
	Conservation	40.12	47.29	56.76	70.52	0.320	0.066	0.752	na
	Pasture renewal	38.21	38.21	14.85	20.69	0.221	0.001	0.221	na
	Nitrogen fertiliser	18.72	11.63	16.78	20.34	0.743	0.532	0.328	na
	Total Fertiliser	26.65	19.56	24.71	28.27	0.741	0.528	0.324	na
	Total farm working expenses	499.00	500.50	557.50	511.70	0.272	0.090	0.242	na
Economic farm surplus ($/ha)[2]		404.90	382.70	404.90	318.20	0.017	0.139	0.138	na

[1] Means with different letters within rows are significantly different (P<0.05).

[2] Economic farm surplus includes depreciation but not interest payments.

policy, as farms with breeding cattle may utilise these surpluses as standing feed in winter (Lambert et al. 2000). The decision to sell surplus feed provided a simple metric to value the extra feed across the range of scenarios that the farms provided.

Fodder beet cost between $75 and $103/whole farm ha to cultivate, sow and re-grass compared with $120/whole farm ha for the brassica systems due to the smaller are required. However, providing a targeted supplement increased purchased feed costs by $87/ha. The modelling did not allow for changes in labour requirement to feed out the supplement. These changes would be relatively small, potentially only an hour or two per day, meaning that the opportunity to employ casual labour to feed out a targeted supplement would be limited. However, this type of input is often on top of already full days and so an intervention such as targeted supplementation may not be taken up. The result of not using targeted supplementation to mitigate the effects of the low protein fodder beet diet on ewe BCS loss and lamb mortality (Hammond et al. 2021) negatively impacted farm income and contributed to increased wastage.

Conclusions

The use of real farm data from different environments, and implementing a range of enterprise types, has provided a robust methodology to examine the outcomes from advanced nutritional science at a whole farm systems scale. Maintaining ewe BCS in late winter resulted in an increase in farm productivity of approximately 10% and translated into an economic farm surplus of approximately 6% compared with a loss of –0.5 BCS during winter in farms in both wet and dry environments. Feeding fodder beet of a protein concentration of 9% to ewes in late pregnancy resulted a further reduction in production of 15% and economic farm surplus of 25%. Restoring the protein concentration of the diet to 18% using a supplement restored overall farm profitability even when the cost of the supplement was accounted for. Outcomes from this type of analysis in two contrasting environments provides a robust demonstration of potential impacts of both BCS change and winter forage choices.

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REFERENCES

Beef + Lamb NZ. 2021a. Economic Service Sheep and Beef Farm Survey, Otago/Southland 2021/22 Forecast and Quintile analysis (P21018). https://beeflambnz.com/sites/default/files/data/files/2020%20SSI.pdf Accessed 27 September 2021.

Beef + Lamb NZ. 2021b. Economic Service Sheep and Beef Farm Survey, Marlborough/Canterbury 2021/22 Forecast and Quintile analysis (P21018). https://beeflambnz.com/sites/default/files/data/files/2020%20CSI.pdf Accessed 27 September 2021.

Chakwizira E, de Ruiter JM, Maley S, Dellow SJ, George MJ, Michel AJ. 2014. Water use efficiency of fodder beet crops. *Proceedings of the New Zealand Grassland Association 76*: 125-134. https://doi.org/10.33584/jnzg.2014.76.2969

De Ruiter J, Wilson D, Maley S, Fletcher A, Fraser T, Scott W, Berryman S, Dumbleton A, Nicol W. 2009. Management practices for forage brassicas. www.dairynz.co.nz/media/izxkzkpt/management_practices_forage_brassicas.pdf Accessed 15 March 2020.

Devantier BP, Stevens DR, Rennie GM, Tozer KN. 2017. The effect of deferred grazing in spring and early summer pastures on pasture growth rate and feed quality. *Journal of New Zealand Grasslands 79*: 189-196. https://doi.org/10.33584/jnzg.2017.79.550

Everett-Hincks JM, Blair HT, Stafford KJ, Lopez-Villalobos J. 2004. The effect of ewe nutrition on maternal behaviour score and litter survival. *Proceedings of the New Zealand Society of Animal Production 64:* 188-191. http://www.nzsap.org/proceedings/2004/effect-ewe-nutrition-maternal-behaviour-score-and-litter-survival

Everett-Hincks JM, Stevens DR, Rendel JM, Smith TR, Smith PJ. 2013. The effect of ewe pre-lamb body condition on triplet lamb performance in a commercial flock. *Proceedings of the New Zealand Society of Animal Production 73:* 126-130. http://www.nzsap.org/proceedings/2013/effect-ewe-prelamb-body-condition-triplet-lamb-performance-commercial-flock

Fennessey PF, Glennie SF, McCorkindale AB. 2016. Innovations behind the farm gate that will influence performance of hill farming. *Hill Country Symposium. Grassland Research and Practice Series 16*. 15-20. https://doi.org/10.33584/rps.16.2016.3253

Flay KJ, Ridler AL, Compton CWR, Kenyon PR. 2021. Ewe wastage in New Zealand commercial flocks: extent, timing, association with hogget reproductive outcomes and BCS. *Animals 11*: 779. https://doi.org/10.3390/ani11030779

Genstat 2017. GenStat for Windows 18th Edition. VSN International Ltd, Oxford.

Gray DI, Reid JI, Horne DJ. 2011. The management of risk in a dryland environment. *Proceedings of the New Zealand Grassland Association 73*: 13-22. https://doi.org/10.33584/jnzg.2011.73.2835

Hammond KJ, Sandoval E, McKenzie CM, Lees S, Pacheco D, McCoard SA. 2021. The effect of a fodder beet versus ryegrass grazing regime during mid-to-late gestation twin-bearing ewes on dam and progeny performance and lamb survival. *New Zealand Journal of Agricultural Research 65*: 145-162. https://doi.org/10.1080/00288233.2021.1879175

Jefferies B. 1961. Body condition scoring and its use in management. *Tasmanian Journal of Agriculture 32*: 19-21.

Johns C, Johns J, Stevens DR. 2016. Increasing lamb survival and lamb weaning weight through feeding high fecundity crossbred sheep. *Hill Country Symposium. Grassland Research and Practice Series 16*. 323-328. https://doi.org/10.33584/rps.16.2016.3244

Kenyon PR, Maloney SK, Blache D. 2014. Review of sheep body condition score in relation to production characteristics. *New Zealand Journal of Agricultural Research 57*: 38-64. https://doi.org/10.1080/00288233.2013.857698

Knol FW, Erichsen C, Jonker A, Sandoval E, Pacheco D, Hea SY, McCoard SA. 2019. Effect of a fodder beet or lucerne-chaff-based diet on triplet-bearing ewe live weight, body condition score and lamb birth weight. *New Zealand Journal of Animal Science and Production 79*: 168-170. http://www.nzsap.org/proceedings/brief-communication-effect-fodder-beet-or-lucerne-chaff-based-diet-triplet-bearing-ewe

Lambert MG, Paine MS, Sheath GW, Webby RW, Litherland AJ, Fraser TJ, Stevens DR. 2000. How do sheep and beef farmers manage pasture quality? *Proceedings of the New Zealand Grassland Association 62*: 117-121. https://doi.org/10.33584/jnzg.2000.62.2378

Marshall PR, McCall DG, Johns KL. 1991. Stockpol: a decision support model for livestock farms. *Proceedings of the New Zealand Grassland Association 53*: 137–140. https://doi.org/10.33584/jnzg.1991.53.2013

Mathias-Davis HC, Shackell GH, Greer GJ, Bryant AI, Everett-Hincks JM 2013. Ewe body condition score and the effect on lamb growth rate. *Proceedings of the New Zealand Society of Animal Production 73*: 131-135. http://www.nzsap.org/proceedings/2013/ewe-body-condition-score-and-effect-lamb-growth-rate

McCoard S, Hea S-Y, McKenzie C, Hammond K, Smith T. 2020. Impact of change in body condition score in mid-late pregnancy in ewes fed a mixed diet on lamb survival and performance. *Journal of New Zealand Grasslands 82*: 211-219. https://doi.org/10.33584/jnzg.2020.82.442

Morgan-Davies C, Waterhouse A, Pollock ML, Milner JM. 2008. Body condition score as an indicator of ewe survival under extensive conditions. *Animal Welfare 17*: 71-77. https://doi.org/10.1017/S0962728600032000

Stevens DR, Casey MJ, Scandrett JS, Baxter GS. 2011. Winter feeding – changing labour requirements and productivity. *Proceedings of the New Zealand Grassland Association 73*: 51-56. https://doi.org/10.33584/jnzg.2011.73.2850

Stevens DR, Young G. 2013. Using data from large scale farming operations to understand the importance of feeding the ewe to improve whole farm performance. *Proceedings of the New Zealand Grassland Association 75*: 97-102. https://doi.org/10.33584/jnzg.2013.75.2929

Taylor A, Stevens D, McCoard S. 2021. Winter crop choice and body condition loss change the eco-efficiency of sheep flocks. *Journal of New Zealand Grasslands 83*: 215-224. https://doi.org/10.33584/jnzg.2021.83.3503

Wheadon NM, Dalley DE, Woods RR. 2023. Variation in kale and fodder beet yield and quality over winter affects nutrient supply to non-lactating dairy cows at the Southern Dairy Hub. *Journal of New Zealand Grasslands 85*: 155-165. https://doi.org/10.33584/jnzg.2024.85.3632