Impact of deferred grazing on profitability of a hill country farm in north-western Waikato

Katherine N. TOZER[1,*], Steven M. HOWARTH[2], Jon SHERLOCK[3] and Ian S. TARBOTTON[4]
[1]*AgResearch, Private Bag 3123 Hamilton, New Zealand*
[2]*AgFirst Waikato, PO Box 9078, Hamilton, New Zealand*
[3] *Otorohaea LTD, 369 Otorohaea Trig Rd, 3794, Ngaruawahia, New Zealand*
[4]*Ballance Agri-Nutrients Ltd, Private Bag 12-503, Tauranga, New Zealand*
*Corresponding author: katherine.tozer@agresearch.co.nz

Abstract
Deferred grazing is a common management practice in which pastures are rested from grazing between mid-spring and the end of summer/early autumn. It has been used to rejuvenate pastures and better manage the spring pasture surplus although its impact on farm profitability is unknown. FARMAX was used to determine the impact of deferred grazing on profitability of a beef and sheep hill country farm in north-western Waikato based on experimental data and likely management responses. The Base scenario modelled farm profitability assuming spring surplus in a typical year. When 15% of the farm was deferred and it was assumed that the increased grazing pressure on the rest of the farm led to greater control of the spring feed surplus and improved pasture quality, there was an increase in ewe performance and the number of lambs sold at target weight. Per head and total farm gross margins increased by 8%. Results demonstrate how the use of deferred grazing as a pasture management tool to increase resilience can also enhance livestock performance and profitability at the whole-farm level.

Keywords: FARMAX, gross margin, pasture fallow, pasture management

Background
Resting pastures from grazing from mid-spring until the end of summer/early autumn (deferred grazing), is a practice that has been used to improve pasture persistence (e.g., Kemp et al. 2000). The timing is critical, as allowing the desirable species to produce seedheads both enables the pasture species to reseed and promotes new tillering from existing plants in the autumn after the deferred period (L'Huillier & Aislabie 1988; Waller & Sale 2001). These benefits have been demonstrated for perennial ryegrass (*Lolium perenne* L.), cocksfoot (*Dactylis glomerata* L.) and other desirable perennial species in sheep, beef and dairy pastures in New Zealand and Australia (e.g., Mackay et al. 1991; McCallum et al. 1991; Dowling et al. 1996; Harris et al. 1999).

In the New Zealand pastoral sector, growth of pasture is typically uneven across the year (e.g., Webby & Sheath 2000) and leads to large variations in pasture quality (Litherland et al. 2002). Hence, managing surplus pasture particularly during spring when there is an increase in stem and reproductive material is crucial so that pasture quality at a farm-scale can be maintained (Webby & Sheath 2000). When deferring, paddocks are removed from the grazing round in mid-spring when pasture growth exceeds feed demand. This increases the stocking rate on the remainder of the farm so that grazing intensity is increased. It follows that increased grazing pressure will reduce stem and seedhead development so that the pasture contains a higher proportion of green leaf of greater pasture quality (Lambert et al. 2004).

As part of a Ministry for Primary Industries Sustainable Farming Fund (SFF) project, component research quantified the effect of deferred grazing on pasture resilience (i.e., recovery and regrowth after summer drought, Tozer et al. 2020a) but there is no published literature available on how this practice may affect profitability at a farm-scale on sheep and beef hill country farms. A whole-farm analysis is required to integrate the multiple impacts of deferred grazing on the farm system. These include the positive impacts of deferred grazing on the pasture performance of the deferred paddocks after the deferred period and on pasture quality on the remainder of the farm, and the negative impact on pasture growth and nutritive value of the deferred paddocks during the deferred period. To this end, the model FARMAX was used to determine the impacts of deferred grazing on livestock performance and whole-farm profitability. The hypothesis tested was that deferred grazing would increase livestock performance and profitability at the farm-scale.

Approach
Farm description
The case study farm, Otorohaea, is situated near Waingaro in north-western Waikato. The farm is 660 ha with an effective (grazable) area of 570 ha that comprises 91, 262, and 217 ha of rolling country (0-15° slope), hill country (15-25°) and hard hill country

(>25°), respectively. The average annual rainfall is 1300 mm, with most rain falling in winter and spring and the least rain falling between late summer and mid-autumn (between January and March). The soil is classified as a Typic Orthic Allophanic soil developed on tephra (Hewitt 1998). The pasture species vary with land class, with perennial ryegrass dominant on the rolling country and other species such as browntop (*Agrostis capillaris* L.) and sweet vernal (*Anthoxanthum odoratum* L.) more prevalent on the steeper land. The annual grass content of the pastures is negligible.

The goals of running a profitable and sustainable breeding and finishing business that is environmentally appropriate for this farm on steep hills are challenged by needing to adapt the Otorohaea farming system to a volatile climate. Summer droughts have become more frequent and damaging impacts of drought have been observed particularly on the steep hill country. Feed shortages on Otorohaea are most critical during summer and early autumn when the steep faces can lose cover rapidly, and in late winter/early spring when ewes are lactating. To address these challenges, management strategies are required that make Otorohaea pastures more resilient to drought. In this context, resilient pastures have been defined as those with a high proportion of desirable species that can recover after drought and maintain productivity.

Based on the experience of other farmers in the SFF project team who recommended deferred grazing as a tool to increase pasture resilience, Otorohaea management decided to determine if deferred grazing could improve the resilience of their pastures to drought while improving livestock performance and whole-farm profitability.

Baseline situation

Pasture growth

Otorohaea has a typical pasture curve, peaking in the spring. Pasture growth for each of the rolling, hill and hard hill country areas was estimated based on actual stock numbers and livestock performance in 2019-2020. Estimated pasture grown per year was 8.2 t dry matter (DM)/ha for rolling country, 7.6 t DM/ha for hill country, and 6.9 t DM/ha for hard hill country, with peak growth rates typically in October and the lowest growth rates occurring between February and June for all three land classes (Figure 1). A whole-farm application of 40 kg N/ha is applied each August. There is no cropping or use of supplements on Otorohaea.

Livestock policy

The farm runs approximately 3000 mature-aged ewes and 960 2-tooth ewes. The average weaning percentage is 136% and lamb liveweight is 28 kg. Ewe lambs are grazed off-farm from weaning (5 January) until the following 5 January (12 months). All non-replacement lambs are sold store at weaning. Approximately 300 beef heifers are purchased as 1-year olds in September with an average liveweight of 300 kg and finished and sold between the following November and January at 26-28 months-of-age, with a cold carcass weight averaging 260 kg.

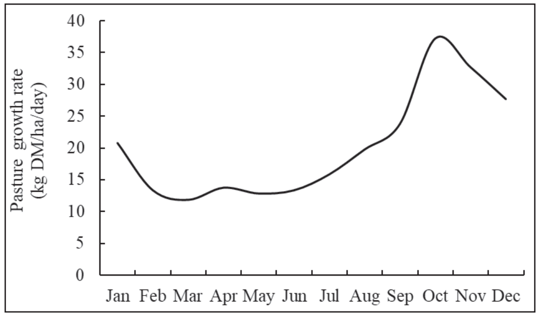

Figure 1 Estimated pasture growth rates for Otorohaea in 2019-20 (weighted average of rolling, hill and hard hill country).

System changes and modelling approach

FARMAX Red Meat Version 8.0.1.04 was used to determine the effect of deferred grazing on livestock performance and farm profitability.

The key function of FARMAX is to enable the user to determine if the planned stocking policy is 'biologically feasible' (White et al. 2010). This is achieved by estimating the minimum pasture cover (i.e., herbage mass) required to meet livestock demand based on the proposed stocking policy. If the pasture cover is less than or far exceeds the livestock demand, the proposed policy is deemed 'infeasible'. The user can then investigate management changes such as deferred grazing to better match the feed supply and livestock demand so that the stocking policy becomes 'feasible'.

The model initially treats a farm as a single block of pasture (minus cropping areas), comprised of green, stem and dead plant tissue. These different vegetation types are assigned metabolisable energy (ME) values which can be altered by the user. However, if the user assigns more than one block to the farm, the pasture quality attributes and ME values for the component blocks are summed and a weighted average ME value is assigned to the whole-farm block.

To model feed supply, the user can enter monthly pasture growth rates for each of the blocks or use generic data based on typical regional pasture growth data. Pasture growth rates are reduced when pasture cover and leaf area are lower than the assumed optimum of 1800 kg DM/ha. Growth rates are also reduced in the model when pasture cover and shading increase above an optimum. This occurs especially during spring and summer when the pasture exceeds 2400 kg DM/ha and there is an increase in senescence and decay and especially in deferred pasture towards the end of the deferred period when there is a large accumulation of poor quality, senescent vegetation (Devantier et al. 2017). This is simulated in the model by a greater proportion of biomass being transferred from the green to stem and dead pools.

To model feed demand, there are inbuilt assumptions regarding livestock. Livestock ME requirements are based on their number, weight, age, sex and physiological status. Intake requirements for each animal are calculated based on these data and the model does not allow the intake requirements to be exceeded (Parks 1982; White et al. 2010).

To run the model, the user enters livestock data and pasture growth rates (such as shown in Figure 1) and creates a range of scenarios to determine their feasibility. Scenarios can be modified by changes such as stock numbers, stock weight gains or supplementary feeding.

Model scenarios

To develop the pasture growth curve for deferred pastures, we used experimental data from replicated grazed-plot studies undertaken on Otorohaea and on a farm in Lower Kaimai (unpublished data), and a split-paddock study undertaken on Otorohaea (Tozer et al. 2020b). All available data were utilised to obtain an average estimate of pasture regrowth following a deferred period on a range of land classes and in different years. In addition, the farm owners made tactical decisions regarding stock policies at a whole-farm level in response to changes in the feed supply due to deferred grazing. Both the experimental data on the pasture growth curve and tactical decisions were incorporated into the model scenarios.

Three scenarios were developed to explore how deferred grazing affected livestock numbers, per head performance and gross margins. For all scenarios, 15% of the farm area was deferred each year, distributed equally between the three land classes (rolling, hill and hard hill country). The choice of deferring 15% of the farm area was based on experience of three other farmers in the mid-northern North Island Beef and Lamb Farmer Council in the SFF project team who use deferred grazing regularly to manage their spring surplus and rejuvenate pastures. This was considered a sufficiently large area to have an agronomically significant impact on the farm system.

For the FARMAX modelling, the farm was split into two FARMAX models ('deferred' (DEF) and 'rest of farm' (ROF) blocks). A feed budget was developed, and livestock numbers and per head performance were quantified for each of the two blocks. The DEF block of 85 ha was split into 13 ha of rolling, 40 ha of hill and 32 ha of hard hill country, and the ROF block of 485 ha was split into 78 ha of rolling, 222 ha of hill, and 185 ha of hard hill country. The two blocks were modelled separately and used for each of the four scenarios developed in FARMAX. This enabled determination of the magnitude of change in stock policy required to ensure a feasible feed budget on both the DEF and ROF blocks.

Four scenarios were developed and tested as the future status quo:

1. Base: which represented a typical year on Otorohaea with no deferred grazing.
2. Deferred: in which it was assumed there was a reduction in herbage consumed but no additional regrowth after the deferred period (compared to the rest of the farm).
3. Deferred + Regrowth: in which it was assumed there was a reduction in herbage production during the deferred period but an average of 15% increase in pasture growth for 12 months after the deferred period based on the data reported in Tozer et al. (2020b) and other unpublished data collected from Otorohaea (Table 1). In this scenario it was assumed that there was no impact on pasture quality on the remainder of the farm.
4. Deferred + Regrowth + Quality: This used the same assumptions as the third scenario and incorporated an improvement in pasture quality and per head performance on the rest of the farm.

Scenario 1 Base (no deferred grazing)

In this scenario, livestock were split over the DEF and ROF blocks. In the DEF block, pastures were not deferred and stock were grazed as on the ROF block. This enabled baseline data to be obtained before deferred grazing was applied in subsequent model scenarios. On the DEF block:

- 45 beef heifers were run year-round, with purchase and sale timing/weights being the same as for the ROF block.

Table 1 Increase in pasture growth (%) in the deferred pastures after the deferred period based on data of Tozer et al. (2020b) and other unpublished data collected from Otorohaea.

Season after deferred period	Increase in pasture growth (%)
Autumn (Mar-May)	15
Winter (Jun-Aug)	25
Spring (Sept -Nov)	25
Summer (Dec-Feb)	10
Autumn (Mar-May)	10

- 460 ewes were run year-round, with the same proportion of deaths and sales, and same reproductive performance as on the ROF block.
- 145 hoggets were moved onto the DEF block in January after returning home from grazing. Hoggets remained on the block until the following April by which time they had aged up to 2-tooths and joined the mob of mature-age ewes.
- All lambs were either sold at weaning or went to grazing.
- All rams were run on the ROF block.

Scenario 2 Deferred

In this scenario, deferred grazing was implemented on the DEF block. The following assumptions were made:

- The DEF block was not grazed between 15 October and 16 February.
- At the end of the deferred period, 300 R2 heifers grazed the deferred pasture for 25 days (16 February - 10 March).
- Each heifer consumed 8.5 kg/head/day which equated to 750 kg DM/ha harvested, assuming a pre-grazing biomass of 3500 kg DM/ha, utilisation of 50%, and post-grazing residual of 2000 kg DM/ha.
- While grazing the deferred pasture, liveweight gain was 0.4 kg/head/day (based on liveweight gain observations of project team farmers who regularly used deferred grazing).
- After grazing the deferred pasture, animals were transferred back to the ROF for 50 days before beginning the late autumn/winter rotations on the DEF block. From 1 May until 16 October, 600 ewes were grazed on the DEF block after which a new deferred period began in different paddocks. In addition, 90 R2 heifers were grazed on the DEF block over winter. On 8 September, all remaining 292 R2 heifers were moved back onto the deferred area to graze pastures to a low and even residual before deferring the pastures on 16 October.
- Sheep numbers and liveweight gains remain unchanged.
- During the late autumn/winter period (1 May-16 October), it was assumed that livestock performance was the same as on the remainder of the farm.
- There was no impact on pasture quality on the remainder of the farm.
- Growth rate assumptions were applied to both the DEF and ROF blocks.

Scenario 3 Deferred + Regrowth

In this scenario, deferred grazing was implemented on the DEF block as described in Scenario 2. It was also assumed that there was an increase in pasture growth of 15% for the year following the deferred period (Tozer et al. 2020b).

Growth rate assumptions were applied to both the DEF and ROF scenarios. For the ROF block, pasture growth was increased proportionately to represent the increase in pasture growth rates in the DEF block from the previous year. In response to changes in the amount of DM harvested, there were changes in the timing of moving sheep and heifers between the blocks. Sheep numbers and liveweight gains remain unchanged.

Scenario 4 Deferred + Regrowth + Quality

A key assumption of deferred grazing is that closing the deferred area increases the feed demand on the remaining area from mid-spring, which corresponds to the time of year when pasture growth rates are highest (Figure 1), and pasture supply is in excess of livestock demand. When deferred grazing is implemented, peak pasture covers are lowered. When stocking rates increase and pastures are grazed more intensively, the surplus is controlled and pasture quality is improved due to pastures containing a lower proportion of reproductive and dead material and higher portion of young and actively growing plants with a higher ME content (Litherland et al. 2002). FARMAX adjusts pasture quality once pre-grazing covers reach a threshold of an average of 2400 kg DM/ha. However, pasture covers were below this threshold in the Deferred + Regrowth scenario, so there was no change in quality when peak pasture covers were lowered. Therefore, a manual adjustment was made to the pasture quality parameters based on the following process described in Table 2:

- The difference between the Base and Deferred + Regrowth scenarios in average pasture cover for the ROF block was calculated for each month by comparing the ROF files in the two scenarios.
- It was assumed that deferred grazing resulted in shorter pre-grazing pasture covers but that the post-grazing pasture covers remained unchanged.
- The change in pasture cover was used to adjust the pre-grazing covers.
- The adjusted pre-grazing covers were used to estimate pasture growth rates and grazing intervals.
- It was assumed that there was an increase on the ROF block of 0.5 MJ ME/kg DM for each 2-week reduction in grazing interval based on the relationship developed by Waghorn & Barry (1987). This relationship was used to estimate changes in pasture quality. When compared to the Base scenario, pasture quality in the Deferred + Regrowth + Quality scenario was similar in mid to late winter (July-August), lower in spring (September-November), and greater in summer, autumn and early winter (December-June).
- This calculated difference in ME was then applied

to adjust the pasture quality in the FARMAX ROF model. Note that no changes were made to pasture quality over winter as the relationship from Waghorn & Barry (1987) covered the spring to autumn period only.

- It was assumed that the same quantity of DM was consumed in the Deferred + Regrowth and Deferred + Regrowth + Quality scenarios so that average pasture cover was similar, but due to the increase in the ME values of the feed (MJ ME/kg DM), stock performance was increased.
- It was assumed further that the finishing heifer enterprise remained the same as for the Deferred + Regrowth scenario.
- The weights of mature-age ewes were increased manually by 3 kg/head throughout the year due to the deferred grazing and improved pasture quality on the ROF block, which enabled higher ewe weights to be maintained. However, because of the increase in ewe weights the number of ewes carried on the deferred area was reduced by 17.

Results

Base scenario

The feed budget for the DEF and ROF blocks showed identical pasture growth and very similar pasture cover and gross margin profit. This demonstrated that stocking rate and performance were distributed evenly between the blocks. The total (whole-farm) gross margin for Otorohaea was $465,600 or $817/ha (Table 3). This provided the baseline for comparison with the three deferred scenarios.

Deferred scenario

Less pasture was harvested by livestock on the DEF block than on the ROF block (4.4 vs 6.6 t DM/ha). Because less pasture was harvested on the DEF block, the number of beef heifers was reduced from 300 to 283 when compared with the base scenario, but sheep numbers remain unchanged. This reduced the gross margin from $817 to $806/ha (Table 3).

Deferred + Regrowth scenario

It was estimated that 4.7 t DM/ha/yr was harvested from the DEF block and 6.7 t DM/ha/yr from the ROF block. Whole-farm gross margin was $465,500 or $817/ha, the same as that of the base model ($465,600 or $817/ha, Table 3).

Deferred + Regrowth + Quality scenario

The improved pasture quality led to improvements in per head stock performance. The gross margin of $501,000 was greater than that of all other model scenarios and lifted profitability by a total of ≈$36,000 (Table 3). The main driver was the increase in the number of lambs sold and to a lesser extent increases in the sale weights and number of lambs finished by weaning.

The same number of ewes were maintained but at a 3 kg/head heavier weight. The number of lambs weaned increased by 6% and their weaning weight by 1 kg/head to an average of 29 kg/head. At weaning, the number of lambs above 33 kg sold to the works increased from 622 to 850, carcass weight increased marginally by 0.1 kg, and the number of lambs sold store decreased from 3704 to 3681, with an average increase in weight of 0.4

Table 2 Differences in pasture covers, grazing interval and pasture quality comparing the 'rest of the farm' block under deferred and no deferred scenarios. ROF: rest of farm. Def + Reg: Deferred + Regrowth.

Month	Pasture cover ROF: Base scenario (kg DM/ha)	Pasture cover ROF: Def + Reg (kg DM/ha)	Pasture cover difference (kg DM/ha)	Pre-grazing difference (kg DM/ha)	Pasture growth rate (kg DM/ha/day)	Change in grazing interval (days)	Change to pasture quality (MJ ME/kg DM)
Jul-19	1424	1365	-59	-118	17	-7	NC
Aug-19	1515	1507	-8	-16	25	-1	NC
Sep-19	1736	1808	72	144	31	5	-0.2
Oct-19	1950	2118	168	336	41	8	-0.3
Nov-19	2075	2120	45	90	34	3	-0.1
Dec-19	2181	2136	-45	-90	28	-3	0.1
Jan-20	2317	2214	-103	-206	21	-10	0.3
Feb-20	2308	2177	-131	-262	14	-19	0.7
Mar-20	2076	2014	-62	-124	12	-10	0.4
Apr-20	1880	1746	-134	-268	14	-19	0.7
May-20	1714	1564	-150	-300	13	-23	0.8
Jun-20	1534	1428	-106	-212	13	-16	NC

NC = assumed no change in winter

kg/head. Overall the number of lambs sold increased by 205.

There was no change to heifer finishing and no change to pasture quality on the DEF area of the farm.

Discussion

Farmers can apply deferred grazing as a tool to improve pasture resilience without a negative impact on livestock production. This is given that the suppression of growth during deferment is compensated by increased regrowth after the deferred period as has been documented by Devantier et al. (2017) and Tozer et al. (2020b), and without assuming benefits to pasture quality on the remainder of the farm. When the Deferred + Regrowth scenario was tested in FARMAX without attributing benefits to the rest of the farm, gross margins were similar in both scenarios. The modelling was conducted assuming typical rainfall; further testing is required to develop insights into its use in variable climatic scenarios and particularly in a drought year.

Regrowth occurs when grazing is excluded from pastures between mid-spring and the end of summer / early autumn and occurs following both wet and dry summers (Tozer et al. 2020b). This timing is critical as it enables reseeding (L'Huillier & Aislabie 1988) and promotes tillering in the autumn following the deferred period (Waller & Sale 2001), both of which can contribute to pasture regrowth following the deferred period. Different regrowth outcomes may occur if the deferred grazing was practised at a different time of year or if the pastures were opened earlier in summer for example, before seed was mature e.g., Devantier et al. (2017). However, given that perennial ryegrass seed-fall usually occurs in January/early February, a significant window of opportunity remains for grazing of the accumulated feed after seed-fall but before the onset of autumn rains when the accumulated feed quality deteriorates. Thus deferred grazing provides the manager with some flexibility, the extent of which will depend on the region, year and farm.

Benefits for the rest of the farm were not a direct effect of deferred grazing. They accrued from the indirect effect of increasing grazing pressure on the rest of the farm over late spring and early summer and the improved pasture quality over summer. This culminated in higher ewe liveweights and reproductive performance which equated to an increase in gross margin of 8% at the whole-farm level.

A basic assumption is that without deferred grazing, pasture quality would be reduced over the whole farm due to many hill country farms having a spring pasture surplus during which reproductive growth occurs and feed quality deteriorates. While this was the case for Otorohaea, this may not hold true for all farms in all years. When a farm's livestock demand matches spring pasture growth more closely, there is likely to be a lower spring surplus and deferred grazing may not be as beneficial with respect to improving feed quality on the rest of the farm. Improvements to livestock reproductive performance will also depend on the type of livestock, their current performance, and management priorities. Further, the relationship between pasture height and ME

Table 3 Impact of deferred grazing on the whole-farm gross margin.

Gross margin ($)	Item	Base ($)	Deferred ($)	Deferred + Regrowth ($)	Deferred + Regrowth + Quality ($)
Sheep revenue	Sales - purchases	481,997	480,184	479,886	516,225
	Wool	81,853	81,807	81,801	82,570
	Total sheep	563,850	561, 991	561,687	598,795
Beef revenue	Sales - purchases	121,965	116,447	124,227	124,227
	Total beef	121,965	116,447	124,227	124,227
Total revenue		**685,815**	**678,438**	**685,914**	**723,022**
Expenses	Total crop and feed	101,633	101,662	101,662	101,662
	Total stock costs	54,529	54,335	54,521	54,520
	Interest on capital	64,006	62,777	64,216	65,651
Total operating expenses		**220,169**	**218,774**	**220,399**	**221,833**
Gross margin	Total farm	465,646	459,664	465,515	501,189
	Per ha	817	806	817	879

identified by Waghorn & Barry (1987) was based on cut swards of Italian ryegrass (*Lolium multiflorum* Lam). This relationship is likely to be affected by pasture type, land class and grazing management, which vary considerably within a farm and between farms. So while it can be assumed that deferred grazing can be profitable given a spring feed surplus, the magnitude of benefit will vary between years and between farms.

A mixture of rolling country, hill country and hard hill country paddocks were deferred in the model scenarios, inferring that deferred grazing is useful on a range of land classes. This is consistent with the experiences of the farmers in the SFF project team, who reported benefits from deferring rolling country, hill country and hard hill country pastures.

The extent of the benefits from deferring a pasture will depend on removing rank vegetation at the end of the deferred period, which can be more difficult on hard hill country than on rolling hill country, especially when large areas are involved (e.g., Sheath et al. 1984). On Otorohaea, it was observed that stock were able to remove the reproductive herbage on all land classes and graze the pastures to low residuals on the remainder of the farm (Tozer et al. 2020b). If grazing is patchy, and the rank vegetation is not removed, a high proportion of dead material is carried into winter which can reduce pasture growth in the following spring (Thompson et al. 2017). However, farmers in the project team were targeting specific paddocks for deferring (rather than large areas of the farm) and increasing grazing pressure during the deferred period on the rest of the farm. Both of these factors would help to ensure that a low proportion of rank vegetation was carried over into winter.

The amount of pasture chosen for deferring will vary from season to season. If feed levels are low, deferred grazing may not be an option or else pasture could be deferred later (for example, in early November given that the desirable pasture species can still produce seed). Conversely, if there is a large surplus, the area deferred may need to increase. Other tools, such as changes to livestock policies to increase spring feed demand or mechanical harvesting of feed or cropping (where possible) should also be considered.

This paper has focused on perennial ryegrass-based swards; further work is required to quantify responses of different pasture types such as those with high proportions of species such as browntop or plantain (*Plantago lanceolata* L.) and different types of clover. Australian research infers that deferred grazing can benefit a wide range of pasture types in different climatic regions, and favour perennial grasses over weedy annual grasses, given that the timing of the deferred period is tailored to the timing of flowering and seed production of the desirable species (Kemp et al. 2000). Deferred grazing has increased the subterranean clover (*Trifolium subterraneum* L.) content of summer-dry hill country pastures in Hawke's Bay, New Zealand, when livestock were excluded from pastures between mid-spring and mid-summer (MAF 2010).

The decision to defer is made without knowledge of what the summer will bring. The flow-on benefits of having a deferred area in a drought may be greater than in an average year by providing more feed in a time of deficit. Drought recovery is important and it was observed for Otorohaea that the deferred area grew approximately 15% more grass compared to other areas (Tozer et al. 2020b). However, modelling would be required to explore the potential impact of deferred grazing during a drought year on farm profitability. Thus in drought years, deferred grazing may contribute greater resilience to the pasture (through enabling recovery of tiller populations and maintenance of herbage production) and resilience to the farm system, by enabling part of the spring surplus to be carried forward into a time of summer-feed deficit and provide forage during drought (Tozer et al. 2020b).

Conclusions/Practical implications/Relevance

The scenario testing clearly demonstrated the financial benefits of deferred grazing on Otorohaea and that it can be used as a tool to improve pasture resilience, increase livestock performance, and profitability given a typical spring surplus. Thus deferred grazing can be used to reseed pastures (given an adequate content of desirable species such as perennial ryegrass) and promote tillering while simultaneously controlling the spring pasture surplus and increasing pasture quality at a farm scale. This contributes to both pasture and farm systems resilience.

While results were specific for Otorohaea, we suggest that the principles are applicable more widely and that deferred grazing could be used judiciously as a tool on many hill country farms in Waikato, and perhaps those in different regions, to improve pasture and farm systems resilience.

ACKNOWLEDGEMENTS

Thanks to Ministry for Primary Industries Sustainable Farming Fund, the mid-northern North Island Beef and Lamb Farmer Council, Beef + Lamb New Zealand, Ballance Agri-Nutrients, Environment Bay of Plenty, Waikato Regional Council and AgFirst for their funding and in-kind contributions in this project. We also thank reviewers from AgResearch, B+LNZ and NZGA and the NZGA editor for their helpful comments.

REFERENCES

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. *Proceedings of the New Zealand Society of Animal Production 79*: 189-196. https://doi.org/10.33584/jnzg.2017.79.550

Dowling PM, Kemp DR, Michalk DL, Klein TA, Millar GD. 1996. Perennial grass response to seasonal rests in naturalised pastures of central New South Wales. *Rangeland Journal 18*: 309-326. https://doi.org/10.1071/RJ9960309

Harris SL, Waugh CD, McCabe RJ, van Vught VT. 1999. Effect of deferred grazing during summer on white clover content of Waikato dairy pastures, New Zealand. *New Zealand Journal of Agricultural Research 42*: 1-7. https://doi.org/10.1080/00288233.1999.9513347

Hewitt AE. 1998. *New Zealand soil classification. 2nd edition. Landcare Research Science Series 1*. Manaaki Whenua Press, Lincoln, Canterbury, New Zealand. http://digitallibrary.landcareresearch.co.nz/digital/collection/p20022coll1/id/264/rec/7

Kemp DR, Michalk DL, Virgona JM. 2000. Towards more sustainable pastures: lessons learnt. *Australian Journal of Experimental Agriculture 40*: 343-356. http://dx.doi.org/10.1071/EA99001

L'Huillier PJ, Aislabie DW. 1988. Natural reseeding in perennial ryegrass/white clover dairy pastures. *Proceedings of the New Zealand Grassland Association 49*: 111-115. https://doi.org/10.33584/jnzg.1988.49.1812

Lambert MG, Clark DA, Litherland AJ. 2004. Advances in pasture management for animal productivity and health. *New Zealand Veterinary Journal 52*: 311-319. DOI: https://doi.org/10.1080/00480169.2004.36447

Litherland AJ, Woodward SJR, Stevens D, McDougal DB, Boom CJ, Knight TL, Lambert MG. 2002. Seasonal variations in pasture quality on New Zealand sheep and beef farms. *Proceedings of the New Zealand Society of Animal Production 62*: 138-142. http://www.nzsap.org/proceedings/2002/seasonal-variations-pasture-quality-new-zealand-sheep-and-beef-farms

Mackay AD, Budding PJ, Ross DJ, Tate KR, Orchard VA, Hart PBS, Kettles HA. 1991. Pastoral fallow for improving low fertility hill country pastures. *Proceedings of the New Zealand Grassland Association 53*: 209-213. https://doi.org/10.33584/jnzg.1991.53.1979

MAF (Ministry of Agriculture and Forestry). 2010. *Using deferred grazing to improve pasture on sheep and beef farms*. Wellington, New Zealand, 4 p. https://www.mpi.govt.nz/dmsdocument/85/direct

McCallum DA, Thomson NA, Judd TG. 1991. Experiences with deferred grazing at the Taranaki Agricultural Research Station. *Proceedings of the New Zealand Grassland Association 53*: 79-83. https://doi.org/10.33584/jnzg.1991.53.1996

Parks JR. 1982. *A theory of feeding and growth of animals*. Springer-Verlag, Heidelberg, Germany. 322 p. https://www.springer.com/gp/book/9783642683329

Sheath G, Webby R, Pengelly W. 1984. Management of late spring-early summer pasture surpluses in hill country. *Proceedings of the New Zealand Grassland Association 45*: 199-206. https://doi.org/10.33584/jnzg.1984.45.1657

Thompson BR, Stevens DR, Wall AJ, Moss RA, O'Neill KT, Cox NR. 2017. Winter grazing and dead material effects on early spring pasture production. *New Zealand Journal of Agricultural Research 60*: 131-139. https://doi.org/10.1080/00288233.2017.1283633

Tozer KN, Müller K, Tarbotton I. 2020a. *Deferred Grazing Handbook. Messages from the Sustainable Farming Fund Project Pasture Management in a Volatile World, July 2017-September 2020*. AgResearch Ltd, Hamilton, New Zealand. 32 p. https://www.agresearch.co.nz/assets/Uploads/Deferred-Grazing-Handbook-e-version-Dec-2020.pdf

Tozer KN, Müller K, Craven C, Tarbotton I, Coster A, Burke R, Sherlock J, Cameron C. 2020b. Effect of deferred grazing during late spring and summer on pasture productivity in Waikato and Bay of Plenty hill country. *Journal of New Zealand Grasslands 82*: 111-119. https://doi.org/10.33584/jnzg.2020.82.448

Waghorn GC, Barry TN. 1987. Chapter 2. Pasture as a nutrient source. In: Nicol AM. Ed. *Livestock feeding on pasture. Occasional Publication No. 10*. Hamilton, New Zealand: New Zealand Society of Animal Production, pp. 21-37.

Waller RA, Sale PWG. 2001. Persistence and productivity of perennial ryegrass in sheep pastures in south-western Victoria: a review. *Australian Journal of Experimental Agriculture 42*: 117-144. https://doi.org/10.1071/EA00049

Webby R, Sheath G. 2000. The impacts of change in forage quality and seasonality on sheep farm profitability. *Proceedings of the New Zealand Grassland Association*: 189-194. https://doi.org/10.33584/jnzg.2000.62.2380

White TA, Snow VO, King WM. 2010. Intensification of New Zealand beef farming systems. *Agricultural Systems 103*: 21-35. https://doi.org/10.1016/j.agsy.2009.08.003