Alternative field-based approaches to animal wintering that deliver some improved environmental and animal welfare outcomes

A stock-take of current knowledge

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1. Executive Summary

This report presents a synthesis of current knowledge about possible alternative approaches to intensive winter forage crop grazing, focussing on field-based systems that are feasible and affordable. This information has been requested by Otago Regional Council as a precursor to possible future initiatives that support farming communities to identify wintering approaches that have lower potential impacts on soil and water quality. The synthesis begins with a review of findings from recently completed projects that have evaluated some pasture-based and lower-intensity mixed forage crop grazing approaches to animal wintering. Common themes and practical experiences from these studies are identified and used to develop a set of design principles that can guide planning and management considerations for future wintering activities.

Three key themes or design principles that potentially deliver improved environmental outcomes were identified. The first is the benefit of ***maintaining a viable plant*** in the system that can take up nitrogen (N) from the soil post winter grazing (thus reducing N leaching) and provide vegetative cover to protect soil from the effects of rain drop splash impacts on soil structure (thus reducing soil erosion risk). Plant cover or thatch can also provide a more comfortable surface for animals to lie on. The second design ingredient is the important effect that ***winter diet*** can have on (estimated) urinary N returns to soil and consequent N leaching risk. Consideration of ***landscape vulnerability*** attributes, in terms of soil type, wetness (winter rainfall) and slope, is a third design element that is required to ensure that successful wintering outcomes are likely.

A suite of relevant planning and management considerations were then identified and aligned with the above design elements.   Reduced grazing pressures, the use of established rather than recently sown pastures, provision of hay and the offering of multi-day breaks are some practical ways that will help to maintain a viable plant following winter grazing of pastures. Where multi-species winter forage mixes are used for winter grazing, selection of plants that provide a range of functional traits such as an ability to re-grow following grazing, greater cool-season activity (N uptake) and/or provide fibrous residues to improve soil strength, will also deliver beneficial outcomes for animals and the environment. Coupled with reduced grazing intensities, the offering of diets that have just enough protein to satisfy the nutritional requirements of pregnant livestock is an effective strategy that can help to minimise urinary N returns to soil and consequently the associated risk of N leaching. Selecting locations that have well-drained and structurally resilient soil types, low (< 10 degrees) slopes and modest winter rainfalls (<250 mm) are key landscape attributes that need consideration to maximise the chances of successful wintering outcomes.

The report concludes with some suggested initiatives that address remaining knowledge gaps and assess the effects that any future changes to animal wintering practices may have on environmental outcomes. Initiatives to explore farm system changes to reduce reliance on intensive winter forage cropping systems will be helpful for providing decision makers with greater confidence. These could be designed to simultaneously address some remaining knowledge gaps (such as dietary protein adequacy) and quantitatively assess outcomes associated with any modified wintering approach that is implemented. This latter goal would require a structured monitoring programme to measure some key indicators (or their proxies) of improved animal and environmental outcomes. Such indicators would include temporal changes in vegetation cover and yields, plant N uptake post winter grazing, animal feed intakes (DM, ME, protein and N) and soil infiltration.

2. Background

2.1 Purpose and Scope

The challenge in a temperate pastoral environment like NZ where animals are grazed outdoors all year is matching feed supply and demand to the regional pasture curve. The use of high yielding forage crops in winter to fill feed gaps can have significant environmental impacts. Traditional winter feed options include grazing forage crops *in situ*, such as swedes, kale and turnips as well as the more recent uptake of fodder beet. The bulk of feed, which is grown during spring, summer and autumn, can be stockpiled into the winter. Thus, winter stocking rates can be optimised to ensure that the abundance of spring feed can be profitably utilised. Pasture replacement after crops provides the opportunity to refresh pasture with new pasture genetics and to replace runout pastures.

Otago Regional Council is seeking to support initiatives that explore possible farm system changes to reduce reliance on such intensive winter forage cropping systems. Such changes are desired to help lower the potential impacts of animal wintering activities on soil and water quality. AgResearch was therefore commissioned to produce a stock-take of current knowledge about possible alternative approaches to intensive winter forage crop grazing, focussing on field-based systems that are feasible and affordable. Off-paddock approaches to animal wintering, such as the use of barn or standoff pad systems, are therefore outside the scope of this short review. So too is the use of catch crops that are planted following winter forage crop grazing[1].

2.2 Definition of some key terms

Some common terms used in our review are defined below:

Relative Stock Units (RSUs): the stock unit system is used extensively in NZ agriculture to capture the effects that different livestock classes, and varying levels of performance within each, can have on productivity and land use pressure. One RSU is assumed to be equivalent to an animal that requires 6000 MJME (megajoules of metabolizable energy) per annum. Conversion factors for applying this metric to different livestock types and performances are described in Parker (1998) and Trafford & Trafford (2011).

Grazing density: a space allowance per animal per unit time e.g. 10 m^2 cow^{-1} day^{-1}. This metric is determined by the amount of fresh feed available and then allocated to livestock.

Grazing pressure: an animal stocking rate equivalent per unit time e.g. 1.0 RSU m^{-2} d^{-1}. This term describes the intensity of animal activity, and thus also likely excretal return, per unit area per unit time. Livestock types can be standardised into Relative Stock Units (RSUs) or liveweight (lvwt.) equivalents to allow for easier comparisons between the likely effects of

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[1] Catch crops have been a focus of recently-completed studies including a project funded by the Sustainable Land Management and Climate Change (SLMACC) fund administered by the NZ Ministry for Primary Industries; summary findings are available at https://www.far.org.nz/resources/catch-crop-guidelines-forages-for-reduced-nitrate-leaching

different classes of stock and grazing intensities on soil and water quality. Some working examples are presented below:

- Assuming a cow is the equivalent of 8 RSUs and is grazing a winter forage crop with a space allowance of 10 m^2 cow^{-1} day^{-1} represents a grazing pressure of 0.8 RSUs m^{-2} d^{-1}.

- Assuming a sheep is the equivalent of 1.3 RSUs and is grazing a winter forage crop with a space allowance of 2 m^2 $sheep^{-1}$ day^{-1} represents a grazing pressure of 0.65 RSUs m^{-2} d^{-1}.

Intensive winter grazing: "Intensive" grazing activities are usually defined in relative terms, recognising that relatively high grazing pressures (e.g. > 0.5 RSUs m^{-2} d^{-1}) are typical of wintering systems where large amounts of feed are available per unit area. This contrasts with pasture grazing pressures imposed outside of winter that are typically less than 0.1 RSU m^{-2} d^{-1}.

Soil armour: The concept of soil armour is one of the key pillars of Regenerative Agricultural practices (McGuire 2018; Rodale 1989) that are increasingly promoted in the farming community. The armour term denotes a defensive shielding for soil that can be provided by root thatch and/or plant residues that act as a protective barrier against hoof treading damage and raindrop impacts on soil aggregate stability (and subsequent loss via water or wind erosion).

Landscape vulnerability: A range of factors can make a landscape vulnerable to soil damage and contaminant loss. Slope, slope length, soil erodibility, rainfall erosivity and a lack of soil cover are recognised as important determinants of soil erosion risk (Renard et al. 1997). Soil wetness is an additional and common factor during winter that makes soil more vulnerable to treading damage and consequent risks for contaminant transport in surface runoff and/or drainage. Shallow or "light" soils, defined as those with Plant Available Water (PAW_{60cm}) contents of less than 85 mm, represent another category of vulnerability due to the greater risk of N displacement by drainage (Monaghan et al., 2021).

Multi-species, multi-graze cropping systems: these are mixtures of forage species that are specifically tailored to deliver a balanced range of functional traits. These could include species that deliver sufficient yield and dietary energy; other species that provide dietary bulk, fibre and bedding litter; legumes for protein and N fixation; and species that have the ability to re-grow after grazing.

Feed transitioning: careful dietary planning considerations are needed when an animal shifts from one feed source to another. This is particularly important when transitioning from pastures low in soluble carbohydrates and high in fibre onto winter forages such as swedes, turnips and fodder beet which are, in contrast, high in soluble sugars and low in dietary fibre.

2.3 Report outline

Our review begins by drawing upon insights from recently completed projects[2] that have evaluated some pasture-based (section 3) and lower-intensity mixed forage crop (section 4) grazing approaches to animal wintering. Common themes from these studies and experiences are captured and used to identify some important design principles in section 5 of the report. The importance of landscape vulnerability factors is discussed, recognising that the interplay between this vulnerability and imposed grazing pressures ultimately determines the level of environmental risk. The report then concludes with an overview of remaining knowledge gaps that need addressing, including some suggested future initiatives that could help to provide decision makers with greater confidence when choosing alternative approaches to animal wintering.

[2] In particular, findings from the SLMACC-funded "Improving wintering outcomes for winter forage systems" projects (MPI-AgResearch Ltd Agreement No. 406380): *Soil Armour* (R Monaghan as project lead) and *Forages to Pasture* (D Stevens as project lead).

3. Pasture-based wintering approaches

We present details from three experiments or case studies that have considered a range of soil or, in some cases, water quality outcomes from pasture-based wintering approaches. Key findings and observations from each are briefly summarised in the sections below. A brief commentary is also provided of some historical experiences that considered the practical and productive implications of all-grass sheep wintering systems in southern NZ.

3.1 Some historical perspectives of all-grass wintering in southern NZ

All grass wintering is not a new management option, having been extensively considered in the 1970s and 1980s. At that time the system was predominantly used by sheep farmers and consisted of three general approaches (Round-Turner, 1974):

(1) The "sacrifice paddock" approach whereby an area is set aside on which to feed out hay to large concentrations of stock. A run-out pasture or one scheduled for cultivation the following year would usually be chosen on the assumption that treading damage by wintering stock would seriously reduce its subsequent value as a productive pasture.

(2) The "set-stocking" approach whereby pastures are stocked at or slightly below their average carrying capacity. Pasture growth and availability was usually below animal maintenance requirements and some hay was therefore fed.

(3) The "slow rotation" approach in which several paddocks are grazed by large mobs two or three times during the winter.

Brown and Harris (1972) noted that the first, and major, problem involved with an all-grass wintering approach was a mental attitude which alienated winter from the rest of the year. Much of their discussion was related to pasture growth and its control in seasons other than winter, as success or failure of any wintering programme was partly determined at those times. They noted that poor management of summer pasture could lower feed availability over winter, whilst animal treading effects during winter grazing would delay spring recovery in feed supplies. Other researchers noted that spring production was only depressed following grazing with high stocking rates coupled with wetter-than-normal winters (Round – Turner 1974)[3]. Stocking densities of between 740 and 900 sheep ha^{-1} have been suggested to give the best results in terms of both animal performance and pasture recovery (Miller 1972).

Drewry et al. (1999) documented some soil and pasture responses to a rotational winter grazing approach that had become common to sheep farms in southern Southland by the 1990s. The reported stocking density of 1800 head ha^{-1} for each 24-hour feed break represents an equivalent grazing pressure of about 0.2 RSUs m^{-2} d^{-1}, which is relatively low for a winter grazing system when compared to grazing pressures currently imposed in many cattle wintering systems (described in detail later in the following sections). Drewry et al. also noted that animal treading damage during winter grazing delayed spring recovery in feed

[3] Equivalent grazing pressures imposed in this study were 0.2 RSUs m^{-2} d^{-1} for a set-stocked wintering treatment and either 0.9 or 1.8 RSUs m^{-2} d^{-1} for treatments assumed to (but did not) create sacrifice paddock scenarios.

supplies, but this did not have a detrimental effect on total annual production due to good pasture recoveries in summer and autumn. Decreased production following winter grazing was attributed to direct plant damage and burial, rather than changes in soil physical condition. Whilst significant reductions in the volumes of large soil pores (> 30 µm) were measured, soil hydraulic conductivities were observed to remain higher than maximum rainfall intensities expected at this location.

Following on from the success of grass wintering with sheep, it was also found that the same principles could be applied to weaner cattle (Halford, 1972). Essential requirements were a slow rotation, high stock concentrations (40 to 60 head ha^{-1}), daily shifts, back-fencing and some form of pad for off-paddock feeding during extremely wet conditions.

3.2 Pasture-silage wintering in south Otago

A recently completed study at Telford, south Otago, compared the performance of a short-rotation ryegrass pasture and pasture baleage feeding regimen (hereafter referred to as "pasture-baleage") as an alternative approach for over-wintering cows. Soil, water and plant responses under this wintering option were compared to those recorded for a Control treatment of either winter swedes (2021 and 2022) or winter kale (2023). The design and management of the experimental treatments was guided by surveys and interactions with selected farmers and rural professionals in Otago who were interested in the performance of the pasture-baleage wintering approach which had been practised by some farmers in the district. Based on this practitioner feedback, and set against the goals of retaining some degree of viable pasture and soil armouring when pastures underwent grazing, pasture allowances and resulting grazing intensities in the pasture-baleage wintering treatment were:

- fresh pasture equivalent to 5 - 7 kg DM $cow^{-1}day^{-1}$, supplemented with pasture baleage equivalent to 8 - 9 kg DM $cow^{-1}day^{-1}$. This feeding regimen resulted in an equivalent daily space offering of 13 (2021) or 16 (2022 & 2023) m^2 cow^{-1}.

Equivalent attributes imposed in the Control (winter crop) treatment were:

- crop equivalent to 10 - 12 kg DM cow^{-1} day^{-1}, supplemented with pasture baleage equivalent to 3 - 4 kg DM cow^{-1} day^{-1}. This feeding regimen resulted in an equivalent daily space offering of 10 m^2 cow^{-1}.

Summary findings from this 3-year study are shown in Table 3.1. In general, only modest benefits were observed in the pasture-baleage wintering treatment. Measurements and observations indicated that soil treading damage was incurred in both wintering treatments, although this damage was more severe in the winter crop treatment. Considerable soil treading damage was noted in the pasture-baleage treatment in 2021, presumably in response to the wet conditions experienced and the slightly reduced space allocation (13 m^2 cow^{-1}) in this first year of study. Despite this treading damage, pasture was noted to eventually recover, although this occurred relatively slowly: on average, 86% of plot areas remained bare approximately three months after grazing[4]. Whilst there was a significant improvement in pasture recovery four months after grazing, about c. 30% of the area of each

[4] Virtually 100% of the Control treatment area remained bare until a following crop was established.

plot remained without pasture cover and therefore required resowing. Pasture recoveries following winter grazings in 2022 and 2023 were faster than observed for 2021, with full pasture cover reached by 8 November and 31 October, respectively, most probably reflecting more favourable weather conditions experienced immediately before and during grazing of the experimental plots. A slight increase in space allowance (from 13 to 16 m^2 cow^{-1} day^{-1}) may have also contributed to these faster recoveries. In general, we can infer that a reasonably high degree of soil treading damage can be expected at the grazing intensities imposed in the pasture-baleage wintering treatment at this site. Combined with the structurally-vulnerable and poorly-drained nature of the soil (Timaru silt loam) at this site, the imposed grazing pressures negated much of the protective armouring expected from the recently-sown[5] pasture. One clear benefit observed for the pasture-baleage treatment was the reduced risk of soil loss, reflecting the modelled effect of greater vegetative cover than observed and modelled in the crop wintering treatment, where soil remained bare for approximately six months of the year.

A surprising result in this study was the lack of a favourable outcome for mitigating N leaching losses that were measured at this site when the pasture-baleage wintering treatment was implemented (Table 1). This may reflect the combined effects of relatively low drainage volumes (to displace soil inorganic N) and presumably a high potential for N removal via denitrification in this poorly-drained soil. An additional effect was observed in 2023 in response to a late autumn grazing of the pasture baleage treatment that was required to control pasture quality. The decision to make such a late grazing was taken on the basis that (i) some form of harvesting was required to ensure that the short-rotation ryegrass maintained a suitable quality for grazing during winter, and (ii) a late mechanical harvesting would have been logistically difficult and deemed a management artefact that would not occur in typical dairy farming situations. An unwanted consequence of doing so was the return of urinary N that would have added to the pool of N that was potentially available for leaching over the subsequent winter.

[5] the decision to use full cultivation to establish annual ryegrass pasture in two of the three years of study would have reduced the levels of soil armour/strength that would otherwise be expected for established pasture.

Table 3.1: Summary soil, vegetation and leaching data for the pasture-baleage and crop wintering treatments averaged over the three years of measurement (2021-2023). Mean annual and winter rainfalls recorded at the Telford site were 592 and 184 mm, respectively.

Key response indicator	Wintering treatment	
	Pasture-baleage	**Crop**
Imposed grazing pressure: Cow hours m^{-2}	1.6	2.4
Relative Stock Units m^{-2} d^{-1}	0.53	0.80
Soil measurements (post-grazing)		
Pug depth (cm)	8.0	10.2
Soil loss risk[a], T $ha^{-1}yr^{-1}$	0.23	1.54
VSA Score[b]	10.8	6.5
Post-grazing (spring) plant data		
Plant cover by Sept/Oct, kg DM ha^{-1}	2986	Minor (weeds)
Plant N removal, kg N ha^{-1}	35	0
Inorganic N leached: kg N ha^{-1} yr^{-1}	28	20

[a]Estimated using the Revised Universal Soil Loss Equation (RUSLE; Renard et al. 1997); [b]as measured in spring 2022 (at the end of a second year of wintering at the site; ideal maximum score = 28).

3.3 Hay bale winter grazing in northern Southland

A recently completed study at Glenlapa, northern Southland, compared the performance of a hay bale and (established) pasture feeding regimen (hereafter referred to as “hay bale grazing”) as an alternative approach for over-wintering cows. Soil, water and plant responses under this wintering option were compared to those recorded for a Control treatment of winter kale that was used in all three years of study. The design and management of the experimental treatments were guided by surveys and interactions with selected farmers in Otago and Southland who were interested in the performance of the hay bale grazing approach which had been practised by some farmers in the district (Plate 1). Based on this practitioner feedback, and again set against the goals of retaining some degree of viable pasture and soil armouring when pastures underwent grazing, pasture allowances and resulting grazing intensities in the hay bale grazing wintering treatment were:

- fresh pasture equivalent to 5 - 6 kg DM $cow^{-1}day^{-1}$, supplemented with large round bales of hay equivalent to 17 kg DM $cow^{-1}day^{-1}$. This feeding regimen resulted in an equivalent daily space offering of 16 m^2 cow^{-1}.

Equivalent attributes imposed in the Control (winter crop) treatment were:

- kale offered at the equivalent of 12 - 13 kg DM cow^{-1} day^{-1}, supplemented with pasture baleage equivalent to 4.5 kg DM cow^{-1} day^{-1}. This feeding regimen resulted in an equivalent daily space offering of 8 m^{2} cow^{-1} in 2021 and 2022 and 10 m^{2} cow^{-1} in 2023[6].

Summary findings from this 3-year study are documented in Table 3.2 and show a range of benefits to soil, water, and plant outcomes in the hay bale grazing treatment. Treading pressure and consequent damage to the well-drained soil at the site was considerably less in the hay bale grazing system. This resulted in the maintenance of a growing plant that could take up N from the soil and provide vegetative cover to reduce the potential risk of soil erosion. Whilst areas used for winter hay bale grazing were removed from the grazing round from late February or early March until grazing during winter (approximately 90 days), these areas did become available within the first or second round of spring grazing as pastures recovered during warming spring conditions. This reasonably rapid recovery in pasture growth resulted in the uptake of between 10 (at the grazing in September 2023) and 63 kg N ha^{-1} (at the time of the mid-October 2021 grazing). The pasture thus effectively acted as a “winter catch crop” mitigation that helped to reduce N losses, akin to the cereal growing options that have been studied elsewhere (Malcolm et al. 2022). Combined with the reduced grazing pressure and associated excretal returns of the hay bale grazing system, this N uptake contributed to a significant reduction in N leaching.

Another clear benefit was seen for soil loss mitigation, reflecting the favourable responses that resulted due to the presence of vegetation cover that would have helped to reduce the disruptive impact of rainfall energy on soil aggregates. Relatively favourable outcomes were also observed in the hay bale grazing treatment in terms of cow welfare assessments. These cows spent more time ruminating and lying in postures indicative of greater thermal comfort, had higher measured skin temperatures and cleaner coats. These responses collectively suggest greater opportunities for thermal comfort compared to cows managed on kale crop (Schutz et al 2024; see also Plate 2).

[6] Lower yields in 2023 required this increase in space allowance to achieve a similar daily kale allocation as offered in 2021 and 2022.

Plate 3.1: Images of hay bale grazing: before and during.

Table 3.2: Summary soil, vegetation and N leaching data for the hay bale grazing and crop wintering treatments averaged over the three years of measurement (2021-2023). Mean annual and winter rainfalls recorded at the Glenlapa site were 705 and 151 mm, respectively.

Key response indicator	Wintering treatment	
	Hay bale grazing	**Kale crop**
Imposed grazing pressure: Cow hours m^{-2}	1.5	2.8
Relative Stock Units m^{-2} d^{-1}	0.5	0.92
Soil measurements (post-grazing)		
Pug depth (cm)	7.3	12.0
Soil loss risk[a], T $ha^{-1}yr^{-1}$	0.86	2.85
VSA Score[b]	16	6.0
Post-grazing (spring) plant data		
Plant cover by Sept/Oct, kg DM ha^{-1}	2986	Minor (weeds)
Plant N removal, kg N ha^{-1}	35	0
Inorganic N leached[c]: kg N $ha^{-1}yr^{-1}$	7	33
kg N cow^{-1} wintered	0.6	2.4

[a]Estimated using the Revised Universal Soil Loss Equation (RUSLE; Renard et al. 1997); [b]as measured in spring 2022 (at the end of a second year of wintering at the site; ideal maximum score = 28); [c]provisional estimate - N deposited in 2023 has not completely leached at the time of writing this summary.

Plate 3.2: Photos of resting cows in the hay bale grazing (top) and kale (bottom) treatments.

3.4 Pasture-silage wintering in southern Southland

Wintering on Italian ryegrass pasture at the Southern Dairy Hub (SDH) was explored in 2022 and 2023. This approach was considered as an alternative to the kale or fodder beet cropping systems that had traditionally been used on the farm, which is located on the naturally well-drained Edendale silt loam soil and where mean winter rainfall is approximately 265 mm. The Italian ryegrass pasture-based approach used space allowances of between 4.6 m^2 (for R2 heifers in 2022) to 7.1 m^2 (for cows in 2023) per cow per day. These allowances represent equivalent grazing pressures of between 1.1 to 1.3 RSUs m^{-2} day^{-1} and are broadly similar to those in the crop-based systems used on the farm (typically in the range of 0.9 to 1.1 RSUs m^{-2} day^{-1}). In 2022 the pre-grazing pasture covers were about 2200 kg DM ha^{-1}. These were increased to 2800-3000 kg DM ha^{-1} in 2023. Pasture was supplemented (100 bales per ha in 2022 and 80 bales per ha in 2023) with baleage made in the paddock or purchased off-farm.

Experiences with the Italian ryegrass pasture system at SDH indicated that this system resulted in a mixed set of outcomes (SDH, 2022). A benefit of the Italian ryegrass was it represented a low-risk feed for cow health, avoiding the need for feed transitioning as required for crops. It was also more flexible as feed offered could be adjusted by choosing the number of bales offered and management responses to wet weather events were easier. Some disadvantages were that it was costlier, especially following a dry summer which resulted in high demand for baleage; variable supplement quality could impact cow weight gain; and there was a lot more bale wrap to dispose of. Importantly, soil and plant damage during winter grazing was severe enough to require re-grassing of the paddock after each winter. This would suggest that the level of soil armour was minimal, perhaps reflecting the relatively high grazing pressure imposed and the relatively wet winters experienced at SDH. Full cultivation during the establishment of young pasture would also have reduced soil strength and contributed to the soil damage observed following winter grazing.

4. Novel crop-based wintering approaches

In this section we outline a programme of work which has observed sheep, beef and deer farmer use of multi-species, multi-graze cropping options to help improve animal feeding outcomes while reducing potential environmental damage.

Six farmers in Otago and Southland volunteered to participate in a programme of recording their wintering practices to develop case studies which could inform others to help improve environmental and animal welfare outcomes. The programme's focus was on the integration of multi-species, multi-graze cropping options. One farm also used hay bale grazing for cattle, using a similar approach to that outlined in Section 3.3. Livestock used included sheep, cattle and deer. Farmers used feed budgeting to allocate feed to livestock classes, based on targeted performance requirements. This included maintenance feeding for mixed age ewes, liveweight gain targets of 100 g d^{-1} for weaner deer, and 0.3-0.5 kg liveweight gain for rising-3-year-old pregnant heifers.

Crop yield and crop nutrient concentration data were collected by the research team during July each year as a general indicator of the types of yield and feed quality that may be expected by farmers. The next available area allocated for grazing at the time of collection, and the area grazed within the past 10 days, were harvested to provide indicators of yield on-offer and residual yield after grazing. Samples for nutrient determination were analysed using commercial laboratory procedures (Hill Laboratories). This study did not attempt to provide an in-depth analysis of crop agronomic practices, but rather sought to detail on-farm processes and outcomes from the application of alternative wintering practices. Information on management practices, grazing days, and in some cases animal performance was recorded by the farmer. We used a discussion-group approach to explore motivations, expectations, practices, and outcomes over a three-year period from 2021-2024.

The information presented here provides a summary of results of crop yields and nutrient concentrations measured and reports the farmers' self-collected data and observations. We use a case study approach to highlight the range of uses and experiences which occurred at the individual farm level, as well as providing some collective experiences. Observations by farmers are also supported by science from the literature where possible. The information provided here gives an insight into the types of issues and variability that are regularly encountered by farmers in their attempts to quantify and incorporate new technologies and techniques, rather than providing conclusive scientific evidence of the application of these practices. Such scientific evidence would need much greater precision and additional structured experimental design.

4.1 Forage yield and feed quality

A range of forage options was used by the farmers over the 3-year period (Table 4.1). The winter yields of these mixtures were quite varied, ranging from approximately 6 to 10 t DM ha^{-1}. Autumn-saved pasture yields will range from 2 to 3.5 t DM ha^{-1} while traditional brassica crops range from 8 to 15 t DM ha^{-1}. All these mixtures also have multi-grazing characteristics and so were used periodically in late summer and autumn before winter grazing. These mixtures also have components (predominantly grasses) which will regrow during the spring, providing further grazing and ground cover at that time.

Table 4.1: The range of multi-species/multi-graze forage crops used in farmer case studies in southern New Zealand.

Case Studies	Forage mixtures	Animal	Winter yield (kg DM ha^{-1})[1]
1	Kale, Turnip, Swedes, Italian ryegrass, Plantain, Phacelia	Sheep	7,100
2	Kale, Turnip, Italian ryegrass, Oats, Phacelia, Balansa clover, peas, Faba beans[2]	Cattle	8,400
3	Kale, Italian ryegrass, Plantain, Faba beans, Peas, Phacelia, Crimson clover, Persian clover[3]	Sheep	9,700
4	Raphnobrassica, Swede, Leafy Turnip, Italian ryegrass, Ryecorn, Plantain	Sheep	6,100
5	Raphnobrassica, Italian ryegrass, Prairie grass, Plantain, white clover, red clover	Deer	nd

[1] Yield measured to ground level in the next available grazing area within the paddock taken in July

[2] This mix also included Quinoa, Crimson clover, Lentils, Buckwheat, Lupins, Common vetch, Sunflower and Millet. These components did not contribute significantly to winter yield.

[3] This mix also included Vetch, Buckwheat, and Sunflower. These components did not contribute significantly to winter yield.

Feed quality (Table 4.2) was another parameter that was measured. Samples collected for yield were oven dried at 60ºC and sent for analysis using commercial laboratory practices

(Hill Laboratories). Multi-species mixtures provided a more balanced nutrition for animals, resulting in the mitigation of requirements to transition-feed animals onto the forage crop.

Table 4.2: Feed quality characteristics of a traditional brassica (Turnip bulb) and multi-species forage mixture. Values with differing letters within rows are significantly different ($P < 0.05$).

	Turnip bulb	Multi-species mixtures	Least significant difference
Energy (MJME kg^{-1} DM)	13.0 a	11.3 b	1.03
Protein (g 100 g^{-1} DM)	9.2 b	16.8 a	3.5
NDF (g 100 g^{-1} DM)	17.6 b	33.6 a	24.1
Soluble sugars (g 100 g^{-1} DM)	47.2 a	20.7 b	3.9
Calcium (g 100 g^{-1} DM)	0.44 b	1.12 a	0.39
Phosphorus (g 100 g^{-1} DM)	0.35 a	0.33 b	0.06
Magnesium (g 100 g^{-1} DM)	0.11 b	0.17 a	0.04
Cobalt (mg kg^{-1} DM)	0.10 a	0.19 a	0.37
Copper (mg kg^{-1} DM)	1.5 b	5.0 a	1.5
Selenium (mg kg^{-1} DM)	0.02 a	0.10 a	0.08
Zinc (mg kg^{-1} DM)	40.0 a	28.2 b	9.3

4.2 Farmer case studies

Information gathered by farmers and a photographic record of the practices were compiled to provide insight and guidance for future practice. Four farms and five examples are provided here as typical of the type of results that were produced.

4.2.1 Case Study Farm 1:

This farm employed an extensive multi-species mixture, aimed at wintering rising-2-year-old beef cattle of approximately 300-400 kg liveweight, with an expectation that some spring grazing may be available.

Saturated soils were disturbed by cattle grazing to approximately 15 cm depth. There was no grazable regrowth though a small amount of groundcover was present in some areas (Plate 4.1c). Plate 4.2 provides a representation of the same crop when utilised by sheep in similar conditions. The paddocks represented in Plates 4.1 and 4.2 were within 100 m of each other. The opportunity for the multi-graze species to recover in Plate 4.2 will be much greater than in Plate 4.1 due to the lower soil disturbance and the remnant forage cover. Rainfall during this time was approximately 85 mm greater than the long-term average of approximately 280 mm.


a)


b)


c)

Plate 4.1: A mixed species crop before (a), directly after grazing (b) by rising-2-year-old cattle of approximately 300-400kg and in November (c) after 3 months of recovery. Rainfall from 1 May until grazing on 5 July totalled approximately 366 mm.

Plate 4.2: A mixed species crop after grazing by sheep of approximately 70 kg liveweight. Rainfall from 1 May until grazing on 5 July totalled approximately 366 mm.

4.2.2 Case study farm 2:

This farm used a multi-species, multi-graze approach with forages being used in summer, autumn winter and spring. The bulk of the forage was utilised in winter with mixed age ewes of approximately 65-70 kg live weight with feed allocated to achieve feeding requirements for mid-late pregnancy. The establishment of multi-species crop allowed different species to establish in areas of the paddock which the brassica component did not (Plate 4.3a). This benefited farmers by providing a more consistent feed supply across the paddock, and protecting the soil, often on steeper and lower fertility parts of the paddock. Rainfall of 260 mm during this time was similar to the long-term average of 270 mm.

During grazing the range of species evident (Plate 4.3b) shows the residual of grasses and plantain. When grazing was complete (Plate 4.3c) the residual herbage mass is depleted (measured at approximately 1400 kg DM ha^{-1}) though still provides some protection for the soil and a residual stubble for regrowth. This paddock recovered to provide feed for late-lambing twin-bearing ewes stocked at 8 ha^{-1} from mid-September until December, with an estimated feed consumption of 2,310 kg DM ha^{-1}.


a)


b)


c)

Plate 4.3: A multi-species forage mixture before (a), during (b) and after (c) grazing by sheep on 6 July 2023. Estimated rainfall from 1 May to the grazing date of 6 July was 260 mm.

Demonstration of multiple grazing benefits:

This case study also provided grazing data to demonstrate the impacts of a change in timing of feed supply compared to a traditional winter crop when using a multi-graze Raphnobrassica, annual and perennial legumes, and Italian ryegrass mixture.

First graze - finishing lambs late January at 50 ha^{-1} for 10 days, liveweight 30 kg, growth rate 300 g d^{-1}, intake 2 kg DM $head^{-1}$ d^{-1} = 1 T DM ha^{-1} eaten.

Second graze - during April with ewes at 50 ha^{-1} for 42 days, liveweight 68 kg, growing at 100 g d^{-1}, intake 1.7 kg DM $head^{-1}$ d^{-1} = 3.57 T DM ha^{-1}.

Note: At the same time pasture area was released to either accumulate feed for winter or improve the feeding of other animals. This is equivalent to an area of 4.25 ha of pasture for every 1 ha of crop grazed.

Winter grazing was programmed for late winter, anticipated at 500 ewes ha^{-1} for 3 days at an intake of 2.2 kg DM $head^{-1}$ d^{-1} = 3.3 T DM ha^{-1}. Total feed used was 7.87 T DM ha^{-1}. Estimated yield of winter crop to replace this is 7.87/0.85 (expected utilisation) = 9.25 t DM ha^{-1}.

Spring grazing – estimated to provide grazing for 8 twin-bearing ewes ha^{-1} from September to December, approximately 2.3 T DM ha^{-1}.

4.2.3 Case Study Farm 3:

A multi-species mixture including Raphnobrassica, turnips and grasses, cereals and plantain (Plate 4.4a) was grazing by mixed age ewes of approximately 65 kg liveweight, allocated to provide a diet to meet feed requirements during mid to late pregnancy. Estimated rainfall was similar to the long-term rainfall during this period of approximately 257 mm.


a)


b)


c)


d)

Plate 4.4: A multi-species forage mixture before (a) and after grazing (b) by sheep on 5 July 2023, and after 20 days of regrowth (c) and in November (d). Rainfall from 1 May until grazing on 5 July was estimated to be approximately 260 mm.

Once grazed a significant cover of the grasses remained (Plate 4.4b). This enabled the rapid recovery of the sward (Plate 4.4c). This recovery growth was not measured. Subsequent grazing during the spring was by hoggets and farmer grazing records estimated that 1,900 kg DM/ha was consumed between August and November (Plate 4.4d).

4.2.4 Case Study Farm 4:

This case study farm provided two examples. The first was weaner deer on a turnip and Italian ryegrass forage crop, and the second used bale grazing on old pasture to feed pregnant heifers.

The turnip/Italian ryegrass crop was grazed during winter to achieve winter liveweight gain targets for weaner growth. Four hundred weaners of approximately 85 kg liveweight were stocked on 13 ha. A total of 5.9 t DM ha^{-1} was harvested, winter liveweight gain of 10 kg $head^{-1}$ was achieved and feed lasted 65 days. This compared with a traditional swede crop which yielded 9.5 t DM ha^{-1} and provided feed for 100 days.

Plate 4.5 compares the soil conditions of the turnip/Italian ryegrass mixture with a traditional swede crop. The Italian ryegrass provided approximately 1.9 t DM ha^{-1} of the 5.9 t DM ha^{-1} yield (Plate 4.5a). Some damage was evident after grazing (Plate 4.5b), while Italian ryegrass regrowth continued throughout winter and spring. The subsequent ground cover of the Italian ryegrass (Plate 4.5c) was too low, and a permanent pasture was sown in late spring.


a)


b)

 c)

 d)

Plate 4.5: Examples of a turnip/Italian ryegrass forage mixture fed to weaner deer on 8 June 2021 depicting conditions before grazing (a), after grazing (b) and on November 8 2021 (c). Rainfall from 1 May until the grazing date of 8 June was estimated to be 110 mm. Also included is a post-grazing representation of traditional swede crop (d).

Bale grazing was done on a pasture where hay was made on 18 January 2023 and the pasture was left to recover until grazing, with 95 rising-3-year-old pregnant heifers of approximately 435 kg, over a 90-day period from 31 May until 30 August 2023. Photographs were taken during sampling on 1 August 2023. Rainfall from 1 May until 1 August was estimated to be approximately 420 mm, compared with the long-term average of 297 mm over that time.

The old pasture helped keep the soil together during bale grazing (Plate 4.6). The amount of feed on offer was measured to be approximately 10,550 kg DM ha^{-1}. Cattle were shifted once every three days and were stocked at a rate of 250 ha^{-1} within each break. While individual hoof damage penetrated to approximately 15-20 cm, the photographs show the intact groundcover over the area. The area in Plate 4.6a slopes downhill from right to left with little sign of sediment movement downslope into the next grazing area.


a)


b)


c)

Plate 4.6: Examples of bale grazing of 435 kg rising-3-year-old pregnant heifers on 1 August 2023 depicting conditions during grazing (a), after grazing (b) and after 10 days of regrowth (c). Rainfall from 1 May until the grazing date of 1 August was estimated to be 420 mm, approximately 120 mm greater than the long-term average rainfall.

4.3 Farmer observations of multi-species, multi-graze winter feeding options and practices

At the beginning of the project farmers were asked about their reasons for changing practices and the lessons they had learnt to date. This process was repeated at the end of the project to gain information about changes in practice and practical outcomes when implementing winter practices using non-traditional cropping approaches.

Several advantages of the use of multi-species, multi-graze mixtures were identified by the farmers. Discussion here highlights the observations made by the farmers and provides evidence from the literature which supports their observations. In some cases, these observations go unsupported, indicating a need for further research to clarify these observations.

4.3.1 People considerations

Looking after people was a primary motivation for changing winter practices. Benefits came both from the management methods and the actual wintering practices.

Shifting to 3-4 day grazing periods enabled a reduction in workload and time for further planning. This also enabled a reduction in weekend work requirements. Moving away from traditional crops also reduced the amount of mud (see Plate 4.7) and so reduced the physical effort required when erecting temporary fences. Greater peace of mind was also generated as farmers reported being more confident that livestock were well fed and that sediment losses were less evident. Using a break grazing system of block, rather than strip, grazing with 3–4-day grazing periods was noted to reduce stock movement and soil disturbance. Lower stock losses were also listed as having a positive effect on morale.

Plate 4.7: Photos of sheep grazing a multi-species mixture. Rainfall since 1 May was 260 mm. Note the lack of mud both on the sheep and on the ground.

4.3.2 Animal welfare considerations

Eight animal-related attributes were identified during the project. These included feed supply, internal parasites, mud, both in the diet and underfoot, foetal loss, liveweight gain, dietary transition and comfort. Altering feed supply may have both positive and negative effects on animal welfare. The flexibility of feed supply was used to offset the impacts of drought in two of the case study farms, providing feed during summer and autumn when pasture supply was limited. However, this utilisation of feed at non-traditional times can also compromise feed availability during winter. This may become an animal welfare issue if livestock cannot be fed adequately during winter.

The exposure to internal parasites is an ever-present challenge for farmed livestock. Faecal egg counting of lambs in case study 2 was used to extend the use of anthelmintic drenching from 4-week to 6-week intervals while grazing the multi-species forages. This may have more than one reason though does indicate a lower burden of internal parasites, and thus a lower stress on the animal during this time. Forage species and sward structure can both play a role in internal parasite control (Bricarello et al 2023). Plant secondary compounds such as tannins are known to reduce the impacts of internal parasites (Min and Hart 2003). Some of the species within these mixtures, such as Faba beans (Moats et al 2018) and Plantain (Stewart 1996), contain tannins. Plant structure also influences the presence of internal parasite larvae in the grazing horizon, with more upright plants reducing potential intake by the grazing animal (Bricarello et al. 2023) The extension of drenching intervals may also translate into a reduced chemical footprint for these farms.

Mud in the diet has the potential to reduce feed intake by between 15 and 30% (NRC 1981) as well as load the diet with potential pathogens. Thus, it has a significant impact on the welfare of the animal when attempting to meet its dietary requirements during winter. Further to this, being confined onto muddy locations increases animal maintenance requirements, particularly of cattle, by up to 40% (Nickles et al. 2022), and the total intake requirement in late pregnancy by 27%. This is because of the greater heat loss under these conditions. Continual contact with mud can also increase the risk of foot problems due to bacterial infections such as footrot (Mulvaney 2013) and fusobacteriosis (Deer Industry NZ 2015). Finally, when offered choice, cattle prefer to rest on pasture rather than mud and increasing depth of mud reduces lying time (Dickson et al. 2022). Observations by the farmers indicated that a residual of dead material from some species such as ryecorn and forage oats remained un-eaten, providing a barrier between the animals and the soil. This may provide the opportunity for animals to increase lying times due to the reduction in mud. Thus, the reduction in the presence of mud has the potential to provide a range of animal welfare and production benefits, including increased lying time, decreased risk of disease, better nutrition and decreased maintenance energy use.

A reduction in late pregnancy foetal loss in cattle, in comparison with historic records, was reported in one case study. The causes of late pregnancy foetal loss can be attributed to a wide range of potential causes, including campylobacter, leptospirosis and listeriosis (Concha-Bermejillo and Romano 2021). Many of these potential causes can reside in soil and may present a greater danger to cattle when wintered on traditional crops than options with a decreased soil intake.

The farmer in Case study 4 monitored liveweight gain as part of meeting livestock performance targets. Individual liveweights of the whole mobs were taken at the beginning of the winter feeding period and again at the end. Results were compared to historical data. Positive effects of liveweight change were measured in both weaner deer and rising-3-year-old heifers during winter. In one instance the liveweight gain of pregnant 3-year-old heifers using a bale-grazing system of 0.6 kg d^{-1} over a 90-day period was recorded. Historical liveweight gain records on traditional crops was approximately 0.4 kg d^{-1} over similar periods. In the second case study the liveweight gain of weaner deer on winter crops was traditionally 100 g d^{-1} over 100 days while those grazing an Italian ryegrass/turnip mixture grew at approximately 150 g d^{-1} over a 65-day period. These differences may be due to several factors. In the case of the cattle, greater exposure to mud may be a major factor as soil ingestion reduces intake (NRC 1981) and residing in mud increases maintenance feed requirements (Nickles et al. 2022). The nutritional density of the diet can also influence liveweight gain and this may be a factor in higher liveweight gain in the weaner deer. Stevens et al. (1994) reported liveweight gain in hoggets grazing a mixed swede/Italian ryegrass forage during winter compared with a traditional swede crop of 132 and 40 g d^{-1} respectively, with associated increases in feed intake and dietary protein intake.

Dietary transitions occur when an animal shifts from one feed source to another. It is particularly important when transitioning from pastures low in soluble carbohydrates and high in fibre onto winter forages such as swedes, turnips and fodder beet which are high in soluble sugars and low in dietary fibre (Nicol et al. 2003). The use of multi-species mixtures provided diets that had moderate soluble sugars (WSC content of 20.7%) and dietary fibre (NDF content of 33.6%) due to the range of plant types included. This approach provided a diet that required little dietary transition with no observed animal health issues that are commonly associated with transitioning to traditional winter crops.

4.3.3 Environmental responses

Grazing of the multi-species mixtures resulted in a residual herbage mass of between 1500 and 1700 kg DM ha^{-1} post-grazing, measured over five farms. This provided ground cover, which is important for maintaining surface tensile strength, interception of rainfall and slowing surface water flow speed (Silburn et al. 2011). Maintaining this ground cover helps reduce surface erosion significantly (Silburn et al. 2011). Grazing of traditional winter crops usually results in complete loss of ground cover. An exception to this result was observed with cattle grazing on saturated soils. In case study 1 Rising 2-year-old cattle of approximately 300-400 kg LW were grazed on a multi-species mixture. Rainfall during the period 1 June 2023 to 31 July 2023 was 275 mm, resulting in saturated soils. Under these soil conditions cattle broke through the surface, removing ground cover and damaging soil structure. Soil saturation results in a significant reduction in soil strength leading to potential damage by heavy animals (Laurenson and Houlbrooke 2016).

Plate 4.8: Soil damage by 1-year-old cattle of 300 – 400 kg grazing a multi-species mixture after 275 mm of rainfall from 1 June to 31 July 2023.

The use of multi-graze mixtures has both potential positive and negative aspects for nitrogen deposition and recovery. After grazing during winter, the regrowth from the forage mixtures contributed between 2,500 and 3,800 kg DM ha^{-1} to spring feed requirements, had a nitrogen concentration of 3.4%, and captured between 85 and 129 kg N ha^{-1}. If the multi-grazed forages were utilised during the autumn this deposits nitrogen onto the soil that may either be used by continued growth of the forage mixture or be available for leaching. The impacts of autumn grazing of these multi-graze, multispecies mixtures on potential nitrogen leaching are yet to be fully explored.

Four case studies included plantain (Plantago lanceolata) in the forage mixtures. Plantain is proven to reduce nitrate leaching when included in pasture mixtures (Carlton et al. 2019) with greater reductions as the proportion of plantain in the mixture increases (Nyugen et al. 2022). The impact of inclusion of plantain in these mixtures may aid in the reduction of nitrate leaching.

Reducing chemical use was one of the stated aims of the farmers involved in this study. The use of multi-species mixtures restricts the type of chemicals that may be used for weed control. Most farmers chose to use a single spray defoliant process, often with glyphosate, followed by forage sowing approximately 24 hours later. Soil temperatures were monitored on case study 3 and sowing only occurred when soil temperatures were above 15ºC, resulting in rapid germination. When combined with the large number of plant species used, the immediate weed burden was minimal, reducing the need for further herbicide treatments. Lower weed infestation is acknowledged as an outcome of using mixed plant species in cropping systems (Malezieux et al. 2009).

One exception to this was infestation with Californian thistle (*Cirsium arvense*). This weed was relatively unaffected by the establishment defoliation and went on to become a significant weed in 4 of the case study farms. Control techniques such as mowing and weed wiping were used. Weed wiper use involves low amounts of chemicals and targets only the thistles, keeping chemical use low. Broadacre spraying may be required in the future for thistle control and may result in restoring previous chemical use.

Combining several forage plants into a single mixture may also reduce the population of pest insects (Malezieux et al. 2009). Farmer observations supported this concept, with no pesticide being used on any of the multi-species mixtures. Generally, farmers noted less severe impacts of pest presence, potentially due to the range of plant species present, limiting the overall impact of an attack to a single component among many.

4.3.4 Farm systems responses

Several opportunities arose from using multi-species mixtures. These included lower cost of imported feed when faced with summer/autumn drought. Reduced feed costs were also noted as no extra feed was required when compared to previous requirements when transitioning animals onto crops such as kale and fodder beet.

Establishment costs were reduced by the reduction in use of chemicals, though seed cost may also increase depending on the number and sowing rate of the range of species within a mixture. Often yields were lower than traditional winter crops, leading to the potential for a greater area to be sown in multi-species mixtures. This then had the potential to negate other cost savings. Often the overall cost of cropping was unaffected by changing practice.

Farmers often cited the inclusion of a range of legumes (e.g. faba beans (*Vicia fava*), peas (*Pisum sativum*), vetch (*Vicia sativa*) and clovers (*Trifolium* spp.)) to fix nitrogen and therefore reduce costs associated with N fertiliser use. The magnitude of this affect is not well documented. Faba beans, for example, may fix approximately 65 kg N T^{-1} DM grown, with 40% of this remaining in the roots (Rochester et al. 1998). Transfer of this to adjacent crops is most likely to occur after harvest or plant death (Schwenke et al. 1998), delivering N during autumn and early winter. Some N may be transferred from legumes to adjacent crops, though this depends on the yield of the legume, and is yet to be measured for these mixtures.

Altering the profile of feed supply is a significant factor that needs managing within the farm system. Farmers can utilise a range of stock classes to harvest the production of multi-species, multi-graze forages over an extended period. Often the mixtures need to be grazed during summer or autumn before the mixture components die off and lose feeding value. Some of the mixture components also maintain greatest productivity (e.g. Italian ryegrass (Lolium multiflorum), rape and Raphnobrassica (Raphanus x Brassica)) with some grazing (e.g. Dumbleton et al. 2022). A dry summer resulted in one farm utilising the Raphnobrassica-based multispecies mixture during summer and autumn, rather than winter, and recorded 11,400 kg DM ha^{-1} on offer over three harvests. Pasture, which had recovered during the autumn, was used to substitute the lack of crop availability during mid-winter. Regrowth which occurred from July to late October (2022) averaged 3,100 kg DM ha^{-1} (range 2,500 to 3,800 kg DM ha^{-1}) when recorded on four of the farms.

Feed supply in spring is particularly important for grazing systems. Estimates of spring grazing attained from multi species crops range from no grazing if winter grazing disrupts soil badly to up to 3,800 kg DM ha^{-1}. Typically, the amount of forage recovery was greater and more consistent after sheep grazing, than deer or cattle grazing. The impact of sheep treading is much less than deer or cattle due to the lower liveweight of sheep. Spring stocking rates of between 0.5 and 0.8 of that of pasture were recorded after sheep grazing.

Low winter yields are often a feature of multi-species mixtures. This is often because components of the mixture die and senesce at the end of summer and are therefore no longer available for grazing during winter. Farmers have adapted to this by shifting to a multi-graze approach. This, however, may leave a deficit in winter feed, unless the pasture that was not utilised when the multi-graze mixture was eaten is stockpiled for winter use. For example, grazing in April by ewes was estimated to remove 3.6 T DM ha^{-1} in one case study. At that time this grazing released an area of pasture equivalent to 4.25 times the crop area. This needs to be recognised and set aside for winter feeding. The traditional winter crop continues to accumulate feed throughout the growing season with no further management decisions to make.

The practice of late sowing, coupled with the regrowth during spring, results in less bare soil exposure both before sowing and after the crop is utilised in winter. Areas used by traditional winter crops may be out from pasture for 450 days, with up to 90-120 days of bare land during spring. Late sowing of the mixtures means that loss of grazing time on pasture during spring is reduced by 30-60 days. Grazing time is also regained after winter when pasture species such as Italian ryegrass and plantain re-grow. The longevity of the Italian ryegrass is variable. If winter damage is significant then sowing to permanent pasture may be required later in spring. However, many of the sheep grazing case studies have extended the life of the Italian ryegrass through a second winter before sowing back to pasture.

The area used for multi-species cropping can be greater than that required for traditional winter crops. However, because the area has multiple uses and can be grazed in spring, the average area is not affected as greatly. For example, with a time out of pasture of 450 days, this spreads effective loss of area over 2 years, having the impact of increasing a traditional cropping area of 5% of the total farm to 8.5%. This under-accounting is common. The area required to replace this nominal 5% was 10% in one case study, creating a difference of only 1.5% when the time out of pasture was considered.

Balancing these factors associated with multi-grazing options leads to increasing complexity. Traditional winter crops are simple to enact and execute. They are established, monitored for disease and weeds and then fed out into a specific feed deficit, often at relatively stable yields. Multi-species, multi-graze mixtures and all-grass wintering add a significant amount of complexity to decision-making. This is added to already complex systems, where reducing complexity is often strived for. Thus, other benefits must be great enough for farmers to implement this system. Techniques such as 3-4-day shifting can ease pressure on labour and provide time for planning.

Further to this, the needed level of management precision is increased to ensure feed flows are managed to fill the winter feed deficit. Planning is required during autumn if a multi-graze crop is utilised then, to ensure spared pasture is set aside to meet winter feed demands. This also requires a level of discipline in feed allocation at that time, avoiding the trap of using the spared feed to achieve other goals such as lamb finishing.

5. Common themes

Some planning and management factors that likely contributed to the outcomes (both positive and negative) documented in sections 3 and 4 are listed below. These are provided as a list of considerations that should be addressed to maximise the likelihood of a successful wintering outcome if moving from an intensive winter forage crop grazing system to some "alternative" approach, such as pasture-based or lower intensity forage cropping systems.

5.1 Planning and management considerations

Planning factors:

- ***Well-drained soil types*** are preferred. The hay bale grazing study described in section 3.3 indicated that reduced soil damage and rapid pasture recovery occurred for this well-drained soil. In contrast, greater soil damage and much slower pasture recovery was observed for the poorly-drained soil studied at Telford, south Otago.

- ***Structurally-resilient soil types*** are also preferred. Experiences at the Telford study site (section 3.2) indicated that soil treading damage and aggregate breakdown occurred to a large extent in both treatments, particularly during the wet conditions experienced in winter 2021. This aggregate breakdown leads to reduced soil infiltration and consequent ponding or surface runoff of water.

- ***Grazing pressure/intensity.*** Our findings suggest that outcomes are heavily influenced by imposed grazing pressures. For cattle, we suggest an equivalent space allowance of at least 16 m^2 cow^{-1} day^{-1} as a feasible planning criterion that could result in satisfactory outcomes for soil condition and spring pasture recovery.

- ***Lower rainfall environments.*** The favourable outcomes reported for the studies reviewed in this report have been undertaken in locations where winter rainfalls were 200 mm or less. The performances of "alternative" wintering approaches in wetter environments have not been quantitatively documented.

- ***Established pastures*** are preferred because of the greater soil strength provided by a mature rooting system and litter thatch layer.

- ***Multi-species mixtures*** for wintering purposes require a range of functional traits to achieve their aims. These include:

  * A high yielding brassica for bulk energy.
  * A regrowing brassica if multiple grazing.
  * One or two pasture grasses with winter activity and feed quality.
  * One or two cereals for bulk, fibre and bedding.
  * Some legumes for feed quality and nitrogen fixation, potentially annual and perennial.
  * Other species may be included for environmental reasons.

Management factors:

- If a new pasture or multi-species forage crop is intended for over-wintering livestock, ***reduced or no-till establishment procedures*** will help maintain some degree of soil strength and resistance to hoof treading pressures.

- The ***provision of hay*** as a source of forage for increased rumination and litter for cows to rest upon will help settle cows. Other residues such as straw could also be provided as loafing surfaces, as needed (most probably determined by weather conditions).

- ***Diet*** selection has an important influence on N excretion and consequent urinary N returns to soil. This is evident from calculations of N partitioning into dung and urine for cows fed low (e.g. hay + pasture or fodder beet) or moderately high (e.g. kale) N diets. Coupled with reduced grazing intensities, this reduced urinary N excretion results in much lower returns of urinary N return per unit area.

- Use of ***multi-day breaks*** helps cows to settle more, reduce walking and decrease instantaneous stocking rate than in intensive crop (or pasture) wintering systems where new breaks are offered daily.

- ***Tactical responses*** to adverse weather will help minimise the severity of soil and pasture damage. Moving cattle on to a next break when these events occur, then coming back to the unfinished break once soil conditions allow (dry out), will help achieve feed utilisation targets and protect soils, pastures and animals. Where available, moving cattle onto a standoff pad is another temporary option that can be considered for such events.

5.2 Grazing pressure, diet and landscape vulnerability are three key factors that influence wintering outcomes

Measurements and observations from the above studies has added to a body of knowledge that documents the effects of wintering systems on soil and water quality and vegetation condition. Current knowledge suggests that some key factors appear to influence these outcomes, namely grazing pressure, diet, landscape vulnerability and tactical management decisions. In this section we focus on the first three of these factors, explaining why we think they are important planning deliberations and how they could be more easily considered by practitioners and policy makers.

5.2.1 Grazing pressure

Maintaining good soil quality in terms of infiltration and aggregate strength is helpful for ensuring that water can infiltrate and soil particles are less easily dislodged in any surface runoff that may occur (Le Bissonnais, 2016). Maintaining a viable plant in the grazed winter paddock will help to reduce the disruptive impact of rainfall droplet energy on soil aggregates (thus reducing soil erosion risk) and will act as a sink for N as vegetation recovers and grows as warmer conditions arrive in late winter/early spring (thus reducing N leaching risk). There is also an obvious productive benefit if recovering vegetation can re-grow and add to spring feed supplies, as mentioned in the above sections.

Some effects of grazing pressure on wintering outcomes can be discerned from the body of research presented in Table 5.1. These datasets are generally arranged in descending order of grazing intensity, as estimated and defined using the grazing metrics of RSU $m^{-2}d^{-1}$ and kg liveweight (lvwt.) $m^{-2}d^{-1}$. The right-hand Table column documents some of the key findings from each study treatment. Taken together, three general patterns can be discerned:

1. The high-yielding cattle-grazed winter forage crops represent the most intensive form of wintering, where grazing pressures equalled or exceeded 0.8 RSU $m^{-2}d^{-1}$ or 45 kg lvwt. $m^{-2}d^{-1}$. These grazing events resulted in bare soil that remained so until a following pasture or crop was established. Relatively high rates of N leaching or soil treading damage were notable consequences of this relatively intensive land use. Visual observations from studies at the Southern Dairy Hub indicate that similar outcomes resulted when winter pastures were intensively grazed by cattle (as described in section 3.4).

2. The pasture-based wintering approaches at the Glenlapa and Telford study sites can be ranked as moderately intensive practices where imposed grazing pressures were approximately 0.5 RSU $m^{-2}d^{-1}$ or 30 kg lvwt. $m^{-2}d^{-1}$. Soil and vegetation responses to these grazing pressures appeared to depend on soil vulnerability factors:

    - at the well-drained Glenlapa site where hay was provided, soil and pasture recovered reasonably quickly in spring, with paddocks coming back into the second round (October) of grazing by the milking herd.

    - at the poorly-drained Telford site, soil and pasture damage was slow to recover in spring, resulting in the soil remaining bare for approx. 2-3 months with an associated risk of erosion.

3. The sheep winter grazing of crops reported by Ghimire et al (2024) resulted in relatively low yields of sediment and P in surface runoff, even in 2021 when a grazing pressure of 0.69 RSU $m^{-2}d^{-1}$ (38 kg lvwt. $m^{-2}d^{-1}$) was imposed as the 8.2 T DM ha^{-1} crop of kale was fed off. Although soil remained bare until a following pasture or crop was established, soil damage was light and infiltration rates exceeded rainfall intensities. We could therefore infer from this study, supported by findings from Round-Turner (1974), that soil damage due to treading by sheep in winter represents a lower level of risk to soil quality than from cattle, and consequently a lower risk of soil loss.

Table 5.1: A summary of grazing pressures imposed at study sites in southern New Zealand where the impacts of winter grazing on soil and water quality and vegetation conditions have been reported or monitored.

Site	**Stock type**	**Forage type**	**Yield**	**Grazing pressure**		**Key findings/observations**
			T DM ha^{-1}	RSU $m^{-2}d^{-1}$	kg lvwt. $m^{-2}d^{-1}$	
SDH[1]	Dairy cow	Fodder beet	18.3	1.1	62	Bare soil, surface damage evident; modest N leaching
Glenlapa[2]	Dairy cow	Kale	16.4	1.0	56	Bare soil, high N leaching
Telford[2,3]	Dairy cow	Kale	12.5	0.94	53	Bare soil, poor soil quality
SDH[1]	Dairy cow	Kale	13.4	0.9	51	Bare soil, surface damage evident; high N leaching
Telford[2,3]	Dairy cow	Swedes	10.7	0.8	45	Bare soil, poor soil quality
Telford[2,3]	Dairy cow	Pasture	4.4	0.55	31	Soil and pasture recovery slow until mid-spring
Glenlapa[2]	Dairy cow	Pasture	4.5	0.5	28	Good soil and pasture recovery; low N leaching
Waitahuna[4]	Sheep	Swedes	10.2	0.44	24	Bare soil, but infiltration rates greater than rainfall, resulting in minimal surface runoff
Waitahuna[4]	Sheep	Kale	8.2	0.69	38	Bare soil, but infiltration rates greater than rainfall, resulting in minimal surface runoff
Waitahuna[4]	Sheep	Kale	5	0.33	18	Bare soil, but infiltration rates greater than rainfall, resulting in minimal surface runoff

[1]Smith & Monaghan (2020) and unpublished results; [2]Monaghan et al. (2024); [3]Simon et al. (2024); [4]Ghimire et al. (2024).

5.2.2 Dietary effects on urinary N returns during winter grazing

Notable differences in dietary N intakes were expected for the studies documented in Table 5.1. These reflected the reasonably wide range in feed protein contents of the different forages that were consumed by the animals, which ranged from 8% for hay fed at the Glenlapa site to 20% for the well-fertilised kale crops fed to cows at SDH. Table 5.2 documents calculations of animal N intakes for the different treatments reported in Table 5.1 where feed N intakes were measured. These results were used to calculate rates of N excretion via dung and urine, which are also shown in Table 5.2. The partitioning of N intake into dung and urine was determined using the NZ Greenhouse Gas Inventory Framework calculation method (MPI, 2024) and assuming that the N retained in the liveweight gain of a pregnant cow is the equivalent of 0.01 g N cow^{-1} day^{-1}. As expected, diets with relatively high levels of crude protein are predicted to result in higher proportions of N excretion in the form of urinary N. This is most evident for the kale + baleage diet of cows in the SDH study where a crude protein content of 17.6% was predicted to result in urinary excretion of 0.27 kg N cow^{-1} day^{-1}, representing 71% of total N excretion. In contrast, the pasture + hay diet of cows in the Glenlapa study had a relatively low crude protein content (8.4%), resulting in a predicted urinary excretion of 0.0.08 kg N cow^{-1} day^{-1}, representing only 40% of total N excretion.

An additional consideration that is needed when determining excretal N returns to the different treatments in Table 5.2 is the need to account for the different grazing pressures of each, recognising that high-yielding forages that are offered at relatively high daily allocations per animal will result in high stocking densities and thus high rates of excretal N returns per unit area. The last 2 rows of Table 5.2 accordingly provide estimates of these returns and clearly show how diet and grazing pressures are important determinants of the amounts of urinary N deposited during winter grazing (urinary N is considered to be the form of excretal N that is most at risk of loss via drainage or surface runoff). Particularly low rates of urinary N returns are evident for the pasture-based wintering treatments at the Telford and Glenlapa study sites, reflecting the combined effects of modest or low dietary N contents and reduced grazing pressures. The per hectare estimates of urinary N returns during winter grazing are plotted against normalised (kg N per 100 mm of drainage) N leaching losses that were measured at these sites (Figure 5.1) to show the broad relationship between urinary N returns and N leaching risk. Whilst the relationship is confounded by the effect of different soil types between each study site[7], it suggests that information about dietary N intakes and grazing pressures can provide a reasonable approximation of N leaching risk for these wintering systems and be used to guide future winter planning decisions.

[7] The N leaching outcome for the Telford Pasture treatment in Figure 5.1 is also slightly confounded (increased) by some additional urinary N deposited during a late autumn grazing of this treatment in one of the three years of this study.

Table 5.2: Calculated N intakes and excretion for winter grazing treatments at the SDH, Telford and Glenlapa study sites.

Site:	SDH[1]		Telford[2,3]			Glenlapa[2]	
Wintering system:	Kale + baleage	Fodder beet + baleage	Kale + baleage	Swedes + baleage	Pasture + baleage	Kale	Pasture + hay
DM and N intakes & excretion, kg DM or N cow^{-1} d^{-1}							
DM intake	13.8	13	15.5	13.0	12.5	15.0	15.6
Dietary protein %	17.6	11.9	11.7	12.4	14.7	15.4	8.4
Dietary N intake	0.39	0.25	0.29	0.26	0.29	0.37	0.21
Dung N excretion	0.11	0.101	0.12	0.10	0.10	0.12	0.12
Urine N excretion	0.27	0.14	0.16	0.15	0.19	0.24	0.08
% of excretal N as urine	71	57	57	59	65	67	40
Stock density, cows m^{-2} d^{-1}	0.14	0.18	0.10	0.10	0.07	0.13	0.06
Excretal N returns, kg N ha^{-1} winter^{-1}							
N return in faeces	153	178	121	102	66	148	76
N return in urine	375	236	159	146	123	302	49

[1]Smith & Monaghan (2020) and unpublished results; [2]Monaghan et al. (2024); [3]Simon et al. (2024).

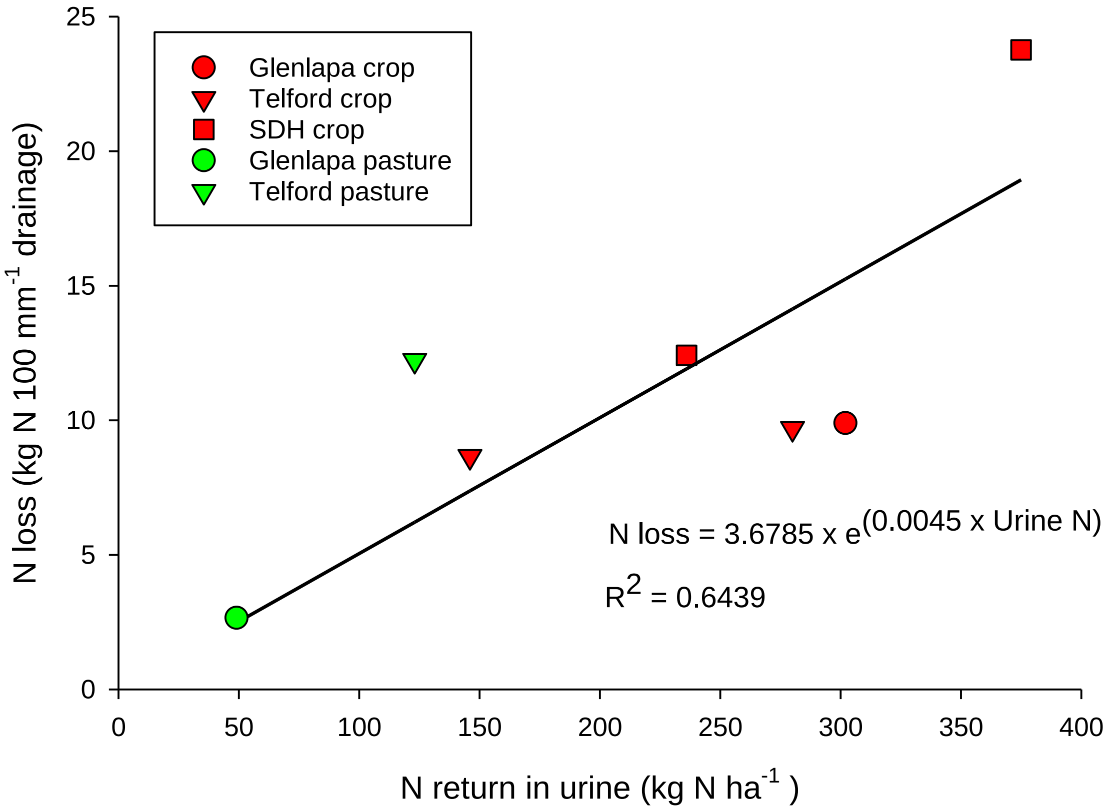

Figure 5.1: Relationship between estimated returns of urinary N during winter grazing and measured N leaching losses at the Glenlapa, Telford and SDH study sites. Losses expressed as amounts of N leached per 100 mm of drainage. Pasture-based wintering treatments shown as green symbols; crop-based wintering treatments shown in red.

5.2.3 Landscape vulnerability attributes

Farmer and scientist experiences with a range of wintering systems indicate that soil type and the amount of winter rainfall are likely to be important determinants of how much soil and pasture damage can be expected. Slope is an additional variable that contributes to the risk of soil erosion. We use the term "likely" to note that there are few studies where quantitative measurements of soil and pasture damage have been made within a winter grazing system and could be used to inform winter planning decisions. The considerations below are thus mostly based on inferential descriptions and experiences, recognising the need for more quantitative and field-based measurements of wintering outcomes.

Soil type. Observations and feedback from stakeholders commonly relay the importance of how soil attributes such as drainage status and structural resilience affect wintering outcomes. This is also evident in the few reported studies where soil and water responses have been measured within some winter grazing treatments (e.g. Monaghan et al. 2017). Some general patterns or observations that can be discerned are:

- Soils that have poor drainage are at greater risk of treading damage. This can result in soil pugging, reduced infiltration and increased amounts of surface runoff, particularly if relatively high grazing pressures are imposed. There is also greater risk of plant damage, which may reduce the ability of any recovering vegetation to take up N deposited at the time of winter grazing. These effects were apparent in studies undertaken at Telford, in both crop and pasture-based wintering treatments (Monaghan et al. 2017 & 2024). Soils categorised as having “Moderate” or “High” vulnerability to waterlogging could be considered as poorly drained in mapping approaches to define this risk.

- Soils that have low structural resilience are also more vulnerable to treading damage. This can result in the breakdown of soil aggregates and blockage of soil pores, with potentially similar consequences as discussed above. Soils categorised as having Structural Vulnerability Indices (Hewitt & Sheperd, 1997) greater than (tentatively) 0.65 could be considered as structurally vulnerable in mapping approaches to define this risk designation, albeit this assignation/threshold is entirely subjective.

- Of note are the positive responses noted for the hay bale wintering system that has been undertaken on the property of M. Anderson in south Otago. Whilst this location has the same poorly-drained and structurally vulnerable soil found at the Telford study site, reasonably favourable outcomes for soil condition and pasture cover have been observed and captured in drone imagery collected in early spring (Plate 5), perhaps reflecting the beneficial effects of introducing hay that provided some litter for cows to lie on.

Plate 5: Drone imagery of soil and pasture conditions in spring following hay bale winter grazing on a Pallic soil in south Otago.

Winter rainfall and wetness. The reasonably favourable outcomes for the pasture-based wintering approaches described in sections 3.2 and 3.3 have been recorded at sites where winter rainfalls were less than 200 mm, on average. We thus caution that we have a very narrow evidence base to guide winter planning decisions in locations that receive greater inputs of winter rainfall and where soils are more vulnerable to treading damage because of poor drainage or low structural resilience. We do also note, however, that a hay bale wintering system has been undertaken with reasonable success on a farm in southern coastal Southland that experiences relatively wet winter conditions and has soil types that are categorised as having "High" or "Moderate" risk of waterlogging. The reasonably favourable outcomes may again reflect the beneficial effects of introducing hay and straw that provided litter for cows to loaf on (Plate 6).

Plate 6: Drone imagery of soil and pasture conditions in spring following hay bale winter grazing on a farm with poorly drained soils in southern coastal Southland.

Slope. The effect of slope on soil erosion risk is generally well understood and described by Renard et al. (1997) as an important input to the Revised Universal Soil Loss Equation (RUSLE). The algorithms for determining slope effects on soil loss show a strong positive relationship between slope and soil loss risk. These responses can be used to inform relative assessments of soil loss risk for planning scenarios where winter grazing activity is being considered on terrains with contrasting slopes.

6. Knowledge gaps and possible next steps

There are many gaps in our knowledge of how contrasting approaches to animal wintering may affect soil and water quality, and farm financial performance. Below, in no order of priority, we suggest some key areas of focus that could address remaining questions and provide farmers and policy makers with greater confidence about decisions regarding how to winter animals in an affordable manner and with reduced impacts on the environment. Some key indicators of wintering outcomes are also suggested, which could be measured as part of a network of case study farms where alternative and lower impact approaches to animal wintering are being considered and then implemented.

- There is an obvious need to evaluate outcomes from alternative wintering approaches that are undertaken in wetter locations, and where soils are more vulnerable to animal treading damage. These evaluations could have a particular focus on some of the additional planning and tactical management decisions that may be required to ensure soil conditions and plant viability are maintained in a satisfactory state to deliver functional benefits such as water infiltration, vegetative cover and plant uptake of winter-deposited N.

- The nutritional adequacy of offered diets in wintering approaches that have relatively low dietary protein levels needs wider scrutiny from qualified animal nutritionists. Whilst these low protein diets have been shown to deliver clear benefits in terms of reducing urinary N returns to soil, consequently reducing N leaching risk (section 5.2.2), the adequacy of these diets for providing sufficient protein to pregnant livestock needs careful evaluation, particularly as animals get close to calving (and perhaps lambing).

- Changes to feed flows/availabilities are important aspects of some of the wintering approaches described in sections 3 and 4 of this report. Further and structured evaluations of these changes are required to quantitatively document likely effects on stock performance and financial outcomes. This would most likely require the use of a farm systems model such as Farmax, supported by measured rates of forage growth and nutritional composition.

- There are very few studies that have quantitatively documented soil, water and vegetation responses to the impacts of sheep winter grazing. Whilst the study of Ghimire et al. (2024) has provided an assessment of surface runoff risk following sheep winter grazing, this single study was undertaken in a location where rainfall inputs and intensities were relatively low/benign.

Some key indicators of wintering outcomes that could be monitored and aligned with the focus areas suggested above are:

- Nutritional composition of winter diets consumed by animals.

- Temporal (perhaps monthly) patterns of soil vegetation cover (for assessments of soil erosion risk).

- Temporal patterns of yields and N uptake in vegetation recovering from wintering grazing.
- Imposed grazing pressures and associated area requirements of each wintering system.
- Temporal changes in soil infiltration rates and soil erodibility. This latter variable is also a key input to the RUSLE equation and highly responsive to the effects of soil treading damage caused during winter grazing.

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