“Achieving Outcomes by Building Capability”

Dispersed forage feeding to minimise negative impacts on soil and water quality

Understanding soil physical properties beneath a kale crop after harvesting or grazing *in situ*

Prepared for Our Land and Water National Science Challenge, Rural Professionals Fund.

Prepared by The AgriBusiness Group

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Contents

Thanks go to our farmer Scott Hassall for being willing to let us undertake this project and take his idea to investigate it further. Scott is a progressive farmer always interested to try new ideas to improve his farm system and surrounding environment. We would also like to extend our thanks to the National Science Challenge Our Land and Water programme for the funding available to invest in researching our farm environmental impacts and challenges at a farm level. The unique funding model for rural professionals to embark on small research projects is a credit to the organisation.

Please Read

1 Executive Summary

The Our Land and Water Rural Professionals fund has been a great opportunity to look further into a good farming idea to assess the viability of the idea, including the benefits or challenges, and the potential for uptake by interested farming parties. Our project was developed subsequent to a discussion between farmers on the strategies and tools implemented after a period of drought and a need to feed multiple stock classes with minimal feed resources.

There is an increasing requirement for farmers to reduce their impact on the environment to restore water quality, reduce nutrient loss and improve animal welfare; especially during the winter months. Regulations being implemented will require farmers to adapt their farming practices to ensure compliance whilst remaining profitable.

Scott Hassall harvests kale at scale on his farm in North Canterbury. Harvesting kale, (mowing, chopping, and feeding out) is not common practice in New Zealand. Scott's farming practices have provided an opportunity to investigate some of the environmental impacts harvesting kale may have. The opportunity this process presents extends further than what we were able to assess. For the purposes of the project we investigated soil compaction and nutrient loss between a harvested system and a grazed *in situ* system. The results demonstrated little difference in soil compaction and a substantial difference in nutrient loss. Further detailed research would be required to statistically analyse the difference in soil compaction between the two different systems and should include different stock classes.

A financial analysis illustrated little difference in the cost of the systems when they are compared on a feed value basis. On a pure cost basis, the costs are higher in the harvesting system than that of a grazed *in situ* system.

Crop utilisation was visually different between the two processes, the harvesting system leaving behind a very clean paddock. This has advantages including no cultivation being required prior to direct drilling with the next crop, and lower loss of topsoil as small weeds or young plants start growing once the kale has been cut and taken away. Harvesting provides the opportunity to plant crops earlier.

This project has identified there is huge promise in the harvesting system, however a more detailed investigation is required to realise the full potential of the system. Future research should focus on scientific analysis and expand the project to use cattle as the main livestock enterprise to assess the benefits of the system on a farm that is highly cattle focused (dairy or beef).

Overall, this system and process is one that Scott Hassall will continue to use in the future. We believe other farmers should adopt the idea and utilise in their own farming systems.

2 Project Introduction

2.1 Project Aim

This project has been based on the experiences of farmer Scott Hassall (Waikari Valley, North Canterbury) who has adapted the utilisation of greenfeed (kale) through harvesting and then feeding out to stock in dispersed locations rather than grazing it *in situ*. This potentially minimizes the negative environmental impacts of feeding *in situ* – or carrying the feed to feedlots or feed pads – which can also result in high concentrations of effluent and runoff, this approach provides an insight on the potential value of this strategy.

Scott harvested the kale crop every two days, picked it up with the silage chopper wagon and then loaded it into a standard feed-out wagon from which it is fed it out to multiple stock classes of sheep, deer and cattle in different paddocks. Feeding out ensures the feed is dispersed across wide areas of pasture which decreases waste concentrations and pollution risks.

The project has reviewed the comparative potential environmental, farm management and economic impacts from adopting this approach. If these are as positive as anticipated, then adopting this style of winter feeding may provide environmental benefits whilst remaining profitable.

2.2 Project Team

Project Lead: Sarah O'Connell, Extension and Facilitation Consultant, The AgriBusiness Group, Lincoln.

Farmer: Scott Hassall, 874 Waikari Valley Rd, North Canterbury.

Agronomist: Simon Thorne, Frame Grain & Seed, Amberley.

Project Advisory: Dr David Scobie, Farm System Scientist, Agresearch, Lincoln.

Jon Manhire, The AgriBusiness Group, Managing Director, Lincoln.

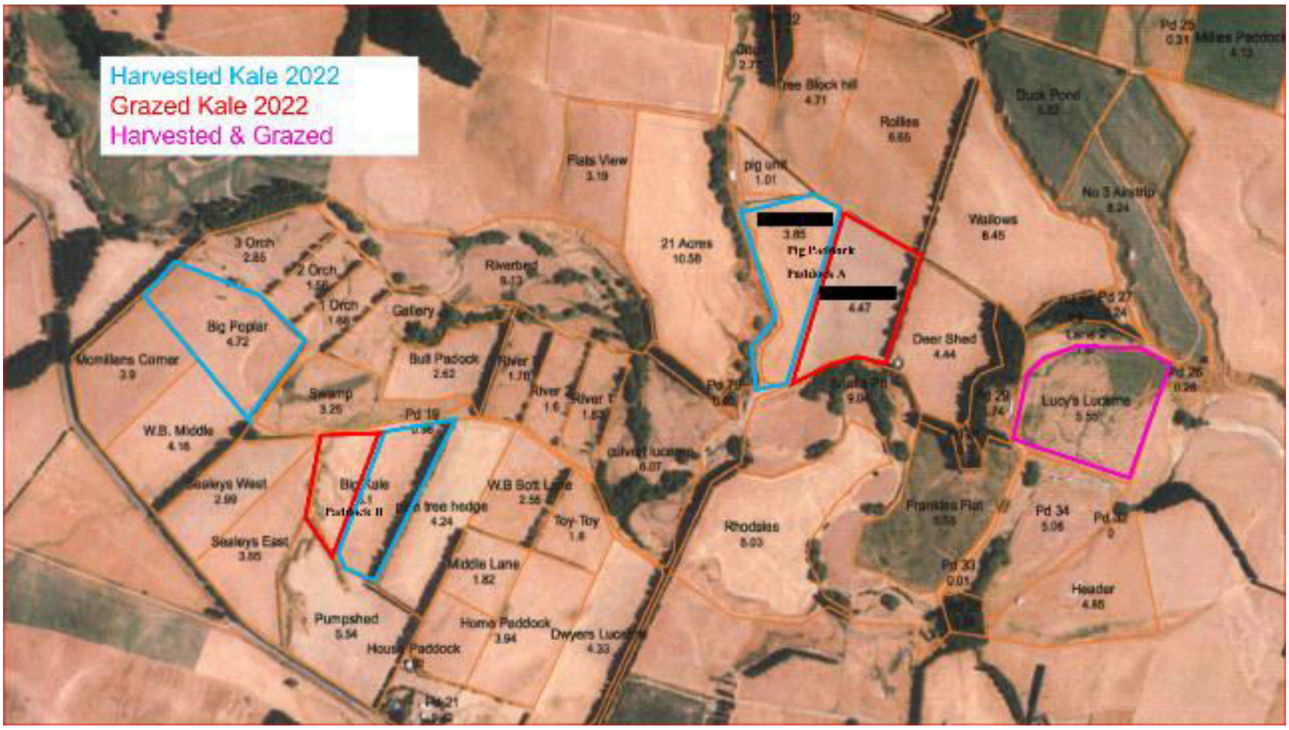
Project Implementation & Assistance: Dave Lucock, Farm Systems Consultant, The AgriBusiness Group, Lincoln.

Stuart Ford, Agricultural Economist, The AgriBusiness Group, Lincoln.

Julie Lambie, Nutrient Specialist, The AgriBusiness Group, Farm Systems Consultant, Lincoln.

2.3 Location

874 Waikari Valley Road, Scargill, North Canterbury.



2.4 Key Findings

- No significant difference in soil compaction was found between the soil that was under harvested conditions compared to soils under deer or hogget grazing conditions.
- Modelled nutrient loss, nitrogen, was lower in harvested conditions compared to grazed conditions.
- Crop utilisation in a harvested situation was visually higher than that in a grazing situation.
- Costs for a harvest system were higher than a grazed system when looking at the direct costs involved.
- Comparing costs on a feed value basis, the costs were the same.
- Minimal paddock work is required after harvesting to return the paddock to pasture or the next crop in the rotation.

3 Literature Review

3.1 Introduction

Traditionally autumn / winter greenfeed crops such as Kale are grazed *in situ* which can result in damage to soil through pugging and increase risks to water quality from nitrate leaching and runoff. Greenfeed crops, however, are an important feed source providing supplements during low pasture production in cold winter or dry summer conditions. These are key to supporting resilience in winter feeding and in adaptation to changing climate and the potential increased risks of drought.

The project worked to review the comparative environmental, farm management and economic impacts from adopting this approach and to assess any benefits. It is now sharing these results to prompt consideration for the adoption of the management practice. Current New Zealand good management practices for the feeding of brassica and other greenfeed crops do not include this management option though it is utilised overseas – often referred to as zero grazing.

This process of harvesting kale is not common in New Zealand given the requirement for specific machinery although the opportunity to research it further to better understand the environmental, and livestock benefits is worth the investment.

A literature review was undertaken at the start of the project to identify relevant research or commentary that could assist in the design of the project and the interpretation of its results.

3.2 Methodology

This literature review was conducted via internet-based searches of the well-known agricultural research institutions such as DairyNZ, Agresearch, Lincoln and Massey Universities along with scholarly articles or papers published in the likes of the Proceedings of the New Zealand Grasslands Association Journal. Words and phrases such as ‘kale harvesting’, ‘winter kale feeding’, ‘nitrogen leaching’, and ‘reduced nitrogen leaching’ were used to find a vast range of published research to get an understanding of the research that exists.

Where available executive summary or introductions of papers and articles were read to assess the value of the information and short bullet point notes were taken (Appendix 10.2) to derive the key information in relation to this project.

Citations of papers read can be found in the appendix, these included annotated bibliographies.

3.3 Literature Review Summary

Several reports were reviewed to discover what research has been done in relation to the harvesting of brassica crops and the associated environmental impacts through reduced nutrient loss, and improved soil conditions. There is a vast amount of winter green feed crop research undertaken in New Zealand, keeping to a select species and topic was challenging.

The reports in this review were more analytical than the work undertaken in this project. They did however highlight the need for further research into the impacts of harvesting on the environment regarding nutrient loss and soil physical properties.

Nitrate leaching losses in grazed systems occur primarily beneath animal urine patches[1]. The Forages for Reduced Nitrate programme run by DairyNZ also found that our annual ryegrasses still grow at low temperatures and utilise soil N and soil moisture when the risk of drainage is high[2].

Much work has been done assessing the benefits or otherwise of differing wintering systems on nutrient losses and how those losses could be mitigated through management and other environmental aspects. The reports all indicated that there is a severe impact on both soil physical properties and nutrient loss with the winter grazing practices that are currently undertaken in New Zealand. Research to mitigate these affects is a current hot topic.

A completed project looking at the impacts of animal wintering on water and soil quality[3] showed that large losses of N may occur when cattle are grazed on crops early in the winter, on light soils and during wet winters. Concentrations of nitrate in drainage also occurs at a high rate. Practical management options mitigate soil damage were discussed such as back fencing, reducing tillage and avoiding vulnerable sites. R Monaghan also noted that there is no ‘ideal’ soil type to choose to winter animals on.

Another project that looked more closely at the soil physical properties under repeated winter forage cropping[4] showed that soil compaction was evident in the top 0-50mm of the soil profile

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[1] The Foibles of Fodder Beet and Other Forage Crops. D Dalley, DairyNZ
[2] Forages for Reduced Nitrate Leaching – Significant leaching reduction achieved by forage research. DairyNZ Led. I Pinxterhuis, G Edwards Lincoln University, M Beare Plant & Food Research.
[3] The Impacts of animal wintering on water & soil quality. R Monaghan, Agresearch October 2012. RE500/2012/029
[4] Recovery of soil physical quality under repeated dryland and irrigated winter forage crops grazed by sheep or cattle. R.J Paton & D.J Houlbrooke

following grazing of winter forage crops measured through macroporosity and bulk density. Recovery of the soil was evident some 11 months later in some of the plots that had been grazed by cattle.

To the best of our knowledge there have been no studies looking at the impact on soil parameters through harvesting kale, a crop that is more commonly grazed in situ.

4 Context/Background

The summer of 2020-2021 in North Canterbury proved to be challenging for growing feed. North Canterbury is prone to drought with the 2019/2020 summer being one of the driest in years. January 2020 to April 2020 saw only 101mm of an annual total of 634mm (on farm rainfall records), the summer of 2020/2021 was marginally better with slightly more rainfall, 110mm of 741mm. These compare to the 2018/2019 season where the Jan-Apr period saw 169mm of 461mm of rainfall.

After 2 summers of poor growth, feed was in short supply around the region and even green feed crops were struggling to grow. Farmer Scott Hassall, Waikari Valley, had a kale crop that was destined for winter feed as the only feed available, this needed to be fed to multiple stock classes – deer, cattle, and sheep. Break feeding the crop would have been a logistical challenge, it was decided to use the machinery and tools on hand to harvest the kale and feed it to the stock on various areas of the farm. The process of mowing the kale, picking it up & chopping it with a silage chopper wagon then feeding it out from a silage wagon proved to be very efficient and a valuable exercise to get the stock through the dry period.

Kale *(Brassica oleracea)* is a crop commonly used in winter to fill a feed deficit for grazing livestock. The crop is grazed via break-feeding, shifting a temporary fence on a daily or regular basis to ensure livestock receive the correct amount of feed. Grazing a crop such as kale over the winter months also presents challenges around nutrient loss and soil damage through high concentrations of livestock in a small area for a long period of time in often wet weather conditions. This is an issue that the agricultural industry is managing currently through regulations and rules specific to winter grazing that seek to minimise the impact of freshwater quality and nutrient loss.

The harvesting process that Scott had implemented in the summer and autumn of 2021 provided an opportunity to look further into the potential benefits of the process to nutrient leaching, nutrient and sediment run-off and soil compaction leading to a reduced environmental impact. It also presented an opportunity to work through the costs of such a system compared to a standard grazing system given this particular process requires access to specific machinery and implements that not every farmer will have available.

5 Methodology & Process

Measurement systems were kept simple to align with the practicality of the project being able to be carried out with little to no impact on everyday farming and utilising the tools available to the everyday rural professional.

Soil impacts

The soil types of the two paddocks chosen for sowing kale were Culverden and Pahau soils. Both soils are shallow silts over clay, well drained with plant available water between 90mm and 103mm through the profile and the top 20cm holding between 38mm and 41mm (15-20%). The soil texture in the top 40cm covers a range of stoniness from 0% - 35%. The lower profile 40cm below tends more towards 35-70% stones.

In October 2021 baseline soil physical property measurements of penetrometer (psi), visual soil assessment and water infiltration were taken on the paddocks that were to be harvested and or grazed in the autumn/winter of 2022. Measurements were also taken on paddocks that had been harvested in the previous autumn of 2021, Scott's first year of this harvesting system. These measurements were taken to get an understanding of what had gone on previously and what the soil physical properties were.

Penetrometer measures were taken approximately every 30m on a straight line transect across the Pig paddock (Paddock A, farm map in appendix) to capture readings in both the harvested and grazed soils. In the Big Kale (Paddock B) paddock straight line measures were taken up either side of the paddock where harvesting or grazing were going to take place, once again approximately every 30m. These points were GPS located so final measures could be taken in similar locations post grazing and harvesting.

Visual soil assessments were taken in 2 or 3 random sites in Paddock B, Lucy's lucerne and Willows, the latter two having been used in the 2021 autumn for harvesting and feeding out on respectively. This was to gain an overall understanding of the soil types in the area under the general sheep, beef and deer farming. Water infiltration measures were also taken although these proved to be redundant due to the overall weather conditions throughout the duration of the project and being unable to take infiltration measures post grazing and harvesting due to the soils being close to saturated.

Figure 1. Paddock B visual soil assessments prior to sowing, showing dry conditions and soil structure.

Kale was sown at a rate of 4kg/ha on the 2/11/2021 in the Paddock B of the variety SovGold. In Paddock A the variety Bombardier was sown, also at 4kg/ha on the 1/11/2021. All sowings also had 150kg/ha DAP fertiliser applied at the time of sowing. No further fertiliser was applied during the season.

At the time of sowing both paddocks were destined for harvesting and grazing (splitting each paddock in half) to provide a direct comparison between the systems on exactly the same soil types.

Feed quality

In early June feed analysis testing was undertaken by Simon Thorne, agronomist with Frame Grain and Seed and analysed by Hill Laboratories to understand the whole feed profile of the crop grown. In this system of mowing, chopping and feeding, Simon estimates a visual utilisation of 90-95% of the crop versus grazing *in situ* of 80-85% with mostly stem being left behind.

The process of harvesting, chopping and feeding out was done entirely with machinery. The crop was mown with a standard disc mower, with the amount mown worked out from experience with the crop and then weighed in the feed out wagon to determine if any further feed was required. After mowing, the self-fed forage wagon, a wagon that picks up the forage and feeds it through knives to chop it into smaller pieces (more commonly used for making grass silage) was brought in and the mown kale picked up and chopped, operated by Scott. The self-fed forage wagon, once full was then unloaded and the cut kale picked up and loaded into a standard silage feed out wagon, the kale cannot be fed out from the chopper wagon. At this point the kale can be taken to many different stock classes anywhere on the farm. The feed out wagon has scales so the correct amount of feed required can be fed out to the right stock class. Once the whole paddock had been harvested the residual crop remaining on the ground that hadn't been picked up by the forage wagon was grazed with a mob of ewes.

Grazing *in situ* was also carried out, after harvesting had been completed, the stock did not have access to the harvested are in Paddock A. The grazing followed the standard winter grazing regime of daily or 2 daily break shifts for deer on Paddock A. In Paddock B due to extremely wet weather conditions at the time, hoggets were grazed on the kale in an *ad libitum* fashion having access to the harvested and standing kale.

Post grazing and harvesting penetrometer measurements and bulk density cores were taken in the spring to determine if there were any differences in compaction between grazed soils and harvested soils. The same transect lines measured pre sowing were measured post sowing with penetrometer and bulk density taken at each site. Bulk density was measured using a core sampler 100mm wide and 150mm deep and taking 2 soil samples, one at 150mm and the other at 75mm and weighing each soil core.

Figure 2. Bulk density core sampling

Measures from both were analysed by biometrics to determine any significance in the data.

Nutrient modelling

Nutrient loss modelling was completed using Overseer FM with baseline modelling assuming all kale crops were grazed *in situ*. Scenario models were then run to compare with the base line to see the differences in nitrogen leaching.

- Scenario 1: Base model assuming all green feed crops were fed in situ to sheep, deer and cattle.
- Scenario 2: Assuming only project kale crops were harvested and all other kale crops were grazed in situ.
- Scenario 3: Assuming all kale crops had been harvested and fed on farm.
- Scenario 4: Assuming all project paddocks were harvested and exported off farm.
- Scenario 5: Actual Project assumptions of two kale paddocks half grazed and half harvested with the remaining kale paddocks grazed in situ.

Financial analysis

Financial analysis was done by considering the inputs of the two systems and the associated costs at a fair market rate. The results were worked through to a dollars per hectare and cents per megajoule of metabolisable energy.

For the grazing system the assumptions included personal hours for shifting break fences, motorbike hours use and a utilisation rate of 85%.

The harvest system included the cost of a second hand silage chopper wagon, mower and feed out wagon. The tractor hours were charged at a rate her hectare. Crop utilisation in the harvest system was assumed at 95% and a factor for enhanced ME also included. An interest rate of 6% was also included in the harvest system to account for the purchase of machinery.

6 Results

6.1 Compaction

Compaction was measured to assess if there was any difference between the harvested soils and the grazed soils. Measurements taken in October 2021 were under dry conditions and taken just prior to sowing. Measurements taken post winter/grazing and harvesting were taken under wet conditions in late August. The paddock(s) had previously been in old pasture under livestock grazing, mostly deer.

The soil type potentially had an influence on the results.

	Paddock A		Paddock B	
Depth mm	At Sowing	Post Winter	At Sowing	Post Winter
100	327 psi	249 psi	325 psi	131 psi
200	367 psi	340 psi	329 psi	208 psi
300	376 psi	470 psi	352 psi	430 psi
400	464 psi	580 psi	495 psi	307 psi
500	773 psi	720 psi	556 psi	393 psi
600	1050 psi	500 psi	529 psi	307 psi

Table 1: Penetrometer readings across each project paddock measured pre sowing and post grazing or harvesting.

At a depth of 300mm across both paddocks there was an increase in pentrometer readings on the post winter measurement compared to 11 months earlier, potentially indicating an increase in compaction.

	Average psi Harvested Soils Paddock A			Average psi Grazed Soils Paddock A		
Depth mm	Pre-Sowing	Post Harvesting	Difference	Pre-Sowing	Post Grazing	Difference
100	335	220	115	300	260	40
200	360	245	115	365	470	-105
300	355	415	-60	427	567	-140
400	373	500	-127	240	600	-360
500	850	720	130			
600						

Table 2: Penetrometer readings using only matched data comparing compaction prior to sowing and after harvesting or after grazing to see the difference between harvesting and grazing systems.

Using a t-test with one degree of freedom in this experimental design revealed no significant difference between the measurements on “Harvested” and “Grazed” paddocks. Looking at the compaction differences between the harvested soils and the grazed soils there were increases in compaction throughout the soil profile in both systems with the grazed system showing compaction higher in the profile than harvesting but with harvesting showing a deeper compaction layer than that of the grazed soils. In order to demonstrate a statistically significant differences, more samples and replication of paddocks would be required.

Soil conditions at the time of measurement and throughout the preceding winter will have had an impact on results. The 2022 winter was a very wet winter with frequent rain events keeping the soil at maximum water holding capacity all winter.

6.2 Bulk Density

Results from bulk density comparing harvested soils with grazed soils showed little difference. As with compaction, there was no significant difference in bulk density measurements between the “grazed” and “harvested” paddocks. The soils in Paddock A were 1% heavier on the grazed soil compared to the harvested soil. In Paddock B a difference of 8% on the harvested soil was measured. Paddock B was harvested and grazed during periods of extreme wet weather and it was grazed with hoggets in an *ad libitum* fashion rather than using break feeding.

6.3 Nutrients

To understand the nutrient losses of the project and potential losses if the property was to implement alternative management practices on the paddocks, five nutrient budgets using OverseerFM V6.4.3 were completed. Overall OverseerFM demonstrated a nitrogen loss from all nutrient budgets as 8 kg N/ha/yr, with varying total farm nitrogen losses. The below scenarios were run, with results displayed in Table 3. *Table 3 Nutrient loss summary between different Scenarios in OverseerFM (V6.4.3)*

- 1.Scenario base: demonstrating the sheep, beef and deer operation with predominant pasture and some lucerne on flat to the steep hill country. Supplementary feed and Fertiliser applications were modelled according to what was applied for the 2021/22 season. This base model was copied and modified to generate the remaining scenarios.

- 2.Scenario: All project paddocks harvested: and fed back to deer with non-project paddocks still being grazed by different stock classes. This modelling was carried out to understand the impact on nitrogen loss if the entire project paddocks were harvested and fed back to the deer on pasture paddocks.

- 3.Scenario: All Kale paddocks harvested: this was to demonstrate what the pasture production would look like if all kale paddocks were harvested and fed back to desired stock on pasture paddocks, as well as understand if there would be a change in overall nitrogen loss.

- 4. Scenario: All project paddocks are harvested and exported This was an exact replica of the base model, however unlike grazing the crop, all kale paddocks were cut and then exported off-farm. This was to understand the nutrient value Overseer assumes if the kale were to go out the farm gate. It is important to note there were no additional supplements brought in to counter the kale not being fed from April through to July in this scenario.

- 5. Scenario: Project Actual: This was a model of actual stock numbers, crop yields, and what happened on the project paddocks. Lucy Lucerne was all harvested and fed back out onto pasture, Pig Paddock was half harvested, and then half grazed by deer, and Big Kale was half harvested and grazed by sheep*.

*To model the half harvested and half grazed paddocks, two separate crop blocks were created. The harvested was modelled as a cut and carry and fed back onto pastoral blocks to desired stock enterprise.

The two scenarios analysed were scenario 1. Scenario Base (All Grazed) and Scenario: Project Actual (Cut & Grazed). The other scenarios were run to understand the different management practices on pasture production as well as the nutrient content Overseer puts on kale if it were to be exported.

The pasture production within the scenarios varied as seen in Table 3 *Nutrient loss summary between different Scenarios in OverseerFM (V6.4.3)*, this was to be expected due to the difference in feeding practices of the animals between harvesting, harvesting and exporting the feed, and grazing the paddocks. All grazing had a lower pasture production as opposed to harvesting.

Table 3 Nutrient loss summary between different Scenarios in OverseerFM (V6.4.3)

Project Paddocks Data										
	Total Farm N Loss		Pasture Grown	Paddock A N loss		Paddock B N loss		Lucy Lucerne N loss		
	kg/ha/yr	kg/yr	T/DM/yr	kg/ha/yr	kg/yr	kg/ha/yr	kg/yr	kg/ha/yr	kg/yr	
Scenario 1: Base, All Grazed	8	7901	2361	25	236	17	86	32	180	
Scenario 2: All Project Paddocks Harvested	8	7231	2646	19	178	12	61	28	159	
Scenario: 3: All Kale Paddocks Harvested	8	7250	2637	19	178	12	61	28	159	
Scenario 4: Project Pdks Harvested & Exported	8	7196	2763	19	178	12	60	28	159	
Scenario 5: Project Actual (Harvested & Grazed)	8	7181	2616	16*	70*	12*	54*	31	176	
				24^	113^	21^	31^			
				20	183	16.3	85			

*= Harvested paddocks ^= Grazed paddocks

Modelled nitrogen losses were very low at 8 kg/ha/yr for the whole farm. The various scenarios showed no change in the whole farm Nitrogen loss per hectare (8 Kg N/ha/yr). However, there were slight changes in the total farm Nitrogen loss in all budgets. This was expected due to the property being an extensive operation with relatively low inputs from purchased feed or fertiliser / Nitrogen applications. It was also expected due to the different effects of harvesting and grazing on the nitrogen cycle over the whole farm.

To understand the differences of harvesting kale or grazing kale nutrient losses, the individual Overseer Paddocks or Project paddocks (Each project paddock was a separate Overseer block) nitrogen losses were investigated. Results are displayed in **Error! Reference source not found.**. The results demonstrated that grazing kale was associated with a higher Nitrogen loss of 25 Kg N/ha/yr in Paddock A and 17 Kg N/ha/yr in Paddock B. This compares to the paddocks being harvested, 20 Kg N/ha/yr in Paddock A and 16 Kg N/ha/yr in Paddock B. This was to be expected due to less dung and urine from stock being deposited on the harvested paddocks compared to the grazed paddocks.

The results in Table 3 demonstrate a difference in nitrogen loss between Paddock A and Paddock B although they had similar management practices. The main differences in losses between Paddock A and Paddock B is the soil types. Paddock A is on an imperfect/well drained soil opposed to Paddock B where it has well drained soil properties.

The third paddock – Lucy Lucerne which was a small part of the project, was entirely grazed by deer and sheep and not harvested. The nutrient loss from the block reduced by 5Kg N/yr over the whole paddock (Reducing N loss from 32 Kg N/ha/yr to 31 kg N/ha/yr). Further investigation found that it was how Overseer allocates feed to animals on crop blocks and the changes in organic pools within the blocks.

A limitation in Overseer is that we cannot differentiate the stock class grazing a crop paddock, only the stock enterprise. Kale paddocks were mainly grazed with weaner deer and not mixed age hinds. However, Overseer can only model deer on the kale and not a specific stock class within the deer enterprise were grazing that paddock. Further modelling could be achieved to understand this however it may generate some inaccuracies elsewhere in the farm system.

Overall, the above nitrogen losses were to be expected due to the different impacts grazing or harvesting have on the nitrogen cycle. Grazing is seen to be adding more nitrogen from dung and urine from the deer and the harvesting is removing nitrogen and other nutrients from that block within the nutrient budget and transferring it to another block within the farm system.

6.4 Financial

This report is to meet the requirements of the "Dispersed forage feeding to minimise negative impacts on soil and water quality" that was carried out by The AgriBusiness Group for the Our Land and Water National Science Challenge.

It meets the definition detailed in the methodology section of the contract which is to "Development of a partial cost benefit analysis that will incorporate both quantitative and qualitative measurements." The partial cost benefit has been adapted to represent a comparison between feeding out kale via a harvester (dispersed forage feeding) with break feeding it *in situ*.

This analysis incorporates the cost of adopting this approach and the overall financial impacts of adoption.

6.4.1 Analysis

This comparison is set up to compare the difference in the way that Scott Hassall's system is set up to mow, pickup and chop the silage and transport it and feed it out to the stock in their paddocks to his other alternative which would be to feed his kale out *in situ*.

6.4.2 Inputs and assumptions used.

The inputs and assumptions that have been made in this comparison are shown in Table 1.

Table 1: Inputs and assumptions made in this comparison.

Factor	Number	Source
Yield (kg DM / ha)	8,800	Actual from the farm.
Utilisation – Harvested (%)	95%	Estimate
Utilisation - Grazed i*n situ* (%)	85%	Estimate
Factor for enhanced ME	1.05	Estimate
Additional tractor hours used (hrs / ha)	3.5	Estimate
Cost of tractor ($ / hr)	65	LU Financial Budget Manual
Cost – mower ($)	15,000	Quoted values on Trade me.
Cost - loader wagon ($)	75,000	Quoted values on Trade me.
Cost - feed out wagon ($)	27,500	Quoted values on Trade me.
Interest Rate (%)	6%	Assumed
Area of kale covered (ha)	26	Actual from the farm.
Labour mowing and chopping (hrs / ha)	1.2	Estimate

Labour feed out wagon (hrs / ha)	2.3	Estimate
Labour break shifting (hrs / ha)	1.7	Estimate
Additional motor bike hours (hrs / ha)	5.00	Estimate
Labour Cost ($ / hr)	65	Estimate
Motor bike cost ($ / hr)	15	LU Financial Budget Manual
Number of days for feeding (days)	60	Estimate.

The yield used in this comparison is the yield of kale that was measured. The figures used for utilisation of the harvested and the grazed *in situ* are based on our estimates of the utilisation which is based on observations of the harvested system and knowledge gained from experience with the grazed in situ scenario.

The factor for enhanced ME is our estimate of the additional feed value which Scott is able to offer his stock as a result of the chopping which makes more of the kale available for digestion in the stocks rumen.

6.4.3 Harvested

The harvested scenario reflects the system which Scott uses now. He mows the crop with a mower and then chops it and collects it in a loader from which he drops it onto the ground and then picks it up into his feed out wagon and then he feeds it out to the stock in the paddocks which they are in. His stock do not graze the paddock which the crop is grown in. The extra equipment which this system requires are the mower and the loader wagon and there is also the extra time using the tractor factored into the comparison.

The labour assumed in this comparison is based on informed estimates made by Scott.

6.4.4 Grazed *in situ*

The grazed *in situ* scenario is based on the way that Scott used to graze the kale. The labour time taken in both shifting the breaks and feeding out additional supplements is based on Scotts estimate of what it used to take.

6.4.5 Results

The results of the comparison between the two systems is shown in Table 2.

Table 2: Results of comparison.

	Harvested	Grazed *in situ*
Yield (kg DM / ha)	8,800	8,800
Utilised (kg DM / ha)	8,360	7,480
Improved ME (kg DM / ha)	8,778	7,480

Costs		
Tractor cost ($ / ha)	225	
Machinery costs ($ / ha)	271	288
Labor Costs ($ / ha)	225	229
Motor bike cost ($ / ha)		75
Total Costs / ha	**721**	**593**
Total costs / feed value	**0.08**	**0.08**

What we can see from Table 2 is:

- That the result of the better utilisation of the crop for the harvested kale sees an additional 880 kg DM / ha which is 12% more than the grazed *in situ* scenario.
- As a result of the improved ME of the crop the harvested scenario is able to offer 1,298 kg DM / ha or 17% more than the grazed *in situ* scenario.
- The costs / ha for the harvested scenario are $128 /ha or 22% dearer than the grazed *in situ* scenario.
- The two scenarios are very even in costs when considered on the cost per kg of feed value at both being about 8c / kg.

6.4.6 Conclusion

Although Scotts system adds additional cost when compared to a grazed *in situ* scenario when compared on a cost / ha it is very similar when compared on the volume and quality of feed offered from the same paddock.

There are additional advantages to the harvest system like the ease of operation of feeding out compared to a grazed *in situ* scenario along with the avoidance of pugging in the kale paddock.

7 Discussion

While the overall hypothesis of harvesting having less effect on soil physical properties than grazing in situ was not proven in the project it did highlight other benefits to the system and provided a template for further research using more robust designs, greater measurements and different stock classes. Harvesting kale to feed out to livestock around the farm has been a worthwhile process for farmer Scott Hassall. Indeed, Scott is already ahead of the changes and did not want to graze the treatments with heavy cattle because he knows what the consequences would be. He grazed treatment paddocks with light weaner deer and light hoggets and would not run the hoggets behind a break fence because it would lead to poor animal welfare and soil damage that he would need to ameliorate for the coming season. Heavy cattle grazing the kale under a break feeding regime for the entire winter would have seen dramatic soil damage, run off and leaching events on these paddocks during the wet winter. This might be implemented on a research farm, but good on him for these considerations.

Harvesting kale in the system we are researching has benefits of not concentrating urinary nitrates in places where they cannot be taken up by a growing plant and are lost through the soil profile to ground water. Animals are not grazing on the crop or the paddock during the winter period rather they are grazing on pasture with the greenfeed kale bought to them. This results in their excreted nutrients/nitrates being spread more widely across the farm where they can be taken up by grass plants when growth conditions improve rather than being lost through the soil profile.

Reductions in nutrient loss was a noticeable benefit when modelled through OverseerFM. In the current environment with regulations in many catchments and regions this reduction could be extremely beneficial to the farmer with the surrounding waterways also benefitting from lower nitrogen levels therefor enhancing aquatic life.

The harvesting process provides the opportunity to sow crops (following the kale) sooner and via direct drill or minimum tillage as the crop residual is minimal and the paddock is very clear and clean of damage or debris. In most *in situ* grazing situations there is substantial crop residue left behind that needs to be broken down and, in some cases pugging from livestock is evident. These need to be remedied before a new crop can be sown. This additional time waiting for the crop to be grazed and having soil exposed with no growing crops increases the susceptibility to soil erosion and nutrient loss.

The short time frame for the project also impacted the overall results, this system would benefit from multiple years of measurements to achieve a good understanding of the effects on soil properties. The weather conditions also had a major impact on the results.

Under full research conditions with more replicates this system may precipitate significant differences in soil physical parameters, within the current project results there are no significant differences to report.

The project highlighted several risk management opportunities in response to adverse weather. While not necessarily implemented at the time, the harvesting system could be utilised when it is known that poor weather is on its way and to keep stock off the crop to reduce the incidence of pugging, surface run off and un-desirable grazing conditions for livestock. The harvesting system also lends itself towards less surface run off through the winter months as there is very little bare soil or pugging compared to a grazed system. While this was not measured in this particular project, visual comparisons of pasture growth post harvesting is evident.

Residual of harvested and grazed areas in Paddock A

Residual of harvested and grazed areas in Paddock A

Residual of harvested and grazed areas in Paddock B

This project also highlighted the potential to run the system using cattle for grazing, with a heavier footprint than that of weaner deer and cattle being a stock class frequently grazed on kale crops over wintertime. This would require further research under controlled research conditions.

An opportunity not explored in the scope of the project although considered during the process was the opportunity for rural contractors with appropriate machinery to harvest crops locally in their 'off - season' making use of their summer silage chopping wagons at a time when they are generally not being utilised. The mowing could be done by either the farmer or the contractor with the cut kale being left in a convenient space for the farmer to load and feed out with their own machinery. The economics of this have not been estimated to understand the feasibility of the opportunity.

8 Acknowledgements

My first acknowledgement must go to Scott Hassall, our farmer. Without his initial idea of harvesting kale because it was the only feed available at the time, the idea of taking this project on wouldn't have happened. Throughout the project Scott has been incredibly accommodating with our requirements and his time. Without farmers like Scott, on farm practical research would not happen.

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9 References

As mentioned in Literature review in appendix 10.2.

10 Appendix

10.1 Farm Map

10.2 Literature Review

10.2.1 Impacts of grazing on ground cover, soil physical properties and soil loss via surface erosion: A novel geospatial modelling approach.

M Donovan, R M Monaghan, Agresearch. June 2021

- Model development to capture changes to ground cover and soil properties as a function of grazing intensity.
- Grazed pastures and winter forage paddocks exhibit distinct changes in soil erodibility and soil losses which are most pronounced for wet soils when plant cover is low.
- Proactive decisions to reduce treading damage and avoid high density grazing will far exceed reactive practices seeking to trap sediments lost from grazed lands.
- Typical pasture grazing increase soil erodibility by 6% compared to 60% for intensive winter forage paddocks.
- Compaction reflects compressive forces that reduce soil spore space and surface infiltration rates.
- Compaction is often measured as a change to macroporosity, bulk density or penetration resistance before, and after grazing events.
- The degree of soil compaction will increase up to the critical water content of a soil – the point at which a given compacting force will result in maximum bilk density.

10.2.2 The Impacts of animal wintering on water & soil quality

R M Monaghan, Agresearch. October 2012. Environment Southland RE500/2012/029

- N lost in subsurface draining from winter forage crops grazed by cattle is relatively high. Concentrations of nitrate-N in drainage from grazed winter forage crop are accordingly relatively high.
- Potentially large losses of N may occur when cattle are grazed on crops early in the winter, on light soils and during wet winters.
- There is potential for relatively large losses of sediment in overland flow from rolling landscapes when grazing forage crops.
- Soils highly susceptible to damage have high Structural Vulnerability Index (SVI, Hewitt & Shepherd 1997)
- Yield can be compromised as well as deterioration in soil physical qualities.
- Practical management options to mitigate soil damage – back fencing, reduced tillage, no double cropping, avoid vulnerable sites.
- There is no “ideal” soil type to choose to winter animals on.
- Main focus is on nutrient loss.

10.2.3 Break Fed Winter Grazing

DairyNZ

- Mostly focuses on set up for winter grazing, paddock selection, critical source area, nutrient loss, catch crops.
- Environmental risks and mitigations.
- Great template for minimising nutrient loss either via leaching or run off.

10.2.4 Assessment of Strategies to Mitigate the Impact or Loss of Contaminants from Agricultural Land to Fresh Waters

R W McDowell, B Wilcock, D Hamilton, June 2013.

While not large emissions of N & P from agriculture they do result in significant water quality impairment.
Faecal matter inputs to NZ waterways are predominantly from pasture, with surface runoff, cattle crossings and drains being major sources.
Natural methods of mitigation – land based treatments, interception of contaminants, bottom of catchment.
Variability in farm management methods.
Limiting nutrients (periphyton growth on riverbed substrate)

10.2.5 N leaching losses fodder beet and kale crops grazed by dairy cows in southern Southland.

L C Smith, R M Monaghan, September 2020.

N loss from Kale is very high compared to that of fodder beet when grazed.
Greater leaching from Autumn lifted/grazed fodder beet than winter lifted/grazed.
No information on impact on soils.

10.2.6 Forage for Reduced Nitrate Leaching – Summary Report

I Pinxterhuis, DairyNZ, 2013-2019.

High N concentrations in cow urine patched and high soil mineral N increase the risk of N leaching if the N is not utilized before draining below root zones.
Italian and annual rye grasses and winter cereals still grow at low temperatures and utilise soil N and soil moisture when the risk of drainage is high (late autumn to early spring)
No-till establishment of winter-grazed crops can reduce soil compaction and improve the N uptake of subsequent catch crops.

10.2.7 Recovery of soil physical quality under repeated dryland and irrigated winter forage crops grazed by sheep or cattle

RJ Paton & DJ Houlbrooke, January 2010

Measured macroporosity & bulk density.
Done under 4 years of repeated cropping.
Triticale & Kale
Yearling cattle & yearling sheep used for grazing.
Direct drilled crops.
Impacts on soil properties were most noticeable under cattle.
Soil recovery levels of macroporosity were similar between the 2 species.

10.2.8 The Foibles of Fodder Beet & Other Forage Crops

D Dalley, DairyNZ

Nitrate leaching losses in grazed systems occurs primarily beneath animal urine patches and, as such, winter forage grazing can contribute a disproportionately large fraction of whole farm N leaching losses because of the high stocking rates at the time of the year ie winter, when minimal amounts of N are taken up by vegetation and soils are regularly draining.

Sequence cropping (catch crops) are well known to be beneficial to soaking up excess nutrients. Grow additional yield not initially planned for. If the land lies fallow for three months after grazing before the next crop is sown then there are no plants growing on the soil to take up the N until late October – during which time much of the urinary N will likely be leached in drainage water.

10.2.9 Compaction induced soil structural degradation affects productivity and environmental outcomes: a review & NZ case study only.

W Hu, J J Drewry, M H Beare, August 2021.

Looked at soil structural degradation (SSD) and the undesirable side effects & impacts on production, contaminant loss, and emissions.

SSD very common and many areas below the target of >30µm for macroporosity.

SSD was greater under intensive land uses.

Compaction SSD leads to lower production levels

Indicators used: VSA, bulk density, macroporosity, air permeability. Penetration resistance, aggregate size distribution, field capacity, available water capacity, hydraulic conductivity and infiltration rate.

SSD generally associated with an increase in bulk density, penetration resistance and dry aggregate size.

Bulk density & macroporosity measured to 10cm depth.

Study touched on traffic induced compaction but noted more needed to be done.

10.2.10 Grazing Strategies for reducing contaminant losses to water from forage crop fields grazed by cattle during winter.

Monaghan RM, Laurenson S, Dalley D, Orchiston T. July 2017. Agresearch, DairyNZ

Swede & kale crops quantified fluxes of N, P, sediment & E.coli.

What effect would strategic grazing have on critical source areas.

Reduced soil infiltration caused by cattle treading was a contributing factor to overland flow in the weeks following grazing.

Soil measurements taken: pore size distribution, bulk density, & macroporosity.

Strategic grazing can considerably reduce the fluxes to similar levels of that of sheep grazed pastures.

10.2.11 Reducing nutrient and sediment losses in surface runoff by selecting cattle supplement feeding areas based on soil type in New Zealand hill country

Fransen P, Burkitt L, Chibuike G, Bretherton M, Hickson R, Morris S, Hedley C, Roudier P. 2021

Soil type has a big impact on the amount of soil loss.

Imperfectly drained soils can lose 2.5 times the amount of sediment, 6.3 times the total phosphorus and 4.5 times the amount of total Nitrogen than a well- drained soil.

Strategic placement of feed supplements on soils less prone to surface runoff can improve freshwater outcomes.

10.2.12 Forages for Reduced Nitrate Leaching: New knowledge register web book

DairyNZ. March 2020

- Farm system modelling to evaluate effects of alternative pasture species and forage crops on production, profitability and environmental impact of livestock and arable farms.
- Looking at N uptake by diverse species on different soil types.
- Scenario modelled studies (for mixed livestock using Farmax Pro & Overseer) for the mitigation of N leaching.
- Sheep & beef model was looking at diverse pasture mixes (50% diverse) – this was modelled to decrease N leaching on average by 35% using APSIM and only 6% using Farmax.

10.2.13 The effect of irrigated land-use intensification on the topsoil physical properties of a pastoral silt loam.

J Drewry, S Carrick, N Mesman, P Almond, K Muller, F Shanhun, H Chau, September 2020.

- Found that irrigated dairy soils were more compacted than those of dryland sheep.
- Dairy land had lower porosity and macroporosity and greater bulk density and volumetric water content that other sites.
- Single replicate of three experimental treatments. Dairy Farm, Sheep Farm & Control Site. Only 1 site at each treatment was measured.
- Macroporosity, water content/pore space, bulk density
- Large differences in macroporosity which was lower on the DF site – consistent with other trials. Decline in macroporosity is linked to more intensive land use through treading.