THE IMPACT OF USING OVERSEER 6.2.2 IN REDUCING NITROGEN LOSSES TO WATER ON DAIRY SUPPORT FARMS USING KALE AND FODDER BEET FORAGE SYSTEMS

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SARAH HAWKINS
1107949

Abstract

Recent intensification of farm systems (especially within Canterbury) has resulted in increased nitrogen losses to water. This has created health risks and the eutrophication of waterways. Winter grazing of dairy cows on forage crops (such as kale and fodder beet) is a particularly “nutrient leaky” system. High stocking rates result in a build-up of soil nitrogen from the nitrogen loading in urine patches. The nitrogen is not taken up by plants (as winter is a low growth season) and is readily leached from the soil.

Government and regional councils have responded by creating regulatory control around nitrogen losses to water for farming systems. The Canterbury regulations are set out in the Land and water Regional Plan (LWRP). The Selwyn Te Waihora zone (a particularly high risk zone) has specific policies and rules outlined in Variation 1 in the LWRP, including nitrogen loss reductions by 2022 (22% for a dairy support farm).

Overseer is the computer modelling tool used by regional councils to measure and regulate nitrogen leaching losses. This research project focuses on management options to reduce nitrogen losses to water, as modelled by Overseer 6.2.2. Due to the irregular updates and new versions of Overseer released this area of study is going to need constant attention, as results will change.

Four case study dairy support farms were used to determine common industry practise for wintering systems. This information was used (along with industry recommendations) to create an Overseer base model for both a kale and fodder beet system. This model was used to determine the success of four management strategies in reducing nitrogen leaching losses. Nitrogen use, feed supplement nitrogen content, soil type and the use of a catch crop were all modelled.

Fodder beet and Kale were not directly compared using Overseer as inconsistencies in the model called into question the reliability of results. Instead a thought experiment was used for a direct comparison.

A number of inconsistencies within the Overseer 6.2.2 model impacted on results. Crop feeding levels were variable between crops and yields, feed supplement had no effect on nitrogen leaching losses and nitrogen losses from kale crops seemed low when compared with published research.

Keywords: Dairy support, wintering systems, fodder beet, kale, Overseer, Selwyn Te Waihora, Variation 1

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1 Introduction

The recent intensification of farm systems in New Zealand and in particular Canterbury has increased nitrogen losses to water, causing health risks and eutrophication of waterways. Nitrate levels are elevated above background nitrate levels in 39% of monitored waterways, with some higher than the NZFSA recommended levels of 11.3ppm (Baskaran, Cullen, & Colombo, 2009).

Government and regional councils have responded by creating regulatory controls around nitrogen (N) losses to water for farm systems, with a future requirement for leaching reductions across entire regions (Parfitt, Baisden, Schipper, & Mackay, 2008). This is particularly important for farm systems that winter dry dairy cows on forage crops (a common system to preserve pasture quantity for the following spring), as it is a particularly "nutrient leaky" system. Dairy support land makes up 9% of the Selwyn Te Waihora catchment zone (Lilburn 2014), with forage crops commonly grown as supplement feed. Forage crops grazed in situ have much higher stocking rates than pastoral grazing, depositing significant amounts of urine nitrogen (which can contain nitrogen loading of 500-1000kgN/ha equivalent). N deposited in urine is far in excess of what plants can take up and utilise, especially in low plant growth periods (or fallow conditions), causing a build-up of N in the soil, which is readily leached in the wet and muddy conditions. (Dalley & Van der Poel, 2008).

Overseer, a computer modelling tool, was initially developed as a fertiliser decision aid for pastoral farmers. Regional councils have recently begun using Overseer as a regulatory tool to measure the nitrogen losses from a farm system. This is despite its limited accuracy, which comes from the many assumptions contained within its complex models (especially the cropping model). Although never designed for use as a regulatory tool (Overseer is better at predicting N loss from a catchment area-not from an individual farm) it has now become the "tool of choice" by many regional councils. Overseer is updated regularly with development from further research, which results in changes in modelled nutrient losses to water. (Cichota & Snow, 2009; Williams et al., 2013)

This study will be based on the analysis of how Overseer models nitrogen losses when management practices are changed. This will provide the information on how to mitigate nutrient losses to water that farmers need to meet regulatory standards. This is specifically regarding Canterbury winter dairy grazing systems. The requirement for individual dairy support farmers to reduce nutrient losses (by 22% from the calculated baseline nitrogen loss by 2022) means that management changes will have to be implemented on farm (Environment Canterbury, 2015). To determine if a management change will make any significant impact to a farms nitrogen loss (as modelled by Overseer), the current Overseer model (v6.2.2) is used to develop and test farm wintering systems for both fodder beet and kale systems. Average farm systems (as determined by case studies from within the Selwyn Te Waihora catchment) are modelled through Overseer, and then adjusted to determine the effect of management changes on nutrient leaching.

There has recently been an increase in research around management practices which can mitigate/ reduce the loss of nitrogen to water. These practices include using a “catch crop”, altering total diet protein through the use of feed supplements, fertiliser use and efficiency of use and the effect of soil type on nutrient losses. However there is little research available on how Overseer measures the effect of these changes, which is critical to farmers given Overseer’s use in regulation.

Further research is required about how Overseer models changes in management practices on nutrient leaching. This will provide the information about mitigating nutrient losses to water that farmers need to meet regulatory standards. Due to the irregular updates and new versions of Overseer released this area of study is going to need constant attention.

2 Honours Literature Review

2.1 Introduction

The purpose of this literature review is to evaluate current research and knowledge of dairy fodder crop wintering systems. It is particularly focussed on the economic and environmental implications of crop and management choices within the farm system, given the increasing regulations surrounding nutrient and water management in New Zealand. Particular focus is given to the current regulations, monitoring/ measurement of environmental impacts and available options to reduce/ mitigate the negative environmental effects. The literature review will identify gaps in knowledge and highlight areas for subsequent research.

2.2 Farm systems theory

Farm systems theory was developed after the1960's Reductionist approach (looking at a single isolated factor) failed to continue to provide further development within the agricultural industry. Farms systems theory is a holistic study of all factors contributing to the farm as a whole (Kelly & Bywater, 2005). This can be further expanded as "an assemblage of components which are united by some form of interaction and interdependence… to achieve specified agricultural objectives" (McConnell & Dillon, 1997).

Successful farm management therefore requires at least a basic understanding of the principles of soil science, plant and animal husbandry, accountancy, finance, economics and sociology (Dent, Harrison, & Woodford, 1986). Altering one aspect may have unintended consequences on other aspects or the farm system as a whole due to the complex interactions between the system elements.

Farm systems revolve around inputs, outputs and the environment (regulatory, economic and physical) and as such will vary significantly across landscapes and disciplines (Kelly & Bywater, 2005). This is important. Within Canterbury the regulatory environment is changing, introducing constraints around nitrogen leaching, as a result of the negative impact that farming systems are having on the physical environment. Farming systems have intensified to maintain economic viability within a constantly evolving economic environment.

The use of OVERSEER is important as it is meeting regulatory requirements through computer modelling of the whole farm system to determine nutrient leaching. By looking at the whole farm system "nutrient leaky" activities can be identified and managed, and opportunities to reduce the nutrient losses to water can be identified and utilised on farm.

2.3 Dairy Wintering

Dairy wintering can be defined as the winter management of dry dairy cows. Correct winter management is critical as it affects the profitability of the whole dairy farm system. The winter diet affects the body condition score of the dairy cows, which in turn impacts on the following season's milk production, reproductive performance and the growth of young stock. (Dalley & Van der Poel, 2008; Pinxterhuis, Dalley, Tarbotton, Hunter, & Geddes, 2013)

Heightened pressure to increase profitability by improving production/ ha on the milking platform has led to the rapid intensification of dairy farms. This, along with low winter pasture growth rates (due to soil temperatures below 9°C and heavy frosts common in the South Island of NZ), have been key drivers in the shift to dairy support blocks for wintering dry cows and raising replacement stock (Dalley & Van der Poel, 2008). To combat the low winter pasture growth rates, spring sown forage crops (commonly brassicas such as kale and swedes, cereals such as forage oats, and more recently fodder beet) are grown and grazed in situ the following winter. (Dalley & Van der Poel, 2008; Gibbs, 2011).

22,000ha of dairy support land is located within the Selwyn region, making up 9% of the catchment area (Lilburn, 2014). Some of which is dairy owned dairy support, and the remainder is owned by independent third parties/ contract graziers.

Control is the motivation for owning/ leasing a runoff dairy support block as opposed to contract grazing winter dry cows and young replacement stock. Substandard experiences for farmers when contracting stock out has resulted in many farmers deciding the cost of outsourcing the work is too high (Dalley, Wilson, Edwards & Judson, 2008). When contracts are successful a long term relationship is often formed between the dairy support and the dairy farmer which may continue for many years.

2.4 Forage wintering systems

There are several dairy wintering systems ranging from housed fully indoors to wintered solely outdoors on fodder crop, as seen in the diagram below. However grazing fodder crops in situ is the most common system, with 60% of surveyed farmers from Southland using the system. This is at least in part due to the low capital investment cost of the system (Pinxterhuis et al., 2013), but also because it provides a high energy, cheap source of feed on a proportionally small area.

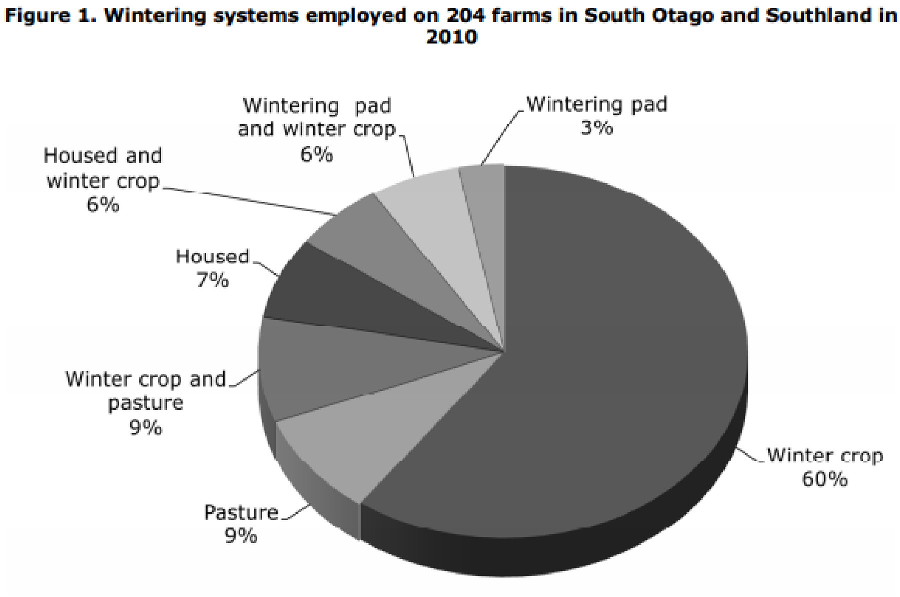

Figure 1(Pinxterhuis et al., 2013)

2.4.1 Fodder beet

Fodder beet as a wintering crop has become increasingly popular over the past 10 years, with an estimated increase in use from 100ha grown nationally in 2006 to 15,000ha in 2014 (Gibbs, 2014). This has been driven by extensive research and extension activities advocating for its use on farm.

Fodder beet , while difficult to grow a successful crop (as it is prone to failure of <10tDM/ha (Oswald, 2011)) can achieve realistic yields of up to 35tDM/ha. Fodder beet is a high energy feed of 11.8-12.5 MJME/kgDM, with low (11%) protein and can be grown at low cost of 8-10 cents/kgDM, with high utilisation of up to 95%. These attributes all contribute to make it a valuable fodder crop during winter months when pasture growth is minimal (Gibbs & Saldias, 2014 a).

Fodder beet is difficult to grow as it is susceptible to many factors which affect the strike rate and yield of the crop. Variation in soil type, cultivation and seed placement can all affect the germination and emergence of fodder beet, which can affect yield by as much at 10tDM/ha across a paddock. (Robinson, 2016). Fodder beet is also very sensitive to soil pH and soil fertility, which needs to be planned for a recommended 18months before planting, as fodder beet has a taproot which can reach as far as 1.5m down. (Munro, 2016)

Fodder beet is considered a “careful” crop, which requires careful management to avoid animal health issues. Fodder beet is very high in water soluble carbohydrates, and mismanagement of feeding can lead to acute ruminal acidosis. In sub-acute cases this will result in live weight loss, reduced animal performance and animals refusing the fodder beet. In acute cases up to 5% of a herd have been known to die from the acidosis (Gibbs & Saldias, 2014 a). Correct management of the transition period onto the fodder beet will allow the rumen microbiology to adapt to the feed, and over 14 days animals can be fully adjusted to an ad- libitum fodder beet diet.

Fodder beet yield can be highly variable throughout a season, within a paddock and between paddocks. Careful and accurate assessment of the yield is necessary to ensure accurate allocation of feed/ head/day.

2.4.2 Kale

Kale has a history of use as a winter crop for dry dairy cows within the South Island of New Zealand. Kale can produce high yields of feed, averaging 13.6tDM/ha, with little deterioration of nutritive quality over the winter. The nutritive value of kale varies within the plant, with the tops and leaves reaching up to 12.7MJME/kgDM, while the tough stem near the base of the plant may only reach an ME of 6.6MJME/kgDM (Judson & Edwards, 2008). Kale is high in protein, (though protein varies between studies from 12-18% crude protein in DairyNZ's feed supplement publication, to 18 -21% crude protein in (Gibbs & Hughes, 2008)), and can be grown for as little as $800-1200/ha (Agricom, 2012). Kale utilisation varies with feed allocation and climatic effects, but an average of 80% utilisation has been measured across Canterbury wintering farms. (Judson & Edwards, 2008).

Kale is an easy forage crop to both grow and feed. Kale is much less susceptible to factors such as soil type, cultivation, seed placement/ drilling depth than fodder beet.

Kale (a brassica) is high in sulphites, and has some risk of containing toxic levels of S-methyl cysteine sulphoxide (SMCO's) which when consumed can cause fatal haemolytic anaemia. The concentration of SMCO's varies with season, region and year, with research providing little understanding of why this occurs. Kale can also cause nitrate poisoning of cattle if they are poorly transitioned onto the crop, a result of rapid plant growth and high nitrogen requirements. (Gibbs & Hughes, 2008).

2.4.3 Feeding levels

Due to the yield of forage crops, wintering dry dairy cows can be contained to a smaller area on kale or fodder beet than if wintered on pasture or pasture/oats. At an estimated average yield of 23tDM/ha fodder beet (for Canterbury), wintering 1000 cows, would require 29ha. For a 14tDM/ha crop of kale it would require 47ha (Judson, 2008). The land for both crops would be utilised from November the previous year through to the end of July. Wintering the same 1000 cows on pasture within Canterbury would take 268ha. At a cover of 3700kgDM/ha, grazed to leave a residual of 1200kgDM (the minimum residual during winter as specified by DairyNZ), there is 2500kgDM available per hectare (Hawkins, A. 2016). The pasture would have to be shut up in March to ensure sufficient cover is retained to meet stock requirements over winter.

It is a far more efficient use of land to winter cows on high yielding, high energy forage crops than pasture.

Getting feed intake right is critical for the success of wintering dairy cows. If insufficient feed is available then the dairy cows will not achieve required live weight gain, impacting on the following season's milk production. To ensure the dry cows receive sufficient feed to meet their energy requirements for maintenance and live weight gain, accurate assessment of crop yield is required. A study completed at 49 sites in Canterbury identified that 2/3 of herds were consuming less than the target intake by more than 1kgDM/head/day. (Judson & Edwards, 2008)

Intakes in excess of 150MJME/day will ensure cows gain the required body condition score over an eight week wintering period (Edwards, deRuiter, et al., 2014). Industry standard feed levels of 11kgDM/day of crop along with 3kgDM/day of supplement are used in a number of animal trials (Edwards, deRuiter, et al., 2014; Farrell, 2015; Rugoho, 2013). There is disparity between dry matter intake (metabolisable energy) and animal metabolisable energy requirements. This is suggested to be for a number of reasons including overestimating the ME of the crop, underestimating the ME requirements for maintenance and live weight gain, over estimating the utilisation of feed, and disparity between actual and estimated digestibility of feed (Edwards, deRuiter, et al., 2014)

2.5 Environmental concerns

New Zealand has an international competitive advantage for dairy due to its low cost pasture and clover based systems. New Zealand is efficient at growing pasture and producing milk due to its temperate maritime climate, which allows for pasture growth and animals to be housed outdoors year round. However due to the increased intensification of the New Zealand dairy systems there is increased pressure on soil and water resources, resulting in increased stocking rate as well as off farm wintering on forage crops. Both dairy farming and dairy wintering systems are significant non-point sources of nutrient (N and P) and faecal bacteria contamination of ground and surface waters. (Monaghan, de Klein, & Muirhead, 2008). Dairy wintering accounts for a disproportional amount of environmental effects, including degraded water quality and soil structure, and increased green-house gas emissions and soil erosion. A recent Southland study found that for a whole dairy farm system, the wintering caused 44% of leaching, from only 15% of the land (Monaghan, Beare, & Boyes, 2009).

2.5.1 Soil degradation

The high densities of stock required to graze high yielding winter fodder crops can cause soil compaction and pugging damage. A study by Drewry and Paton (2005) found that a kale/ swede wintering system with a stocking density of 556 cows/ ha resulted in severe soil compaction, increasing the bulk density of the soil and reducing the porosity. This damage will be more severe for weaker soil structures, such as a pallic or gley soil, and will be further compounded if there is high water content in the soil- such as is common in winter. (Monaghan, 2012)

Soil damage and compaction weakens soil structure, increasing the susceptibility of soils to P and sediment loss with surface water runoff. The compaction damage from pugging and treading can reduce the productivity of soil, impacting on the growth of future crops/ pasture covers (Monaghan, 2012). DairyNZ estimates that pasture production can be reduced by 20-80% for four to eight months. From Northland, New Zealand, Farmers Grant and Christine Wes have measured their paddocks and found that they produce 29% less DM/year if severely compacted from stock during winter (Anonymous, 2013).

The damage from winter grazing compaction can be fixed if it is short term/ part of a pasture renewal program. Repeated cropping can result in cumulative damage, reducing future productivity of the soil. Irrigated pastures have been found to suffer longer effects of soil compaction, while dryland pastures recover more quickly (Paton & Houlbrooke, 2010). A good cropping rotation with permanent pasture as well as direct drilling/ minimum tillage between crops can also help improve soil structure stability, reducing the risk of stock damage. (Monaghan, 2012)

2.5.2 Nitrate leaching

Nitrate leaching is increasingly becoming the focus of environmental concerns all over New Zealand. Nitrate (NO_3^-) is the most commonly available form of mineral nitrogen, and as a negatively charged ion it is repelled from the negatively charged soil ion exchange sites. This means it is readily leached from the soil profile when water drains through (McLaren & Cameron, 1996). Canterbury in particular is focussing on regulating the nitrate losses from soil as over 200,000ha of the Canterbury region has shallow stony soils which are free draining, and therefore are particularly vulnerable to nitrate losses from high intensity systems (Di & Cameron, 2002).

Animal urine patches are the single biggest source of N for leaching from grazed farmland (Monaghan et al., 2008). Dairy cattle urine patches can load 500-1000kgN/ha equivalent, which is far beyond the amount that growing plants can uptake and assimilate. Excess urine N accumulates in the soil profile, which unless immobilised in the soil organic matter or lost to the atmosphere, is then readily leached (McLaren & Cameron, 1996). The higher the stocking rate, the greater the density of urine patches, and the more nitrate nitrogen is likely to be lost from the soil.

Grazed forage crop systems have a higher risk of nitrogen losses to water due to low plant growth and nutrient uptake and high stocking rate, increasing the deposition of excretal and urine nitrogen. Also, large amounts of mineral nitrogen are still in the soil from the soil cultivation and crop establishment from the previous spring. (de Klein, Monaghan, Ledgard, & Shepherd, 2010; Monaghan et al., 2008)

2.5.3 Water quality

Studies have found that 39% of New Zealand's monitored ground water has levels of nitrate elevated above the natural background nitrate content, with some areas exceeding the New Zealand Food Safety Authorities (NZFSA) drinking water nitrate concentration limit of 11.3ppm. (Baskaran, Cullen, & Colombo, 2009).

Degrading water quality can lead to eutrophication of waterways. This is where an increase in algal bloom and noxious aquatic plant growth reduces oxygen levels, killing aquatic life off and severely limiting recreational activities. Elevated levels of nitrate in drinking water can also cause methaemoglobinaemia (blue baby syndrome), causing asphyxiation and death in extreme cases (McLaren & Cameron, 1996).

Dairy and dairy wintering has contributed to this state of water quality. Individually the farm agronomic practices have minimal effect, but as an industry the contribution to water degradation is significant. If current farm management practices continue then water quality will further degrade, which may impact on New Zealand's global clean green image (Baskaran et al., 2009).

2.6 Regulations for nutrient leaching

Within New Zealand there are increasing concerns over the environmental impact on land and water quality of dairy farming and wintering dairy cattle. The intensification of dairy farming over the previous 15 years, especially in water sensitive areas such as Canterbury and Otago, is attracting the general public's attention (Baskaran et al., 2009). The Parliamentary Commissioner for Environment has outline issues associated with the recent intensification, and called for a redesign of farm systems (Parfitt, Baisden, Schipper, & Mackay, 2008).

New Zealand Regional councils have the authority to introduce regulatory controls on land use, and many, including Environment Canterbury (ECan), have introduced a nitrogen loss cap based on the land’s baseline figure for historical land use, as calculated through nutrient budgets (Parfitt et al., 2008). Environment Canterbury, Otago Regional Council, Environment Southland, Waikato Regional Council, and Environment Bay of Plenty currently specify using OVERSEER (a computer based nutrient modelling tool) to estimate nutrient losses from agricultural properties (Williams et al., 2013).

2.6.1 Environment Canterbury

The Environment Canterbury (ECan) region is the focus of the study due to the basis of the research location and specific rules and regulations.

ECan has redefined how water and land is managed, “Since the 1970’s land use intensification has increased pressure on rivers and aquifers. Communities have become increasingly concerned about water quality and cultural health of waterways. This has led to a complete change in the way we manage water.” (Environment Canterbury, 2016a).

Ten Water Management Zones have been defined within the Canterbury region, each with their own committee which determines the target areas and time specific goals within that nutrient zone/ catchment (see figure 2).

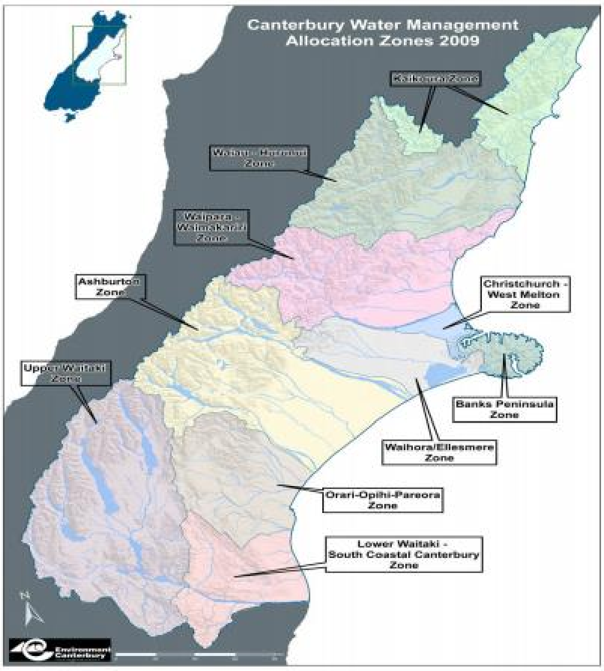

Figure 2 Canterbury Water Management Zones (Environment Canterbury, 2009)

Land areas are then further defined and managed according to their nutrient allocation risk zones. If located within a high risk zone with poor water quality then most farming activities are not permitted activities unless consented. The three most relevant nutrient allocation zones to farming activities are:

- Red- water quality outcomes are not met
- Orange- at risk
- Green- meets water quality outcomes

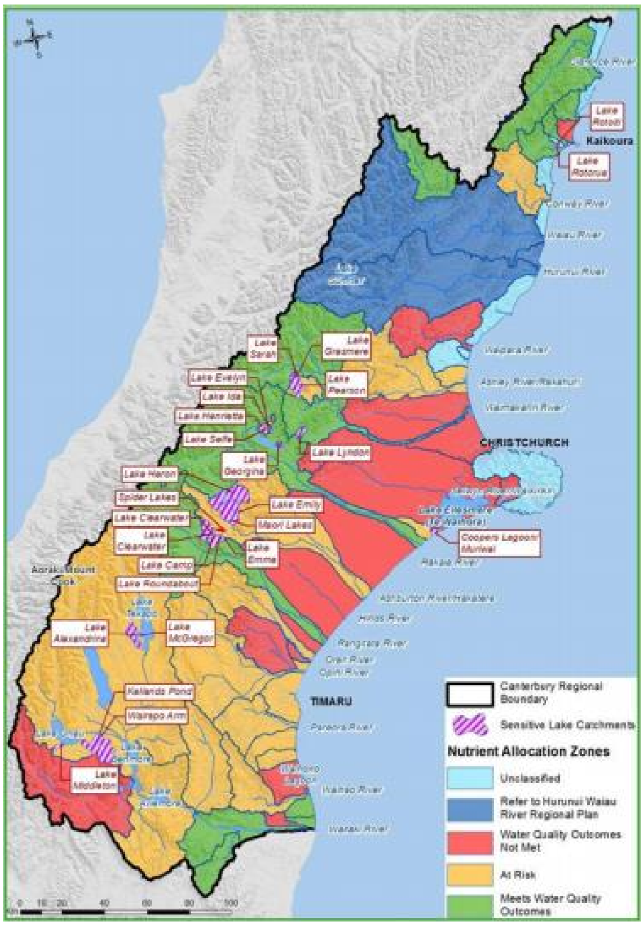

Figure 3 Nutrient Allocation Zones (Environment Canterbury, 2012)

2.6.2 Selwyn Te Waihora -Variation 1

The Selwyn Te Waihora zone, north of the Rakaia River and south of the Waimakariri River is considered a particularly high risk zone. Reduced water flows in rivers and lowland streams along with increasing measured nitrate concentrations in waterways have all contributed to the decreasing health of Lake Ellesmere. (Environment Canterbury, 2016b)

Plan change 1 (Variation 1) of the Land and Water Regional Plan has outlined specific rules and policies to improve the land use management and water quality within the Selwyn Te Waihora zone. These rules and policies have particular focus on managing water abstraction and use, and the discharge of contaminants, to reduce the cumulative effects on water quality within the catchment (Environment Canterbury, 2015). Policy is in place to reduce nitrogen losses to water by 14% beyond what is readily achievable through good management practice by 2022. Farming activities under an irrigation scheme are managed as a collective- under an umbrella consent with permitted quota nutrient losses to be distributed by the irrigation scheme as seen fit. (Environment Canterbury, 2015)

2.6.3 What this means for farmers

Different farming systems are expected to achieve different reductions in nitrogen losses to water. The N loss reduction is measured as a percentage decrease from the baseline N loss figure for the property- as calculated using Overseer nutrient budgets for the 2009-2013 time period unless the farming system is already operating with less than 15kgN/ha loss.

- Dairy farms 30% reduction
- Dairy support 22% reduction
- Irrigated sheep beef and deer 5% reduction
- Arable 7% reduction
- Dryland sheep and beef 2% reduction

This N loss reduction must be achieved by 2022, and is backed up by a farm environmental plan (FEP). Farmers are expected to achieve these reductions by implementing changes to farming practices halfway between good management practice and maximum feasible mitigation, depending on financial viability of the changes. (Environment Canterbury, 2015)

2.7 Overseer Nutrient Budgets

Reliable estimation of nutrient losses from farming systems is of increasing interest, driven by both economic and environmental concerns. Accurate measurements of nitrogen leaching losses are difficult to obtain and impractical given the scale and variability in farming systems. Computer modelling of a farm system is the most practical alternate for assessing potential nutrient losses from a system (Cichota & Snow, 2009; Lilburne, Webb, Ford, & Bidwel, 2010).

As mentioned previously, Overseer is a computer model originally designed as a tool to support pastoral farming in New Zealand with nutrient and fertiliser use by producing a nutrient budget. Overseer has evolved into a model which evaluates the nutrient cycles of the whole farm system and is now widely used as a regulatory tool for regional authorities to understand and manage nutrient loss to water. (Williams et al., 2013)

Overseer generates a report based on empirical relationships and readily available farm data, evaluating the farm system and nutrient inputs and outputs (Cichota & Snow, 2009). Within the Overseer program there are numerous background models containing equations based on researched knowledge. Where knowledge is incomplete, assumptions have been made (Selbie, Watkins, Wheeler, & Shepherd, 2013). Overseer analyses information at a block and a farm system level, modelling nutrient movements for the whole system. N loss is modelled through two pathways, the urine and background N models. Typically urine N is lost at 60-90% of ingested N from feed supply (Selbie et al., 2013). However current understanding on N pathways is lacking, with uncertainty about the proportion of N lost to water, de-nitrification, volatilisation and erosion (Parfitt et al., 2008). More research is required to fill in the gaps.

More recent developments of Overseer have seen a cropping model included in the program. While Overseer is likely to still be the best tool available to model the complex cropping systems, it contains many simplifications in the crop, soil and nutrient interactions. Further research is required to determine if these simplifications are suitable to measure the cropping system, or if they impair Overseer's ability to accurately model the cropping interactions (Williams et al., 2013).

2.8 Management options to reduce leaching

A number of studies have been completed to determine the effectiveness of different mitigation strategies to reduce nitrogen leaching losses. Nitrogen losses are affected by climatic effects as well as management; however some changes are possible without dramatic changes to farm systems.

Obvious management strategies include dropping stock numbers or changing the farm system away from nitrogen expensive farm systems such as wintering dairy cattle. Other options such as dicianamide (DCD), a chemical nitrification inhibitor, are no longer legal to use within New Zealand farming systems. DCD has proven to be effective at reducing N loss to water by 37-54% through slowing down the pathway converting ammonium into nitrate, which is more readily leached (Malcolm, Cameron, Edwards, & Di, 2015). The use of feed pads and restricted grazing are also proven methods to reduce nitrogen leaching from wintering systems (Monaghan et al., 2008), however they are outside the scope of this research due to their high capital investment requirements.

The locations of growing winter forage crops are important as light stony soils, such as are common in Canterbury, are highly susceptible to N leaching losses. However lighter soils are less susceptible to water saturation, which can cause pugging, resulting in increased surface runoff taking sediment and phosphorus into waterways (McDowell, Wilcock, & Hamilton, 2013).

Nitrogen fertiliser needs to be used efficiently; to both maximise N use efficiency by crops, as well as avoiding wastage. Crop choice has a significant effect on N use efficiency, as a recent study found that fodder beet was much more efficient, producing 99kgDM/kg N applied compared with only 45-58kgDM/kgN applied for early and late kale crops respectively (Edwards, deRuiter, et al., 2014).

Irrigation management is important as it can both increase plant nitrogen uptake by stimulating growth in a dry season and reduce water drainage (through a soil through correct irrigation scheduling). The more water passing through a soil, the more nutrients will be leached out. (Selbie et al., 2013)

Planting a "catch crop" directly behind a grazed winter crop is an uncommon practice. Normal practice involves a winter fodder crop grazed in situ, remaining fallow until re-planted with next winter's crop in 3-4 months' time. All the winter deposited urine N will remain in the soil unless leached out to ground water. By planting a follow up "catch crop" some nitrogen in the soil can be taken up. Recent studies conducted using lysimeters in Canterbury found that a green 'chop' oats crop planted within 63 days of grazing will reduce nitrate leaching by 34% on average (19-49% range), taking up 60-80kgN/ha from the soil. The effectiveness of a catch crop is likely to be affected by the season's climate- as certain growing conditions need to be met for a successful crop to be grown. (Carey, Cameron, Di, Edwards, & Chapman, 2016). While crops such as oats can access the shallow deposited urine N from winter, a deeper rooted crop such as chicory has the potential to absorb nutrients from much lower down in the soil profile. An estimated >70% of soil nitrogen may be located below the root zone at 30cm. In a trial comparing cereals with deep rooted crops such as chicory, chicory recovered the most N (75kgN/ha) over the trial period, from spring to the following autumn. It was highlighted that there is an issue with the length of time required for a crop to develop a deep root system to access the mineral N below the conventional root zone. Retaining more mineral N higher up in the soil profile (by grazing later) would allow for more N to be taken up (Lucci, Shephard, & Carlson, 2015).

Reducing the nitrogen concentration in urine will have a significant impact on nitrogen loss to water, as the majority of nitrogen loss to water from winter fodder crops is from urine deposited nitrogen. The nitrogen concentration in urine is directly affected by dietary nitrogen. Different fodder crops contain different nitrogen levels. Fodder beet is low in nitrogen with only 11% crude protein (CP), resulting in low urine nitrogen concentrations of only 2.1 gN/L. In comparison to this a kale based diet with higher CP of 15% has urine nitrogen concentration of 2.3-2.7gN/L. Both the kale and fodder beet diets are low in protein at less than 300g N/day (based on 8kgDM crop, 6kgDM pasture silage for fodder beet and 11kgDM crop and 5kgDM green chop oats for a kale crop) compared with pasture based diets which often far exceed 300gN/day. (Edwards, De Ruiter, et al., 2014). Further studies simulating a fodder crop wintering system (fodder beet and kale) align with this, showing the fodder beet study as leaching 64-79kgN/ha (averages for the 2013 and 2013 seasons (Malcolm et al., 2016), while the kale study had leaching levels of 213kgN/ha (Malcolm et al., 2015).

2.9 Conclusion

The recent intensification of farm systems in New Zealand and in particular Canterbury has increased nitrogen losses to water, causing health risks and eutrophication of waterways. Nitrate levels are elevated above background levels in 39% of monitored waterways, with some higher than the NZFSA recommended levels of 11.3ppm.

Government and regional councils have responded by creating regulatory controls around N losses to water for farm systems, with a future requirement for leaching reductions, in some cases across entire regions. This is particularly important for farm systems which winter dry dairy cows on forage crops (a common system to preserve pasture quantity for the following spring), as it is a particularly "nutrient leaky" system. Dairy support land makes up 9% of the Selwyn Te Waihora catchment zone, with forage crops commonly grown as supplement feed. Fodder crops grazed in situ have much higher stocking rates than pastoral grazing, depositing significant amounts of urine nitrogen (which can contain nitrogen loading of 500-1000kgN/ha equivalent). N deposited in urine is far in excess of what plants can take up and utilise, especially in low plant growth periods (or fallow conditions), causing a build-up of N in the soil, which is readily leached in the wet and muddy conditions.

Overseer, a computer modelling tool, was initially developed as a fertiliser decision aid for pastoral farmers. Regional councils have recently begun using Overseer as a regulatory tool to measure the nitrogen losses from a farm system, despite its limited accuracy caused by the many assumptions contained within its complex models, especially the cropping model.

There has recently been an increase in research around management practices which can mitigate/ reduce the loss of nitrogen to water. These practices include using a "catch crop", altering total diet protein through the use of feed supplements, fertiliser use and the effect selective grazing of crops on different soil types on nutrient losses. However there is little research available on how Overseer measures the effect of these management practices on nitrogen leaching, which is critical for farmers given Overseer's use in regulation.

Further research is required about how Overseer models changes in management practices on nutrient leaching. This will provide the information about mitigating nutrient losses to water that farmers need to meet regulatory standards.

3 Research methods

3.1 Introduction

As discussed in the literature review it is becoming increasingly important for farmers to be able to implement management changes which result in a decrease in nitrogen losses to water. Therefore this study will be based on the analysis of how Overseer models nitrogen losses when management practices are changed. This will provide the information on how to mitigate nutrient losses to water that farmers need to meet regulatory standards.

Case study farms, industry experts and published research will all be used to develop an accurate model for both a kale forage crop wintering system and a fodder beet forage crop wintering system.

3.2 Research objective

The research objective for this research is:

- To determine the effectiveness of different management options on reducing nitrogen losses to water from a kale or fodder beet forage system, as measured by Overseer 6.2.2.
- Identify the differences in the two forage crops and determine if one crop is particularly favoured over the other considering increased nitrogen loss regulations, particularly within the Selwyn Te Waihora catchment.

NB: This project will be completed using the current version of Overseer, OVERSEER 6.2.2. The results and discussion are specific to this overseer version. Once Overseer is updated (on the 7th November 2016) these results may no longer be current.

3.3 Research approach

The research approach is quantitative. Specific data collected from case study farmers was collated with current research and good management practices (as determined through discussions with industry experts on fertiliser use, crop and feed management) to model dairy support units through Overseer 6.2.2. The nitrogen loss to water figures for both fodder beet and kale will be critically analysed.

A qualitative discussion on the results generated by Overseer, the confidence in the results and their impact on the farm management system (including the practicality of the forage crops) will follow. Industry expert opinion, environmental regulations and “common farm practice” (as determined through the case study visits) will all be analysed. This will determine the effect of fodder crop selection on the whole farm system, the nitrate leaching regulations, the size or scale of the system and any scope for change.

3.4 Obtaining data

Data gathered from the case study farmers focuses on the dairy support system within the whole farm system. This is for ease of comparison between kale and fodder beet. Four case study farms were identified by Guy Trafford and Marv Pangborn as suitable for the project. Farms are all located within the Selwyn Te Waihora catchment in Canterbury.

Case study farmers were contacted first by phone to identify their willingness to participate. This was followed up by a detailed explanatory email, specifying the information required and why it is required. A personal on- farm visit was then conducted to collect all the required information. Only one visit was necessary for each farm.

Experts identified from Agricom, PGG Wrightsons and DairyNZ were contacted along the same lines once the case study farms were visited, and all information collated. Information on fertiliser regimes, crop rotations, potential crop yields and best management practice was all collected.

3.5 Quantitative research methods

3.5.1 Nutrient analysis

A nutrient budget for each case study farm has been constructed using OVERSEER 6.2.2. This information was used to compare the current farm system with the farm's nutrient baseline, to determine the effect of any farm system changes if there were any.

OVERSEER is a comprehensive nutrient budgeting computer tool which calculates the inputs and outputs of nitrogen (N), phosphorous (P) and other macronutrients. It produces a simulation based on specific farm location, climate and historical data about the farm's production, livestock, and fertiliser regime and soil types. It is commonly used on New Zealand dairy farms to develop fertiliser recommendations and has recently become mandatory for all farms in the Canterbury region to model nitrogen leaching (Environment Canterbury, 2014).The nitrogen leached to groundwater (available in the Overseer reports) will be the focus of the environmental analysis, as this is the figure which is used by regional councils as a regulatory control. It is acknowledged that both N lost to atmosphere and P loss is also relevant, but is outside the scope of this project.

The information gathered from the case study farms was used to create a model within OVERSEER to represent the average Canterbury dairy support unit. This model was then adjusted to determine the effects of management changes on nitrate leaching, for both fodder beet and kale crops.

3.6 Qualitative research

While collecting specific numbers and figures from case study farms for the quantitative research, qualitative information is also required. Information regarding how the fodder crops fit into the whole farm system, ease of use, and crop rotation has also been gathered. Opinions from the farmers about stock performance and health, crop yields and soil degradation have all been collected to determine how both forage crops fit into the whole system. This information is unlikely to have been measured by the farmers, and therefore is not quantitative. This surveyed information is to be critically compared to published literature to determine if common on farm management practices are consistent with current good management practices, as outlined by research and industry recommendations.

4 Case study farms

4.1 Farm selection

As outlined in research methods above, four case study farms were identified and contacted to collect data for kale and fodder beet crops, which was used to create a representative model of a dairy support unit. This model was then run through Overseer 6.2.2 with different management options.

Four case study farms were identified with the help of Guy Trafford and Marv Pangborn. To be suitable for the research the farms had to meet certain specifications.

- Farms were to all be located within the Selwyn Te Waihora catchment zone in Canterbury. The research focus is on Variation 1 in the Land and Water Regional Plan, which outlines policies and rules regarding management practices and nutrient loss to water restrictions specific to this zone.
- The farms were all to have dairy support as a component of the whole farm system. This research focuses on the environmental issues of dairy wintering systems and the management options available to reduce nitrogen losses to water.
- An equal number of kale and fodder beet crops between all the selected case study farms was necessary to ensure enough data was available to conduct a fair analysis.
- The farmers were required to be open to participating in the research and have good historical farm records to ensure any data collected is both reliable and relevant.

Data collection occurred on farm after initial contact by phone and email. Data relevant to farm system, current management practices, farm physical attributes and financials for the kale and fodder beet crops were all recorded. Sufficient information on the current farm system had to be available to ensure an accurate Overseer nutrient report could be completed. Data gathered is outlined in table 1 below. More detailed information is recorded in appendices 10.1 to 10.4.

4.2 Case study farm quantitative information

Table 1 Overview of case study farms

	Dairy Support Land Farm Data			
	Farm A	**Farm B**	**Farm C**	**Farm D**
Area (total)	523, 483 ha effective	455ha	330ha	550ha
Location	North Rakaia River vicinity	Hororata	North Rakaia River vicinity	Hororata
Climate	Annual rainfall - 712 mm, average temperature - 11.3, PET- 880mm	Annual rainfall - 794mm, average temperature - 11.3, PET- 882mm	Annual rainfall - 735 mm, average temperature - 11.1, PET- 1020mm	Annual rainfall - 872 mm, average temperature - 11.1, PET- 860mm
N Baseline	61kgN/ha/year	36kgN/ha/year	32kgN/ha/yr	NA
N current system	61kgN/ha/year	78kgN/ha/year	32kgN/ha/year	
CPW	yes	yes	yes	yes
Kale	45ha	70ha	0ha	42ha
Fodderbeet	45ha	30ha	27ha	0ha
Farm system	Dairy support	Arable + Dairy support	Arable + Dairy support	Sheep, beef, arable, dairy support
Stock classes	290 MA Carry-over cull dairy cows, 5400 wintered dairy cows (all friesian)	800 Dairy calves, 90 Coopworth sheep, 50 Trading steers, 1800 MA dairy cows wintered.	50 trading steers, 300 dairy heifers, 1000 MA dairy cows for wintering	2200 MA Coopworth ewes, 310 MA Angus cows, 70 trading cull cows, 650 Friesian calves, 320 MA dairy cows
Dominant soil type	Eyre silty loam	Lismore silt loam	Lismore silt loam	Claremont silt loam
Soil Features	Well drained, gravelly loam, moderate to high PAW (70-104mm in top 60cm)	Well drained, moderate PAW (86mm in top 60cm)	Well drained, moderate PAW (86mm in top 60cm)	Poorly drained, moderate to deep soil with high PAW (90mm)
Other soil types	Numerous well drained loam soils. 100ha stony fluvial loam, with low PAW (46-55mm). 109 ha of Waimakariri silty loam with very high PAW (109-141mm), 109ha of Lismore shallow silty loam with moderate PAW (86mm)	Darnley silt loam, stony, moderately well drained with low PAW (54mm in top 60cm)	Numerous silt loam soils ranging from Waimakariri (PAW of 141mm) to Eyre soil (PAW of 70mm)	Two shallow silty loams (Ruapuna and Darnley soils), well drained with a high PAW (94mm) aand low PAW (54mm) respectively. A deep silty loam Mayfield soil with moderate PAW (81mm) and a riverbed soil- basically stones.
Irrigation	473 ha irrigated, 59 ha dryland	Fully irrigated	242ha Irrigated	210ha irrigated
Type	Centre pivot and lateral irrigators	Centre Pivot	Centre Pivot and Travelling irrigators	Centre pivots
Water supply	170ha of CPW irrigation, 303ha Rakaia Gallery	CPW	CPW	CPW
Irrigation Management	Some precision Irrigation, neutron probes and irrigation scheduling	Irrigation scheduling, soil moisture content readings from 3 neutron probes	Irrigation scheduling and visual assessment of soil to determine moisture	Some VRI irrigation, visually asses soil moisture for irrigation scheduling
Supplement feeds	4000T/ DM	250T DM	360T DM	256 T DM
Source	On farm	On Farm and purchased	On farm	On farm and purchased
Type	Cereal and Grass Silage	Barley Straw and Pea Vine harvested, RG straw purchased	Barley straw and grass silage	Barley grain and straw, pasture and cereal silage all harvested on farm, RG straw purchased
Destination	Wintering dairy cows (6kgDM/d for 55 days) and sold off farm	Barley straw to wintering MA dairy cows, pea vine to replacement heifers on pasture	80% silage/ straw fed out on winter crops, remainder fed to replacement heifers	Barley- MA ewes, P and C silages- farm stock, barley straw- wintering dairy cows. RG straw- calves on crop
Winter crop mgmt	Sold standing at $0.23/kgDM (current prices)	Sold standing at $0.21/kgDM (current prices)	Sold standing at $0.21/kgDM (current prices)	Sold standing at $0.21/kgDM (current prices)
Grazing revenue Kale				
Yield	Average 16tDM/ha	Average 14tDM/ha	-	Average 12.5tDM/ha
Cost	$1299/ha	$1690/ha	-	$1732/ha
Income	$3680/ha	$2940/ha	-	$2625/ha
Gross Margin	$2380/ha	$1250/ha	-	$893/ha
Grazing revenue Fodder beet				
Yield	26tDM	23tDM	26.5tDM	-
Cost	$2535/ha	$2331/ha	2815/ha	-
Income	$5980/ha	$4830/ha	$5565/ha	-
Gross Margin	$3444/ha	$2499/ha	$2749/ha	-
Yield test methods	Commercially tested	Tested on farm	Commercially tested	Tested on farm

Crop rotation	Fodder beet> barley> pasture for 3 years> Kale> barley> Pasture for 3 years	Pasture> Fodder beet (spring)> fallow> Kale (spring)> Barley> Greenfeed oats	Fodder beet> Fodder beet> Barley grain> Pasture for 3 years	Pasture> Kale> Cereal (barley or wheat) > Rape> Pasture for 3 years
Fertiliser use practises				
Kale	when Olsen P<20 then NPKS is 170:60:60:3 when Olsen P>20 NPKS is 156:45:70:2	200kg/ha DAP at sowing, 2x 150kg/ha Urea, early January and Mid february.	-	250kg/ha borated DAP at sowing, 100kg/ha Urea January, 150kg/ha Urea March.
Fodder beet	when K<7 NPKS is 129:45:105:26 when K>7 NPKS is 91:41:30:18	200kg/ha DAP + 150kg/ha KCl + 80kg/ha Kieserite + 20kg/ha NaCl at sowing. 150kg/ha Urea mid February	385kg/ha Fodder beet Base (Ballance) + 5t/ha poulfert	-

4.3 Case study qualitative information

Table 2 Case study farms qualitative information

	Dairy Support Land Farm Data			
	Farm A	**Farm B**	**Farm C**	**Farm D**
Contracts/ relationships	Long term winter grazing contract with Southern Pastures Dairy fams.	Regular winter dairy graziers	Regular winter dairy graziers	Family connection to dairy farm.
Reason for wintering crop selection	Fodder beet and kale work together well as feed sources and crop rotation.	Kale been grown on farm historically- easy and simple. Fodder beet has higher crop potential on smaller area.	Historically grew kale but yields were dropping and contracted winter grazing wanted FB so switched.	Kale used as simple and safe feed, and used historically. Fits pasture rotation and renewal and is profitable.
Outlook going forward	Whole farm system is based on dairy support,	Needs higher profit for winter grazing to be continued.	Needs higher profit for winter grazing to be continued.	-
Animal Health	Acidosis common on fodder beet, not kale. Break out over wires more common in fodder beet.	Fodder beet is higher risk for animal health- acidosis and death, than kale.	-	Kale is simple to grow and is a safe feed.
Soil Damage	Fodder beet suffers heavier pugging damage than Kale	-	Historical kale yields dropping, soil responds better to fodder beet now	-

5 Pilot study

5.1 Initial Overseer analysis

A necessary component of the project is analysing the surveyed farms with OVERSEER to assess their nutrient budgets in relation to current and impending Environment Canterbury regulations. Overseer, while used as a regulatory tool for nutrient management for farms within the Canterbury region, has shortcomings in accuracy and reliability (Williams et al., 2013). Designed to model pastoral system nutrient flows, it is inconsistent for cropping and horticulture.

An initial analysis of kale and fodder beet wintering systems using Overseer found an anomaly which limited confidence in the results when directly comparing the two crops. Overseer has upper and lower feeding limits for crops, which varied with crop yield and crop type (as seen in table 3 below).

Table 3 OVERSEER upper and lower feeding limits

		Min feed intake	Max feed intake
	Crop Yield	kgDM/hd/day	
Kale	8tDM/ha	8.2	11.7
	16tDM/ha	11.7	15.5
Fodder Beet	15tDM/ha	6.9	9.7
	29tDM/ha	8.8	12

Considering industry practice allocates 11kgDM crop/ head/day, four of the scenarios modelled above are feeding below industry standard (Industry standard feed levels of 11kgDM/day of crop along with 3kgDM/day of supplement are used in a number of animal trials (Edwards, deRuiter, et al., 2014; Farrell, 2015; Rugoho, 2013)). The crop type, or crop yield should not influence animal feed allocation. This indicates that Overseer has models and equations within the program which allocate feed based on crop type and crop yield, rather than animal energy requirement. As the complex models within Overseer are not public knowledge, it was impossible to determine how feed levels are allocated between different crops and crop yields and overcome this issue. Being unable to match feed allocation of crops on Overseer to the feed allocation of common wintering systems (a comparative study was considered impractical) and so an alternate method was used for the comparison.

5.2 Thought experiment

Due to differences in feeding levels (and thus energy intake) associated with the yields and crop varieties, it was determined that a direct comparison between fodder beet and kale using Overseer was not beneficial. To overcome its shortcomings a thought experiment based on published data has been conducted and is used to “create a story” to compare fodder beet and kale as winter fodder crops and assess the relative influences on N leaching.

5.2.1 Model parameters:

- 1000 cows to be wintered off farm on 3rd party dairy support.
- Friesian-Jersey cross bred cows, average of 500kg live weight (LW).
- Dry cows in calf with a 35kg LW calf, calving 1st August.

- Wintered on either fodder beet or kale for 61 days (1st June to 31st July).
- Feed offered 14kgDM/head/day, 11kgDM crop, and 3kgDM barley straw; as this has been identified as common practice from case study farmers.

5.2.2 Nitrogen application required for fodder beet and kale crops

Table 4 Thought Experiment- Nitrogen Application

Nitrogen application		
	Fodder beet	**Kale**
Yield (estimated Canterbury average)	23tDM/ha	14tDM/ha
Stocking rate/ area (ha)	*1000 cows at 11kgDM/day for 61 days*	
	660 kgDM/head	
	660000 kgDM total	
	660000/23000	*660000/14000*
	28.7	*47.1*
Area (ha)	29 ha	47 ha
Nitrogen use for growth	*Assume N at a rate for protein in crop potential*	
	23tDM/ha	*14tDM/ha*
CP%	*12% crude protein*	*15% crude protein*
kg CP/ t DM	*120kg/ 1000kgDM*	*150kg/ 1000kgDM*
Nitrogen/ tDM	*19.2 kgN/t crop potential*	*24 kg N/ t crop potential*
N/ha	*19.2 * 23*	*24 * 14*
	441.6	336
	Assume Urea to supply 80% of crop potential N requirements, remainder supplied by soil mineral N, rainfall, irrigation	
	*441.6 *0.8*	*336*0.8*
Fertiliser N applied / ha	353.28	268.8
Total applied for 1000 cows	*353.3 * 29*	*268.8 * 47*
Tonnes N applied (total)	10.2	12.6

To winter 1000 cows at 11kgDM/crop/day for 61 days requires 29 ha of fodder beet, or 47 ha of kale. The high yield of fodder beet (23tDM/ha) relative to kale (14tDM/ha) requires a higher stocking rate so less land is required.

Nitrogen application is assumed to be at 80% of crop requirements for the estimated crop yield. Crop fertiliser requirements are determined by the crude protein proportion of each crop (12% for fodder beet (Oswald, 2011) and 15% for kale (DairyNZ, 2015)).

Fodder beet requires 353kgN/ha applied, 10.2 tonnes of nitrogen in total. Kale requires 269kgN/ha, 12.6 tonnes of nitrogen in total.

5.2.3 Nutrition requirements for dry dairy cows over winter

Table 5 Thought Experiment- Stock Nutrition Requirements

Stock requirements		
Energy requirements	**(MJME)**	
Maintenance	*500kg LW cow*	57MJME/day
Live weight gain	*1/2 BCS = 16.5 kg LW*	
	48 MJME/kg LWG	
	*48*16.5 = 792*	
	792/ 61 days	13 MJME/day
Pregnancy	*35 kg LW calf*	
	June Average (6weeks)	17 MJME/day
	July Average (2weeks)	30 MJME/day
June Total MJME/day	*57 + 13 + 17*	87 MJME/day
July Total MJME/day	*57 + 13 + 30*	100 MJME/day
Protein requirements	**(gN/day)**	
Maintenance	*500kg LW cow*	211gMP/day
Live weight gain	*300g MP/kg LWG*	
	*300*16.5/ 61 days*	81gMP/day
Pregnancy	*35kg calf*	
	June average (6 weeks)	141gMP/day
	July average (2 weeks)	222gMP/day
June Total Protein	*(211+81+141)/6.25*	69.3gN/day
July Total Protein	*(211+81+222)/6.25*	82.24gN/day

Stock requirements for energy and protein are calculated using equations given in Pasture and Supplements (Nicols and Brookes, 2007). As stated in 3.2.1, nutrition requirements are calculated for a 500kgLW cow, gaining half a body condition score (16.5kg LW) and supporting a foetus growing into a 35kgLW calf. Protein (in metabolisable protein, MP) and energy (in mega joules of metabolisable energy, MJME) requirements are averaged separately for June and July due to the increasing pregnancy requirements over winter.

June nutrition requirements are 87MJME/head/day and 69.3gN/head/day consumed (not offered). July nutrition requirements are 100 MJME/head/day and 82.2gN/head/day consumed.

5.2.4 Daily nutrition supplied by a 11kgDM crop and 3kg DM supplement diet

Table 6 Thought Experiment- Diet Nutrition

Daily nutrition		
	Fodder beet	**Kale**
Energy /cow/day	*12.5 MJME/kgDM*	*11.5 MJME/kgDM*
(MJME)	*12.5 * 11*	*11.5 *11*
	137.5	126.5
	at 95% utilisation	*at 80% utilisation*
	137.5 0.95*	*126.5 *0.8*
	130.625	101.2
PLUS	*3kgDM barley straw/ head/day*	
	*3 * 7 MJME/kgDM*	
	*21 *80% utilisation*	
	16.8	
Total MJME/cow/day	*130.6 + 16.8*	*101.2 + 16.8*
	147.4	117.9
Protein/cow/day	*12% CP*	*15% CP*
	*11 *12% = 1.32 kgCP*	*11 * 15% = 1.65kgCP*
	1.32/6.25 = 211g N/day	*1.65/ 6.25 = 264gN/day*
	at 95% Utilisation	*at 80% Utilisation*
	200.5	211.2
PLUS	*3kgDM barley straw/ head/day*	
	*5% CP * 3kgDM = 150gCP*	
	*150/6.25*80% = 19.2gN/head/day*	
Total gN/cow/day	*200.5 + 19.2*	*211.2 +19.2*
	219.7	230.4

Fodder beet

- 12.5MJME/kgDM (Gibbs, 2011)
- 12% crude protein (Oswald, 2011; DairyNZ, 2015)
- 95% utilisation (Gibbs, 2014; Edwards et al., 2014)

Kale

- 11.5MJME/kgDM (DairyNZ, 2015)
- 15% crude protein (DairyNZ, 2015)

- 80% utilisation (DairyNZ, 2015; Judson, 2008)

The fodder beet and straw diet provides 147.4 MJME/head/day and 219.7gN/head/day. The kale and straw diet provides 117.9MJME/head/day and 230.4gN/head/day.

5.2.5 Nitrogen balance for the 1000 cow wintering system

Table 7 Thought Experiment- Nitrogen Balance

Nitrogen balance		
	Fodder beet	**Kale**
	29ha	47ha
Nitrogen inputs		
In crop potential		
80% Urea	*10.2tN*	*12.6tN*
20% Other	*2.6tN*	*3.2tN*
Crop total	12.8 TN/ha	15.8tN
In supplement	*3kgDM at 5%CP for 1000 cows for 61 days*	
	*(3*0.05*1000*61)/6.25*	
	1.46tN	
Total nitrogen inputs	*12.8+1.46*	*15.8+1.46*
	14.26 tN	17.26 tN
Nitrogen outputs		
protein removed in products	*LWG and pregnancy for 1000 cows over 61 days(maintenance N replaces N excreted)*	
June removed	81+141gMP/day	
	222/6.25	*35.52gN/hd/day*
	35.52*1000*30	1.065tN
July removed	81 + 222gMP	
	303/6.25	*48.48gN/hd/day*
	*48.5*1000*31*	1.5tN
Total N outputs	*1.065T N + 1.5T N*	
	2.565tN	
Therefore excess N in system	11.7tN	14.7tN
	Excess N in system for 1000 cows	
Excess N / cow	11.7kgN/cow	14.7kgN/cow
Excess N/ ha	403kgN/ha	313kgN/ha

Nitrogen inputs and outputs to the 1000 cow dairy wintering system were calculated. Nitrogen input to the system (from fertiliser, soil mineralisation and supplement imported) is 14.26 tonnes nitrogen for fodder beet, and 17.26 tonnes of nitrogen for kale. Nitrogen removed in products (animal live weight gain and pregnancy) is calculated at 2.56 tonnes of nitrogen for 1000 cows. Maintenance nitrogen replaces the excreted endogenous nitrogen. Excess nitrogen in the system is calculated at 11.7kgN/cow for fodder beet, vs 14.7kgN/cow for kale. However per hectare there is 403kgN/ha excess for fodder beet, and 313kgN/ha excess for kale.

Not all excess N is leached- some will be lost to ground water, some lost to atmosphere through volatilisation and de-nitrification and some will remain in the soil either immobilised or as part of the organic soil pool. The extent of the partitioning of the excess N within the system is beyond the scope of this thought experiment and research.

Key assumption:

- Feeding levels are reasonable for winter grazing, based on case study farms. However according to a recent study wintering dry dairy cows should be fed in excess of 150MJME/head/day to meet all energy requirements (Edwards, 2014). This disparity between calculated feed requirements and nutrient intake needed has been highlighted before (see Edwards 2014). So assumptions are actually underfeeding the dry stock- more so for cows on Kale.

5.2.6 Conclusions from thought experiment

Table 8 Fodder beet and Kale nitrogen use comparison (for 1000 cows)

	Fodder beet	**Kale**
Yield	23tDM/ha	14tDM/ha
Area	29ha	47ha
Nitrogen application		
Per hectare	353kgN/ha	269kgN/ha
Total	10.2tN	12.6tN
Excess nitrogen		
per hectare	403kgN/ha	313kgN/ha
per cow	11.7kgN/cow	14.7kgN/cow
total	11.7tN	14.7tN

Fodder beet is a higher yielding crop than kale, with a lower crude protein content. Due to its high yielding energy dense crop, fodder beet can winter 1000 dairy cows on only 29ha, as opposed to kale's 47ha. Fodder beet requires less nitrogen per tonne of dry matter (low crude protein content), but more nitrogen per hectare grown (due to its high yield) than kale. Total nitrogen use is less for fodder beet than kale, to feed 1000 cows, at 10.2 ton vs 12.6 ton.

A fodder beet diet provides more energy than a kale diet, due to its high water soluble carbohydrate content, resulting in a low fibre high energy feed. While both the kale and the fodder beet diets provide more than the calculated daily energy requirements for the dry stock, neither diet provides more than 150MJME/head/day eaten (after wastage), as recommended in a study by (Edwards, 2014) to achieve body condition score gain of a half score over the winter period.

A fodder beet crop results in less excess nitrogen over the whole 1000 cow dairy wintering system than kale, at 11.7 vs 14.7 ton nitrogen. A fodder beet crop has less excess nitrogen per cow, but more excess nitrogen per hectare than a kale crop.

6 Management options for reducing nitrogen leaching

The input data in tables 9 and 10 was used as the base system to model the effect of various management systems on nitrogen leaching for both a 10ha kale crop and a 10ha fodder beet crop (not wintering 1000 cows). All management changes are easily achievable, with no large capital expenditure involved. The model inputs were chosen to reduce confounding factors in the model, so any changes can be easily assigned to a cause and effect.

The management options modelled included

- Altering the nitrogen application rate up to the calculated requirement of nitrogen for a 23tDM/ha crop of fodder beet or a 14tDM/ha crop of kale. Nitrogen applied ranged from the nitrogen in 250kg DAP applied at sowing through increases of 100kgUrea increments, up to theoretical optimum application amount of 353kgN/ha for fodder beet and 269kgN/ha for kale, as determined in 5.2.2.
- Altering the feed supplement selection. The five feed supplements used were barley straw, at 6.5MJME/kgDM and 4.5% crude protein, good quality grass silage, at 11MJME and 17% crude protein, Cereal silage at 9-10.5 MJME/kgDM and 13-16% crude protein, maize silage at 10 MJME/kgDM and 8% crude protein, and balage at 10MJME/kgDM and 11% crude protein (DairyNZ, 2015).The amount (in kgDM) allocated was kept constant for all supplements, feeding at a ratio of 11kgDM crop: 3kgDM supplement, at 38tDM for 10ha kale and 63tDM for 10ha fodder beet.
- Altering the soil type the forage crops were grown on, using variety of soil types to determine the effect of soil on nitrate leaching. Soil types were selected along a spectrum from soils commonly found in Canterbury. These ranged from very light, well drained soils such as the Lismore sib 18, to very heavy poorly drained soils such as the Flaxton sib 4 soil.
- Altering the length of fallow period for each crop after grazing. Modelling the effect of a paddock left fallow for spring or the effectiveness of a catch crop of oats in reducing nitrogen leaching losses. A catch crop of forage spring oats was sown due to the crops ability to germinate early in spring whilst still cool soil temperatures.

The model used in Overseer is 10ha for both kale and fodder beet. Supplement is provided at a level consistent with 11kgDM crop: 3kgDM supplement. Stocking rate was aimed to be set at a rate that allowed for 11kgM/head/day of crop to be consumed. This was outside the model feeding limits for both kale and the fodder beet crops. Instead the mid-point between upper and lower feeding bounds was found, with the stock numbers set at that point. This resulted in 242 cows wintering on kale, feeding on 9.5kgDM kale with 2.6kgDM straw a day, and 526 cows wintering on fodder beet, feeding on 7.2kgDM fodder beet with 2.0kgDM straw a day.

Table 9 OVERSEER Kale Model

Overseer 6.2.2 Base Model Input Data 14tDM Kale Crop		
General	**Inputs**	**Justifcation**
Location	Canterbury	Selwyn Waihora region
Blocks	10ha Kale crop block	Reduces confounding factors within Overseer 6.2.2, allowing a clearer understanding of results
Enterprises	Beef/ Dairy grazing	
Structures	None	As feedpads are not common for 3rd party winter dairy grazers
Animal Distribution	Even	
Supplements Imported	38t DM Barley straw	Based on 11kg crop plus 3kg supplement offered daily feed (as common from case studies)
Beef/ Dairy Grazing		
Stock class	Dairy Grazing (milking cows)	
Numbers	242	Based on mid-point between upper and lower feed limit as set by Overseer 6.2.2 model
Months grazing	June, July	61 days of wintering
Breed	Friesian Jersey cross	Common dairy cow breed NZ
Weight	500kg LW	
Crop block		
Distance from coast	30km	
Crop rotation final month	September	
Climate	Climate station tool used for Dunsandel region	
Rainfall	660mm/rain/year	
Average Temperature	11.8 °C	
PET	914mm/year	
Soil	Lismore soil, Lism_1a.1 using SMap inputs	Most common soil type found in Selwyn Waihora district
Irrigation	Centre Pivot/ lateral irrigation	
Block History	0 years in pasture, crop previously grown	To remove influence of mineralising past crops/ pastures on soil N
Crop rotation	Kale > fallow > Kale (14t DM/ha)	Removes affect of other crops on soil N
Sown/ grazed	Sown November in year 1 and reporting year, grazed June/ July by on farm stock	
Fertiliser	250kg cropmaster DAP at sowing, Urea split evenly between November and March	Common fertiliser regime, Urea split evenly between months to remove effect of "dumping" urea which would increase volatilisation and leaching losses
Irrigation	Irrigation Nov to Mar, soil water budget,trigger point and depth applied to achieve target	Common irrigation management

Table 10 OVERSEER Fodder Beet Model

Overseer 6.2.2 Base Model Input Data 23tDM/ha Fodder beet Crop		
General	**Inputs**	**Justifcation**
Location	Canterbury	Selwyn Waihora region
Blocks	10ha Fodder beet crop block	Reduces confounding factors within Overseer 6.2.2, allowing a clearer understanding of results
Enterprises	Beef/ Dairy grazing	
Structures	None	As feedpads are not common for 3rd party winter dairy grazers
Animal Distribution	Even	
Supplements Imported	63t DM Barley straw	Based on 11kg crop plus 3kg supplement offered daily feed (as common from case studies)
Beef/ Dairy Grazing		
Stock class	Dairy Grazing (milking cows)	
Numbers	526	Based on mid-point between upper and lower feed limit as set by Overseer 6.2.2 model
Months grazing	June, July	61 days of wintering
Breed	Friesian Jersey cross	Common dairy cow breed NZ
Weight	500kg LW	
Crop block		
Distance from coast	30km	
Crop rotation final month	September	
Climate	Climate station tool used for Dunsandel region	
Rainfall	660mm/rain/year	
Average Temperature	11.8 °C	
PET	914mm/year	
Soil	Lismore soil, Lism_1a.1 using SMap inputs	Most common soil type found in Selwyn Waihora district
Irrigation	Centre Pivot/ lateral irrigation	
Block History	0 years in pasture, crop previously grown	To remove influence of mineralising past crops/ pastures on soil N
Crop rotation	Fodder beet > fallow > Fodder beet (23t DM/ha)	Removes affect of other crops on soil N
Sown/ grazed	Sown November in year 1 and reporting year, grazed June/ July by on farm stock	
Fertiliser	250kg cropmaster DAP at sowing, Urea split evenly between November and March	Common fertiliser regime, Urea split evenly between months to remove effect of "dumping" urea which would increase volatilisation and leaching losses
Irrigation	Irrigation Nov to Mar, soil water budget,trigger point and depth applied to achieve target	Common irrigation management

7 Overseer results

7.1 Introduction

The purpose of this chapter is to outline the results of the Overseer analysis of management options to reduce nitrogen losses to water. Both kale and fodder beet forage crops have been analysed to determine the success of different nitrogen loss mitigation measures. These measures are:

- Altering the nitrogen application rate
- Altering the feed supplement used in the animal diet
- Growing the crop on a variety of soil types
- Growing a catch crop after grazing as opposed to leaving the ground fallow

7.2 Kale Results

7.2.1 Effect of Nitrogen application rate on Nitrogen losses for a Kale wintering system

Table 11 Kale-Nitrogen application leaching results

Effect of Nitrogen application rate on Nitrogen losses for a Kale wintering system								
Nitrogen Application	**N Inputs (kg/ha/year)**				**N Losses (kg/ha/year)**		**Nitrogen Pools**	
	Fertiliser	Biological Fixation	Irrigation	Supplement	Atmospheric	Water (Urine/ Other)	Plant material	Organic pool
250kg DAP + 0kg Urea	43	2	8	24	20	21 (16, 5)	48	-34
250kg DAP + 100kg Urea	90	2	8	24	23	22 (17, 5)	48	9
250kg DAP + 200kg Urea	136	2	8	24	27	23 (18, 5)	48	49
250kg DAP + 300kg Urea	182	2	8	24	33	24 (19, 5)	48	88
250kg DAP + 400kg Urea	228	2	8	24	41	30 (20, 10)	48	120
250kg DAP + 500kg Urea	274	2	8	24	50	42 (22, 21)	48	123
250kg DAP + 600kg Urea	320	2	8	24	59	56 (24, 32)	48	121

Nitrogen losses to both atmosphere and water increase with increased nitrogen application per hectare. Total N losses to water increase slowly when urea applied increases from 0kg/ha up to 300kg/ha, at an increase of only 1kgN/ha for each 100kg urea increase. Past this tipping point nitrogen losses increase at a rate of 10 or more kgN/ha with each 100kg increase in urea application.

The loss of nitrogen to water is separated into two sources, leaching from urine patches and leaching from other. As seen in table 11 above, losses from urine make up the majority of total nitrogen losses initially. Once the tipping point of 300kg/ha Urea is reached, nitrogen losses from both urine and other sources increase, with the majority of the increase in N losses to water from other sources (see figure four below).

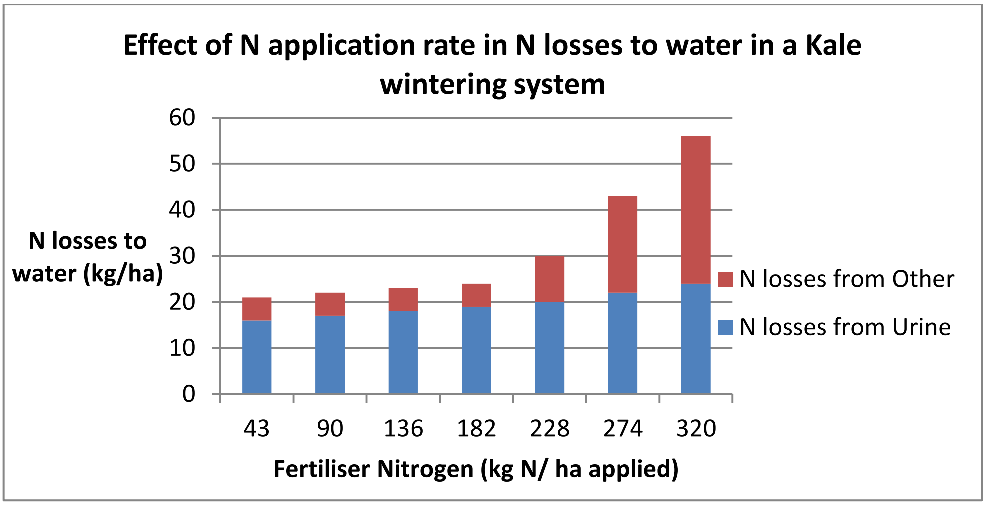

Figure 4 Kale- Nitrogen application leaching results

7.2.2 Effect of feed supplement choice on Nitrogen losses for a Kale wintering system

Table 12 Kale- Supplement selection leaching results

Effect of feed supplement choice on Nitrogen losses for a Kale wintering system								
Supplement type	**N Inputs (kg/ha/year)**				**N Losses (kg/ha/year)**		**Nitrogen Pools**	
	Fertiliser	Biological Fixation	Irrigation	Supplement	Atmospheric	Water (Urine/ Other)	Plant material	Organic pool
Barley straw	182	2	8	24	35	26 (19, 7)	48	102
Good quality grass silage	182	2	8	110	35	26 (19, 7)	48	182
Baleage	182	2	8	61	35	26 (19, 7)	48	137
Maize silage	182	2	8	43	35	26 (19, 7)	48	120
Cereal silage	182	2	8	61	35	26 (19, 7)	48	137

As seen in table 12 above, nitrogen inputs into the system from the import of supplements differs according to the feed composition of the supplement, with 24kgN/ha provided by barley straw and 110kgN/ha provided by good quality grass pasture silage.

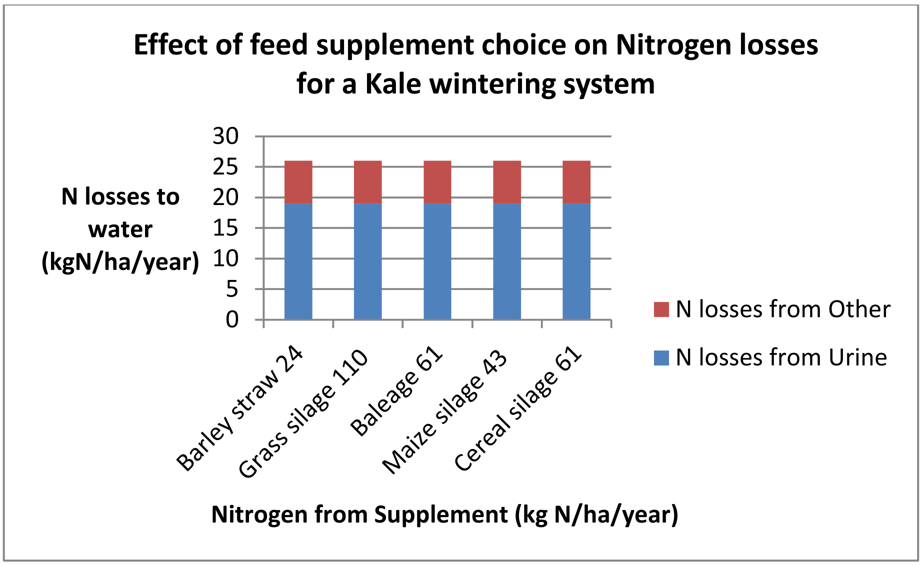

Figure 5 Kale- Supplement selection leaching results

As modelled by Overseer 6.2.2 there is no relationship between the nitrogen provided by the supplement and the level of nitrogen lost to water, through either urine or “other”. There is no change in N lost to water, remaining constant at 26kgN/ha (see figure 5). All excess nitrogen from feed supplement accumulates in the organic pool. This is not a reasonable result. Logic suggests there to be some increase in nitrogen loss to water.

7.2.3 Effect of soil type on nitrogen losses to water under a kale wintering crop

Table 13 Kale- Soil type leaching results

Effect of soil type on Nitrogen leaching from kale crops					
Soil Type (SMap ref)	**Lism_18a.1**	**Darn_1a.1**	**Lism_1a.1**	**Temp_1a.1**	**Flaxt_4a.1**
Soil Name	Lismore sib 18	Darnley sib 1	Lismore sib 1	Templeton sib 1	Flaxton sib 4
Soil order	Brown	Pallic	Brown	Pallic	Gley
Natural drainage	Well drained	Moderately well drained	Well drained	Moderately well drained	Poorly drained
PAW (top 60cm)	Low (49mm)	Moderate (80mm)	Moderate (86mm)	High (97mm)	Very high (146mm)
Total Nitrogen inputs (kgN/ha/year)	216	216	216	216	216
Annual rainfall (mm/year)	660	660	660	660	660
Annual irrigation to crop (mm/year)	342	310	318	317	338
AET (mm/year)	710	740	749	743	781
Total drainage water (mm/year)	293	230	230	233	217
water in	1002	970	978	977	998
water out	1003	970	979	976	998
	high	low	med	med	high
Nitrate concentration in Drainage water (ppm)	22.2	12.1	11.5	10	5.2
N lost to water (urine, other) (kgN/ha/year)	63 (40, 23)	27 (20, 7)	26 (19, 6)	23 (16, 7)	11 (6, 5)
Atmospheric N losses (kgN/ha/year)	30	38	35	49	71
Organic pool (kgN/ha/year)	69	98	102	93	85

As the profile available water (PAW) increases (PAW mm in the top 60cm of soil), the nitrate concentration in the drainage water drops and the total nitrogen losses to water decrease. In the moderate range of PAW there is little difference between soil types, but there is a difference between the two extremes in soil type.

The Lismore sib 18, a very light stony soil, has a low PAW of 49mm and leaching of 63kgN/ha. The Flaxton sib 4 soil, a heavy Gley soil with poor drainage, modelling the same system, has leaching of only 11kgN/ha (PAW of 146mm). The N concentration of the drainage water for the Lismore is very high, past the health recommendations of 11.3ppm, at 22.2ppm, while the Flaxton drainage water has a low concentration of only 5.2ppm.

Nitrogen loss is a function of drainage and nitrogen concentration. Irrigation is the same on the light Lismore and heavy Flaxton soils. The low nitrogen loss from the Flaxton soil is mostly due to low nitrogen concentration (5.2ppm) in drainage.

Any further understanding of the water balance model within Overseer is beyond the scope of this project.

7.2.4 Effect of crop rotation on nitrogen leaching from kale crops

Table 14 Kale- Crop rotation leaching results

The effect of crop rotation and fallow period on N loss to water			
		N loss to water (urine, other)	**Nitrate conc in drainage water (ppm)**
Combined	June/ July grazed as 1 block	26 (19,5)	11.5
Split	June block	35 (26,9)	15.5
	July block	24 (17,6)	10.6
	Farm average	30 (22,8)	
Oats sown in June block	July	29 (24,5)	13.5
	August	31 (25,6)	13.9
	Not sown	35 (26,9)	15.5

By splitting months grazed (June and July) into different blocks (with otherwise identical farm management) it can be seen that the June grazed kale crop loses more N to water (35 vs 24 from the July grazed block).

It is noted that the farm average nitrogen loss for the split grazing (30kgN/ha) is not the same as the nitrogen loss for the combined average (26kgN/ha).

The length of time a paddock is fallow will affect the N losses to water. A fallow paddock, without crop or pasture cover, is at risk of any rainfall passing straight through the soil, leaching any available nutrients as it goes. The longer the fallow period is, the greater the N loss. By establishing a crop such as fodder oats in July, directly behind the kale crop, and harvesting it for cereal silage in

November, N loss to water drops by 6kgN/ha to 29kgN/ha. A crop planted in August (following the kale crop) leaches more than a crop planted in July (31 vs 29kgN/ha), but is still less than having no crop planted before the kale is sown again in November (35kgN/ha leached).

7.3 Fodder beet results

7.3.1 Effect of Nitrogen application rate on N losses from a fodder beet wintering system

Table 15 Fodder beet- Nitrogen application leaching results

Effect of Nitrogen application rate on Nitrogen losses for a Fodder beet wintering system								
Nitrogen Application	**N Inputs (kg/ha/year)**				**N Losses (kg/ha/year)**		**Nitrogen Pools**	
	Fertiliser	Biological Fixation	Irrigation	Supplement	Atmospheric	Water (Urine/ Other)	Plant material	Organic pool
250kg DAP + 0kg Urea	44	2	8	40	24	37 (22, 15)	13	7
250kg DAP + 100kg Urea	90	2	8	40	27	41 (23, 18)	13	46
250kg DAP + 200kg Urea	136	2	8	40	31	45 (25, 21)	13	85
250kg DAP + 300kg Urea	182	2	8	40	36	50 (26, 24)	13	122
250kg DAP + 400kg Urea	228	2	8	40	43	58 (29, 29)	13	147
250kg DAP + 500kg Urea	274	2	8	40	53	74 (32, 42)	13	144
250kg DAP + 600kg Urea	320	2	8	40	63	91 (37, 54)	13	139
250kg DAP + 700kg Urea	366	2	8	40	74	108 (41, 67)	13	135
250kg DAP + 800kg Urea	412	2	8	40	85	125 (46, 79)	13	130

An increase in nitrogen fertiliser application results in an increase in nitrogen losses to water. Nitrogen losses to water increase by 4 -5 kgN/ha up to a rate of 300kg urea applied/ha. Past this point nitrogen losses to water increase at a greater rate, up to 125kgN/ha leached when 800kg of Urea is applied.

The organic pool of nitrogen increases up to a maximum of 147kgN/ha, achieved at 400kg Urea, before decreasing with each further increase in urea application.

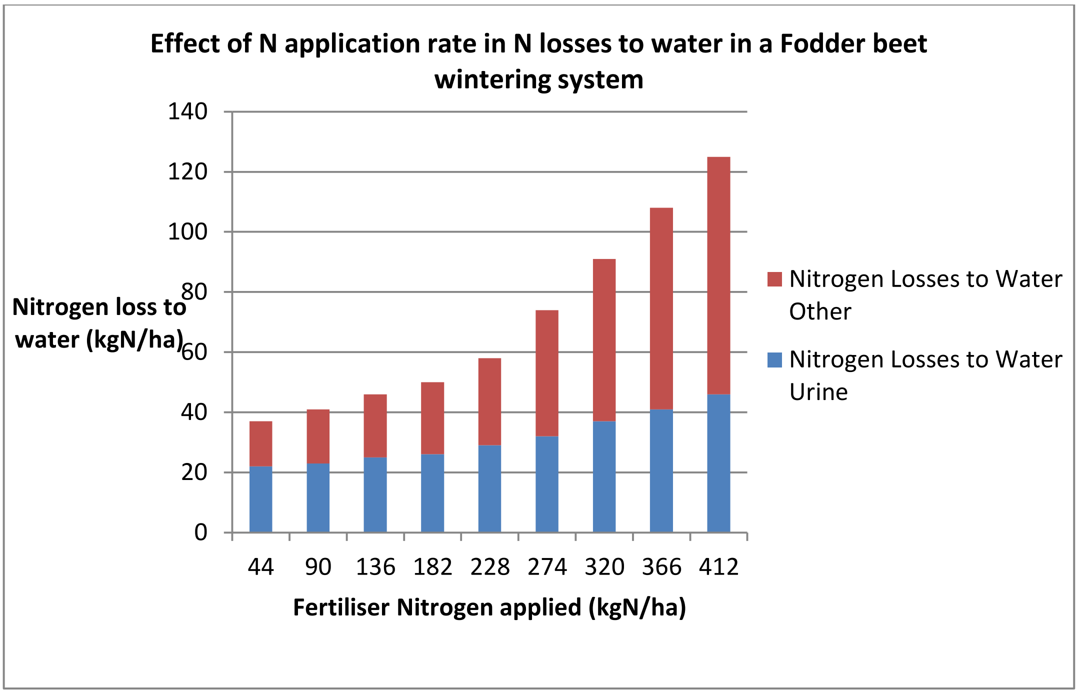

Figure 6 Fodder beet- Nitrogen application leaching results

N losses from urine increase steadily with each increase in nitrogen application. Nitrogen losses to water from "other" sources increase at a greater rate with each increase in nitrogen application.

7.3.2 Effect of feed supplement on nitrogen losses for a wintering fodder beet crop

Table 16 Fodder beet- Supplement selection leaching results

Effect of feed supplement choice on Nitrogen losses for a Fodder beet wintering system								
Supplement type	**N Inputs (kg/ha/year)**				**N Losses (kg/ha/year)**		**Nitrogen Pools**	
	Fertiliser	Biological Fixation	Irrigation	Supplement	Atmospheric	Water (Urine/ Other)	Plant material	Organic pool
Barley straw	182	2	8	40	36	50 (26, 24)	13	122
Good quality grass silage	182	2	8	183	36	50 (26, 24)	13	252
Baleage	182	2	8	101	36	50 (26, 24)	13	179
Maize silage	182	2	8	72	36	50 (26, 24)	13	152
Cereal silage	182	2	8	101	36	50 (26, 24)	13	179

All supplement feeds result in the wintering system leaching the same nitrogen to water irrespective of the nitrogen content of the supplement. The fodder beet wintering system with a barley straw feed supplement loses 50kgN/ha to water. This does not change if a good quality grass silage feed supplement is used. 63 tonnes (DM) of barley straw adds 40kgN/ha into the system, while the same amount of grass silage adds 183kgN/ha. As with kale, this does not seem likely.

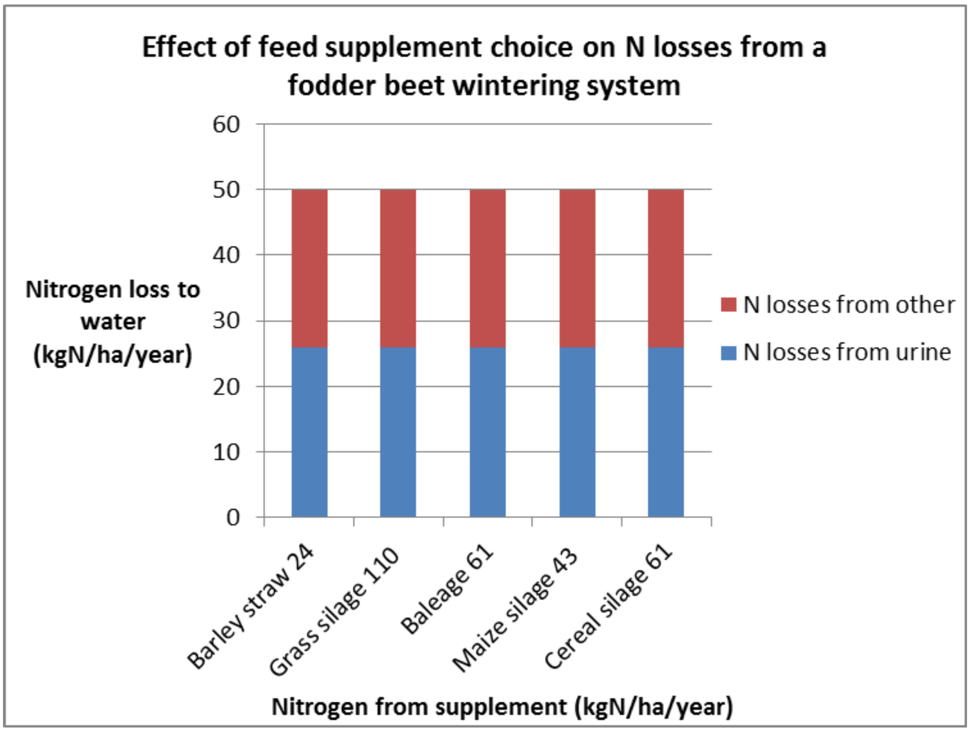

Figure 7 Fodder beet- Supplement selection leaching results

7.3.3 Effect of soil type on nitrogen losses to water for a fodder beet wintering crop

Table 17 Fodder beet- Soil type leaching results

Effect of soil type on Nitrogen leaching from fodder beet crops					
Soil Type (SMap ref)	**Lism_18a.1**	**Darn_1a.1**	**Lism_1a.1**	**Temp_1a.1**	**Flaxt_4a.1**
Soil Name	Lismore sib 18	Darnley sib 1	Lismore sib 1	Templeton sib 1	Flaxton sib 4
Soil order	Brown	Pallic	Brown	Pallic	Gley
Natural drainage	Well drained	Moderately well drained	Well drained	Moderately well drained	Poorly drained
PAW (top 60cm)	Low (49mm)	Moderate (80mm)	Moderate (86mm)	High (97mm)	Very high (146mm)
Total Nitrogen inputs (kgN/ha/year)	232	232	232	232	232
Annual rainfall (mm/year)	660	660	660	660	660
Annual irrigation to crop (mm/year)	349	322	326	323	342
AET (mm/year)	720	748	759	751	786
Total drainage water (mm/year)	289	234	228	233	216
water in	1009	982	986	983	1002
water out	1009	982	987	984	1002
	high	low	med	med	high
Nitrate concentration in Drainage water (ppm)	34.8	23.3	22.4	19.3	9.7
N lost to water (urine, other) (kgN/ha/year)	97 (53,44)	53 (27,20)	50 (26, 24)	44 (22,22)	20 (8,12)
Atmospheric N losses (kgN/ha/year)	30	38	36	50	73
Organic pool (kgN/ha/year)	81	116	122	113	114

As the profile available water increases (PAW mm in the top 60cm of soil), the nitrate concentration in the drainage water drops and the total nitrogen losses to water decrease. In the moderate range of PAW (the Darnley, Lismore 1a.1 and the Templeton soils) there is little difference between soil types, but there is a difference between the total extremes in soil type (between the Lismore 18a.1 and the Flaxton 4a.1 soil). The Lismore sib 18, a very light, well drained stony soil, has a low PAW of 49mm, and leaching of 97kgN/ha. When the Flaxton sib 4 soil, a heavy Gley soil with poor drainage, models the same system, it has leaching of only 20kgN/ha (PAW of 146mm). The concentration of the drainage water for the Lismore is very high, past the health recommendations of 11.3ppm, at 34.8ppm, while the Flaxton drainage water has a lower concentration of only 9.7ppm.

The light well drained with low PAW received high irrigation inputs, with low annual evapotranspiration rates (AET) and had high annual drainage. In comparison the heavy poorly drained soil also received high irrigation, but lost a lot of water to AET with little lost through drainage.

7.3.4 Effect of crop rotation on nitrogen losses to water from fodder beet crop

Table 18 Fodder beet- Crop rotation leaching results

The effect of crop rotation and fallow period on N loss to water			
		N loss to water (urine, other)	**Nitrate conc in drainage water (ppm)**
Combined	June/ July grazed as 1 block	50 (26,24)	22.4
Split	June block	55 (31, 25)	24.5
	July block	46 (23, 23)	20.8
	Split farm average	51 (27, 24)	
Oats sown in June block	July	41 (26, 14)	19.6
	August	44 (29, 15)	20.8
	Not sown	55 (31, 25)	24.5

The length of the fallow period affects the N losses to water. When winter grazing is split into two blocks the June grazed block leaches more than the July grazed block (55kgN/ha vs 46). It also has a higher concentration of nitrates in the drainage water, 24.5ppm vs 20.8ppm. The average of the two blocks is similar to the total of the single combined block, at 51kgN/ha vs 50kgN/ha respectively.

When a crop (forage spring oats) was sown after the June fodder beet crop was finished grazing (to be cut for silage and exported off farm) both the nitrogen losses to water and the nitrate concentration in the water dropped. The length of fallow drove the extent of N losses to water. The July sown oats leached only 41kgN/ha, the August sown oats leached 44kgN/ha, while having no crop sown, with the block remaining fallow until the fodder beet crop is re-sown, leached 55kgN/ha.

The N concentration in drainage water is 19.6ppm for a July sown crop, 20.8 for an August sown crop, and remains at 24.5 if no catch crop is sown.

7.4 Modelling a 22% nitrogen reduction

7.4.1 Kale nitrogen loss reduction

Table 19 Nitrogen leaching loss % reductions from crop management strategies

Changes in Kale crop management to reduce nitrogen leaching losses					
Nitrogen					
500kg Urea applied	56kgN/ha leached				
300kg Urea applied	24kgN/ha leached				
			% change	*-57.1%*	
Crop rotation					
Fallow	30kgN/ha leached				
Catch crop	26kgN/ha leached				
			% change	*-13.3%*	

When nitrogen application is reduced from crop recommendations to common farmer practice (see section 4, case study farmer notes) (500kg Urea to 300kg Urea) nitrogen losses decrease from 56kgN/ha leached to 24kgN/ha leached. This achieves a reduction of 57.1% in nitrogen lost to water.

The use of a catch crop planted in July behind the June grazed winter kale crop further reduces nitrogen losses to water by 13.3% over the whole farm (including the July grazed block). On just the June grazed block the nitrogen reduction is 17% (see section 7.2.4).

Table 20 Nitrogen losses from kale crops on different soils, with selective timing of grazing

Timing of grazing various soils types (Kale)			
Lismore soil only		**kgN loss/ha**	Mean N loss
	Grazed June only	36	30
	Grazed July only	24	
	Grazed June and July	26	
Flaxton soil only			
	Grazed June only	17	13.5
	Grazed July only	10	
	Grazed June and July	11	

As outlined in table 20 above, the combined nitrogen losses from a kale block grazed in June and July does not match the average nitrogen loss from the split grazing (26kgN/ha and 30kgN/ha respectively). To determine the reduction in nitrogen loss to water when grazing the heavier soil crops first simple arithmetic is used.

If grazing paddocks at random, with half the crop on the light Lismore (sib1) soil and half on the heaver Flaxton (sib 4) soil, it is expected that the farm nitrogen leaching loss is the total farm average. (36 + 24 + 17 + 10)/ 4 = 21.75kgN/ha lost.

If instead the light Lismore is grazed in June, followed by the heavy Flaxton soil grazed in July, the farm nitrogen losses calculate as (36 + 10)/ 2 = 23kgN lost.

If instead the heavy Flaxton soil is grazed in June, and the Lismore soil is grazed in July, the farm average calculates out at (17 + 24)/2 = 20.5kgN/ha lost.

The % reduction in nitrogen loss achieved by this is 5.7% (from grazing unselectively) and 10.9% (from grazing the Lismore soil in June).

7.4.2 Fodder beet nitrogen loss reduction

Table 21 Nitrogen leaching loss % reductions from crop management strategies

Changes in fodder beet crop management to reduce nitrogen leaching losses					
Nitrogen					
700kg Urea applied	74kgN/ha leached				
300kg Urea applied	36kgN/ha leached				
			% change	*-51.4%*	
Crop rotation					
Fallow	51kgN/ha leached				
Catch crop	43kgN/ha leached				
			% change	*-15.7%*	

When nitrogen application is reduced from crop recommendations to common farmer practice (700kg Urea to 300kg Urea) (see section 4) nitrogen losses decrease from 74kgN/ha leached to 36kgN/ha leached. This achieves a reduction of 51.4% in nitrogen lost to water.

The use of a catch crop planted in July behind the June grazed winter fodder beet crop further reduces nitrogen losses to water over the whole farm by 15.7% (including the July grazed block). The use of a catch crop reduces nitrogen leaching in just the June block by 25% (see section 7.3.4).

Table 22 Nitrogen losses from kale crops on different soils, with selective timing of grazing

Timing of grazing various soils types (Fodder beet)			
Lismore soil only		**kgN loss/ha**	Mean N loss
	Grazed June only	56	51
	Grazed July only	46	
	Grazed June and July	52	
Flaxton soil only			
	Grazed June only	20	17
	Grazed July only	14	
	Grazed June and July	16	

As outlined in table 22 above, the combined nitrogen losses from a fodder beet block grazed in June and July does not match the average nitrogen loss from the split grazing (52 kgN/ha and 51kgN/ha respectively), though it is closer than the figures for a kale crop. To determine the reduction in nitrogen loss to water when grazing the heavier soil crops first simple arithmetic is used.

If grazing paddocks unselectively (at random), with half the crop on the light Lismore (sib1) soil and half on the heaver Flaxton (sib 4) soil, it is expected that the farm nitrogen leaching loss is the total farm average. (20 + 14 + 56 + 46)/ 4 = 34kgN/ha lost.

If the light Lismore is grazed in June, followed by the heavy Flaxton soil grazed in July, the farm nitrogen losses calculate as (56 + 14)/ 2 = 35kgN lost.

If instead the heavy Flaxton soil is grazed in June, and the Lismore soil is grazed in July, the farm average calculates out at (46 + 20)/ 2 = 33kgN/ha lost.

The % reduction in nitrogen loss achieved by selectively grazing different soils at different times is 2.9% (from grazing unselectively) and 5.7% (from grazing the Lismore soil in June).

8 Discussion

8.1 Regulatory framework

8.1.1 Land and Water Regional Plan

Within New Zealand there are increasing concerns over the environmental impact of dairy farming and the wintering of dairy cattle, on land and water quality. Nitrate levels are elevated in 39% of monitored waterways, with some higher than the NZFSA recommended levels of 11.3ppm (Baskaran, 2009).

New Zealand regional councils are required by the Resource Management Act to introduce regulatory controls on land use. Many regional councils, including Environment Canterbury (ECan), have introduced a nitrogen loss cap based on the land's historical baseline figure for land use, as calculated through nutrient budgets (Parfitt et al., 2008). The Land and Water Regional Plan (LWRP) is a framework developed for Canterbury which provides clear direction on how land and water will be managed.

There are ten water management zones (including the Selwyn Te Waihora zone), each with their own zone committee. Target objectives and time specific goals are defined to meet the environmental requirements within the zone.

8.1.2 Selwyn Te Waihora

The Selwyn Te Waihora zone is considered particularly high risk due to reduced water flow levels and increasing concentration of nitrate decreasing the health of Lake Ellesmere (Environment Canterbury, 2016b).

Plan change 1 (Variation 1) of the Land and Water Regional Plan has outlined specific policies and rules to improve the land use management and water quality within the Selwyn Te Waihora zone. Policy is in place to reduce nitrogen losses to water by 14% across the catchment beyond what is readily achievable through good management practice by 2022.

"Where a property's nitrogen loss calculation is greater than 15kgN/ha/year, further reduce losses of nitrogen from farming activities by implementing management practices that are in the order of <u>half-way between good management practice and maximum feasible mitigation</u>" (page 197-B, policy 11.4.16 (1) Environment Canterbury, 2015). Any farming property leaching more than 15kgN/ha (the farm's nitrogen baseline period is from 1st July 2009 to the 30th June 2013) is required to reduce nitrogen leaching losses by 2022 to a level determined by the farm system. The reductions are a 30% nitrogen reduction for a dairy farm, 22% dairy support, 5% irrigated sheep, beef, deer and by 7% if an arable farm (or a reduction to 15kgN/ha is it is a lesser nitrogen loss).

Nitrogen reductions are specified according to farm system. However there could be uncertainty as to how a farm is classified as many have a mixed farming system. This can be seen through the four case study farms used for this project. Two farms are mixed arable and dairy support, one farm is a sheep, beef, arable and dairy support farm, and only one farm is solely dairy support. More discussions and guidelines are needed to determine how to classify farming systems.

8.2 Overseer and its use in regional policy

Overseer is a nutrient budgeting computer tool which was developed to help pastoral farmers identify their properties fertiliser requirement. However Overseer is increasingly being used as a regulatory tool, with Environment Canterbury, Otago Regional Council, Environment Southland, Waikato Regional Council, and Environment Bay of Plenty all using it to estimate nutrient losses from agricultural properties (Williams et al., 2013). The nutrient management rules in Canterbury's LWRP rely on Overseer. This is difficult as Overseer is continually being developed and updated, with each upgrade altering past results.

Overseer is seen as the most practical tool available (Williams et al., 2013). Accurate physical measurements of nitrogen leaching losses are difficult to obtain and impractical given the scale and variability in farming systems. Computer modelling of a farm system is the most practical alternate for assessing potential nutrient losses from a system (Cichota & Snow, 2009; Lilburne, Webb, Ford, & Bidwel, 2010). However, Overseer does have some shortcomings. Overseer is attempting to model the interactions between the crops, pasture, animal and soil models within the program, at times with limited research. The crop model is particularly limiting. It contains many simplifications in the crop, soil and nutrient interactions. Further research is required to determine if these simplifications are suitable to measure the cropping system, or if they impair Overseer's ability to accurately model the cropping interactions (Williams et al., 2013).

A number of these limitations were identified during this project, with 'work arounds' developed or published research used for a better understanding when applicable.

- Crop feeding levels within Overseer differed with crop yields (see section 5.1). Overseer has upper and lower limits on what can be fed. For example an 8tDM/ha crop of kale has feeding level limits between 8.2kgDM/head/day and 11.7kgDM/head/day, whereas a 16tDM/ha kale crop has feeding level limits between 11.7kgDM/day and 15.5kgDM/day. This is saying that upper and lower intake limits change with the yield of a crop for identical stock classes. This is clearly not correct. Feeding levels also varied between kale and fodder beet crops. The lower feed limits often didn't meet animal nutritional requirements or correspond with realistic on-farm feeding levels. A change in crop yield should not impact on the amount stock are fed. This made a direct comparison between fodder beet and kale using Overseer 6.2.2 difficult, with questionable reliability. Instead a thought experiment was developed using logic and published equations (see section 5.2) to allow for a direct comparison between fodder beet and kale.

- The Overseer 6.2.2 calculated nitrogen losses from the kale wintering system seemed low given the protein content of the crop, stocking rate and management practices associated with the system. Leaching of only 26kgN/ha for a 14tDM/ha crop, with 300kg Urea applied (182kgN applied) and grazed over winter is seems low. A trial conducted in Southland measuring the nitrogen leaching losses to water from a kale winter grazed crop recorded losses of up to 213kgN/ha (Malcolm et al., 2015).
- Supplement feeds have different nitrogen content due to the differing nitrogen/ protein. Logic would suggest that changing the nitrogen inputs into the system would cause a change in the nitrogen outputs. This was not reflected in the Overseer modelling, with barley straw (4.5% crude protein) and good quality grass silage (17% crude protein) having the same nitrogen losses to water from the system.

8.3 Management Options for Farmers

Farmers within the Selwyn Te Waihora zone are required to achieve a reduction in nitrogen leaching of 22% (for dairy support farms) by 2022. Therefore management changes which can assist in reducing nitrogen losses to water are required. Some options, such as reducing stock numbers or building feed pads/ feed lots may reduce profitability of the farming system or require a large capital expenditure. Other options such as using dicianamide (DCD) are no longer legal, despite the proven ability to reduce nitrogen losses to water. However some management changes are available to reduce nitrogen losses to water.

8.3.1 Fodder beet vs kale crop selection

Fodder beet has become increasingly popular in recent years, with 100ha grown in 2006 and 15,000ha in 2014 nationally (Gibbs, 2014). During the LWRP 2009-13 baseline period, kale was still more commonly used as a winter feed crop for wintering dry dairy stock than fodder beet. Therefore many properties will have a baseline measured for kale use, not fodder beet. LWRP requires management practices to be implemented beyond good management practice (GMP) to reduce nitrogen leaching. However it is unclear in the LWRP if the reduction in nitrogen losses is measured from the baseline nitrogen loss or if it is measured from the nitrogen loss level estimated from good management practice. Part of the decision about future use of fodder beet and kale is likely to be about the crops ability to minimise nitrogen losses while still remaining profitable, along with reliability of crop yield, animal health and soil performance over time.

Due to the difficulty of a direct comparison of the two crops using Overseer (see sections 5.1 and 8.2) a thought/ logic experiment was completed to attempt a direct comparison.

Fodder beet typically has a lower protein content than kale, at 11% crude protein (CP) compared to 15% for kale. Given that fertiliser is applied at a level to meet crop requirements, fodder beet has a lower nitrogen requirement per ton of dry matter than kale. Fodder beet also achieves significantly higher yields, at 23tDM/ha compared to 14tDM/ha, which results in a greater requirement for nitrogen/ha for fodder beet (353kgN/ha vs 269kgN/ha for kale). This is similar to Plant and Foods crop nutrient uptake calculator, which specifies 280kgN/ha for a 14tDM kale crop (there is no fodder beet calculator) (see appendix 10.5).

To winter 1000 dry dairy cows requires 29ha of fodder beet, or 47ha of kale crop (at 23tDM and 14tDM respectively). The results of the thought experiment suggest that fodder beet requires more applied nitrogen/ha, but less in total to feed 1000 cows than kale. The thought experiment shows that a fodder beet crop results in more excess nitrogen /ha, but less excess nitrogen /cow (and total nitrogen used for 1000 cows).

1000 cows can be wintered on 29ha of fodder beet, while kale requires 47ha. This frees up 18ha for other uses. So changing from kale to fodder beet for 1000 cows reduces total nitrogen loss. The nitrogen loss for the whole farming system will depend on how the 18ha is alternately used.

8.3.2 Winter forage crop management practices

As defined in sections 6 and 6.1, four management practices were modelled through Overseer 6.2.2 to determine their nitrogen loss mitigation. The management practices are: nitrogen use, feed supplement selection, soil type selection and growing a catch crop rather than leaving a paddock fallow after grazing.

8.3.2.1 Nitrogen use

These comments are based on taking the Overseer 6.2.2 results at face value. The impact of nitrogen use on both crop yield and nitrogen leaching should be considered, though these results look only at leaching. A study by Chakwizira (2009), found that kale response to nitrogen is significant, with an increase in kale yield of 2.5 t DM/ha when 170 kg N/ha was applied compared with 70 kg N/ha.

For a 14tDM/ha crop of kale nitrogen has been modelled ranging from 44kgN/ha (250kg/ha DAP) up to 302kgN/ha (250kg/ha DAP + 600kg/ha Urea). The tipping point for nitrogen use is at 182kgN/ha (250kg/ha DAP + 300kg/ha Urea), where the most nitrogen can be applied while nitrogen loss (24kgN/ha)does not increase much. Any further increase in nitrogen application results in increase in nitrogen loss, while any decrease in nitrogen application results in little change to nitrogen loss. This is for a continuously cropped paddock, so there is little soil nitrogen available from the soil.

It should be noted that common fertiliser practice (as identified through case study farms) applies 200-250kg/ha DAP at sowing, with an additional 250-350kg/ha urea applied, similar to Overseer's tipping point. This is well below the recommendation from Crop and Food's nutrient calculator, of 280kgN/ha (609kg/ha Urea), and what was calculated in the thought experiment (269kgjN/ha).

The Overseer 6.2.2 figures for urine losses of nitrogen from the kale crop are stable with only a minor increase with each increase in urea application rate. This suggests that the nitrogen that has been taken up by the crop, and is able to be utilised by the dry dairy cows, is maximised at the 300kg/ha urea application. Any further increase in nitrogen is excess to crop requirements, and remains in the soil till leached.

As with the kale crop, a fodder beet crop optimum nitrogen application is 300kg urea +250kg DAP/ha for a 23tDM/ha crop. This results in leaching of 50kgN/ha. This again is for a crop with limited soil nitrogen available. Any further increase in nitrogen application results in rapid increase in nitrogen loss, while any decrease in nitrogen application results in only minimal decreases to nitrogen loss.

At the "tipping point" level of nitrogen application only 182kgN is applied/ha. The thought experiment conducted in section 5.2 estimates that nitrogen application of 353kgN/ha is required to achieve the full potential of a 23tDM/ha fodder beet crop. Common practice fertiliser use for a fodder beet crop varies from 129kgN/ha (280kg/ha of Urea) to only 113kgN/ha (150kg/ha Urea + 250kg/ha DAP). The disparity between common practise and recommended fertilizer application is even greater for fodder beet than kale. The Crop and Food nutrient calculator has no setting to calculate the nutrient requirement for a fodder beet crop. More research is required to better understand the fertility requirements for a successful fodder beet crop.

8.3.2.2 Feed supplement

As seen in section 8.2, the results generated from Overseer 6.2.2 showed no change in nitrogen loss to water when feed supplement is changed between grass silage and barley straw or cereal silage.

This does not seem a logical result. It is expected that changing the diet of the animal and changing the nitrogen (protein) consumed by an animal would have an effect on the nitrogen concentration in the urine, if the nitrogen content of the diet is greater than the animals' nutritional requirement. Any nitrogen in urine is excreted, forming a urine patch, from which nitrogen is readily leached to water (Di et al., 2002). Further research is needed regarding this, but it could be expected that changing the feed supplement and hence changing the nitrogen content of the diet will affect nitrogen leaching losses from a farming system.

8.3.2.3 Soil type

A light, free draining soil type with low water holding capacity (PAW) shows higher leaching than a heavy, poorly drained soil. In the Overseer 6.2.2 model, a light Lismore sib 18 soil leached 69kgN/ha from a kale crop, and 97kgN/ha from a fodder beet crop. A heavy gley Flaxton sib 4 soil leached only 11kgN/ha from a kale crop and 20kgN/ha from a fodder beet crop. A light soil requires more water applied as irrigation, as the water drains easily through the soil profile, leaching nutrients with it. A heavy soil with poor drainage will have less water passing through the soil. Water only moves slowly through the soil profile, giving the plants more opportunity to take up soil minerals before they are leached from the root zone. The primary difference between the heavy Flaxton and light Lismore soil is the difference in the estimated nitrogen concentration in the drainage water.

The effect on soil structure must be considered, and it is not measured by Overseer. Grazing a crop on a heavy, poorly drained soil will reduce leaching in winter (20kgN/ha leached from a heavy soil vs 97kgN/ha from a light soil when grazing fodder beet). However the soil is much more susceptible to pugging and treading damage from stock, especially when highly stocked. This can have an effect on future productivity (Monaghan, 2012). This would also affect the feed utilisation of the crop, increasing feed wastage and could result in underfeeding the dairy cows (Judson and Edwards, 2009, Dalley et al., 2008).

8.3.2.4 Crop/ fallow management

Fallow soil leaches more than a paddock with crop or pasture cover. This can be seen in the Overseer 6.2.2 model by splitting the crop blocks in two, with one grazed in June and the other in July. June grazed crops leach more than July grazed crops (35kgN/ha and 24kgN/ha respectively for a kale crop, and 55kgN/ha and 46kgN/ha respectively for a fodder beet crop). When the land is left fallow it is exposed to rainfall with no plants growing to take up nutrients within the soil, so nutrients are more easily lost from the soil to groundwater.

Planting a cereal crop directly after the wintering crop is grazed off, allows the cereal to establish itself using the nutrients already within the soil- increasing nutrient uptake, reducing N loss to water. Planting a catch crop in July (directly behind the June grazed crop) reduces nitrogen loss to water by 6kgN/ha (17%) in a kale crop and 14kgN/ha (25%) in a fodder beet crop. The reduction modelled in Overseer is less than the 34% average reduction measured in a recent kale study (Carey, Cameron, Di, Edwards, & Chapman, 2016). More research to determine the mitigation effect of catch cropping after winter grazing would be useful. There is a two-fold difference in nitrogen loss reduction between the kale crop modelled in Overseer 6.2.2 and the kale field trial (17% vs 34%).

The effectiveness of a catch crop is likely to be affected by the season's climate as certain growing conditions need to be met for a successful crop to be grown. The choice of crop is essential as the soil temperature will still be low at sowing. A crop with a lower temperature requirement is capable of growing earlier in the season.

8.4 Meeting 22% reduction in nitrogen losses to water

Four management strategies have been modelled for both kale and fodder beet winter forage crops, with the nitrogen loss reductions measured. The general pattern of the results were the same for both kale and fodder beet crops.

Reduction of nitrogen fertiliser application was the most effective management strategy, reducing nitrogen leaching losses by 57.1% and 51.4% for kale and fodder beet respectively. However effectiveness will depend on actual crop fertiliser requirements; as determined by soil nitrogen already available to the crop. A thorough soil test prior to crop establishment is critical. Initial nitrogen applications of 250kg/ha DAP, 500kg/ha Urea (kale) and 700kg/ha Urea (fodder beet) were based around theoretical nitrogen requirement to meet the protein requirements for a 14tDM/ha crop of kale and a 23tDM/ha crop of fodder beet (see section 5.2.2). Fertiliser use was reduced to 250kg/ha DAP plus 300kg/ha Urea, for both crops, as this was identified as the "tipping point" within the Overseer model, as well as being common farm fertiliser use. This highlights the discrepancy between theoretical fertiliser requirements and how Overseer 6.2.2 models nitrogen use and nitrogen cycles. However the usefulness of reducing nitrogen application as a management practice will be limited for farmers depending on current farmer practices. In the information gathered from case study farms, all were already applying 300kg Urea/ha (equivalent) or less to their fodder beet and kale crops.

The use of a catch crop was the next effective strategy at reducing nitrogen leaching losses. As modelled by Overseer 6.2.2, the crop of oats sown in July (following a June grazed winter forage crop) reduced nitrogen leaching losses over the whole system by 13.3% in a kale crop and 15.7% in a fodder beet crop and by 17% and 25% (kale and fodder beet respectively) in the block the catch crop is grown in. The catch crop grown and the location/ climate will determine how practical and successful this strategy is.

Managing the timing of grazing to minimise nitrogen losses from various soil types is only going to be a successful management strategy for farms with a range of soils types from heavy to light. However with a range of soil type's nitrogen leaching losses can be reduced by 3-10% depending on the forage crop and previous soil grazing management. Grazing a heavier soil in June, followed by a lighter soil in July is the most effective at reducing nitrogen losses, leaching only 20.5kgN/ha from a kale crop and 33kgN/ha from a fodder beet crop.

As discussed earlier in section 8.2, changing the supplement type does not have an impact on leaching levels as measured by Overseer 6.2.2. However logic would suggest otherwise. It is likely that in updated versions of Overseer this issue will be dealt with. This would mean that changing supplement type would also result in a nitrogen loss reduction, though to what extent is unknown.

8.5 Practical farm changes

It is possible that some management practices can be adopted on farm, helping to reduce nitrogen losses to water. This may make it possible for farms to meet the reduction in leaching required by Variation One in the LWRP by 2022.

For both kale and fodder beet the following changes can be made.

- If a property has a winter feed crop on range of soil types then crops on heavier soils can be grazed earlier winter. Heavy soils leach less nitrogen than a lighter soil, but as they are susceptible to pugging and treading damage, grazing them earlier in winter when conditions are still relatively dry will help maintain soil structure. Also if a paddock is going to be left fallow after grazing then it is better to have a heavy soil grazed earlier and left fallow for longer than a light soil. A lighter free draining soil grazed later in winter will remain fallow for a shorter time. However a heavier soil may not be able to have a catch crop sown in it as early as a free draining soil due to the water content of the soil.
- Following a winter crop with a catch crop such as spring oats, once the winter crop has been fully grazed, can reduce nitrogen losses to water. A catch crop can be planted in July following a June grazing, and (reliant on suitable germination conditions) can establish itself, taking up soil available nutrients before they are leached.

- Farmers should consider the supplement feed used with the crop so sufficient but not excess protein is available in the diet. This will reduce the excess nitrogen in the diet, and therefore reduce the nitrogen concentration in urine. This will ultimately lower nitrogen loss.
- Finally nitrogen application can be reduced to decrease nitrogen losses to water. As a first step a comprehensive soil test before crop sowing is crucial to ensure fertiliser needs are met, but not exceeded. Beyond that reducing nitrogen application reduces nitrogen loss to water, but the significance of the reduction depends on the farms starting soil nitrogen and fertiliser use.

8.6 Limitations of this research project

Using modelling software as opposed to carrying out a physical trial and collecting actual results is a limitation to the accuracy of this study. All results were limited to the accuracy of the assumptions that exist within Overseer 6.2.2.

Like all modelling software, the results generated are only as accurate as the model being used. As such the results can vary from what would happen in reality. When generating the model a consistent diet of 11kgDM crop and 3kgDM supplement was designed to be used for both fodder beet and kale. However this diet was outside Overseers feeding limits for both kale and fodder beet crops. To ensure the models generated usable results the stocking rate was set at a level which resulted in stock eating a diet of 9.5kgDM kale with 2.6kgDM straw, or 7.2kgDM fodder beet with 2.0kgDM straw (see section 6).

Other limitations related to using Overseer were a result of 'bugs' in the programme. Those relevant to this study have been identified throughout, with "work arounds" used when possible. Overseer is the required tool for modelling nitrogen losses for farming systems, and as Overseer is the tool used by regional councils to measure and monitor nitrogen losses, any inaccuracies will effect both farmer and community.

The small number of case study farmers visited is a limitation to research. With only four case study farms it is difficult to determine if any one farm is unusual in their on farm practice's and results. With a larger pool of farmers to study a better understanding of common on-farm practice would be generated. This would improve the reliability of all assumptions made when generating the models.

Any update in to Overseer will change the specific nitrogen loss results found in this project (modelled in Overseer 6.2.2). While the theories are likely to remain true, the specific nitrogen losses to water are not.

8.7 Future research

Nitrogen leaching losses to water is a significant issue for all farming systems within New Zealand. Therefore there is huge potential for research into management strategies which can help reduce those nitrogen losses. Physical replication of those management strategies modelled in this study would be useful, giving real world results which hold more credibility.

Also to be considered is further research into Overseer, how it models the complex biophysical interactions in a farming system, and whether its accuracy and reliability can be improved on.

Other areas of potential research could involve the impact of combining different crops together and the potential for strip sowings to reduce cultivation costs and soil mineralisation.

Further research into standoff areas and cow barns, while applicable to this study were not investigated due to the time constraints around this study, and a lack of case study farmers within the area to examine.

9 Conclusion

As identified in the literature review there is a gap in the understanding of how Overseer models various management strategies to reduce nitrogen leaching losses. This research project aimed to address this information gap by modelling various management strategies, and measuring the nitrogen losses to water.

The research objectives were outlined in section 3.2

- To determine the effectiveness of different management options on reducing nitrogen losses to water from a kale or fodder beet forage system, as measured by Overseer 6.2.2.

Of the four management strategies modelled in Overseer 6.2.2, reducing nitrogen fertiliser applications is the most effective. This highlights the necessity of a comprehensive soil test to determine the current nitrogen status of the soil, allowing the bare minimum fertiliser to be applied.

The use of a catch crop grown after the winter forage crop is also an effective management strategy, taking up excess nitrogen in the soil before it is leached out in late winter and spring. Leaving the ground fallow (as is common) results in much higher nitrogen losses than a oat crop grown and cut for silage before being re-sown into crop or pasture.

A heavier, poorly drained soil will leach less N to groundwater than a light, free draining soil due to the rate of water movement through the soil. Growing winter forage crops on a heavy soil will reduce nitrogen loss to water. However heavier soils are likely to result in pugging and treading damage with lower crop utilisation. If possible winter crops grown on heavier soil should be grazed earlier in winter, followed by grazing on a lighter soil in late winter.

Changing supplement feeds had no effect on nitrogen losses to water when modelled through Overseer. The composition of feed supplements had no effect on nitrogen losses despite the range in protein contents modelled, from 17% crude protein in good quality grass silage, to 4.5% crude protein in barley straw. In practice on farm, logic suggests using a lower nitrogen feed supplement (such as barley straw) is likely to result in less N loss to water.

- Identify the differences in the two forage crops and determine if one crop is particularly favoured over the other considering increased nitrogen loss regulations, particularly within the Selwyn Te Waihora catchment.

Due to difficulties with how Overseer 6.2.2 modelled fodder beet and kale the two crops were instead directly compared with a “thought experiment”, following logic and published facts and figures.

Fodder beet is a higher yielding, higher energy crop with lower crude protein levels than kale. Despite its lower crude protein levels, fodder beet has a greater requirement for nitrogen fertiliser per hectare than kale to meet the needs for the greater yield. Fodder beet requires 353kgN/ha while kale requires 268kgN/ha.

Due to its higher yield fodder beet requires less area to winter over cows than kale. Kale requires 47ha to winter 1000 cows (14tDM/ha yield), while fodder beet only uses 29ha (23tDM/ha yield).

The thought experiment shows that a fodder beet crop results in more excess nitrogen /ha (403kgN/ha vs 313kgN/ha), but less excess nitrogen /cow (11.7kgN/ha vs 14.7).

The usefulness for fodder beet/ kale going forward mostly depend on

A) How much area is available to winter dry dairy cows on.
B) Whether profit is more important to a farmer or nitrogen loss.
C) The effect of the crop selection on animal health, crop variability and soil performance over time.

10 Appendices

10.1 Farm A. Overview

Husband, wife and farm manager run a complete dairy support farm. It is located north of the Rakaia River. It is made up of 2 separate farms/ entities which are run together. In total the farm is 523ha, 483 effective. 290 carry over dairy cows (owned by the farmer) remain on farm year round. These are high BW and PW (150BW and 210PW) empty cows which are bought, kept on farm and sold in calf the following year. 5400 dairy cows are wintered on property. The DSL unit is run to suit a large corporate dairy farm business. The remainder of the year there are no stock on farm (excluding the 290 carry over cows). Pasture and cereal silage is grown and harvested and is then either stored for use or sold. Of the total property 45ha is in Kale for winter, and 45 ha is in Fodder beet for winter. The area of crop is calculated out to meet the energy requirements for the dairy stock over winter. All crop will be eaten, plus some pasture for transitioning on and off the crops. The 90 ha is planted in cereal barley after winter to produce cereal silage. The remainder of the property is planted in a pasture mix of RG (AR37 150) WC, RC and plantain.

10.1.1 Soils

The soil type over the farm is highly variable due to the close proximity to the Rakaia River. The majority of the farm is an Eyre soil, an Orthic recent soil, which is a well-drained shallow gravelly loam. It has a moderate to high PAW of 70-104mm in the top 60cm of soil. There are a number of fluvial recent soils, the Rakaia and Rangitata soils are both shallow stony loams with low PAW of 46-55mm in the top 60cm of soil. The Waimakariri soil however, is a deep silt loam soil with no stony and a very high PAW of 109-141mm. The remainder of the soil is a Lismore silt loam, which is a shallow soil with moderate PAW of 86mm.

10.1.2 Irrigation

The majority off the property is irrigated, with 473ha irrigated and 59 ha dryland. The majority of the water is sourced from a bore which accesses Rakaia river gallery water. The remaining area has recently been irrigated with the addition of 170 (approx.) ha of central plains water (CPW). The top property (with mostly CPW water has precision irrigation which is monitored with profile available water using neutron probes. The irrigation on the lower property is not precision irrigation, but is managed using more neutron probes measuring soil water content and an irrigation budget/ scheduling. Due to the shape of the property central pivot, lateral, wipers and turbo-rainer irrigation are all used.

10.1.3 Supplements and winter feed

4,000,000 kgDM of silage is harvested (approx.) a year. If sold during winter this is sold at the winter grazing price, but if sold during the summer season (20th September to 20th April) then summer prices apply. This season this was 22C/kgDM while last season it was 25C/kgDM.

Wintering dairy cows covers 55 day on crop. Cows come onto the property already transitioned onto 4 kg of crop, either beet or kale. R2 in calf heifers arrive earlier, on the 28th of April, leaving earlier in July. Cows turn up later, and leave in the springing mob. All dairy cows will be off farm by late August/ early September. Cows are offered 14kgDM/ day, while the heifers are offered 12kgDM/day. Cows are offered 8kg of crop with 6 kg of silage (beet gets grass silage while the kale receives cereal silage). The heifers are fed 6kg of crop and 6kg of silage. This is to meet protein and fibre requirements on the various fodder crops.

The winter feed is contracted out this season at 23c/kgDM. The crop is sold standing (dairy farms shift the stock) and the silage is fed out by Don. The wintering price is variable, with last seasons' price at 28c/kgDM.

Due to the close relationship with the dairy farming business the property is locked into grazing dairy cows for the next 2 seasons. Good relations are maintained to achieve repeat seasons.

10.1.4 Crop rotation

The crop rotation follows an 8 year rotation. Year 1 is a crop, either Beet or Kale, this is followed by barley. The paddock then goes into pasture for 3 years, before going into the other crop (from beet to kale or vice versa), followed barley then another 3 years of pasture. This allows for disease breaks, for the soil structure to be built back up and nutrients restored. It is believed the barley grown after the winter crop sucks up all excess nutrients which have not yet leached through.

10.1.5 Kale/ Fodder beet

"Fodder beet gets stressful, if people muck up animals get killed". Much higher chance for human error than kale due to the complication of transitioning and small break sizes. Fodder beet can achieve better yields, lowering cost/ kgDM, as well as using less area to grow the same amount of feed. However variable yields are achieved by fodder beet, 20-30tDM/ha but averages at 28tDM/ha. Wouldn't want a higher yield as cannot stock it on current paddocks (crop face space per cow).

Fodder beet requires more work generally as putting cows on 2 breaks/ day rather than 1. Evens out intake, prevent from gorging and getting too hungry resulting in cows breaking out. Generally feed out silage BEFORE shifts are moved. Allows for a full gut which causes less acidosis cow health issues.

However as a combination fodder beet and kale are good as sick cows can be shifted from FB to kale with no health issues. Also having both fodder crops on farm allows for a better crop rotation to maximise annual yields.

10.1.6 Winter crop gross margins

Table 23 Farm A Fodder beet gross margin

Beet Gross Margin	**total area**	**45**			
Expenditure	**Amt (t)**	**$/unit**		**total $**	**$/ha**
Soil Testing				792	17.60
Lime and Spreading	346	26		9016	200.36
N and Spreading	43.5	240.73		10471.77	232.71
Super and Spreading	30.03	688.75		20683	459.62
Drilling +cultivation				18929.5	420.66
Spray and Chemical				36054.6	801.21
Seed				18114.78	402.55
Plant Testing				30	0.67
	Total $/ ha				**2535.37**
Income	0.23	$/kgDM	26	tDM/ha	**5980.00**
Net Income					**3444.63**

Table 24 Farm A Kale gross margin

Kale Gross Margin	total area	45			
Expenditure	**Amt (t)**	**$/unit**		**total $**	**$/ha**
Soil Testing				176	3.91
Lime and Spreading	28	54		1512	33.60
N and Spreading	79.25	134.34		10646.21	236.58
Super and Spreading	28.13	419.46		11799.41	262.21
Liquid and applying				6208	137.96
Drilling +cultivation				4066	90.36
Spray and Chemical				19638.3	436.41
Seed				4079.78	90.66
Plant Testing				362.6	8.06
	Total $/ ha				**1299.74**
Income	0.23	$/kgDM	16	tDM/ha	**3680.00**
Net Income					**2380.26**

10.2 Farm B. Overview

Husband and wife own a 455 ha farm located at Hororata. Within the last year the farm has undergone significant system change, with the introduction of 410 ha of irrigation through the Central Plains Water scheme (CPW). The farm was previously a sheep finishing property, with 250 ha of pasture and Lucerne crop. The remaining 200 ha wintered dairy cattle on kale. With the addition of CPW water, the farm system has altered to 150 of arable cash cropping. Growing barley, peas for Watties and potatoes. 100ha of the property is cropped in fodder crops, with 70 ha of Kale and 30 ha of Fodder beet for wintering dairy cows. The remaining area (200 ha) remains in pasture and is used for young dairy support, grazing dairy replacement calves from 100kgLW in December all the way through to the May before calving as a heifer cow.

10.2.1 Soils

The soil type over most of the farm is a Lismore silt loam, well drained, with moderate profile available water (86mm in 60cm of topsoil). The remaining area of the farm is a Darnley silt loam, which is stony, moderately well drained, and has low profile available water (54mm of water in the top 60 cm).

10.2.2 Irrigation

The irrigation through the centre pivots is managed through water budgeting and soil moisture content monitoring over various areas of the farm. 3 neutron probes (one in pasture, one in fodder crop and one in cash crops) measures the soil moisture. This is recorded and documented by an irrigation specialist, who then calculates the water requirements (using weather predictions for rainfall and evapotranspiration) to determine the suitable rate for irrigation. This minimises water drainage through the soil profile.

10.2.3 Supplements

Supplements made on farm include barley straw and pea vine. This is a method to remove crop residue while retaining a profit from it. 700 barley straw bales are made at 300kg fresh weight. These are sold to the dairy farmers wintering dairy cows on the Cookson property, as is all fed out on the kale and fodder beet crops as a fibre supplement. The barley straw is sold generating $25.00 net profit (sold to the dairy farmers at $50- $55 total, covering the cost of harvesting the supplement). There are 210 medium square bales of pea vine harvested a year, which is fed to the 1 year old calves on farm in august when the pasture growth does not meet the calves requirements. All supplement made on farm is eaten on farm.

10.2.4 Stock

Stock on farm include replacement dairy heifer calves, a mob of 50-90 sheep, 50 steers and over June and July the farm stocks dairy milking cows. The sheep and steers are owned by the farmer, while all other stock are grazed on property by contract. There are approximately 800 dairy calves from 4 individual farms. These arrive in the December after birth at 100kgLW. From December till the following may the calves are grazed at a rate of $7.50/head/week. From May till the following May (a 1 year contract) the heifers are grazed at a contract of $12.50/head/week, increasing in live weight up to 460kg. They are naturally mated during this time. At the end of this year contract the heifers then go onto a winter grazing contract, which is paid per kgDM offered/day standing.
The dairy cows wintered on farm arrive on the 1st of June and leave on the 31st of July. 1800 dairy cows plus the 800 in calf heifers already on farm are wintered on the kale and fodder beet crops.

10.2.5 Winter feed

The winter crops are sold standing, and fed out at 11kgDM/head/day of crop, with additional supplement. The price received per kgDM offered per day varies with the milk prices. The current price received is 21C/kgDM offered a day, while last year 28C was received. The farmers have refused to accept less than 25C/kgDM going forward in previous seasons, as it is not profitable for the farming system. If the price drops below this then the farmers will not winter any dairy cows.

10.2.6 Crop rotation

Pasture > beet (spring) > kale (spring) > barley for grain (spring) > greenfeed oats (autumn) > pasture (spring)

10.2.7 FB/Kale- why?

Kale has been used as a dairy wintering fodder crop on the farm for many years. The farmer has the knowledge of how to grow it successfully, so is an “easy crop”, with lower risk for both animal health and crop yield.

Fodder beet has been grown previously under dryland conditions, but never more than 5 ha. Current FB has a much higher cost to grow, but has a much higher yield potential. FB also has much higher risk for both yield variability and animal health.

10.2.8 How is the fodder crop yields tested/ measured?

Both the farmer and the dairy cow owners participate in testing the yield. 10m stretches of crop are removed and weighed, separated for bulb and leaf. This is repeated multiple times over a paddock. Bulb and leaf samples are then sent to be tested professionally. This gives the DM content as a proportion of the fresh weight, which is averaged over the paddock and extrapolated out. The average across all paddocks tends to be similar for FB, but the variation within a paddock can be significant. Crop yield for fodder beet is aimed at 22-23 tDM/ha. Currently an average of 20tDM/ha is achieved. Kale is tested similarly and yield is aimed at 14tDM/ha.

10.2.9 Winter crop gross margins

Table 25 Farm B Fodder beet gross margin

GROSS MARGIN FOR BEET

Standards used
* Farmer in share ownership of header and cultivation equipment, charged
  at 0% of contract rate.
* Cultivation - grown in 2nd crop or later.

Roterra	1	Hr/Ha
Plough	0.8	
Rotocrumbler	0.8	
Drill	0.8	

Total	3.4	Hr/Ha

GROSS REVENUE PER HECTARE

	23000	kg	@ $	0.21	per kg	**4830.00**	per ha

DIRECT COSTS PER HECTARE

Cultivation/Drilling	3.4	hours	@ $	40.00	per hour	**250.00**	per ha
Seed	5	kg/ha	@ $	15.00	per kg	**300.00**	per ha
D.A.P fertiliser	250	kg/ha	@ $	800.00	per tonne	**200.00**	per ha
Urea	200	kg/ha	@ $	550.00	per tonne	**110.00**	per ha
Weed&Pest : Magister/No	15	g/ha	@ $		per kg	**98.00**	per ha
: Betanal Qu	1.5	l/ha	@ $		per l	**393.00**	per ha
Application	3		@ $	20.00	per ha	**60.00**	per ha
Irrigation	150	mm	@ $	0.32	per mm	**830.00**	per ha
fert spreading	3		@ $	30.00	per ha	**90.00**	per ha
Freight - field to silo	0	tonnes	@ $	0.00	per tonne	**0.00**	per ha
- off farm	0	tonnes	@ $	0.00	per tonne	**0.00**	per ha

TOTAL DIRECT COSTS PER HECTARE					$	**2331.00**	
GROSS MARGIN PER HECTARE					$	**2499.00**	

Sensitivity Analysis

		Gross return ($/tonne)				
		170.00	180.00	200.00	230.00	280.00
	8	-971.00	-891.00	-731.00	-491.00	-91.00
Yield	10	-631.00	-531.00	-331.00	-31.00	469.00
(t/ha)	12	-291.00	-171.00	69.00	429.00	1029.00
	15	219.00	369.00	**669.00**	1119.00	1869.00
	20	1069.00	1269.00	1669.00	2269.00	3269.00
	25	1919.00	2169.00	2669.00	3419.00	4669.00

		Gross return ($/tonne)				
		170.00	180.00	200.00	230.00	280.00
Direct	-20%	3908135	4138135	4598135	5288135	6438135
Costs	-10%	3907902	4137902	4597902	5287902	6437902
($/t)	average	3907669	4137669	**4597669**	5287669	6437669
	+10%	3907436	4137436	4597436	5287436	6437436
	+20%	3907203	4137203	4597203	5287203	6437203

Table 26 Farm B Kale gross margin

GROSS MARGIN FOR KALE

T

Standards used
* Farmer in share ownership of header and cultivation equipment, charged at 0% of contract rate.
* Cultivation - grown in 2nd crop or later.

Roterra	1	Hr/Ha
Plough	0.8	
Rotocrumbler	0.8	
Drill	0.8	

Total	3.4	Hr/Ha

GROSS REVENUE PER HECTARE

	14000	kg	@ $	0.21	per kg	**2940.00**	per ha

DIRECT COSTS PER HECTARE

Cultivation/Drilling	3.4	hours	@ $	40.00	per hour	**250.00**	per ha
Seed	5	kg/ha	@ $	15.00	per kg	**75.00**	per ha
D.A.P fertiliser	200	kg/ha	@ $	800.00	per tonne	**160.00**	per ha
Urea	300	kg/ha	@ $	550.00	per tonne	**165.00**	per ha
Weed&Pest : magister	15	g/ha	@ $		per kg	**30.00**	per ha
: monarch	1.5	l/ha	@ $		per l	**50.00**	per ha
Application	2		@ $	20.00	per ha	**40.00**	per ha
Irrigation	150	mm	@ $	0.32	per mm	**830.00**	per ha
fert spreading	3		@ $	30.00	per ha	**90.00**	per ha
Freight - field to silo	0	tonnes	@ $	0.00	per tonne	**0.00**	per ha
- off farm	0	tonnes	@ $	0.00	per tonne	**0.00**	per ha

TOTAL DIRECT COSTS PER HECTARE					$	**1690.00**	
GROSS MARGIN PER HECTARE					$	**1250.00**	

Sensitivity Analysis

		Gross return ($/tonne)				
		170.00	180.00	200.00	230.00	280.00
	8	-330.00	-250.00	-90.00	150.00	550.00
Yield	10	10.00	110.00	310.00	610.00	1110.00
(t/ha)	12	350.00	470.00	710.00	1070.00	1670.00
	14	690.00	830.00	**1110.00**	1530.00	2230.00
	16	1030.00	1190.00	1510.00	1990.00	2790.00
	18	1370.00	1550.00	1910.00	2450.00	3350.00

		Gross return ($/tonne)				
		170.00	180.00	200.00	230.00	280.00
Direct	-20%	2378648	2518648	2798648	3218648	3918648
Costs	-10%	2378479	2518479	2798479	3218479	3918479
($/t)	average	2378310	2518310	**2798310**	3218310	3918310
	+10%	2378141	2518141	2798141	3218141	3918141
	+20%	2377972	2517972	2797972	3217972	3917972

10.3 Farm C. Overview

Farm C is owned by a multigenerational family. It compromises of 3 separate blocks located along the north bank of the Rakaia River. The deer block is 131ha, Top block is 199ha and Home block is 180 ha. Most of the Home block is leased out to a neighbouring dairy farmer, with the remaining 30 or so hectares a lifestyle block for the current farmers parents. The Deer block and Top block are run as a mixed cropping and dairy support farm, with dairy heifers grazing year round, dairy cows wintered on crop and additional barley and silage grown and harvested.

Prior to irrigation much of the farm was planted in Lucerne as it is a good summer safe crop. Kale was also used as a winter fodder crop for the contracted dairy cows. Since the irrigation has been installed there is no Lucerne on the properties, with high quality pasture, wheat (22ha) and barley and fodder beet as a winter fodder crop for the dairy cows grown instead.

10.3.1 Soils and Irrigation

Over the top block the soil is a shallow Lismore silty loam soil which is well drained with moderate water holding capacity (86mm in 60 cm of topsoil). High evapotranspiration rates in summer (due to the strong nor'west winds) and moderate to low rainfall can result in summer dry conditions. To compensate for this Central Plains irrigation was bought for the Top block, with centre pivot irrigators and rotorainers being used to irrigate as required.

The Deer block is closer to the Rakaia river, and has numerous silty loam soils, all of which are well drained but with varying water holding capacities (from very high at 141mm/60 cm of topsoils in the Waimakariri soil to moderate at 70mm/60cm of topsoil in the Eyre soil. The Deer block also has CPW water allowing for a centre pivot to irrigate much of the block.

Irrigation is managed through water budgets and by visually assessing soils to determine the moisture content of the soil.

10.3.2 Stock

No stock are owned by the family excluding 50 beef cattle which are raised from 100kgLW through to finishing. 150 dairy heifers arrive at 100kgLW in December. These remain on farm year round till the 2nd May, when they go off for winter grazing prior to calving. Currently 1000 dairy cows are wintered on fodder crop for July and August. Previously more dairy cows have been wintered, but this season with the low milk price dairy farmers have been wintering cows on farm as an attempt to reduce costs. The dairy heifers are grazed on a weekly contract price. From December till May the farmer is paid $8.50/hd/week, while from May till May the weekly price ranges from $12-$14/ head/week. That price is determined by the price of silage at the time.

10.3.3 Supplement and winter crops

There is 27 ha of fodder crop grown in total over the Deer and top blocks. Some dairy heifers are wintered on 6ha of Fodder beet on the deer block, while the remaining 21 ha is fed to the wintering dairy cows on the top block.

Fodder beet has been grown on the property for 4 years. An average yield is 25-28tDM/ha, but recent season yields of 30-32 tDM/ha have been achieved. Yield is assessed by Canterbury Feed Assessment and is then sold standing at a current price of 21c/kgDM. The previous season the FB was sold for 25c/kgDM while Mike estimates a price of at least 22c/kgDM for wintering dairy cows to be profitable. If the price for winter grazing stays low then winter grazing will not be continued.

The fodder beet is sold standing, and is fed out at 8kgDM/head/day. With the balance of the diet made up by straw and silage (which is harvested on farm and sold to the stock owner). Silage bales are sold as big bales (325kgDM) at a price slightly below the fodder beet. This season bales are 21c/kgDM, last season was 23 and next season is estimated to be at 20-21c/kgDM. Silage is harvested to maintain quality pasture cover, removing a 3tDM/ha cut each time. 80% of silage is sold, while 20% is kept to be fed out to heifers during the year to meet a feed deficit.

10.3.4 Why growing FB not Kale?

Have grown Kale in the past- but yield was dropping and so switched to FB as that was what the contracted dairy farmers wanted at the time. Kale was achieving yields of 13-16tDM/ha while fodder beet yields are much higher, averaging 25-28tDM/ha.

10.3.5 Fodder crop rotation

Two years of beet > Barley grain > 3 years in pasture> beet

10.3.6 Fodder beet gross margin

Table 27 Farm C Fodder beet gross margin

Beet Gross Margin	**total area**	**27**			
Expenditure	**Amt (t)**	**$/unit**		**total $**	**$/ha**
Soil Testing				792	29.33
Poulfert	5t/ha	$70		$9,450	350.00
FB Base (Ballance)	385kg/ha	$781		8122.4	300.83
Drilling	1	150		4050	150.00
ploughing	1	80		2160	80.00
cultivation	2	50		2700	100.00
roller	1	20		540	20.00
Spray and Chemical				36054.6	1335.36
Seed		450		12150	450.00
	Total $/ ha				**2815.52**
Income	0.21	$/kgDM	26.5	tDM/ha	**5565.0**
Net Income					**2749.48**

10.4 Farm D. Overview

The property is a 550ha (effective) mixed cropping property located in the Hororata/ Coalgate region. The farm is made up of 5 blocks. These are all located within 5 km of each other. The property runs breeding and finishing sheep, cattle (trading and breeding) as well as cash crops such as barley. Replacement dairy heifers and wintering dairy cows are also run on the property. 210 ha of the property is irrigated, with the irrigation having been in place for only 1 season. The farm receives 875ml of rainfall annually, with strong nor west winds and high evapotranspiration rates during summer.
The irrigated land is used for all dairy stock, fattening lambs, cash crops and winter fodder crops, while the dryland supports the breeding stock and all beef cattle.

10.4.1 Soils

There are 4 soils types over the property. The majority of the soils are a Claremont deep silt loam, which has a soil pan impeding drainage. It has a high PAW of 90mm in the top 60cm of soil. There are two shallow silt loam soils- the Ruapuna which has a high PAW of 94mm, and the Darnley which has a low PAW of 54mm. There is 36 ha of a Mayfield soil, deep silt loam over clay, which is well drained with a moderate PAW of 81mm. The final soil type is a riverbed, so gravel and stones with a loose sandy matrix.

10.4.2 Stock

2200 MA Coopworth ewes, 65kg LW. Currently 30% are kept as replacement to increase numbers. They achieve 155% lambing (on average) with a mean lambing date of the 10th September. 50% of ewes are put to a terminal ram (Suffolk Texel cross) and the remainder are purebred Coopworth. All sale lambs are fattened on farm, with the mean kill date of 15th March.
310 MA Angus cows at 550kgLW are run on dryland. They average a 94% in calf rate, with 30% replacements currently (due to building herd numbers). 47 in-calf heifers (480kgLW) calve two weeks earlier than the MA cows, in early August. All male calves are sold at weaning (in February), averaging 232kgLW. Heifer calves are put to the bull and sold as in calf heifers or kept as replacements. 5 Angus bulls remain on farm year round, weighing between 60 and 100kgLW.
An additional 600-650 Friesian calves are grazed on property on a year contract. Of these, 290 arrive in November/ December at weaning (100kgLW). These remain on farm till July 18months away. They leave the farm in a springer mob at calving. November arrive at 100kg LW, by the first May they have reached 230kgLW, by the second May they have achieved 470kgLW, which is maintained over the final June and July.
320 MA Friesian milking cows are wintered on property for June and July, at 500kgLW.

An additional 70 trading cows (cull dairy cows) are on farm from April till August, arriving at 457kgLW and sold at 520kgLW to the works.

10.4.3 Feeding contracts

For dairy heifers- $7/hd/week November- May, May- May $12.50/hd/week.
For wintering MA dairy cows (including heifers) $/kgDM. Current season $0.21, previously $0.30, going forward want at least $0.24/kgDM. Cattle are fed 12kgDM crop and 2kgDM straw.

10.4.4 Supplements/ crops

42 ha of kale is grown, 30 ha for wintering dairy cows, and 12ha dryland crop for beef calves. Irrigated kale averages a 12.5tDM/ha, while the dryland kale averages 9tDM/ha. Rape and swedes are also grown as fodder crops for ewes, lambs and yearling heifers. Most years 40ha of barley is grown, this season only 12 ha has been grown. Most barley grain is sold, while some 30T remains on farm as a supplement for the ewes prior to tupping and for the ewes with multiples just prior to lambing. Triticale is also grown for whole crop cereal silage.
37ha of pasture is cut for silage (3tDM/ha), and another 18 ha of triticale is made into cereal silage. 100 big bales of barley straw is made on farm, which is fed out on the fodder crop blocks which are going into barley next season. This is all eaten by stock on farm. An additional 135 big square bales of rye grass straw is bought and fed out to calves on crop.

10.4.5 Crop rotation

Pasture > Kale > Cereal > Pasture (or rape if weeds) > Pasture 3 years

10.4.6 Irrigation

210 ha of the property is irrigated under pivot irrigation. One pivot has VRI technology, while the other two don't. Currently no soil moisture sensors are used but soil is visually assessed for moisture content.

10.4.7 Kale vs FB

Use kale as is a simple good and safe feed which has been used historically. With irrigation more land can be developed into it- more feed available. The kale and the wintering dairy cows fits into the current farm system- fits the irrigation, the pasture renewal as well as being profitable and helping with family (as is son's dairy cows being grazed).

10.4.8 CPW

Understanding that with CPW irrigation can increase leaching up to 29kgN/ha, and that as long as farms with BMP is a legal consented activity. If had to further reduce N leaching would decrease stock units and increase cash crops.

10.4.9 Financials

$903/ha to grow kale (dryland), but another $829/ha to grow under irrigation (CPW plus pumping). Direct drill is owned, so would cost another $80-85/ha. Fertiliser is applied based on Ravensdown advice and common sense (learnt from historical applications). Listens to different stories, cross references them and uses common sense.

10.5 Plant and Food crop nutrient uptake calculator

Crop Nutrient Uptake Calculator **Version 2.3 Jan-11**

How to use: Enter expected yield into yellow cells

Please Note the following:

⇒ The average concentrations are based on the best information available at the time.
⇒ Variation in concentration will occur due to factors including site, cultivar, climate, maturity at harvest and plant stress.

⇒ Of these nutrients, K appears to show the largest range of values, due to differing levels of luxury uptake.

⇒ **Straw residue management affects nutrient removal:-**
* **Burning** residues results in **~60-90% of N and S** being lost to atmosphere (depending on how good the burn is), with all other nutrients returned to the soil.
* **Baling** removes **~80% of all** above-ground nutrients
* **Cutting for silage** removes **~90-95% of all** above-ground nutrients (typically cut at 5cm ht).

Crop	Plant component	Fresh Wt (FW) or Dry Weight (DW)	Typical yield (t/ha)	Harvest Index	Enter Expected Yield into yellow cells (t/ha)	Avg Concentrations at harvest (kg/t) N	P	K	S	Mg	Ca	Crop nu N
Ryegrass seed prod.	Straw	FW	6-8		8.0	15	2	15	3	1.5	1	120
Clover seed (white)	Seed	FW	0.4-0.6	0.8	0.7	52	6	13	2	1.5	0.3	36
FORAGE BRASSICAS (NOTE: NOT Nutrient Removal, due to *in situ* grazing)												
Swede	bulb+leaf	DM	10-15t DM		15.0	25	3	15	5.6	2		375
Kale	leaf+stem	DM	8-15t DM		14.0	20	2.8	25	5.6	2		280
Pasja	leaf	DM	5-12t DM		11.0	25	3	16	5.6	1.75		275
Turnip	leaf+bulb	DM	7-15t DM		10.0	25	3	15	5.6	2		250

Figure 8 Plant and Food- crop nutrient uptake calculator

10.6 Overseer 6.2.2 Kale base model nutrient reports

Client reference:

Farm name: S/W N rate

Farm Nutrient Budget - Whole farm

	N	P	K	S	Ca	Mg	Na
				(kg/ha/yr)			
Nutrients added							
Fertiliser, lime & other	44	50	0	2	0	0	0
Rain/clover N fixation	2	0	2	4	2	4	17
Irrigation	8	0	5	8	30	7	30
Supplements imported	24	3	68	6	11	9	5
Nutrients removed							
As products	0	0	0	0	0	0	0
Exported effluent	0	0	0	0	0	0	0
As supplements	0	0	0	0	0	0	0
To atmospheric	21	0	0	0	0	0	0
To water	21	0.2	4	24	41	3	9
Change in internal pools							
Plant material	48	5	0	13	0	0	0
Organic pool	-18	-17	0	-17	0	0	0
Inorganic mineral	0	13	-13	0	-1	-2	-2
Inorganic soil pool	5	52	84	0	3	18	46

Figure 9 Kale base model nutrient budget

Client reference:

Farm name: S/W N rate

Block Nitrogen

Block name	Total N lost (kg N/yr)	N lost to water (kg N/ha/yr)	N in drainage * (ppm)	N surplus (kg N/ha/yr)	Added N ** (kg N/ha/yr)
Kale	214	21	9.6	78	44
Other farm sources	0				
Whole farm	214	21			
Less N removed in wetlands	0				
Farm output	214	21			

* Estimated N concentration in drainage water at the bottom of the root zone. Maximum recommended level for drinking water is 11.3 ppm (note that this is not an environmental water quality standard).

** Sum of fertiliser and external factory effluent inputs.

N/A: N in drainage not calculated for easy and steep pastoral blocks, or for tree and shrubs, riparian, wetland or house blocks.

Figure 10 Kale base model block nitrogen report

11 References

Agricom. (2012). *Agrinote; Fodder beet*. Retrieved from http://www.agricom.co.nz/assets/files/nz/content_files/Fodder%20Beet%20Fact%20Sheet%20-%20Agricom.pdf

Anonymous. (2013). Countering the cost of pugging [Press release]. Retrieved from http://www.beeflambnz.com/news-events/News/2013/august/countering-the-cost-of-pugging/

Baskaran, R., Cullen, R., & Colombo, S. (2009). Estimating values of environmental impacts of dairy farming in New Zealand. *New Zealand Journal of Agricultural Research, 52*(4), 377-389. doi:10.1080/00288230909510520

Carey, P. L., Cameron, K. C., Di, H. J., Edwards, G. R., & Chapman, D. F. (2016). Sowing a winter catch crop can reduce nitrate leaching losses from winter-applied urine under simulated forage grazing: a lysimeter study. *Soil Use and Management, 32*(3), 329-337. doi:10.1111/sum.12276

Chakwizira, E., Fletcher, A. L., de Ruiter, J. M., Meenken, E., Maley, S., & Wilson, D. R. (2009). Kale dry matter yield responses to nitrogen and phosphorus application. In *Proceedings of the Agronomy Society of New Zealand* (Vol. 39, pp. 59-70).

Cichota, R., & Snow, V. O. (2009). Estimating nutrient loss to waterways—an overview of models of relevance to New Zealand pastoral farms. *New Zealand Journal of Agricultural Research, 52*(3), 239-260. doi:10.1080/00288230909510509

Dalley, D., Wilson, D., Edwards, G., & Judson, G. (2008). *Getting the most from your dairy support land –Tips for allocating winter forages* Paper presented at the South Island Dairy Event, Lincoln, New Zealand.

Dalley, D. E., & Van der Poel, G. (2008). *Southland monitor farm project.* Paper presented at the South Island dairy event, Lincoln, New Zealand.

de Klein, C. A. M., Monaghan, R. M., Ledgard, S. F., & Shepherd, M. (2010). A system's perspective on the effectiveness of measures to mitigate the environmental impacts of nitrogen losses from pastoral dairy farming. In G. R. Edwards & R. H. Bryant (Eds.), *Meeting the Challenges for*

Pasture-Based Dairying (pp. 14-28). Proceedings of the 4th Australasian Dairy Science Symposium, Lincoln University, Christchurch, New Zealand,.

Dent, J., Harrison, S., & Woodford, K. (1986). The Principles of Farm Planning. In J. Dent, S. Harrison, & K. Woodford (Eds.), *Farm Planning with Linear Programming: Concept and Practice* (pp. 1-7). Victoria, Australia: Butterworks.

Di, H. J., & Cameron, K. C. (2002). The use of a nitrification inhibitor, dicyandiamide (DCD), to decrease nitrate leaching and nitrous oxide emissions in a simulated grazed and irrigated grassland. . *Soil Use and Management, 18*(4), 395-403. doi:10.1111/j.1475-2743.2002.tb00258.x

Edwards, G. R., De Ruiter, J., Dalley, D., Pinxterhuis, J., Cameron, K., Bryant, R., . . . Chapman, D. (2014). *Urinary nitrogen concentration of cows grazing fodder beet, kale and kale-oat forage systems in winter.* Paper presented at the Proceedings of the 5th Australasian Dairy Science Symposium.

Edwards, G. R., deRuiter, J. M., Dalley, D. E., Pinxterhuis, J. B., Cameron, K. C., Bryant, R., . . . Chapman, D. (2014). *Dry matter intake and body condition score change of dairy cows grazing fodder beet, kale and kale-oat forage systems in winter.* Paper presented at the Proceedings of the New Zealand Grassland Association.

Environment Canterbury. (2009). *Canterbury water management strategy*. Retrieved from http://ecan.govt.nz/publications/Plans/cw-canterbury-water-wanagement-strategy-05-11-09.pdf.

Environment Canterbury. (2012). *Land and water regional plan: Nutrient allocation zones*. Retrieved from http://ecan.govt.nz/publications/Plans/lwrp-nutrient-allocation-zones-map.pdf.

Environment Canterbury. (2015). *Land and Water Regional Plan*. Retrieved from http://files.ecan.govt.nz/public/lwrp/LWRP-Plan-Volume_1.pdf.

Environment Canterbury. (2016a). New beginnings. Retrieved from http://ecan.govt.nz/get-involved/canterburywater/telling-our-story/Pages/decade-in-making.aspx

Environment Canterbury. (2016b). Understanding the Selwyn te Waihora plan change (plan change 1). Retrieved from http://ecan.govt.nz/our-responsibilities/regional-plans/lwrp/v1/Pages/understanding_variation_1.aspx

Farrell, L. J. (2015). Urination behaviour of non-lactating dairy cows in late gestation offered fodder beet and kale winter forages: Lincoln University.

Gibbs. (2011). *Wintering dairy cows on fodder beet.* Paper presented at the Conference Proceedings of the South Island Dairy Event, Lincoln.

Gibbs, & Hughes, T. (2008). *Support land for the dairy industry – the supply of supplements.* Paper presented at the Proceedings of the Society of Sheep and Beef Cattle Veterinarians of the NZVA.

Gibbs, & Saldias, B. (2014 a). Feeding Fodder Beet in New Zealand Beef and Sheep Production. *Proceedings of the Society of the Sheep and Beef Cattle Veterinarians of the New Zealand Veterinary Association, 11*, 83-90.

Hawkins, A. (2016). [Wintering dry dairy cows on pasture]Dairy Consultant North Canterbury

Judson, H. G., & Edwards, G. R. (2008). Survey of management practices of dairy cows grazing kale in Canterbury. *Proceedings of the New Zealand Grassland Association, 70*, 249-254.

Kelly, T., & Bywater, T. (2005). The whole-farm systems approach. In N. Shadbolt & S. Martin (Eds.), *Farm management in New Zealand* (pp. 62-79). Melbourne, Australia: Oxford University Press.

Lilburne, L. (2014). *Land use statistics for the Selwyn- Waihora zone*. Landcare Research. Retrieved from http://files.ecan.govt.nz/public/lwrp/variation1/land-use-statistics-selwyn-waihora-zone.pdf.

Lilburne, L., Webb, T., Ford, R., & Bidwel, V. (2010). *Estimating nitrate-nitrogen leaching rates under rural land uses in Canterbury*. Retrieved from Christchurch [N.Z.]: https://researcharchive.lincoln.ac.nz/handle/10182/3547

Lucci, G., Shephard, M., & Carlson, W. (2015). *Can a deep-rooted spring crop recover winter-deposited urine nitrogen?* Paper presented at the Proceedings of the New Zealand Grassland Association, Masterton.

Malcolm, B. J., Cameron, K. C., Edwards, G. R., & Di, H. J. (2015). Nitrogen leaching losses from lysimeters containing winter kale: the effects of urinary N rate and DCD application. *New Zealand Journal of Agricultural Research, 58*(1), 13-25. doi:10.1080/00288233.2014.961644

Malcolm, B. J., Cameron, K. C., Edwards, G. R., Di, H. J., de Ruiter, J. M., & Dalley, D. E. (2016). Nitrate leaching losses from lysimeters simulating winter grazing of fodder beet by dairy cows. *New Zealand Journal of Agricultural Research, 59*(2), 194-203. doi:10.1080/00288233.2016.1150307

McConnell, D. J., & Dillon, J. L. (1997). Farm management for Asia: a systems approach. *Food & Agriculture Org*.

McDowell, R., Wilcock, B., & Hamilton, D. (2013). *Assessment of Strategies to Mitigate the Impact or Loss of Contaminants from Agricultural Land to Fresh Waters*. AgResearch Retrieved from http://www.mfe.govt.nz/publications/fresh-water/assessment-strategies-mitigate-impact-or-loss-contaminants-agricultural.

McLaren, R., & Cameron, K. (1996). *Soil Science: Sustainable production and environmental protection.* Victoria, Australia: Oxford University Press.

Monaghan, R. M. (2012). *Impacts of animal wintering on water and soil quality*. Retrieved from Report prepared for Environment Southland:

Monaghan, R. M., Beare, M., & Boyes, M. (2009) The Environmental Impacts of Dairy Cow Wintering in Southland. *AgResearch review document prepared for DairyNZ*.

Monaghan, R. M., de Klein, C. A., & Muirhead, R. W. (2008). Prioritisation of farm scale remediation efforts for reducing losses of nutrients and faecal indicator organisms to waterways: a case study of New Zealand dairy farming. *Journal of Environmental Management, 87*(4), 609-622.

Munro, M. (2016). [Fodder beet].

Oswald, A. (2011). *Fodder beet use in sheep and beef farming*. Paper presented at the Proceedings of the Society of Sheep and Beef Cattle Veterinarians of the New Zealand Veterinary Association.

Parfitt, R. L., Baisden, W. T., Schipper, L. A., & Mackay, A. D. (2008). Nitrogen inputs and outputs for New Zealand at national and regional scales: Past, present and future scenarios. *Journal of the Royal Society of New Zealand, 38*(2), 71-87. doi:10.1080/03014220809510547

Paton, R. J., & Houlbrooke, D. J. (2010). Recovery of soil physical quality under repeated dryland and irrigated winter forage crops grazed by sheep or cattle. *Proceedings of the NZ Grassands Association, 72*, 223-226.

Pinxterhuis, J. B., Dalley, D., Tarbotton, I., Hunter, M., & Geddes, T. (2013). Evaluating dairy wintering systems in Southern New Zealand. *Extension Farming Systems Journal, 9*(1), 141-148.

Robinson, S. (2016). [Fodder beet].

Rugoho, I. (2013). *Intake and performance of dairy cattle on forages in winter.* Lincoln University. Retrieved from https://researcharchive.lincoln.ac.nz/handle/10182/5440

Selbie, D., Watkins, N., Wheeler, D., & Shepherd, M. (2013). *Understanding the distribution and fate of nitrogen and phosphorus in OVERSEER®.* Paper presented at the Proceedings of the New Zealand Grassland Association.

Williams, R., Brown, H., Dunbier, M., Edmeades, D., Hill, R., Metherell, A., . . . Thorburn, P. (2013). A critical examination of the role of OVERSEER® in modelling nitrate losses from arable crops. *Occasional Report*(26), 8.