FLEMINGTON FARM LTD

Greenhouse gas and nitrogen loss mitigation in the Hinds catchment

A case-study on environmental performance and the effect on production and profitability

Meeting a Sustainable Future

Selwyn and Hinds | Inspiring High Performance. Low footprint farms

DairyNZ

Executive Summary

The overall objective of this project is to partner with farmers, industry, scientists, rural professionals, and government to demonstrate the feasibility and practicality of reducing GHG emissions and N-loss to water from real dairy farms, while maintaining the farm's profitability and meeting other environmental obligations.

Phill Everest, Jos and family have been involved in this project as "We care for the environment but need a balance between social, economic, environment – can't go broke individually or as an industry/country. This project gives the opportunity to carefully review options. We are prepared to give things a go, examples are spreading plantain out of the fertiliser bulk spreader truck, duals on pivots to reduce ruts, focus on labour/time efficiency, our men only milk once a day with the automation in the dairy shed."

This case study uses the Flemington farm's 2012 and 2013 year end nutrient budgets to set the N loss baseline as required by ECan for the Hinds Catchment. The 2018-19 financial and physical performance parameters have been used to generate the base file in Farmax to model scenarios against.

Phill and Jos Everest are great advocates for adoption of new technologies and for change. They have been early adopters implementing technologies and systems that improve efficiency, resource use, and sustainability. A few examples being plantain, diverse pastures, low application effluent through the pivots and very efficient irrigation using variable rate centre pivots and automation in the rotary shed to improve labour efficiency and make the farm an attractive place to work.

The farm has achieved significant reduction in through improved irrigation efficiency dropping from 34 kg N/ha to the level required in 2025 of 29 kg N/ha in 2018/19 This reduction has largely been achieved through improved irrigation efficiencies.

As the farm runs a low imported feed system, the main mitigation to reduce N loss is using less fertiliser N. Reducing methane emissions is more challenging and if a significant reduction is required with existing known mitigations this could/will only come from a land use change away from grazing animals to possibly more cropping. This will reduce profit significantly given the lower returns from cropping compared to dairy.

As Flemington farm runs a largely all grass system and have made infrastructure changes to be efficient with irrigation, reduction in N loss can only come from reducing N fertiliser inputs. Where N fertiliser can be reduced to ~ 187 kgN/ha and milk production maintained, profit will be increased. Further reductions in N use to 134 kg N/ha will result in the farm being compliant. However, operating profit (income less expenses) will be reduced by a net of -$77,500.

Small changes in cropping area or changing the replacement policy from all replacements to a mix of heifers and high quality carry-over cows has no effect on N leached or GHG emissions as there is no significant changes in N surplus or dry matter intake (DMI).

The Everest's have some major concerns on the direction of travel for N loss in the Hinds catchment with the recent Essential Fresh Water (EFW) plan of nitrate levels in water to 2.4 ppm. The lower Hinds catchment is naturally a swamp with the waterways being spring fed streams, fed by groundwater which is influenced by land-use over a much larger area upstream. If ECan require the catchment to achieve the 2.4 ppm over a generation (number of years currently unknown) where they are currently starting at 12.8 ppm the only option is likely to be dryland sheep farming with no cropping or irrigated land dairy, beef or sheep unless catchment scale solutions are found.

GHG targets for Flemington are also a concern as they are already running a low intensity farm system for irrigated Canterbury. Where methane reductions need to come from reduced DMI this will require a land use change to a less profitable land use such as cropping that is likely to have as high or higher N loss.

Further reductions in N loss and GHGs will therefore need to come from emerging technologies such as such as breeding for low N cows, low methane cows, vaccine to reduce methanogenic bacteria and plant species such as plantain and winter active growing species. Plantain at plot scale has been shown to reduce N loss however, farm scale N loss is still unknown. Plantain is not an easy mitigation to implement on heavy soils and is likely to require annual to biannual renewal to maintain 20% or more in the sward which will reduce profit from lost pasture production introducing plantain and cost of renewal.

Goals, Principles and Values

1. To achieve the best milk production possible within the constraints of the pasture grown on the farm.
2. To control the cost of production to achieve a system that is profitable and sustainable even at low pay-outs.
3. To minimise the amount of people time and effort to achieve production and profit targets by allowing cows to harvest the feed and making supplements only when pasture quality is being seriously compromised.
4. To generate flexibility for the farm owners and staff to take time away from the farm to meet family obligations and lifestyle goals.
5. To take up opportunities that suit Flemington Farm for specialty milks (for example, A2) as they become available.
6. To have a happy work environment, a "can do" attitude, and career development for all staff.
7. To have an aesthetically pleasing farm environment for staff, animals and the community.

Farm Overview

Flemington Farm, is in the Hinds Catchment, located 10 km south of Ashburton and is owned by Phill and Jos Everest and run by Paul Everest, their son. The dairy farm is 273 ha, is flat terrain, with a milking platform of 217 ha and 38 ha used for winter/feed crops and some young stock, the balance, 18 ha is in trees, laneways and buildings. No cows are wintered on milking platform and young stock are grazed off from weaning.

The "sweet spot" for cow numbers for this farm to achieve the Flemington goals and meet their values is around 750 cows with the balance of land in crop and young stock.

The soils on farm are a 'Waterton silt loam' or silt loam over clay with a , alluvium parent material. These soils are heavy and all of the farm is tile drained. The average $PAW_{0\text{-}60}$ is 135mm, resulting in very little drainage out of the root zone (0-60 cm). The soils have very low N loss vulnerability. Atypical for most of Canterbury

Irrigation water is supplied from two bores (50-60 m deep) and the farm is an independent irrigator i.e. not in an irrigation scheme. There are three centre pivots irrigating 202 ha. One pivot being variable rate irrigation. A Turborainer (travelling irrigator) applies water to 18 ha. There is 36 ha of dryland. The benefits of VRI on heavy soils is more about preventing pugging and damage around troughs, laneways and gateways than the differential of irrigating in spring and autumn. In 2019/20 the plan was to add VRI to the second pivot at an estimated cost of around $50,000. This is now on hold for another year awaiting technology advancement.

The farm has a 54-bale rotary with in-bale teat spray, mastitis detection, cup removers, heat detection camera and auto draft (Protrack). This allows the staff, 3 permanents (plus Phill & Jos), to have a roster where no one milks more than once a day.

The effluent system consists of a weeping wall and 52 days liquid storage in a separate pond. Effluent is applied by being injected into two of the farm pivots at 1-2 mm of depth for 115 ha (45% pastoral area).

The farm operates with 3.5 FTEs which equates to approximately 97,000 kg MS and 196-202 cows per person compared to the average in Ashburton of ~ 174 cows and 78-80,000 kg MS per person. The in-shed automation and other labour saving features of 93% of the farm irrigated with pivots and effluent injected into two of the pivots, makes the farm an attractive place for people to work.

The farm supplies to Synlait and is part of Synlait's lead with Pride scheme which rewards the farms for achieving dairy farming best practice. At the last audit (2020) the farm did very well with 100/100 for the Environmental pillar and an overall score out of 400 for the four pillars of 391 (Social responsibility100/100; Environmental 100/100; Animal Health & Welfare 97/100; Milk quality 94/100).

Farm Maps

Figure 1: Flemington Irrigation Map

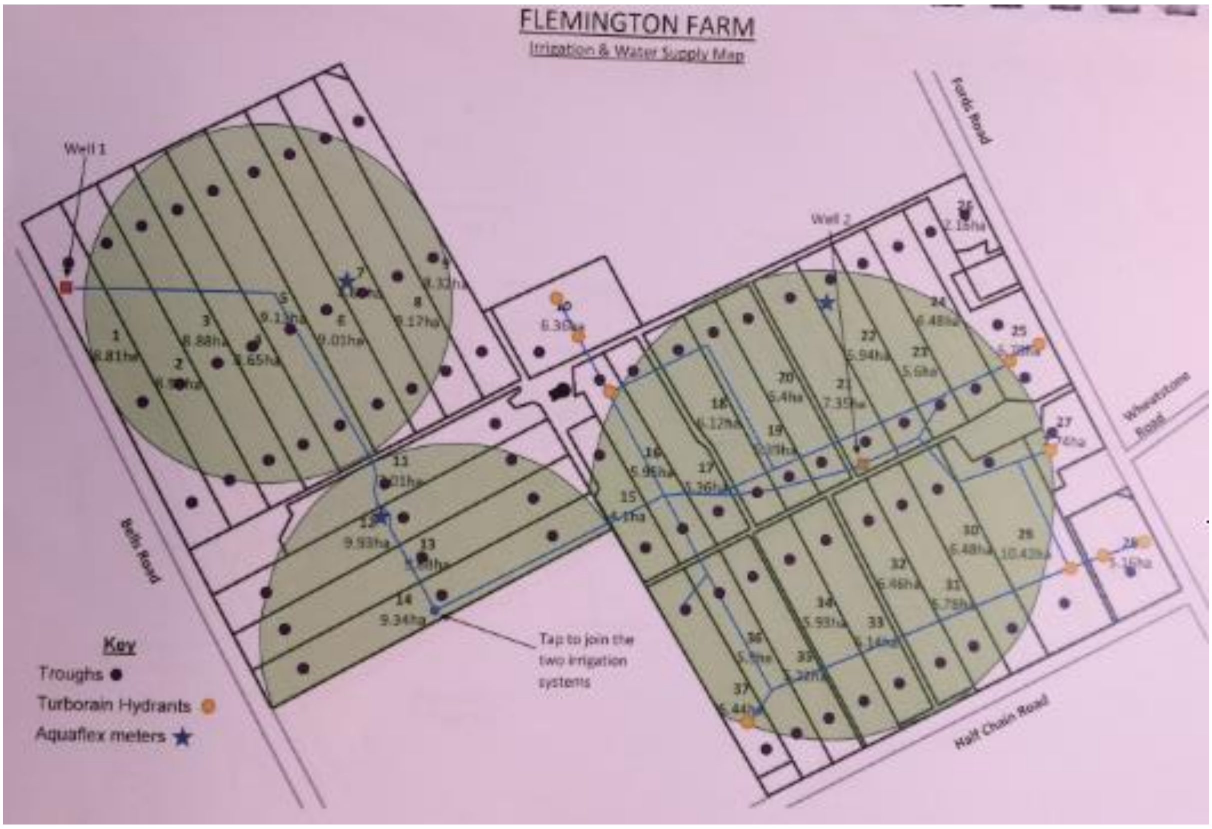
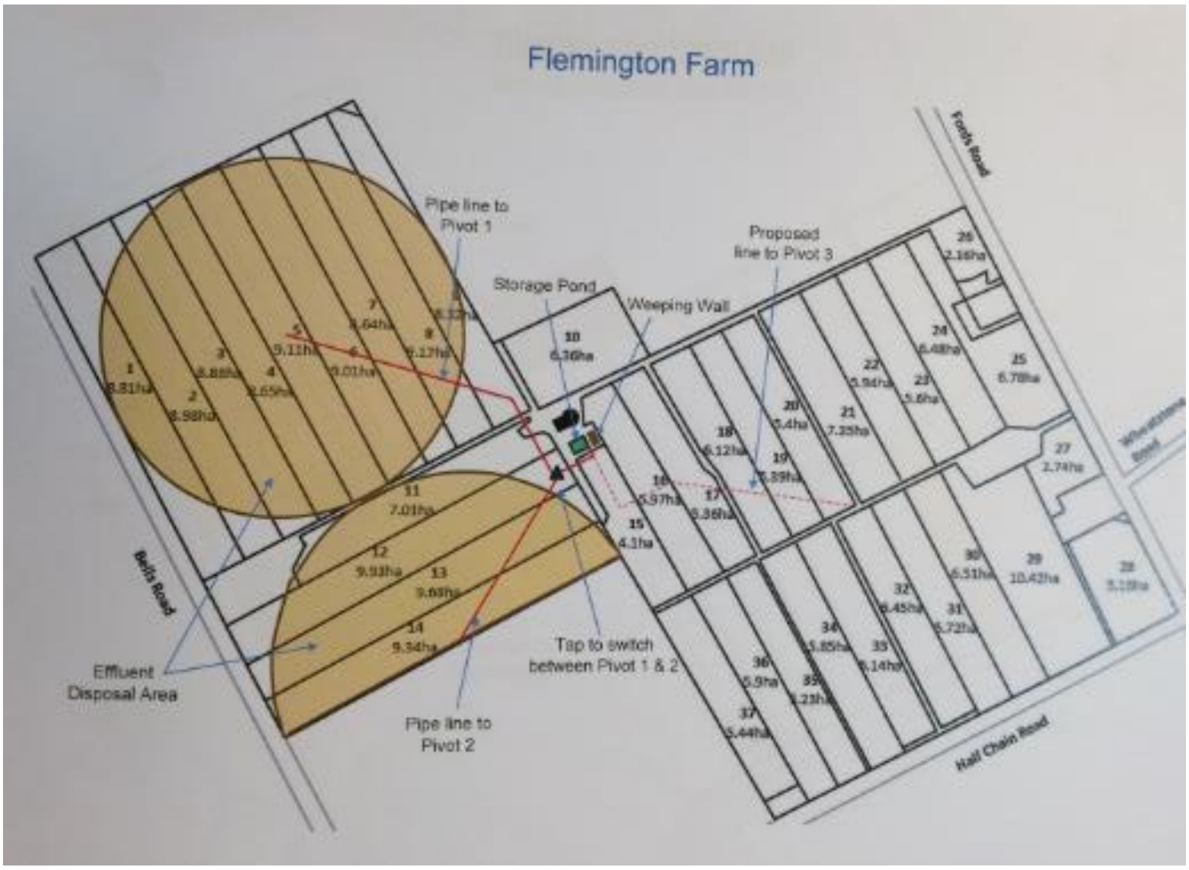


Figure 2: Flemington Effluent Map



Baseline N Loss and Benchmark Seasons

The 2012 and 2013 seasons set the baseline number for N loss as required by ECan. The 2018-19 season has been used to benchmark against for physical and financial performance for changes in the farm system.

The farm system currently being run is a System 2/3 with little feed imported to milking cows. In 2018-19 pasture comprised 83% of the cows' intake with imported feed 8% and wintering off 9%.

Environmental Regulation

Hinds Plan Change 2 covers the Hinds/ Hekeao Plains became operative on 1 June 2018. It is a framework for action to enhance ground water quality, protect drinking water supplies, improve flows in lowland streams for ecological, cultural and social values and to sustainably manage ground water storage. The plan states that further intensification, changes in land use or new irrigation is prohibited until nitrate levels in shallow groundwater are at or below 6.9 milligrams per litre (the national bottom line) at the time. The median nitrate nitrogen concentration in shallow groundwater for 2016 (July 2015 to June 2016) was 9.1 mg/L and the latest is 12.8 mg/L (July 2018 to June 2019). The lower Hinds catchment is naturally a swamp with the waterways being spring fed streams, fed by groundwater which is influenced by land-use over a much larger area upstream.

From 1 January 2017, farms in Hinds and Selwyn Te Waihora need to meet the good management practice (GMP) nitrogen loss rate as calculated for a farms baseline land use (2009-13). When using Overseer to calculate the baseline average N Loss for the 2009-13 seasons, the annual irrigation application depth can be no greater than the Irricalc average annual volume, plus one system application depth. *For example, for Flemington Farm, with pivots and PAW 120-140, Irricalc = ~ 360 mm plus one application depth 10 mm (pivot application rate) = 370 mm annually applied. Currently the application rates in Overseer for Flemington are 310-320 mm so well within the requirements.*

For farms in the Hinds Area with a Baseline loss greater than 20 kg N/ha/yr they need to make further reductions and will be progressively required to reduce their N loss beyond GMP levels by 15% from 2025, 25% from 2030 and 36% from 2035.

Plan Change 5 operative in November 2018 introduced Mahinga kai[1] and new requirements for Farm Environment Plans (FEPs). For any farms with streams and drains, a map in the FEP needs to identify the location of any mahinga kai, wāhi tapu or wāhi taonga and the FEP covers the good management practices for drains and other waterways to protect food gathering. *Flemington Farm has drains that lead into Mahinga kai sites close to the farm, so they have all their drains fenced off (for over 28yrs) and have recently planted on the northside of the drains to provide shade to enhance the environment in the drains for biodiversity.*

Mitigation Strategies

Phill and Jos haver reviewed the original scenarios that were modelled in 2018 as they have already made some changes. The following scenarios are what they want to target in the short term (Scenario 1) and longer-term mitigations (Scenario 2). The Everest's do not want to reduce milk production as they are currently running a largely all grass system and any reduction in production would need to come from a reduction in area farmed in dairy.

Scenarios Modelled

1. Reduce N fertiliser to 187 kgN/ha, and maintain milk production through improved N use efficiency
    - Use less N fertiliser from an average of 349 kg N/pastoral ha (313 kgN all ha) to 203 kg N/pastoral ha (187 kgN all ha). On pasture blocks 210 kgN/ha applied to non-effluent and 185 kg N/ha to effluent blocks and no change in milk production, with no more inputs as improve feed use efficiency
2. Reduce N fertiliser 187 kg N/ha, same N use efficiency, to maintain milk production purchase in more barley grain.
    - Use less N fertiliser from an average of 349 kg N/pastoral ha (313 kgN all ha) to 203 kg N/pastoral ha (187 kgN all ha) as per above.
    - Maintain milk production by feeding more barley grain silage to replace the reduced pasture yield from less N applied double up

[1] Mahinga kai is about the value of natural resources that sustain life, including the life of people

3. Reduce crop are:
    - From 23.3 ha to 18.9 ha (5.9 ha wheat, 6.0 ha barley and 7 ha fodder beet)
4. Reduce replacement rate to 20%
    - Keep 150 replacements and add 30 good empty carry-over cows to the replacements at the end of the season. No longer exporting live heifers.
5. Combination of 1,3 and 4
6. Reduce N fertiliser further to 134 kgN/ha (total hectares) and maintain milk production
    - Reduce N to 187 kg N/ha and maintain milk production
    - Remove another 43 kg N/ha to 134 kg N/ha (all hectares) and buy in barley grain to make up lost DM grown from removing last 43 kg N/ha; 134 kg N/ha average of 157 kg N/ha non-effluent blocks, 117 kg N/ha effluent

Results

Table 1: Flemington Scenarios Modelling Results by Mitigation

Scenario Overseer v6.3.3	**2018-19**	**Sc 1: Less N 187 kgN/ha =Same pasture**	**Sc2: Less N 187 kg N/ha =Less pasture, buy in barley grain**	**Sc13. Less replacements**	**4. Less cropping**	**5. 1,3&4 Less N 187 kgN/ha =Same pasture**	**6. Less N 134 kg N/ha buy in barley grain to replace last 43 kgN/ha removed**
N Surplus (Overseer)	**280**	**226**	**224**	**280**	**282**	**226**	**201**
N loss kg/ha from root zone (60cm)	**29**	**25**	**24**	**29**	**29**	**24**	**20**
Total N loss (KgN)	7,860	6,723	6,421	7,857	7,819	6,660	5,554
N loss % change Baseline 2012-13 9,265 kg N	**-15%**	**-27%**	**-31%**	**-15%**	**-16%**	**-28%**	**-40%**
Methane kg/ha	**9048**	**9048**	**8931**	**9025**	**9064**	**9044**	**8929**
NO2 kg/ha	3504	2939	2791	3496	3526	2946	2648
CO2 kg/ha	2282	1714	2024	2282	2267	1682	1610
Total GHG kg/ha	14834	13701	13746	14802	14857	13672	13220
Total GHG % change from 2018-19	**-**	**-8%**	**-7%**	**0%**	**0%**	**-8%**	**-11%**
Operating Profit	$2,980	$3,290	$2,760	$3,000	$2,990	$3,320	$2,640
Change profit to 2018-19 season	**0%**	**10%**	**-7%**	**1%**	**0%**	**11%**	**-11%**

Mitigations

To get N loss there needs to be a surplus of mineral N in the soil and drainage. As none of the mitigations modelled improved irrigation efficiency (as the farm already runs an efficient irrigation system) any reductions in N loss from the root zone (0-60cm) come from reducing the N surplus as shown above in Table 1.

- Applying less N fertiliser and maintaining milk production through improved N use efficiency resulted in an increase in profit and a reduction in N loss scenarios 1 and 6)
- Where more pasture cannot be harvested and feed needs to be purchased in to replace the pasture grown from nitrogen, N loss is reduced further than in Sc1 as the N content of the barley grain is less than that of pasture, reducing the N surplus further (scenarios 2 and 6 (mix of more pasture harvested and more purchased barley grain))
- Changing the replacement policy or reducing the cropping area do not significantly change N loss (as no change in N surplus), GHG or profit (scenarios 3 and 4). The Everest’s are not keen to reduce replacement rate as they would like to introduce any new genetics that will reduce N loss (low N cows) or GHG as soon as proven
- As all the scenarios were based on maintaining 2018-19 milk production, there is no change in methane emissions as methane is driven by dry matter intake.

Scenarios farm may implement

Table 2 looks at the likely scenarios (5 and 6) the Everest's would like to implement. Scenario 5 being the target for year end 2022 to align with the recently announced cap of 190 kg synthetic N/ha.

Table 2: Baseline year end 2012 and 2013, 2018-19, Scenario 5 and Scenario 6.

Overseer Version 6.3.3	Baseline 2011-12, 2012-13	2018-19	Scenario 5	Scenario 6
Farm parameters				
Total area (ha)	273.4	273.4	273.4	273.4
Overseer (effective ha, excl crops)	255.4	262.1	262.1	262.1
DairyBase Milking Platform (eff. ha)	228.2	228.2	228.2	228.2
Effective Pasture Area Overseer (ha)	222	238.8	243.2	243.2
Production (KgMS)	358,511	367,400	367,400	367,400
Peak cows	763	750	750	750
Milk production (kg MS/ha)	1,652	1693	1693	1693
Milk production (kg MS/cow)	470	490	490	490
Pasture & crop eaten (t DM/ha)[1/]	14.7	16.8	16.5	16.5
Purchased feed eaten (t DM/ha)[1/]	0.9	1.7	1.5	1.5
Grazing Off (t DM/ha)[1/]	1.1	1.8	1.7	1.7
Total Feed Eaten (t DM/ha)[1/]	16.9	20.2	19.8	19.8
N fertiliser use (kg N/total ha)	221	313	187	134
Crop Area (ha)	32.1	23.3	18.9	18.9
Nitrogen				
Total Farm N Loss (kg N)	9,265	7,860	6,660	5,554
N Loss/ha	34	29	24	20
N Surplus/ha (Overseer)	257	280	226	201
Purchased N Surplus/ha	222	238	112	67
Greenhouse gases				
Total GHG (tCO_2e/ha/yr)	14.8	14.8	13.7	13.2
Methane (tCO_2e/ha/yr)	9.0	9.0	9.0	8.9
N_2O (tCO_2e/ha/yr)	3.5	3.5	2.9	2.7
CO_2 (tCO_2e/ha/yr)	2.3	2.3	1.7	1.6
Profitability				
Operating Profit ($/ha)		$2,980	$3,320	$2,640
Changes	**Year Compared to**			
N loss % change	Baseline 2012 & 2013	-15%	-28%	-40%
GHG losses % change	2018-19	-	-8%	-11%
Profitability % change	2018-19	-	+11%	-11%

Note 1/ All Overseer calculated t DM eaten/ha including beef area = 243

If the farm can reduce N use and maintain production, profit will increase. If the farm needs to buy in supplement the break-even price milk price is around $7.00/kg MS (Jeremy Savage pers. comm). The modelling above was done on $6.00/kg MS price so purchasing supplement to replace N boosted pasture eaten results in a loss of profit.

Scenario 6 could be implemented in the next 2 years, but it comes a significant loss in operating profit (gross income less expenses) from 2018-19 (-11%) or $180/ha, which equates to $41,000 a year. This scenario meets the Hinds Catchment target reduction in N leached under the current Environment Canterbury plan.

Conclusions

N Loss

To get a reduction in N loss from the root zone (0-60 cm) need to:

1. Reduce drainage out of the root zone through efficient irrigation and /or
2. Reduce the N surplus (Overseer) = N Inputs (Fertiliser N, Supplement N Clover fixation and N in Irrigation) less N Outputs (N in product, milk and meat)
3. Avoid N applied over the high-risk months May to July and minimise N in the shoulder months, April and August.

Figure 3 shows the reduction in N loss from Baseline for the 2018-19 season and modelling. The reduction in N loss from Baseline to 2018-19 of 34 kg N/ha to 29 kg N/ha has come from improved irrigation efficiency (applying less water and getting less drainage). The N surplus (calculated by Overseer) increased from the Baseline years of 257 kg N/ha to 280 kg N/ha in 2018/19 (Figure 4).

As the farm is now well set up with very efficient irrigation and the soils are not free draining there is little opportunity to be more efficient with irrigation than currently being achieved in 2018-19 and no irrigation scenarios have been modelled. Further reductions in N loss modelled have therefore come from reducing the farm's N surplus by applying less N fertiliser and reducing the N surplus as shown in Figure 4.

Figure 3: N Loss from Root Zone 0-60 cm

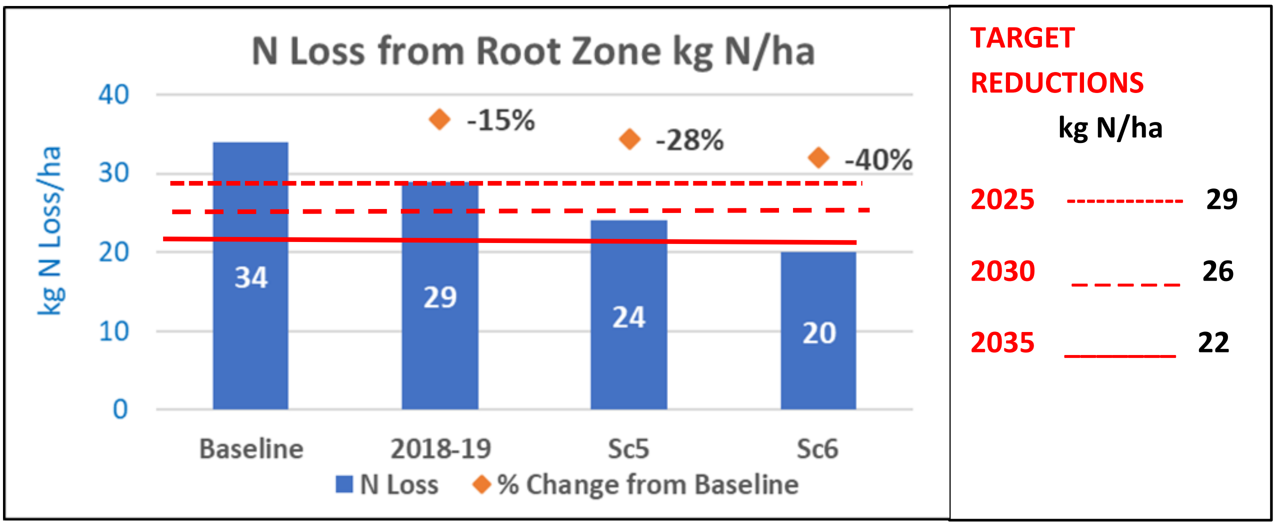
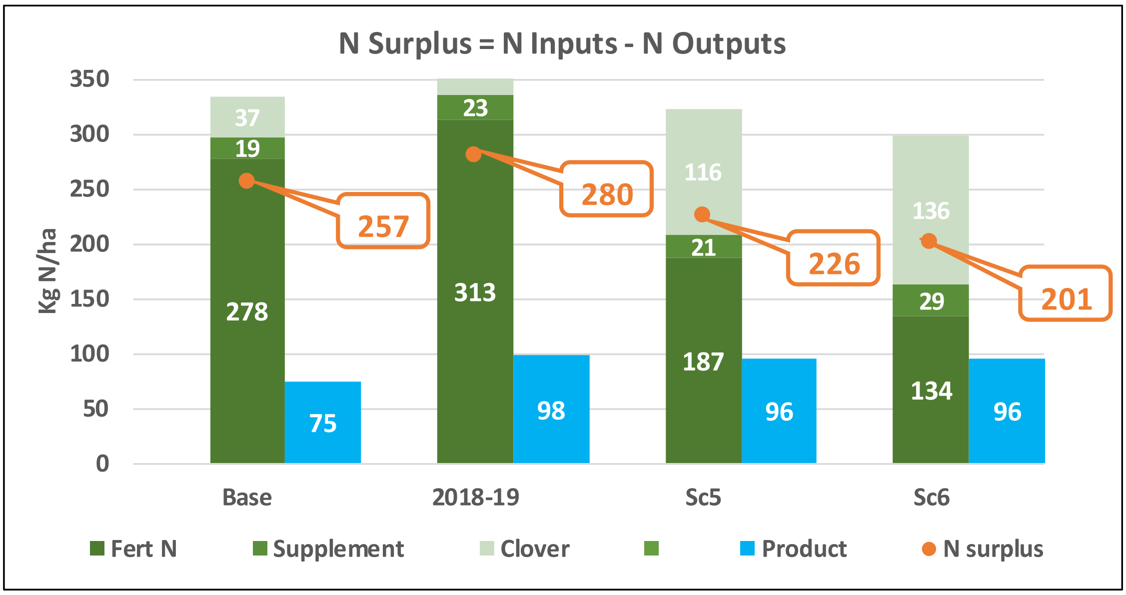


Figure 4: N Inputs and N Surplus per Hectare



The farm's N loss numbers are atypical for Canterbury due to:

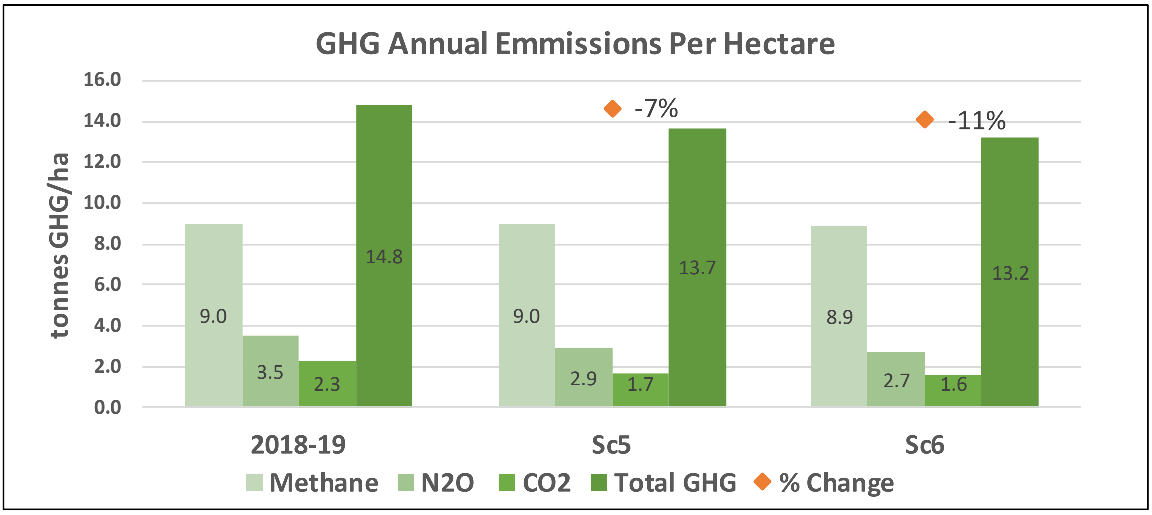
1. Heavy soil type:
   a. The soils have high water holding capacity known as profile available water (PAW). The PAW at 0-60 cm (root zone) is an average of 135 mm
   b. Very little drainage of the root zone (0-60cm) with an average of 35 mm/year resulting in the PAW only draining 0.26 times a year
2. Low intensity farm system
   a. Very little bought in supplement with 84% from pasture grown on farm, 5% supplement fed to milking cows and 11% from wintering off
3. Investment in Technology
   a. Very efficient irrigation with variable rate centre pivots – average annual water applied to pasture is approximately 325mm/ha as predicted by Overseer
   b. A weeping wall and effluent injected into pivots at a low depth of 1-2 mm, resulting in the average liquid effluent applied in 2015-16 of 42 kg N/ha/year

Reduction GHG

Figure 5 shows the total and change in GHG from 2018/19. Total GHGs can be reduced while maintaining production where less N fertiliser is used, as less nitrous oxide is produced. However, where milk prediction is maintained there is no change in dry matter intake (DMI) that drives enteric methane production so methane production is largely unchanged.

If the farm is required to reduce methane emissions, this can only be achieved from a significant farm system change as the farm imports very little supplement. For example, methane production can be reduced by increasing the area cropped for grain and doing less milk production as total DMI for the farm will need to be reduced.

Figure 5: Green House Gases (GHG)



Profit

Figure 6 shows the changes in operating profit (income less expenses).

Reducing N use to 187 kg N/ha and maintaining milk production shows profit increase by 11%. It is considered possible to implement this scenario with no loss in profit and possibly a small loss in milk production. The key is a gradual removal of N fertiliser to the 187 kg N/ha target to allow clover to respond and management to adjust.

Further reductions in N loss will require N fertiliser to reduce to around 134 kg N/ha. His will result in more barley grain being purchased in the maintain milk production, a goal of the Everest's. The additional cost of the barley compared to N fertiliser sees profit reduce to $2640/ha, an -11% loss and a total loss of operating profit (before drawings, tax, debt servicing) of -$77500.

Summary

As the farm is well set up with very efficient irrigation, and the soils have low drainage, there is little opportunity to be more efficient with irrigation. The opportunities to change the farm system and maintain profit are also low as the farm uses little supplement.

The scenarios modelled show that the farm can meet the current Hinds catchment N reductions. However, these come at a cost to profit unless alternative mitigations such as plantain, winter active species and low N cows being feasible farm system options.

Plantain has the potential to reduce N loss further and possibly methane. However, plantain is unlikely to persist when farmed on heavy soils and the cost of replacing the plantain to maintain 30% plus in the cows' diet over late summer/autumn may be significant. If "low N" cows are proven to significantly reduce N, this option is a practical to implement into a farm system and one the Everest's are keen to pursue. However, changing a herd's genetic profile takes time, 10-15 years.

Phill and Jos are very concerned for the farm's future under the proposed Essential Fresh Water plan and how this maybe implemented in the Hinds catchment. If it is applied where all water ways have to achieve a nitrate concentration of less than 2.4 ppm this reduction it is likely that only dry land sheep farming will meet the criteria unless catchment scale mitigations such as aquifer recharge and significant land use change are implemented.