AG & PJ Tait Family Trust – Ashburton, Canterbury

‘Greenhouse gas and nitrogen loss mitigation in the Hinds catchment’

A 2019 case study on environmental performance and the effect on production and profitability

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 (GHG) and nitrogen (N) loss to water from dairy farms, while maintaining the farm's profitability and meeting other environmental obligations.

Farm owner, Campbell Tait says "DairyNZ modelling provided invaluable information to help them reduce nitrogen (N) loss and greenhouse gas emissions (GHGs). It showed us where we could get the biggest impact, sometimes by making relatively small changes." Campbell hopes his learnings and those of the other project farmers will help others identify the best ways to reduce N loss on their farms.

This case study looks at the Tait Family Trust 2016-17 dairy operation and how the farm can reduce its GHG emissions as well as meet future compliance requirement for the Hinds catchment by 2035 for N leaching while maintaining profitability.

The Tait Family Trust is an intergenerational family-owned dairy business based in Lowcliffe, Ashburton. The home farm (275ha total) produces around 1,601 kg MS/ha, 513kg MS/cow operating a System 4 production system. A 123ha support block, located 1km east of the dairy farm, provides young stock grazing and winter grazing.

Two scenarios were analysed to highlight alternative pathways to achieve the businesses' environmental obligations under Environment Canterbury's (ECan) 'Plan Change 2' (PC2) and mitigate GHG emissions. The 2016/17 season is used as the baseline model for physical, financial, and environmental comparisons. Scenario 1 demonstrates a low investment move to a lower-input system. Mitigations included reducing fertiliser N use (-40%), lifting the Olsen P status, improving irrigation efficiency, reducing cropping, use of catch crops, and rearing additional beef weaners. This option is a lower-output higher-margin model, provides the lowest breakeven milk price, and builds the business' resilience. The model also provides a moderate (10%) reduction in GHG emissions, reducing exposure to any likely future emission liabilities.

Table 1. *Summary of performance indicators for the tested scenarios against the base system (2016/17).*

Performance Indicators	Base System (2016/17)	S1 'Low Intensity'	S2 'Infrastructure'
Stocking rate (cows/ha)	*3.1*	*3.2*	*3.4*
Production (kg MS/ha)	*1,601*	*1,558*	*1,650*
Operating profit ($/ha)	$4,105	$4,767	$4,844
Return on Asset (ROA) (%)	5%	6%	6%
N leaching losses (kg N/ha)	103	63	62
N surplus (kg N/ha)	211	159	180
N conversion efficiency (%)	34%	38%	36%
Total GHG emissions (t CO2 eq./ha)	12.70	11.48	12.52

Scenario 2 includes many of the reduction strategies utilised in Scenario 1 as well as investing in a feed pad. The system provides similar reduction in N leaching losses, highest operating profit, and is a higher-output lower-margin model compared to Scenario 1. The system provides more flexibility to adjust between seasons and may provide further opportunity to improve profitability over time. Conversely, $520,000 would be needed to support capital investments.

Both scenarios achieved the reductions needed to meet the farm's 2030 target under PC2, with further reductions assumed to be meet with mitigation options that are still under development (i.e., plantain, low N breeding, salt etc.). Each scenario provides a different pathway, and each has pros and cons. Encouragingly, the analyses show the targets can be meet without compromising productivity or profitability.

Campbell and Martina Tait: Goals, Principles and Values

From the Whole Farm Assessment conducted by Leighton Parker (Perrin Ag Consultants), the following vision/goals, values and farming principles were identified:

Vision & Goals

- Maintain a largely self-contained operation, reducing vulnerability to biosecurity and other risks
- Have the ability to "step away" from the farm for travel and to spend time with family and be confident it will continue to operate well.
- Reduce debt to a more manageable level.

Farming Principles & Values

- A strong focus is placed on animal welfare, high milksolids (MS) performance, low herd wastage rates and "happy/contented" cows.
- Environmental awareness and stewardship are taken seriously.
- Looking after the team's wellbeing is a priority (zero harm, home safe every day).
- Contributing to community and industry good is encouraged, by both family members and employees.
- Honesty is important and mistakes are encouraged to be brought forward.
- "Know where we stand" by benchmarking against industry leaders.

Farm Overview

Tait Family Trust is an intergenerational family-owned dairy business based in Lowcliffe, Ashburton. The home farm (275ha) was previously operated as a sheep farm with some cropping and beef. The property was converted in 2010/11 to commence milking in the 2011/12 season. A 123ha support block, located 1km east of the dairy, was purchased in 2014 providing dairy support to the business and allowing for an increase in livestock numbers.

Table 2 *Summary of Tait Family Trust physical resources.*

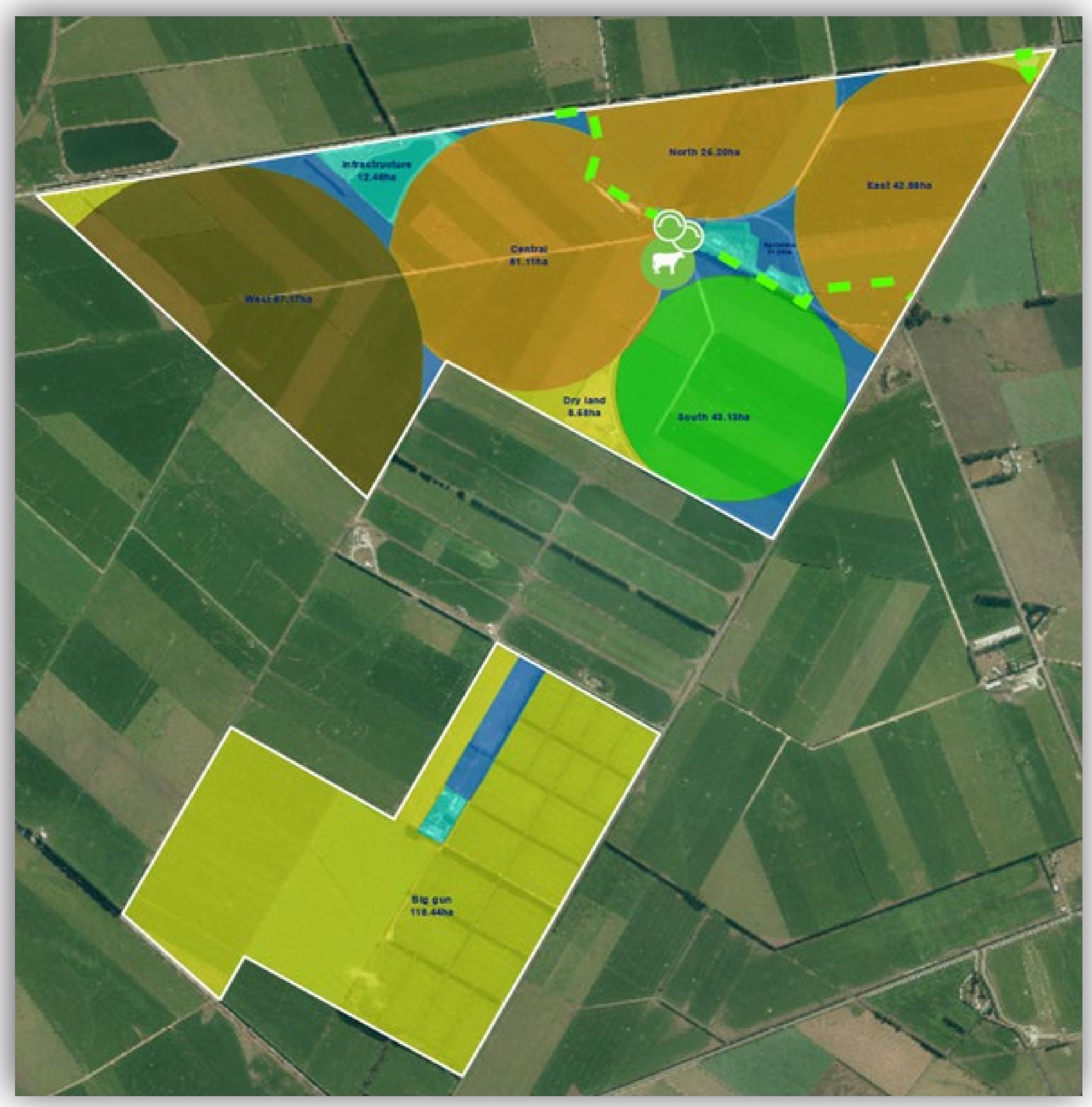
Physical Resources	Home Farm	Support Block
Effective Area ha	250 ha	115 ha
Soils: Very free draining, low PAW, and very vulnerable to drainage and N leaching	86% Lismore shallow silt loam (PAW_{0-60} 63mm) 14% Lowcliffe shallow silt loam (PAW_{0-60} 51mm)	45% Lismore shallow silt loam (PAW_{0-60} 63mm) 55% Lowcliffe shallow silt loam (PAW_{0-60} 51mm)
Irrigation: Mayfield Hinds Valetta (MHV) scheme plus deep bore	Pivots 93%; Sprinklers 5%; dryland 2%	Pivot 41%; Gun 50%; Sprinklers 9%

For the 2016/17 season, the farm peak milked 780 spring calving crossbred cows (3.2c/ha) producing a total of 400,225kg MS (513 kg MS/cow or 1,614 kg MS/ha). The Taits operate a System 4 production system feeding 763kg DM/cow of imported feed with fodder beet utilised to extend lactation in the autumn. Around 235kg N/ha is applied to the effective pastoral area with no N applied for the months of June and July. Approximately 81ha is cropped (1/3 home farm: 2/3 support block) in either fodder crop (i.e., kale, fodder beet, sugar beet) or cereal silage to support wintering of the dairy cows and young stock.

Effluent solids are separated mechanically with the liquid injected into the pivots and spread over 231ha. This ensures nutrients are utilised efficiently and the N loading from effluent is low (25-30kg N/ha/year).

Campbell, with the support of Martina, operates the business as an Operations Manager. The farm employs 6.5 full time equivalents (FTEs), including Campbell and Martina, a runoff manager, a 2IC, a dairy assistant and casuals to meet seasonal demand. The Taits have a strong focus on operating the farm to its profitable potential while operating a mostly self-contained model.

Figure 1 *Tait Family Trust farm area*



Mitigation Strategies

Two scenarios were analysed to highlight alternative pathways to achieve the businesses' environmental obligations under PC2 and mitigate GHG emissions. As MHV Water has yet to establish a baseline period the 2009/10 to 2012/13 period has been used to form the baseline N loss rate for the purpose of this case study. A 25% target reduction in N loss below the baseline N loss rate has been modelled to align with the farm's 2030 reduction target. Further reductions will be required to achieve the 2035 target (a 36% reduction). It is assumed these can be achieved through future scientific breakthroughs.

Data for the 2016/17 season is used for the current farm system and provides the base model for physical, financial, and environmental comparisons. This system is currently operating at 104kg N/ha/year leaching losses (OVERSEER v.6.3.1), 19kg N/ha/year above the estimated baseline N loss rate of 85kg N/ha/yr. Accounting for the 25% reduction from the baseline N loss rate, the strategies described target an N leaching loss equal to or lower than 63kg N/ha, or a total reduction of 39% from 2016/17 levels.

Scenario 1: Low intensity strategies focused on resource use efficiency

1. Reduce N fertiliser use from 235kg N/ha to 142 kg N/ha (-40%).
2. Lift the dairy farm's Olsen P status from 16-17 to an optimum status of 30.
3. Target high loss activity on less leaky soil (i.e., cropping).
4. Reduce fodder and cereal crop area from approximately 81 to 57 hectares per year (-30%).
5. Utilise catch crops where possible to minimise bare soils.
6. Lower sprinkler annual applications by installing a timer on the sprinkler pump (i.e., 700mm -> 465mm/year).
7. Increase the number of beef weaners reared from 30 to 300. This strategy provides additional beef income, provides a closer match to the pastoral feed supply, and supports a lower feed demand in late autumn/winter when N leaching risk increases.

Scenario 2: Resource efficiencies plus added infrastructure

Scenario 2 includes many of the reduction strategies utilised in Scenario 1 as well as investing in a feed pad. The feed pad allows for a slightly higher input/output system. Capital investment is required ($520,000) to increase cow numbers, construct the feed pad and provide additional effluent storage, as well as working capital for maize silage.

1. Reduce N fertiliser use from 235 kg N/ha to 160 kg N/ha (-32%).
2. Lift Olsen P status, targeting high loss activity on less leaky soils, use of catch crops, lower sprinkler annual applications, and the rearing of beef weaners as per ii, iii, v, vi, and vii above.
3. Reduce fodder and cereal crop area from approximately 81 ha per year to 49 (-40%).
4. Construct a 450-cow feed pad to capture urine on the milking season shoulders and winter months, plus provide the ability to feed maize silage to lower urinary N concentrations. Approximately 275 t DM of maize needs to be fed from March through to mid-September. Capital requirements are assumed at $425/cow ($191,250) allowing 3.5 to 4m^2/cow. An additional effluent holding pond, at an estimated cost of $45,000, is needed to maintain 30 days' storage.

Table 3 *Summary of performance indicators for the base model (2016/17) compared to the two tested scenarios.*

Farm parameters (OVERSEER Version 6.3.1)	Base system 16/17	Scenario 1 – Low Intensity	Scenario 2 – Infrastructure
Total area (ha)	398	398	398
Total Effective area	365	365	365
- Milking platform (effective)	250	250	250
- Support block (effective)	115	115	115
Peak cows	780	800	840
Production (kg MS)	400,171	389,383	412,413
- Per hectare (kg MS/ha)	1,601	1,558	1,650
- Per cow (kg MS/cow)	513	487	491
Dairy Beef Calves Raised	30	300	300
Purchased feed eaten (t DM/ha)	1.2	0.9	1.4
Pasture Eaten (t DM/ha)	13.7	13.8	14.2
Total Feed Eaten (t DM/ha) *	14.9	14.7	15.6
Comparative stocking rate (kg LWT/t DM offered)	76	79	78
N fertiliser use (kg N/total ha)	235	142	160
Crop Area (ha)	81	57	49
Nitrogen			
Total Farm N Loss (kg N)	41,247	25,114	24,882
N loss/ha	104	63	62
N surplus/ha	211	159	180
Greenhouse gases			
Total GHG (tCO2e/ha/year)	12.70	11.48	12.51
Methane (tCO2e/ha/year)	7.99	7.90	8.54
N2O (tCO2e/ha/year)	2.70	2.15	2.32
CO2 (tCO2e/ha/year)	2.01	1.43	1.65
Emissions efficiency (kgCO2e/kg MS)	12.5	11.6	12.1
Profitability			
Gross Farm Income ($/ha)	$11,047	$11,426	$12,010
Operating Expenses ($/ha)	$6,942	$6,658	$7,166
Operating Profit ($/ha)	$4,105	$4,767	$4,844
Operating breakeven milk price ($/kg MS)	$5.13	$4.68	$4.78
Return on Asset (ROA%)	5.1%	5.8%	5.8%
Operating Profit/t CO2e ($)	$203	$261	$243
Change from current system			
N leaching (%)		-26%	-27%
GHG losses (%)		-10%	-1%
Profitability (%)		+16%	+18%

*Total feed eaten is calculated from the total business including drystock and support land

Productivity

The low intensity scenario operates a slightly higher stocking rate compared to the base system (3.2 vs 3.1 cows/ha) and is designed to increase the pastoral grazing intensity while maintaining high pasture utilisation and requiring less imported feed. Pasture eaten is like the base model (13.8 vs. 13.7 t DM/ha eaten) even though 83kg N/ha has been removed from the farm, offset by increasing the Olsen P status. Overall, total production is only down 3% despite imported feed and cropping reducing by 25% and 30%, respectively.

Scenario 2 operates at a higher stocking rate, peak milking 840 cows. Imported feed increases by 0.2 t DM/ha however, much of the increased feed demand is met by pasture eaten lifting by 0.5 t DM/ha. The latter arose from raising the Olsen P status to optimum and achieving high utilisation of pasture with less silage made. Total production is 3% higher than the base model with 17% more purchased supplement and 40% less cropping.

Profitability

Gross farm income increased in both scenarios due to the beef income generated from 300 dairy beef calves reared and sold in the autumn (refer to **Table 2**). This strategy provides an economic means to increase farm income, mitigate the impact of milk price volatility and operate an enterprise that matches the pastoral feed supply. Scenario 2 has the highest gross farm income from beef and milk.

Operating expenses are lowest for Scenario 1, being 4% less than the base model. Although additional expenses are incurred with the autumn beef enterprise, substantial savings are made in purchased supplementary feed and less cropping. Consequently, operating expenses are $0.06/kg MS lower. Scenario 2 has 3% higher operating expenses than the baseline model. Although cropping area and associated expenses are lower, purchasing 200 t DM of maize silage (and the additional vehicle expenses incurred) along with the extra cows milked (higher animal health, breeding, and milk harvesting expenses) generates a net increase in total expenses. Operating expenses per kilogram of milksolids however, is the same as the base model at $4.34/kg MS.

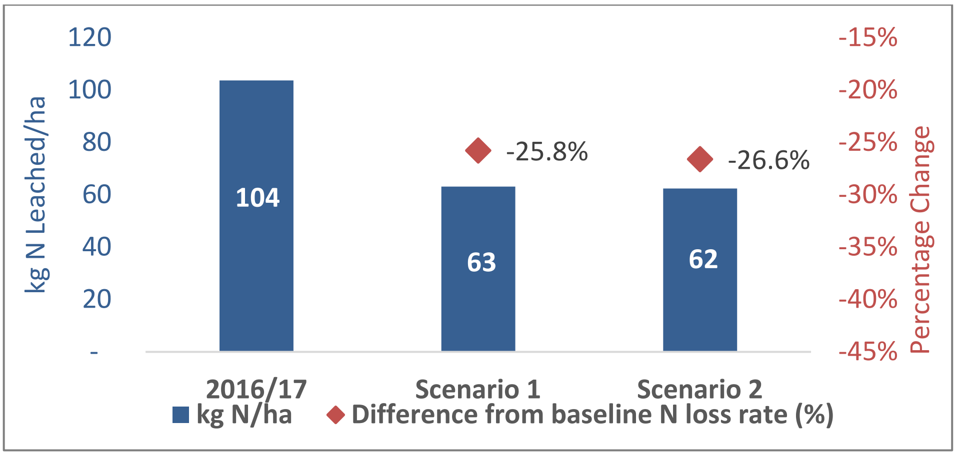
Scenario 2 achieves 15% more profit than the base model and 2% more than Scenario 1. Both systems provide a large increase in overall operating profit reflecting improvements in resource use (less cropping and N fertiliser). However, accounting for interest for additional capital requirements, the two test scenarios provide equal levels of discretionary cash. Return on assets (%) was 0.7% higher for the two scenarios indicating improved asset use efficiency compared to the base scenario.

N Leaching

Scenario 2 demonstrated the largest reduction in N loss, 27% below the baseline N loss rate and 40% below the 2016/17 base system. A small reduction in N surplus (-31 kg N/ha) is achieved and the same N conversion efficiency is maintained.

The low intensity scenario also meets the farm's 2030 target of 63 kg N/ha. This scenario achieves the highest reduction in N surplus (-52 kg N/ha) and improves the N conversion efficiency (+2% or 38%) due to lower input requirements while maintaining good productivity.

Figure 2 *Nitrogen Leaching Losses (kg N/ha)*



Overall, reductions were made by lowering N inputs (less N fertiliser and imported feed), enhancing N uptake by plants (catch crops and N fertiliser timing), reducing high N loss activity (cropping), maintaining more N within the root zone (improved irrigation efficiency), and modifying N deposition to pasture (capturing urine on the feed pad).

Irrigation

The land irrigated by sprinklers represents 8.4% of the total effective area. This is a small proportion of the farm but on a per hectare and total basis contributes significantly to N losses due to poor irrigation efficiency and high drainage volumes. Lowering the amount of annual irrigation applied from 700 to 465mm/year reduces drainage from 625-655 to 364-412mm per year (37 to 42% reduction).

Table 4 *Impact of reducing sprinkler application rates (700 to 465mm/year) on drainage and N leaching losses/ha.*

Parameters	Baseline (2016/17)	S1 Low Intensity	S2 Infrastructure

Soil type*	Lism_2a.1	Lowc_1a.1	Lism_2a.1	Lowc_1a.1	Lism_2a.1	Lowc_1a.1
Rainfall (mm/year)	644					
Irrigation applied (mm/year)	700		465			
Drainage (mm/year)	625	655	364	412	364	412
PAW_{0-60}	63	51	63	51	63	51
Pore Volumes (PV)*	9.9	12.8	5.8	8.1	5.8	8.1
N leaching loss/ha	119	148	50	66	52	69
Change from current system						
N leaching loss/ha			-58%	-45%	-56%	-53%

* The farms soils are classified as Lismore shallow silt loam (Lism_2a.1) and Lowcliffe silt loam (Lowc_1a.1).

** One poor volume of drainage is equivalent to the sum of total water holding capacity within the root zone (i.e., PAW_{0-60}).

The number of times the profile available water (PAW) for a soil drains over a year, defined as a pore volume (PV), has a big impact on N leaching. In 2016/17, OVERSEER estimates 9.9 to 12.8 PV. This is well above the pivot irrigated areas of 4.4 to 6.2 PV. Improving the irrigation efficiency of the sprinklers, through installing a timer on the pump and reducing application rates, lowers the number of PV to 5.8 to 9.1 (-37 to -42%). On a per hectare basis, N leaching losses reduce by 45 to 58%. Whole farm N leaching losses reduce by approximately 6 kg N/ha/year contributing to 9% of the total reduction.

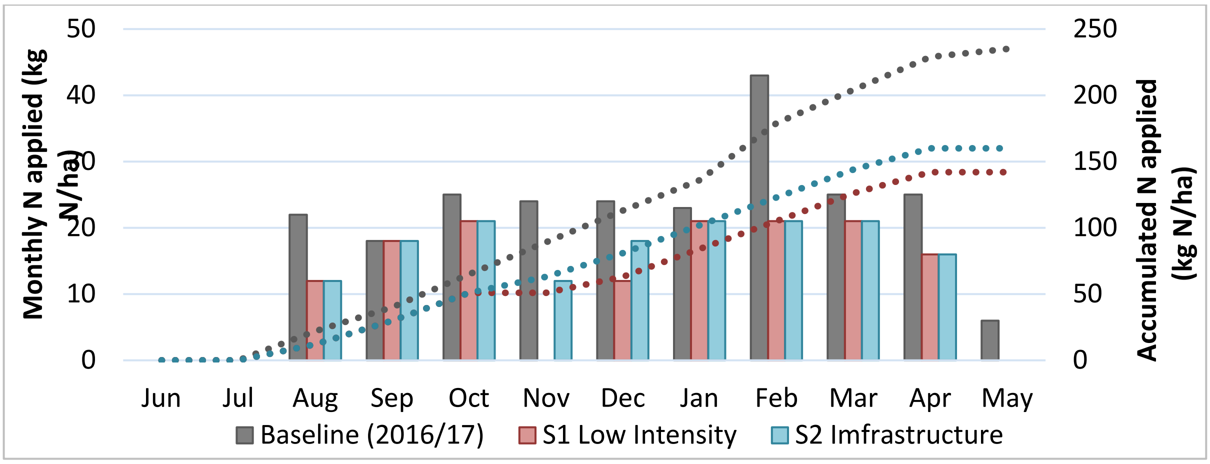
Nitrogen Fertiliser

Reducing the amount of N fertiliser applied from 235 to 142kg N/ha/year (total ha) in Scenario 1 contributed 24% to the 41kg N/ha reduction in N loss. Scenario 2 lowered N fertiliser to 160 kg N/ha/year contributing 19% to the 42 kg N/ha reduction in N loss. The reductions were achieved by: (a) eliminating May N, (b) creating geospatial application zones to reduce the area N is applied to and improved N use efficiency (i.e., avoiding stock camps, gate ways, troughs, fronts of paddock); and (c) reducing N fertiliser use on crops through deep nitrate testing.

Increasing the Olsen P from 16-17 (85% pasture growth potential) to an optimum of 30 (97% pasture growth potential) meant there was little change in pasture eaten (+0.1 to 0.5 t DM/ha).

Reducing fertiliser N, lowered N surplus (-52 and -31 kg N/ha) and improved N conversion efficiency (+4% and +2%). This mitigation highlights an opportunity to reduce and improve the efficiency that N is used while maintaining productivity (similar pasture eaten) and improving profitability (reduced expenditure).

***Figure 3** Comparison of monthly N applied (bars) and accumulated N applied (dotted line) for the low intensity (S1) and infrastructure (S2) scenarios against the base 2016/17 system.*

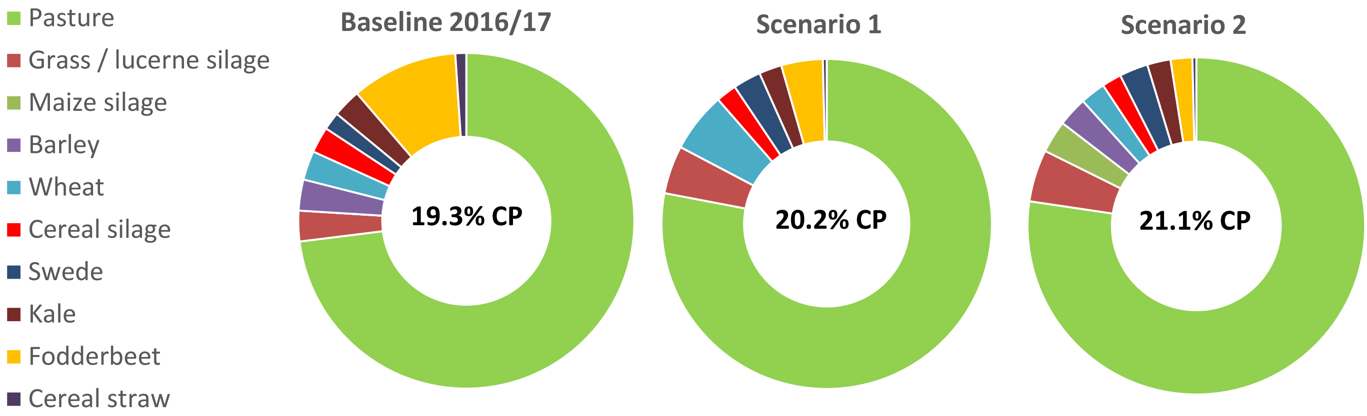


Feed pad

The original hypothesis for investing in a feed pad to reduce N leaching losses in Scenario 2 were twofold: (1) modifying N deposition to pasture (capturing urine on the feed pad) and applying effluent during low-risk periods; and (2) including maize silage in the diet (low protein content) to reduce urinary N concentration, particularly during late autumn when there is a higher risk of N being lost.

The inclusion of the feed pad in Scenario 2 resulted in the removal of autumn fodder beet and a slight reduction in winter crop. Total cropped area was 10% lower than Scenario 1 and 40% lower than the 2016/17 base system. These factors supported a moderate reduction in N leaching losses which allowed more N fertiliser to be applied and consequently more pasture to be harvested (+0.4-0.5 t DM/ha). This resulted in pasture harvested as a percentage of total feed eaten being highest for Scenario 2. The average crude protein content of feed eaten was 1.8% higher than the 2016/17 base system and 0.9% higher than Scenario 1 (refer to **Figure 5**) which overall would support higher urinary N concentrations - an unintended consequence of system change. Therefore, the key factors lowering N loss from the feed pad were modifying N deposition and reducing the area cropped.

Figure 4. *Impact of the percentage of home grown and imported feed eaten on the average crude protein (CP) content of feed eaten. Note PKE and molasses have been excluded from the pie charts due to their low percentage of total feed eaten.*



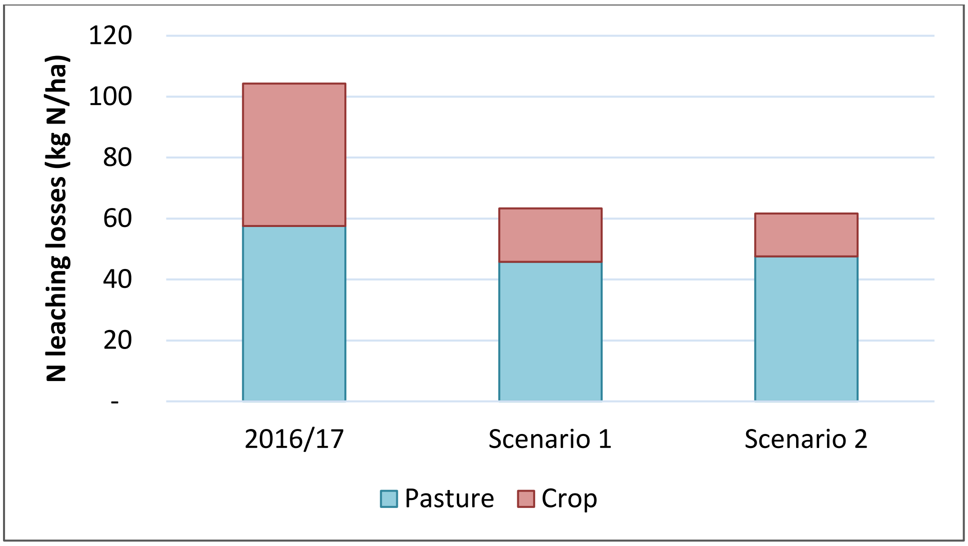
Cropping

Figure 5 highlights the large contribution cropping makes to N leaching losses. Losses from cropped areas for the 2016/17 base system ranged between 78 to 402kg N/ha depending on the stage in the crop rotation. This is 1.4 to 7.3 times higher than the pastoral area which was 55kg N/ha.

Reductions in crop area were achieved by wintering 200 cows on pasture plus utilising targeted once a day milking (OAD) to reduce body condition score (BCS) gain requirements during winter. Feed utilisation improved with the cows operating under a tighter winter allocation. Scenario 2 achieved a further 10% reduction in cropped area with the inclusion of the feed pad negating the need for autumn fodder beet and slightly reducing the winter crop area.

Utilising deep nitrate testing supported targeted N use to meet the crops requirements. This played a key role in reducing losses on a per hectare basis. The combination of reduced area and less N fertiliser being used resulted in crop associated N leaching losses for S1 and S2 reducing by 63 and 70%, respectively. On a per hectare basis this contributed to the farm's N loss reducing by 30 and 33kg N/ha compared to the 2016/17 base system.

Figure 5 *Comparison of N leaching losses (kg N/ha) contributed by land use.*

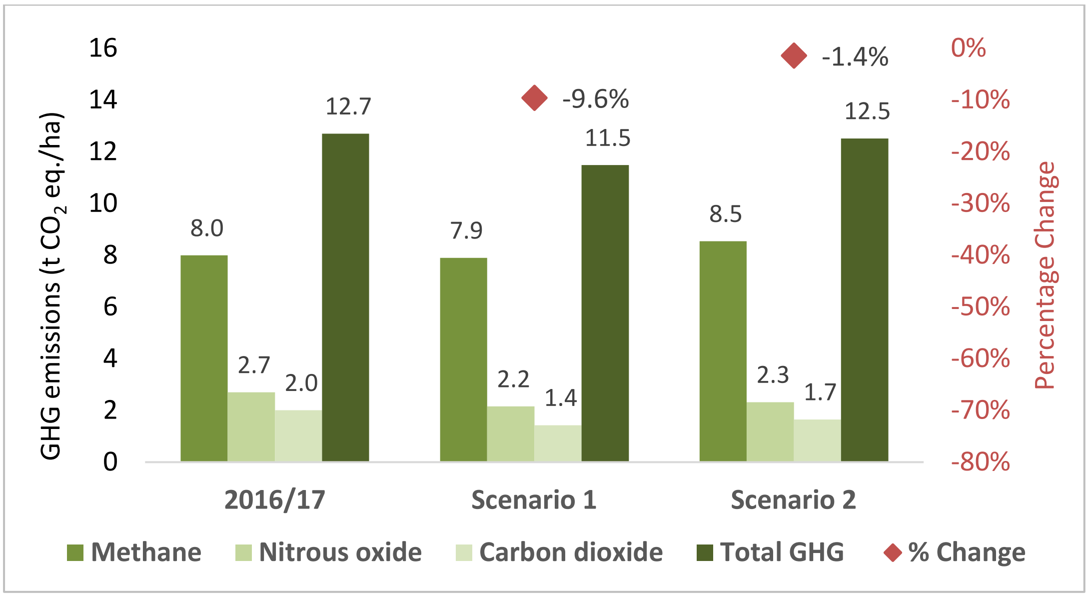


Green House Gas Emissions (GHG)

Figure 6 summarises the changes in GHGs. Both the farm system and management can affect methane and nitrous oxide. Methane is directly related to dry matter intake (DMI x 21.6 g/kg DM eaten x 25 = Methane CO_2e). The amount of nitrous oxide (N_2O) is driven by: Nitrogen fertiliser use, total annual nitrogen excreted, and soil type (higher losses on heavier soils).

Scenario 1 demonstrates a 10% reduction in GHG (t CO_2 eq./ha) compared to the base system. Reductions were achieved by lowering DM intake per hectare (lowering methane emissions) and reducing fertiliser N use (lowering N2O emission). As less supplement and fertiliser was used, CO_2 emissions also dropped significantly (-29%). Scenario 2 demonstrated similar GHG emissions to the base model. Reducing fertiliser use lowered N_2O and CO_2 emissions. However, increased supplementation and DM intake per hectare boosted methane emissions.

Figure 6 *Comparison of Green House Gas (GHG) emissions.*



Further reductions in GHG emissions could be achieved either by lowering N fertiliser use and/or reducing dry matter intake. However, this would negatively impact profitability and the efficient use of capital invested into infrastructure.

Summary

Scenario 1 demonstrates a low investment move to a more grass-based system. This option is a lower-output higher-margin model, provides the lowest breakeven milk price of the three systems, and builds the business' resilience. The model also provides a 10% reduction in GHG emissions, reducing exposure to any likely future emission liabilities. Conversely, the system would be more challenging to operate from a grazing management skills perspective than S2 and provides less capacity for further reductions in environmental externalities if future mitigation options are not sufficient or suitable.

Scenario 2 combines a focus on resource use efficiency with infrastructure investment to reduce environmental externalities and supports moderate intensity farming. The system provides similar reduction in N leaching losses to Scenario 1, highest operating profit, and is a higher-output lower-margin model compared to Scenario 1. The system provides more flexibility to adjust between seasons and may provide further opportunity to improve profitability over time. Conversely, $520,000 would be needed for the capital investment in the feed pad and effluent system. GHG emissions will be similar to the existing farm system due to no change in DM intake and more effluent excreted off the paddock (lower emissions from urine excreted onto pasture).

Both scenarios achieved the N reductions needed to meet the farm's 2030 target under PC2 with further reductions assumed to be met with mitigation options still under development (i.e., plantain, low N breeding, salt etc.). Each scenario provides a different pathway, and each has pros and cons. Encouragingly, the analyses show the targets can be meet without compromising productivity or profitability.