Meeting nitrogen leaching reductions while retaining a profitable system – a Selwyn catchment example

Farmers in Canterbury are some of the first to face the challenge of reducing their nitrogen (N) losses, many to well below their current level. As more regional councils develop and implement policies to improve water quality, all farmers will benefit from key learnings of their Cantabrian counterparts. Here we investigate options for one Canterbury business, Canlac Holdings, by using scenario modelling to identify management strategies that meet requirements while retaining profitability.

Key findings

- Many catchments will require reduced agricultural nutrient loss to improve water quality.
- Options to reduce N leaching include: more efficient use of water, fertiliser and effluent; using low-N supplements; and reducing cow numbers in autumn.
- These strategies reduce the amount of surplus N in the farm system and N deposited on pasture in autumn when plant N uptake is slowing and risk of drainage is increasing.
- Each farm will require its own reduction strategies to achieve nutrient obligations, yet options are available to improve the efficiency of N use while retaining a profitable system.

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The majority of N loss to water comes from urine patches in grazed dairy systems, but also includes N leached from areas between urine patches, N loss from run-off and direct deposit of dung or urine into waterways (if accessible by animals). N leaching is defined as all N drained to below 60 cm soil depth, assumed to be the depth of the root zone. Poor irrigation management contributes to drainage while over-application of N from fertiliser and effluent increases the risk of N leaching.

Environment Canterbury, and regional zone committees, have developed policies in response to the National Policy Statement for Freshwater Management. The policy for the Selwyn/Te Waihora catchment became operative in February 2016. This policy requires all farms to implement good management practices (GMP) from 2017 as defined by the Matrix of Good Management (MGM) Project[1].

By 2022, dairy farms that have an N loss of more than 15 kg N/ha/yr, as estimated with the nutrient budget tool, OVERSEER®, must reduce losses by 30% (dairy milking platform) and 22% (dairy support) of the N loss rates. These have to be consistent with GMP for the property's baseline land use (the seasons 2009-2013). From 2037 no farm will be permitted to leach more than 80 kg N/ha/yr.

To achieve these requirements, farmers must know:

- Their baseline N loss rate consistent with GMP.
- The options available that will reduce N loss to meet their target.
- Decide which are most appropriate for their farm.
- Implement the chosen options successfully.

Industry effort is essential to make information available, to develop new practical and cost-effective options, and to help build suitable support for farmers.

Options to reduce N leaching

Options to reduce N leaching from agricultural farming systems were investigated in the Pastoral 21 (P21) research project, and

further studies are being conducted in the Forages for Reduced Nitrate Leaching (FRNL) programme.

P21 farmlet studies in Waikato, Manawatu, Canterbury and Otago[2] compared current practice with strategies predicted to reduce N leaching significantly. These are less fertiliser and supplement N input, lower stocking rate, and standing cows off pasture from several hours per day to all day during wet conditions or in autumn/winter.

FRNL aims to find pasture plants and forage crops that reduce the surplus N intake of animals, reduce or alter urinary N excretion, and increase plant N uptake from the soil, e.g. through deeper rooting or cool season growth[3]. New Zealand's standard perennial ryegrass-white clover pastures contain more protein than grazing animals require, and the surplus N is excreted, mainly via urine. The urine patch, in turn, contains levels of N which are higher than pasture plants can take up. The soil mineral N, dissolved in soil moisture, is at risk of draining below the root zone and may end up in ground and surface water.

OVERSEER® contains key water and nutrient management principles confirmed in P21 farmlet trials and FRNL experiments. So far, it does not consider novel options of contol, e.g. combinations of plant species. Key components are:

- Apply irrigation efficiently to avoid drainage or plant water stress by monitoring soil moisture and taking account of the weather forecast and soil water holding capacity. This increases herbage production and plant N uptake, while managing the risk of N leaching, i.e. loss of water containing dissolved nutrients below the root zone.
- Align N inputs with plant growth: apply fertiliser or effluent only when plants are able to utilise the applied nutrients well (e.g. not during drought, high rainfall or low temperatures). This reduces the surplus N in the soil that is at risk of leaching.
- Use supplements with relatively low N content. This reduces the animals' N intake and hence N excreted in urine.
- Reduce N inputs to increase N use efficiency and reduce the farm N surplus. The farm N surplus is the amount of N input that is not converted to products and therefore is at risk of loss through leaching, ammonia volatilisation and gaseous loss, e.g. nitrous oxide, a potent greenhouse gas.
- Stand cows off pasture in wet or cold periods when pasture growth is low. This avoids depositing urine on the soil when risk of drainage is high or plant N uptake is less, and gives the opportunity to spread effluent on crop or pasture at times of the year when plants are growing and utilising the nutrients applied.

Canlac Holdings

Canlac Holdings, an FRNL dairy monitor farm in the Selwyn catchment, was modelled with OVERSEER® and Farmax (a physical and financial farm system model). Scenarios to achieve the future N loss requirements were developed using the principles outlined above, and tested in the models for impact on N leaching, production and profitability.

Canlac Holdings

Canlac Holdings is located 5 km west of Dunsandel in the Selwyn catchment. Since 2013 the dairy farm has been operated by Tony Coltman and Dana Carver, 50:50 sharemilkers with an equity interest. Physical and financial performance of the farm for the 2015-16 season are in Table 1. Most of the milking platform comprises a well-draining Lismore soil and 43 ha is a moderately well-draining Mayfield soil. Eighty two percent of the farm is irrigated by two large pivots, the remainder is irrigated by two rotorainers (9% of the area) and sprinklers (the remaining 9% of the area). Effluent is irrigated onto 41% of the milking platform, and a feed pad is used to optimise utilisation of purchased feeds.

Modelling good management practice

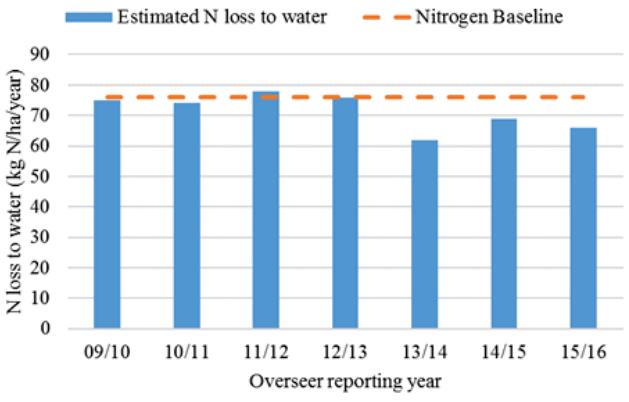
OVERSEER® (version 6.2.3) nutrient budgets were prepared for the 2009-10 to 2015-16 seasons. The first four years, i.e. 2009-10 to 2012-13, are considered the farm's nitrogen baseline, with an average N leaching of 76 kg N/ha/yr (Figure 1).

Improvements in irrigation and enlargement of the effluent area in 2013 reduced the estimated N leaching to 62 kg N/ha.

The Selwyn/Te Waihora Zone sub-regional regulation requires farms to operate at or below their baseline N loss at GMP from 2017-2018. We translated GMP into modelling rules for OVERSEER®:

- No N fertiliser applications in the months of May, June and July
- No more than 50 kg N/ha fertiliser applied per month on pasture blocks
- No more than 400 kg N/ha applied per annum from fertiliser and effluent combined on pasture blocks
- Total N/ha applied on the effluent block does not exceed the average N applied on non-effluent blocks
- Less water applied in shoulders of the season (September, October and March) than in summer (November to February). When selecting irrigation scheduling based on soil water budget or soil moisture sensors in OVERSEER, the model adjusts the amount of water applied to the

Figure 1. OVERSEER® estimated N leaching for the milking platform of Canlac Holdings. Nitrogen baseline is the average of the 2009-10 to 2012-13 years.



predicted rainfall. But if fixed depth and return rate are selected in the model, these should be altered in the shoulders of the season to avoid over-application of water

- Have less than three months fallow after cropping. If not, use a catch crop in between the main crops, e.g. an annual grass or (winter) cereal crop (e.g. oats)

Applying these rules to the nitrogen baseline OVERSEER files reduced the average N loss from 76 kg N/ha to 71 kg N/ha. The milking platform is currently operating below this baseline GMP N loss (Figure 1).

Targeting a 30% reduction

From 2022, milking platforms need to operate at 30% below their GMP baseline for N leaching, meaning a target of 50 kg N/ha N loss for Canlac Holdings.

Two scenarios were modelled:

1. Reduce the number of cows in autumn by culling 90% of the non-pregnant cows and other cull cows early (1 April)
2. Reduce the overall number of cows by 50 and maintain the current culling strategy.

Both scenarios reduced N fertiliser use from an average of 290 kg N/ha to 215 kg N/ha (less on the effluent blocks than elsewhere) and reduced the amount of N fertiliser in April. Through re-nozzling, water application by the rotorainers was reduced from 35 to 30mm every 6 days (5 mm/day). The proportion of low-N imported feed was increased from 8% to 52% by swapping pasture silage and some PKE for maize silage and fodder beet. In all scenarios, supplements were offered on the feed pad.

Table 1 summarises the modelling results. The scenario with early culling achieved an N loss below the target of 50 kg N/ha. The scenario with 50 fewer cows throughout the year did not. This illustrates that OVERSEER responds strongly to cow numbers and feed eaten in autumn, reflecting the relatively high risk of N leaching from urine patches at a time when plant growth and associated N uptake is slowing down and risk of drainage is increasing in the months ahead.

Both Scenario 1 and Scenario 2 reduced farm profit by 5% from Current, using a milk price of $6.00. This was due to 4% lower milk production from less pasture eaten (due to less N fertiliser applied), less PKE, and a 1-2% increase in costs (mostly feed).

Nitrogen efficiency parameters for the scenarios reflected the reduced amount of N brought onto the farm: the N surplus (without N fixation) was reduced by almost half and the N conversion efficiency was improved by a third.

Eco-efficiency is a measure of how much is produced per unit of environmental impact, e.g. kg MS produced per kg N surplus. Eco-efficiency can also be monetary, e.g. operating profit $ per kg surplus. Both measures were improved considerably in the scenarios: kg MS/kg N surplus increased by 64-69% and operating profit $/kg N surplus increased by 61-67%.

Table 1. Summary of results of modelling scenarios to reduce N leaching for Canlac Holdings. Current = modelled current system (2015-2016); Scenario 1 = early cull; Scenario 2 = 50 fewer cows at peak.

Physical Indicators	Current	Scenario 1	Scenario 2
Dairy farm total area (ha)	346	346	346
Effective area (ha)	335	335	335
Cows wintered	1,484	1,474	1,432
Peak cows milked	1,410	1,400	1,360
Stocking rate (peak cows milked/ha)	4.21	4.18	4.06
Production (kg MS)	698,031	671,083	671,455
– per hectare (kg MS/ha)	2,084	2,003	2,004
– per cow (kg MS/cow)	495	479	494
Pasture Eaten (t DM/ha)	18.5	18	18
N Fertiliser applied (kg N/ha)	290	215	215
Purchased feed (t DM)	1,032	976	898
Grass silage	148	0	0
Maize silage	41	532	401
PKE	801	381	442
Fodder beet bulb	42	63	55
– per hectare (t DM/ha)	3.1	2.9	2.7
– per cow (t DM/cow)	0.7	0.7	0.7
Winter crop (t DM/ha)	3.2	3.2	3.1
Financial Indicators			
Total income ($/ha)	13,731	13,240	13,211
Total operating expenses ($/ha)	8,154	7,965	7,922
– $/kg MS	3.91	3.98	3.95
Total operating profit ($/ha)	5,578	5,275	5,289
Change in profit (%)		-5%	-5%
Environmental Indicators			
Total N leached (kg N/yr)	21,076	16,995	18,368
N leached (kg N/ha/yr)	61	49	53
N surplus (kg N/ha/yr)[1]	215	126	122
N conversion efficiency (%)1	39	52	53
kg MS/kg N surplus[1]	9.7	15.9	16.4
Operating profit $/kg N surplus[1]	25.94	41.87	43.35

[1]*Excludes N fixation as input; see text for explanation.*

Benchmarking environmental performance

N leaching estimates for the current Canlac system are similar to the 64 kg N/ha estimated average for Canterbury dairy milking platforms[4]. However, N leaching varies widely in Canterbury due to differences in soil type and climate. Therefore, to assess nutrient management it is more useful to compare N surplus and N conversion efficiency (NCE) with relevant published data.

From the Matrix of Good Management project, the Canterbury average for N surplus (excluding N fixation) was 146 kg N/ha and

NCE was 48%[5]. The current high input Canlac system exceeds these averages, yet the modelled scenarios indicate this farm can make some changes to achieve better results than the MGM averages. Results from the P21 study indicate further potential to improve environmental outcomes.

Table 2 provides the key results for the two P21 farmlet systems implemented in Canterbury[6]. These systems were well-managed with maximum pasture production and utilisation, and efficient use of fertiliser and supplements. N leaching estimated for the P21 farmlets on Templeton sandy loam were lower than for Canlac, which has more freely draining soil types.

Table 2. N surplus and NCE (excluding N fixation) from well-managed dairy milking platforms of Canterbury Pastoral 21 farmlets[6]. Lower-Input = 3.5 cows/ha, 509 kg MS/cow and 1,782 kg MS/ha, 154 kg N fertiliser/ha, 70 kg DM cereal grain/cow and $4,302 operating profit/ha[1]; Higher-Input = 5.0 cows/ha, 476 kg MS/cow and 2,378 kg MS/ha, 309 kg N fertiliser/ha, 680 kg cereal grain/cow and $4,205 operating profit/ha[1].

Physical Indicators	Lower-Input	Higher-Input
N leaching (kg N/ha)	32	46
N surplus (kg N/ha) [1]	57	286
N conversion efficiency (%) [1]	68	36
kg MS/kg N surplus	31.3	8.3
Operating profit $/kg N surplus [2]	75.47	14.70

The two scenarios for Canlac show a significant improvement in N surplus, NCE and eco-efficiency (kg MS or operating profit per kg N surplus), but they do not achieve the efficiency of the P21 Lower-Input system. The P21 Lower-Input system operated at a considerably lower N input than Canlac's current and modelled systems and the P21 Higher-Input system, resulting in a much lower N surplus and higher NCE, higher eco-efficiency and lower N leaching.

Conclusion

The scenario modelling showed that a high-performing dairy farm such as Canlac Holdings has options available to reduce N leaching to the limits set in the catchment's regulations, i.e. a reduction of 30% from its baseline at good management practice. Major investments by Canlac, in the irrigation system and a feed pad, have already reduced N leaching and improved N efficiency since the baseline years, and, therefore, already contributed to achieving the 30% reduction. Nonetheless, a high profit was still achieved.

The Canterbury Pastoral 21 farmlet study showed that further reductions in N leaching are possible by reducing N inputs and N surplus even further.

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