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Issue 41

# TECHNICAL SERIES

SCIENCE IN ACTION

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# Antibiotics:

## what does the future look like?

DairyNZ

# CONTENTS






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*Mastitis control accounts for about 85 percent of the antibiotics used on Kiwi dairy farms.*

# Antibiotics: changing how we look after dairy cows

**To help control the risk of antibiotic resistance, dairy farmers and veterinarians are changing the way they use them at dry off. So, how do we decide which cows should receive antibiotic treatment and how do we reduce our reliance on them?**

**Jane Lacy-Hulbert,** animal and feed team leader, DairyNZ

**Scott McDougall,** research director, Cognosco, Anexa Animal Health

## Concerns about antibiotic use in food-producing animals

Concerns have been raised by the medical sector over the past few years about the use of antibiotics in food-producing animals, specifically those antibiotics critical to human health. This is because, however well intentioned, any use of antibiotics increases the risk that bacteria will develop resistance. As reports of people dying from infections caused by multi-drug resistant bacteria increase, the pressure to change the way we use antibiotics, in medicine as well as in agriculture, ramps up.

These risks were clearly illustrated in the Netherlands in the late 2000s. At the same time as methicillin-resistant *Staphylococcus aureus* (MRSA) bacteria became more common in pigs, there was an increase in the number of people presenting at hospital with MRSA-infections. Many of those who showed up at hospital were farmers and vets involved with the pork industry[1]. When antibiotic use in pig management was scaled back, the rate of MRSA infections declined. Lower rates of antibiotic use in the dairy sector in the Netherlands have since been associated with less antibiotic resistance.

Mastitis cases due to *Staphylococcus aureus (Staph. aureus)* that are resistant to penicillin have been known about in New Zealand for many years, but there's no evidence that

## KEY POINTS

- Overuse of antibiotics can increase bacteria resistance: for this and other reasons, vets and farmers should use antibiotics prudently.
- Herd test somatic cell count is currently the best tool for selecting which cows need antibiotics.
- Internal teat sealants:
  - reduce rates of new infections over the dry period
  - reduce rates of clinical mastitis in the subsequent lactation
  - achieve these results at least as well as dry cow antibiotics.
- Pathogens can be introduced into the mammary gland if poor hygiene is used when sealants are infused.
- Work with your vet to ensure anyone administering these products receives thorough training first.

the prevalence of resistance has increased, nor any evidence of MRSA. So far, no New Zealand data associates antibiotic use with resistance in dairy cattle, nor is there any evidence of transmission of resistance (either by bacteria or horizontal gene transfer) from cattle to humans[2]. However, some evidence is emerging of resistance in gut bacteria[3] and this tells us we must be more cautious in the way we use antibiotics.

## Reducing long-acting antibiotic use

To support a global push towards better stewardship of antibiotics, New Zealand veterinarians recommend dry cow antibiotics be reserved for cows with evidence of bacterial infection. This means, for most herds, it will no longer be appropriate to treat every gland of each cow in a herd with long-acting antibiotics.

If you'd like to read about the history behind these changes, refer to *Technical Series* March 2017 *(pages five to eight)*[4].

## What is prudent use?

Using antibiotics prudently means doing so in a rational and targeted way. It's about maximising their therapeutic effect and minimising the risk of antibiotic resistance. This includes not using antibiotics unless there is evidence of a need.

The New Zealand Veterinary Association has developed a framework to support the future use of antibiotics in managing animal health and welfare, which focuses on:

- **recognising** where a problem exists or is likely
- **responsibility** being taken by all those who can make a difference: farmers, vets (and pet owners)
- **reducing** the use of antibiotics, particularly products that are critically or highly important to human health, and reducing reliance on preventative treatments
- **refining** the use of existing products by making more use of diagnostics to better match the right patient to the right drug, right dose, right route and right time
- **replacing** the use of antibiotics with alternatives, such as immune modulators, vaccines, genetics or solutions such as teat sealants, to better prevent disease.

## What does this mean for mastitis control?

Antibiotics may continue to be used when cows suffer clinical disease. However, it is not prudent to use antibiotics for the prevention of infection in uninfected animals. An example of imprudent use would be giving antibiotic dry cow therapy (DCT) to animals with a low somatic cell count (SCC) at the end of lactation.

In most herds, this will mean targeting cows with evidence of infection, and protecting other cows with a non-antibiotic alternative, such as an internal teat sealant.

For cows requiring treatment for clinical mastitis, this will mean your vet will place more emphasis on identifying the likely bacteria, and bacterial sensitivity to antibiotics, for cases that typically occur in your herd.

## Can we still use dry cow antibiotics?

Yes, dry cow antibiotics can still be used, but they should be reserved for cows with evidence of infection, such as a history of treatment for clinical mastitis, or a high SCC.

For most herds, some of the herd will receive dry cow antibiotics, and then decisions will be necessary on how to treat the remainder of the herd.

These decisions must be made with a vet who provides the prescription. The vet must know the health history and environment of your herd. In some situations, vets may still prescribe dry cow antibiotics for all cows, but this will be justified, based on individual cow health records and information relevant to the whole herd.

## Which cows to treat with dry cow antibiotics?

Before you can decide if a cow is eligible for antibiotic DCT, you'll need to see evidence of bacterial infection.

The usual 'gold standard' for indicating the presence of bacteria is bacterial culture, carried out in a laboratory. In countries such as Denmark, Finland, Norway and Sweden, evidence of bacterial infection based on culture or DNA analysis is required before DCT is prescribed. Carrying out a farm-based form of bacterial culture has been accepted as a means of detecting infection[5].

Under New Zealand systems, with seasonal calving, the logistics, time and direct costs make it difficult to hygienically sample all glands of every cow for bacteria culture, before drying off. Instead, we should use indirect tests such as SCC, which are cheaper, easier to implement and have a reasonably high level of accuracy.

Studies by DairyNZ over the past three years have helped refine the selection of cows for DCT. These studies have confirmed the value of individual cow SCC data, collected by herd testing, to identify cows eligible for DCT. We have confirmed the ability of SCC to:

- maximise the number of cows identified as likely to be infected with a major mastitis pathogen, such as *Staph. aureus* or *Streptococcus uberis (Strep. uberis).*
- minimise the likelihood of cows being missed that should receive DCT
- enable significant reductions in the amount of antibiotic required.

## Why use cow SCC?

In a multi-herd study in 2017, we tested the connection between individual cow SCC in lactation and the presence of major mastitis pathogens, such as *Staph. aureus* and *Strep. uberis,* in individual glands at dry off. Approximately 2500 cows, selected from 36 herds, were milk-sampled at dry off. We compared bacterial culture results with SCC data collected during lactation[6].

A threshold SCC of greater than 150,000 cells per millilitre

**Table 1: Somatic cell count (SCC) threshold cut-points and likelihood of finding cows with major pathogen infections**

| Cut-point | SCC above or below cut-point | Major pathogen infection | | Total number of tubes of antibiotics use |
|---|---|---|---|---|
| | | Yes | No | |
| 125 | SCC + | 33 | 154 | (33+154) x 4 = 748 |
| | SCC - | 4 | 308 | |
| 150 | SCC + | 31 | 128 | (31+128) x 4 = 636 |
| | SCC - | 6 | 333 | |
| 175 | SCC + | 30 | 107 | (30+107) x 4 = 548 |
| | SCC - | 7 | 354 | |
| 200 | SCC + | 29 | 94 | (29+94) x 4 = 492 |
| | SCC - | 8 | 367 | |
| 225 | SCC + | 26 | 82 | (26+82) x 4 = 432 |
| | SCC - | 11 | 380 | |

Classification of cows using different maximum herd test SCC (x 1000 cells/mL) cut-points to define cows as likely infected with a major pathogen (SCC+) or likely uninfected (SCC-), compared with bacterial culture results. A cow was defined as infected if one or more glands was culture-positive for a major pathogen. This table assumes a cow-level prevalence of a major pathogen infection in one or more glands at dry off, of 7.5 percent in a group of 500 cows[6].

of milk (>150,000 cells/mL) within the last 80 days of lactation identified cows likely to be infected, with reasonable accuracy. Approximately 85 percent of the cows considered infected (because they were over the SCC threshold) were truly infected with a major pathogen (i.e. *Staph. aureus, Strep. uberis, Escherichia coli*), and only 15 percent of truly infected cows were missed.

Different thresholds, or SCC cut-points between 125,000 cells/ml and 225,000 cells/ml (*Table 1*), illustrate the trade-off, between infected cows that miss out on DCT because they are under the SCC threshold, but are actually infected with a major pathogen at dry off (shown in red in *Table 1*), and uninfected cows that receive DCT because they are over the threshold, but may not actually be infected (shown in blue in *Table 1*).

Nevertheless, increasing the threshold reduced the total amount of antibiotic required, compared with whole herd DCT. There was a 63 percent decline for a cut-point of 125,000 cells/mL, and 78 percent for 225,000 cells/mL.

## Why are there exceptions to the connection between SCC and infection?

Some uninfected cows may have a high SCC, due to a previous infection, low milk yield or infections due to minor mastitis pathogens. The high SCC should resolve over the dry period and these cows are unlikely to benefit from antibiotic treatment.

Conversely, some infected cows may be missed due to natural fluctuations in the SCC during an infection, causing the SCC to be below the SCC threshold when tested, or the cow acquires a new infection in the days between herd testing and dry off.

## Which herd test information best identifies cows for DCT?

From DairyNZ's study[6] across 36 herds, we found that a single herd test within the last 80 days of lactation was as accurate as the maximum SCC from three or four tests during lactation, or the average of all herd tests, for detecting cows with a major pathogen infection.

For herds that aren't routinely tested, a single test in late lactation could be sufficient to define cows as infected or not and, therefore, to help farmers decide which cows receive DCT.

## What happens to infected cows that miss DCT?

Across three New Zealand studies on internal teat sealants (ITS)[7], there were good outcomes for cows that received ITS at dry off but were already infected. The incidence of clinical mastitis over the dry period was less than two percent of cows, and the bacterial cure rate of these quarters was over 90 percent. These outcomes were equivalent to those achieved for cows where DCT had been used. This illustrates that ITS alone can be an effective way of preventing new infections over the dry period.

## What should happen to the rest of the herd?

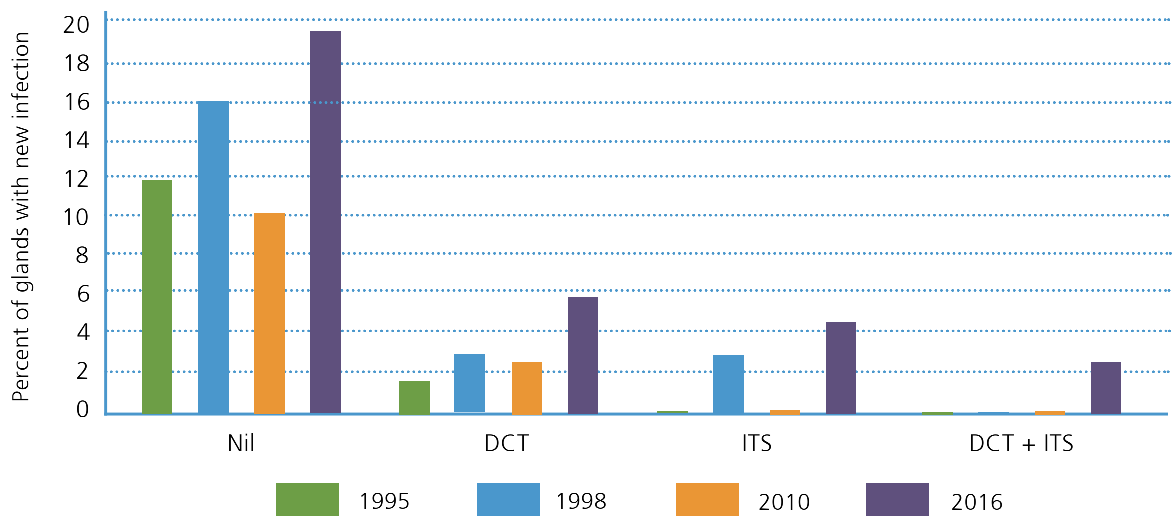
For cows left unprotected at dry off, the rate of new infection during the dry period can be high. Across several studies, this new infection rate varied from nine to 13 percent of glands[8-11] (see *Figure 1*).

Infusing an ITS, which contains no antibiotic, at the end of lactation provides a physical barrier inside the teat and can reduce the rate of new infections over the dry period. A meta-analysis indicated a lower new infection rate, and lower clinical mastitis incidence rate in the next lactation, for glands that received ITS infusion compared with no treatment or DCT alone[12].

### Acknowledgments

The research described in this article was funded by DairyNZ and the Ministry for Primary Industries' Sustainable Farming Fund.

**Figure 1: Protecting glands at dry off prevents infections at calving**

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# Plantain helping farmers to achieve environmental targets

**Once considered a weed, a modern plantain *(Plantago lanceolata L.)* cultivar is showing promise for reducing nitrate leaching and greenhouse gas emissions.**

**Elena Minnée,** post-doctoral scientist, DairyNZ
**Cecile de Klein,** principal scientist, AgResearch
**Dawn Dalley,** senior scientist, DairyNZ

### KEY POINTS

Compared to cows fed ryegrass/white clover diets, when plantain exceeded 30 percent of the diet:

- urine volume increased and urine nitrogen (N) concentration decreased, reducing N loading and N leaching risk from urine patches
- total daily N excreted in urine was reduced as more dietary N was partitioned to milk and faeces
- the amount of drinking water consumed was reduced, so care must be taken when medicating drinking water and feeding plantain.

Nitrous oxide ($N_2O$) emissions from individual urine patches was also reduced by increasing the percentage of plantain in the sward and in the diet. The latter is most likely due to a reduction in the N content of the urine.

## The link between plantain, nitrogen, and the environment

### Why it's important

Regional councils are committed to establishing targets for fresh water quality that must be implemented by 2025 under the National Policy for Freshwater Management Statement. Also, as signatories to the 2016 Paris Agreement, the New Zealand Government has committed to reducing greenhouse gas (GHG) emissions to 30 percent below 2005 levels by 2030. Further, the proposed Zero Carbon Bill aims to set more stringent long-term GHG reduction targets. To achieve these water and GHG targets, reductions in nutrient and GHG emissions are required from all sectors of the economy.

In agricultural systems, nitrogen (N) loss from the soil contributes to freshwater pollution. The main source of N loss is from urine excreted by livestock during grazing. The high N loading rates in urine patches (about 600 kilograms of N per hectare or ~ 600kg N/ha[1]) exceed plant requirements, with surplus N susceptible to leaching below the root zone and subsequently into fresh water. N in urine deposits can also be lost to the atmosphere as nitrous oxide ($N_2O$). While $N_2O$ makes up only about 10 percent of New Zealand's agricultural GHG emissions[2], it is a potent GHG with significant global warming potential.

### What we're doing

The DairyNZ-led Forages for Reduced Nitrate Leaching Programme (FRNL) and the New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC) have focused on developing proven, adoptable mitigation options for farmers to minimise the environmental effects of farming. Emerging from this work, and supported by associated projects, is evidence to suggest the concentration of N in cattle urine is reduced when the plantain cultivar *Ceres Tonic* is included in the diet[3, 4, 5].

Reducing urinary N concentration reduces the N surplus in urine deposits, thus reducing the risk of N leaching and $N_2O$ emissions. What is not well understood are the mechanisms responsible for reduced urine N concentration, how much plantain is required in the diet to achieve this, and what the effects of lower urine N concentration has on $N_2O$ emissions. To address these questions, DairyNZ and AgResearch carried out two detailed experiments, jointly funded by the Ministry of Business, Innovation and Employment (MBIE) and NZAGRC, from January to June 2018.

## Plantain studies

### Nitrogen partitioning and excretion

To evaluate the effect of plantain in the diet of dairy cows on urine N, cows were housed in metabolism stalls at DairyNZ's Lye Farm in Hamilton. The stalls allowed us to measure how much N was eaten and where that N went (to milk, or excreted in dung and urine), which we can't do in outdoor grazing trials.

Cows in late lactation were offered one of four diets and could eat as much as they chose to. These diets contained 0, 15, 30 or 45 percent fresh plantain (with the balance as ryegrass/white clover pasture). This was because previous research suggested reduced urine N concentration would be achieved within this range, and agronomic studies also suggest it is feasible to achieve these levels of plantain in ryegrass-based swards.

Dietary N intake is determined by the N content of feed and how much is eaten. In this experiment, the N content of plantain was much less than ryegrass: 2.2 grams versus 3.7 grams per 100 grams of dry matter (g DM). However, because cows consuming diets including plantain ate more DM *(Table 1)*, total N intake (g/cow/day) was similar across the diets.

Generally, N excreted to urine (g per day) is highly correlated with N intake[6], so at similar N intakes, similar amounts of urinary N were expected. However, cows offered diets with 45 percent plantain excreted 25 percent less N/cow/day in urine than cows consuming pasture. Examining where N went indicated that as the percentage of plantain in the diet increased, cows partitioned more N to milk and faeces and less to urine *(Figure 1)*.

These differences in N partitioning between diets may be explained by differences in the forms of N in ryegrass and plantain. N in feed can be categorised in three groups: soluble non-protein N, rumen-degradable protein N (RDP) and rumen-undegradable protein N (RUP). Plantain contains less soluble and more rumen-undegradable N than ryegrass. Soluble N is very quickly degraded to ammonia in the rumen. When the production of ammonia exceeds what can be used immediately by rumen microbia, it is absorbed into the blood and excreted as N in urine[7].

Therefore, forages with high proportions of soluble N are not desirable. Further, because N is rarely a limiting nutrient in pasture-based farming, an increased proportion of RUP in plantain is not a concern. Rather, RUP will pass through the digestive tract and be metabolised or excreted as faeces[6]. Greater partitioning of excreted N to faeces, rather than urine, is desirable, as faecal N is less susceptible to leaching and conversion to $N_2O$[8].

N concentration in urine declined in diets containing more than 15 percent plantain, with a steep decline observed when plantain content was 30 percent and above *(Figure 2)*. Differences in N partitioning explain part of this decline, but there is evidence that when fed at high levels (≥ 30 percent in diet) plantain reduced urine N concentration via increased urine volume (i.e., a 'dilution effect'). Cows consuming 45 percent plantain produced around 10 litres (L) more urine per day (~ 30 percent; *Figure 2*) through slightly larger and more frequent

## Table 1: Effects of increasing plantain in cows' diet

| | % plantain in diet | | | | |
|---|---|---|---|---|---|
| | 0 | 15 | 30 | 45 | Significance |
| Total DM intake (kg DM/cow/d) | 14.8 | 16.5 | 16.8 | 17.4 | P < 0.05 |
| N intake (g/cow/day) | 553 | 575 | 529 | 525 | NS |
| N excreted in urine (g/cow/d) | 268 | 268 | 237 | 202 | P < 0.05 |
| Milk solids (kg/cow/d) | 0.96 | 1.14 | 1.16 | 1.24 | P < 0.05 |

**Figure 1:** Dietary nitrogen partitioning in relation to % of plantain in cows' diet

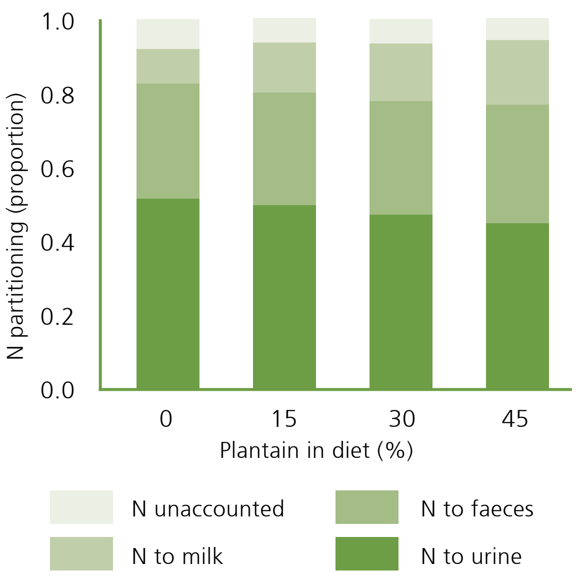
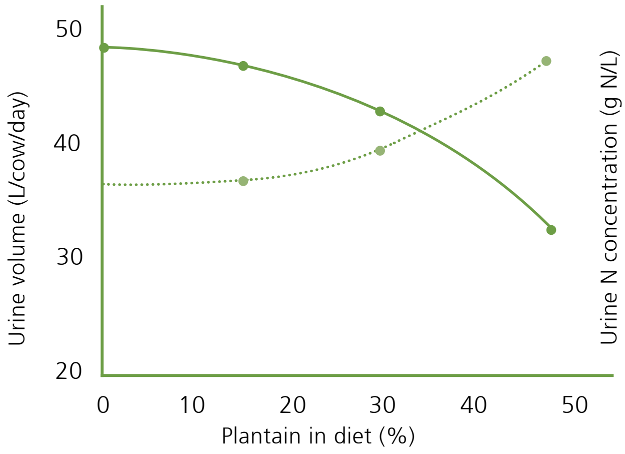


**Figure 2:** Urine N and volume in relation to increasing plantain in cows' diet




Total daily urine volume (⋯⋯) and mean daily urine nitrogen (N) (——) concentration from dairy cows fed increasing percentage of plantain in the diet.

urination events than cows consuming pasture only.

The mechanism driving increased urine volume (diuresis) is still uncertain. The low DM content of plantain (~ 9.5 percent) may cause diuresis simply through the consumption of large amounts of water in the plantain[9, 10]. Alternatively, plantain contains bioactive compounds that may induce an osmotic diuresis[11]. Both diuretic mechanisms work to inhibit water reabsorption, but further research is required to determine to what extent each is responsible for increased urine volume of cows fed plantain.

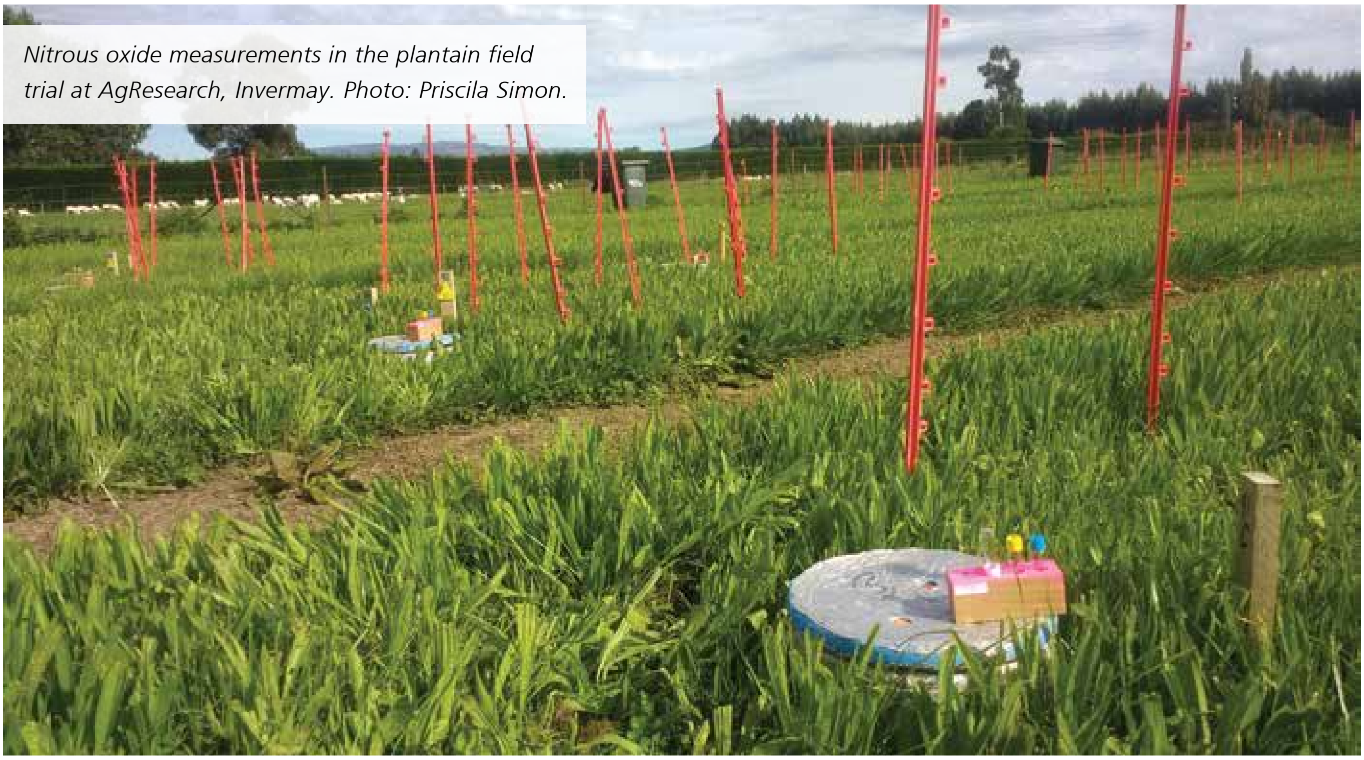
Greater urine volumes of cows on high plantain diets was not a result of greater consumption of drinking water. Cows tended to drink less water from the trough as the amount of plantain in the diet increased. Total water consumed, i.e. in feed plus drinking water, was greatest in cows fed 45 percent plantain, despite these animals drinking virtually nothing from the trough. Assessment of the blood showed no evidence of dehydration from high plantain diets.

The reduction in water consumed from the trough in systems incorporating plantain into pastures is an important consideration for farmers who deliver medication or minerals to cows via drinking water.

## Nitrous oxide ($N_2O$)

The effect of plantain in the diet on $N_2O$ emissions from urine was explored using urine collected from cows in the metabolism stall experiment. The urine was used in a field trial at AgResearch Invermay.

Urine collected from cows on a 0, 15, 30 and 45 percent plantain diet was gently poured onto plots with the corresponding percentage of plantain in the sward (i.e., 0 percent urine/0 percent sward, 15 percent urine/15 percent sward, etc.). $N_2O$ emissions were measured using a standard chamber technique (*see example in photo below*). Cumulative $N_2O$ emissions from 30 and 45 percent treatments were about 50 percent lower than the cumulative emissions from the 0 and 15



*Nitrous oxide measurements in the plantain field trial at AgResearch, Invermay. Photo: Priscila Simon.*

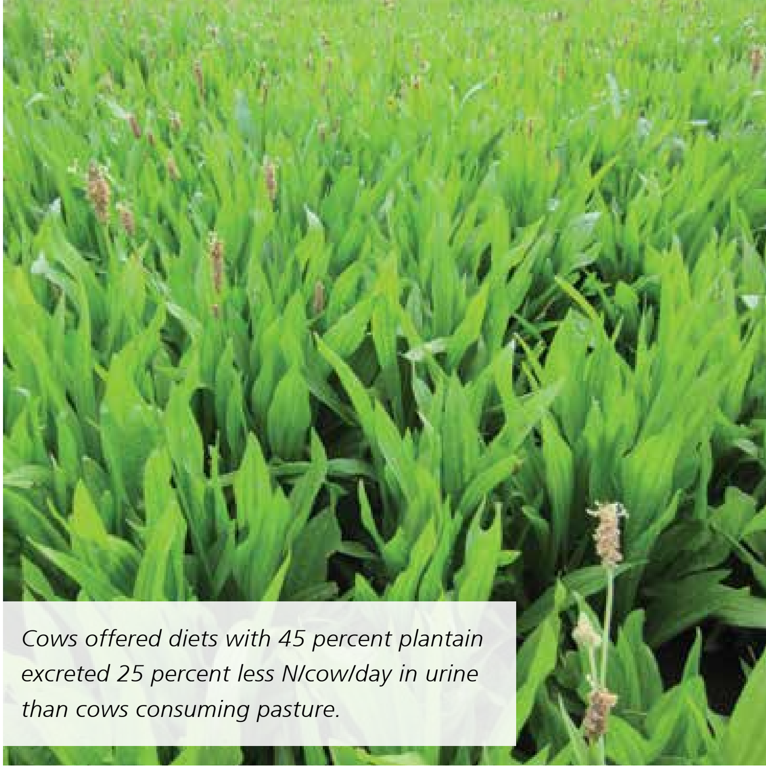
percent treatments. This is most likely due to a reduction in the urinary N concentration achieved by increasing proportions of plantain in the diet.

## But is there also a direct plantain plant effect on $N_2O$ emissions?

To start answering that question, we did a second experiment, where we applied the same type of urine (collected from cows on diets of 0 percent plantain) to plots with increasing plantain content in the sward (0, 30, 60 and 100 percent plantain).

Preliminary results show that $N_2O$ emissions progressively reduced with the percentage of plantain in the sward, with emissions from the 100 percent plantain swards being about 40 percent lower than from the 0 percent plantain swards. As these plots received the same type and rate of urine, these results suggest a 'plant' effect of plantain on $N_2O$ emissions.

Right now, NZAGRC is conducting further investigations to better understand how plantain can reduce $N_2O$ emissions, as well as its potential for maintaining soil carbon stocks and reducing methane emissions from cows fed diets containing plantain. Keep an eye out for the results on the NZAGRC website.



*Cows offered diets with 45 percent plantain excreted 25 percent less N/cow/day in urine than cows consuming pasture.*

## More information

- The Forages for Reduced Nitrate Leaching Programme (FRNL) has principal funding from MBIE. The programme is a partnership between DairyNZ, AgResearch, Plant & Food Research, Lincoln University, the Foundation for Arable Research and Manaaki Whenua. Learn more at **dairynz.co.nz/FRNL** and find out more about plantain at **dairynz.co.nz/plantain**
- You might also like to check the Tararua Plantain Project, which capitalises on research findings from the FRNL programme. See **dairynz.co.nz/Tararua**
- The New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC) is funded by the Ministry for Primary Industries (MPI) via its Primary Growth Partnership Fund and is a partnership (non-financial) of nine New Zealand research organisations: AgResearch, DairyNZ, Manaaki Whenua, Lincoln University, Massey University, National Institute of Water and Atmospheric Research (NIWA), Pastoral Greenhouse Gas Research Consortium (PGgRc), Plant & Food Research and Scion. Learn more about NZAGRC at **nzagrc.org.nz**

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*Forages for Reduced Nitrate Leaching research underway to capture nitrogen in catch crops. Photo: Plant & Food Research.*

# N surplus shows performance

**Nitrogen leaching varies significantly depending on soil type and climate, which means it's not a straightforward performance indicator. An alternative approach is to look at a farm's nitrogen surplus.**




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It's a goal of many farmers to improve sustainability, with a significant focus on N leaching in many regions. However, nitrogen (N) leaching varies significantly depending on soil type and climate, factors that cannot be changed (though irrigation can alleviate dry conditions, but also increase drainage).

Focusing on N surplus instead is an easier method of determining farm performance and gaining environmental benefits. Reducing N surplus can also save farmers money.

In this article, we'll look at what N surplus is, its background as an indicator and how farmers can use it as part of a targeted nitrogen management plan to determine and improve their farm's performance.

## What is N surplus?

Nitrogen surplus is the balance between N inputs and N outputs, i.e., how much N was lost in the N cycle of the production of milk, meat, wool, crops, etc. It varies widely

### KEY POINTS

- Some factors influencing N leaching (like soil type and climate) cannot be changed by farmers.
- N surplus (the balance between N inputs and N outputs) is an N management performance indicator that is easier to interpret.
- N surplus indicates the potential environmental risk of N leaching and ammonia and nitrous oxide emissions.
- Reducing N surplus not only benefits the environment, it can also contribute to farm profitability.

**Table 1.** Summary of 2015/16 Overseer N budget data from 382 farms participating in the DairyBase Baseline project

| | Milksolids (kg MS/ha) | Fertiliser | Biological fixation | Supplements | Removed product | Removed atmospheric | Removed water | N surplus | MS/kg N surplus |
|---|---|---|---|---|---|---|---|---|---|
| Median | 1143 | 115 | 90 | 28 | 68 | 66 | 37 | 180 | 6 |
| Q1 | 970 | 67 | 62 | 13 | 53 | 53 | 27 | 139 | 5 |
| Q3 | 1362 | 177 | 122 | 51 | 81 | 87 | 51 | 224 | 8 |

Data in kg N/ha unless stated otherwise. NCE = N conversion efficiency; median = 50% of the farms have a value greater or smaller than the value given; Q1 = first quartile (25% of farms have a value below the value given); Q3 = third quartile (25% of farms have a value greater than the value given).

between farms. Of the 382 farms participating in the 'Baseline' project within DairyBase in 2015/16, 25 percent had an N surplus of less than 139 kilograms of nitrogen per hectare (kg N/ha) and 25 percent had an N surplus greater than 224kg N/ha. The median N surplus was 180kg N/ha *(Table 1).*

## Reducing N surplus: the benefits

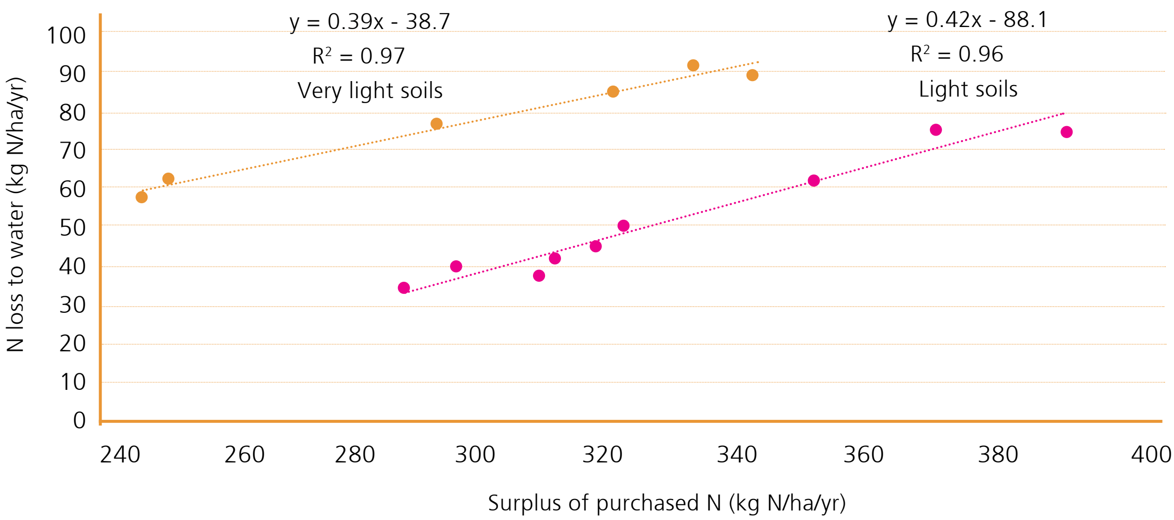
Reducing N surplus generally reduces N loss to the environment[1] while increasing the cost-effectiveness of N use. Most farmers purchase more N as fertiliser and supplementary feeds (inputs) than they sell in products as milk, meat or crop (outputs). By reducing fertiliser and feed inputs and becoming more efficient, farmers can maintain production and reduce costs. Soil type, climate, and factors influencing gaseous losses control how much of the N surplus eventually leaches below the root zone. For example, the same N surplus results in higher leaching from freely-draining soils[2]. This relationship between N surplus and N leaching is illustrated in *Figure 1* for dairy farms in Canterbury[3].

## N surplus research

N surplus is not a 'new' indicator. Twenty years ago, AgResearch and DairyNZ researchers wrote about how N surplus rose as the use of fertiliser and imported supplementary feeds increased[4]. Higher N inputs resulted in more production, but the efficiency of the use of N decreased, especially that of fertiliser.

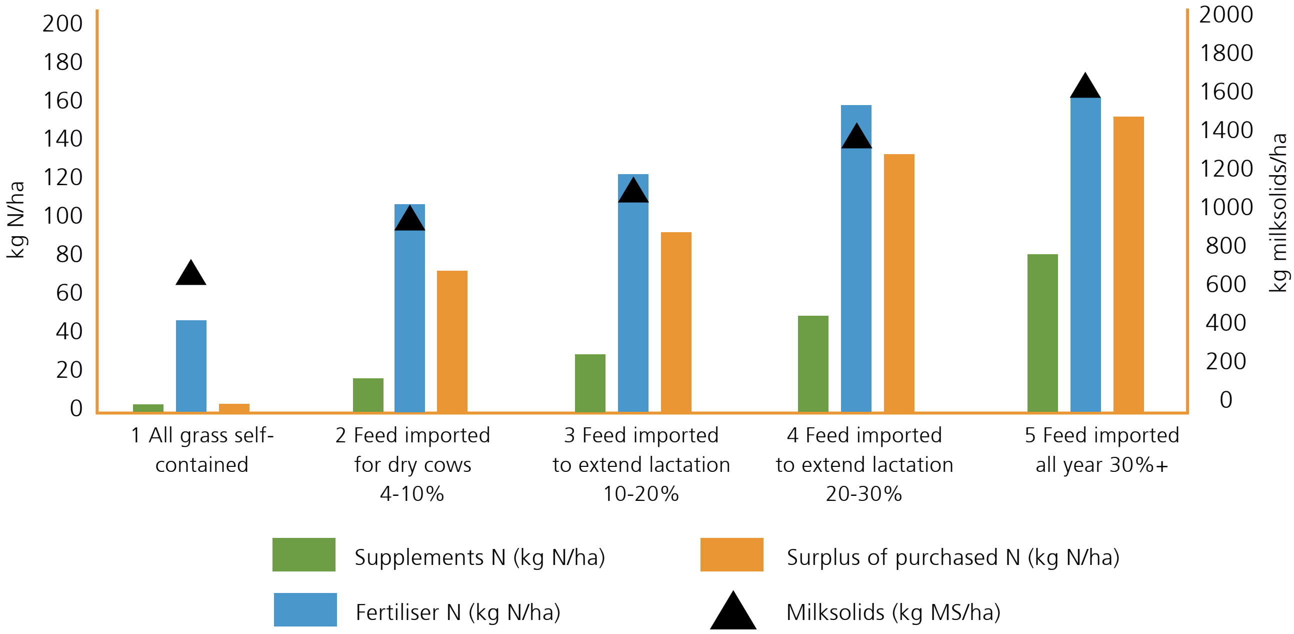
They also showed that a higher N surplus was associated with higher nitrate leaching, ammonia volatilisation and emission of

**Figure 1.** Overseer 6.3.0 three-year estimates of N loss to water (predominantly N leaching) and farm N surplus for five Canterbury dairy farms[3]




Equations and $R^2$ for linear regressions are given for farms on very light soils (top line) and farms on light soils (bottom line). The $R^2$ indicates how close the data are to the fitted regression line ($R^2$ = 1 if the regression explains all variability).

**Figure 2.** Average N fertiliser and supplement N purchased, milk produced and surplus of purchased N in 2015/16 on 382 dairy farms




The 382 farms are grouped into five production systems according to their use of imported supplementary feeds (see **dairynz.co.nz/5-systems**). The difference between fertiliser and supplement N inputs and the N in outputs (milk, meat and crops sold off-farm) is the surplus of purchased N. (Data sourced from the DairyBase Baseline project.)

nitrous oxide. At the time, the average N fertiliser use of New Zealand dairy farms was 40kg N/ha; additionally, 4kg N/ha was imported with purchased feed.

Since then, the use of fertiliser and supplements has increased substantially: by 2015/16, DairyBase data showed medians of 115kg N/ha N fertiliser and 28kg N/ha purchased feed *(Table 1)*.

Despite an improved eco-efficiency (kg MS produced per kg N surplus), the N surplus and hence N's environmental effects also increased. In 1997, the average New Zealand dairy farm had an estimated N surplus of 131kg N/ha and an eco-efficiency of 4.6kg MS/kg N surplus[5]. Median values for 2015/16 DairyBase data were 180kg N/ha N surplus and 6kg MS/kg N surplus *(Table 1)*.

## Benchmarking

The large variation in N surplus in the DairyBase dataset indicates that there are opportunities to improve farm management. Some of the variation is explained by the farm system: highly productive high-input farms generally have a higher N surplus than low-input, less productive farms. This is illustrated in *Figure 2* which shows a simplified N surplus: the surplus of purchased N (fertiliser and supplements). Within each farm system the variation was also large, indicating that on many farms, improvements are possible without large system changes.

The surplus of purchased N is easy to calculate and circumvents some of the assumptions used in Overseer to estimate biological N fixation. Farms that rely mostly on biological N fixation by clover can even achieve a surplus of purchased N below zero: more N is produced in milk than is purchased in fertiliser and feed, which indicates high efficiency of purchased N and reduced risk to the environment.

## N budget comparisons

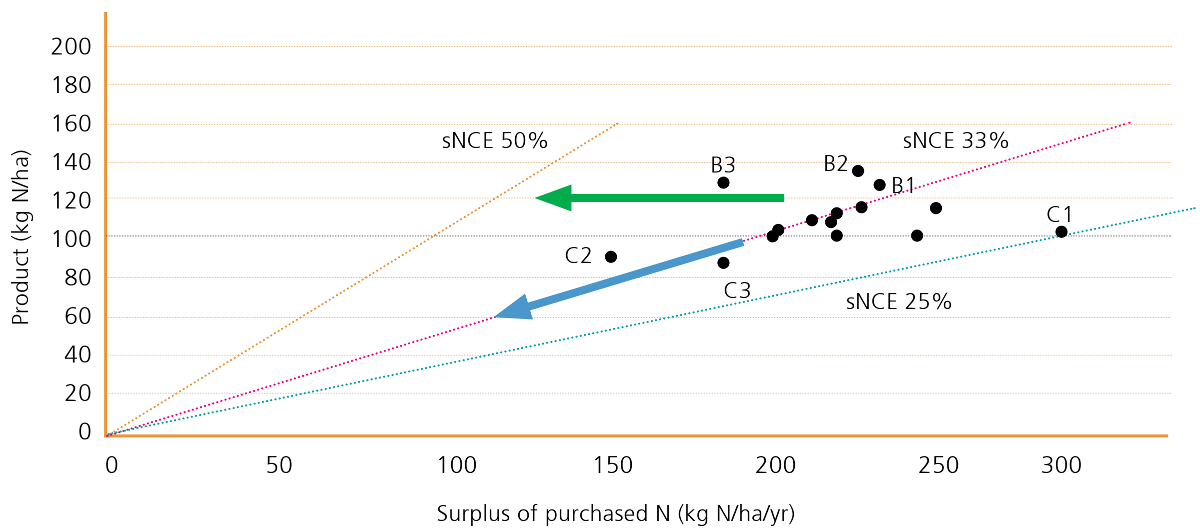
A comparison of the N budgets of five Canterbury monitor farms in the Forages for Reduced Nitrate Leaching programme (FRNL)* showed their relatively high N fertiliser and supplement inputs resulted in high production, but also in relatively high N surplus[3]. During the FRNL programme, these farms implemented changes to reduce N leaching, e.g. establishing plantain in pasture, reducing N fertiliser use and swapping high-N supplements (Palm Kernel Expeller or PKE, pasture silage) to low-N feeds (maize and fodder beet). These changes did not necessarily result in reduced production, but reduced N surplus, as illustrated in *Figure 3*.

*Figure 3* shows a framework designed to benchmark farm performance of N management[6]. To improve N management, farmers should aim to move to the top left of the graph, i.e. reduce N surplus and maintain or increase milk production by improving the N conversion efficiency (green arrow).

The results of the FRNL monitor farms are shown, with changes from years 1 to 3 for two farms labelled (B and C). These two farms achieved the largest reductions in the surplus of purchased N. For farm C, a substantial reduction in N fertiliser and supplement use resulted in a reduction in milk production from 1660kg to 1400kg MS/ha.

Farm B achieved an increased milk production from 2040 to

**Figure 3.** A framework illustrating the relationship between surplus of purchased N and N output in product[6]




Diagonal lines depict equal conversion efficiency of purchased N (sNCE; 50%, 33% and 25% are shown). Results of five FRNL monitor farms are plotted; two farms that made the largest N surplus reductions are labelled (farm B and C, years 1, 2 and 3 of the FRNL programme).

The arrows depict two different ways of improving N surplus: one by reducing inputs and maintaining N conversion efficiency, leading to reduced production (blue arrow) and the other by reducing N inputs and improving N efficiency, so that production can be maintained (green arrow).

2150kg MS/ha by using more low-N supplements (e.g. fodder beet on the milking platform to extend lactation). The efficiency of N fertiliser use was improved through reducing the amount applied on the effluent block, reducing the amount applied per application, skipping some applications when pasture growth was sufficient, and above all, utilising all pasture grown.

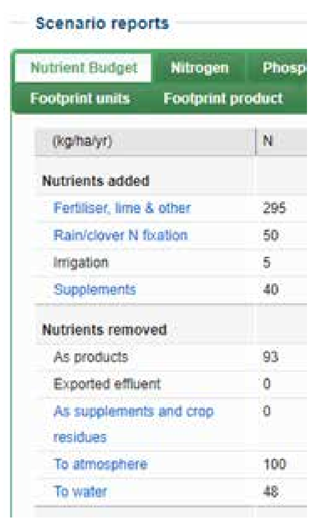
## Overseer and N surplus

Overseer gives valuable information on the N balance for the whole farm and for each block. Fonterra suppliers receive some of this information in their nitrogen reports. Examples of Overseer output and the surplus calculations are given in *Figure 4* and *Figure 5*.

The 'nutrient budget' tab of the Farm Scenario Reports in Overseer *(Figure 4)* summarises N inputs and outputs. The 'nitrogen' tab (*Figure 5*) shows N loss, N surplus and N added from fertiliser and effluent. The latter indicates how the purchased N was distributed over the farm and if due account was taken of the effluent N applied. This information is highly illustrative of N management but not often reported to the farmer.

While N surplus is an important indicator for the amount of N that could be leached, other aspects of the farm's environment and farm management drive the actual loss due to drainage of water with dissolved N to below the root zone and out of the reach of plants. These are soil type and climate, and irrigation

**Figure 4.** Example of Overseer Farm Scenario report – 'nutrient budget' tab*




This tab gives a summary of N inputs ('nutrients added') and N outputs ('nutrients removed'). Overseer calculates the N surplus as the difference between all inputs and the N removed as products, exported effluent and supplements and crop residues. In this example, the N surplus is (295+50+5+40) – (93) = 297kg N/ha.

The surplus of purchased N includes only the fertiliser and supplement N as inputs, and is (295+40) – (93) = 242kg N/ha.

Fonterra suppliers can find the data used for these calculations in their nitrogen reports.

* *Presentation of data will be different in OverseerFM.*

**Figure 5.** Example of Overseer farm scenario report – 'nitrogen' tab*

**Scenario reports**

Nutrient Budget | Nitrogen | Phosphorus | Comments | Summary | Nitrogen overview | Phosphorus overvi
Footprint units | Footprint product | Effluent | Pasture production | Other values | Full parameter report

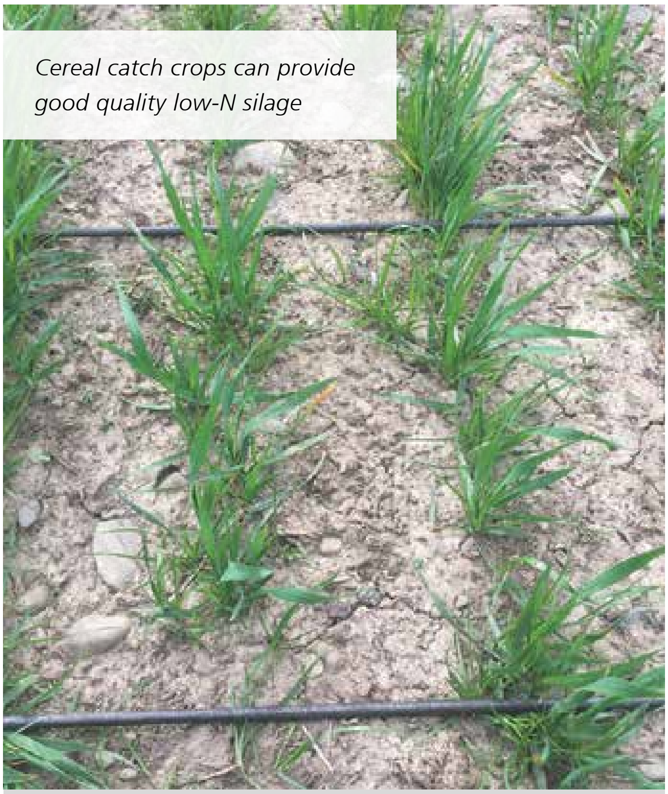
| Block name | Total N lost<br>kg N/yr | N lost to water<br>kg N/ha/yr | N in drainage *<br>ppm | N surplus<br>kg N/ha/yr | Added N **<br>kg N/ha/yr |
|---|---|---|---|---|---|
| Pivot - large | 16,087 | 93 | 24.3 | 300 | 321 |
| Pivot - Effluent | 4,308 | 135 | 35.0 | 479 | 519 |
| K-line | 2,698 | 102 | 23.0 | 312 | 330 |
| Dryland | 887 | 62 | 17.2 | 248 | 284 |
| Dryland -Effluent | 1,268 | 135 | 37.5 | 552 | 624 |

This tab gives an overview of the key N parameters per block. 'Added N' is the sum of N applied in fertiliser, imported organic fertiliser and effluent. The first step to improve N surplus and N leaching in this case, would be to reduce fertiliser applied on the effluent blocks to align the total amount of N applied to the other blocks.

** Presentation of data will be different in OverseerFM.*

system and management (if applicable). Overseer takes account of these factors in its estimates of N loss to water, which is important for accounting purposes and reconciliation with measured water quality.

*The Forages for Reduced Nitrate Leaching Programme (FRNL) has principal funding from MBIE. The programme is a partnership between DairyNZ, AgResearch, Plant & Food Research, Lincoln University, the Foundation for Arable Research and Manaaki Whenua. Learn more at **dairynz. co.nz/FRNL**



*Cereal catch crops can provide good quality low-N silage*

## DEFINITIONS OF PERFORMANCE INDICATORS FOR N MANAGEMENT

Nitrogen (N) surplus Overseer = N in inputs (fertiliser, purchased supplementary feed, biological fixation (e.g. by clover), irrigation, atmospheric deposition (via rainfall) – N in outputs (milk, meat, crops sold) (kg N/ha).

N conversion or N use efficiency (NCE or NUE) = N in product/N in inputs (as a %).

Surplus of purchased N = (N in fertiliser + purchased feed) – N in outputs.

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Taranaki has New Zealand's longest history of using riparian management as a tool for mitigating the effects of land use.

# Science backs riparian management

**We highlight the science behind riparian management, so you have confidence in its ability to help improve water quality on your farm and its downstream environments.**


**Aslan Wright-Stow,** environment and catchment manager, DairyNZ

**Dr Tom Stephens,** (previously DairyNZ), senior freshwater specialist, Auckland Council


## KEY POINTS

On-farm studies confirm that riparian management:

- improves water quality, by intercepting contaminants before loss from the farm to water
- can be highly effective over three- to five-metre buffers of grass or plantings (natives or willow and poplar)
- improves fish and invertebrate habitat, by stabilising banks, providing shade, cooling water and enhancing oxygenation.

Get hassle-free guidance in the Riparian Planner – **dairynz.co.nz/riparian-planner**

One of the goals of riparian fencing and planting is to improve water quality. Planting leads to a wide range of environmental benefits (such as improved fish and insect life habitats). However, it also makes good sense economically and from an animal welfare perspective, as it reduces the chances of stock injury or loss from cows falling into unfenced waterways.

It's also important to remember that riparian management doesn't replace good management practices such as effective nutrient budgeting and ensuring sufficient effluent storage for keeping contaminants out of water – rather, it complements them.

That's why DairyNZ's levy-funded research on improving water quality aims to help farmers understand why water quality is important, how riparian planting can help them to meet catchment limits and what the full range of benefits from it are. Our development of various riparian planting-related resources and tools also aims to make it easier for farmers to carry out riparian fencing and planting on their properties.

In this article, you'll find out what riparian management is, and how science confirms its beneficial effects on water quality. You'll also read about some of the tools farmers are using to include riparian management as part of their overall farm approach and planning. We've also provided a few tips on identifying where plantings will have the best effect and outlined where you can get information, guidance and support on establishing riparian planting on your farm.

## What is riparian management?

Riparian management covers a lot more than just planting. It includes stock exclusion, vegetating excluded margins, and maintaining what you've planted against weeds, bankside erosion and natural events (e.g. floods). Whether you plant natives or exotics or just leave the grass to grow rank depends on the water quality issue being addressed. Using just grass filters in many farm situations is likely to deliver a cost-effective strategy for water quality but less so for biodiversity. Also, whether planting natives or exotics, it's not necessarily the type of plant that's the issue, it's also about the ecosystem processes they regulate (for example, filtering, uptake, stabilisation, provision of shade) and the outcomes desired.

## Effects of riparian management

### Water quality

As we mentioned earlier, riparian management can improve water quality, which in turn benefits our native fish and insects, but more broadly, affects many other values such as biodiversity and on-farm aesthetics. The effects of riparian margins on contaminant loss, whether the planted areas are grass or native plantings, vary with slope, soil type, climate and setback width. However, water quality benefits for filtration and contaminant uptake tend to reduce rapidly after five to 10 metres, with most filtration or deposition occurring within the first few metres from a fence[1, 2, 3].

Research has demonstrated that riparian management can help reduce the amount of nutrients (phosphorus, P; and nitrogen, N), sediment and faecal pathogens *(E. coli)* entering the water[4, 5, 6]. For instance, livestock exclusion on Southland dairy farms has been linked to a 20 percent reduction in *(E. coli)* contributions and a 40 percent reduction in P loss. Those estimates vary between farms, but they're driven by reduced bank disturbance and stock defecation directly into water[7].

For nutrient and sediment lost in overland runoff, rank grass can generate equivalent or better reductions in these contaminants as native planted margins[3, 4, 8, 9]. An international review found grass filters of five metres can reduce N, P and sediment loss by 54 to 74 percent, while a study in the Bay of Plenty reported grass filters of three metres can reduce N, P and sediment loads by 35 to 87 percent[3, 8].

### Physical habitat, bank stability and biodiversity

Planting natives or sterile willows and poplars (available from most regional councils) is generally of greater benefit than grasses and sedges when it comes to reducing riverbank erosion or enhancing biodiversity[10, 11].

Other studies have shown riparian vegetation benefits water quality by stabilising banks, removing and filtering contaminants, providing shade and, therefore, cooling water temperature. Temperature is a key constraint on the in-stream oxygen available to native fish and invertebrate communities[12, 13, 14]. Shading can also effectively prevent nuisance algal growths on small-to-moderate channels (four to five metres wide)[4, 13].

Be aware though, many studies caution of long timeframes needed to see improvements tied to riparian plant growth rates. That's because of a legacy of fine sediment already in waterways from two centuries of land use. It's also affected by the time needed to re-colonise insects and fish to healthier waterways. These waterways need to have the in-stream habitat complexity that insects and fish need to support their sensitive populations[4, 6].

For example, wood in a stream might be critical to biodiversity, but grass filters – that don't survive under heavy shade – actually provide suitable spawning environments for many native Galaxiid fish[6, 15, 16, 17, 18]. The scientific community is investing heavily to better understand how to best improve habitat and connectivity, not just the geochemistry or physical condition of water.

## Wetland riparian management

Wetlands are unique environments. Their chemistry and hydrology are ideal for treating nitrogen in shallow subsurface and runoff from dairy farms[19, 20, 21]. Wetlands sometimes contain open water but typically are smaller areas where ponding quickly occurs and remains after rainfall, where springs emerge and where soils are generally saturated. You're likely to recognise these areas on your farm as locations that pug easily.

The vast majority of wetlands on pastoral land (90 percent) have been drained over the past 200 years[22]. That's undoubtedly contributed to historic water quality degradation, but it also means many farms will have areas suitable for wetlands re-establishment.

### Wetland contaminant reduction

A wetlands 'denitrification' process involves bacterial communities converting nitrate into harmless nitrogen gas before it can reach a waterway. A recent review of scientific studies in New Zealand found that wetlands can reduced the nitrate entering them by 75 to 98 percent[21, 23, 24, 25, 26].

### Sediment and phosphorus trapping

Wetlands are also great for trapping sediments and sediment-bound phosphorus[5, 27, 28, 29]. Through the levy paid by dairy farmers, DairyNZ, along with the National Institute of Water and Atmospheric Research (NIWA) and regional councils, are investing in science to further refine these estimates so they can determine the potential for wetlands to be re-established on farms. Once we have this information, we can help farmers contribute to addressing the total reduction in contaminants achievable through wetlands management in New Zealand.

## Using the research and tools

### Dairy farmers and tools in action

The most recently published data available at the time of writing this article shows more than 98 percent of waterways more than a metre wide on dairy farms had been fenced to keep out stock[30]. The next step involves farmers creating a farm-specific riparian plan to show council and milk processors what has been achieved, and plan fencing and planting for smaller waterways.

One of the ways you can do this is to use DairyNZ's Riparian Planner, which has been used by 2200 dairy farmers so far with great success. The Riparian Planner allows you to map waterways and wetlands, and plan and cost additional fencing and planting[30].

We've developed this tool with regional councils and Manaaki Whenua. It includes regionalised riparian planting guides and it's currently undergoing further development to enable user-defined data-sharing with regional councils and milk suppliers. This will simplify Farm Environment Plan reporting requirements.

### Ongoing research

Further studies aim to increase riparian effectiveness, quantify the performance of constructed wetlands and buffers that specifically target overland flow runoff (critical source areas) and reward farmers for their efforts through regulatory-recognised nutrient credits. We are also working with partners including Manawatu's regional council, Horizons, and Sustainable Wairarapa to carry out a study into grass filter effects, and investigating the potential to engineer floodplain management through two-stage channels (see our *Tech Series* December 2018 article and podcast at **dairynz.co.nz/techseries**) to reduce contaminants carried by flood-flows, so we'll be keeping a close eye on the results of those, as well.

## TARANAKI'S RIPARIAN EFFORTS PAY OFF

The Taranaki region has the longest history of recognising and using riparian management as a tool for mitigating the effects of land use. Established in 1993, the region's riparian programme has seen more than 4100 kilometres (km) of streambank fenced, including more than 2300km planted.

Aquatic macroinvertebrates (insects) are often used as an indicator of water quality, because they integrate water quality and habitat conditions over time and respond to pressures in a predictable way. Out of 57 monitoring stations, none reported a statistically significant decline from 1995 to 2014 for insect health. Better yet, 30 were found to have improved significantly over this period[31].

These changes are centred on lowland and middle catchments where land use is most intense and with its impacts likely to be greatest. Given our understanding of insect health, the reductions in sediment loss and decreasing temperatures, together with more diverse in-stream habitats and food supply reflected in these changes, can be linked to the adoption of riparian action plans on farms in those areas.

## RIPARIAN TIPS

Before using the Riparian Planner, assess your property next time it rains heavily. Look for overland flow across your paddocks. Consider whether this can be slowed with riparian buffers before it reaches a waterway, and whether wetlands could be re-established in low-lying areas on your farm. Aligning fences smartly to take in those 'critical source' areas increases the ability for rank grass or native plant communities to then filter out nutrients, sediment and faecal pathogens.

## Accessing tools, guidance and support

DairyNZ's website has plenty of information, resources and tools related to environmental sustainability, improving water quality and carrying out riparian planting. Go online to **dairynz.co.nz** – you'll also find our Riparian Planner at **dairynz.co.nz/riparian-planner**

Talk to your local DairyNZ consulting officer (contact details at **dairynz.co.nz/co**) and/or your regional council for more information and guidance on water quality, riparian planting and regulatory compliance and support.

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# Aiming high with grazed forages

**Is it possible to produce 25 tonnes of dry matter per hectare from grazed forages, while also lifting milk production and profit? DairyNZ principal scientist David Chapman summarises a recent DairyNZ experiment.**

The quest to find pasture and crop options that can surpass perennial ryegrass/white clover for production and profit is important for the future sustainability of our dairy sector. A recent example of this work is a DairyNZ farmlet experiment at Scott Farm, Waikato. This project aimed to produce 25 tonnes of dry matter per hectare (t DM/ha) from grazed forages – 20 to 30 percent above what the best farms are currently producing – while also achieving increases in milk production and profit[1].

## Testing two approaches

Two approaches to the 25t DM/ha target were compared separately, and in combination, for three years.

Our first approach was to change the 'base' pasture from perennial ryegrass/white clover (PR/WC) to tall fescue/white clover (TF/WC), to exploit the better drought and heat stress tolerance of tall fescue.

Our second approach was to grow high-yielding, high-quality, summer-active forage crops on 20 percent of the farmlet to support high milk production through summer, when perennial ryegrass struggles to deliver enough high-quality feed. Two options were compared: chicory/red clover mixture (CH/RC) and lucerne (LU).

Combining the two approaches resulted in six farmlets, each stocked at 3.5 cows/ha: two base pasture types (PR/WC, TF/WC) each with three summer crop options (nil, CH/RC and LU).

## What were the results?

The TF/WC pasture grew an average of 22.4t DM/ha/year versus 19.5t DM/ha/year for PR/WC. However, milksolids (MS) production and estimated operating profit were lower: 1370kg MS/ha and $4320/ha for TF/WC, versus 1390kg MS/ha and $4475/ha for PR/WC.

The shortfall in MS production and profit in TF/WC was due to the lower yield and nutritive value of tall fescue compared with perennial ryegrass during spring, resulting in lower daily MS production. The deficit in spring production was not recovered, despite greater growth from TF/WC during summer and autumn.

Incorporating crops reduced both annual DM yield and MS production. This lowered farm income. It also increased operating expenses associated with crop renewal and additional supplementary feed purchased to meet feed demand.

## In summary

For this Waikato experiment, we nearly achieved the 25t DM/ha target by changing the forage base from perennial ryegrass to tall fescue. However, the 'drag' of poorer feed quality from tall fescue-based pastures and/or higher costs of summer cropping with special-purpose grazeable forages meant animal production and profit were lower than the industry standard system based on PR/WC.

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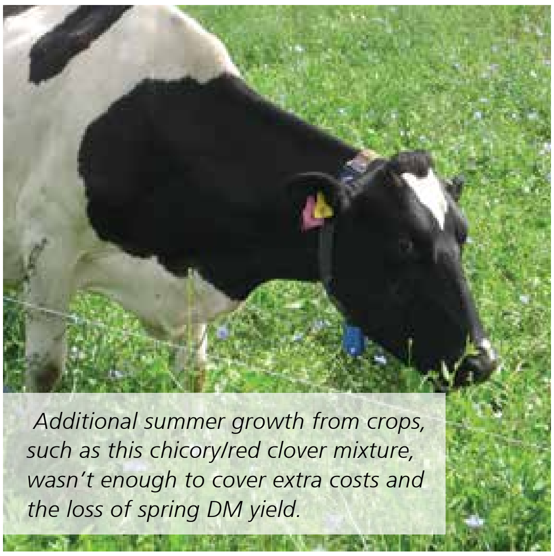

*Additional summer growth from crops, such as this chicory/red clover mixture, wasn't enough to cover extra costs and the loss of spring DM yield.*

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