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

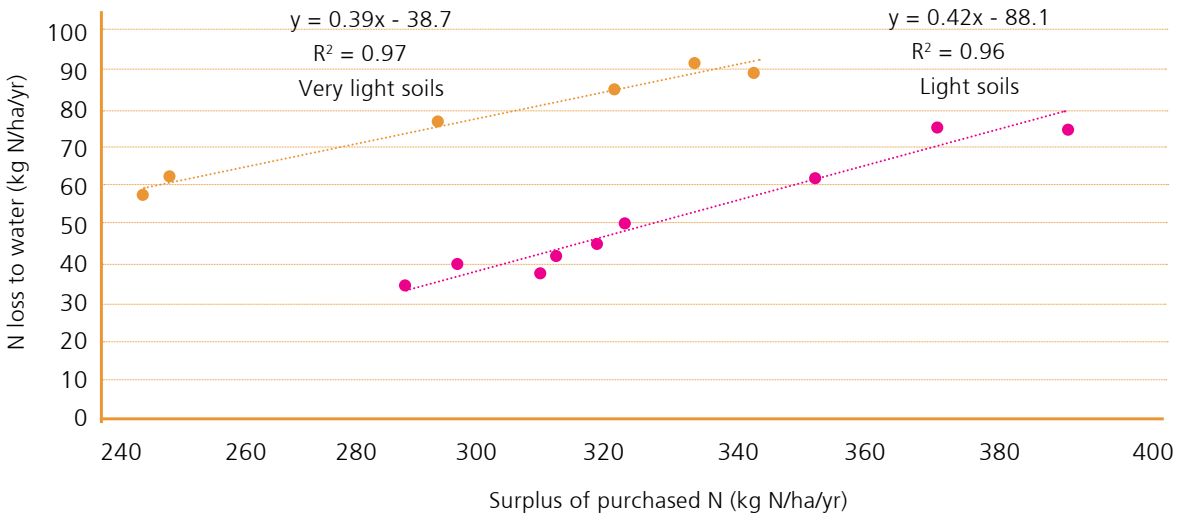
Reducing N surplus generally reduces N loss to the environment[1] while increasing the cost-effectiveness of N use. Most farmers purchase more N as fertiliser and supplementary feeds (inputs) than they sell in products as milk, meat or crop (outputs). By reducing fertiliser and feed inputs and becoming 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.

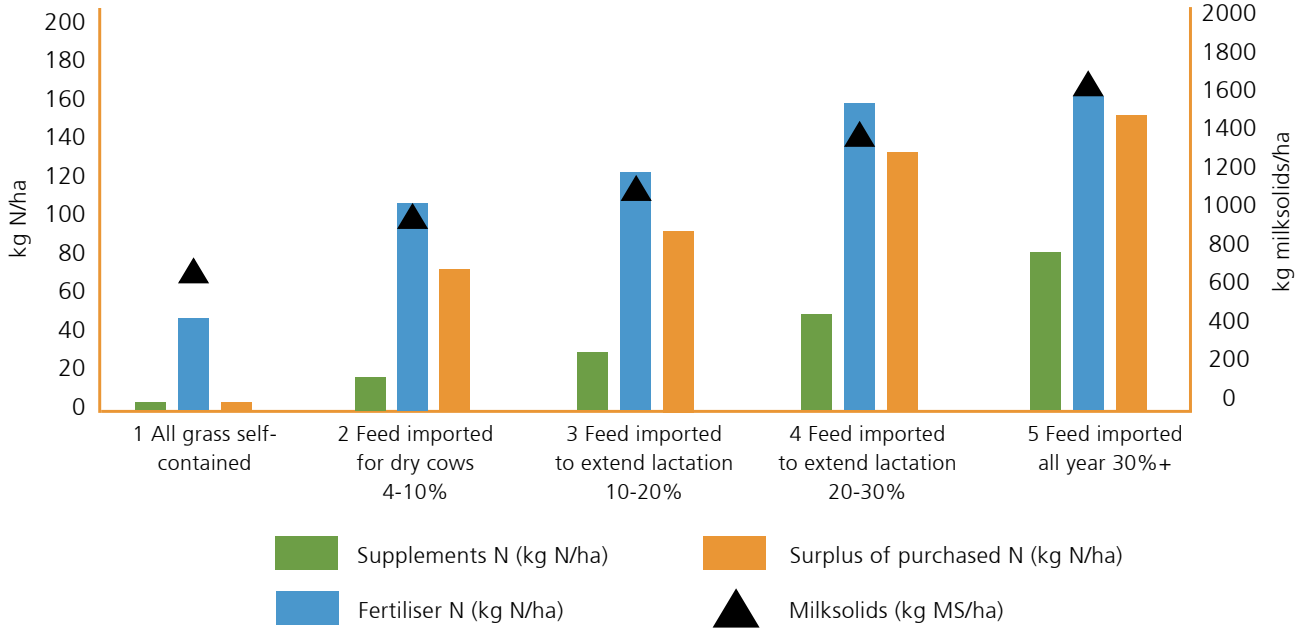
They also showed that a higher N surplus was associated with higher nitrate leaching, ammonia volatilisation and emission of

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

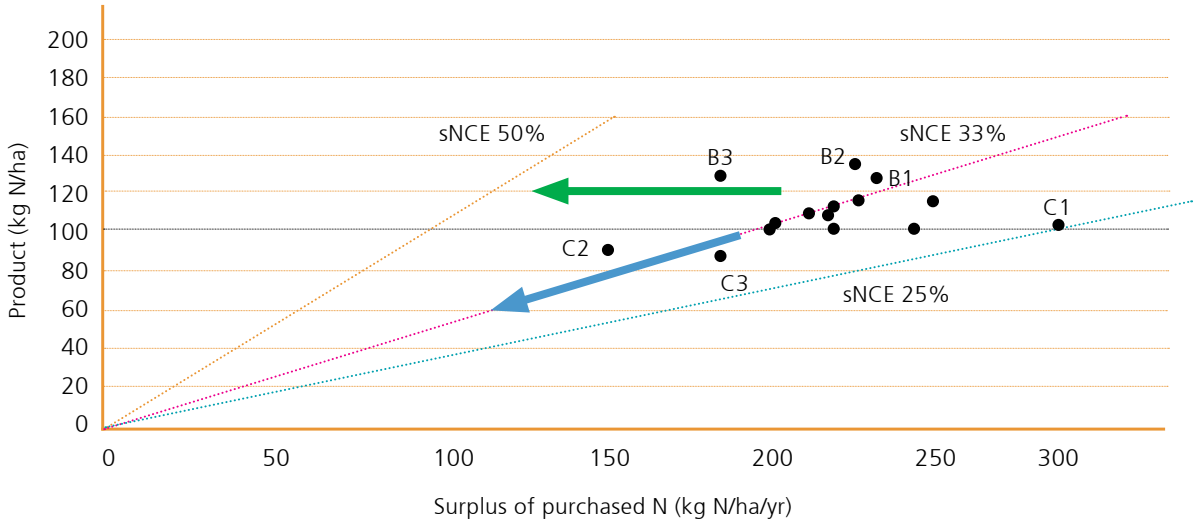
A comparison of the N budgets of five Canterbury monitor farms in the Forages for Reduced Nitrate Leaching programme (FRNL)* showed their relatively high N fertiliser and supplement inputs resulted in high production, but also in relatively high N surplus[3]. During the FRNL programme, these farms implemented 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*


Scenario reports

Nutrient Budget | Nitrogen | Phosp

Footprint units | Footprint product

(kg/ha/yr)	N
Nutrients added	
Fertiliser, lime & other	295
Rain/clover N fixation	50
Irrigation	5
Supplements	40
Nutrients removed	
As products	93
Exported effluent	0
As supplements and crop residues	0
To atmosphere	100
To water	48

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 kg N/yr	N lost to water kg N/ha/yr	N in drainage * ppm	N surplus kg N/ha/yr	Added N ** kg N/ha/yr
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.

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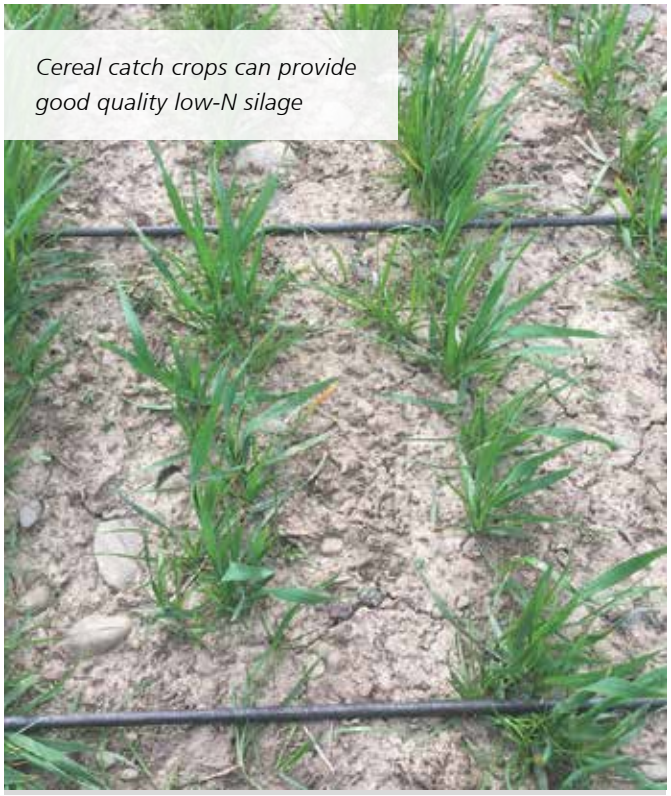

Cereal catch crops can provide good quality low-N silage

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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