# Optimising on-farm nitrogen management in the face of regulated fertiliser input

A report prepared for Our Land and Water National Science Challenge

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## 1.0 EXECUTIVE SUMMARY

The key purpose of this project was to investigate how farmers had responded to the regulatory capping of synthetic nitrogen fertiliser at a maximum of 190 kg N/ha onto pastoral farms, and the impact this had had on nitrogen leaching and greenhouse gas emissions.

The analysis was carried out on 12 irrigated Canterbury and 3 Southland dairy farms via:

- An analysis of their OverseerFM files for 2023 versus 2020,
- An interview as to how they had managed any changes, and
- A workshop to discuss the results of the OverseerFM analysis and further thoughts around nitrogen management.

While fertiliser nitrogen is often a key productive input into a pastoral farming system, other nitrogen inputs via supplementary feeding, cropping, and fixation by legumes are also important, and a reduction is fertiliser nitrogen can be compensated for via these other sources, albeit not as cheaply. The overall impact therefore is very dependent on the total amount of nitrogen within the system, and how this changes.

The analysis shows that the impact of the restriction on synthetic nitrogen fertiliser application has seen all farms reduce applications to (in most cases) well below the 190kg/ha limit. Overall, application on the Canterbury farms has fallen 30% on average (range -3% to -46%) and 41% (range -23% to -51%) for the Southland farms.

The amount of total nitrogen input into the system had also reduced, but much less due to "compensatory" inputs in the form of increased supplementary feeds and increased cropping, and in particular an increase in nitrogen fixation by clovers. Overall, total nitrogen within the system has reduced by 9% on average for the Canterbury farms, and 18% for the Southland farms.

The key differences between the two regions largely comes back to differences in the supplementary feed/cropping response; in Canterbury, the level of supplementary feed input increased (by 25%) while cropping decreased (10%) whereas for Southland the level of supplementary feed input decreased slightly (-4%) whereas cropping (measured as Tonnes DM grown) basically doubled (98%).

The key effect though was that nitrogen leaching decreased on average by 15% in Canterbury and 32% in Southland.

Average nitrogen input and change 2023 vs 2020

| Canterbury | 2020 | 2023 | kg N/ha change | % Change |
|---|---|---|---|---|
| kg fertiliser N/ha | 233 | 161 | -73 | -31% |
| Total N/ha | 369 | 338 | -32 | -9% |
| kg N/ha N Leaching | 41 | 35 | -6 | -15% |
| **Southland** | | | | |
| kg fertiliser N/ha | 260 | 151 | -109 | -42% |
| Total N/ha | 385 | 316 | -69 | -18% |
| kg N/ha N Leaching | 69 | 47 | -30 | -32% |

The impact on greenhouse gas emissions was somewhat mixed. For Canterbury, methane emissions increased by 3% due to higher DM intake (more supplementary feed) but dropped 2% for the Southland farms. Nitrous oxide emissions were down in both regions; Canterbury by 9% and Southland by 9%. Total biological emissions were static for Canterbury but dropped 6% in Southland.

Average GHG Emissions

| | Canterbury | | | | Southland | | |
|---|---|---|---|---|---|---|---|
| | 2020 | 2023 | % difference | | 2020 | 2023 | % difference |
| **Methane (T $CO_2$e/ha)** | 9.3 | 9.6 | 3% | | 9.3 | 9.0 | -2% |
| **Methane (kg $CH_4$/ha)** | 373 | 385 | 3% | | 370 | 362 | -2% |
| **Nitrous Oxide (T $CO_2$e/ha)** | 2.8 | 2.6 | -9% | | 2.7 | 2.2 | -18% |
| **Total Biological Emissions (T $CO_2$e/ha)** | 12.1 | 12.2 | 0% | | 12.0 | 11.2 | -6% |
| **Gross GHG Emissions* (T $CO_2$e/ha)** | 14.7 | 14.6 | -1% | | 15.2 | 13.8 | -9% |

*Includes $CO_2$

The main management changes made by the farmers, in order to compensate for the decreased feed availability due to a lesser nitrogen fertiliser input were:

- In most of the Canterbury case study farms, the amount of supplementary feed being purchased in increased.
- For the Southland farms the main increase in feed input was via increased DM grown as forage cropping.
- Within Canterbury, average stocking rate and production per hectare has increased slightly (3% and 4% respectively) whereas for Southland both had dropped slightly (-2% and -3 % respectively).

In discussion with the case-study farmers they were surprised at how (relatively) low the N fertiliser applications had reduced and put this down to 2 key factors: still getting to grips with the regulatory regime and dealing with the vagaries of the climate where N fertiliser applications were not justified but more supplementary feeding was.

There was also a concern that if the restriction was tightened, then it would directly affect the profitability of their business given nitrogen is an integral component within an irrigated system.

## 2.0 BACKGROUND

The Freshwater Regulations, introduced as part of the National Policy Statement on Freshwater Management, introduced in September 2020, and effective from 1 July 2022 stated that:

*Synthetic nitrogen may be applied as a permitted activity at a rate of no more than 190kg/ha/year to each hectare of land not used to grow annual forage crops and as an average rate over all of the land.* [Applications in excess of 190 kg N/ha would require a consent]

This was an attempt to reduce nitrogen leaching from pastoral land, and, while applying to all pastoral farms above 20 hectares, was primarily aimed at dairy farms.

The reason for this is that, on average, dairy farms use much more nitrogen fertiliser than sheep & beef farms. This is illustrated via analysis carried out in 2020 (Journeaux, 2020):

Table 1: Fertiliser nitrogen application by quartile for the main dairying areas, 2017/18 (kg N/ha)

| | Q1 | Q2 | Q3 | Q4 | Mean |
|---|---|---|---|---|---|
| Northland | 36 | 92 | 127 | 192 | 102 |
| Waikato/Bay of Plenty | 61 | 116 | 158 | 222 | 138 |
| Taranaki | 71 | 122 | 161 | 242 | 155 |
| Canterbury | 104 | 224 | 265 | 309 | 222 |
| Southland | 113 | 174 | 193 | 230 | 185 |

Source: DairyBase

Table 2: Fertiliser Nitrogen application on sheep & beef farms (kg N/ha)

| | Q4 | Mean |
|---|---|---|
| South Island High country | 7 | 1.5 |
| South Island Hill country | 11 | 4.7 |
| North Island Hard Hill country | 20 | 6.8 |
| North Island Hill country | 31 | 11.1 |
| North Island Intensive finishing | 60 | 18.8 |
| South Island Finishing breeding | 53 | 16.8 |
| South Island Intensive finishing | 39 | 16.7 |
| South Island Mixed finishing | 267 | 119.1 |
| All Class Average | 34 | 13.6 |

Source: Beef + Lamb NZ Economic Service. 5-year average 2013/14 – 2017/18

As can be seen by this, (a) nitrogen fertiliser use on sheep & beef farms is generally low, while (b) all of the dairy farms in the 4$^{th}$ quartile are over 190 kg N/ha, and all but the bottom quartile farms in Canterbury are over the 190 kg N/ha limit.

The reason Canterbury farms use a greater level of nitrogen fertiliser is that for irrigated dairy farms, nitrogen fertiliser is a significant component of the farming system given the reliability of a response as moisture is not a limiting factor and that it is usually the cheapest form of providing additional feed. This is discussed in more detail in Journeaux et al 2019.

An estimated 33-35% of dairy farms were above the 190kg N/ha limit, and therefore the restriction on the use of synthetic fertiliser could potentially have ramifications for the way the system is managed, and on profitability.

## 2.1 Sources of Nitrogen

There are three main sources of nitrogen into a pastoral farming system in New Zealand:

(i) Fertiliser nitrogen
(ii) Nitrogen (as protein) in supplementary feedstuffs
(iii) Nitrogen fixed by legumes (e.g. clover)

Without the risks that impact a cropping rotation, the main driver of nitrate leaching within a solely pasture based system is from animal urine; animals are part of the nitrogen cycle, and in a pasture only system, it is the total amount of nitrogen within the cycle which is important rather than any one source. While there is some nitrate leaching direct from fertiliser nitrogen applications, particularly if applied at individual heavy rates, this can be minimised via small regular applications. The main aspect of nitrogen leaching from nitrogen fertiliser in pasture only systems therefore is via animals grazing; the nitrogen fertiliser increases pasture growth, which is eaten by animals, with the excess nitrogen then excreted as urine, from which the nitrate then leaches.

If the amount of forage available on the farm is reduced as a result of a limit on nitrogen fertiliser, then often the next best option (in an economic sense) is to use supplementary feed to "plug the gap". Whether or not to use supplement is essentially a marginal cost versus marginal benefit calculation, but not withstanding this, it is (a) a ready option, and (b) means that the total amount of nitrogen operating within the cycle on a farm could be maintained, such that there is no reduction in nitrate leaching.

### *2.1.1 Clover Fixation of Nitrogen*

Nitrogen fixation by legumes is/can be an important source of nitrogen in grazed pasture, and much of New Zealand pastures are a ryegrass/white clover mix, where the clover provides (a) a high quality forage, and (b) fixes atmospheric nitrogen which is then available as a pasture nutrient.

There is a strong relationship between the amount of nitrogen fixed by clovers within a pasture, and the amount of nitrogen fertiliser applied; as the amount of nitrogen fertiliser increases, it suppresses the fixation of nitrogen by clovers (mainly via a shading out of the clover by the grasses), and conversely, as nitrogen fertiliser input is reduced, clover fixation increases. This is illustrated below.

Table 3: Relationship between fertiliser and clover nitrogen fixation

| | | | |
|---|---|---|---|
| **Fertiliser N (kg/ha)** | 0 | 220 | 360 |
| **Clover nitrogen (kg/ha)** | 210 | 170 | 70 |

Source: Walker, 1995

This shows a strong correlation between the two of -0.93, with a $R^2$ of 0.87.

Ledgard and Steel (1992) noted that nitrogen fixation by clovers in a grazed mixed sward varied between 55 to 296 kg/ha/year, depending on varying factors.

### *2.1.2 Rainfall and Irrigation*

There is also a fourth source of nitrogen, albeit usually relatively small, from rainfall and/or irrigation water. US studies (Gaughan 2018) indicated an application rate from rainfall equivalent to 3.3kg N/ha, while a New Zealand study based around Rotorua (Fish 1976) indicated an application rate of 0.8 kg N/ha from rainfall. In both these studies the nitrogen was a combination of $NH_4$ and $NO_3$.

The amount of nitrogen in irrigation water varies depending on the amount of nitrogen in the source water. But assuming a total application rate of 600mm/ha, and 5ppm of $NO_3$ in the source water, the irrigation water would be applying around 4 kg N/ha/year.

Overall therefore, if nitrogen fertiliser application is decreased, nitrogen inputs from other sources, particularly clover fixation and supplementary feed input, can make up much of the difference. In other words, the total amount of nitrogen within the farm system may not shift that much depending on these other sources.

### *2.1.3 Other Factors*

Climate impacts the response to nitrogen and therefore the decision to apply nitrogen with the intent of boosting dry matter production. Responses to nitrogen fertiliser are maximised when moisture is adequate, nitrogen from other sources (such as clover) is less available and when plant growth is rapid. In very wet and cold conditions, farmers are not able to apply nitrogen fertiliser in the Canterbury region, not only because it impacts the dry matter response, but also because it would not align with Good Management Practices outlined within their audited Farm Environment Plans that form part of their farming consent obligations.

An increase in cropping (a response noted latter in the report) can also impact on nitrogen leaching. Nitrogen released via mineralisation at the end of a crop is very difficult to manage (because the weather also plays a very big factor) and poses a risk to increasing nitrogen loss from the bottom of the root zone if farmers increase the area of forage crop associated with their pastoral system.

## 3.0 OBJECTIVES

The objectives for the project were:

(i) To analyse the impact of the 190kg N/ha restriction, relative to its impact on nitrogen leaching, and on farm profitability, and any change in farm management this may have induced.

(ii) Discuss how farmers can best manage the farming system to optimise the use of nitrogen fertiliser, and the use of nitrogen fertiliser substitutes, i.e supplementary feed, while reducing nitrogen losses.

(iii) Analyse as to the impact the reduction in fertilizer nitrogen has had in reducing greenhouse gas emissions.

As per Table 1, farms in Canterbury and Southland were chosen given they had the highest average nitrogen fertiliser inputs and the impact of the reduction down to the 190 kg N/ha limit could be assessed.

## 4.0 METHODOLOGY

The methodology for the project involved:

(i) A "before and after" assessment across 12 irrigated dairy farms in Canterbury and 3 dairy farms based in Southland. The "before" period was the 2019/20 season, with the "after" period being the 2022/23 season. These farms were geographically spread around the region (see Figure 1 below).

(ii) The information collated included:
- Nitrogen fertiliser applications – type and rate of application
- Amount and type of bought-in supplementary feed
- Amount of supplementary feed and cropping on-farm
- The profitability of the farms system – this would include the actual profit in the years in question, as well as the profitability when the payout is standardized across both years.
- Any changes made to the farm system arising from the nitrogen fertiliser restriction.

(iii) A nitrogen balance is provided for each farm, for both years, as to the nitrogen input from the various categories, relative to the level of nitrate leaching, as measured by OverseerFM.

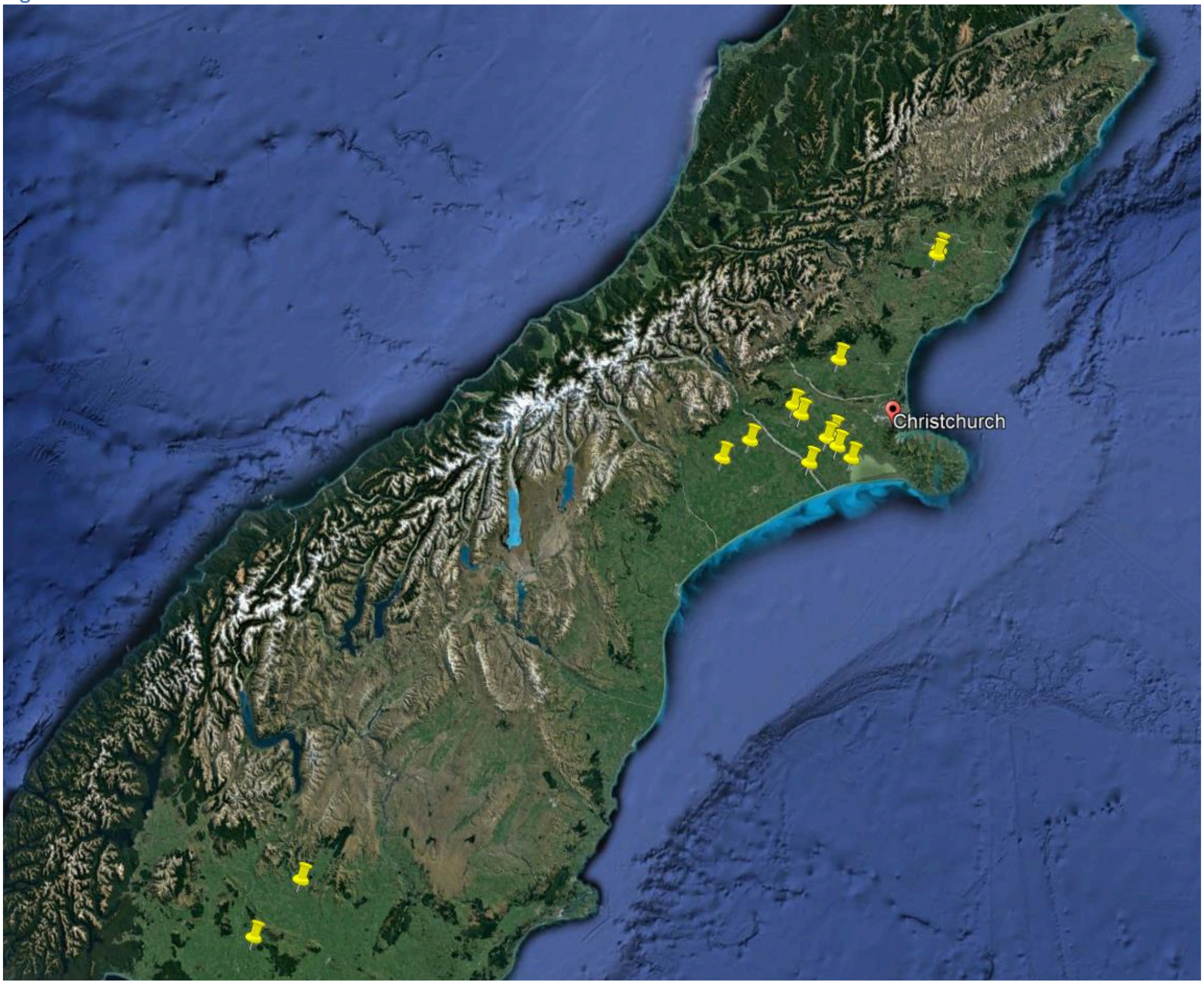
(iv) Similarly, biological greenhouse gas emissions, is documented and compared for each farm relative to the nitrogen inputs for each of the before and after seasons.

(v) Interviews were held with the farmers as to how they managed the nitrogen fertiliser balance within the farm, as well as discussing whether the farmers had altered their effluent management in order to maximise the nitrogen benefit from this, and whether the current high price of nitrogen fertiliser has/will influence their use of it.

(vi) A workshop was run for the case-study farmers to discuss through the results of the analysis, their interpretation of this, and thoughts on integrated management of nitrogen within the farm system going forward.

(vii) Discussion of means of achieving greater efficiency of nitrogen fertiliser usage, e.g. via fertigation.

Figure 1: Farm Location




## 5.0 RESULTS

### 5.1 Nitrogen Input/Leaching: Canterbury

The average nitrogen balance across the 12 Canterbury farms was:

Table 4: Canterbury average nitrogen inputs and outputs

| | 2020 | 2023 | Difference | % Difference |
|---|---|---|---|---|
| Fertiliser N (kg/ha) | 233 | 161 | -73 | -31% |
| Irrigation N (kg/ha) | 8.5 | 8.1 | 0.4 | -5% |
| Supplement N (kg/ha) | 33 | 46 | 13 | 38% |
| Clover N (kg/ha) | 95 | 123 | 29 | 30% |
| Total N kg/ha | 369 | 338 | -32 | -9% |
| kg N/ha Leached | 41 | 35 | -6 | -15% |
| N Surplus kg/ha | 267 | 238 | -29 | -11% |
| PNS* kg/ha | 171 | 110 | -61 | -36% |

*PNS = Purchased Nitrogen Surplus = Nitrogen from fertiliser and supplementary feed less nitrogen extracted as product.

Table 4 shows that while nitrogen fertiliser has reduced by 31%, nitrogen input from clover fixation and supplementary feed has increased, such that the net change in total nitrogen within the system is reduced by 9%, and nitrogen leached reduces by 15%.

There is some variation between the individual farms (details in Appendix 1), where 2 farms had increased N leaching, and 2 had shown no change in N leaching.

The range of fertiliser N input across the farms shows (a) a significant range in both 2020 and 2023, with the mean and median in 2023 well below the 190kg N/ha limit.

Table 5: Range of fertiliser N input (kg N/ha)

| | Min | Max | Mean | Median |
|---|---|---|---|---|
| 2020 | 197 | 346 | 233 | 222 |
| 2023 | 105 | 186 | 161 | 166 |

The constituency of the amount of nitrogen within the system changed, as could be expected, with the proportion provided by clover fixation and supplementary feed increasing.

Table 6: Canterbury average proportion of total nitrogen

| | 2020 | 2023 |
|---|---|---|
| % Fertiliser N | 63% | 48% |
| % Irrigation N | 2% | 2% |
| % Supplement N | 9% | 13% |
| % Clover N | 26% | 36% |

The physical changes between the years were:

Table 7: Canterbury average physical changes

| | **2020** | **2023** | **% difference** |
|---|---|---|---|
| **Cows/ha** | 3.4 | 3.5 | 3% |
| **kg MS/ha** | 1,437 | 1,493 | 4% |
| **T Supplement DM/ha** | 1.9 | 2.4 | 25% |
| **T Supplement DM/cow** | 0.6 | 0.7 | 24% |
| **T Crop DM/ farm ha** | 1.3 | 1.2 | -10% |

Within the farm sample, 5 farms had increased their stocking rate, whereas the rest had either reduced or held their stocking rate. One farm had significantly increased its stocking rate (by 42%). If this is removed from the sample, stocking rate is stable between the years, at 3.5 cows/ha.

Table 7 also shows that bought-in supplement had increased by 25%, whereas the amount of dry matter supplied by crops decreased by 10%. Again, there is some variation in this for the individual farms. The type of supplement bought in, and crops grown, varied little between the years.

## 5.2 Nitrogen Input/Leaching: Southland

The average nitrogen balance across the 3 Southland farms was:

Table 8: Southland average nitrogen inputs and outputs

| | 2020 | 2023 | Difference | % difference |
|---|---|---|---|---|
| Fertiliser N (kg/ha) | 260 | 151 | -109 | -42% |
| Irrigation N (kg/ha) | 1.7 | 1.3 | 0.4 | -20% |
| Supplement N (kg/ha) | 68 | 66 | -2 | -3% |
| Clover N (kg/ha) | 55 | 98 | 43 | 78% |
| Total N kg/ha | 385 | 316 | -69 | -18% |
| kg N/ha Leached | 69 | 47 | -22 | -32% |
| N Surplus kg/ha | 284 | 211 | -73 | -26% |
| PNS kg/ha | 230 | 118 | -113 | -49% |

Table 8 shows a significant reduction in nitrogen fertiliser applied, a small reduction in nitrogen from supplementary feed, and an increased in nitrogen from clover fixation. The net effect has been a 32% reduction in nitrogen leached.

The proportional changes in the source of nitrogen are:

Table 9: Southland average proportion of total nitrogen

| | 2020 | 2023 |
|---|---|---|
| % Fertiliser N | 68% | 48% |
| % Irrigation N | 0% | 0% |
| % Supplement N | 18% | 20% |
| % Clover N | 14% | 32% |

The physical changes between years shows:

Table 10: Southland average physical changes

| | **2020** | **2023** | **% difference** |
|---|---|---|---|
| **Cows/ha** | 3.0 | 3.0 | -0% |
| **kg MS/ha** | 1,448 | 1,411 | -3% |
| **T Supplement DM/ha** | 3.4 | 3.1 | -9% |
| **T Supplement DM/cow** | 1.2 | 1.1 | -4% |
| **T Crop DM/farm ha** | 0.2 | 0.4 | 100% |

This is slightly different to Canterbury in that stocking rate has remained stable, production has decreased slightly, the amount of supplementary feed input has declined whereas the dry matter input from cropping has increased.

## 5.3 Greenhouse Gas Emissions

The key determinants of GHG emissions at a farm level are:

- The amount of dry matter (DM) consumed by the animals. There is a direct correlation with the amount of methane produced, and a strong correlation with nitrous oxide emissions, which is then also heavily influenced by;
- The amount of protein in the diet. Protein levels in New Zealand pastures are generally quite high – well above average ruminant requirements.
- The amount of nitrogen fertiliser used. While there are some direct $N_2O$ and $CO_2$ emissions when nitrogen fertiliser is applied to the soil, the key reason for most New Zealand farmers using nitrogen fertiliser is to grow more pasture – i.e. increase the amount of DM on offer to the animals.

The reduction in the use of nitrogen fertiliser would therefore be expected to reduce the amount of dry matter on offer to the farm animals, potentially offset by any increase in supplementary feed and/or crop dry matter. It would also decrease the amount of direct emissions from applying the fertiliser.

The OverseerFM analysis on the case study farms showed:

Table 11: Average GHG Emissions

| | Canterbury | | | | Southland | | |
|---|---|---|---|---|---|---|---|
| | **2020** | **2023** | **% difference** | | **2020** | **2023** | **% difference** |
| **Methane (T $CO_2$e/ha)** | 9.3 | 9.6 | 3% | | 9.3 | 9.0 | -2% |
| **Methane (kg $CH_4$/ha)** | 373 | 385 | 3% | | 370 | 362 | -2% |
| **Nitrous Oxide (T $CO_2$e/ha)** | 2.8 | 2.6 | -9% | | 2.7 | 2.2 | -18% |
| **Total Biological Emissions (T $CO_2$e/ha)** | 12.1 | 12.2 | 0% | | 12.0 | 11.2 | -6% |
| **Gross GHG Emissions* (T $CO_2$e/ha)** | 14.7 | 14.6 | -1% | | 15.2 | 13.8 | -9% |

*Includes $CO_2$e emissions

As can be seen in Table 11, there is some difference between the two regions. In Canterbury, methane production has increased due to the greater amount of supplement and cropping DM being fed, while nitrous oxide emissions have decreased. Conserved forage supplements have lower energy density compared to nitrogen boosted pasture meaning that more kg DM are required to achieve the same energy intake – resulting in more methane production.

Overall, total biological/gross emissions have changed very little. For Southland, methane emissions have decreased due to a lower dry matter consumption, and nitrous oxide emissions have also decreased significantly due to the reduction in nitrogen fertiliser usage. This in turn sees total biological/gross emissions also reduce.

# 6.0 FINANCIAL ANALYSIS

The farm accounts were also analysed as to any changes in farm profitability that may be linked to the changes brought about by the restriction in nitrogen fertiliser application.

This was done by comparing the 2019/20 versus 2022/23 accounts. Milksolids income was analysed two ways: (a) using the actual payouts in 2019/20 and 2022/23, and (b) standardised by using a 5-year average payout (2018/19 – 2022/23) of $7.71/kg milksolids, plus the farm working expenses for 2022/23 were deflated using the dairy primary producers index (PPI) for the years from June 30, 2020, to June 30, 2023 (27%). The reason for using the standardised payout is that it removes the impact of changes in payout.

The general thesis was that costs would have increased; inasmuch as nitrogen is the cheapest form of additional feed, this has been replaced with more expensive bought-in supplementary feed and cropping.

Table 12: Change in Farm Income & Costs; 2022/23 versus 2019/20

| | Nominal | Real |
|---|---|---|
| Change in Gross Income (Actual payouts) | 13% | -11% |
| Change in Gross Income (Standardised payout) | 1% | -22% |
| Change in Farm Working Expenses | 42% | 12% |
| Change in Feed Costs | 76% | 29% |
| Change in Fertiliser Costs | 49% | 9% |
| Change in Surplus (GI-FWE) (Actual payouts) | 8% | -4% |
| Change in Surplus (GI-FWE) (Standardised payout) | -29% | -11% |

What Table 12 indicates is:

- In real (deflated) terms income has reduced
- Farm working expenses, particularly feed and fertiliser costs have increased significantly, particularly in real terms. Note that most of the farm accounts did not differentiate nitrogen fertiliser costs from general fertiliser costs – while nitrogen fertiliser usage has decreased over the period, the cost of such fertilisers has risen significantly.
- Given the actual payouts, the "surplus" has increased in nominal terms but decreased in real terms. With a standardised payout, the "surplus" has decreased, both in nominal and real terms. In essence therefore, the rise in the actual payout over the period has masked the impact of the increased costs.

It is difficult to be too definitive as to the financial implications of the restriction on synthetic nitrogen fertiliser usage, given the significant impact of on-farm cost inflation (27%) over the period. Nevertheless, Table 12 does indicate that expenditure on feed, as a substitute for nitrogen fertiliser, has risen significantly, both in nominal and real terms.

## 7.0 FARMER INTERVIEWS

At the time the information was gathered to run the Overseer analysis, the farmers were also asked a number of questions:

### 7.1 On-Farm Supplements

The question here was; has reduced nitrogen fertiliser applications altered when surpluses are available to harvest? Have imported supplements changed? Have pasture growth curve surpluses shifted?

While 4 of the Canterbury farmers were buying in less supplement in total, only 2 had reduced the amount on a per-cow basis. For Southland, 2 of the 3 farms had reduced bought-in supplement both in total and on a per cow basis.

Most had not noticed a change in the pasture curve, but some noted they had seen a shift in the pasture curve, noting that while surpluses were appearing at the same time, there was a reduction in the quantity of the surplus.

## 7.2 Cropping

The question here was; any changes in changes in management of crops as a result of the 190kg N/ha limit?

Across the 15 case study farms, 6 had reduced the cropping area, 6 had increased the cropping area, and 3 had no change. Generally, there was no change in the type of crop grown.

## 7.3 Altered Grazing Management

Generally, there has been no change in grazing management, although one farmer noted they were now using a longer rotation period and some mentioned they were tightening up on post-grazing residuals, which effectively also extends the rotation length.

## 7.4 Effluent Management

The question was around any changes in effluent management as a result of the 190kg N/ha restriction. Essentially the answer was “no” - most already had applied less fertiliser N to the effluent area. One farmer had installed an underslung area for the effluent green water equivalent to around 17% of the effective area of the farm, at the time of the implementation of the cap, and has found that they could significantly reduce N fertiliser inputs.

## 7.5 Irrigation Management

None of the farmers had altered their irrigation management as a result of the nitrogen cap. Most had also not considered the idea of fertigation, although there was some interest in this by a few.

## 7.6 Change in Pasture DM Production

There was a mix of answers to this question around any reduction in pasture dry matter production as a consequence of the less N fertiliser.

- A couple noted “not much difference”.
- A couple noted “a slight reduction”.
- The rest indicated that there had been a reduction, in some cases significant;
    - Roughly 600kg DM/ha less [this farm had significantly increased the area in crops].
    - The peak is now around a week later, moving from 20 September to end of September, due to slower pasture growth.
    - Farm is growing 1Tonne DM less/day, so that’s 300T DM in a year – have had to reduce cows and total production.
    - Up to 2 T DM/ha less – making less silage on the milking platform as a result.

## 7.7 Implications Around Nitrogen Management

This was around management of nitrogen fertiliser into the future. Again, there were a variety of responses:

- If we need to keep reducing - taking more tools out of the toolbox - losing availability of options, in a low payout year N fertiliser is a cheap source of feed.
- The fertiliser suppliers and application trucks need to improve the accuracy of their records of applications so that there is accurate proof of placement to pass onto Ecan.
- No major issues - adapt as we have to.
- Any further reductions in the cap will cause issues.
- If the cap is reduced, then will have to reduce cows further.
- Urine patches/cows wintering on crops are the issue rather than N fertiliser.
- Loss of quality of pasture - N keeps pastures lush, could start to be less palatable. N fixation higher in summer months so that is when people are peeling back on the N applications in order to utilise it in other months.

## 8.0 FARMER WORKSHOP

As part of the project, a workshop was held with the case-study farmers to discuss through the results of the analysis, and their thoughts around how to best manage nitrogen inputs into the farming system.

A summary of the discussion was:

- They were surprised at how relatively low the nitrogen fertiliser inputs had dropped. Part of this they felt were due to climatic factors over recent years such as a dry summer in Southland/wet summer in Canterbury/cool spring conditions where responses to nitrogen would be reduced. The dry summer/cool spring also meant more supplement was fed.

  They also felt that in general more farm managers are modelling and calculating exactly how much N they can apply within the cap, but it takes a couple of seasons to see how the compliance framework works and therefore where "the line" is.

  Some had left a buffer just in case they needed to apply N later in the autumn, but then found that climatic conditions were favourable and therefore did not apply the N fertiliser.

- While nitrogen fertiliser prices were high in 2022, it was, generally, still the cheapest form of supplementary feed. But there was a feeling that some farmers did not "do their sums" and just bought supplement instead.
- The response to the question of what they would do if the nitrogen fertiliser restrictions was tightened further varied:
  - Look to promote clover growth as much as possible – introduce new clovers with higher growth/greater N fixation potential.
  - If profitability was threatened, then look at alternative "N" sources, e.g. more supplements.
  - Grow more forage crops and ensile these – outside the 190 kg N/ha restriction.
  - If fertiliser N is constrained further then returns would be impacted, with flow on effects on land values which in turn would erode equity and bank assets.

Within the Canterbury region, irrigation is necessary to operate a profitable farm, and nitrogen is integral to an irrigated system.

- There was some concern at the "lag" effects of reduced nitrogen (fertiliser and mineralised deep N) – could take several seasons to manifest.

- The response to the question around increased supplement costs was – "it depends" – on its relativity to the payout and other alternatives such as cropping.

- There was a strong preference for an "effects based" system where farmers would have more flexibility around how they could respond to the various issues, i.e. water quality, biosecurity, and GHG emissions. Within this there were a couple of views:
    - Emissions costs and nitrogen leaching reduction is central to farmer minds in the Canterbury group – Fonterra scope 3 announcement might mean they have to reduce inputs anyway.
    - Any effects based planning framework from council will become more constraining anyway so there is a need focus on finding a way to secure profitability and reduce N fertiliser and GHG emissions.

- Greenhouse gas reductions were front of mind for many of the farmers – they were focused on means of mitigations and had directly connected the "less than 190kg N/ha" with GHG reductions, realising that reducing N fertiliser inputs also assisted in reducing GHG emissions.

- There was something of a difference in approach depending on farm governance. The more corporate type farms were focused on good EGS reporting and had therefore moved early, whereas the more family type farms are focussed on changing when they need to and learning but not moving significantly as yet.

## 9.0 DISCUSSION

As the analysis shows, the impact of the restriction on synthetic nitrogen fertiliser application has seen all farms reduce applications to (in most cases) well below the 190kg/ha limit. Overall, application on the Canterbury farms has fallen 31% on average (range -3% to -46%) and 41% (range -23% to -51%) for the Southland farms.

The amount of total nitrogen input into the system had also reduced, but much less due to "compensatory" inputs in the form of increased supplementary feeds and increased cropping, and in particular an increase in nitrogen fixation by clovers. Overall, total nitrogen within the system has reduced by 8% on average for the Canterbury farms, and 17% for the Southland farms.

The key differences between the two regions largely comes back to differences in the supplementary feed/cropping response; in Canterbury, the level of supplementary feed input increased (by 25%) while cropping decreased (10%) whereas for Southland the level of supplementary feed input decreased slightly (-4%) whereas cropping basically doubled (98%).

The key effect though was that nitrogen leaching decreased on average by 15% in Canterbury and 32% in Southland.

The impact on greenhouse gas emissions was somewhat mixed. For Canterbury, methane emissions increased by 3% due to higher DM intake (more supplementary feed) but dropped 2% for the Southland farms. Nitrous oxide emissions were down in both regions; Canterbury by 9% and Southland by 18%. Total biological emissions were static for Canterbury but dropped 6% in Southland.

The main management changes made by the farmers, in order to compensate for the decreased feed availability due to a lesser nitrogen fertiliser input were:

- In most of the Canterbury case study farms, the amount of supplementary feed being purchased in increased.
- For the Southland farms the main increase in feed input was via increased DM grown as forage cropping.
- Within Canterbury, average stocking rate and production per hectare has increased slightly (3% and 4% respectively) whereas for Southland both had dropped slightly (-2% and -3 % respectively).

In the discussion with farmers there was some surprise that nitrogen fertiliser applications had dropped as low as they had. In many respects this was due to a combination of the farmers coming to grips with the new regulatory regime and looking to "fine tune" their systems, as well as coping with the vagaries of climatic conditions.
There was also a concern that if the restriction was tightened, then it would directly affect the profitability of their business given nitrogen is an integral component within an irrigated system.

There was strong support for an "effect" based approach to environmental issues rather than input controls, as it gives more flexibility in addressing the issues.

## 9.1 Canterbury N Reduction

A recent report (Thompson et al 2023) shows that nitrogen leaching in Canterbury has reduced by 27.5% over the 5 years to 2021/22. This is based on an analysis of 1,269 farm records via OverseerFM.

This showed a reduction in the mean loss of 63.8 kg N/ha in 2016/17 down to 46.2 kg N/ha in 2021/22. The analysis was a statistical analysis of the Overseer data, and the drivers for this reduction were not analysed.

## 10.0 REFERENCES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| | Farm 1 | | Farm 2 | | Farm 3 | | Farm 4 | | Farm 5 | | Farm 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2020 | 2023 | 2020 | 2023 | 2020 | 2023 | 2020 | 2023 | 2020 | 2022 | 2020 | 2023 |
| Effective Area (ha) | 124 | 124 | 424.9 | 424.9 | 360 | 360 | 163.9 | 158.9 | 256 | 256 | 302.7 | 320.6 |
| Fertiliser N (kg/ha) | 224 | 160 | 186 | 181 | 276 | 173 | 209 | 162 | 197 | 141 | 346 | 186 |
| Irrigation N (kg/ha) | 8 | 8 | 9 | 7 | 9 | 9 | 9 | 11 | 9 | 9 | 12 | 11 |
| Supplement N (kg/ha) | 25 | 37 | 0 | 11 | 42 | 47 | 15 | 11 | 8 | 27 | 53 | 28 |
| Clover N (kg/ha) | 90 | 140 | 126 | 102 | 133 | 182 | 142 | 157 | 112 | 67 | 47 | 106 |
| Total N kg/ha | 347 | 345 | 321 | 301 | 460 | 411 | 375 | 341 | 326 | 244 | 458 | 331 |
| N Leach kg/ha | 49 | 51 | 35 | 31 | 30 | 30 | 52 | 46 | 28 | 20 | 44 | 20 |
| N Surplus kg/ha | 265 | 255 | 211 | 227 | 337 | 293 | 282 | 257 | 218 | 155 | 340 | 227 |
| PNS kg/ha | 168 | 108 | 110 | 117 | 195 | 101 | 131 | 89 | 133 | 84 | 282 | 111 |
| | | | | | | | | | | | | |
| Cows | 430 | 453 | 1,325 | 1,442 | 1,548 | 1,575 | 644 | 606 | 557 | 570 | 1,050 | 1,072 |
| kg MS | 160,000 | 175,537 | 471,030 | 482,572 | 695,000 | 672,141 | 227,265 | 204,567 | 235,200 | 264,675 | 533,727 | 525,079 |
| | | | | | | | | | | | | |
| Bought-in Supplement (T DM) | 132 | 229.8 | 299 | 222.8 | 650 | 716 | 230 | 149 | 145.92 | 478.6 | 997.5 | 555 |
| T DM/ha | 1.1 | 1.9 | 0.7 | 0.5 | 1.8 | 2.0 | 1.4 | 0.9 | 0.6 | 1.9 | 3.3 | 1.7 |
| T DM/cow | 0.3 | 0.5 | 0.2 | 0.2 | 0.4 | 0.5 | 0.4 | 0.2 | 0.3 | 0.8 | 1.0 | 0.5 |
| | | | | | | | | | | | | |
| Area in crops (ha) | 5.5 | 5.5 | 0 | 41.1 | 0 | 0 | 0 | 0 | 140 | 81.4 | 27.6 | 35.7 |
| Crop T DM/ farm ha | 0.9 | 0.9 | 0.0 | 2.1 | 0 | 0 | 0 | 0 | 6.8 | 3.0 | 1.0 | 1.2 |
| Gross GHG Emissions | | | | | | | | | | | | |
| Methane (kg $CO_2$e/ha) | 8,699 | 9,323 | 8,493 | 9,632 | 11,503 | 11,241 | 10,296 | 9,561 | 7,619 | 7,718 | 10,165 | 9,373 |
| Nitrous Oxide (kg $CO_2$e/ha) | 3,303 | 3,128 | 3,038 | 3,083 | 4,220 | 3,727 | 3,607 | 3,394 | 2,915 | 2,366 | 4,024 | 3,060 |
| $CO_2$ (kg/ha) | 1,744 | 1,525 | 1,357 | 1,286 | 2,288 | 2,059 | 1,898 | 1,498 | 1,706 | 1,533 | 2,995 | 2,307 |
| Total | 13,746 | 13,976 | 12,888 | 14,001 | 18,011 | 17,027 | 15,801 | 14,453 | 12,240 | 11,617 | 17,184 | 14,740 |
| Biological Emissions | | | | | | | | | | | | |
| Methane (kg $CO_2$e/ha) | 8,699 | 9,323 | 8,493 | 9,632 | 11,503 | 11,241 | 10,296 | 9,561 | 7,619 | 7,718 | 10,165 | 9,373 |
| Nitrous Oxide (kg $CO_2$e/ha) | 2,719 | 2,546 | 2,540 | 2,563 | 3,586 | 3,150 | 2,975 | 2,822 | 2,437 | 1,976 | 3,270 | 2,569 |
| Total | 11,418 | 11,869 | 11,033 | 12,195 | 15,089 | 14,391 | 13,271 | 12,383 | 10,056 | 9,694 | 13,435 | 11,942 |

| | Farm 7 | | Farm 8 | | Farm 9 | | Farm 10 | | Farm 11 | | Farm 12 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **2020** | **2023** | **2020** | **2022** | **2020** | **2023** | **2020** | **2023** | **2020** | **2023** | **2020** | **2023** |
| Effective Area (ha) | 555.2 | 525.6 | 346.9 | 346.6 | 160.2 | 160.2 | 428.2 | 208 | 173.5 | 173.5 | 151.4 | 157.4 |
| Fertiliser N (kg/ha) | 217 | 139 | 260 | 184 | 272 | 170 | 220 | 182 | 228 | 145 | 163 | 105 |
| Irrigation N (kg/ha) | 12 | 8 | 4 | 4 | 9 | 9 | 7 | 8 | 7 | 6 | 7 | 7 |
| Supplement N (kg/ha) | 38 | 69 | 47 | 54 | 35 | 42 | 57 | 103 | 42 | 43 | 33 | 74 |
| Clover N (kg/ha) | 106 | 75 | 91 | 161 | 116 | 167 | 44 | 109 | 71 | 116 | 58 | 99 |
| Total N kg/ha | 373 | 291 | 402 | 403 | 432 | 388 | 328 | 402 | 348 | 310 | 261 | 285 |
| N Leach kg/ha | 58 | 42 | 37 | 35 | 42 | 32 | 47 | 52 | 37 | 25 | 34 | 34 |
| N Surplus kg/ha | 256 | 196 | 285 | 285 | 322 | 277 | 250 | 291 | 249 | 211 | 191 | 185 |
| PNS kg/ha | 149 | 126 | 190 | 120 | 197 | 101 | 199 | 183 | 172 | 89 | 128 | 94 |
| | | | | | | | | | | | | |
| Cows | 1,496 | 1,413 | 1,250 | 1,273 | 640 | 637 | 1100 | 765 | 600 | 580 | 588 | 535 |
| kg MS | 712,339 | 671,817 | 618,064 | 625,000 | 279,000 | 281,000 | 491,542 | 321,166 | 275,000 | 277,000 | 197,368 | 246,633 |
| | | | | | | | | | | | | |
| Bought-in Supplement (T DM) | 768.9 | 1,471.6 | 990.0 | 1,098.8 | 305 | 433 | 1,268 | 1,002 | 417 | 515 | 434 | 571.4 |
| T DM/ha | 1.4 | 2.8 | 2.9 | 3.2 | 1.9 | 2.7 | 3.0 | 4.8 | 2.4 | 3.0 | 2.9 | 3.6 |
| T DM/cow | 0.5 | 1.0 | 0.8 | 0.9 | 0.5 | 0.7 | 1.2 | 1.3 | 0.7 | 0.9 | 0.7 | 1.1 |
| | | | | | | | | | | | | |
| Area in crops (ha) | 31.2 | 139.9 | 0 | 0 | 5.2 | 0 | 37.2 | 0 | 15.1 | 18.4 | 2 | 17.8 |
| Crop T DM/ farm ha | 1.1 | 3.9 | 0.0 | 0.0 | 3.2 | 0.0 | 1.3 | 0.0 | 1.2 | 0.8 | 0.3 | 2.4 |
| Gross GHG Emissions | | | | | | | | | | | | |
| Methane (kg $CO_2$e/ha) | 9,334 | 8,524 | 11,317 | 11,604 | 10,764 | 11,003 | 8,029 | 10,542 | 9,127 | 9,159 | 6,639 | 7,833 |
| Nitrous Oxide (kg $CO_2$e/ha) | 3,215 | 2,577 | 3,836 | 3,684 | 4,062 | 3,532 | 2,923 | 3,420 | 3,154 | 2,782 | 2,352 | 2,202 |
| $CO_2$ (kg/ha) | 2,062 | 2,062 | 2,416 | 2,260 | 1,895 | 1,818 | 2,484 | 2,460 | 1,841 | 1,830 | 1,671 | 2,215 |
| Total | 14,611 | 13,163 | 17,569 | 17,548 | 16,721 | 16,353 | 13,436 | 16,422 | 14,122 | 13,771 | 10,662 | 12,250 |
| Biological Emissions | | | | | | | | | | | | |
| Methane (kg $CO_2$e/ha) | 9,334 | 8,524 | 11,317 | 11,604 | 10,764 | 11,003 | 8,029 | 10,542 | 9,127 | 9,159 | 6,639 | 7,833 |
| Nitrous Oxide (kg $CO_2$e/ha) | 2,612 | 2,101 | 3,241 | 3,123 | 3,365 | 2,976 | 2,393 | 2,844 | 2,619 | 2,338 | 1,955 | 1,796 |
| Total | 11,946 | 10,625 | 14,558 | 14,727 | 14,129 | 13,979 | 10,422 | 13,386 | 11,746 | 11,497 | 8,594 | 9,629 |

| | Farm 1 | | Farm 2 | | Farm 3 | |
|---|---|---|---|---|---|---|
| | **2020** | **2023** | **2020** | **2023** | **2020** | **2023** |
| Effective Area (ha) | **250.4** | **250.4** | **250** | **250** | **469** | **469** |
| Fertiliser N (kg/ha) | 258 | 127 | 290 | 146 | 103 | 179 |
| Irrigation N (kg/ha) | 0 | 0 | 0 | 0 | 5 | 4 |
| Supplement N (kg/ha) | 52 | 32 | 78 | 60 | 74 | 106 |
| Clover N (kg/ha) | 49 | 127 | 72 | 124 | 44 | 42 |
| Total N kg/ha | 359 | 286 | 440 | 330 | 355 | 331 |
| N Leach kg/ha | 35 | 28 | 70 | 48 | 125 | 65 |
| N Surplus kg/ha | 263 | 198 | 328 | 226 | 262 | 210 |
| PNS kg/ha | 215 | 72 | 256 | 102 | 220 | 179 |
| | | | | | | |
| Cows | 827 | 807 | 859 | 817 | 1,100 | 1,130 |
| kg MS | 373,935 | 341,860 | 419,640 | 391,463 | 550,339 | 611,072 |
| | | | | | | |
| Bought-in Supplement (T DM) | 727 | 444 | 937 | 720 | 1,635 | 2,152 |
| T DM/ha | 2.9 | 1.8 | 3.7 | 2.9 | 3.5 | 4.6 |
| T DM/cow | 0.9 | 0.6 | 1.1 | 0.9 | 1.5 | 1.9 |
| | | | | | | |
| Area in crops (ha) | 3.6 | 3.6 | 4.3 | 10.4 | 173 | 140 |
| Crop T DM/ farm ha | 90.0 | 90.0 | 43.0 | 174.0 | 3.3 | 4.2 |
| Gross GHG Emissions | | | | | | |
| Methane (kg CO2e/ha) | 9,178 | 8,789 | 10,435 | 9,932 | 8152 | 8394 |
| Nitrous Oxide (kg CO2e/ha) | 3,082 | 2,604 | 3,812 | 2,974 | 3106 | 2540 |
| $CO_2$ (kg/ha) | 2,358 | 1,450 | 2,637 | 1,812 | 2659 | 2924 |
| Total | 14,618 | 12,843 | 16,884 | 14,718 | 13,917 | 13,858 |
| Biological Emissions | | | | | | |
| Methane (kg $CO_2$e/ha) | 9,178 | 8,789 | 10,435 | 9,932 | 8152 | 8394 |
| Nitrous Oxide (kg $CO_2$e/ha) | 2,618 | 2,196 | 3,132 | 2,428 | 2359 | 2000 |
| Total | 11,796 | 10,985 | 13,567 | 12,360 | 10,511 | 10,394 |

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