THE CONTEXT AND PRACTICE OF NUTRIENT MITIGATION ON ROTORUA DAIRY FARMS

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Abstract

Dairy farmers in the Lake Rotorua catchment have been involved with multiple initiatives to manage nutrient losses to water since the early 2000s. These have included:

- Rule 11 which capped nitrogen (N) and phosphorus (P) losses at 2001-2004 levels, and its subsequent implementation via farm-based Overseer assessments
- Setting a sustainable catchment nitrogen load limit of 435 tonnes via changes to the Regional Policy Statement, associated Environment Court appeals and their resolution
- Economic studies e.g. Rotorua Nitrogen Discharge Allowance (NDA) Impacts
- Two Sustainable Farming Fund Projects, including the current SFF11-023 project titled "Meeting nutrient loss targets on dairy farms in the Lake Rotorua catchment".

The current policy context for Rotorua farmers is dominated by the collaborative development of new N rules, incentives scheme and advisory services. While several farmers are actively involved in the policy process, they generally remain concerned at the complexity, extended development, uncertainty, potential costs and the scientific validity/necessity of large N leaching reductions. The latter concern is exacerbated by Lake Rotorua actually meeting its water quality target for the last three years due to ongoing alum dosing in two streams which limits in-lake P and (consequently) algal growth. The Regional Council anticipates that new N rules will be notified by mid-2015.

The magnitude of current N losses from Rotorua dairy farms, and changes since 2001-04, were assessed within SFF11-023 using Overseer 6.1.3. The 13 surveyed dairy farms had an average 27% productivity increase while total N leaching reduced by 12% i.e. improved N use efficiency. Key farm management changes were reduced cropping area, reduced N fertiliser use and increased imported feed.

As part of SFF11-023, a farm grazing trial was set up in 2012 on the Parekarangi Trust dairy farm to evaluate effects of reduction in N fertiliser use. Results over the past two winter drainage periods have shown significantly lower N leaching rates on the nil N fertiliser treatments relative to standard N (140-160 kgN/ha/yr), albeit with large differences between years.

There has been no deterioration in grass species when N fertiliser was withheld over 2 years and monitoring will continue for another year. Farmers have stated that they want to see both pasture composition and N leaching results over a longer period.

Background

Dairy and drystock farmers in the Lake Rotorua catchment have been the focus of multiple efforts to quantify and manage contaminant losses for several decades, all aiming to protect lake water quality. The broader soil conservation objectives of the Upper Kaituna Catchment Control Scheme extend back to the 1970s. In 2005 "Rule 11" was introduced to cap nitrogen and phosphorus losses at 2001-2004 levels, based on individual farm Overseer assessments (see Park and McCormick, 2009). Rule 11 was accompanied by a lake water quality target expressed as a Trophic Lake Index (TLI) value of 4.2, corresponding to 1960s water quality (Burns et al, 2000; BOPRC 2008).

In 2010 Bay of Plenty Regional Council set a "sustainable annual nitrogen lake load" of 435 tonnes (tN/yr) via the now operative Regional Policy Statement (BOPRC, 2014). Following Environment Court proceedings in 2012, the target deadline was extended 10 years to 2032. Catchment modelling by NIWA (Rutherford et al., 2011) indicated the steady state load to the lake, based on current land use, was 755 tN/yr. Therefore a reduction of 320 tN/yr is needed to achieve the 2032 target of 435 tN/yr[1].

Due to the modest scope for engineering mitigations (~50 tN/yr), a 270 tN/yr reduction is sought from pastoral farming. This represents a 50% reduction from status quo farm N leaching losses and the RPS plainly signalled this would be achieved primarily through new rules. However, negotiations with central Government resulted in a supporting $40 million incentive fund, shared 50:50 between tax and ratepayers.

Dairy and other farmers organised themselves into the Lake Rotorua Primary Producers Collective (the "Collective") in 2011. The Collective engaged with BOPRC and others via the collaborative Stakeholder Advisory Group to inform the evolving "rules and incentives" package. A key outcome of the Stakeholder Advisory Group process was an "Integrated Framework" (StAG, 2013) which shared the 270 tN/yr nitrogen reduction as follows:

- 140 tN/yr – rules with Nitrogen Discharge Allowances (NDA) applied to each property, to be met by 2032[2] (see http://www.rotorualakes.co.nz/Draft_rules for more)
- 100 tN/yr – Incentives Fund, for reductions below NDA levels, to be met by 2022.
- 30 tN/yr – Gorse conversion fund, to be met by 2022, with separate BORPC funding.

While the recent policy development has focused on reducing pastoral N losses, the scientific consensus is that the lake was historically co-limited by N and P. Therefore BOPRC initiated continuous alum dosing via two Rotorua streams. This has dramatically lowered in-lake P concentrations and reduced lake sediment P release. The lake has met its TLI 4.2 target since 2012. However, funding and consents for the dosing expire in 2019 (BOPRC, 2013b).

Some key Lake Rotorua catchment facts:

- The groundwater catchment is ~46,700 ha, with ~42,300 ha in the surface catchment
- There are ~5000 ha of dairy (milking platform); ~17,000 dry stock (including dairy support and "lifestyle"); ~8900 ha forestry; ~7000 ha native bush and scrub
- Annual rainfall varies from 1300 mm to 2500 mm
- Free-draining soils dominate, with pumice, podzol, pumice ash and recent soils.

[1] Although the 435 tN/yr target refers to 2032, catchment groundwater lags mean it will be several decades before actual lake N inputs decline to this level i.e. the target effectively applies at the root-zone.

[2] The 435 tN/yr and 140 tN/yr values are in-lake targets. Due to attenuation, the 140 tN/yr equates to about 200 tN/yr at the root-zone, as estimated by Overseer version 6.1.3

SFF Project Overview

A key early initiative of the farmers' Collective was initiating the SFF project that is the main subject of this paper. The project "Meeting nutrient loss targets on dairy farms in the Lake Rotorua catchment" is supported by MPI, BOPRC, DairyNZ and Ballance Agri-Nutrients (see Kingi et al., 2012 for more project detail).

The three project components are:

(i) Field trials at the Parekarangi Trust monitor farm to measure biophysical responses to low and nil N fertiliser inputs. There is a separate GIS exercise to identify Critical Source Areas (CSAs), linked to the MitAgator project (Stafford and Peyroux, 2013).

(ii) Modelling farm systems in Overseer and Farmax to explore potential farm system and management changes and their impact on farm profitability and nutrient loss.

(iii) Establish discussion groups within the catchment.

The project started in July 2011 and is due to finish in March 2015, thus allowing three years of data collection, analysis and extension.

A critical context point is that when the SFF project started, there were no specific nutrient reduction targets in place. Although the catchment policy framework has evolved (as described in the Background above), individual farm NDA levels are still not defined[3].

Parekarangi Trust Farm Field Trials

The Parekarangi Trust Farm is a 665 hectare farm situated approximately 10 kilometres south of Rotorua. It has a 246 hectare dry stock unit and a 355 hectare dairy unit milking over 1,000 cows with production (2012) of 1,057 kgMS/ha. On the dairy unit, a feed-pad is used with some brought-in pasture silage and palm kernel expeller. About 80% of the cows are grazed off for eight weeks over winter. The farm is of rolling contour, receives about 1,550 mm rainfall/year and the main soil is Taupo pumice (see Collective 2015 for more background).

The two field trials at Parekarangi are designed to assess different N fertiliser rates and the impacts on pasture response, pasture composition and N leaching. The methodology and results below are an update on previously published interim results (Park et al., 2014).

Trial Methodology

The **plot trial** has nine replicates of three urea N fertiliser treatments: no fertiliser N, strategic application of N in autumn and spring, and N applied regularly as per current Parekarangi farm practice. Pasture production was measured by rising plate meter pre- and post-grazing. Pasture species composition was determined in spring and autumn.

The **farm system trial** started April 2012. It has two fertiliser treatments of current N and nil N, using a 6 x 2 paired paddock set-up. Stock access to the paired paddocks is managed to simulate a farmlet trial, including limiting stock pasture intake prior to grazing and cows going through a nil-N lead-in paddock before grazing the nil N paddocks. Each of the 12 paddocks has 25 ceramic suction cup samplers at 600mm depth i.e. 300 samplers in total. In addition to pasture production/composition measurements, pasture N content and N leaching is measured plus rainfall and soil/air temperature.

[3] The NDA allocation debate has been contentious. Although BOPRC intends to notify new regional plan rules and NDA limits by June 2015, it may take some time before rules become fully operative.

Field Trial Results and Discussion

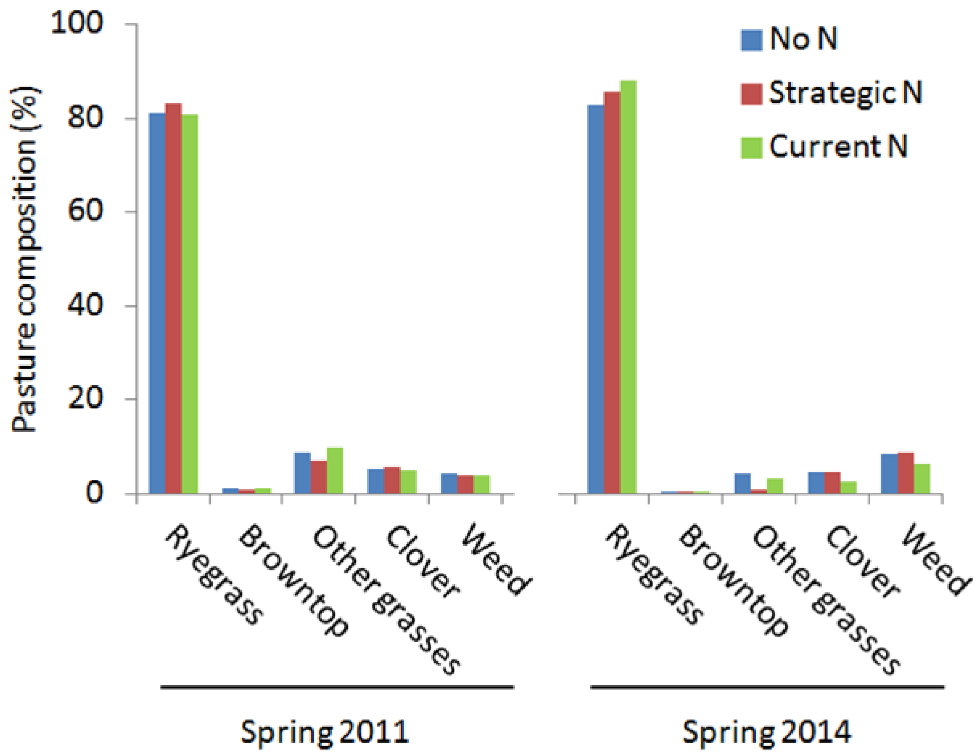
The **plot trial** results are summarised in Table 1 and Figure 1 below.

Table 1: Plot trial pasture production from August 2012 to July 2014

	Aug 2012 – July 2013			**Aug 2013 – July 2014**		
Treatment	nil-N	strategic-N	regular-N	nil-N	strategic-N	regular-N
Annual fert N applied, kg/ha	0	67	176	0	70	186
Annual pasture production, t DM/ha	10.6	11.0	11.7	10.6	11.0	11.7
N response, kg DM/kg N applied		7.1	6.7		14.3	8.2

The pasture response to applied N fertiliser was low in the year to July 2013, probably due to the major summer-autumn drought in early 2013. The response was closer to industry norms (DairyNZ, 2008) in the year to July 2014, with the "strategic-N" treatment (urea at 70 kgN/ha) giving the highest response at 14.3 kgDM/kgN urea applied.

Figure 1: Plot trial Spring pasture composition from 2011 to 2014



At the outset of the trials, Rotorua dairy farmers flagged their concerns about maintaining pasture quality with little or no fertiliser N inputs. The results shown in Figure 1 indicate no adverse trend towards lower fertiliser species after three years. While the overall clover contents are low (5-6%), this is partly due to sampling in spring and not summer when clover is more prevalent.

The pasture plots are set out in an adjacent grid pattern and therefore dung and urine fertility transfers between plots is inevitable. This is likely to have muted differences between treatments.

The **farm system trial** results for the second and third years are summarised in Figures 2 and 3 below, respectively summarising N leaching and the associated drainage pattern. The farm systems pasture response to N fertiliser is shown in Table 2. Please note that the first year (May to December 2012, as reported in Park et al., 2014) was both incomplete and essentially a settling-in period, and therefore deemed to be of limited value.

Table 2: Farm system trial pasture production from May 2012 to April 2014

	May 2012 – April 2013		**May 2013 – April 2014**	
Treatment	nil-N	plus-N	nil-N	plus-N
Annual fert N applied, kg/ha	0	163	0	142
Annual pasture production, t DM/ha	6.6*	7.7*	12.6	14.7
Additional DM, kg/ha/yr		1080		2100
N response, kg DM/kg N applied		6.6		14.8

*just under 12 months

As with the plot trial, pasture production was low in both treatments for the year ending April 2013 due to drought, with consequent impacts on pasture response rates to fertiliser N.

Figure 2: Farm systems nitrate-N leached 2013 and 2014

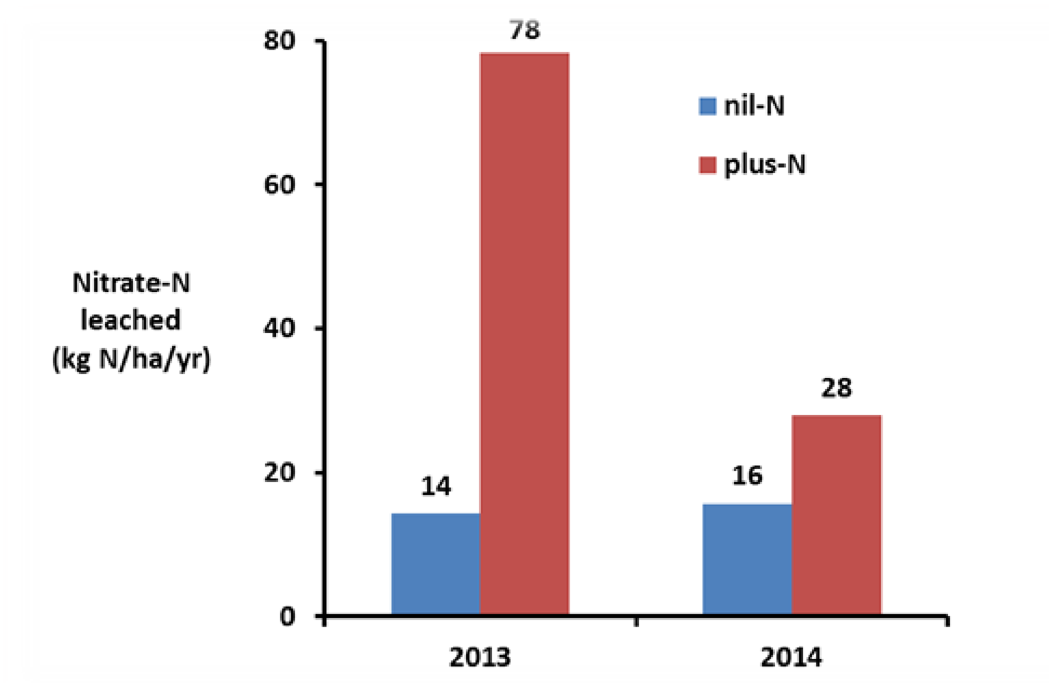


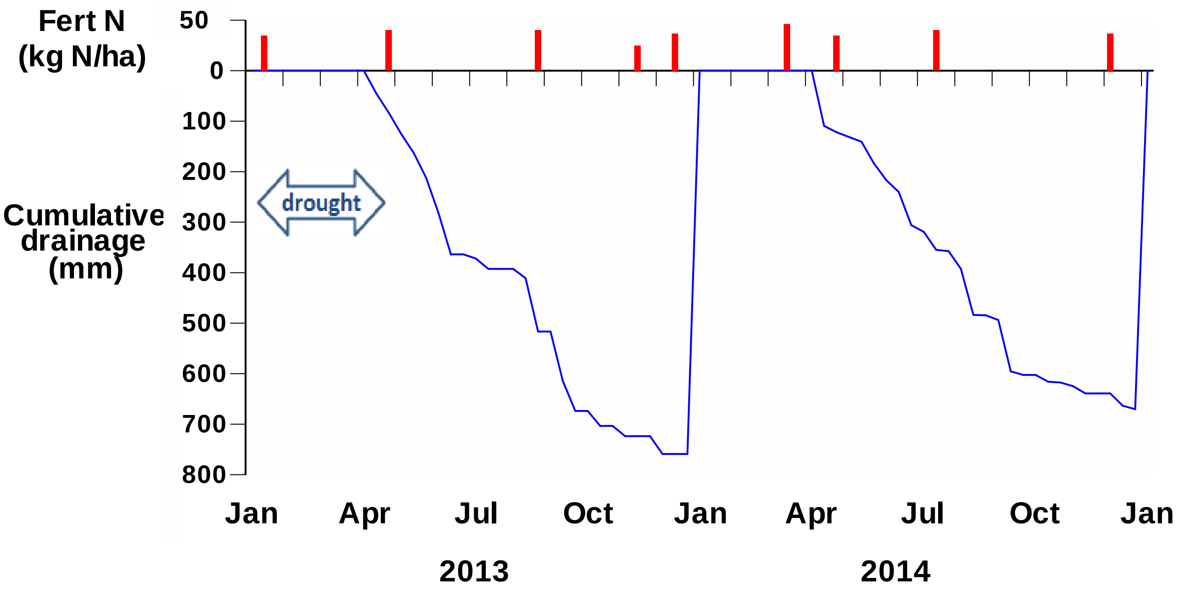
Figure 2 shows that the plus-N treatment nitrate-N leaching in 2013 (Jan-Dec) was 78 kgN/ha/yr, more than five-fold greater than for the nil-N treatment. The difference reduced to an approximately two-fold difference in 2014, more typical of comparable N leaching studies (e.g. Ledgard et al., 2006). The large variability in plus-N nitrate-N leaching between 2013 and 2014 is apparent and some explanation is suggested in Figure 3 below where two factors probably contributed:

- The 2013 summer-autumn drought allowed nitrate-N to accumulate in the soil profile (including that from summer N fertiliser use) with little plant uptake and no leaching until major drainage (>300mm) occurred in April/May 2013
- The urea application in late April 2013 was quickly followed by heavy rain and soil drainage, probably leading to some direct urea-N leaching.

In addition to these trial-specific factors, there are two mechanisms which typically drive higher N leaching with increasing N fertiliser use:

- Extra pasture growth and higher total cow N intake and urine-N excretion
- N-boosted pasture has a higher percentage of N (3.5% N cf 3.0% for nil-N) and most or all of this extra plant-N goes to urine-N.

Figure 3: Cumulative soil drainage in farm system trial 2013 to 2014



The farm system trial pasture composition analysis was similar to the plot trial results shown in Figure 1 with one minor exception. The nil-N treatment had more Browntop than the plus-N treatment in both years due to one nil-N replicate having a higher Browntop composition from the start of the trial.

Modelling Rotorua dairy farm changes in N loss since 2001-2004

Rationale and Methodology

The SFF project's farm modelling component has evolved through several "what-if" analyses (e.g. Park et al., 2014) and related projects led by Perrin Ag, notably the "Rotorua NDA Impact Analysis" (Perrin Ag, 2014). This work cumulatively covered 15 dairy farms and was carried out separately from the prior Rule 11 assessments covering the 2001-2004 period.

Rotorua dairy farmers, policy makers and the Lake Rotorua Stakeholder Advisory Group wanted to know what changes, if any, had occurred since 2001-2004. This would help inform the setting of 2032 NDAs and any interim N reduction targets. This comparative analysis was possible due to mutual trust and data access developed through the SFF and related projects.

The available recent dairy farm Overseer files and their corresponding 2001-2004 files were all converted to Overseer version 6.1.3. N losses were adjusted to reflect the groundwater catchment boundary[4]. Initial filtering showed that 13 valid farm comparisons could be made out of the 15 farm file sets available. This comprised about 60% of the total dairy land in the catchment. The recent farm data including files for the year ending June 2012 and June 2013. The Overseer files were then reviewed to identify any common reasons for changes in N loss.

Modelling results and discussion

The main modelling results are shown in Table 3 below in aggregate form, with some accompanying comments.

Table 3: Aggregate modelled N leaching changes from 2001 to 2012-2013

	2001-2004	2012 or 2013*	Change	Comment
Total area, ha	2734	2612	down 4%	Due to disaggregation of some farm units, not "land use change"
Total cows	7300	7300	no change	A large increase in productivity from essentially the same area and number of cows
Total kg MS	2,100,000	2,700,000	up 27%	
Average kg MS/cow	287	365	up 27%	
Total N loss, tN	204	180	down 12%	Reduction in N leaching while production increased
N leached, kgN/ha/yr	75	69	down 8%	

*All years shown end 30 June

The reasons for decreased N leaching while simultaneously increasing dairy production include:

- The effective area has decreased 4%
- The area in forage crop has reduced from 6% of the total area farmed to 4% (56 ha less). Given forage crops such as winter brassica can leach up to four times that from "average" dairy pasture N losses, this may account for up 65% of the assessed N loss reduction.
- Average N fertiliser application has dropped from 142 to 117 kgN/ha/yr.
- More maize silage and PKE was imported to offset reduced forage cropping / N use

Overall, N use efficiency appears to have increased across most dairy farms analysed. A key driver for this improvement is considered to be farmers reducing costs, rather than an explicit environmental concern about N leaching levels. This improvement is arguably due to farmers selecting some "low-hanging fruit" N mitigation options, including those in the bulleted list above. The draft NDAs for dairy farms represent an average 35% reduction from the Rule 11 baseline, possibly around 47 kgN/ha/yr (Overseer 6.1.3 values), although a NDA range

[4] Several farms straddle the catchment boundary but only the portion within the catchment is subject to the current NDA policy process.

straddling this figure is possible. It is likely that the marginal cost of further N mitigation effort will rise significantly as farmers approach their respective NDAs.

Final field day and farmer feedback

The trial results above were presented at the final SFF project field day held at Parekarangi on 3rd March 2015. The field trial results were accompanied by a Farmax analysis indicating that a comparable farm-scale nil-N policy would reduce operating profit (EBIT) from the status quo $2,093/ha to $1,711/ha or $1,877/ha. This analysis was based on a milk payout of $6.50 and N fertiliser cost of $1.60/kgN applied and maize cost of 35c/kg DM. The larger EBIT reduction (-$382/ha) was associated with using substantial maize silage imports to maintain status quo production. In contrast, there was a smaller EBIT reduction relative to status quo (-$216/ha) by allowing production to fall, using low levels of maize silage and taking advantage of lower farm costs.

Farmer feedback at the field day included:

- Caution is needed on using imported maize given the higher N loss signature from land where maize is grown i.e. a farmer reluctance to transfer the problem to another catchment
- A desire to see field trials continue in order to:
    - confirm pasture quality persistence under nil/low N fertiliser regimes
    - address the large variability in N leaching across years.
- Greater extension efforts are needed to reach a larger set of catchment farmers.

Although the SFF project is ending, BOPRC and DairyNZ have agreed to fund an additional 12 months of field work. This is expected to produce a field data set suitable for validation and/or calibration of Overseer for local Rotorua conditions.

Conclusions

The Rotorua dairy SFF project has coincided with a period of substantial nitrogen policy development and uncertainty in the Lake Rotorua catchment. Dairy farmers have been engaged with the project through a series of discussion groups and farm field days. A partly overlapping set of dairy farmers have also been engaged with the Stakeholder Advisory Group and the farmers' Collective leadership team.

It is acknowledged that many dairy (and other) farmers are waiting to see what specific NDA limits are proposed for their individual farms in the new rules. This wait-and-see approach is reinforced by the unexpected success of the alum dosing which has "fixed" Lake Rotorua's water quality, at least in the short-term. Meanwhile, there is some reassurance that recent efforts by dairy farmers to reduce costs and improve productivity have also reduced average N leaching rates by about 8% per effective hectare.

The draft NDA levels for dairy farms still represent a substantial challenge to farmers collectively and individually. BOPRC is anticipating the need for individually tailored advice and has recently established an "Advice and Support" service (BOPRC, 2015). It is likely that dairy farmers will look for a range of proven N mitigation methods to meet their NDAs while minimising impacts on farm profitability. The SFF project has provided some answers but will need to be followed up with an ongoing applied research and extension effort.

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