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Meeting nutrient loss targets on dairy farms in the Lake Rotorua catchment:

Final report on Sustainable Farming Fund Project 11/023

RE500/2013/057

March 2015

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Meeting nutrient loss targets on dairy farms in the Lake Rotorua catchment

Final report on Sustainable Farming Fund Project 11/023

Report prepared for:

- Ministry for Primary Industries
- Bay of Plenty Regional Council
- DairyNZ
- Ballance Agri-Nutrients
- Lake Rotorua Primary Producers Collective

March 2015

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1. Summary

Dairy farmers in the Lake Rotorua catchment will need to make large reductions in farm nitrogen (N) leaching losses to meet the annual catchment target of 435 tonnes N by 2032. Dairy farmers initiated a Sustainable Farming Fund Project in 2011 to promote the adoption of N mitigation methods using three strands of work: (i) farm trials of differential N fertiliser rates, (ii) farm system modelling and (iii) farmer engagement. These three strands of work were led respectively by AgResearch, Perrin Ag Consultants and DairyNZ. This final project report summarises the main results from each strand.

Farm trials:

The impacts of different N fertiliser rates were assessed in two trials that ran in parallel for approximately three years on the Parekarangi Trust dairy farm south of Rotorua. A **pasture plot trial** compared nil, strategic (~60 kgN/ha/yr) and regular (~160 kgN/ha/yr) urea fertiliser applications to grazed dairy pasture. The average annual responses to N fertiliser were 6-14 and 7-8 kg DM/kg N applied for the strategic and regular N treatments, respectively. There was no significant treatment differences in pasture composition from first sampling in August 2011 to the final sampling in February 2014.

The **farm system trial** at Parekarangi compared nil-N and plus-N (~140-160 kgN/ha/yr) fertiliser application to grazed dairy pasture on twelve paired paddocks. Grazing was managed to simulate a "farmlet" trial system. In addition to regular pasture production and composition monitoring, the farm system trial measured pasture N content and N leaching (latter via 300 suction cup samplers). The first year (2012) proved to be a "settling-in" period with treatment differences developing in 2013 and 2014 (denoted as years 1 and 2). The farm system pasture production response to applied N varied greatly between years 1 and 2 from ~7 to ~15 kg DM/kg N applied (respectively). As in the plot trial, there were no significant trends in pasture composition. N leaching was significantly greater in the plus-N treatment, being five-fold and two-fold more than the nil-N treatment in years 1 and 2. The significant leaching and pasture response differences between years 1 and 2 in the plus-N treatment was probably due to a combination of drought in year 1, accumulated soil nitrate-N levels and some direct fertiliser N leaching when >200mm autumn drainage occurred shortly after urea application.

Some practical implications from this on-farm research are:

1. Strategic N fertiliser use in late-winter/spring, rather than regular applications, could achieve good pasture growth responses and reduced N leaching risk.

2. Where the use of N fertiliser is reduced or ceased, pasture management in spring should target good control of pasture covers to avoid clover shading by grasses and encourage increased clover N fixation, with reduced browntop ingress.
3. N fertiliser can provide useful increases in pasture growth at relatively low cost but it is of low farm N efficiency and can lead to significant increases in N leaching. Thus, reducing or ceasing N fertiliser use and replacing it with a low-protein feed source (from outside the catchment) can significantly decrease N leaching from farms.
4. The coarse texture of the pumice soils (with associated limited water holding capacity) and relatively high rainfall (including risk of heavy rainfall events) mean that care is needed in timing of N fertiliser application. It also means that using lower rates more often will reduce risk of direct fertiliser-N leaching.

Farm modelling:
Three dairy farms were initially modelled in Overseer and Farmax for status quo and future mitigated scenarios, based on each farmer's perspective on what mitigation practices they could adopt. This analysis was expanded to other dairy farms through related projects funded by Bay of Plenty Regional Council. The cost-effectiveness of a wide range of on-farm mitigations were assessed in terms of "capitalised" cost ($/kgN mitigated) and annual profit impact ($/ha). Capitalised N mitigation costs ranged from just under $100/kgN (e.g. substituting N boosted pasture with bought-in maize silage) to over $700/kgN (partial conversion of pasture to pines). Access to Overseer files of historic N losses (2001-2004) enabled a comparison with current losses (generally 2012-2013) for 13 dairy farms, representing ~54% of dairy land use in the catchment. This comparison over approximately 10 years showed that while productivity per hectare had increased by 27%, N leaching losses had decreased by 8% per hectare.

Farmer engagement:
A series of farm discussion groups and four field days have been run during the project. Farmer participation has varied during the project and it is too early to determine what level of practice change has occurred on-farm. Rural professionals have been regular attendees. Recurring messages from Rotorua dairy farmers include the need for: (i) practical, local and long-term farm trials; (ii) cost-effectiveness modelling of N mitigation options, both singly and in combination across a farm system; (iii) certainty around Council policy in order to understand their individual farm constraint.

The anticipated new N rules and individual farm "Nitrogen Discharge Allowances" are still being developed (as of March 2015). This uncertainty made it more difficult to engage the catchment dairy farmers. However, the leading catchment dairy farmers have been closely involved in influencing policy through the Stakeholder Advisory Group where project and related presentations have helped ground the policy debate.

2. Introduction

Dairy farming in the Lake Rotorua catchment is a significant contributor to nutrients entering the lake. The Bay of Plenty Regional Council (BOPRC), in its Regional Policy Statement (RPS), has established nutrient reduction targets that require farmers to reduce inputs to Lake Rotorua by 270 tonnes of nitrogen (N) per year by 2032. Dairy farms have been estimated to contribute approximately half of the current nitrogen load from all farm sources. The Lake Rotorua Primary Producers Collective (the “Collective”) was established in 2011 to protect farmer interests and investigate sustainable solutions. The Collective’s SFF project, “Meeting nutrient loss targets on dairy farms in the Lake Rotorua catchment”, aims to provide: (i) field data on current nutrient losses and strategies to reduce these; (ii) farm system modelling showing mitigation costs; and (iii) engagement with dairy farmers on potential solutions (Kingi et al., 2012). This report addresses these three strands of work in Sections 2, 3 and 4 below.

3. Parekarangi field research

AgResearch established field trials on the Parekarangi Trust farm, approximately eight kilometres south of Rotorua. The Parekarangi Trust dairy farm is 352 ha (effective area) carrying approximately 2.7 cows/ha and producing approximately 800 kg milksolids/ha/year (in 2009/2010). A feed-pad is used with some brought-in pasture silage and palm kernel expeller and one-third of the cows are grazed off for two months in winter. The farm is of rolling contour and the main soil series is a Haparangi soil from Taupo pumice. There is also a small area of Ngakuru soil from Taupo Tephra.

Two main field research studies were carried out on the Parekarangi Trust dairy farm to evaluate the effects of reducing or ceasing use of N fertiliser. This was in response to local dairy farmers identifying reduced N use impacts as a key concern in meeting anticipated tough on-farm N leaching targets. One study was a pasture plot trial within one of the paddocks on the farm and the other was a farm system trial.

3.1 Plot trial

The plot trial was established following grazing in August 2011, with three N fertiliser treatments:

1. Regular – with regular N fertiliser use corresponding with farm practice
2. Strategic – two tactical applications of N fertiliser in early-spring and autumn
3. Nil – no N fertiliser applied.

The treatments were replicated nine times, giving a total of 27 plots, each 275 m^2 in area. The total annual amounts of N fertiliser applied are shown in Table 1, with the regular N plots receiving N fertiliser at the same time and rate as the rest of the farm for areas not receiving effluent and used for silage production.

Grazing management followed standard farm practice and cows were able to move freely between plots. Rising plate meter readings (approximately 80 per plot) taken before and after grazing were used to estimate pasture growth. Pasture samples from all plots were collected for analysis of botanical composition in spring and autumn (except in autumn 2013 when the prevailing drought conditions caused short-term changes in species abundance).

Table 1: Timing and rates of N fertiliser application (kg N/ha) in the plot trial.

	Treatment	
Date	**Standard N**	**Strategic N**
August 2011	46	46
September 2011	46	
October 2011	26	
December 2011	37	
February 2012	46	
March 2012	37	
April 2012	28	30
Year 1 total	**265**	**76**
August 2012	43	
September 2012	37	37
November 2012	21	
January 2013	35	
April 2013	40	30
Year 2 total	**176**	**67**
August 2013	40	
September 2013	37	37
November 2013	25	
March 2014	46	
April 2014	35	30
July 2014	40	
Year 3 total	**186**	**70**

3.2 Farm system trial

The farm system trial commenced in April 2012. The trial consisted of six paired paddocks. One paddock in each pair received N fertiliser applications at the same time and rate as the rest of the farm (Plus-N), while the other received no N fertiliser (Nil-N). To prevent any fertility transfer from paddocks receiving N fertiliser to nil-N paddocks, the cows grazing the nil-N paddocks grazed a lead in paddock, which received no N fertiliser, before moving through to the nil-N treatment paddocks. The timing and rates of N fertiliser application are given in Table 2.

Table 2: Timing and rates of N fertiliser application on farm system trial.

Year 1		**Year 2**		**Year 3**	
Apr2012-Mar2013	kg N/ha	Apr2013–Mar2014	kg N/ha	Apr2014–Dec2014	kg N/ha
April	30	April/May	40	April	35
August	43	August/Sept	40	August	40
September	37	November	25		
November	21	December	37	December	37
January	35				
Annual total	**166**	**Annual total**	**142**	**Total (Apr-Dec)**	**112**

Rising plate meter readings were taken before and after grazing to estimate pasture growth. Grazing management and N fertiliser application followed standard farm practice and both sets of nil-N and plus-N treatment paddocks were grazed as closely together as possible. In all years, pasture samples were collected in late-winter/early-spring and late-summer and analysed for botanical composition. Sub-samples of pasture were analysed colourmetrically for total-N concentration after Kjeldahl digestion.

In April 2012, 25 porous ceramic cup soil moisture collectors were installed in each treatment paddock at a depth of 60 cm, i.e. 300 samplers in total. After an average of approximately every 50 mm of drainage in 2012 and every 75 mm of drainage in 2013 and 2014, a sample of leachate from the 60 cm depth was collected from each ceramic cup. The samples of leachate were frozen at -20°C and subsequently analysed for ammonium-N and nitrate-N (including nitrite-N) colourmetrically using a Skalar SAN++ segmented auto flow analyser (Skalar Analytical B.V., Breda, Netherlands).

Drainage was estimated using a water balance model (Woodward et. al. 2001) using farm soil characteristics. Daily rainfall was measured on the farm while temperature and solar radiation data were obtained from the NIWA Rotorua airport meteorological station. The amount of nitrate-N (and ammonium-N) leached below 60 cm depth was calculated by multiplying the nitrate-N concentration by its associated drainage.

All pasture and leachate data were statistically analysed using Analysis of variance (ANOVA) using the GenStat (13th Edition, version 13.2.0.4682) statistical programme. Results were summarised and treatment effects compared using Least Significant Difference (LSD) values at 5% significance (i.e. $p<0.05$).

3.3 Plot trial results

The regular N treatment produced significantly (p<0.01) more pasture production than the control nil-N treatment in all three years of the trial, equating to an annual increase of 11-19% or 1.1-2.0 t DM/ha/year (Table 3). The strategic N treatment produced significantly more growth immediately following fertiliser N application but on an annual basis it was not significantly different to the nil-N treatment. The average annual responses to N fertiliser were 6-14 and 7-8 kg DM/kg N applied for the strategic and regular N treatments, respectively.

There was no significant difference between any of the treatments in pasture botanical composition when sampled at the start of the trial in August 2011 and at the final sampling in February 2014 (Table 4).

Table 3: Plot trial pasture production as affected by N fertiliser application over three years. LSD = Least Significant Difference at p<0.05.

Year 1 (Aug 2011-Aug 2012)	**Nil-N**	**Strategic N**	**Regular N**	**LSD**
Annual pasture production (t DM/ha)[1]	10.66	11.09	12.68	0.94
N response (%)		4.1	18.9	
Additional DM (kg/ha)		432	2015	
Annual fertiliser N applied (kg/ha)		76	265	
N response (kg DM/kg N)		5.7	7.6	

Year 2 (Sept 2012-Aug 2013)	**Nil-N**	**Strategic N**	**Regular N**	**LSD**
Annual pasture production (t DM/ha)[1]	10.56	11.03	11.73	0.68
N response (%)		4.5	11.1	
Additional DM (kg/ha)		476	1176	
Annual fertiliser N applied (kg/ha)		67	176	
N response (kg DM/kg N)		7.1	6.7	

Year 3 (Sept 2013-Aug 2014)	**Nil-N**	**Strategic N**	**Regular N**	**LSD**
Annual pasture production (t DM/ha)[1]	9.51	10.51	11.03	1.00
N response (%)		10.5	16.0	
Additional DM (kg/ha)		999	1517	
Annual fertiliser N applied (kg/ha)		70	186	
N response (kg DM/kg N)		14.3	8.2	

[1] Pasture growth figures have not been adjusted to account for growth that occurred in the interval between the pre- and post-grazing plating measurements.

Table 4: Summary of botanical composition of pasture (% dry matter) at the initial late-winter sampling (August 2011) and final late-summer sampling (February 2014). LSD = Least Significant Difference at p<0.05.

	Ryegrass		**Browntop**		**Other**		**Legume**		**Weed**	
Treatments	2011	2014	2011	2014	2011	2014	2011	2014	2011	2014
Nil-N	85	52	<1	<1	6	9	5	22	4	17
Strategic N	86	60	<1	1	6	6	4	19	3	14
Regular N	84	49	1	2	7	13	4	21	4	15
LSD	4.2	15	0.8	2	3.4	11	2.6	9	2.7	9

3.4 Farm system trial results

3.4.1 Pasture N response

Nitrogen fertiliser increased pasture production by 14-17% across all three years (Table 5), although only the year two increase was statistically significant (p<0.01). In year 1, pasture production was measured over a slightly shorter period than 12 months and additionally the values in Table 5 have not been adjusted to account for pasture growth between the periods of measurement of the pre- and post-grazing plating measurements. Adjustment for the latter would increase the estimated pasture production and N response by approximately 10%. The amount of extra pasture grown with N fertiliser use varied between 1.1 and 2.1 t DM/ha/year. Response to N fertiliser per unit of N fertiliser applied varied greatly between years from 6.6 to 14.8 in years 1 and 2, respectively.

The total-N concentration in the pasture followed a similar trend, with higher N concentrations in the pasture receiving regular N fertiliser applications in all years. This result was was statistically significant (p<0.05) in the last two years (Table 6).

The ryegrass content of the pasture in the nil-N paddocks was initially similar for both treatments but tended to be lower for the nil-N paddocks at subsequent samplings, although it was not statistically significant (Figure 1A). There was no significant change in browntop content between plus-N and nil-N paddocks over the course of the study. One paddock in the nil-N treatment had a relatively high percentage browntop from the start of the study, which gave an apparent higher overall level in the nil-N treatment, but this was unchanged over time (Figure 1B). There were no clear trends over time in pasture composition for other grasses, clover and weeds (Figures 1C-1E).

Table 5: Pasture growth in the grazing trial comparing nil and regular N fertiliser use on the Parekarangi farm between autumn 2012 and autumn 2014. LSD = Least Significant Difference at $p<0.05$.

Year 1 (May 2012-March 2013)[1]	**Nil-N**	**Regular N**	**LSD**
Annual pasture production (t DM/ha)[2]	6.61	7.69	1.77
N response (%)		16.4	
Additional DM (kg/ha)		1081	
Annual fertiliser N applied (kg/ha)		163	
N response (kg DM/kg N)		6.6	
Year 2 (April 2013 – March 2014)	**Nil-N**	**Plus-N**	**LSD**
Annual pasture production (t DM/ha)	12.64	14.74	1.35
N response (%)		16.6	
Additional DM (kg/ha)		2099	
Annual fertiliser N applied (kg/ha)		142	
N response (kg DM/kg N)		14.8	
Year 3 (April 2014 – January 2015)	**Nil-N**	**Plus-N**	**LSD**
Pasture production (t DM/ha)	8.44	9.63	1.47
N response (%)		14.1	
Additional DM (kg/ha)		1193	
Annual fertiliser N applied (kg/ha)		112	
N response (kg DM/kg N)		10.7	

[1] Just under 12 months; [2] Pasture growth figures have not been adjusted to account for growth that occurred in the interval between the pre- and post-grazing plating measurements.

Table 6. Nitrogen concentration in mixed pasture samples (% dry weight) collected in spring over time in the Parekarangi grazing trial. LSD = Least Significant Difference at $p<0.05$.

Treatments	**Aug2012**	**Aug 2013**	**Sep 2014**
Nil N	3.29	2.93	3.64
Regular N	3.52	3.50	4.09
LSD	0.25	0.56	0.15

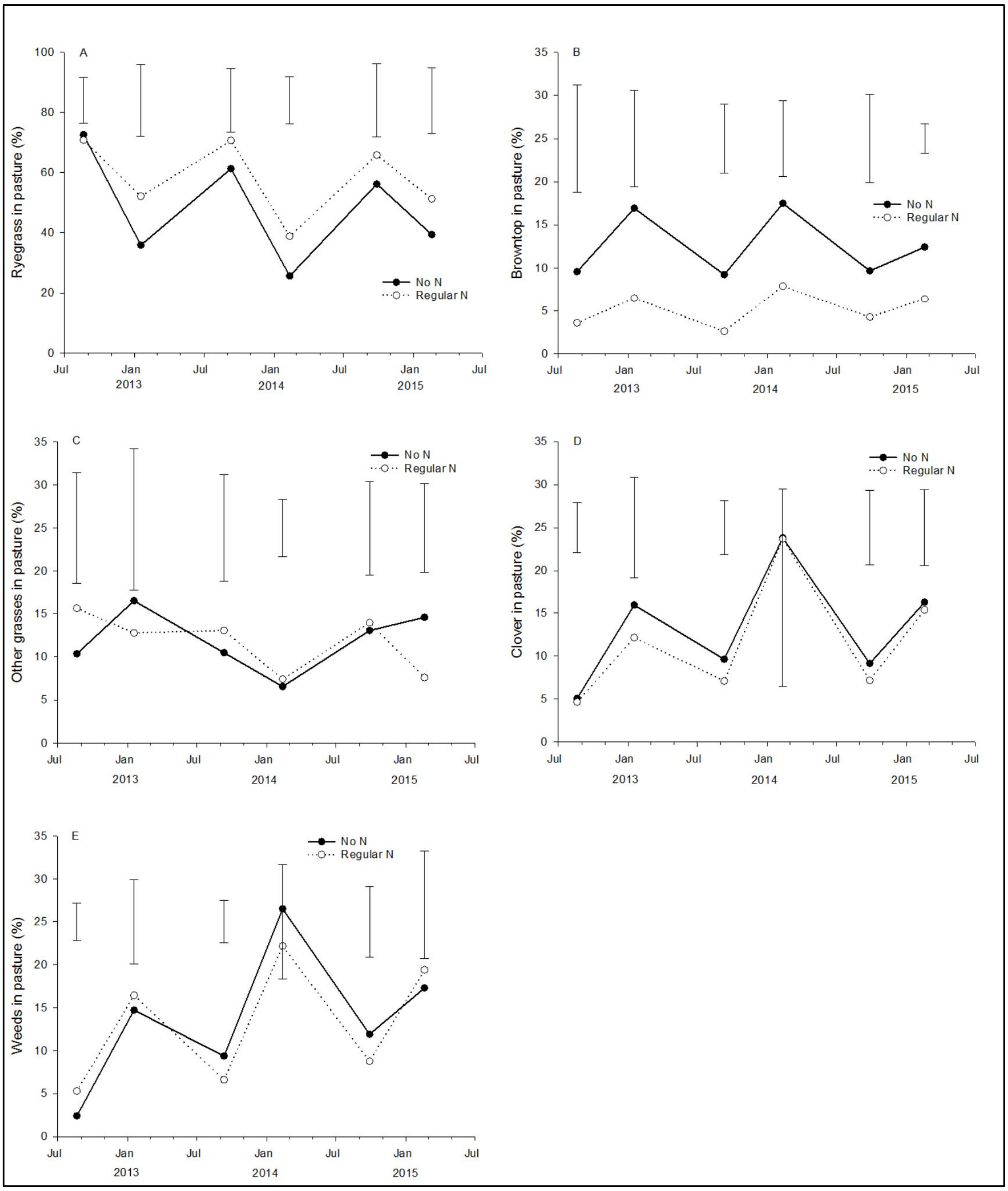


Figure 1: Changes in pasture species composition (% dry weight basis) over time in the nil and regular N fertiliser treatments on the Parekarangi farm. Vertical bars show Least Significant Difference at $p<0.05$.

3.4.2 Nitrogen leaching

During the first winter of the trial, there was no difference in nitrate-N concentrations in leachate between nil-N and regular-N treatments (Figure 1). However, the leachate samplers were only inserted in late-autumn (at 600 mm depth) and during the subsequent 3 months there was only about 150 mm drainage. Thus, there was no significant difference between treatments in the amount of N leached during the period of measurement in 2012. While the trial only commenced in autumn and leachate sampling did not start until May, there had been over 200 mm of drainage in 2012 before sampling commenced and this represented a significant component of the estimated 770 mm of drainage that occurred in 2012. Hence the data for N leached in 2012 underestimated the annual leaching loss.

In the second year (2013), the average nitrate-N concentrations in leachate from the regular-N treatment were significantly higher ($p<0.05$) from the fourth through to the eighth samplings, with the difference rising to a maximum at the June sampling (Figure 2). There was a significant drought during the autumn of 2013 and drainage did not commence until April (Figure 3). However, this was followed by heavy rainfall in May and a large amount of drainage during May at over 300 mm. In 2013, over four times as much nitrate-N was leached from the regular-N treatment than from the nil-N treatment (Figure 3). In 2013, sampling began from the commencement of drainage and the total annual drainage was 760 mm.

During 2014, there was a more gradual onset to drainage (Figure 3) during winter and the total amount of drainage over the winter/spring drainage period was 670 mm. Nitrate-N concentrations in leachate from the regular N treatment did not increase to the same levels as measured in 2013 but were significantly higher ($p<0.05$) than the nil-N control treatment during the later samplings (Figure 2). Thus, during the 2014 year the annual amount of N leached was 16 and 28 kg N/ha for the nil and regular N treatments, respectively (Figure 4, $p<0.1$).

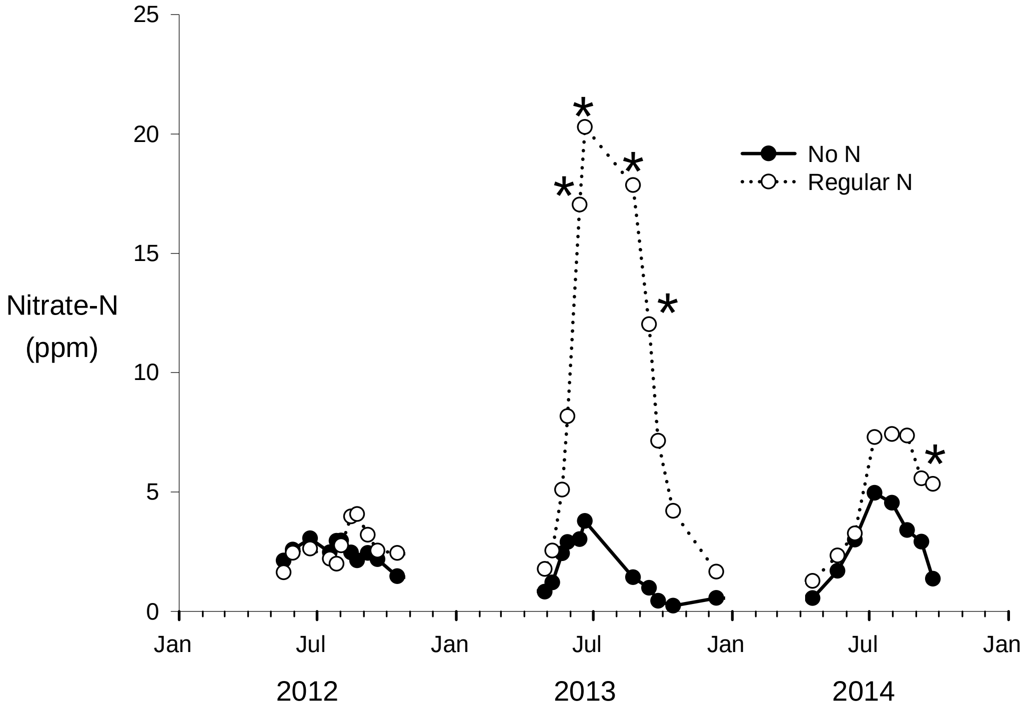


Figure 2. Nitrate-N concentrations in leachate during winter/spring of 2012 and over the full years for 2013 and 2014. Data was log transformed for statistical analysis and back transformed for presentation. Asterisks indicate differences significant at $p<0.05$.

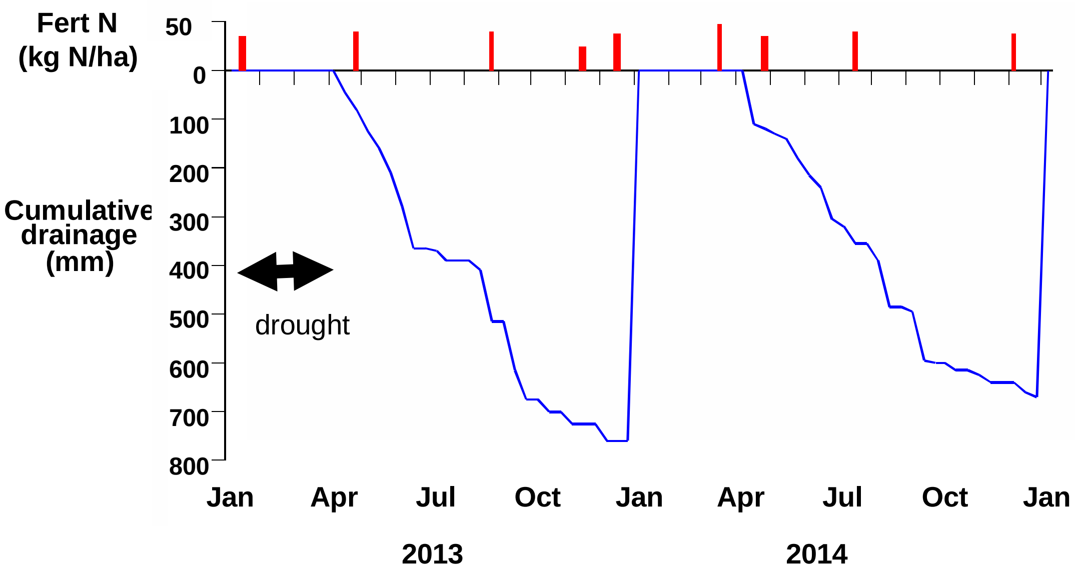


Figure 3. Temporal pattern of drainage and N fertiliser applications during 2013 and 2014 in the grazing trial on the Parekarangi farm. The period of significant drought in 2013 is marked.

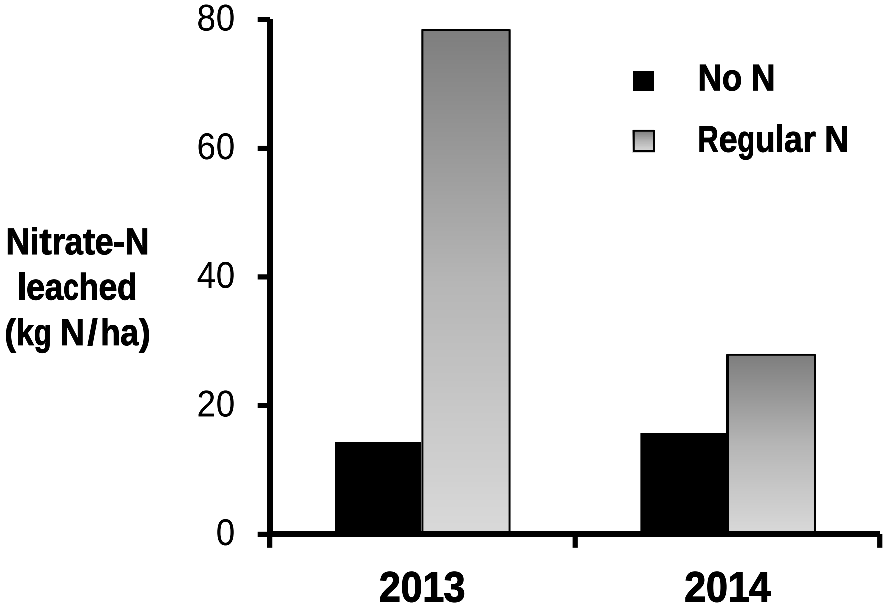


Figure 4. Amount of nitrate-N (kg N/ha) leached below 60 cm from the nil and regular N fertiliser treatments on the Parekarangi farm. Least Significant Difference values at $p<0.05$ were 46 and 15 kg N/ha for 2013 and 2014, respectively.

3.5 Field trial discussion

3.5.1 Pasture response to N fertiliser

Pasture responses to regular N fertiliser use in the plot trial were 7-8 kg DM/kg N, while the strategic N fertiliser treatment showed N responses of up to 14 kgDM/kg N. Previous small plot studies with single applications of N fertiliser have been carried out in large national series trials throughout New Zealand in the 1970s. These studies showed pasture responses to urea on pumice soils in the Central Plateau region of approximately 6 kg DM/kg N (range 4-10) following April application and approximately 12 kg DM/kg N (range 6-20) following August application (During 1984; Ledgard 1984). These were of a similar magnitude to those for other regions across the North Island.

This plot trial included nine replicates of plots in a randomised block within a paddock which resulted in greater precision in the data collection than if they had been spread across many paddocks around the farm. However, it also meant that the responses were specific to the N fertility of the soil in a single paddock of the plot trial and recent research has shown that paddocks can vary within a farm in their responsiveness to N fertiliser (Rajendram et al. 2009).

The plot trial was also communally grazed by cows, since it was not feasible to arrange for the small plots to be separately grazed. A consequence of this was that all plots were likely to have received the same return of N in excreta, even though the high N plots may have produced more pasture and with a higher N concentration compared to the nil-N treatment plots. Thus it is likely that the even return of excreta will have tended to reduce the magnitude of the differences in production between treatments over time compared to a situation where cows had previously grazed pasture from their specific treatment.

The farm system trial was managed in such a way that cows entering paddocks for grazing of the nil-N treatment had previously been grazing nil-N paddocks (including a nil-N lead-in paddock to avoid carry-over from plus-N paddocks). Similarly, the cows grazing the plus-N treatment had previously grazed pasture from this same treatment. In the first year of the farm system trial the pasture response to N fertiliser from the plus-N treatment compared to the nil-N treatment was relatively low at 7 kg DM/kg N. This coincided with a year of significant drought conditions in summer/autumn 2013, which would have reduced the magnitude of pasture response to N fertiliser (during 1984). In the second year of the farm system trial the pasture response to N fertiliser was much higher than that in the first year at 14.8 kg DM/kg N. This response was of a similar magnitude to that of the 10-year average from a farmlet grazing trial in Waikato comparing nil-N and 200 kg N/ha/year (Glassey et al. 2013). In the third incomplete year the N response was 11 kg DM/kg N, which is about the average value commonly assumed for N fertiliser use on New Zealand pastures (e.g. Ledgard 2006).

A key concern of farmers in the Rotorua area was that if N fertiliser use was greatly reduced or withheld completely there would be significant and rapid deterioration in pasture species composition and ingress of browntop. Results from this research to date has indicated that over 3 years in the plot trial (under communal grazing and excreta return) and 2 years under separate grazing systems there has been no increase in browntop content of the pastures. However, where N fertiliser was withheld there was a trend for a small decline in ryegrass content, although the effects were not significant. Similarly, there was an indication of minor increases in clover content of pasture in the nil N treatment but effects were not consistent. Previous research has shown that spring pasture management that avoids high pasture covers is critical for enhancing the clover content of pastures and that would be important where reduced or nil N fertiliser use is practiced in order to achieve high levels of fixation of atmospheric N_2 by clover (Ledgard et al. 2001). Longer term measurements are needed in order to understand the longer term implications of reducing or withholding N fertiliser use on pasture species changes and the possible need for more frequent renovation of pastures.

3.5.2 Nitrogen leaching

In the first year of measurement of leachates in the farm system trial, the N fertiliser treatments had only just commenced and there was insufficient time for treatment effects to develop over the first winter. The leachate samplers were located at 60 cm depth and therefore there had been insufficient time for treatments to generate differences in urine-N cycling and for urine and/or applied fertiliser N to be moved down through the soil with drainage water to reach the leachate sampler depth. By the second year there were large differences between treatments with 75% less N leaching from the nil-N treatment compared to the regular-N treatment. This difference was statistically significant ($p<0.05$), even though there was relatively high error associated with the calculated N leaching values due to the large spatial variability caused by urine patches (Cuttle 1992). It is likely that the seasonal conditions influenced this high level of N leaching from the regular-N treatment. 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 (>300 mm) occurred in April/May 2013. Additionally, the urea application in late-April 2013 was quickly followed by heavy rain and soil drainage, probably leading to some direct N leaching from the applied urea.

In the third year with a more gradual onset of drainage and a more typical growing year, there was approximately a two-fold difference in N leaching between treatments, being highest in the regular N treatment. Several factors contribute to this higher N leaching. Regular N fertiliser use will have increased pasture growth and plant N uptake which would have been eaten by cows and returned in excreta leading to some increase in leaching loss from cow urine (which is the main source of N leaching in grazed pasture). Pasture analysis also showed that the pasture had a significantly higher N concentration (by about +0.5% N; Table 6) which will have exacerbated the N surplus and most of the excess N will have been excreted in urine and contributed to N leaching (e.g. Ledgard 2001).

Large differences in N leaching associated with N fertiliser use have been measured in other farmlet trials in New Zealand. A five-year farmlet trial in the Waikato on ash soils where average annual rainfall was 1200 mm average showed N leaching of 30 and 65 kg N/ha/year for 0 and 200 kg fertiliser-N/ha/year treatments, respectively i.e. 55% lower N leaching without N fertiliser use (Ledgard et al. 1999).

The large variation in N leaching between years in the Parekarangi trial and the climatic variability mean that more data on N leaching is required before the likely average magnitude of N leaching associated with dairy farm systems in this region can be estimated with any confidence. Recent support has been obtained from Bay of Plenty

Regional Council and DairyNZ to continue this grazing trial for another year and obtain an additional year's leaching data. This data will be valuable for validation of the Overseer nutrient budget model for a higher rainfall site and very free-draining soils than has been available from other New Zealand N leaching trials.

3.5.3 Some practical implications from this research

1. Strategic N fertiliser use rather than regular applications could be used to achieve good pasture growth responses (e.g. application in late-winter/spring) and reduced direct N leaching risk.
2. Where the use of N fertiliser is reduced or ceased, pasture management in spring should target good control of pasture covers to avoid shading of clover by grasses and encourage increased clover growth and natural N inputs through clover N^2 fixation. This is also likely to reduce ingress of browntop, while increased fixed-N inputs can help in ryegrass retention.
3. N fertiliser can provide useful increases in pasture growth at relatively low cost but it is of low farm N efficiency and can lead to significant increases in N leaching. Thus, reducing or ceasing N fertiliser use and replacing it with a low-protein feed source (from outside the catchment) can significantly decrease N leaching from farms.
4. The coarse texture of the pumice soils (with associated limited water holding capacity) and relatively high rainfall (including risk of heavy rainfall events) means that care is needed in timing of N fertiliser application. It also suggests that using lower rates more often will reduce risk of direct fertiliser-N leaching.

4. Farm system modelling

4.1 Methodology

The project's generic methodology for the scenario modelling, utilising modelling in Farmax Dairy and Overseer software, is covered in previous SFF reports and in tandem project work (Farmer Solutions Project – funded by BoPRC, and NDA Impact Analysis – funded by DairyNZ and BoPRC) that assessed the overall costs to farmers of meeting the proposed nitrogen leaching restrictions. In all cases, the economic impact of implementing N loss mitigations was only considered at a farm-gate operating profit (EBIT) level, although how this was expressed often differed depending on how the impact was being illustrated. This initially focused on equating the impact with a potential capital N value ($/kg N leached) that might be used to define the required compensation, loss of asset value or more simply the "cost" associated with meeting N loss limits. However as the project progressed and the extent of proposed N allocations became better defined, annual loss of profitability ($/ha) became a more important measure, particularly for the participating farmers.

4.2 Modelling Results

Related modelling work (Farmer Solutions Project, NDA Impact Analysis) undertaken during the SFF project, proved to be useful in two main ways:

1. Highlighting the range of mitigations that might be possible on the dairy farms systems within the Rotorua catchment and providing insight in their relative efficacy and potential "cost" of implementation; and
2. Demonstrating the range of annual N losses from existing dairy farms and identifying the key drivers for such variation

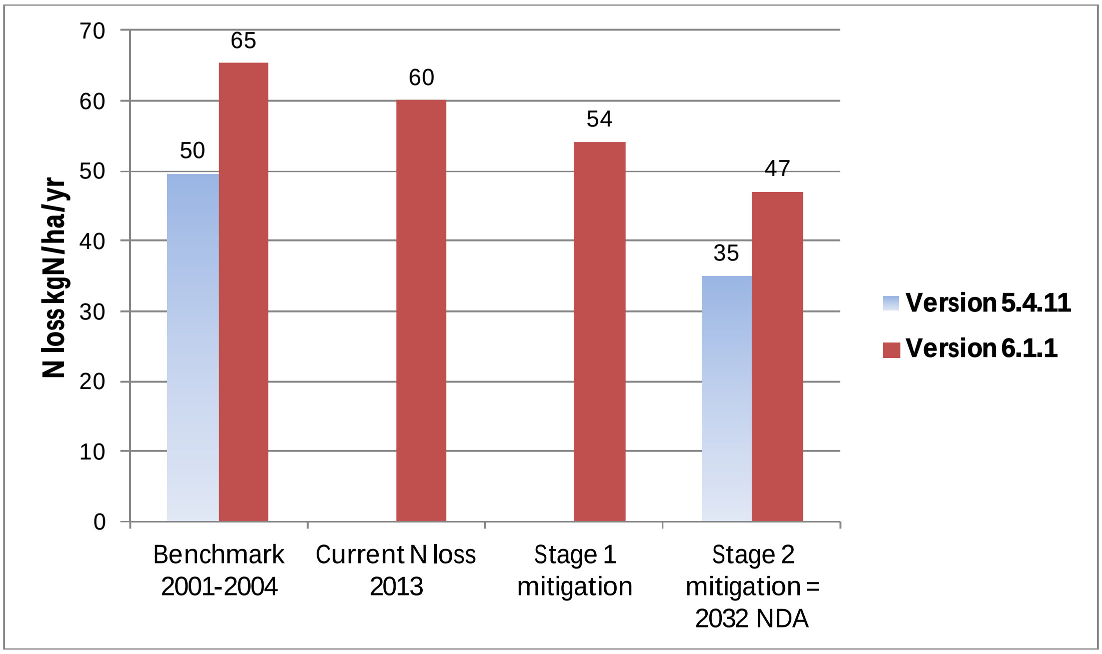
An indicative dairy sector Nitrogen Discharge Allowance (NDA) of 35 kgN/ha/yr (Overseer 5.4.11 values) was identified through the Lake Rotorua Catchment Stakeholder Advisory Group process (see StAG, 2013). This is the (draft) N leaching target that dairy farmers will need to meet by 2032, applied to their milking platform area. The SFF project tested this draft dairy NDA by modelling a Rotorua dairy farm that was mid-range in overall N loss at 50 kgN/ha/yr (the farm's nitrogen "Rule 11" benchmark from the 2001-2004 period). This benchmark N loss equates to 65 kgN/ha/yr in Overseer 6.1.1. The same adjustment ratio (32% increase) was applied to estimate a "version 6" NDA target of 47 kgN/ha/yr.

Key farm parameters include: 200 ha milking platform; 390 kgMS/cow, 120 kgN/ha urea and 2100mm rainfall. The farmer has reduced N loss since the benchmark period (e.g. by ceasing the winter fodder crop, increasing pasture utilisation) which effectively constrained the options for further N reductions. In discussion with the farmer, a two-stage mitigation analysis was explored:

- Stage 1 mitigation: no summer turnip crop; additional PKE purchased; 6 kgN/ha/yr saving; net $14,000 annual cost
- Stage 2: winter barn used 16 hours/day for 5 months; an additional 7 kgN/ha/yr saving; approximately $1million capital cost.

The Stage 2 winter barn capital cost is significant and has not yet been converted to a profit impact, partly due to the challenge of modelling barns within Overseer and Farmax. However, it indicates the difficulty of meeting an NDA when there are few "low hanging fruit" mitigation options. The farmer considered that such investments may be needed to ensure the farm remained an attractive business proposition for any future owner. The modelling results, potential mitigation pathway and the contrast between versions 5 and 6 of Overseer are summarised in Figure 5. This analysis helped form the basis of an interactive project workshop with farmers held in November 2013.

Figure 5: Rotorua dairy farm example of a modelled pathway to meet its NDA



The Parekarangi Trust dairy farm was modelled in Overseer and Farmax to explore overall farm system impacts similar to those being tested in the field trials, namely a status quo N fertiliser regime contrasted with two nil N fertiliser regimes based on (i) importing additional feed to maintain status quo production levels and (ii) allowing production to fall while seeking to optimise on-farm nitrogen use efficiency. The modelling results were presented at the final field day in March 2015 and are shown in Table 7.

Table 7: Status quo and nil N fertiliser modelling for Parekarangi Trust farm

	Status quo N fertiliser	**Nil N fertiliser and maintain production**	**Nil N fertiliser and reduce production**
Milking platform (ha)	350	350	350
Cows	**1040**	**1040**	**930**
Stocking rate (cows/ha)	**2.97**	**2.97**	**2.66**
Full Time Employees	5.29	5.29	4.71
Replacement rate	21%	21%	21%
Fertiliser N use (kg N/ha)	**178**	**0**	**0**
PKE (tonnes DM)	380	392	362
Maize (tonnes DM)	0	735	144
Grass silage (tonnes DM)	80	80	73
Cows winter-off 8 weeks	865	865	760
Heifers grazed off 52 wks	220	220	200

	Status quo N fertiliser	Nil N fertiliser and maintain production	Nil N fertiliser and reduce production
Calves grazed off 20 wks	230	230	210
Crop (ha)	9	9	9
Regrassing (ha)	9	9	9
Silage cut (ha)	75	75	75
Production (kg MS)	**370,000**	**370,000**	**330,000**
/ha	1057	1057	943
/cow	356	356	355
INCOME			
Milksolids, $5.75/kg MS	$2,127,500	$2,127,500	$1,897,500
Cattle sales	$78,592	$78,592	$70,249
TOTAL INCOME	**$2,206,092**	**$2,206,092**	**$1,967,749**
TOTAL INCOME	**$2,206,092**	**$2,206,092**	**$1,967,749**
FARM WORKING EXPENSES	**$1,421,714**	**$1,555,303**	**$1,258,809**
$/kg MS	$3.84	$4.20	$3.81
OPERATING SURPLUS	**$784,378**	**$650,789**	**$708,940**
less Depreciation (IRD)	$52,000	$52,000	$52,000
OPERATING PROFIT (EBIT)	**$732,378**	**$598,789**	**$656,940**
/ha	**$2,093**	**$1,711**	**$1,877**
/kg MS	**$1.98**	**$1.62**	**$1.99**
/kg N leached	**$28**	**$38**	**$44**
Capitalised impact of change in EBIT @ 8.0%	**$0**	**$1,669,865**	**$942,974**
Nitrogen leaching (kg N/ha/year)	**74**	**45**	**43**
N conversion efficiency	**25%**	**39%**	**37%**
Reduction Vs status quo		30	32
Reduction (%)		40%	43%
Implied capital cost per kg N reduced from status quo	**0**	**$161**	**$85**

Note: N leaching based on Overseer version 6.1.3; 2012 farm and industry data used

The broader trends in dairy farm N leaching, profitability and farm practices were explored by a comparative analysis of 13 dairy farms that represented 54% of all dairy farms in the Lake Rotorua catchment.

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. While the farm data was drawn from a range of SFF project and other sources, the analysis itself was a key SFF project output.

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. Initial filtering showed that 13 valid farm comparisons could be made out of the 15 farm file sets available. 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.

Table 8: Aggregate modelled N leaching and productivity changes from 2001-2004 to 2012-2013 for 13 Rotorua dairy farms

	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	
Total kg MS	2,100,000	2,700,000	up 27%	A large increase in productivity from essentially the same area and number of cows
Average kg MS/cow	287	365	up 27%	
Total N loss, tN/yr	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 decreased 4%
- The area in relatively high leaching forage crops has reduced from 6% of the total area farmed to 4% (i.e. 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 and/or N fertiliser 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.

This “progress” analysis suggested that some key potential mitigations identified by other modelling work had already been adopted, but productivity improvements had also occurred. It is probable that such productivity gains occurred as a result of farmers simply looking to improve profitability, rather than offset N loss mitigation. However, this does indicate productivity gains into the future are achievable.

4.3 Limitations of modelling

The limitations of the modelling, as undertaken, were two-fold. The first limitation related to farmers’ scepticism around the validity of the outcomes. This scepticism was underpinned by the view that modelled outcomes (e.g. milk production, feed conversion efficiency, pasture growth rates with reduced fertiliser N inputs etc.) were achievable in practice. The contribution of the modelling was the quantification of these outcomes or benefits. Scenario modelling within this programme presented viable solutions that farmers could explore and potentially implement with confidence. A parallel modelling process (a linear programming approach) that many farmers in the catchment had participated in, independent of the SFF funded work, may have also had an influence in farmer engagement with the SFF modelling approach (using Farmax). Some farmers appeared to have greater confidence in the alternative output. This potentially relates to the second limitation below.

The level of influence that models have on the capacity of farmers to adapt mitigation technologies (or not) in response to the challenges of meeting a [significant] N loss cap has proved to be contentious. The SFF project team work assumed that, in general, farmers were already operating close to the limit of their management capability (and hence productivity) and that the imposition of an N cap would not, on aggregate, cause farmers to suddenly improve. Accordingly, all the modelling work undertaken assumed static productivity (i.e. improving per cow production was not available as a “mitigation” to offset the economic impact of a reductions in stocking rate). This also prevented the comparison between mitigations being confused with productivity improvements.

However, where individual farmers might possess the capacity to improve productivity in conjunction with N-loss mitigations, then (i) the negative economic impact of such actions might be reduced or negated all together (as per outputs from the NDA Impact Study, where some productivity improvement was modelled as deemed appropriate), or (ii) a different mitigation approach might be more appropriate. The linear programming modelling that occurred in tandem with the SFF work potentially provided for some productivity improvement, which may have indicated less significant system change was required than the SFF work suggested. Reality is likely to sit somewhere in the middle.

4.4 Lessons from modelling

Modelling work to assess the validity and impact of farm system changes to meet environmental limits is likely to continue into the future, both in the Lake Rotorua and other catchment areas. Based on our experiences from this SFF project, we note the following:

- Modelling of mitigations probably needs to be undertaken in three ways: (i) initially assessing the economic impact of mitigations with a productivity constraint (i.e. to an un-optimised farm); (ii) assessing the economic impact of optimising the farm system; and (iii) then assessing the economic impact of applying mitigations to the optimised farm system.
- Ideally a project would undertake a modelling exercise with individual case study farms, then implement agreed mitigation plans and then monitor against the modelled expectations. This wasn't possible in this instance given the lack of a final NDA allocation framework (i.e. NDA rules are still draft as of March 2015) and an unwillingness for farmers to implement potentially loss-incurring farm system changes to achieve N loss reductions.
- Where alternative modelling processes exist, it would be helpful to validate one against the other, ensuring consistency in assumptions and application. This might lead to a preferred modelling framework that farmers and rural professionals alike can accept and have confidence in.

5. Engagement with Rotorua dairy farmers

5.1 Outline

A series of farm discussion groups and field days have been run throughout the project. Farmer participation has varied during the project and it is too early to determine what level of practice change has occurred on-farm. Rural professionals have been regular attendees.

Four field days have been run on Parekarangi Trust Dairy Farm: May 2012, May 2013, May 2014 and March 2015. These events focused on reporting nitrogen use trial results from the farm and technical aspects of nutrient loss mitigation. During spring 2012 two additional farm discussion "workshop" events were held on the two SFF project farms in addition to Parekarangi, with a similar event in November 2013. The breakdown of attendees at the four field days and three workshop events is given in Table 9.

Table 9: Attendance at Project Engagement Events

	May 2012	**Sept 2012**	**Nov 2012**	**May 2013**	**Nov 2013**	**May 2014**	**March 2015**
Event	field day	workshop	workshop	field day	workshop	field day	field day
Total Dairy Farmers - Owners, Trustees and Staff	17	13	8	31	13	23	8
Lake Rotorua Farms Represented	8	6	6	6	8	7	6
Maori Dairy Farm Trustees or Iwi Staff	2	0	0	10	0	2	3
Regional Council and MPI staff	1	0	4	9	1	2	6
Farm Consultants	3	1	2	5	2	4	3
Total Rural Professionals	11	2	14	23	14	24	16
Total Attendees	**28**	**15**	**22**	**60**	**27**	**52**	**35**

5.2 Commentary on farmer engagement

Attendance at both field days was disappointing in that only about one third of the 22 Lake Rotorua catchment dairy farms were represented at each. The second field day saw increased total attendance (60 total) due to the numbers of rural professionals, Maori land owners and regional council staff from BOPRC, Hawkes Bay and Waikato.

Farmers present at all events engaged well on the practical pros and cons of the various modelled options. Generally the difficulties were more highly weighted than the positives, with the final conclusion being that any significant changes (over and above the efficiencies already undertaken by catchment farmers) would require a shift in the regulatory environment and/or provision of incentives.

Given the relatively low turnout of Rotorua dairy farm owners at the 2012/13 events, a farmer meeting was held in July 2013 to review the N leaching results from Parekarangi and to glean ideas that may improve engagement from the catchment – suggestions included:

1. Gather the modelled farmers (both SFF project and FSP participants) for a follow up to thrash out the practicalities and barriers to adoption of mitigation options that are common across a number of farms.
2. Discuss with modelled farmers how we can support the decision-making around one mitigation option i.e. going beyond the technical and economic changes.
3. Identify someone already implementing a commonly recommended mitigation that would be willing to share their story and hold a discussion group to review how they have implemented the change and how others could do it.
4. Going outside the catchment to a farm with similar resources that is effectively applying a common mitigation option and do as per (3) above.
5. Revisit Parekarangi more frequently as a focus point, provided there is new knowledge to be shared.

As indicated at the July 2013 field day and other events, there is a strong farmer appetite to see specific low N use/discharge farming practices applied in the catchment and followed at a farm (or at least farmlet) level. Farmers have stated they would be most likely to make changes if they could see similar changes applied locally.

Apart from the normal logistics of timing and advertising, the three most significant challenges to farmer participation throughout the project have been:

- alternative opportunities for engagement with evolving nutrient policy via the Lake Rotorua Primary Producer Collective and the Stakeholder Advisory Group
- some legacy of disconnectedness between the regional council and the farmers
- uncertainty about the extent of nutrient loss reduction required on their farm. The introduction of Rule 11 effectively stopped further land use intensification but, despite recent stakeholder collaboration and progress with a rules and incentives framework, each farmer still doesn't know exactly what will be required of them.

More recently, water quality in Lake Rotorua has improved, driven by BOPRC's alum dosing of two local streams which has reduced in-lake phosphorus concentrations (BOPRC, 2013b). This has caused some farmers to query the ongoing policy focus on nitrogen and seek a "dual nutrient" approach.

Several of the projects engagement initiatives are described in sections 5.2.1 to 5.2.7.

5.2.1 Farm discussion event: November 2013

The farm discussion event held in November 2013 was the first opportunity within this SFF project to test the draft Nitrogen Discharge Allowances (NDAs) being developed by the parallel Stakeholder Advisory Group policy process. Participants considered the challenges of meeting the draft 35 kg N/ha/yr limit given the farm's physical characteristics e.g. only 30% of the farm can be mowed for silage. Status quo and mitigated scenarios were presented using Overseer 6 analysis. Key points were:

- Need the right trade-off with stocking rate, pasture utilisation and per cow MS
- Importance of skilled staff and/or sharemilkers to achieve production and profit goals at lower stocking rates – the latter being a key driver of N loss
- Farmers need to know what NDA limits will apply to their farm in order to fully engage and make plans for change. This included any NDA changes going from Overseer version 5 to 6.

5.2.2 Farmer workshop: February 2014

Catchment farmers and regional council staff attended an interactive workshop run by DairyNZ. A "nitrogen cycle quiz" tested and extended nutrient knowledge. This was followed by further modelling results from the same farm visited in November 2013, with a two-stage mitigation scenario to meet the farm's NDA.

5.2.3 Field Day: May 2014

In light of the desire to take a dual nutrient approach, this field day included a farmer panel sharing their experiences with building and managing phosphate detention bunds. Photos that clearly illustrated the bunds' ability to drop sediment out of flood waters along with farmer testimony generated a lot of interest, with the topic of phosphate mitigation ranking as being of more interest than nitrogen mitigation. In feedback from the event (received from about half the participants), farmers indicated intention to change ten practices - all having the theme of phosphate mitigation, three focusing on cropping, five including bunds or other ways to slow runoff, one on wintering practices and one on fertiliser management.

Results from the nitrogen trial were not straightforward - most agreed that extending the trial time to get reliable results was important.

5.2.4 Draft Rules Consultation: July 2014

BOPRC made their draft rules for reducing nitrogen loss to Lake Rotorua open for feedback in July 2014. While not an SFF project event, the series of public meetings demonstrated a high level of engagement from the dairy farmers. As other affected landowners became more engaged, the dairy farmers lifted their own level of both interaction and leadership. Meetings of the Lake Rotorua Primary Producer's Collective executive have become more regular.

A key issue that undermines farmers' confidence to engage in nutrient loss mitigation discussions is the vexing problem of different versions of Overseer producing vastly different numbers. While current nutrient budgets, produced by fertiliser companies or dairy companies, are prepared in Version 6, targets and rules are still discussed with numbers from Version 5.

5.2.5 Use of the Collective's website www.rotoruafarmers.org.nz

The Collective farmer group (responsible for this SFF project) established a website in September 2014 to promote the farmer perspective on Lake Rotorua nutrient policy and science. The website is promoted via a monthly e-newsletter sent to about 300 people, including all 26 dairy farmers in the Lake Rotorua catchment. Several SFF11-023 project reports can be found in the "Resources" tab, including the FLRC papers from 2012, 2014 and 2015. The feature story in the March 2015 e-news was titled "Farming without N fertiliser? Local trial results" and focused on the final SFF Parekarangi field day.

The Collective's e-newsletter has a typical "open rate" of 50%, well above the industry average of 19%. While it is difficult to say how effective the e-news and website are in raising awareness about this SFF project, it is an enduring and flexible platform to promote science information. The anecdotal evidence from the Collective's leadership "executive" (11 members, including 8 dairy farmers) is very positive about the information conveyed in the e-news and website. It is also apparent (via Mail Chimp® analysis and anecdote) that regional councillors, staff and management regularly read the Collective's e-news.

5.2.6 AARES Field Trip: February 2015

A field trip in February for attendees at the Australasian Agricultural and Resource Economics Society focused on water quality, policy and impact on dairy farmers in the Lake Rotorua catchment. Two dairy farms were visited. Both had a long list of changes in farming practices that they had implemented since the benchmark years of 2001-2004. Common to both were:

- Nitrogen fertiliser management - not applied in winter and always at lower rates;
- Improved effluent system (including storage), increased area for application and consistent monitoring of application rate and nutrient composition;
- Improved productivity of stock, so more nitrogen exported from farm;
- Reduced area of grazed forage crops.

5.2.7 Final Field Day: March 2015

The final project field day was expected to attract at least as many farmer participants as the 2014 event and was promoted similarly to previous events. There were 35 attendees including eight dairy farmers. The modest farmer turnout was disappointing and probably reflects the ongoing challenge to engage with farmers while there is considerable policy uncertainty. In particular, the individual farm nitrogen leaching targets ("nitrogen discharge allowances") have not been determined, with the associated regional plan change deferred several times. However, there was a good cross-section of rural professionals

Key farmer feedback from the final field day included:

- Economic analysis needs to be presented alongside the science results – the Parekarangi cost-benefit modelling was rated as the most useful topic covered at the field day
- Practical local field trials are critical to farmers gaining confidence in new mitigation methods
- Long term trials are needed to address year-to-year variability and to assess pasture composition/quality under low or nil N fertiliser systems

5.3 Lessons learned on farmer engagement

1. Many farmers appear to be waiting and watching before deciding on potentially expensive and/or profit-limiting mitigation initiatives. The political context, especially uncertainty on individual farm constraints, needs to be factored into extension and event planning. Some farmers feel frustrated at the 'lack of answers' to a question 'they don't know.' Several famers have expressed that once they know what is required they will have the desire for knowledge to bring practice change to meet the new requirements.
2. The economic driver to improve nitrogen efficiency and reduce costs can deliver significant reductions in N leaching (~8%, see section 4.2). Extension efforts should seek to build on this existing momentum, acknowledging that there will be limits to such "low-hanging fruit" options.
3. The opportunity to promote the SFF project and its results via the Collective's website arrived late in the project's life. The website provides a platform for ongoing extension of project outputs and related work.
4. Farmer input into planning and running project events was constrained by heavy commitments of key local farmer leaders influencing nutrient policy development, particularly via the catchment Stakeholder Advisory Group. This involvement was effectively competing for limited farmer "discretionary" time beyond normal farming commitments.
5. Attendance was consistent with industry expectations and satisfactory in light of the factors noted above. Research (e.g. Journeaux 2009) shows that there are always only a few 'early adopters' of new science/ideas (i.e. start of the bell curve) and it takes time for other people to come on-board and often they will wait until there is a need to change.

6. There has been a high rural professional attendance at all field days. This should be seen as an opportunity to use field days to educate the rural professionals on spreading key messages. This would require an explicit focus on how they can use the field day information and the trial results to benefit their clients' decision making. Comparable future projects should also look for opportunities to integrate project results into extension events and field days run by other primary industry agencies in the region concerned.

6. Conclusions and Recommendations for Further Research

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 success of the alum dosing which has apparently "fixed" Lake Rotorua's water quality, at least in the short-term. Meanwhile, there is some reassurance that efforts by dairy farmers over the past decade to reduce costs and improve productivity have also reduced average N leaching rates by about 8% per hectare.

The Parekarangi field trials have successfully identified the dairy farm system impacts from adopting nil and "strategic" N fertiliser applications, while still maintaining pasture quality. The trials also proved to provide a practical setting for field days and engagement with dairy farmers and rural professionals.

The NDA levels for dairy farms are still expected to present a substantial challenge to farmers collectively and individually. 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.

The results of this project suggests two areas of potential future research including: (1) Establishing a similar low N input trial on an intensive beef breeding/finishing farm located in another part of the catchment (i.e. different soil types and rainfall pattern); and

(2) Evaluating systems design and management options to reduce nutrient leaching and increase profitability on alternative low N input farm systems.

7. Project Deliverables and Outputs

The project's performance against the original contracted milestones are set out in Table 10 below, adapted from the MPI's standard SFF progress reporting template. Table 10 effectively summarises all project outputs.

Table 10: Project milestone summary

Milestone Number	Milestone *[As per SFF contract schedule]*	Delivery, Outputs
1	**Establish Monitor Farm** field trials on Parekarangi Trust; carry out initial testing and measurements of specific N and other nutrient/contaminant mitigation strategies (yr 1); collect information to map farm using GIS and model spatial management practices for reducing nutrient losses; report outputs (yr 1).	• Both field trials became fully operational in 2012 and continued to December 2014 • GIS and soil mapping completed in 2013 and used to test ongoing development of Ballance's "MitAgator" tool • Reports delivered to MPI and project described in FLRC paper (Kingi et al., 2012)
2	**Interim outputs from Monitor Farm** for inclusion into other Project Objectives; write reports to be circulated to the Project Team and Project Community (yr 2). Produce final reports at the completion of the Project.	• Monitor farm outputs and mitigation options used to inform similar "what-if" analysis on the two other SFF focus farms and associated projects, notably the Farmer Solutions Project (FSP) • Interim report on Parekarangi trials completed June 2014 and circulated to project partners • Final report submitted
3	Draw up selection criteria, identify suitable farms within the catchment and invite 2 additional farmers within the Collective to participate as model farms; interview farmers and collect information to **produce base-line Farm Systems Models** in Farmax Dairy^{TM} and Overseer^{TM} (yr 1).	• Two dairy focus farms identified and modelled in Farmax and Overseer during 2012 • 9 dairy farmers interviewed in 2012 as part of FSP • Further dairy farms modelled in Farmax and Overseer during the project (total = 13)
4	Interim outputs from the systems models including **optimisation options**, systems reconfiguration, and management changes produced; outputs from Monitor	• Farm system optimisation methodology developed by Perrin Ag, based on mitigation cost-effectiveness per kgN mitigated

Milestone Number	**Milestone** ***[As per SFF contract schedule]***	**Delivery, Outputs**
	Farm included in the systems models; interim reports produced for the Discussion Groups (yr 2). Produce final reports at completion (yr 3).	• Method summarised in FLRC paper (Park et al., 2014) and used in scenario presentations at farm discussion events • Final report submitted
5	Identify 2 suitable farms within the Collective to **establish Focus/Discussion Groups** alongside Parekarangi Trust; appoint group facilitator; establish groups and draw up schedules (1 field day per Focus Group per year); invite other dairy farmers within the Collective and within the district; prepare interim reports for Collective and the Project Community (yr 1).	• Two farm focus discussions held in 2012 and one workshop 2013 • Farmer discussions were integral to all four Parekarangi field days • All farmer engagement events organised by DairyNZ with feedback incorporated into our two FLRC papers, SFF progress reports and Section 5 of this report.
6	Incorporate findings from the Monitor Farm and Farm Systems Models into Focus Groups; **establish forums for farmers to test findings** and learn about applying potential N reduction strategies; develop methods and processes to document/record learnings; write interim reports and present at industry conferences and publish in industry media (yrs 2 and 3).	• Findings from Parekarangi trials and modelling work reported to farmers via focus farm events • 13 farm modelling summary presented to Stakeholder Advisory Group October 2014 • Presentations given to FLRC in 2012 and 2014 on interim results (as noted above) • Presentations given to Collective AGMs on related projects: FSP in 2013 and NDA Impacts in 2014 • Substantive project findings reported to FLRC in 2015 (Park et al., 2015). • Final field day featured on the Collective's website and e-news for March 2015 • Project report published in DairyNZ's "Inside Dairy" in March 2015 (pp 30-31)

8. Acknowledgements

We thank MPI, BOP Regional Council, DairyNZ and Ballance Agri-Nutrients for funding this research. We are also grateful to James Warbrick, chair of Parekarangi Trust, and the trustees for their generosity in allowing the farm to be used for this research and to the farm management team for assistance in conduct of the research. We appreciate the input and support of the members and leaders of the Lake Rotorua Primary Producers Collective, including those that made their farm data available for analysis.

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