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Meeting nutrient loss targets on dairy farms in the Lake Rotorua catchment: Report on 2014-2015 results from the Parekarangi Trust farm

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Meeting nutrient loss targets on dairy farms in the Lake Rotorua catchment: Report on 2014-2015 results from the Parekarangi Trust farm

Report prepared for: Bay of Plenty Regional Council and DairyNZ

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1. Executive Summary

The aim of this research was to provide data on current nitrogen (N) leaching losses from dairy farms in the Lake Rotorua catchment and the effect of reducing N fertiliser input on pasture growth and N leaching. A farm-systems-scale experiment using 12 paddocks on the Parekarangi Trust dairy farm commenced in autumn 2012. Six paddocks received N fertiliser as per current farm practice (between 112 and 163 kg N/ha/year over the first three years of pasture growth measurements), while the other six received no N fertiliser. The two sets of paddocks were grazed separately to avoid any fertility transfer. Averaged over the whole research period, the pasture dry matter (DM) response to N fertiliser was 15.6%, equating to an additional 10 kg DM/kg fertiliser N applied. There was no significant change in the botanical composition of the pasture over the duration of the trial but the N concentration of the pasture was significantly higher in the plus-N paddocks than the nil-N paddocks at several sampling times.

Each paddock in the farm system trial had 25 ceramic cup samplers (150 per treatment) to measure N leaching. In the first full drainage year (2013) after commencing the trial, nitrate-N leaching from the plus-N and nil-N treatments was 75 and 17 kg N/ha, respectively ($P<0.05$). The relatively high N leaching from the plus-N treatment was associated with N use around the dry summer/autumn period. In 2014 the corresponding nitrate-N leaching was 26 and 20 kg N/ha ($P>0.05$) while in 2015 it was 24 and 10 kg N/ha ($P<0.05$) for the plus-N and nil-N treatments, respectively. The lower nitrate-N leaching in 2015 is likely attributable to less drainage than in previous years (544 mm in 2015 compared with an average of 726 mm/year in the previous three years).

Average nitrate-N leaching from the plus-N treatment in 2013 and 2014 (51 kg N/ha) was similar to that predicted by the OVERSEER® nutrient budgeting model (58 kg N/ha; Watkins et. al. 2015). However, average nitrate-N leaching from the nil-N treatment over the corresponding period was lower than predicted (19 versus 40 kg N/ha). This may relate to the developing nature of the farm (about 20 years since conversion to dairying) with a relatively lower soil and pasture N status than a long-term developed dairy farm.

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 proposed Regional Policy Statement (RPS), has established nutrient reduction targets that require farmers to reduce total 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 Rotorua Dairy Collective's project, "Meeting nutrient loss targets on dairy farms in the Lake Rotorua catchment", was initiated to provide data on current nutrient losses and strategies to reduce these. In 2012, as part of this study, AgResearch established a three year farm-paddock-scale trial on the Parekarangi Trust dairy farm, approximately eight kilometres south of Rotorua. The study aimed to examine the effects of N fertiliser use on pasture production and composition, and on N leaching. An interim report was compiled in 2014 and the trial was extended for an additional year. This report updates the results from the trial and provides an overall summary of the research.

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. One-third of the cows are grazed off farm 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.

3. Trial setup

3.1 Fertiliser treatments

The farm system trial commenced in late 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 the 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 rate of N fertiliser application is given in Table 1. On a calendar year basis, application rates were 128, 177, 112 and 146 kg N/ha for years 2012 – 2015.

Table 1. N fertiliser application on farm system trial based on a May-April year except in year 4 (May to January).

Year 1		Year 2		Year 3		Year 4	
May 2012-Apr 2013	kg N/ha	May 2013-Apr 2014	kg N/ha	May 2014-Apr 2015	kg N/ha	May 2015-Jan 2016	kg N/ha
April/May	30	April/May	40	April/May	35	April/May	35
August	43	August/Sept	40	August	40	August	46
September	37	November	25			October	46
November	21	December	37	December	37	November	19
January	35						
Annual totals	166		142		112		146

3.2 Pasture measurements

Rising plate meter readings taken before and after grazing were used 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 and analysed for botanical composition in late winter/early spring and again in late summer. Sub-samples were analysed for N concentration. These measurements continued through to January 2016.

3.3 Leachate collection and analysis

In April 2012, 25 porous ceramic cup soil moisture collectors (Grossmann and Udluft 1991) were installed in each treatment paddock. Samples of soil moisture from at 60 cm depth were collected regularly using the ceramic cups and were analysed for nitrate and ammonium-N concentrations. The aim was to collect samples after 50-75 mm of drainage had occurred but this was not always possible in practice due to the irregular nature of rainfall. Drainage was estimated using a water balance model (Woodward et. al. 2001) set up for analysis using soil characteristics from the farm. Daily rainfall was measured on the farm and temperature and solar radiation data were obtained from the Rotorua airport meteorological station belonging to the National Institute of Water and Atmospheric Research (NIWA). The amount of nitrate-N leached below 60 cm depth was calculated by multiplying the nitrate-N concentration by its associated drainage. Leachate sampling continued through to late-September 2015 and drainage ceased in early October.

4. Results

4.1 Rainfall and drainage

The rainfall pattern in 2015 was similar to 2013 and 2014 (Figure 1), although late-summer/early-autumn was not as dry. Cumulative annual rainfall in 2015 was 1125 mm which was less than the Rotorua 30 year average of 1330 mm. All 2015 drainage occurred between April and October (Figure 2). Calculated annual drainage for years 2012 to 2015 was 776, 760, 642 and 544 mm. However, In 2012, considerable drainage occurred before the trial began in April.

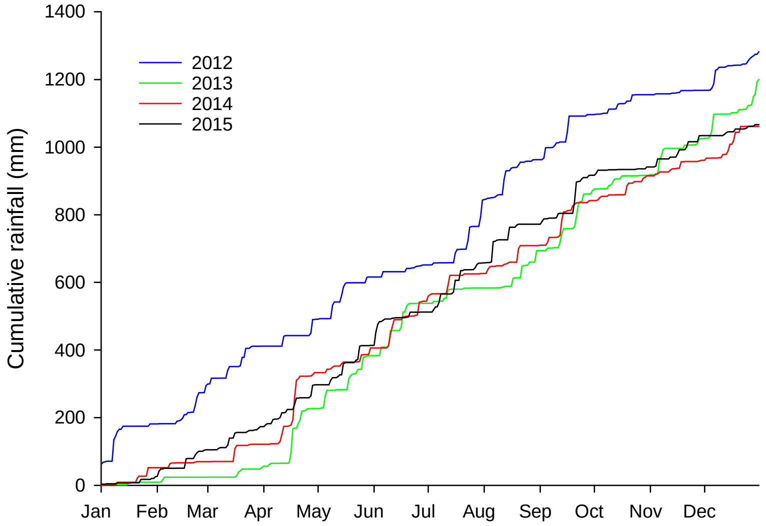

Figure 1. Cumulative annual Rotorua rainfall 2012-2015 (NIWA station 1770).

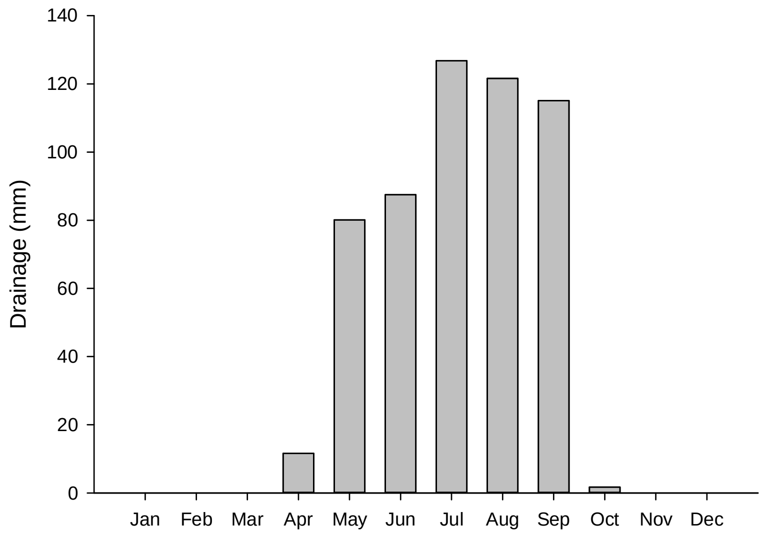

Figure 2. Monthly drainage at Parekarangi during 2015.

4.2 Pasture N response

From May 2014 to April 2015 nitrogen fertiliser increased pasture production by 12.5% giving an N response of 10.9 kg DM/kg N (Table 2). The difference in total annual pasture production between the plus-N and nil-N paddocks was not statistically significant. However, there was a significant difference ($P<0.05$) at the January 2015 silage cut with 25% more dry matter on the plus-N paddocks. All paddocks were harvested for silage in November 2014 and January 2015.

Production measurements continued on the trial until the silage cut in early January 2016. There were no statistically significant pasture production differences between treatments at any of the individual grazings after the January 2015 silage cut. The plus-N treatment produced 17% more pasture from May 2015 until January 2016 but this was not statistically significant. On a calendar year basis, pasture production for the period following the January 2015 silage cut up to and including the January 2016 silage cut was 8.0 and 9.2 t DM/ha on the nil-N and plus-N paddocks, respectively. This difference was not statistically significant.

Because pasture measurements coincided with grazing, annual pasture production figures do not equal exactly 365 days growth. Additionally, pasture production figures have not been adjusted to account for pasture growth between the pre- and post-grazing plating measurements. Adjustment for the latter would increase estimated pasture production by approximately 10%.

N concentration in the pasture followed a similar trend to previous years, with higher N concentrations in the plus-N pasture at both the February and September herbage samplings in 2015. The difference was only statistically significant ($P<0.05$) at the February sampling (Table 3).

There was a downward trend in pasture ryegrass content from August 2012 to September 2015 (Figure 3). However, the trend affected nil-N and plus-N paddocks similarly and there were no significant differences in ryegrass, browntop or weed content in pasture between the two treatments (Table 4). Legumes (predominantly white clover but with small amounts of lotus and red clover) made up a smaller proportion of the plus-N pasture than the nil-N pasture but the actual percentages (8 and 12%, respectively) were low and the difference was not statistically significant.

Table 2. Pasture growth from autumn 2012 to January 2016. LSD = Least Significant Difference at P<0.05.

Year 1 (May 2012-April 2013)	Nil-N	Plus-N	LSD
Annual pasture production (t DM/ha)[1]	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 (May 2013 - April 2014)	**Nil-N**	**Plus-N**	**LSD**
Annual pasture production (t DM/ha)[1]	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 (May 2014 - April 2015)	**Nil-N**	**Plus-N**	**LSD**
Annual pasture production (t DM/ha)[1]	9.74	10.96	1.68
N response (%)		12.5	
Additional DM (kg/ha)		1217	
Annual fertiliser N applied (kg/ha)		112	
N response (kg DM/kg N)		10.9	
Partial Year 4 (May 2015 - January 2016)	**Nil-N**	**Plus-N**	**LSD**
Total pasture production (t DM/ha)[1]	6.74	7.92	2.14
N response (%)		17.5	
Additional DM (kg/ha)		1177	
Annual fertiliser N applied (kg/ha)		146	
N response (kg DM/kg N)		8.1	

[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 3. Nitrogen concentration in mixed pasture samples (% dry weight). LSD = Least Significant Difference at P<0.05.

Treatments	February 2015	Sep 2015
nil-N	2.62	3.79
plus-N	2.80	4.50
LSD	0.16	0.99

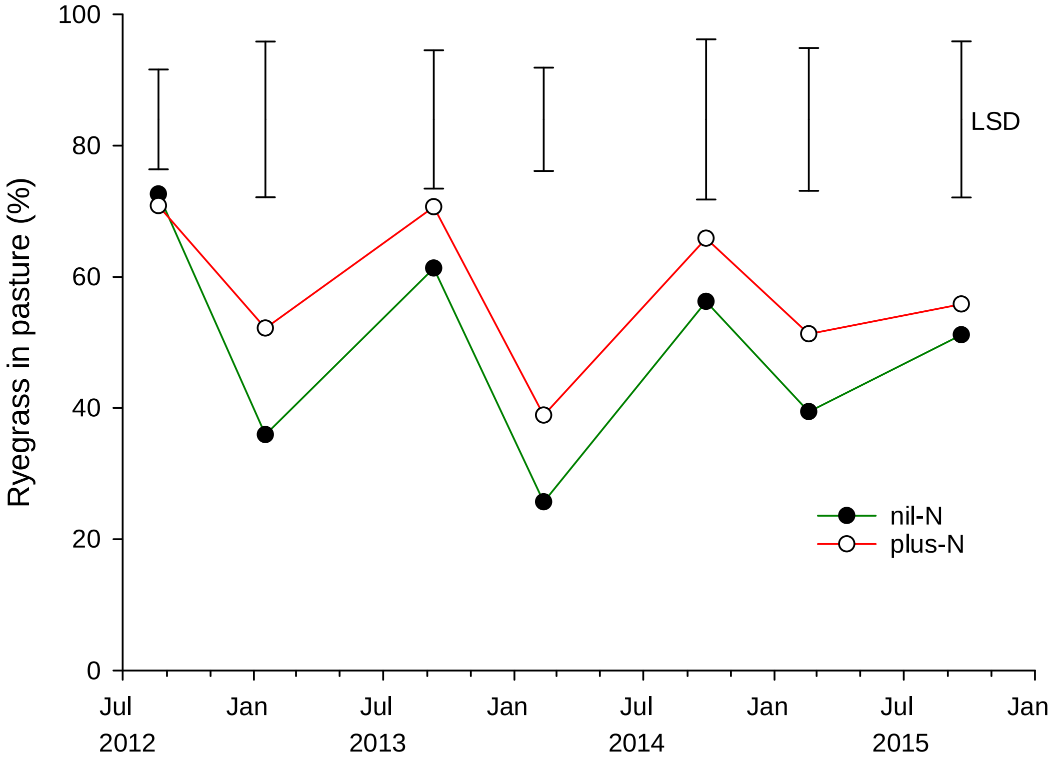

Figure 3. Pasture ryegrass content from 2012 - 2015. Error bars are least significant difference (LSD) at P<0.05.

Table 4. Botanical composition of pasture (% dry weight): August 2012 and September 2015. LSD = Least Significant Difference at P<0.05.

	Ryegrass		Browntop		Other grass		Legume		Weed	
Treatments	2012	2015	2012	2015	2012	2015	2012	2015	2012	2015
nil-N	73	51	10	10	10	18	5	12	2	10
plus-N	71	56	4	6	16	22	5	8	5	9
LSD	15.2	23.8	12.5	8.1	12.8	22.0	5.7	6.7	4.4	4.6

4.3 Nitrogen leaching

In 2015, average nitrate-N concentrations in leachate peaked in late July after 290 mm of drainage. Although the peak occurred at the same sampling in both the nil-N and plus-N paddocks, the plus-N peak was significantly higher ($P<0.05$) than the nil-N peak at 6.9 and 3.8 ppm, respectively (Figure 4).

In 2015, significantly more ($P<0.05$) nitrate-N was leached from the plus-N paddocks than the nil-N padocks with averages of 24.0 and 9.7 kg N/ha, respectively (Figure 5).

Ammonium-N leaching averaged 0.8 kg N/ha overall, with no difference due to treatment.

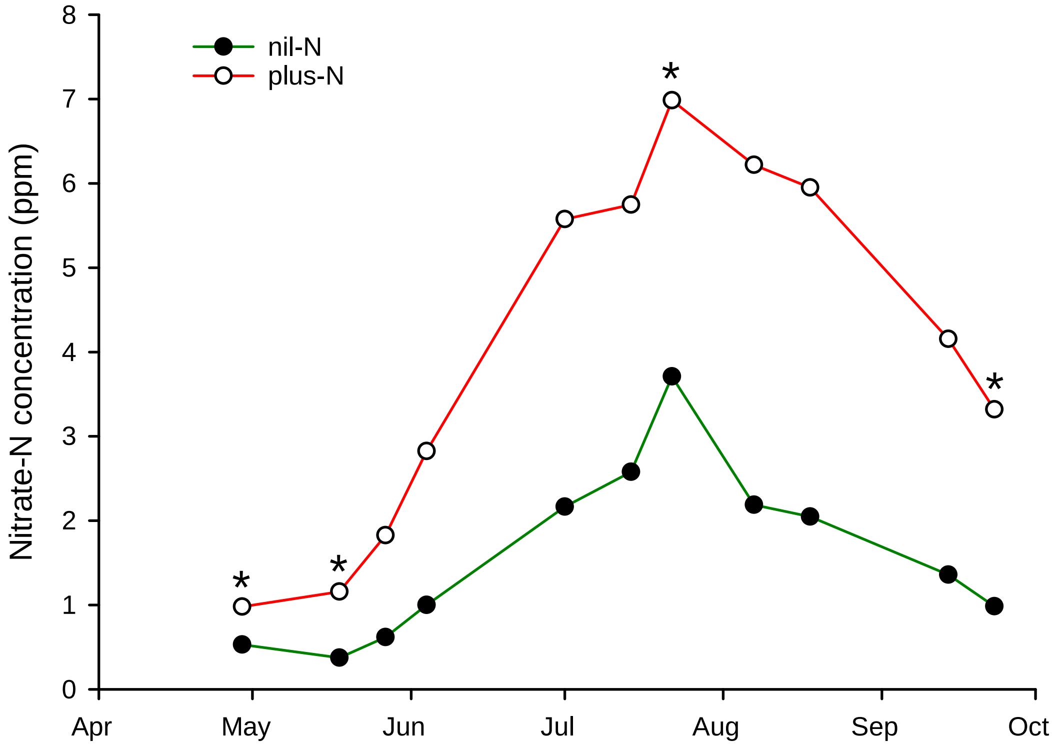

Figure 4. Nitrate-N concentrations in leachate during 2015. Data was log transformed for statistical analysis and back transformed for presentation. Asterisks indicate differences significant at $P<0.05$.

Figure 5. Annual amounts of nitrate-N leached below 60 cm depth. Note: 2012 sampling did not cover the full drainage period and hence underestimates total leaching (treatments only commenced in late April 2012 and therefore 2012 should be considered as a lead-in period only). Error bars are least significant difference (LSD) at P<0.05.

5. Discussion

5.1 Pasture response to N fertiliser

In the May 2014 to April 2015 year the pasture response to N fertiliser from the plus-N treatment compared to the nil-N treatment was 10.9 kg DM/kg N. This was similar to the average response over the full duration of the trial (10 kg DM/kg N). However, it should be noted that the severe drought in the summer of 2012/2013 limited pasture growth and hence N response in the first year of the trial. In comparison, the 10-year average response from a farmlet grazing trial on a Waikato dairy farm comparing nil-N and 200 kg N/ha/year was 16 kg DM/kg N (Glassey et. al. 2013).

5.2 Nitrogen leaching

In 2012, the different N fertiliser treatments did not commence until April. There was therefore insufficient time that winter for any treatment changes to become apparent at the 60 cm depth where the leachate samplers were buried. In 2012, unusually heavy summer and autumn rainfall (see Figure 1) meant considerable drainage had occurred before the collectors were installed. As a result, leaching measurements showed no treatment differences and underestimated total nitrate-N loss for the whole of the 2012 drainage period. In 2013, over four times as much nitrate-N (75 kg N/ha) was leached from the plus-N paddocks as from the nil-N paddocks (17 kg N/ha). The size of this difference was due in part to the interaction between N fertiliser timing and rainfall in that particular year. N fertiliser was applied in January (during a severe drought) and in late April as the drought broke (over 200 mm of rain fell in April and May). This resulted in a build-up and subsequent loss of nitrate-N in the plus-N treatment.

In 2014, the nitrate-N leaching was 26 and 20 kg N/ha ($P>0.05$) for the plus-N and nil-N treatments, respectively, while in 2015 it was 24 and 10 kg N/ha ($P<0.05$), respectively. The lower nitrate-N leaching in 2015 was associated with less drainage than in previous years (544 mm in 2015 compared with an average of 726 mm/year in the previous three years).

The OVERSEER® nutrient budgeting model was used to calculate nitrate-N leaching at Parekarangi in 2013 and 2014 (Watkins et. al. 2015). Average nitrate-N leaching from the plus-N treatment in 2013 and 2014 (51 kg N/ha) was similar to that predicted by the model (58 kg N/ha). However, average nitrate-N leaching from the nil-N treatment over the corresponding period was lower than predicted (19 versus 40 kg N/ha). A possible partial explanation is that the pasture %N analyses for the nil-N farmet showed relatively low levels over the years (e.g. 2.6-3.8%), which is below what OVERSEER would assume and therefore with less N cycling to contribute to N leaching. This may relate to the developing nature of the farm site, as discussed later.

Large variations in measurements of nitrate-N leaching from year to year are not unusual. Ledgard et. al. (2008) recorded annual N leaching losses of 81, 45 and 48 kg N/ha over three years on a Rotorua dairy farm receiving 72 kg fertiliser N/ha/year. Similarly, a three-year farmlet trial in the Waikato on ash soils, where average annual rainfall was 1200 mm, showed N leaching of 101, 78 and 59 kg N/ha/year for the 200 kg fertiliser-N/ha/year treatment (Ledgard et. al. 1999). That Waikato farmlet trial included a nil-N treatment (no N fertiliser applied) and over three years the nil-N farmlet averaged slightly less than half the amount of nitrate-N leaching compared to the 200 kg N/ha/year farmlet. Thus, the Waikato trial showed a similar relative reduction from stopping N fertiliser use to that achieved at Parekarangi in 2015. The actual amounts of nitrate-N leached in the Parekarangi trial in 2014 and 2015 were less than the losses recorded in the earlier Waikato and Rotorua trials. This may be due to the relatively recent conversion to dairying at Parekarangi (less than twenty years). Jackman (1964) looked at chronosequences of carbon and N accumulation in a range of soils and locations. The half-life for accumulation was >10 years for Oropi soil (the nearest regional comparison), indicating that some of the N input at Parekarangi might have been retained in the soil organic matter.

Ammonium-N leaching averaged 1 kg/ha/year over the four years of the trial and there was no significant difference between treatments.

6. Conclusion

From May 2014 to April 2015, with-holding N fertiliser reduced pasture growth by 11% (1217 kg DM/ha), while from May 2015 to January 2016 growth was reduced by 15%. These differences were not statistically significant and there was also no significant difference in the botanical composition of the pasture between the nil-N and plus-N treatments over the three years of the trial.

In 2015, the nil-N paddocks leached less than half the amount of nitrate-N as the plus-N paddocks (24 vs. 10 kg N/ha), a significant 60% reduction. This was similar to the N leaching recorded in 2014 (26 vs. 20 kg N/ha) and may more closely represent typical N leaching than the 75 kg N/ha leached from the plus-N paddocks in 2013.

Leaving aside 2012 as a lead-in year, the average reduction in pasture growth (January 2013 to January 2016) from with-holding fertiliser N was 13% (1.5 t DM/ha/year). The corresponding reduction in nitrate-N leaching for 2013 to 2015 was 67% (29 kg N/ha/year).

7. Acknowledgements

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8. References

Glassey C B, Roach C G, Lee J M and Clark D A 2013. The impact of farming without nitrogen fertiliser for ten years on pasture yield and composition, milksolids production and profitability; a research farmlet comparison. Proceedings of the New Zealand Grassland Association 75: 71-78.

Grossmann J and Udluft P 1991. The extraction of soil water by the suction-cup method: a review. Journal of Soil Science 42: 83-93.

Jackman R H 1964. Accumulation of organic matter in some New Zealand soils under permanent pasture. New Zealand Journal of Agricultural Research 7: 445-471.

Ledgard S F, Penno J W and Sprosen M S 1999. Nitrogen inputs and losses from grass/clover pastures grazed by dairy cows, as affected by nitrogen fertilizer application.. Journal of Agricultural Science 132: 215-225.

Ledgard S F, Ghani A, Redding M, Sprosen M S, Balvert S, Smeaton D 2008. Farmers taking control of their future: Research into minimising nitrogen and phosphorus from pasture land into Rotorua lakes. In: *Carbon and nutrient management in agriculture.* (Eds L.D. Currie and L.J. Yates). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 21. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 14 pages.

Watkins N, Shepherd M and Ledgard S F 2015. OVERSEER® Nutrient Budgets information base for the Rotorua catchment. Report prepared for Bay of Plenty Regional Council. RE500/2015/030

Woodward S J R, Barker D J and Zyskowski R F 2001. A practical model for predicting soil water deficit in New Zealand pastures. New Zealand Journal of Agricultural Research 44(1): 91-109.