NITROGEN LOSSES FROM LAKE ROTORUA DAIRY FARMS - MODELLING, MEASURING AND ENGAGEMENT

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Abstract

Dairy and drystock farmers in the Lake Rotorua catchment need to make large reductions in farm nitrogen (N) loss to meet the annual catchment target of 435 tN by 2032. Dairy farmers initiated a Sustainable Farming Fund Project in 2011 to promote adoption of N mitigation methods using three approaches: (i) differential N rate fertiliser trials on-farm; (ii) farm system modelling; and (iii) farmer engagement. These three strands of work were led respectively by AgResearch, Perrin Ag and DairyNZ.

Farm trials: Interim results from the N-rate plot trials on the Parekarangi Trust farm have indicated smaller pasture production differences than expected between the standard, strategic and nil N fertiliser treatments, with indicative fertiliser N response rates of 5.7-7.6 kg DM / kg N applied. Pasture composition is relatively consistent across treatments, with little indication yet of reversion to low productivity grasses in the strategic and nil N treatments. In contrast, a separate farm system trial at Parekarangi has shown that changing from regular to nil N fertiliser use has more than halved the nitrate-N leachate concentration.

Farm modelling: Three dairy farms were 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 nine dairy farms (plus three drystock farms) with additional BoPRC support, and extrapolated across all pastoral land in the catchment. Potential changes to land management were generally much more cost effective than land use change options, with average respective costs (capitalised) of $171 and $559 per kg N mitigated. Surveyed farmers also had a clear preference for management changes, compared with land use change. Based on farmer preferences, the overall cost of achieving the assumed pastoral share of catchment N reduction (270 tN/yr) was estimated at $88.1 million with additional capital value losses accruing to drystock farms.

Farmer engagement: 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. Project members have been active in working with BoPRC's collaborative Stakeholder Advisory Group (StAG) which is tasked with developing a "rules and incentives" package to achieve the pastoral share of catchment targets. Recurring messages from Rotorua dairy farmers include: practical, local and long-term farm trials and modelling are both important to understand N mitigation options; policy proposals need to be accompanied by explicit costings that are relevant to their farm situation.

The SFF project has received additional support from MPI and co-funders BoPRC, DairyNZ and Ballance Agri-nutrients through to March 2015. This will enable additional field trial results to be assessed and more robust science developed and disseminated on N mitigation efficacy and costs.

Background

The history of Lake Rotorua and its catchment provides important context for the farmer response to evolving policies on nutrient loss from farms. The farmer response included initiating the SFF project which is the subject of this paper.

The Lake Rotorua catchment faces major reductions in nitrogen losses to meet the sustainable annual nitrogen load of 435 tonnes (tN/yr) as defined in the Proposed Bay of Plenty Regional Policy Statement (RPS). Catchment modelling indicates that a reduction of 320 tN/yr is needed to meet the RPS target. With "engineering" reductions limited to 50 tN/yr[1], the balance of 270 tN/yr load reduction must come from the pastoral sector. Of the approximately 21,000 ha in pasture, about 5000 ha is dairy and 15,000 ha drystock land.

The context of the evolving catchment development and nutrient policy is summarised in Table 1 below (adapted from BORPC 2013 and other referenced documents).

Table 1: Lake Rotorua catchment development and policy timeline

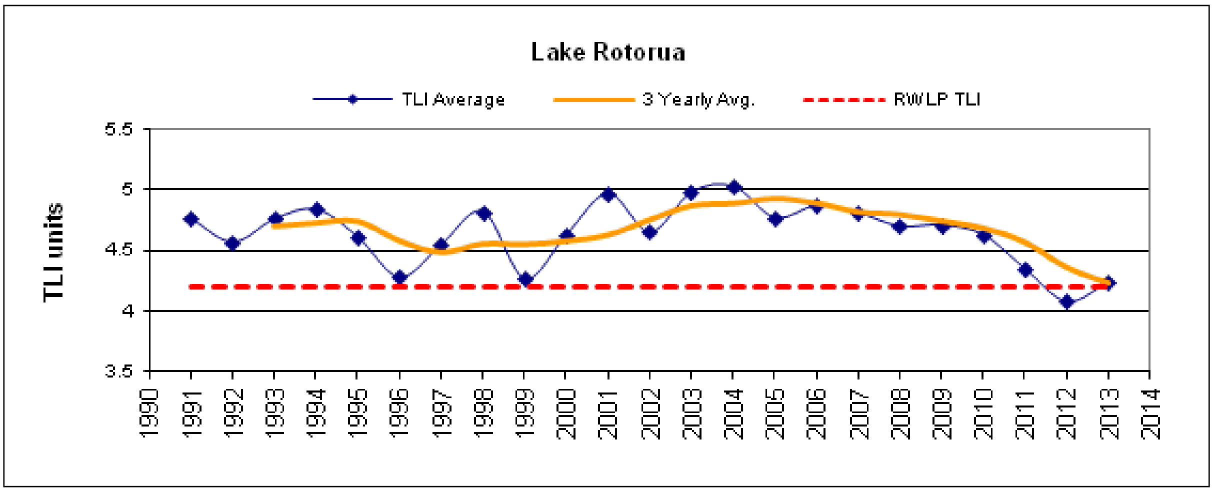
1890s - 1990s	**Land development**, influenced by land balloting (1920s), aerial topdressing (1950s) and progressive intensification
1970s and 1980s	The **Upper Kaituna Catchment Control Scheme** promoted subsidised soil conservation work on farms, including comprehensive stream margin retirement and planting, and gully erosion controls.
1991	**Rotorua sewage upgrade** incorporating treated effluent irrigation to Whakarewarewa forest. This scheme reduced N and P loads to the lake.
2002-	**Regional Water and Land Plan** was proposed in 2002 and became operative in 2008. It included a water quality target (TLI 4.2) and Rule 11 which caps N and P loss at 2001-2004 levels (BOPRC, 2008). Rule 11 benchmarking, using Overseer, occurred from 2008 onwards (Park and McCormick, 2009).
2007-2009	**Rotorua-Rotoiti Action Plan** initially proposed in 2007 and later finalised (see BOPRC 2009) with actions focused on engineering options, not land use, despite identifying pastoral land use as 72% to total N load.
2010	**Regional Policy Statement** proposed with specific 435 tN/yr sustainable load
2011	**ROTAN catchment modelling** by NIWA confirming the magnitude of reductions needed from the pastoral sector (Rutherford et al, 2011).
2011	**Lake Rotorua Primary Producers Collective and SFF project** established with a dairy focus (Collective now includes some drystock farmers); Collective and Lakes Water Quality Society sign Waiora Agreement on common goals.
2012	**Stakeholder Advisory Group** formed as collaborative effort to develop a rules and incentives package to achieve lake Rotorua nutrient targets from rural land.
2013	**Oturoa Agreement signed and RPS appeals resolved** (March/April) **–** this paved the way for rules development with the 435 tN/yr target stretched to 2032
2013	**Draft Rules and Incentives Framework** developed by the Collective and StAG, and subsequently endorsed by BOPRC in September 2013 (see details below).

[1] The 50 tN/yr engineering reductions are a combination of upgrades to sewage reticulation and treatment, septic tank upgrades, stormwater systems and, most significantly, denitrification of the N-rich Tikitere springs.

The Draft Rules and Incentives Framework developed in late 2013 was the first time that specific farm "Nitrogen Discharge Allowances" (NDAs) were proposed, being: 35 kgN/ha/yr for dairy farms, and; 13 kgN/ha/yr for drystock farms. When all farms meet their NDA, the net reduction will be 140 tN/yr. The balance of the 270 tN reduction from rural land will come from an incentive fund[2] (100tN) and gorse removal (30tN). Assumptions regarding the draft policy framework[3] include: NDAs need to be met by 2032; ranges are likely to replace single value NDAs; adjustments will be made to convert to Overseer version 6; farm nutrient plans will be a key part of farm NDA resource consents; permitted activity status is likely for small and/or low N loss properties (See StAG 2013 and BOPRC 2014 for more rules detail).

The nutrient policies being developed by BOPRC – with stakeholder input – are driven by a history of poor lake water quality. The water quality target was set at 4.2 TLI units (Trophic Level Index[4]), based on "acceptable" water quality comparable to the 1960s, and formalised within the Regional Water and Land Plan (BOPRC, 2008). BOPRC monitors water quality in Lake Rotorua monthly and reports TLI results annually, as shown in Figure 1 below. While the TLI was higher (i.e. worse) than the 4.2 target for much of the 1990s and 2000s, there is a marked recent improvement with the three-year rolling average TLI to 2013 actually meeting the lake target. This improvement has been attributed to the alum dosing of two streams that flow into Lake Rotorua and consequent lower in-lake P concentrations (BOPRC, 2013b).

Figure 1: Lake Rotorua water quality indicated by Trophic Level Index



Project Overview

In 2011 Rotorua dairy farmers formed the Lake Rotorua Primary Producers Collective and initiated a Sustainable Farming Fund project titled "Meeting nutrient loss targets on dairy farms in the Lake Rotorua catchment". The three project components are:

(i) Field trials at the Parekarangi Trust monitor farm to measure biophysical responses to interventions and mapping the farm to model management options.

(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.

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[2] The Government contribution to the $40m incentive fund is subject to Cabinet approval as at March 2014.
[3] All listed assumptions, caveats and draft NDAs are not BORPC policy and have no formal status.
[4] The TLI is used by the Ministry for the Environment as one of their national environmental indicators. It is calculated using four separate water quality measurements – total nitrogen, total phosphorous, water clarity and chlorophyll-a. A higher TLI means poorer water quality. See Burns et al (2000).

(iii) Establish discussion groups within the catchment to act as 'learning forums' where farmers will meet regularly with each other, scientists and regional council staff to test the efficacy of the intervention strategies (MAF, 2011).

The project started in July 2011 and was due to finish in June 2014 but has been extended to March 2015 to allow three years of data collection and analysis, plus dissemination of results.

Measuring: Parekarangi Trust Farm Field Trials

The two main field trials underway at Parekarangi are designed to assess different N fertiliser rates, plus a separate GIS mapping exercise to identify Critical Source Areas (CSAs).

Methodology

The **plot trial** has three urea N fertiliser treatments with nine replicates each:

(i) Standard "Plus-N", equal to N fertiliser use on the rest of the farm – this has equated to 265 kgN/ha/yr in Year 1 and 216 kgN/ha/yr in Year 2, with nil winter applications.

(ii) Strategic, with N fertiliser used only twice per year

(iii) Control, with nil N fertiliser applied

Standard farm rotational grazing occurs with associated pre and post grazing measurement by rising plate meter to estimate pasture growth. Urea is applied to the plots and surrounding area, usually at the same time as the post grazing plating. Herbage samples are collected for pasture composition analysis in autumn and spring of each year.

The **grazing system trial** started April 2012. It has two N treatments using a 6 x 2 paired paddock set-up with:

(i) Plus-N, with "typical" N fertiliser rates – this was 164 kgN/ha/yr in five applications April 2012-March 2013, and 105 kgN/ha/yr in 3 applications to date, April-Nov 2013

(ii) Control, with nil N fertiliser applied.

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. Measurements taken are: pasture production (plate meter); species composition; cow DM and N intake; N leaching after drainage events (giving 9 samplings May-October 2012); rainfall and soil/air temperature.

Interim Field Trial Results

The **plot trial** results for the first two years is summarised in Table 2 below.

Table 2: Plot trial pasture production from August 2011 to September 2013

	Year 1			**Year 2**		
Treatment	nil-N	strategic-N	plus-N	nil-N	strategic-N	plus-N
Annual fert N applied (kg/ha)	0	76	265	0	67	216
Annual pasture production (t DM/ha)	10.7	11.1	12.7	10.6	11.0	11.7
N response		4.1%	18.9%		4.5%	11.1%
additional DM (kg/ha)		432	2015		476	1176
N response (kg DM/kg N applied)		5.7	7.6		7.1	5.5

Table 2 is indicating relatively low N response rates, ranging from 5.5-7.6 kg DM per kg N applied. This contrasts with typical rates of 10-15 kg DM per kg N (DairyNZ, 2008).

The pasture composition has shown little variation between plot treatments. While the first two years showed no evidence of browntop reversion, a longer trial period is needed to be definitive. There appears to have been a slight clover increase in the nil N treatment.

The **grazing system trial** results for the first two years is summarised in Figures 2 and 3 below, respectively summarising N leaching and cumulative pasture growth.

Figure 2: Nitrate-N concentration in leachate April 2012 to December 2013

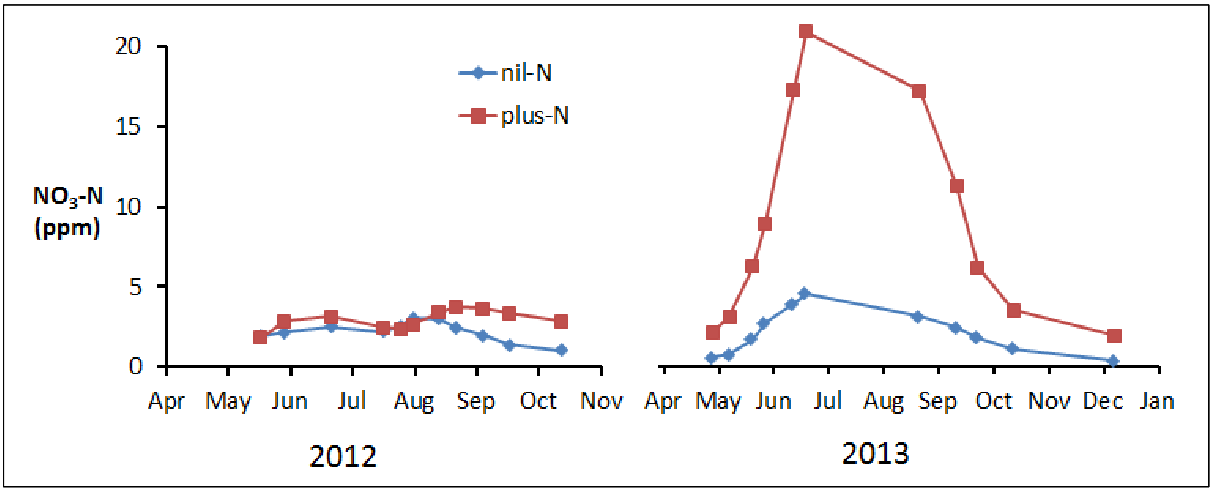
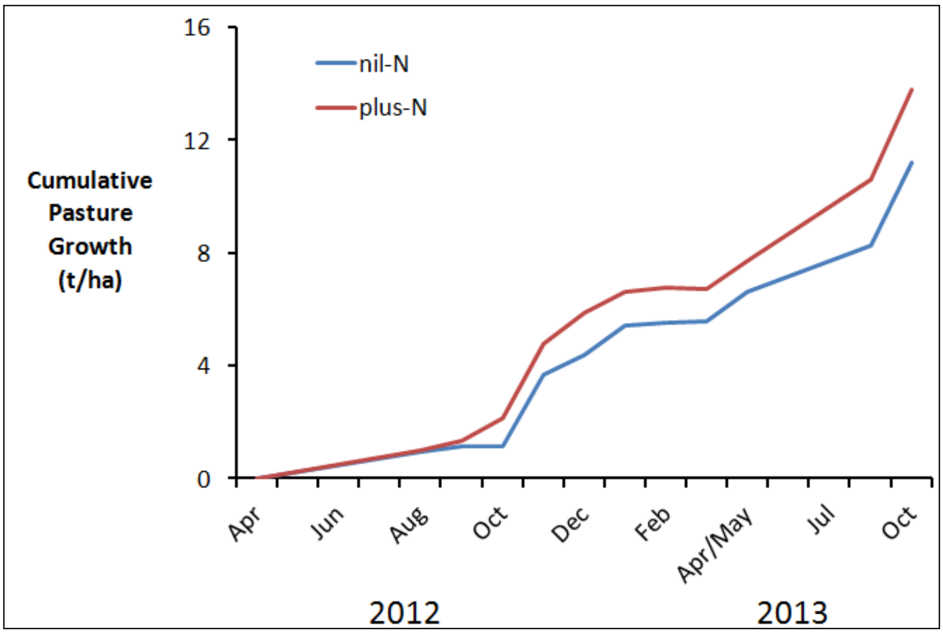


Figure 3: Cumulative pasture growth from grazing system trial April 2012 to October 2013



The field trial results presented in Figures 2 and 3 above are interim results. An additional year of data collection and statistical analysis is needed before drawing any firm conclusions. However, the following indicative observations can be made on treatment differences in the grazing trial:

(i) Nitrate concentrations in leachate appear much lower in the nil-N treatment.

(ii) Cumulative pasture production over 18 months was 19% lower in the nil-N treatment.

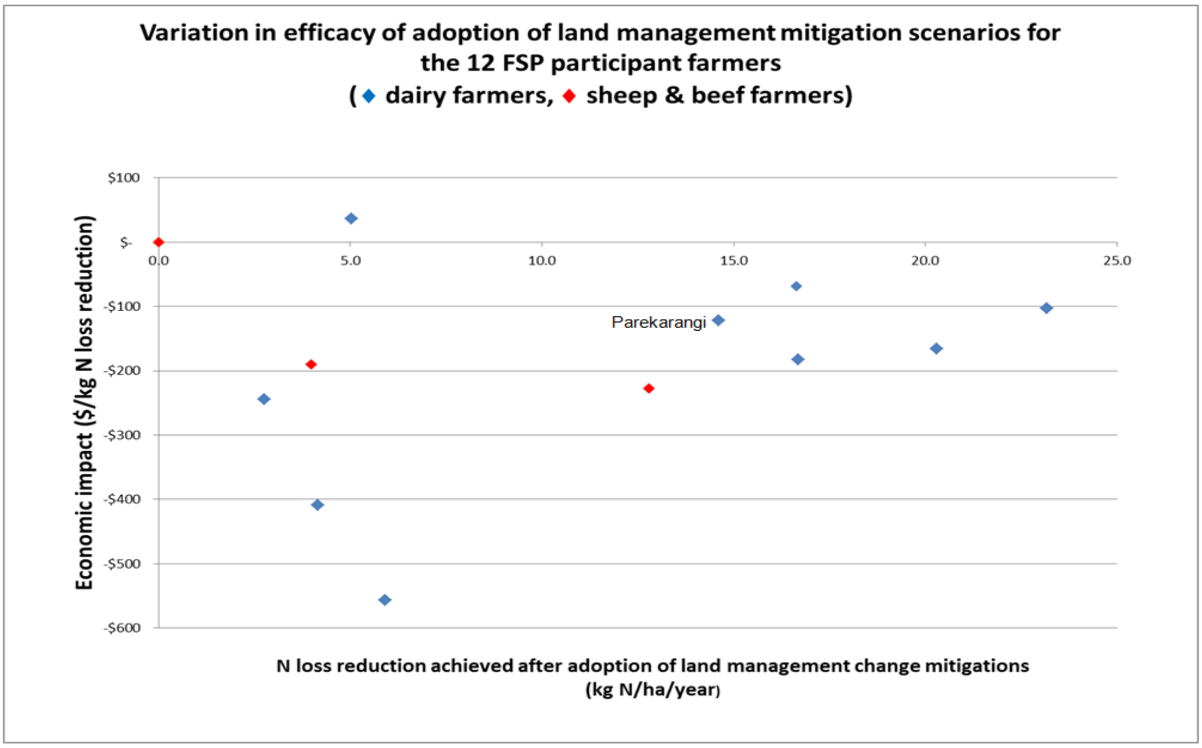
Modelling Rotorua Farms

The scope of Farmax and Overseer modelling has expanded from the three original project "focus farms" to 14 out of the 22 dairy farms in the Lake Rotorua catchment. Part of this expansion was via BOPRC funding of the Farmer Solutions Project (FSP) which built on SFF methodology, covering nine dairy farms and three drystock farms (Perrin Ag, 2012). This paper provides some FSP modelling results and a more recent single farm analysis.

Farmer Solutions Project

The 12 farms in the FSP were analysed for their current (2012) profitability and N loss using Farmax and Overseer (version 5.4.11) respectively. Mitigation scenarios were developed based on farmer preferences i.e. they were not optimised for cost-effectiveness. It should be noted that when the analysis was carried out by Perrin Ag, there were no farm-specific NDA values to target, even in draft form. In order to develop a "cost" per kg N loss reduction, the annual change in profitability was capitalised at a discount rate of 5% and then combined with any change in the capital position of the farm operation (investment, change in stock numbers). The results illustrate the wide range in N mitigation costs faced by different farms, as illustrated in Figure 4 below:

Figure 4: Farmer Solutions Project mitigation modelling results



In terms of the Parekarangi Trust farm where the SFF field trials are based, a relatively "modest" mitigation cost of $122/kgN was modelled for a 15kgN/ha/yr reduction. This reduction was based on halving N fertiliser use from approximately 200 kgN/ha/yr to 100 kgN/ha/yr, replacing the foregone pasture production with imported maize silage, an improvement in marginal N response and a slight reduction in stocking rate and associated reduction in PKE supplement. While this appears to be a promising N mitigation strategy, there are risks including:

- Volatility in cost of maize versus N fertiliser price

- Practicalities in feeding the required volumes of maize
- Is risk profile acceptable to the owners?
- Is the reduced stocking rate feasible on rolling country without reducing land area?
- A feed pad could be uses to improve efficiencies but it requires capital input.

Modelling the suggested dairy Nitrogen Discharge Allowance (NDA)

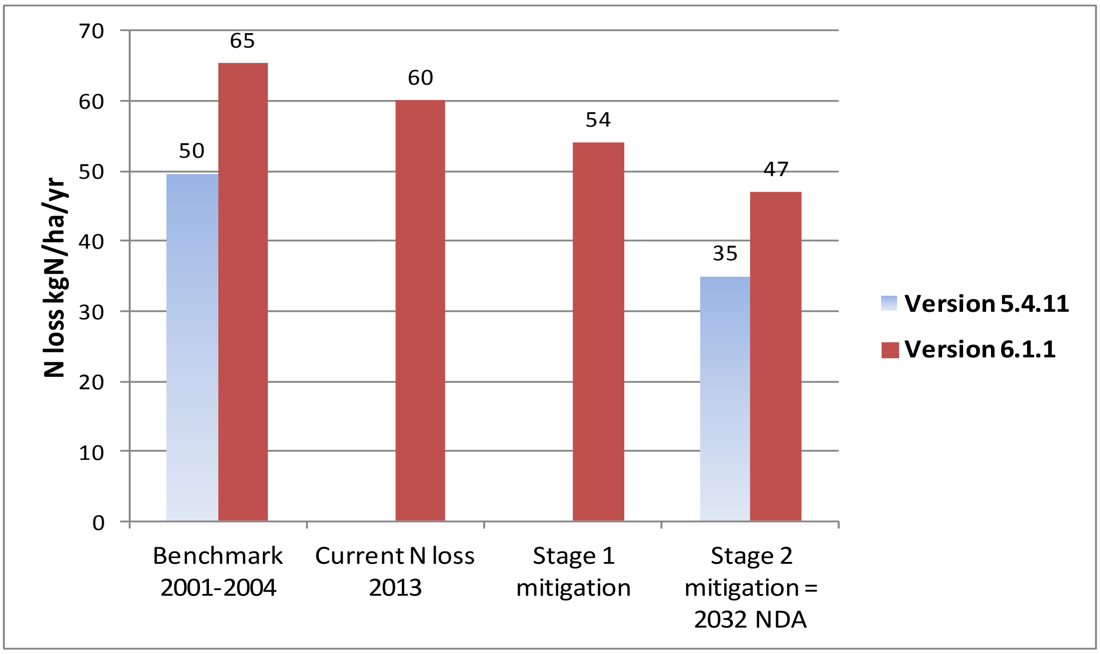
As noted in Background section, the suggested dairy sector NDA is 35 kgN/ha/yr which needs to be met by 2032. This was tested in February 2014 using an example Rotorua dairy farm that was mid-range in overall N loss at 50 kgN/ha/yr (its Rule 11 benchmark period of 2001-2004). This benchmark N loss equates to 65 kgN/ha/yr in Overseer 6.1.1. The same adjustment ratio (32%) was applied to estimate a "version 6" NDA target of 47 kgN/ha/yr.

Key farm parameters include: 200ha milking platform; 390kgMS/cow, 120kgN/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 7kgN/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 below.

Figure 5: Rotorua dairy farm N loss and NDA pathway



Engagement with Rotorua dairy farmers

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. Recurring messages from Rotorua dairy farmers include:

- practical, local and long-term farm trials and modelling are both important to understand N mitigation options;
- policy proposals need to be accompanied by explicit costings that are relevant to their farm situation.

Two field days have been run on Parekarangi Trust Dairy Farm in the autumns of 2012 and 2013, focusing 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 two field days and three workshop events is given in Table 3.

Table 3: Attendance at Project Engagement Events

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

Commentary on farmer engagement

Attendance at both field days was disappointing in that only about one third of the 22 Lake Rotorua catchment dairy farm 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:

(i) 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.

(ii) Discuss with modelled farmers how we can support the decision-making around one mitigation option i.e. going beyond the technical and economic changes.

(iii) Identify someone already implementing a commonly recommended mitigation who 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.

(iv) Going outside the catchment to a farm with similar resources that is effectively applying a common mitigation option and do as per (iii) above.

(v) Revisit Parekarangi more frequently as a focus point, provided there is new knowledge to be shared.

As indicated at the July 2013 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:

- a legacy of disconnectedness between the regional council and the farmers
- alternative opportunities for engagement with evolving nutrient policy via the Lake Rotorua Primary Producer Collective and the Stakeholder Advisory Group
- 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.

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 kgN/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 – 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.

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, as reported in the modelling section of this paper.

Conclusions

The project combination of field trials, modelling and farmer engagement is a powerful combination of methodologies to explore dairy farm nitrogen mitigation options.

The interim field trial results are showing greater than expected N leaching differences between the standard and nil N fertiliser treatments, associated with lower than expected pasture N response rates. The project extension to March 2015, plus robust statistical analysis, is needed to verify these trends, including the degree of pasture composition change. The final trial results should be suitable for future Overseer validation work.

Modelling of farm mitigations using Overseer and Farmax is a useful tool but there is a general farmer wariness of models, including how the change to Overseer version 6 has impacted the more familiar version 5 values associated with Rule 11 benchmarking and earlier modelling work. There have also been modelling challenges in addressing some mitigations such as wintering barns. Mitigation cost-effectiveness varies widely between farms and many farms will face substantial costs in meeting their NDAs.

Farmer engagement during the project has been more difficult than expected, due to a combination of competing policy-focused fora (e.g. Stakeholder Advisory Group) and the uncertainty of farm-specific NDA limits. The latter challenge was inevitable given that the project commenced when the regional policy framework was only established at the catchment level i.e. the 435 tN/yr by 2032 target in the Regional Policy Statement. Farmers also have a strong desire to see recommended mitigations fully tested locally at the farm scale rather than just modelled or tested in small plot trials.

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