N-leaching in hill country; farmer led research

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Abstract

There is scant information on nitrate-N leaching in East Coast hill country. Castlepoint Station, a focus farm in the Wise Use of Fertiliser Nitrogen (N) project and in the face of potential restrictions on fertiliser N use, ran a 3 year trial focused on the impacts of N fertiliser on pasture and animal production as well as nitrate leaching. The paddock-scale trial was run by the focus farm community group, a farm consultant, and representatives from the Regional Council and AgResearch. Fertiliser N (0, 60 and 120 kg N/ha) (0N, 60N and 120N, respectively) was applied as urea annually in early August. Twinning ewes were stocked at rates modelled by Farmax for poor pasture growth. Young cattle were added to maintain pasture control in the event of an average or favourable growing season. Application of fertiliser N increased pasture and animal production for both of the rates used. The 3 year mean annual amount of nitrate-N leached from the 120N treatment was 3x that from the 0N treatment and 2x that from the 60N treatment ($P<0.05$). There was no significant difference in the 3 year mean annual amount of nitrate-N leached between the 0N and 60N treatments ($P>0.05$). Early August application of fertiliser of 60N had no significant impact on annual nitrate-N leaching in this East Coast hill environment. Research initiated and led by farmers successfully contributed to increased understanding of management impacts on nitrate-N leaching losses in East Coast hill country. Implications for on-farm research are discussed.

Keywords: fertiliser nitrogen, nitrate-N leaching, East Coast hill country, community group

Introduction

In March 2005 Castlepoint Station was asked by the Wairarapa Monitor Farm Committee if they would take over hosting the local Wise Use of N project. Media discussions at the time about the effects of nitrate-N leaching on Lake Taupo meant Castlepoint Station had concerns about potential restrictions of fertiliser N use based on policy developed elsewhere, dealing with situations which may not be analogous. In the Wise Use of N project (national series) nitrate-N leaching was measured at Ballantrae (southern Hawkes Bay) and Invermay (Otago). There were no data collected on nitrate-N leaching in dry hill country. There was local interest in collecting water quality data to determine the effect of a single late-winter urea application on nitrate-N leaching in summer-dry hill country. The leachate work required an additional $32 000 to set up and $15 000 p.a. for the 3 year trial.

The objective of the Castlepoint Nitrogen (N) Trial was to measure the impact of fertiliser N application on pasture and animal production and on nitrate-N leaching from pastures which had received 0, 60 and 120 kg N/ha/yr as urea, in a single late-winter application in each of 3 years (mid 2005-mid 2008). The pasture and animal production results have been covered elsewhere (www.wisenuse.co.nz). This paper focuses on the leaching results and on lessons learned by the participants about the process of on-farm research.

Materials and Methods

Trial site and management

Castlepoint Station is a 3 000 ha coastal hill sheep and beef property located in the Wairarapa (40°55'S, 176°10'E). Just over half the station's area is classified as easy undulating terrain, with 37% rolling to steeper land and10% flat land. The soils are derived from mudstone and are intergrades between yellow-grey and yellow-brown earths. The soils at the trial sites are a mixture of Taihape steepland and Atua silt loam on easier topography. Average annual rainfall is 1 026 mm, falling mainly over the late autumn and winter, with occasional summer rain events. Late spring and summer are typically dry, particularly with the onset of equinoxial winds in late September/October. These drying northwest winds are often extreme at Castlepoint Station. In 2005, at the start of the N Trial, the station carried 21 500 sheep and 1 300 cattle. The N Trial was located on two northwest faces of medium-steep hill country. The area had been in pasture for about 50 years, with the herbage species a mixture of the high fertility demanding ryegrass (*Lolium perenne*) and the low fertility tolerant grasses, crested dogstail (*Cynosurus cristatus*) and danthonia (*Danthonia sp.*), and white clover (*Trifolium repens*).

In May/June 2005, two northwest faces about 500 m apart were selected as trial sites. Each of the areas was fenced into 3, 10 ha paddocks. The three experimental N treatments (0, 60 and 120 kg N/ha/yr) were arranged in a randomised block design on these two areas (referred to in this paper as the Northern and the Southern blocks) and the fertiliser treatments randomly assigned to one of the 3 paddocks within each of the blocks. Fertiliser N was applied in a single application of urea in early August of each year.

Castlepoint Station supplied pasture growth data from another trial (Pasture Plan) so that stocking rates could be modelled using FARMAX. The trial was designed so that the set-stocked ewes and their lambs could remain in the paddocks in a poor growth year. If the pasture growth rates were average or better, rising 1 year-old heifers would be added for pasture control. The paddocks were set-stocked with twinning ewes a week after the urea application. The ewes and their lambs grazed the paddocks until weaning in late November. To keep control of the pasture in the spring flush, heifers were added to the trial areas to keep pasture covers in the target range (1 200-1 800 kg DM/ha). Stock was weighed on and off the trial areas so that animal production could be calculated. Pasture covers were estimated weekly with an electronic probe ('Grassmaster II') during the time that ewes and lambs were set-stocked. After weaning, various classes of sheep and cattle grazed the pasture for the remainder of the year.

Nitrate-N leaching measurements

Ten mini-lysimeters per paddock were used to measure the quantity and quality of water draining to 300 mm below the soil surface. These were positioned along the hillside to represent a balance of low (0-12°), medium (13 – 25°), and high (>25°) slope areas in each paddock. The lysimeters (150 x 300 mm) were rammed *in situ*, with the surface of each lysimeter being about 2 mm below the soil surface (Sakadevan *et al*. 1993). Once installed, each lysimeter was left to settle for about 4 weeks before leachate collection began (July 26, 2005).

Collection and sub-sampling of lysimeter drainage water was conducted by Greater Wellington Regional Council (GWRC) staff. The drainage water or leachate from each lysimeter was collected monthly or after 100 mm of rainfall, whichever occurred first. At each collection the volume of drainage water was measured and its nitrate-N concentration was determined by flow-injection spectroscopy. The amount of nitrate-N leaching from each individual lysimeter was calculated as the product of the volume of drainage water and the concentration of nitrate-N at that sampling.

Two field days were held during the trial and stakeholders in the project held discussions at various stages throughout the project. It was from these discussions that key points on the perceived successes of the project were constructed. These key points are presented in the discussion section of this paper. Formal collection of data to determine the success of the project was not conducted.

Statistical Analysis

The effect of block, N rate, year and the interaction between N rate and year on the amount of nitrate-N leached was subject to analysis of variance using GenStat 10 (2007).

Results

Rainfall and drainage

Annual rainfall was close to the 20 year average of 1 026 mm for the 2005/06 and 2007/08 years (960 and 978 mm, respectively), but below average in 2006/07 (722 mm) because of a dry summer. In 2005/2006 drainage through the mini-lysimeters was 60% of rainfall compared with 53 % of rainfall in 2007/08. In the lowest rainfall year (2006/07), 55 % of rainfall was measured as drainage.

There was no significant difference between N rates for water drainage from 300 mm below the soil surface (Table 1). Over the three measurement years drainage from the Southern block (S) lysimeters was 20% greater than from the Northern block (N) for all

Table 1 Annual drainage (mm) from 300 mm below the soil surface as affected by block, slope, fertiliser N rate and year over 3 years at Castlepoint Station 2005 – 2008.

	Annual drainage (mm)						
N rate	0N	60N	120N	mean	Effect	Probability	LSD
2005/06	539	528	672	580 b[1]	Block	0.05	S > N
2006/07	347	372	459	392 a	Slope	<0.001	L,M >H
2007/08	470	484	576	510 b	N rate	NS (>0.10)	127
					Year	<0.005	105
Mean	452	461	569		N rate x Year	NS	

[1]values followed by different letters within the annual mean column are different at the 5 % level

of the N treatments (447 versus 541 mm, respectively). Interestingly, across all years and N rates, low (0-12°) and medium slope (13-25°) areas drained more than twice as much water than did high slopes (>25°) (613, 523 and 241 mm, respectively).

Nitrate-N leaching

Over the 3 year trial, nitrate N leached annually from the 120N treatment exceeded that from the control and 60N treatments ($P<0.001$). The nitrate-N leaching from the 120N treatment averaged about 3x the control and twice that from the 60 N treatments (24 and 40 versus 79 kg nitrate-N/ha, respectively). Over all years and N fertiliser treatments the amount of nitrate-N leaching from the Northern block was 1.4 x that from the Southern block (56 versus 39 kg nitrate-N/ha/yr, respectively), and low and medium slope areas leached 5 x the nitrate-N than did the high slope areas ($P<0.001$) (61, 53 and 12 kg nitrate-N/ha/yr, respectively).

The annual volume weighted concentrations of nitrate-N were higher for low and medium slopes than for the high slopes for all N rates (Table 2). The range in concentrations of nitrate-N for all slope categories and for all N rates was large, especially for the medium and low slopes.

The FARMAX modelling proved to be accurate, despite dry springs in Years 2 and 3, although no ewes and lambs had to be removed.

Table 2 Mean (range in brackets) annual volume weighted concentrations of nitrate-N (mg nitrate-N/L) in the leachate at each slope category and overall for the three fertiliser N rates.

	Volume weighted concentration of nitrate-N (mg nitrate-N/L)		
N rate	0	60	120
Low slope	5.6 (0.2 – 29.5)	11.4 (0.1 – 36.1)	48.6 (1.4 – 287.2)
Medium slope	15.8 (0.5 - 143.8)	21.3 (1.2 – 115.1)	21.7 (0.1 – 106.1)
High slope	4.8 (0.6 – 12.5)	8.8 (0.1 - 39.1)	13.2 (2.9 - 31.1)
Overall mean	12.1	16.8	26.3

Discussion

Conducting grazing and leaching measurement trials in hill country is challenging due to the physical constraints and the spatial heterogeneity of pasture and soil in this environment.

Over the 3 year measurement period, paddocks which had received 120 kg fertiliser N in late winter leached approximately two to three times as much nitrate-N as paddocks that had received either no fertiliser N or 60 kg in late winter. There are few reports of hill country grazing trials in which the direct measurement of nitrate-N leaching has been attempted. The results presented in this paper are therefore unique and comparisons with work from other environments are limited.

In any grazing trial the number and placement of devices to measure N leaching is particularly crucial as excreta N (the major contributor to N leaching in grazing systems) is deposited in a non-uniform manner (Haynes & Williams 1993). Because of animal camping behaviour, medium and low slope areas of hill country are more likely to receive excretal N input than high slope areas. In hill country nutrient transfer from areas of high slope to more moderately sloped or flat areas has been well documented (Saggar *et al.* 1990). In addition to the non-uniform return of excreta N, slope and aspect are major determinants of differences in soil chemical and physical characteristics, soil temperature and moisture and thus pasture production (Lopez *et al.* 2003). In this study the aspect (northwest) was identical for all paddocks. In all paddocks the medium and low slope areas leached more nitrate-N than the high slopes. This was partly because high slope areas leached less volume of leachate compared to the low and medium slopes. However, the volume weighted concentration of nitrate-N was also higher for medium and low slopes than for the high sloped areas.

The absolute amount of nitrate-N measured as leaching from all of the treatments, including that from the control areas, was higher than expected. The lysimeters used were shallower than lysimeters commonly used to measure nitrate-N leaching in New Zealand (300 mm versus 500-1 000 mm depth). They were also shallower than ceramic cups which are commonly placed to measure nitrate-N leaching in grazed areas in New Zealand (300 versus 600 mm depth). The shallower measurement depth may partly account for the higher than expected amounts of nitrate-N leaching (Pakrou & Dillon 2000), however, we are aware of no other comparable published information. One study conducted in New Zealand hill country, albeit in a higher rainfall environment, gave values of volume weighted concentrations of nitrate-N in lysimeter drainage water within the range measured in this trial, at comparable levels of management intensity (Puha *et al.* 2008).

Although we report the amount of nitrate-N measured as having leached from below the root zone of the pasture plants, there is no published information available to assist in determining the impact of the results on surface and ground water within the catchments concerned. Indeed, few studies have been done on the transformations of nitrate-N which occur at depth in the soil profile, or how long these nutrients remain in the soil profile before being transported to the nearest surface or ground water. Hence, the actual quantitative N leaching values presented here should be treated with caution.

1. There were a number of issues that made setting up an on-farm trial difficult:
2. Finding adequate area for a replicated trial.
3. Allocating paddocks that were consistent in contour and soil fertility.
4. Having similar pasture covers on the areas at the start of the trial.

From a scientist's perspective, the enthusiasm, dedication and determination of the owners and staff of Castlepoint Station, the community group and farm consultant, firstly to make this trial a reality and then to see it to conclusion, was vital to its success. From previous experience of working with farm owners on science trials, and then with the Castlepoint N trial, the key elements of success for on-farm science trials are:

1. Farmer ownership and enthusiasm both initially and throughout the trial.
2. Mutual trust between the farmer and the scientist. The farmer needs to trust that what the scientist is suggesting for the trial set-up, management and monitoring is important to its success. The scientist needs to trust that the trial management is carried out as previously agreed, and that the vital measurements previously agreed to will indeed be made.
3. Constant and open communication between all parties involved. In the case of the Castlepoint trial, regular meetings kept everyone up to date and involved. All parties may be out of their comfort zones and may have very different perceptions of a situation so nothing should be taken for granted.
4. Trust by all parties involved in the trial (i.e. farm owners, farm staff, community group, regional council and scientists) that they will be listened to.

The benefits of conducting on-farm research from a scientist viewpoint were:

1. Enables the scientist to keep in touch with the farming community and the various pressures that the farming community experiences from one year to the next. It also helps the scientist to maintain enthusiasm about their own area of research.
2. Reinforces the need for scientists to communicate their results effectively to a wide range of audiences.
3. Encourages scientists to listen and consider the opinions and ideas of another group of people whom they may not otherwise make contact with or discuss their ideas with.
4. Ability to conduct paddock scale trials, which hold greater weight with farmers, rather than small plot trials.

From a farmer's viewpoint, more work was generated in the weighing of stock and estimating pasture covers. However, being more "scientific" had many advantages:

1. Large numbers of actual weights brought into focus issues that do not stand out in small sample weight averages (i.e. a 20 kg range in ewe body weights).
2. Having data can provide unanticipated benefits. Since Castlepoint Station had data from the Pasture Plan trial, we could produce more accurate inputs for the FARMAX modelling of the N trial. Since we were already doing extra monitoring work for the N trial, doubling up with another study looking at ewe death rates uncovered the high cost of a low level of foot rot in the ewe flock, which then could be addressed.
3. The trial provided a new approach to spreading urea on hills; 60 kg N/ha is applied to only the top two thirds of the paddock rather than 40 kg N/ha applied over the whole paddock. This reduces application cost and keeps urea further from waterways. It also promotes grass growth at the top of hills where sheep tend to congregate.
4. The trial also provided the opportunity to rub shoulders with scientists and other specialists.

Conclusions

Under intensive grazing management, late winter applications of up to 60 kg fertiliser N/ha are unlikely to increase the annual amount of nitrate-N leaching from sheep and cattle-grazed summer-dry East Coast hill country compared with areas that receive no fertiliser N. In this environment applications of 120 kg fertiliser N in late winter are likely to increase the annual amount of nitrate-N leaching compared to areas that receive no fertiliser N or up to 60 kg/ha.

Low (0-12°) and medium (13-25°) slopes leached more nitrate-N than high (>25°) slopes irrespective of whether the area had received 0, 60 or 120 kg N/ha in late winter. This was due to both soil water drainage volume and the concentrations of nitrate-N being greater in low and medium rather than high sloped areas. There may be scope to use this information to apply fertiliser N in hill country differentially based on slope class, although simultaneously altering the behaviour of animals grazing these areas could be difficult. There is a need for further studies into the movement and cycling of N in these soils and in this summer dry environment.

From a farmer's viewpoint, more urea grew more grass. However, if the system is not adjusted to consume the extra grass it will not be profitable. Likewise, with the price of urea increasing 66% ($504/t applied in Aug 2005, $838/t in Aug 2009) and the price of prime lambs only increasing 19% ($3.95/kg in Dec 2005, $4.70 in Dec 2005) applying N as described would not be profitable if taken in isolation. Applying the trial method on a whole farm basis would not be feasible as insufficient stock could be carried through winter to fully utilise the feed that is grown after applying 120 kg N/ha.

With an on-farm science trial all stakeholders examined resources and farm management practices more closely than they would have otherwise, which increased understanding of the implications of farm management decisions by all. The opportunity for different organisations to work together can be productive, leading to a greater understanding of the issues.

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