NITROGEN LEACHING AS AFFECTED BY DAIRY INTENSIFICATION AND MITIGATION PRACTICES IN THE RESOURCE EFFICIENT DAIRYING (RED) TRIAL

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Abstract
The Resource Efficient Dairying (RED) farmlet trial evaluated the environmental implications of intensification of dairy farming. It included a low-input farmlet with 2.3 cows/ha (nil N fertiliser), a “control” with 3.0 cows/ha (fertiliser N at 170 kg N/ha/year), a “stand-off” farmlet (same as the control except that cows spent 18 hours/day on a stand-off pad from mid-May to early-July), a “low supplementation” farmlet (same as the control except that cows were supplemented with maize silage at the equivalent of 5.5 t DM/ha/year; 3.8 cows/ha), a “moderate supplementation” farmlet (same as the control except that cows were supplemented with maize silage at the equivalent of 13.2 t DM/ha/year and soybean meal at the equivalent of 0.1 t DM/ha/year; 5.3 cows/ha) and a “high supplementation” farmlet (same as the control except that cows were supplemented with maize silage at the equivalent of 21.7 t DM/ha/year and soybean meal at the equivalent of 1.6 t DM/ha/year; 7.0 cows/ha).

Detailed measurements were made of nitrogen (N) leaching within the low input, control, stand-off and low supplementation farmlets. Calculation of N leaching losses from all the RED farmlets were also made using Overseer nutrient budget model. Application of N fertiliser at 170 kg N/ha/year increased milksolids production by approximately 20% but increased N leaching per hectare by at least 2-fold. The stand-off farmlet had similar milksolids production to the control farmlet but had about 25% lower N leaching per hectare. Low maize supplementation increased milksolids production by 30% but produced no significant increase in N leaching loss per hectare. However, leaching losses were relatively high in the area of land used to produce supplementary feed, and therefore the whole-system efficiency (total kg N leached per kg milksolids produced) was reduced when supplementary feed increased.

Introduction
Milk production on dairy farms can increase through several factors including increased feed supply through greater use of N fertiliser and increased use of supplementary forage feeds. Potentially, the integration of low-protein forage (e.g. maize) to reduce dietary-N concentration can reduce N leaching losses and increase efficiency (e.g. Jarvis et al., 1996). Strategic use of a feed pad or stand-off pad (e.g. 6-hour grazing and 18-hour stand-off per day) during wet winter season can also potentially reduce N leaching. Effects of these strategies on resource use efficiency and environmental emissions such as greenhouse gas emissions and N leaching need to be tested in the field.

A Dexcel Resource Efficient Dairying (RED) farmlet trial to evaluate new intensive dairy farm systems commenced in 2001, involving treatments with integration of N fertiliser, maize silage and winter management strategies (Clark, 2003). A key goal of this trial was to define farm systems that can increase milk production and profitability while at the same time minimising N losses to the environment. The economic and environmental effects of different feed inputs and management practices were examined. In this paper we summarise data of milk production and N leaching obtained from the dairy farm systems in the RED trial. Detailed production and economics were described by Jensen et al. (2005), while greenhouse gas emissions from these dairy farm systems were reported by Luo et al. (2006).

Materials and methods

Six experimental farmlets were located on the Scott Research Farm, Dexcel near Hamilton. Feed varied from 15 to 40 t DM/ha/year, with stocking rate ranging between 2.3 and 7 cows per ha (Table 1). The treatment design was based on achieving the same comparative stocking rate (CSR) of about 85 kg LW/t feed DM across all treatments. There were 21 Holstein-Friesian cows on each farmlet with farmlet size varying from 3 to 9 hectares.

Table 1. Resource efficient dairying (RED) trial design. Farmlet stocking rate, N fertiliser rates and feed inputs representing the averages for 2003-2005.

Farmlet	Stocking rate (cows/ha)	N fertiliser (kg N/ha/yr)	Maize silage (t DM/ha/yr)	Soybean meal (t DM/ha/yr)
Low input	2.3	0	0	0
Control	3.0	170	0	0
Stand-off	3.0	170	0	0
Low supplement	3.8	170	5.5	0
Moderate[1] supplement	5.3	170	13.2	0.1
High[1] supplement	7.0	170	21.7	1.6

[1] These farmlets were also irrigated on an ‘as required’ basis.

All farmlets were based on perennial ryegrass-white clover pastures (perennial ryegrass, *Lolium perenne*; white clover, *Trifolium repens*) receiving 170 kg fertiliser N/ha per year except the ‘Low input’ farmlet which received no N fertiliser and carried four yearling heifers as replacements throughout the year. The ‘Control’ farmlet was estimated to grow 17.5 t DM/ha/yr with a stocking rate of 3.0 cows/ha. The ‘Stand-off’ farmlet was similar to the ‘Control’ but cows had access to an uncovered, bark-sawdust pad that was used from late autumn-early spring. The ‘Low supplement’ farmlet had 3.8 cows/ha with bought in maize silage. The ‘Moderate supplement’ farmlet had 5.3 cows/ha with irrigation based on measured water deficit and higher maize silage input. The ‘High supplement’ farmlet had 7.0 cows/ha with irrigation and maize silage plus soybean meal to achieve sufficient crude protein for lactation. The farmlets were spread over three soil types: a poorly drained Te Kowhai silt loam, a moderately well drained Te Rapa humic silt loam and a well drained Horotiu silt loam, which is typic orthic allophonic soil (Soil Survey Staff, 1990).

Nitrogen leaching losses from four farmlets (Low input, Control, Stand-off and Low supplement) were measured during drainage seasons in 2004 and 2005. Maize growing for silage followed by annual ryegrass was carried out on nearby land and the annual maize yield was about 21 tonnes dry matter ha^{-1}. N leaching losses were also measured from the maize-growing land. Porous ceramic cup collectors were used to collect soil solution below plant rooting depth. About 72 collectors were installed in replicate paddocks of each farmlet. Collectors were inserted approximately 90 cm below the soil surface. At each sampling a small tension was placed on the ceramic cup to collect a sample of the surrounding soil solution. Samples were analysed for nitrate and ammonium-N by using a segmented flow autoanalyser. Drainage was estimated by collecting water draining through nearby lysimeters containing intact soil cores.

Results and discussion

Milk production

Average milksolids production between 2002 and 2005 is summarised in Figure 1. All farmlets produced around 400 kg milksolids per cow. Application of N fertiliser at 170 kg N/ha/year increased milksolids production by approximately 20%. The stand-off farmlet had similar milksolids production to the control farmlet. Supplementary feed increased milksolids production by 35% to 150%, depending on the supplementary feed rate.

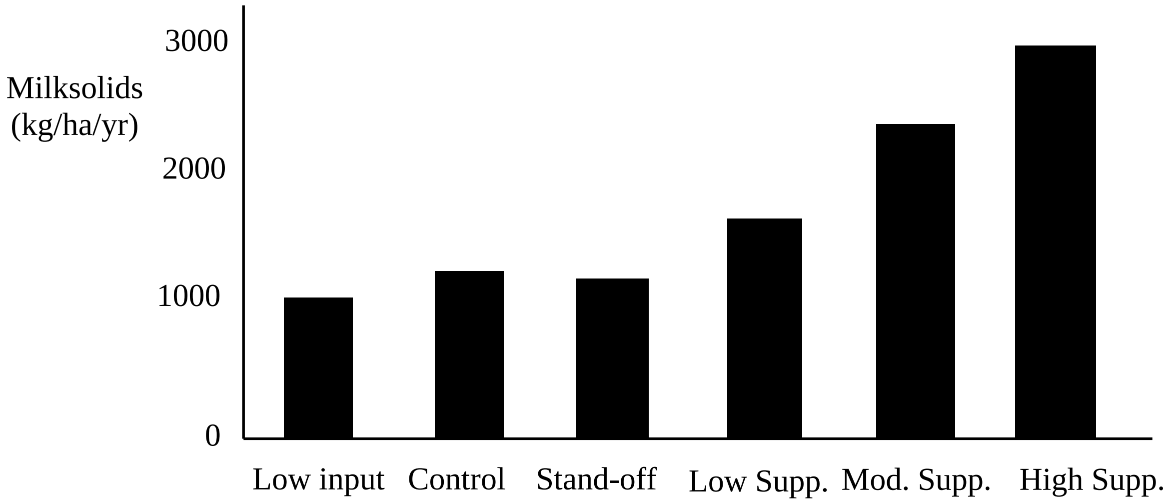

Figure 1. Average annual milksolids production (2002-2005).

Nitrogen leaching

Ammonium-N concentrations in most of samples taken from the farmlets were below the detection limit of 0.4 mg l^{-1} for the method (data not shown). The nitrate-N concentrations showed temporal variation between sampling times (data not shown). Average annual nitrate leaching rates for 2004 and 2005 from the dairy farms were given in Figure 2. These data demonstrate that the control farmlet due to application of N fertiliser at 170 kg N/ha/year increased N leaching per hectare by at least 2-fold compared to the low input farmlet. The stand-off dairy farmlet reduced annual nitrate leaching losses by 25% compared to the control farm, while the maize supplementation farmlet (low supplementation farmlet) had similar annual nitrate leaching losses with the control farm.

As expected, the lower N leaching losses from the stand-off farmlet (Figure 2) would be due to less excreta input to the soil during the high risk wet winter and early spring seasons (Ledgard et al., 1996). Similar N leaching losses between the low supplementation farmlet and the control farmlet may have been caused by a reduction of the N concentration in urine patches resulting from the supplemental feed of low N maize silage (Jarvis et al., 1996).

While the stocking rate was 3.8 cows ha^{-1} on the low supplementation farmlet compared to 3.0 cows ha^{-1} on the control farmlet, the amount of excreta N deposited on the low supplementation farmlet was only slightly higher than that on the control farmlet (Luo et al., 2006).

Nitrogen leaching losses were relatively high (about 70 kg N/ha/year) in the area of land used to produce maize silage. The high leaching loss was mostly due to increased mineral N resulting from soil cultivation and application of N fertilisers (a total of 178 kg N ha^{-1} was applied during maize growing season). The cultivation increased soil porosity and consequently increased diffusion of O_2 into the soil which would promote nitrification and increase nitrate levels. As the maize silage yield was about 21 tonnes of dry matter ha^{-1}, it can be estimated that producing one tonne of maize silage was associated with the N leaching of about 3.3 kg N.

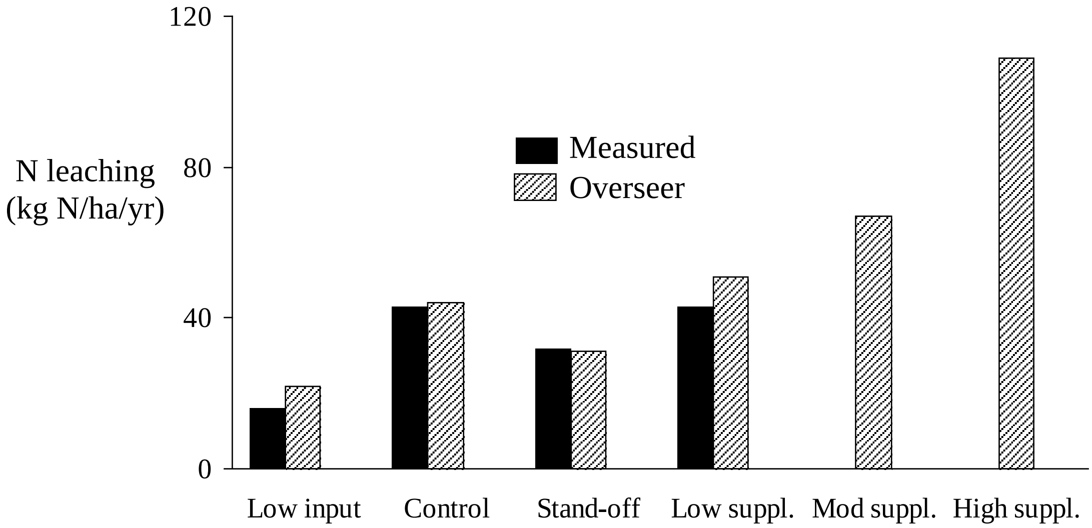

Figure 2. Average annual N leaching (measured and predicted using overseer model) from dairy farmlets.

Calculated N leaching losses from the low input, control, stand-off and low supplementation farmlets using the Overseer nutrient budget model were similar to those measured (Figure 2), indicating that the Overseer nutrient budget model is a useful tool for assessing the N flows for different N management systems.

Environmental efficiency

It was calculated that for the production of one tonne of milksolids the N leaching losses were 24, 39, 29, 32, 31 and 39 kg N from the low input, control, stand-off, low supplementation, moderate supplementation and high supplementation farmlets, respectively (Figure 3). The N leaching loss per tonne of milksolids from the control farmlet (with application of 170 kg fertiliser N/ha/year) was about 60% higher than from the low input farmlet (without application of N fertiliser). The N leaching losses per tonne of milksolids from the stand-off, low supplementation and moderate supplementation farmlets were 25%, 18% and 20% lower than from the control farmlet, while, the N leaching loss per tonne of milksolids from the high supplementation farmlet was similar to that from the control farmlet.

When considering the whole systems (e.g. N leaching losses from land for rearing replacements and forage cropping were included), we estimated total N losses of 24, 43, 32, 46, 52 and 60 kg N for the production of one tonne of milksolids under the low input, control, stand-off, low supplement, moderate supplement and high supplement dairy systems, respectively (Figure 3). The total N leaching loss per tonne of milksolids from the control dairy system was about 80% higher than from the low input dairy system. The total N leaching loss per tonne of milksolids from the stand-off dairy system was 25% lower than from the control dairy system, while the leaching losses per tonne of milksolids from the three supplement dairy systems were higher than from the control dairy systems. This calculation highlights that using supplementary feed can increase milk productivity in the dairy farm system but decrease environmental efficiency in terms of N leaching per unit of milk production. This was due to relatively high leaching losses in the area of land used to produce supplementary feed. The use of the stand-off pads increased environmental efficiency in terms of N leaching per unit of milk production, when compared to the control system. Intensification in an N-sensitive catchment using low protein forage such as maize silage produced from outside the catchment may result in little increase in N leaching within the N-sensitive catchment, particularly if linked to other practices such as the use of winter stand-off or feed pads.

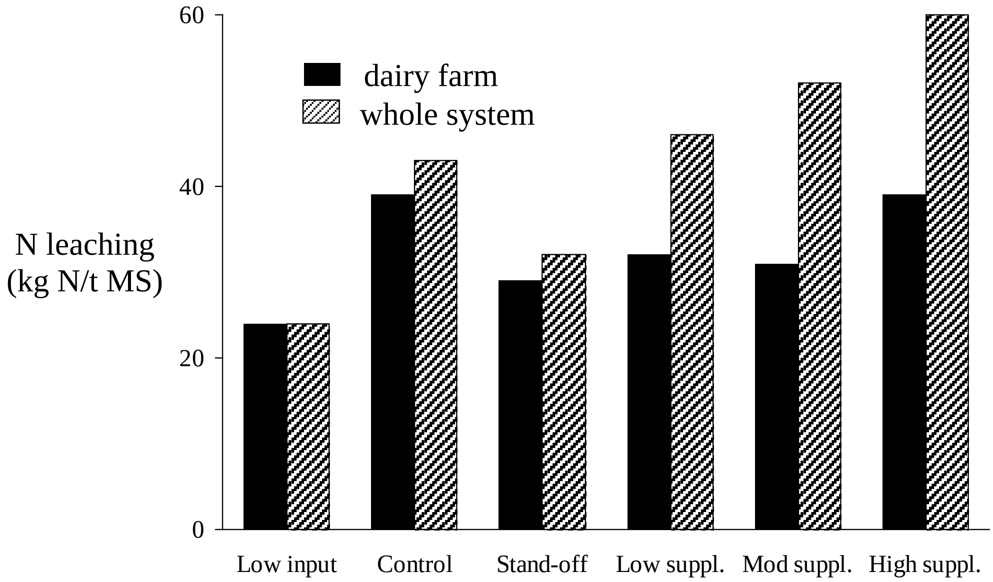

Figure 3. Nitrogen leaching losses from dairy farms and whole systems.

Conclusions

Application of N fertiliser at 170 kg N/ha/year increased milksolids production by approximately 20% but increased N leaching per hectare by at least 2-fold. The use of stand-off pads as a winter management practice or the use of maize silage reduced N leaching losses per kg milksolids on dairy farmlets. However, leaching losses were relatively high in the area of land used to produce supplementary feed, and therefore the whole-system efficiency (total kg N leached per kg milksolids produced) was reduced when supplementary feed increased.

Acknowledgements
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