STRATEGIC CAPTURE OF EFFLUENT TO REDUCE N LEACHING ON DAIRY FARMS WITH FREE DRAINING SOILS: ASSESSING IMPLICATIONS FOR EFFLUENT MANAGEMENT AND COST

J A Hanly, D J Horne, M J Hedley & C L Christensen

Fertilizer & Lime Research Centre, Massey University

Abstract

The urine-N deposited by dairy cows grazing in late-summer and autumn is particularly vulnerable to leaching in the initial drainage events of the subsequent winter period. Therefore, significant reductions in N leaching can be achieved if cows are stood off-paddock for longer durations during this period. This paper explores the potential to use a dairy farm's existing uncovered feedpad to reduce estimated N leaching. This involved evaluating the potential to retro-fit free-stalls to the pad so as to allow cows to be stood off-paddock for longer duration in the late-summer and autumn. A hypothetical farm in an Upper Manawatu River catchment within the Tararua District was used for this assessment. OVERSEER® Nutrient Budgets was used to estimate the likely reduction in N leaching as a result of increased standoff.

Introduction

Standing cows off paddock is a practice dairy farmers use, particularly on poorly drained soils, to reduce treading damage to pastures and/or reduce losses of nutrients and contaminants in surface runoff and drainage (de Klein & Ledgard, 2001; Collins *et al*., 2007; Christensen *et al*., 2012). Wet soil conditions prone to treading damage mostly occur in winter and spring, whereas, late-summer and autumn are likely to be the most effective seasons to stand cows off pasture to reduce nitrogen (N) leaching (Shepherd *et al*., 2011; Christensen, 2013). Increasing standoff time increases the cost (capital and maintenance) of standoff facilities and creates new management challenges, particularly to effluent management.

Nitrogen leaching from free draining soils is often greater than leaching from comparable, neighbouring farms on fine textured soils. Standing cows off-paddock is an effective way to reduce N leaching from free draining soils. However, treading damage is not usually a major problem on these soils. Therefore, the standoff period on free draining soils can be mostly confined to the summer/autumn period. This raises the interesting question as to whether N leaching can be adequately mitigated following relatively low cost modifications to an existing feedpad to allow greater standoff of cows later in the lactation season. To evaluate the feasibility of such a change, it is important to assess the cost, particularly the capital cost of such modifications. The requirement to manage greater volumes of effluent will contribute to the cost associated with increased standoff times.

This paper explores the potential to retro-fit free-stalls to a dairy farm's existing uncovered feedpad, to allow cows to be stood off-paddock for longer durations in late-summer and autumn. The objective of this paper is to estimate the impact of these changes on estimated N leaching, effluent management and cost.

Methods

A hypothetical case study farm was used to assess the impacts of feedpad modification and of increased durations of cow stand-off. It is assumed that the farm is located in a Horizons Regional Council One Plan (Horizons Regional Council) priority catchment and is required to comply with N leaching allowances. The farm details include:

- Seasonal supply dairy farm (spring calving)
- Tararua district (One Plan priority catchment)
- 84 ha of mostly river flats (Manawatu and Heretaunga soils)
- 1280 mm mean annual rainfall
- 220 cows (2.6 cows/ha; Friesian x Jersey)
- 962 kg MS/ha/y
- Cows wintered-off farm (100% Jun, 50% Jul, 24% Aug, 12% Sep)
- 90 kg N/ha/year as urea fertiliser (applied as 3 applications of 30 kg N/ha in August, September and October)
- Feedpad is originally used 2 hours/day (Aug to Sep, Dec to May)

OVERSEER® Nutrient Budgets (Version 6.1 Build 1; hereafter referred to as "Overseer") was used to estimate the likely reduction in N leaching as a result of standing cows off pasture for specific durations. The duration of cows standing off pasture was increased from 2 to 12 hours/day from February to May inclusive. Two feedpad modification scenarios were considered in this analysis:

Scenario 1: Adding 220 free-stalls (480 m^2) to an existing 1200 m^2 uncovered concrete feedpad.

Scenario 2: Adding 220 free-stalls (480 m^2) plus increase the area of an uncovered concrete feedpad by 400 m^2 (from 800 to 1200 m^2) i.e. in this scenario, the original pad is extended so as to increase cow comfort during standoff.

With the increased time cows spend on the modified feedpad, more effluent will be captured. The Dairy Effluent Storage Calculator was used to estimate this increase in effluent volume and storage requirement as a result of changes to the feedpad and increased durations of standoff by cows. Overseer was also used to estimate the increase in the quantity of N applied in effluent.

The modified feedpad strategies for reducing N leaching were compared with a more common N leaching mitigation option of replacing N fertiliser, used to grow pasture, with imported maize silage.

Results & Discussion

Nitrogen leaching

The One Plan leaching allowances for this farm, which consists of 30 ha of Land Use Class (LUC) II land and 54 ha of LUC III land, are presented in Table 1.

Supplementary feed and N fertiliser management on the case study farm were modified to mitigate N leaching. The farm originally applies an average of 90 kg N/ha as urea fertiliser. In order to reduce N leaching, while maintaining current cow numbers and milksolids production, one option is to remove all the N fertiliser and replace the estimated resulting reduction in pasture growth with purchased maize silage. It was assumed that the N fertiliser provided a 1:10 response (i.e. 1 kg N providing 10 kg of extra pasture DM), so 90 kg N/ha was replaced with 900 kg DM/ha as maize silage (75.6 T DM total for farm).

At a cost of $700/T urea (including transport and spreading) and $420/T maize silage DM, the net difference in the cost of this substitution is an increase of $20,248/y ($241/ha/y). Replacing the pasture grown using N fertiliser with maize silage reduces the annual average N loss to water from 29.2 to 25 kg N/ha/y (estimated by Overseer). The resulting total reduction in estimated N leaching for the farm is 354 kg N. Therefore, the average cost of this mitigation equates to $57 per 1 kg N/ha/y reduction in N leached. This provides a value for which the cost of increased cow standoff can be compared. Implementing this mitigation, of removing all N fertiliser, would allow the farm to comply with the Year 1 N leaching allowance, however, it exceeds the Year 5 allowance by 3 kg N/ha (Table 1).

Table 1. *A comparison between N leaching from the case study farm and Horizons Regional Council One Plan N leaching allowances for this farm.*

Year	**N leaching Allowance (kg N/ha/y)**	**Farm's current estimated N leaching (kg N/ha/y)**	**Difference (kg N/ha/y)**
Year 1	25	29.2	+4.2
Year 5	22	29.2	+7.2
Year 10	20	29.2	+9.2
Year 20	19	29.2	+10.2

Increasing the duration of cow standoff in late- summer and autumn was investigated to achieve further reductions in N leaching i.e. over and above that achieved by removing the N fertiliser. Increasing duration of cow standoff from 2 to 12 hours from February to May, reduces the daily time cows spend on paddock over this period from 18 hours to 8 hours (56% reduction). When combined with the N fertiliser removal mitigation, the increased duration of standoff further reduces N losses to water from 25 to 20.5 kg N/ha/y (4.5 kg N/ha or 18% reduction). This reduction would provide a 1.5 kg N/ha/y surplus from Year 5 to 9, relative to the One Plan N leaching allowance, and would be only 0.5 kg N/ha/y above the Year 10 allowance (Table 1).

Effluent management

For both Scenario 1 and 2, the increased duration of cow standoff is estimated to result in an additional 390 m^3 of scraped manure, which can be applied back to paddocks with a slurry tanker or manure spreader (Table 2). Increasing the area of rainfall catchment by 480 m^2 (stalls only) for Scenario 1 and by 880 m^2 for Scenario 2 (stalls plus a 400 m^2 increase in the feedpad area) increases annual liquid farm dairy effluent (FDE) volumes by 995 and 1,508 m^3 for scenarios 1 and 2, respectively. As a result, liquid FDE storage requirements increase by 208 m^3 for Scenario 1 and 586 m^3 for Scenario 2. Due to the additional cow urine collected in the liquid FDE from increased standoff, the quantity of N applied back to the current FDE block is estimated to increase by 1464 kg/y for both scenarios. As a consequence, the effluent irrigation area will need to be expanded by 10 ha.

The greater liquid FDE volume also increases the labour requirements to shift a small travelling irrigator between irrigation runs, which were assumed to be an additional total of 10 hours for Scenario 1 and 16 hours for Scenario 2. A contractor will be employed to spread the scraped feedpad manure on to land using a slurry tanker or manure spreader.

Feedpad management

The feedpad will need to be managed i.e. scraping the feedpad manure and cleaning stalls. Scenario 1 assumes a requirement of 1 hour/day for feedpad management. Scenario 2 was assessed at two different levels of labour input for feedpad management; either 1 or 2 hours/day (February-May). These two levels of labour input were used to demonstrate the sensitivity of total cost to changes to labour input. Actual labour requirements will vary depending on a range of factors, including the type of equipment available to assist with these tasks.

Table 2. *Effect of greater durations of cow stand-off on estimated changes to effluent and the effluent system.*

Changes to effluent and effluent system (increases)	**Scenario 1 (220 stalls only)**	**Scenario 2 (220 stalls + 400 m^3)**
Scraped manure	390 m^3	390 m^3
Liquid FDE volume	995 m^3 (13%)*	1,508 m^3 (21%)
FDE pond storage requirement	208 m^3 (25%)	586 m^3 (88%)
N content of liquid FDE	1464 kg N (79%)	1464 kg N (79%)
Liquid FDE application area	10 ha (71%)	10 ha (71%)

*Values in parentheses are % increase compared to the original hypothetical farm details.

Costs

The total capital cost is estimated to be $146,370 for Scenario 1 and $202,042 for Scenario 2, which includes the cost of the new stalls (e.g. base, mattress and dividers), increasing the size of the feedpad (Scenario 2 only), costs associated with expanding the effluent area and enlarging the capacity of the FDE pond (Table 3). When these costs are annualised (20 years; 8% interest) they are $14,681 for Scenario 1 and $20,264 for Scenario 2.

Table 3. *Increases in cost for greater durations of cow stand-off, including costs of modifications to feedpad*

Estimated cost ($)	**Scenario 1 (+ 1 hour labour/day Feb-May*)**	**Scenario 2 (+ 1 hour labour/day Feb-May)**	**Scenario 2 (+ 2 hours labour/day Feb-May)**
Capital costs ($) from:			
Stalls (220 x $600)	132,000	132,000	132,000
Increase pad area by 400 m^2	-	50,000	50,000
10 ha increase FDE area	11,250	11,250	11,250
Increase FDE pond capacity	3120	8,792	8,792
Total capital cost	***146,370***	***202,042***	***202,042***
Annualised capital cost (20 years; 8% interest)	***14,681***	***20,264***	***20,264***
Labour costs ($) from:			
*Feedpad management**	3060	3060	6120
Extra FDE irrigator moves	262	397	397
Total labour cost	***3322***	***3457***	***6517***
Contractor costs ($):			
Scraped manure spreading	***2356***	***2356***	***2356***
Total annual cost ($)	**20,259**	**26,077**	**29,137**
Per hectare cost ($/ha/y)	**242**	**310**	**347**

*Increased labour for feedpad management.

Higher labour costs for the extended standoff systems are due to the time assigned to feedpad management and the additional time required for shifting the FDE irrigator. There are also increased costs for a contractor to spread the scraped feedpad manure on to land using a slurry tanker or manure spreader.

The total increase in annual costs ranged from $20,259/y ($242/ha/y) for Scenario 1 (+1 hour labour/day February-May) to $29,137/y ($347/ha/y) for Scenario 2 (+2 hours labour/day February-May). The additional costs associated with effluent management ranged from 14-20% of the total cost increase.

In order to compare the cost of different scenarios it is useful to express the cost in terms of dollars ($) per kg reduction in N leaching per hectare per year (Table 4). The nitrogen leaching reduction in Scenario 1 needs to be greater than 4 kg N/ha/y for the cost to be similar to or less than mitigating N leaching by replacing N fertiliser with maize silage ($57/kg N reduction/ha/y).

As previously stated, increasing stand-off from 2 to 12 hours, from February to May, reduces estimated N losses to water from 25 to 20.5 kg N/ha/y (i.e. 4.5 kg N/ha/y reduction). At this level of N reduction Scenario 1, Scenario 2 (+1 hr labour) and Scenario (+ 2 hrs labour) would equate to $54, $69 and $77/kg N reduction/ha/y (Table 4). Therefore, only Scenario 1 would achieve a cost similar to the cost of replacing N fertiliser with maize silage. Whereas, an N leaching reduction of greater than 6 kg N/ha/y would be required for Scenario 2 (+2 hrs labour) to cost similar to replacing N fertiliser with maize silage.

Table 4. *Effect of increasing stand-off of cows from 2 to 12 hours/day (Feb-May) on estimated cost per kg reduction in N leached per hectare per year.*

	Cost ($/ha/y)	Reduction in N leaching (kg N/ha/y)				
		4	5	6	7	8
		Cost ($/kg N reduction/ha/y)				
Scenario 1 (+1 hr labour)	242	61	48	40	35	30
Scenario 2 (+1 hr labour)	310	78	62	52	44	39
Scenario 2 (+2 hr labour)	347	87	69	58	50	43

Shaded cells in table are for values greater than $57/kg N reduction/ha, which was the cost of replacing N fertiliser with maize silage.

Greater standoff of cows from pasture using modified existing feedpads can be used to reduce N leaching at costs comparable to modifications to N fertiliser management. However, a significant component of the cost of increased standoff is capital cost, which is paid off over a 20-year period. The capital cost makes this option less flexible compared to altering N fertiliser management, which can be altered each year.

There is limited research on the use of standing cows off pasture during the late lactation period on N leaching on a range of soil types and climates. Therefore, further studies are required to ensure that the full benefits of such practices can be accurately simulated by Overseer. This is particularly important given the potential capital costs associated with implementing the use of increased cow standoff and because there are few alternative mitigation options available that do not involve reducing productivity.

Conclusions

For the farm information used in this analysis, removing all N fertiliser and replacing the estimated reduction in pasture grown with purchased maize silage allowed the farm to comply with the One Plan's Year 1 N leaching allowance. However, further reductions in N leaching would be required for the farm to comply from Year 5 and beyond. Modifying an existing uncovered feedpad, by adding freestalls to allow greater durations of cow standoff from pasture during late-summer and autumn, which further reduced estimated N leaching at a cost comparable to replacing N fertiliser with purchased supplementary feed. Less than 20% of the cost increase associated with extended standoff was due to changes to the effluent system and management. Modifying the feedpad was the most costly component of the three scenarios. The combination of removing N fertiliser and increased cow standoff would enable this farm to comply with the N leaching allowance in the first 9 years of One Plan implementation and be very close to compliance during the subsequent 10 years.

References

de Klein CAM, Ledgard SF (2001). An analysis of environmental and economic implications of nil and restricted grazing systems designed to reduce nitrate leaching from New Zealand dairy farms. I. Nitrogen losses. *New Zealand Journal of Agricultural Research* 44, 201-215.

Christensen CL (2013). Duration controlled grazing of dairy cows: impacts on pasture production and losses of nutrients and faecal microbes to water. PhD thesis, Massey University.

Christensen CL, Hedley MJ, Hanly, JA and Horne DJ (2012). Nitrogen loss mitigation using duration-controlled grazing: Field observations compared to modelled outputs. *Proceedings of the New Zealand Grassland Association*, 74, Pages 115-119.

Collins R, McLeod M, Hedley M, Donnison A, Close M, Hanly J, Horne D, Ross C, Davies-Colley R, Bagshaw C, Matthews L (2007). Best management practices to mitigate faecal contamination by livestock of New Zealand waters. *New Zealand Journal of Agricultural Research* 50:267-278.

Horizons Regional Council. http://www.horizons.govt.nz/about-us/one-plan/

Shepherd M, Phillips P and Snow V (2011). The Challenge of the later summer urine patches. In: *Adding to the Knowledge Base for the Nutrient Manager*. (Eds L.D. Currie and C L. Christensen). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 4. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 8 pages.