Assessments of N leaching losses from six case study dairy farms using contrasting approaches to cow wintering

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Abstract

The expansion of the southern dairy herd in New Zealand has raised a number of concerns about the sustainability of grazing brassica forage crops. Here we provide an assessment of the contribution of these crops to the potential for N losses to water at a whole-farm system level, and compare these with metrics derived for systems that use alternative approaches for wintering cows. The risks of nutrient losses to water from six Monitor Farms that use contrasting approaches to dairy cow wintering were assessed using the Overseer® Nutrient budgets model (Overseer). This modelling assessment was supplemented with detailed information about the management of effluent generated from off-paddock cow wintering facilities such as wintering pads and covered housing. Predictions of N losses from individual farm blocks indicated that both winter- and summer-grazed brassica forage crops have a relatively high potential for N leaching losses. Expressed at a whole-system level (i.e. accounting for the milking platform, winter forage crop and other support land), the winter forage crops accounted for between 11 and 24% of total N leaching losses, despite representing only 4 to 9% of the area. The high N leaching losses predicted for summer-grazed forage crops were attributed to the limited opportunity for N uptake of excreted urinary N by the following new pasture. Another risk identified for some farms was the current practice of applying effluents collected from off-paddock facilities to land during winter. These assessments suggest that off-paddock cow wintering systems can help to minimise N losses from farms to water, although the storage and safe return to land of effluents and manures generated from the housing facilities is essential if this potential benefit is to be realised. Our assessments also suggest that summer crop paddocks have a relatively high potential for N leaching losses, although further research is needed to confirm this.

Keywords: dairy cow wintering, Southland, nitrate leaching, grazed brassica forage crops.

Introduction

Common practice for wintering dairy cows in Southland, New Zealand, is to graze brassica crops *in situ*. Recent evidence (e.g., Smith *et al.* 2012) suggests that this farming practice can contribute a disproportionately large fraction of whole-farm losses of water contaminants such as nitrogen (N) (Monaghan *et al.* 2007). Cow confinement systems (such as slatted-floor barns, free-stall barns, deep litter barns and wintering pads) are being increasingly used by farmers in Southland as an alternative approach to over-wintering cows. Studies conducted in other regions of New Zealand have shown that removing stock from pasture or crop during winter months can reduce soil damage and losses of N, phosphorus (P) and faecal microorganisms (Luo *et al.* 2008; McDowell *et al.* 2003). However, there is little regional data related to the environmental risks and benefits of these alternative wintering systems.

The purpose of this work was to analyse and compare N leaching losses from six dairy farms in southern New Zealand that use contrasting approaches for wintering cows. Assessments of N losses were made for the whole dairy system (milking platform (MP) and wintering and support land). Consideration was also given to the potential environmental risks associated with the management of the various effluents and manures generated from the different systems. These assessments will aid in identifying knowledge gaps and areas of the farming systems requiring further investigation. These six farms were part of the Southern Wintering Systems Initiative, a DairyNZ led winter monitoring programme, and included the following wintering systems: (i) brassica crop grazing on the milking platform, (ii) all-grass wintering on a support block, (iii) use of a bark chip wintering pad and (iv) covered herd shelters. This latter category included a free-stall barn, a slatted-floor system overlying an effluent bunker and a deep litter barn.

Approach

A case study approach was undertaken whereby six southern dairy Monitor Farms (MFs) that used contrasting approaches to cow wintering were described using expert farmer knowledge and formal modelling tools, in particular the Overseer® Nutrient Budgeting model (Overseer) (Wheeler *et al.* 2003). Where relevant, this was supplemented with specific on-farm measurements of the volumes of effluents generated on winter pads and shelters. A preliminary questionnaire was completed for each MF to capture as much information as possible pertaining to productivity and environmental metrics that were required to complete an Overseer model run. Each of the six MFs was visited in early March 2011 to confirm the information captured in the questionnaires and conduct a farm tour focusing on wintering and effluent management systems. Soil types were confirmed during these visits using on-site soil profile examinations.

Case study farms were described using Overseer version 5.4.8 (Wheeler *et al.* 2003). Overseer is a New Zealand-based farm-specific tool that examines the impact of management decisions on nutrient use, flows and losses to the environment. Particular attention was given to describing each farm system accounting for all hectares used to support the farming operation. Nutrient budgets for all six properties were thus prepared to include areas used for milking (MP), cow wintering, supplement production and rearing young stock. Key metrics derived for each farm included N leaching, P loss risk and nutrient surpluses of N, P, potassium (K) and sulphur (S). The focus for the rest of this paper is on N leaching risk.

As part of the assessment process, particular attention was given to the impact of using a brassica forage crop, which is the most common system used for over-wintering cows in southern New Zealand. In an effort to remove the variation between farms caused by variables such as soil type, climate, and stocking rate (SR), each MF was re-modelled under a hypothetical scenario that assumed all stock were wintered on crop. The hypothetical winter crop land was assumed to be land that was used to support the existing wintering system (e.g. cut and carry crop or silage areas). The soil type, topography and climate remained the same as the land in the existing system. This enabled comparison between the existing system, with its current wintering practice (often including some off-paddock or all-grass wintering options), to the same farm with all stock wintered on crop. The DairyNZ crop calculator (DairyNZ 2012) was used as a tool to guide the assumptions required to re-run the models.

Table 1. Some summary attributes of the six Monitor Farms evaluated.

	Monitor Farm Wintering System					
	All crop	Pasture	Wintering pad	Herd Shelter		
				Free stall	Slatted floor	Deep litter
Block Areas (ha)						
Main[1]	160	171	80	49	15	162
Effluent[1]	66	49	110	60	80	103
Wintering	33	238[2]	0	24	0	38
Young stock and Silage purchased	57		70	52	116	104
Rainfall (mm/yr)	1,100	1,000[3] 850[4]	1,000	1,040	900	950
Number of cows	803	820	345	310	305	850
Milksolids (kg MS/cow)	355	387	430	422	426	400
% stock wintered on crop	100%	0%	0%	61%	0%	58%
Days off pasture or crop	0	85	75	80	85	60
Effluent system	N/A	N/A	Separate wintering pad effluent storage. LARS, slurry tanker	Solids separator, FDE[5] pond, LARS[6], slurry tanker	Slatted floor, weeping wall, FDE pond, LARS, muck spreader	Weeping wall, FDE pond, gun irrigator, slurry tanker, muck spreader

(Footnotes)
[1] Milking Platform – Main + Effluent blocks
[2] Young stock and wintering combined
[3] Milking Platform
[4] Support block
[5] Farm Dairy Effluent (FDE)
[6] Low application rate sprinklers (LARS)

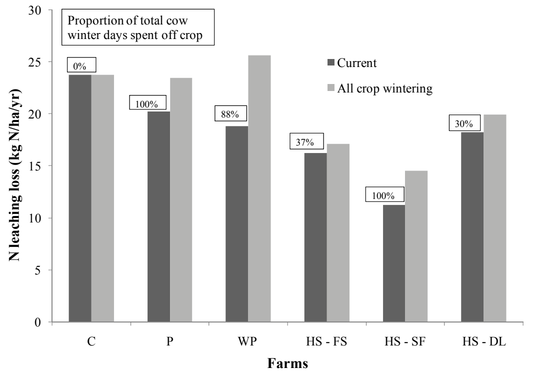

Figure 1. Whole farm system N leaching losses (kg N/ha/yr) estimated for each current farm and for an "All-Crop Wintering" scenario for that system. Wintering systems compared were: Crop (C); All-pasture wintering (P); Wintering pad (WP); Herd Shelter – Free-stall (HS - FS); Herd Shelter – Slatted-floor (HS - SF); and Herd Shelter – Deep litter (HS - DL). Values given for "Proportion of total cow winter days spent off crop" is the product of proportion of herd off crop × proportion of winter days off crop.

It was assumed that a swede crop provided 70% of the diet requirement over the 90-day winter period, with pasture silage making up the remaining 30%. Feed intake was calculated for a 0.5 unit increase in body condition score (BCS) over the 90-day winter period.

Farm Attributes and N leaching losses

Some summary attributes for each farm are outlined in Table 1. Modelled whole-system N leaching losses from the current farms are shown in Figure 1 and ranged from 12 to 24 kg N/ha/yr. An examination of N losses from individual blocks showed a much wider range, from 6 kg N/ha/yr for pastoral support land grazed by young stock to 71 kg N/ha/yr for a summer-grazed forage brassica crop (Fig. 2). Figure 2 indicates that both summer- and winter-grazed forage brassica crops are predicted to have high leaching losses relative to those estimated for pastures on the milking platform or on support land used for grazing by young stock. The relatively high N losses predicted for some of the summer-grazed crop blocks are supported by measurements of nitrate-N levels remaining in the soil (0–300 mm depth) in late autumn, which showed a significantly higher potential for N leaching losses compared to adjacent pasture sites (Fig. 3).

The higher N leaching losses predicted for the grazed forage crops reflects the asynchrony between plant demand for N and the potentially large amounts of mineral N that may accumulate in the soil due to the mineralisation of soil organic matter or returns of N in

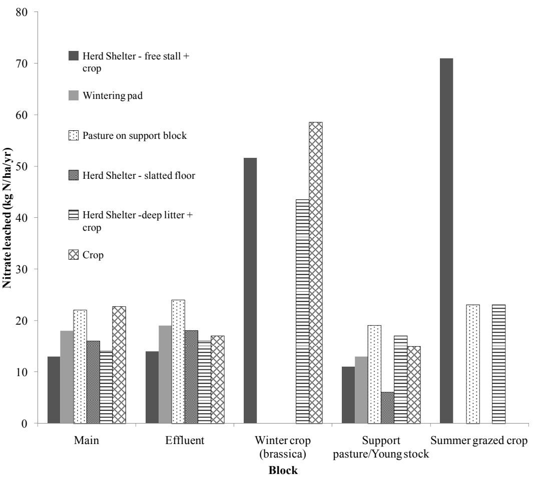

Figure 2. Modelled N leaching losses from each of the monitor farm blocks (kg N/ha/yr).

cow urine. In the case of summer-grazed forage crops, there is a relatively narrow window of opportunity for the uptake of mineralised and urinary N by the re-sown pasture before winter rains arrive. Re-sowing these pastures as early as possible will help to minimise the amounts of unused mineral N remaining in the soil in late autumn, and thus potential leaching risk. In the case of winter-grazed forage crops, the asynchrony is even greater as the large amounts of N returned in cow urine at the time of crop grazing are to soil that often remains bare until new crops or pastures are established in the following late spring or early summer. Expressed at a whole-system level, the winter forage crops were estimated to account for between 11 and 24% of total N leaching losses, despite representing only 4 to 9% of the area.

Due to differences in soil type, climate, topography and farm management (e.g. supplement use) between the farms, it is not possible to directly compare the impacts of different wintering systems between farms. To remove the variability introduced by these (non-winter) factors, we can instead compare each existing system with a hypothetical scenario where an all-crop wintering system is assumed and modelled for each property. When this exercise was completed for each of the properties that do not currently winter 100% of their cows on crop, total farm N leaching losses were predicted to increase by between 5 and 36% (Fig. 1). The size of these increases was influenced by the current percentage of stock on crop (range of 0 to 100%; Table 1), stocking rate and the soil type assumed for the winter crop block, although it ultimately reflects the asynchrony noted above between plant demand and soil mineral N supply.

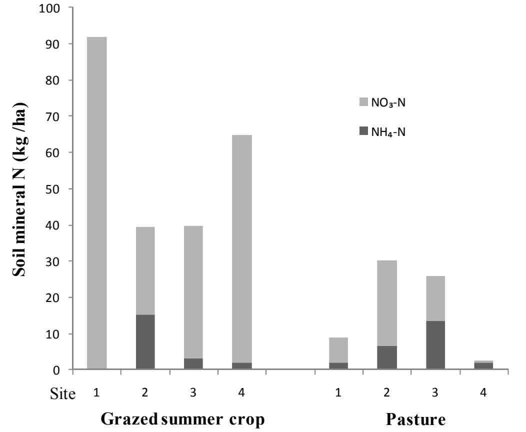

Figure 3. Ammonium-N (NH4-N) and nitrate-N (NO3-N) levels remaining in the soil (to a depth of 300 mm) in early May in grazed summer crop paddocks and adjacent pasture sites.

Other management considerations

A common management challenge for many of the properties currently utilising an off-paddock wintering system was the safe storage and handling of effluent collected over winter. Some properties were using existing farm dairy effluent (FDE) systems that were designed prior to wintering system installation, but were now also required to store liquid effluent generated from the off-paddock system. Some therefore often applied liquid effluent to land over the winter period. Potential risks associated with this practice are poor utilisation of the effluent and loss in drainage, although this is likely to have a greater impact on farm-scale losses of P and faecal micro-organisms than on N. The use of low application rate effluent irrigation techniques is likely to minimise these risks, although more research is needed to improve our understanding of the relative risks associated with this aspect of the wintering system.

Another obvious management challenge is how to cost-effectively reduce the relatively high N leaching losses predicted and measured (e.g., refer to Smith *et al*. 2012) from the grazed winter forage crops. This is a particularly urgent challenge for those farms currently wintering on soil types that are excessively drained and thus predicted to have high N leaching losses.

Evaluations of nutrient budgets derived for the effluent- and manure-treated parts of the farms indicated that, in general, the winter-derived effluents and manures were being spread to sufficiently large areas so as to avoid the build-up of excessive levels of soil fertility. Although one farm applied 150 kg N/ha/yr as effluent to one of the farm blocks, none of the other modelled farm blocks applied more than 82 kg N/ha/yr as effluent or manure N. Potassium returns in effluent were in some cases much higher than estimated maintenance requirements for pasture production, although this could be easily remedied by management changes e.g. taking cuts of silage or increasing the treated area.

Uncertainties and future research

Some limitations of our approach include uncertainties about the quality and accuracy of model inputs, the accuracy and flexibility of the model used, and errors introduced by subjective operator opinion. Care was taken to minimise these potential limitations by extracting as much detailed information from each of the farms as possible, and applying the Overseer model to each farm in a consistent manner. There were limitations with Overseer's ability to describe some wintering systems in version 5.4.8 of the model, although these have been addressed in version 6 of the model. We suggest that our assessments can be used as a guide to explore the potential impacts of within-farm changes in cow wintering systems on nutrient losses to the environment.

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