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NITROGEN LEACHING, PRODUCTION AND PROFIT OF IRRIGATED DAIRY SYSTEMS USING EITHER LOW OR HIGH INPUTS OF FERTILISER AND FEED:

THE PASTORAL 21 EXPERIENCE IN CANTERBURY

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Abstract

Dairy farm businesses in many sub-regions of Canterbury will need to reduce their nitrate leaching losses to comply with regional environmental management plans. Dairy systems in Canterbury are based on two main parcels of land: 1) the milking platform, plus 2) support land for growing winter crop to feed dry cows, rear replacements, or grow extra feed for the milking platform. Little information is available on the systems strategies farmers can adopt on these different land parcels to reduce nitrate leaching while maintaining, or improving, production and profit. A ‘higher input’ and a ‘lower input’ milking platform system (denoted ‘HIHE’ and ‘LIHE’, respectively) were compared for four years in farmlets (unreplicated herds of 29-34 cows) at Lincoln, Canterbury. Both systems were managed optimally to maximise pasture production and the efficiency of conversion of N fertiliser and feed inputs to milk production. Three winter crop feeding options were also compared: two based on kale (one where kale was followed by a catch crop of oats), and one based on fodder beet (replicated groups of 50 cows per treatment). Key farm system production, profit, and environmental indicators are presented. When results were scaled to the equivalent of a 160 ha milking platform, all combinations of the two milking platform and wintering options were analysed, and all hectares used for production were accounted for, the range in total nitrate leached was more than two-fold: from around 7.2 (LIHE with fodder beet) to 16.5 (HIHE and kale plus oats) tonnes N per year. The results illustrate the limitations of focussing solely on one part of the system (which, currently, is usually the milking platform) when seeking ways to reduce the total footprint of dairying in a catchment context. Importantly, the evidence presented here demonstrates that there are system options that Canterbury farmers could adopt to reduce their nitrate leaching footprint from both the milking platform and the total system. This is important information for building farmer confidence in the face of regulatory change.

Introduction

The Canterbury region of New Zealand experienced rapid growth in land area used for dairy production from 1990/91 to 2008/09 (18,500 hectares to 190,000 hectares respectively, Pangborn and Woodford 2010). This growth trend of 7,300 ha/year equates to an additional 25,000 cows/year, assuming a mean stocking rate of 3.5 c/ha on milking platform land. Meanwhile, estimated total amounts of nitrate nitrogen (N) leached into receiving waterways in the Canterbury region increased from around 11,000 tonnes in 1990/91 to 21,000 tonnes in 2009/10 (Taylor 2012). There is little doubt that these trends are linked although the intensification of other land uses and growth in urban populations will also have contributed to increased environmental emissions.

The National Policy Statement on Freshwater Management (NPSFM), released by the New Zealand Government in 2011, marked the beginning of far-reaching changes in the regulation of land uses throughout the country to safeguard the quality of freshwater in aquifers, streams, rivers and lakes. Relatively intensive industries, such as dairying, in sensitive catchments, of which there are several in Canterbury, will need to implement practice changes to reduce nutrient emissions and meet the NPSFM goals. In 2011, it was not known if Canterbury dairy farm systems could be operated productively and profitably while meeting the nutrient loss limits foreshadowed by the NPSFM. The default expectation was that large reductions in nitrate leaching would substantially restrict production and erode profits – clearly an undesirable outcome for the industry, but also for the country given the $12b of export earnings and $5b contribution to GDP generated by dairying.

Thus, an over-arching objective of the Pastoral 21 (‘P21’) programme funded from 2011-2016 was to develop and demonstrate dairy farming systems that could reduce nutrient emissions by 30% relative to regional benchmarks while maintaining or increasing production and profit. This challenge was met using a farm systems approach based on farmlet comparisons in four regions of New Zealand as explained by Shepherd et al. (2017). This paper describes the comparisons conducted in Canterbury and presents the high-level biophysical and economic results.

Methods

General approach

Most dairy farm businesses in Canterbury are based on a milking platform area for lactation from August to May inclusive, with dry cows wintered on a separate support land area sown with a winter forage crop of either kale or fodder beet. Zero (or, at most, very low) grazing feed demand on the milking platform in winter means target pasture covers for spring calving can be achieved despite low winter growth rates (between 0 and 10 kg DM/ha per day during June and July, depending on location). Thus around 0.8 t DM of total annual feed demand per cow is met from the winter crop plus supplements: effectively supporting a higher stocking rate for the milking platform during August-May than would be the case if cows were wintered on the platform. To fully understand the true total environmental footprint of the farm business (which is what matters for catchments), emissions from both parcels of land must be considered. Previously, the role of support land has largely been ignored in benchmarking farm performance: however, Canterbury dairy farm systems could not operate in their current configuration without the support land.

Winter crops are often grown on free-draining soils, hence there is potential for substantial N leaching under the high stocking densities (and, therefore, high urinary N load) applied to consume 12 – 25 t/ha of crop dry matter over 2 months in winter. There is little information available on nitrate leaching rates for milking platform and, especially, support land in Canterbury, let alone the management strategies that could be applied to reduce leaching. Hence, the objective of the P21 study in Canterbury was to compare management systems on both the milking platform and on support land, so that production and environmental footprint could be analysed based on the total hectares required to support production. The target for the study was to identify systems capable of reducing nitrate leaching from around 45-50 kg N/ha to 25-35 kg N/ha (all hectares counted, milking platform plus wintering area) while maintaining high production and profit.

Milking platform (MP) comparison

Two systems were compared for four years in unreplicated farmlets of 29 and 34 cows using management strategies based on the results of pre-experimental modelling described by Beukes et al. (2011). The systems represented two possible development pathways for dairying in Canterbury. In the descriptions that follow, the terms 'more' or 'less' are used in relation to benchmark data for Canterbury farms sourced from the DairyBase farm database for the 2010/11 year. Key benchmark indicators of production are shown in Table 1. In addition, the Lincoln University Demonstration Dairy Farm (LUDDF, van Bysterveldt and Christie, 2007), provided a well-documented example of a high performing dairy farm in the region with a strong focus on pasture for feeding and profitability, consistently lying in the very top group of farms in the region for profit. LUDDF thus served as another form of benchmark for the P21 study and a sterner measure of success for the systems tested in P21 was whether or not they matched or exceeded LUDDF physical performance and profit indicators, which are also shown in Table 1.

The first P21 system, denoted 'higher input-high efficiency' (HIHE), mirrored the traditional path of increasing milk production per hectare with more cows, more feed imported to the milking platform, and more N fertiliser inputs. A core element of this system at the outset was the use of the nitrification inhibitor DCD to counter the increase in N inputs and rate of N cycling via the animal into urine, which increases the risk of N leaching. However, after the first year of the study, DCD was voluntarily withdrawn from sale by the manufacturer in response to trade issues resulting from the detection of trace amounts of DCD residues in milk products. Without DCD, it was expected that this system would not meet future N leaching restrictions: however, it is such a well-understood development pathway that it was deemed important to understand what the implications of it could be in the future if production was increased well beyond current benchmark performance. In this case, the target based on modelling was around 2170 kg milksolids per hectare (Table 1).

The second system represented a lower input approach to farming, reducing N fertiliser and purchased supplements to restrict the total amount of N imported into the farm. This 'lower input-high efficiency' system (LIHE) relied on achieving significant gains in the efficiency with which a self-imposed fertiliser limit of 150 kg N/ha per year (cf. Canterbury benchmark 260 kg N/ha, Table 1) could be converted to increased pasture growth and, in turn, the extra pasture grown could be converted to milk with minimal reliance on imported feed.

A core concept adopted in both systems was production efficiency. In the LIHE system, the first step was to match stocking rate to the expected feed supply from reduced inputs such that direct-grazed pasture supplied around 90% of total feed eaten on the milking platform. This was not a low stocking rate system: the stocking rate (both cows/hectare and liveweight per hectare) was similar to the Canterbury benchmark, and comparative stocking rate (CSR: kg liveweight per tonne total feed offered) was c. 82, within the range considered optimum for NZ dairy systems (75-85; Macdonald et al. 2008). The expected driver of lower nitrate leaching in LIHE was the reduced import of nutrients, combined with higher N conversion efficiency (NCE: kg N exported in milk per kg N imported in feed and fertiliser). Together, these: 1) limit the urinary N load returned to soil; and 2) restrict the rate of N enrichment of the bulk soil which will otherwise occur with low NCE, recognising that higher rates of N enrichment will ultimately lead to higher N losses at some point in the N cycle (Whitehead 1995).

The modelling indicated that high per-cow production from pasture would be required for this system to exceed benchmark per hectare production (Table 1). The important associated research question was: could the required feeding levels be maintained given that only a thin ‘safety net’ was available from the self-imposed fertiliser and imported supplement limits? If target pasture covers could not be maintained and/or pasture quality was lost, the options for recovery were limited. A consistent high standard of daily feed assessment and allocation was therefore required. By contrast, the HIHE system had more inputs to draw on and greater grazing pressure could be applied to pastures if required to control quality by virtue of the higher stocking rate.

Management and measurements

The comparison commenced in October 2011 at Lincoln University Research Dairy Farm on 15 ha of Templeton sandy loam soil, approximately two-thirds of which had been in pasture grazed by young dairy stock for three years, while one-third was sown with new pasture in May 2011 on land that had previously been cropped. The strategic management policies of the two farmlets were based on the pre-experimental model simulations and have been described by Clement et al. (2016). Briefly, the LIHE farmlet (8.25 ha) was grazed by a herd of 29, spring-calving Holstein-Friesian x Jersey cows (mean breeding worth (**BW**) in 2011 = 140 and mean liveweight in December = 507 kg) while the HIHE farmlet (6.75 ha) herd comprised 34 cows (mean **BW** = 133, mean December liveweight = 499 kg) balanced for age structure, breed and calving date. Farmlets were based on 22 (LIHE) or 18 (HIHE) paddocks of perennial ryegrass-white clover pasture, except that 6 paddocks in LIHE were sown to a mixture of perennial ryegrass, white clover, red clover, chicory and plantain (‘diverse pasture’).

Pasture cover was assessed weekly on every paddock using a rising plate meter calibrated by pasture cuts to ground level carried out every two weeks (Clement et al. 2016). A feed wedge was generated for each farmlet each week and used to allocate pasture area each day for the following week. The feed wedge was also used to add or remove supplements and/or dry off or remove cull cows as required to maintain target post-grazing residuals (1500 – 1650 kg DM/ha), increase or decrease rotation length as required, and ensure key pasture cover targets at drying-off (2000 kg DM/ha on LIHE, 2200 kg DM/ha on HIHE) and calving (2400 kg DM/ha on LIHE and 2600 kg DM/ha on HIHE) were met.

Milk yield (kg milk/cow) was measured at every milking for every cow. Milk protein and fat content was measured fortnightly using standard herd test procedures (Clement et al. 2016). Body condition score was recorded on all cows once per fortnight. Pasture botanical composition, % DM, and nutritive value was also measured every fortnight.

Both herds were wintered on their own crop area at Lincoln University Ashley Dene farm. The LIHE herd was fed on kale, supplemented with green-chop oats while the HIHE herd grazed fodder beet supplemented by pasture silage.

Wintering experiment

Two replicate herds of 35-50 mixed-age cows grazed each of three winter crop feeding treatments established on stony, free-draining Balmoral soil at Ashley Dene farm, as described by Edwards et al. (2014). Briefly, the three treatments were:

1. ‘Early-sown kale’ (EK) crop sown in October and fallowed post-grazing until the crop is re-established again in mid-spring. This represented common practice for wintering in Canterbury.
2. ‘Late-sown kale crop’ (LK) sown in December following harvest of an oat crop that was sown after the cows move off the kale crop (the oats were harvested for green-chop silage). Delaying the sowing of the kale crop opens a window from roughly mid-August to early December in which a short-term crop such as annual ryegrass or a cereal could be grown to ‘mop up’ surplus N left behind after winter grazing and remove some of the nitrate that might otherwise leach during the spring drainage period.
3. Fodder beet (‘FB’, sown mid-October. Fodder beet can produce high yields and is also attractive because the crop (mainly bulb) is highly digestible and of relatively low N concentration. Land area sown to fodder beet has increased rapidly in Canterbury since 2010.

All crops were irrigated from late spring to autumn. Feeding regimes during June-July inclusive were: EK - 14 kg crop DM plus 3 kg straw DM per cow/d; LK – 11 kg crop plus 5 kg green chop oats per cow/d; and FB – 8 kg crop plus 6 kg pasture silage per cow/d. Feed allocations were kept the same in all three years during which the experiment was conducted (winter 2012, 2013 and 2014). Further details of crop agronomy, feeding and crop and animal measurements are in Edwards et al. (2016). Only the LK and FB treatments are included in the analyses reported here.

Analyses

Data for the milking platform are for all four years of the experiment, with the missing data from the start of the 2011/12 lactation (the herds were not established until 1st October) estimated, using the DairyNZ whole farm model (WFM) based on subsequent lactation data. Hence, means and statistical significance of key variables presented here may differ slightly from Clement et al (2016) where this adjustment was not included.

Nitrate leaching was estimated in all instances using OVERSEER® version 6.2.2 operated using the standard industry operating protocol (Anon 2016). Operating profit was estimated using a spreadsheet tool designed specifically for analysis of farmlet experiments (C. Glassey, DairyNZ, pers. comm.). Actual inputs and outputs were entered, and combined with industry benchmark costs for each year to scale to a farm business with a 160 ha milking platform (which matches the LUDDF business). A standard milk price of $6.10/kg MS was used for all years.

Likewise, the analysis of all land resources required to support farm production used was applied to a “standard” farm with a 160 ha milking platform. Actual stocking densities used on the winter crop treatments (Edwards et al. 2014) were applied to estimate total winter area required, including areas of pasture for transition of animals on and off crops. Total herd size was a simple product of farmlet stocking rate and milking platform area, from which total areas required for wintering, rearing replacements, and growing imported grain concentrate and supplement were calculated. Nitrate leaching was estimated (using OVERSEER®)) for the milking platform plus winter crop areas only, since these were the only land uses for which direct physical production data were available.

It was assumed that winter crop was grown on a support block alongside an area of pasture for transitioning cows onto and off their crop diets. The ratio of area of pasture to crop on this support block was 0.67 for kale + oats (1 ha grass per 2 ha crop) and 2.0 for fodder beet (2 ha grass for 1 ha crop), reflecting differences in the yield potential of the crops. The pasture on the winter block was also used for silage, yielding an assumed 6 t/ha for LIHE and 10 t/ha for

HIHE, reflecting a general management strategy of using higher inputs in the latter. Grain concentrate was sourced from an arable crop farm with the following assumptions: the crop was feed barley, yielding 7 t grain/ha, grown as part of a rotation of three crops in two years. Therefore, the area required to produce the 7 t crop was reduced by a factor of 0.67 to account for the use of the land for other production purposes. Replacement stock were assumed to be reared on pasture growing 11 t DM/ha per year.

The consistency of farmlet differences over the duration of the trial was tested using GenStat 16.2 (Payne 2011). Farmlet means for all reported variables were calculated for each month of each year. These farmlet monthly means for each year were then analysed as mixed models including month, farmlet and the interaction of month and farmlet as fixed effects and year, farmlet within year, and month within farmlet within year as random effects.

Results and discussion

Milking platform

Mean (for four years) production, profit and nitrate leaching of the two farmlet systems are presented in Table 1. Total pasture harvested in HIHE exceeded LIHE by 1.3 t DM/ha. This difference is most likely due to the additional N fertiliser applied, which translates to an apparent N fertiliser response efficiency of 8.7 kg DM per kg N applied. This is less than the commonly assumed response efficiency of c. 10 kg DM/kg N, reflecting that pasture production in the HIHE system may have been limited by other factors, such as moisture. Over 5 tonnes of supplement DM was imported per hectare per year in HIHE which would have added approximately 140 kg N/ha per year to the system assuming a mean N content of that feed of 2.5% DM. Hence, total N imports (excluding N fixation) exceeded 450 kg N/ha per year, compared with around 180 kg N/ha per year in LIHE (estimated 26 kg N/ha from imported supplement plus 154 kg N/ha from fertiliser). N export in milk was 164 versus 123 kg N/ha in HIHE and LIHE, respectively. Thus, per hectare, the additional 270 kg N imported in HIHE generated only 41 kg of additional N exported, giving a relatively low apparent N conversion efficiency of 0.15.

The calculated low efficiency is a crude estimate since other N cycle processes will have been operating. OVERSEER® captures these processes: the difference between HIHE and LIHE in estimated (using OVERSEER® v.6.2.2) nitrate leaching (46 versus 32 kg N/ha per year) is consistent with the crude N balance analysis above, and with the principles via which intensification affects C and N cycling in grazed pasture systems (Parsons et al., 2016). ‘Intensification’ in this case, via more C (in feed) and N (in fertiliser and feed) inputs, moved the production system into a state of diminishing production returns but accelerating N emissions compared with the LIHE system. This occurred despite a high standard of management implementation which should have ensured efficient use of those additional inputs for production. The LIHE system fell within the bounds of sustainable milk production, N emissions and CO_2-equivalent emissions for dairy systems proposed by Parsons et al. (2016) for which, interestingly, 150 kg N applied as fertiliser per hectare per year was the critical pivot point (see Figure 5 in Parsons et al., 2016).

Table 1. Predicted and observed physical production, profit and nitrate leaching for the ‘lower input, high efficiency’ (LIHE) and ‘higher input, high efficiency’ (HIHE) milking platform (MP) systems in Canterbury based on pre-experimental modelling with the DairyNZ whole farm model (WFM; Beukes et al, 2011). Canterbury benchmark information for 2010/11 (from DairyBase) and Lincoln University Demonstration Dairy Farm (LUDDF) data are presented for comparison. ‘Observed’ data are for 2012/13 to 2014/15 inclusive, excluding 2011/12 which was an incomplete lactation. LUDDF and LIHE/HIHE nitrate leaching data are from OVERSEER® v. 6.2.2. P value is for LIHE and HIHE only.

	LIHE – predicted	**HIHE - predicted**	**Canterbury benchmark 2010/11**	**LUDDF 2011/12-2013/14**	**LIHE – observed**	**HIHE - observed**	***P***
Stocking rate at peak (cows/ha)	3.5	5.0	3.5	3.94	3.5	5.0	
Nitrogen fertilizer used (kg N/ha)	150	400	260	313	154	309	
Pasture grazed directly (t DM/ha)	15.6	18.3			15.1	16.7	0.053
Total pasture conserved (t DM/ha)	0.43	0			0.33	0	
Total pasture harvested (t DM/ha)	16.0	18.3	14.2	16.3	15.4	16.7	
Feed offered (t DM/cow):							
Pasture for grazing	4.45	3.66			4.83	3.66	
Concentrate[1]	0.10	0.80			0.07	0.68	
Pasture silage[2]	0.38	0			0.23	0.44	
Pasture for grazing as % total on MP	90	80			93	77	
Winter crop	n.m.	n.m.			0.78	0.62	
Supplement to winter crop	n.m.	n.m.			0.33	0.60	
Total					6.23	6.00	
Comparative stocking rate					81.8	83.3	
Milksolids production							
Days in milk	277	280			267	256	
Milksolids per cow (kg)	451	434		463	509	476	<0.05
Milksolids per hectare (kg)	1,578	2,170	1,500	1,821	1,782	2,378	<0.01
Profit and nitrate leaching							
Operating profit ($/ha)[3]	4,334	4,810	3,300	4,395	4,302	4,205	NS
N leached (kg/ha)[4]	29	43	45-50	57[5]	32 (27-35)[6]	46 (40-52)[6]	<0.05

[2] Concentrate = cereal grain; [2] Home grown and purchased; [3] at milk price = $6.10/kg milksolids; [4] for milking platform area only; [5] average, 2009-2013; [6] range over 4 years

Both systems exceeded the levels of milk production per cow and per hectare predicted by the pre-experimental modelling (Table 1). In LIHE, milk production per cow of > 500 kg MS/year from a diet comprising 93% direct-grazed pasture was an emergent property of the system. The result was that per hectare production from LIHE exceeded Canterbury benchmark by 280 kg MS/ha/year at the same stocking rate with 100 kg less N from fertiliser, and was similar to LUDDF which operated a higher stocking rate and used > 150 extra kg N/ha per year from fertiliser. Pasture quality in LIHE was clearly not limiting cow production. The additional 33 kg MS/cow/year produced in LIHE compared with HIHE can be explained by slightly higher feed offered per cow (Table 1: 230 kg DM/c, at 12.2 kg DM per kg MS = 19 kg MS) and an additional 9 days extra in milk (Table 1: mostly in late lactation when daily production = c. 1.4 kg MS/c/day = 12 kg MS).

This analysis implies that overall feed quality was similar between the two systems. It also leads to an affirmative answer to the core research question about whether or not it was possible to manage feeding in the LIHE system successfully with a small safety net in the form of extra N and imported supplement. Consistent assessment of pasture cover on every paddock every week, by the same person was central to this: as was the disciplined use of this information to allocate pasture to meet daily feed demand, plan to ensure future pasture cover targets were met, adjust rotation length in a timely way, identify pasture surpluses in spring/summer for silage conservation, and add or remove supplements. These tools and decision processes are available to all farmers and their successful use in commercial farming has been demonstrated (van Bysterveldt and Christie 2007). In this study, they were also used to make decisions about N fertiliser use, so that N could be withheld if the pasture wedge indicated additional feed was not required. Thus, mean N fertiliser use in both LIHE and HIHE (Table 1) was also an emergent property of the system – not a pre-determined, fixed target.

Including support land

Extending the analysis to include support land shows that the total footprint of the systems compared here exceeded that of the milking platform alone by a factor between 1.75 and 2.5 (Table 2) and therefore that the management of support land must also be addressed to reduce total emissions. This is self-evident, but has seldom been considered. Ignoring support land brings a risk that effort and resources intended to reduce the farming footprint could be mis-directed. In this context, while the HIHE system produced over 2350 kg MS/ha when total milk was attributed to the MP only, this falls to less than 1000 kg MS/ha when land required to winter cows (high stocking rate means a larger herd to feed over winter), rear replacements (herd size is a driver of land requirement here too) and grow imported supplements is accounted for (Table 2). The difference between HIHE and LIHE in MS/ha (Table 1) disappears when all land parcels are included (Table 2). Thus, lowering input intensity does not necessarily mean total milk volume by region will decline. For example, some of the 150 hectares of land ‘spared’ per 100 ha milking platform business (Table 2) by staying at regional benchmark stocking rates but improving production efficiency could be used for milk production from a LIHE-type system, depending on the sustainable catchment nutrient loads. In some cases, this land might need to go to other uses with a much lower nutrient footprint to meet water quality targets.

Table 2. Analysis of production and nitrate leaching for two milking platform (MP) systems each operating with two wintering options (kale followed by oats, 'K + O', fodder beet, 'FB') scaled to the equivalent of a 160 ha milking platform using the stocking rates applied in the farmlets (3.5 c/ha and 5.0 c/ha for LIHE and HIHE respectively). All values for nitrate leaching per hectare are derived from OVERSEER® v. 6.2.2.

	Lower-input, high efficiency (LIHE)		**Higher input, high efficiency (HIHE)**	
	Wintering system		Wintering system	
	K + O	FB	K + O	FB
MP area (ha)	160		160	
Total herd size at peak	560		800	
	Support land required			
Winter crop yield at grazing (t DM/ha)	12.0	19.9	12.0	19.9
Mean area of winter crop per cow (m^2)[1]	613	264	613	264
Total area winter crop (ha)	36	14	52	20
Area of pasture on winter support block (ha)	24	28	35	40
Area for purchased silage (ha)[2]	0	23	15	54
Area for purchased grain (ha)	3	3	40	40
Area for replacement stock (ha)	57	57	82	82
Total area required (ha)	280	285	384	396
Support land as proportion of MP	0.75	0.79	1.40	1.48
	Milk production			
Total milksolids (kg)	285,120		380,427	
Milksolids kg/ha: MP only	1,782		2,378	
Milksolids kg/ha: all land used	1,016	997	992	960
	Nitrate leaching (MP and winter crop only)			
MP: kg N/ha	32		46	
MP: total tonnes	5.16		7.32	
Winter crop: kg N/ha	181	145	181	145
Winter crop: total tonnes	6.41	2.08	9.16	2.97
MP plus winter crop: kg N/ha	60	43	76	55
MP plus winter crop: tonnes	11.57	7.24	16.48	10.29

[1] Total for 65 days feeding

[2] Silage in addition to that conserved on the MP and on the pasture area on the winter support block

OVERSEER® predicted lower nitrate leaching from below a fodder beet crop than from the kale crop (Table 2). This was a result of lower predicted losses from mineralisation due to cultivation compared with kale (data not presented) which was in fact a double-cropping system (a catch crop of oats following the kale). The catch crop strategy on land used for winter cropping can reduce nitrate leaching from urine deposits by 20-40% (Carey et al. 2016) by largely eliminating the fallow period when going from fodder crop to fodder crop so that there is uptake of mineral N for plant growth during spring and less N at risk of leaching. Direct N leaching measurements conducted in the experiment reported here also show lower nitrate leaching under fodder beet than kale (K. Cameron, pers. comm.), but not necessarily for the same reasons as OVERSEER® The direction of the difference in nitrate leaching from different assessment techniques is consistent but more research is needed to understand the processes.

The target for the study, of reducing nitrate leaching by c. 30%, was nearly achieved with a reduction of c. 25 - 28% occurring when both milking platform and winter support land were considered. The LIHE/fodder beet combination came closest to the target at an estimated 43 kg N/ha per year (Table 2). Nonetheless, the results demonstrate that there is scope to manage N losses: further research in programmes such as Forages for Reduced Nitrate Leaching (Edwards et al. 2015) will lead to more options for footprint reduction in the future.

Conclusions

The inclusion of winter grazing support land can more than double the total N leaching footprint (kg N/year) of dairy farm businesses compared with N leaching estimates based on the milking platform only. Clearly, all land used to support the production system should be considered to identify where the most cost-effective opportunities for reducing the footprint of the business lie. The fact that dairy support land is often owned by a sheep, beef or arable farmer should not be an excuse for ignoring this. All farm businesses will in future be required to operate to a nutrient emission target, therefore nutrient losses from all enterprises will come under scrutiny. This could alter the supply and cost of support land as farmers make individual decisions that are best for their continued viability in a regulated future.

Based on the evidence presented here, and other sources, we now know that there are system options that Canterbury farmers could adopt to reduce their nitrate leaching footprint. This is important information for building farmer confidence in the face of regulatory change. On the milking platform, reducing inputs of N in fertiliser and feed, adjusting cows per hectare to maintain the CSR in the range shown by research to maximise profit, and consistently monitoring pasture cover and using this information to make good grazing management and feeding decisions, can lead to high NCE and mean estimated nitrate leaching that is c. 30% below the Canterbury benchmark (Table1). The management principles, practices and decision tools required to operate such a system are all well known and freely available to farmers. Thus, such a system should be viable, and profitable, commercially: as demonstrated successfully by LUDDF (Pellow 2017). Coupling this with use of a fodder beet crop for winter feeding can further reduce the total environmental footprint of the business.

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