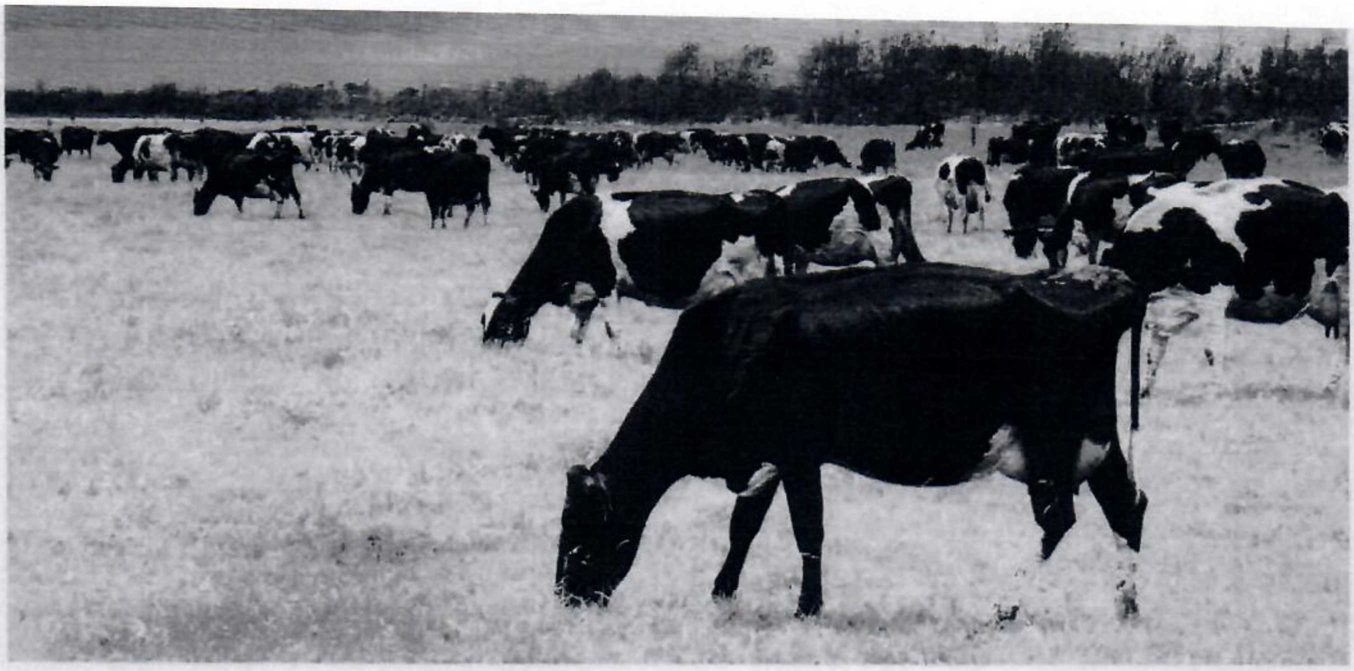

Principles from Pastoral 21: Optimising dairy system strategies to meet nutrient limits

The New Zealand Government released its National Policy Statement on Freshwater Quality in 2011 to trigger Regional Council planning processes aimed at improving long-term water quality throughout the country. It is now clear that dairy farmers in many regions will need to reduce the amount of nitrogen (N) leached from their farm systems to comply with regional nutrient limits. In some regions, phosphorus (P) losses via sediment erosion or transport in overland flow into streams must also be addressed.

Key points:

- Pastoral 21 (P21) has demonstrated that reducing nitrogen (N) inputs in fertiliser and feed, while increasing N use efficiency and conversion of feed to milk, can reduce N leaching by 30-40% relative to current practice.
- However, this outcome requires a high standard of pasture and grazing management and is associated with small, but important, reductions in profit.
- Identification, and targeted management, of critical source areas for phosphorus (P) loss is a successful, simple approach for reducing P movement into waterways.
- These findings provide confidence that Regional Council limits on the amounts of N and P that can be emitted from farm systems can be met by changes in farm practice that retain the fundamental principles of low-cost, pasture-based dairying.

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The task for P21

In 2011, we did not know if there were practical dairy farm systems that could reduce nutrient losses by 30% or more from current practice while retaining high levels of profitability.

The 'default' thinking was that such large nutrient loss reductions would also substantially erode profits – clearly an undesirable outcome. The research and development programme Pastoral 21 (P21) was initiated in 2011 to address this knowledge gap using farm systems demonstrations plus component research[1].

The task for the dairy systems demonstration projects conducted in P21 was to apply current scientific knowledge of the ways that nutrients cycle and move around the farm. This helped to identify where management interventions could reduce nutrient movement into waterways. Whole farm systems studies were undertaken to assess production and profit alongside the nutrient balance outcomes.

Core principles

The complexity involved in managing nutrient losses can be almost overwhelming, since there are so many processes involved and these are highly variable in space and time. To cut through the complexity, it is helpful to settle on some core management principles and cascade the options under these. The management principles stem from biophysical principles, particularly those that define how nutrients move in soil-plant-animal systems. Nitrogen (N) and phosphorus (P) are very different in this regard.

Nitrogen

Nitrogen is a highly mobile element. It has been described as having 'slippery chemistry' because it exists in many forms, and can change between these forms rapidly in response to environmental conditions. The form of N leached below the root zone is nitrate. Nitrate is not retained on soil particles, so moves with water in drainage. In contrast, ammonia is weakly bound to the soil and doesn't move as readily.

Nitrogen is also lost to the air as nitrous oxide (N_20) and dinitrogen gas (N_2). Nitrogen hits the soil under pasture as urea (in cow urine or fertiliser), where it is transformed to ammonia, then to nitrate, and finally to N_2O and N_2. Transformation beyond ammonia means increased risk of N losses. Nitrogen not taken up by plants as ammonia or nitrate (which are continually in flux) or immobilised into soil organic matter is destined to be lost from the system.

It is well known that, across all agricultural land uses, the more N that is added to the system, the more that is lost – this is an inevitable result of the chemistry of N[2,3]. Systems that are highly enriched in N will leach or volatilise (lose to the atmosphere) a lot of N, and vice-versa. It is impossible to 'close' the N cycle and stop N moving: but it is possible to restrain it by not over-enriching the system. For dairy farms, this principle points immediately to the management of N inputs in fertiliser (urea is 46% elemental N), but also in imported feed (since elemental N typically comprises 2-3% of feed dry matter) as an opportunity to reduce losses.

The good news is we already have the scientific knowledge and management tools that can help lift the efficiency with which N fertiliser is used to grow and harvest more pasture[4], and the efficiency with which imported supplement is used to produce milk[5]. The thinking in the P21 farm systems demonstrations carried out in Waikato, Canterbury and South Otago was that, if these are applied accurately and often, large reductions in the amount of N input and N leaching footprint could be achieved while maintaining high production and profit (Table 1).

The other approach applied in P21 was to capture N in urine at critical times and re-distribute it evenly across pasture, rather than in concentrated urine patches. This management principle was used in the P21 system studies in Waikato and South Otago (Table 1) i.e. to capture (and, where feasible, re-use) nutrients on a part of the farm.

This was achieved either with a built facility like a stand-off pad, or in a natural collection and discharge point in the landscape called a critical source area (CSA)[6].

Phosphorus

Phosphorus is a different proposition to N. Phosphate ions, the form that plant roots can access, are relatively immobile forms of P that bind moderately to strongly (depending on soil type) to soil particles. Leaching is much less of a concern with P for most soils.

The main routes by which P leaves the farm are via attachment to sediment (e.g., in sediment run-off after grazing of a winter crop on the downlands of Otago and Southland[7]) or via run-off that may occur on poorly drained or sloping soils shortly after the deposition of P-rich materials, such as dung or soluble P fertilisers[8].

In the P21 study in South Otago (Table 1) the thinking was tested, that if the CSAs that channel most of the P lost from the farm into waterways can be identified, then the amount of P entering the CSA could be reduced, or losses from the CSA could be capped in some way.

Table 1: Principles, strategies and management considerations for targeting reduced N and P losses. P21 sites were in Waikato (W), Manawatu (M), Canterbury (C) and South Otago (SO)

	Management principle	Applies to:	Strategy	Target nutrient	P21 sites	Key management considerations
1	The more you use, the more you lose	Whole farm	• Reduce N fertiliser	N	W, C, SO	N fertiliser efficiency, pasture production, feed supply/demand balance
2			• Reduce imported feed	N	W, C, SO	Feeding efficiency, pasture utilisation, feed supply/demand balance
3	Capture and re-use	Parts of the farm	• Use a stand-off	N	W, M, SO	Timing of use, capital and other costs
4			• Manage critical sources areas	P	SO	Practical implementation

Table 2. Key inputs used in, and results from, P21 dairy systems comparisons in three regions. Results are averages of three (South Otago), four (Canterbury) or five (Waikato) years.

	Waikato		Canterbury		South Otago	
	Regional control[A]	Alternative system	Regional control[A]	Alternative system	Regional control[A]	Alternative system
Strategy (see column 3 in Table 1)		1, 2 and 3		1 and 2		1, 2 and 4
N fertiliser on pasture (kg N/ha/year)	135	60	313	159	109	42
Imported feed offered (t DM/ha/year)	1.2[1]	1.4[2]	1.7[1]	0.9[6]	0.6[9]	0.2[9]
Stand-off/restricted grazing	No	Yes[3]	No	No	No	No
Stocking rate (cows/ha)	3.2	2.6	3.9	3.5	2.9	2.8
Comparative stocking rate (CSR, kg liveweight per tonne feed offered)	89	79	79	83	89	89
Key results						
Pasture eaten (t DM/ha/year)	14.2	13.0	16.3	15.1	11.9	11.3
Milksolids (kg/ha/year)	1201	1151	1821	1782	963	930
Estimated operating profit ($/ha/year)	4310[4]	4083[4]	4395[7]	4205[7]	2234[10]	2103[10]
Nitrate-N leached (kg N/ha)	60[5]	34[5]	57[8]	34[8]	18[11]	14[11]
Phosphorus loss risk (kg P/ha/year)	n.m.	n.m.	n.m.	n.m.	0.60[11]	0.41[11]

A 'Current' farmlet, operated alongside the alternative system, B Lincoln University Dairy Farm (LUDF) 2011/12 to 2013/14 seasons, C 'Control' farmlet operated alongside the alternative system.
[1] all pasture silage; [2] 57:43 pasture silage : maize grain; [3] cows on stand-off for 8 or 16 hours between March and June, [4] at milk price $7.30/kg milksolids; [5] measured using suction cup samplers; [6] 76:24 pasture silage : cereal grain; [7] at milk price $6.30/kg milksolids; [8] modelled Overseer version 6.2; [9] pasture and cereal silage; [10] at milk price $6.45/kg milksolids; [11] a risk-based approach using a combination of measured values (milking platform and winter forage crop areas) and modelled estimates (remaining areas).
n.m. not measured.

P21 comparisons and conclusions

In all regions, one or more strategies for reducing nutrient losses were tested against a regional 'control' system. The main differences in inputs between the alternative system and the regional control are shown in the top half of Table 2. For example, in Waikato, the alternative system reduced N inputs by more than 50% compared with the control (total of 75 kg N/ha less applied), kept similar imported feed amounts, reduced actual and comparative stocking rate, and stood cows off on a wood chip loafing pad for between eight (milking cows) and 16 (dry cows) hours per day from March until June (Table 2). There were other factors that differed between the two systems in all cases, and though these were important in some situations, they cannot be covered in detail here.

The key results are shown in the bottom half of Table 2.

Lower inputs

The lower input strategy as applied in Waikato and Canterbury reduced N leaching by around 20-40% compared with the control system (in Waikato, about half of the N leaching reduction was attributed to the stand-off). Production and profit per hectare were lower than the control system, but proportionally less than the substantial reductions in fertiliser N and in the case of Canterbury and South Otago, imported feed.

In 2014/15 and 2015/16, after the results of the first three years of the P21 systems study in Canterbury were available, the Lincoln University Dairy Farm (LUDF), herd size 560 cows, adopted the same management practices used in the P21 alternative system.

Over those two seasons, LUDF exceeded the production achieved in the P21 farmlet and maintained its profit ranking position relative to a group of leading Canterbury farms that LUDF is benchmarked against each year[9]. This provides evidence that the strategy can be implemented at commercial scale, giving a level of confidence that there are ways in which farms can cope with N leaching limits while retaining the fundamentals of successful NZ dairy systems: pasture-based and low-cost.

What you need to know - managing a Low N system.

What is required to make the lower input strategy work?

- Recognition that lower inputs = lower total feed supply, and willingness to adjust cows/ha to maintain comparative stocking rate (CSR) in the target range of 80-85 kg liveweight/t DM[10] with 90% of feed requirements coming from grazed pasture. In P21 Canterbury, 95% of total requirements on the milking platform came from grazed pasture. This strategy is about balancing feed supply and demand, using pasture first and minimising supplement required.
- Strong focus on pasture monitoring (feed wedges) leading to good pasture allocation decisions and achieving consistent target residuals in the range 1500 – 1650 kg DM/ha[11].
- A 'little and often' approach to N fertiliser application, including preparedness to withhold N for one or more rounds if expected feed supply meets current and expected demand so that N can be spared for use at the key times of start and end of lactation.
- Close adherence to body condition score and pasture cover targets.

What must be considered on farm to meet these requirements?

- Pasture growth potential, as set by climate and soils – adjust CSR based on expected pasture grown (including expected reduction in total pasture growth if N fertiliser is reduced).
- Cow liveweight – which is why CSR is a more useful tool than just cows/ha.
- Skills available for pasture monitoring and decision-making.
- What surprises emerged, and what should farmers be mindful of?

1. Pastures receiving lower N fertiliser can appear visibly N deficient at times (e.g. with urine patches showing out strongly), but this may not be reflected in the feed wedge/growth rates. The wedge is a better indicator, and the deficiency symptoms will pass with time.
2. Cows can respond very well to the management regime if it is well executed. In P21 Canterbury, and LUDF, per cow production increased to over 500 kg MS/cow (we expected about 450kg) from a pasture-dominant diet, even though high per cow production was not a target.
3. There is a lower margin for error in the lower input system if the N fertiliser use and feeding efficiencies required to achieve the N leaching reductions are to be realised. There is a smaller safety net in the form of available N and imported feed to dig yourself out of a hole. It is more risky, but the risk is manageable if the skills are available.

Nutrient capture

In the P21 alternative system in South Otago, the risk of P loss was reduced by about one third (Table 2), due to large reductions in sediment run-off under the winter crop (kale) that was grown and fed on the milking platform. The solution in this case was relatively simple. In the crop paddock, the CSA where sediment was likely generated and then discharged into surface water was identified, and this became the crop block that was grazed last.

The effects of doing so were two-fold: it reduced the amount of soil treading damage, and thus sediment generation, and the standing crop in this area helped to trap sediment transported in overland flow originating in the upper areas of the paddock.

Preparedness to forego some crop harvest in the CSA is necessary if soils are very wet. Otherwise, the strategy is relatively simple, and incurs little direct or indirect cost. Most producers on downland country should be able to implement the strategy with ease, and thereby substantially improve their P loss footprint.

Concluding comment

In 2011, when regulations to limit nutrient losses from farms became government policy, there was no evidence available to show dairy farmers that farm systems options existed that could meet those limits.

With the benefit of the findings from P21 systems demonstrations and other work, we now know there are viable system options that can reduce N and P losses by 30-40% below current practice. We also know that those options generally come with associated reductions in profit. Reductions in profit and nutrient losses are not linearly related: the relationship can be 'de-coupled' so that substantial water quality gains can be achieved without eroding the fundamentals of the low-cost, pasture-based system.

These outcomes should provide some confidence to farmers that they can continue to operate profitably in the new regulatory environment. Research underway currently will present farmers with further viable options.

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Science snapshot

Increased stocking rate without imported feed but with shorter lactation length reduced nitrate-N leached[1].

The effect of intensive agricultural systems on the environment is of increasing global concern, with nitrate (NO_3-N) leaching to groundwater being a focus for most regions in New Zealand. Many consider stocking rate to be a key contributor to the amount of NO_3-N leached from dairy pastures; however, in most situations stocking rate has been confused with the importation of feed from off farm to feed the additional cows. In recent research from Ireland, NO_3-N was reduced, even though stocking rate was increased; however, there were many changes to farm management and it was not possible to determine the actual effect of stocking rate from that work. A subsequent Irish study showed no effect of stocking rate on N leaching when this was the only factor changed.

In New Zealand, Macdonald et al.[2, 3] compared five different stocking rates ranging from 2.2 to 4.3 cows/ha in self-contained farmlets (i.e., no purchased feed) producing approximately 18 t DM of pasture with 200 kg applied N/ha. The amount of NO_3-N leaching was measured using ceramic cups placed below the root zone. The results indicated a linear decline in NO_3-N leached as stocking rate increased (12 kg NO_3-N less leached/ha for every extra cow/ha in stocking rate).

It isn't clear why this unexpected result occurred. All treatments deposited similar amounts of urine N per hectare in the February-June period, leading to an expectation that N leaching would be similar as in the Irish study. Further research is being undertaken to understand the reason for the reduction in NO_3-N leaching with increasing stocking rate in this experiment. Possible explanations include:

- Lower urinary N concentration in dry cow urine compared to lactating cows during the high leaching risk autumn period. The high stocking rate treatments dried cows off earlier.
- Soil compaction under high stocking rates leading to urine patch spreading.
- Differences in N balance due to pasture uptake.
- High variability in the trial data leading to an overestimate of the true effect, noting that an underestimate is equally statistically likely.

It is very important to note, however, that this work was undertaken in a closed system, i.e. almost no feed was imported. The increase in stocking rate was managed through a lower feed allowance/cow and by reducing lactation length. If stocking rate was increased AND additional feed was purchased onto the milking platform or for the winter period, NO_3-N leached would probably have increased, unless cow urine was captured in a stand-off facility and applied evenly to the pasture. This would require considerable capital investment in depreciating assets and, even then, may not limit an increase in NO_3-N leached completely.

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