A FARM SYSTEMS PERSPECTIVE ON SENSIBLE OPTIONS FOR REDUCING NITROGEN LOSS FROM DAIRY FARMS USING INDICATORS RELATED TO NITROGEN SURPLUS AND NITROGEN CONVERSION EFFICIENCY (NCE%)

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Abstract:
Recommendations for dairy farms aimed at reducing nitrogen (N) leaching, require thorough analysis of their impact on the whole farm system, and not just their likely impact on single Overseer® indicators. Without this analysis, there is a risk of recommendations leading to increased N leaching, reduced profit, and increased financial risk for farmers with no reduction of N loss to waterways. A common example is a simple recommendation to lower the protein (N content) of a herd's diet by increased feeding of maize silage to improve a farm's N conversion efficiency. We provide an example scenario where increased maize silage feeding, could have the undesirable effect of increasing a farm's N surplus and N leaching. An important consideration for the impact of any recommendation is whether it involves significant change to the farm system (e.g. increased total feed supply, herd size and additional infrastructure), as opposed to seeking improved efficiency within the existing system.

The concept of efficiency, such as in the N conversion efficiency measure reported in Overseer, is useful for determining how all external N inputs (fertiliser and supplements) are used for milksolids output, but this is not always well correlated to N leaching.

In this paper we outline a process and useful measures by which farmers and their advisors can assess recommendations for reduced N leaching against overall farm performance and efficiency, and tailor these to meet goals of continued business viability and improved water quality in their region.

Introduction:

Implementing farm system change for reduced nutrient loss is complex. Poor understanding and over-simplification can put both the achievement of reduced nutrient loss and the financial viability of the dairy farm business at risk.

An example of an over simplified message farmers are receiving is;

"Feeding maize silage - a relatively low crude protein feedstuff - reduces the amount of nitrogen in urine and can greatly reduce leaching losses" (Anon, 2013)

In a farm systems context reducing the concentration of nitrogen in urine, as suggested above, is only part of the equation for reduced N leaching. Additional questions to consider are:

- Will the introduction of maize silage result in increased cow numbers, more urine patches and increase the total volume of urinary N excreted by the herd?

- Where and how will this maize silage be grown and fed and how does this impact on N loss for a farm, or the wider catchment?

A purpose of this paper is to alert farmers and their advisors to a pair of potential indicators, comparative stocking rate (CSR) and the ratio kgMS/kgN applied, which can point to the need for change of current farm management practices which impact on farm N surplus. This is not a comprehensive review of all management practices associated with N loss.

Identifying critical points where farm management changes N loss

We have endeavoured to summarise critical points where farm management decisions impact on a farm's N surplus, and, therefore, a farm's potential to leach N (Figure 1). Clearly identifying the farm management changes also enables linkages to farm profit to be made.

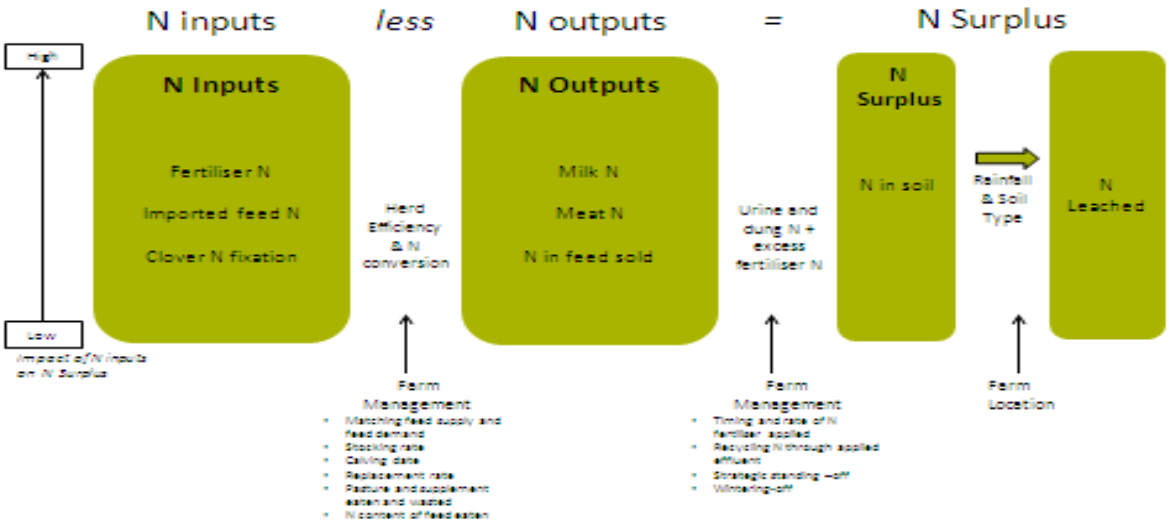
From a farm management perspective, N surplus is the parameter over which dairy farmers have some control. **N surplus** is the nitrogen that remains after the conversion of nitrogen inputs to saleable product such as milk, meat, and supplements sold off the farm, (N inputs - N outputs = N surplus) . The N surplus is mostly excreted by animals in urine and dung. The amount of **N leached** is related to the N surplus, with this relationship influenced by use of farm infrastructure which may enable the capturing of urine, and non-management factors such as rainfall and soil characteristics.

In summary, Figure 1 shows farmers have three main options for reducing N surplus;

1. Reduce N inputs
2. Convert N inputs to product (N outputs) more efficiently
3. Intercept and capture a proportion of the N surplus excreted by the cows, and redistribute this in a manner that reduces the risk of N leaching.

Information from relevant research provides valuable indicators for farmers about the appropriateness of farm management changes for the first two of these three options.

Figure 1. Relationship between Nitrogen Inputs & Outputs, Nitrogen (N) Surplus and Nitrogen (N) Leaching for a dairy farm.



Option 1: Reduce N inputs by better matching feed supply and demand

CSR is an indicator of the balance between feed supply and feed demand and indicates the likelihood of N inputs being driven upwards by a feed demand higher than optimum. The need for high N inputs on a dairy farm can be driven upwards by extra feed demand created by high stocking rates (cows/ha) and earlier calving dates. Increasing amounts of N fertiliser and supplementary feed are introduced to a farm to support higher feed demand and milk production. The NZ dairy industry was developed through farm practices aimed at increasing pasture utilisation and milksolids (MS) per hectare (ha) by increasing stocking rate. Historically, the link to profitability of these practices was strong. More recently, the link to increased profitability through increasing MS/ha was broken by increased amounts of supplements introduced into farms, the associated costs of feeding them and potential inefficiencies they can create if not well managed. The broken link between MS/ha and profitability has not always been recognised by dairy farmers. More recognition is required for the concept that farm profit is maximised at a lower level of production than where maximum production is achieved, (Wright and Pringle, 1983). The principle is supported by farmlet research (Macdonald et al., 2008, Macdonald et al., 2011) which reinforces the concept that there is an optimum rather than a maximum stocking rate linked to profitability for a farm. The ratio, comparative stocking rate (CSR) is used to describe this. CSR is a ratio between liveweight (LWT) and feed offered per hectare.

For a farm stocked at 3.0 cows/ha with average cow liveweight of 500 kg /cow, the total liveweight is 1500 kg/ha. If, on an annual basis, the total feed offered was 20 t dry matter (DM)/ha (pasture grown + supplement offered) then CSR is 1500 divided by 20 = 75 kg LWT/ t DM.

The optimum CSR for profit is estimated to be 75-85 kg LWT/tDM offered (Macdonald, et al. 2011). Farm systems analysis suggests that 50% of dairy farms examined are operating at a CSR above this range (Wendy Dewar, pers.comm). This suggests that, on some dairy farms, there are cows that are contributing little to farm profit but are potentially impacting on nutrient loss. Identifying the farms where this is the case will be important in meeting targeted reductions in nutrient loss from a catchment.

It is therefore recommended that an opening step for planning any farm system change required for managing nutrient loss is the calculation of CSR. Assistance for this can be found at http://www.dairynz.co.nz/page/pageid/2145863039/Comparative_Stocking_Rate

Step1: Calculate CSR

Step 2: Check the consequences of changing CSR on production and profitability.

A whole farm budget for the new CSR is required.

To assist with step 2, Glassey et al. (2012) determined that a one unit reduction in CSR resulted in a 0.47% reduction in pasture utilisation, and an increase in MS of 4.5 kg/cow. This analysis confirmed that it is possible for a farm to lower CSR and maintain production, with potential for also changing N inputs.

Reduce N input: by reducing fertiliser N

There is a wide range in efficiency of N fertiliser use on dairy farms. One indicator of efficiency is the ratio of kg MS produced per kg N applied.

In a sample of 25 dairy farms in the Horizons region this ratio ranged from 5 kg MS/kgN (less efficient) to 28 kg MS/kg N applied (more efficient). This measure is not an absolute efficiency measure as between farm comparisons need to consider the annual pasture yield potential of the farms being compared. Nevertheless it does provide an indication of which farms to suggest for reduced N fertiliser input.

Applied fertiliser N has a strong link to farm N surplus (DairyNZ , unpublished data). Data from these dairy farms in the Horizons area showed that for every kg of N fertiliser added per ha, the N surplus increased by 0.9 kg/ha.

Therefore, it is suggested that in planning any farm system change for managing nutrient loss a quick check of farm performance is made using the following;

Step 1: **Check the ratio of MS produced /kg N applied.**

Step 2: **Calculate the reduction in annual DM production/ha from any change in N fertiliser use.** If the ratio points to a reduction in N fertiliser use, then the anticipated reduction in annual pasture yield needs to be estimated. This estimate is then applied to the CSR calculation (above) to determine if any reduction in stock numbers is required when N fertiliser input is reduced. For example, if the N response was assumed to be 10 kg DM/kg N applied, or 1 t DM/100 kg N) then a farm using 200 kg N/ha and estimated to be growing 17 t DM/ha annually, would be expected to grow 16 t DM/ha annually if it reduced N fertiliser use to 100 kg N/ha.

Step 3: Calculate the change in comparative stocking rate (CSR) due to lower annual feed supply. If the CSR was previously 75 kg LWT/tDM , then a 1 tonne reduction in annual pasture yield would result in a requirement to reduce LWT/ha by 75 kg to maintain the same CSR . The case study farm of 3.0 cows/ha – 1500 kg liveweight /ha , needs to adjust to 1425 kg LWT/ha, which with cows weighing 500 kg /cow is 2.85 cows/ha. If the previous stocking rate was maintained the new CSR calculation would be 1500 kg LWT/19 t DM/ha = 79 kg LWT/t DM.

Step 4: Check the consequences of changing CSR on production and profitability
The impact of reduced N application on profit is likely to be more favourable where gains in efficiency of N fertiliser use can be made. Changes in the ratio of milk price and the cost of N fertiliser change the profitability of N fertiliser use (see Table 1). A 10 year farmlet study at DairyNZ (Glassey et al., 2013), showed that for 6 out of the 10 years this ratio was not favourable for profitably increasing milksolids production by using N fertiliser.

Table 1. Current, historical and projected ratios between milk price and cost of urea and the implications for profitable N use.

Year	Milk price	Cost of applied N	Ratio	Profitability under good management
Current	$8.65	$1.87	4.6	Very good
2010-11	$7.50	$1.98	3.8	Good. More than 10% change
2009-10	$6.07	$1.98	3.1	Profitable Less than 10% change
2004-05	$4.60	$1.98	2.3	Less profitable compared with using zero N
Current Milk price. Urea price changed to $1200/tonne	$8.60	$2.86	3.0	Borderline Less than 10% change

Option 2: Convert N inputs to product (N outputs) more efficiently

The concept of efficiency, such as the N conversion efficiency measure reported in Overseer, is useful for determining how all external N inputs (fertiliser and supplements) are used for milksolids output. However, N conversion efficiency is not always well correlated to N leaching. It is also important to consider the method of how this efficiency is achieved, and it's likely impact on the farm's N surplus, which ultimately determines N leaching. For example, it is possible when seeking an improvement in N Conversion efficiency to create a change in the farm system that results in increased N surplus.

A good example of this was illustrated by farmlet comparisons in the Resource Efficient Dairying trial at Dairy NZ (Table 2, Jensen et al., 2005). Increasing amounts of maize silage brought into the farmlet resulted in increased milksolids production/ha, increased nitrogen conversion efficiency but higher N surpluses, with increased N leaching.

For example the farmlet producing 1500 kg MS/ha, using 5 t DM/ha of maize silage, increased MS/ha to 2200 kg MS/ha by increasing maize silage use to 10 t DM/ha. Nitrogen conversion efficiency improved from 34 to 37%, an apparently desirable result. The reality is that the farms N surplus/ha increased from 212 to 351 kg N/ha and N leaching from 48 to 113 kg N/ha. This change required significant investment in livestock and infrastructure, as well as increased the farms risk to costs associated with feeding and fluctuations in milk price.

These data reinforce the over-simplification of the message quoted in the introduction, that "Feeding maize silage - a relatively low crude protein feedstuff- reduces the amount of nitrogen in urine and can greatly reduce leaching losses (Anon, 2013)." An addition to this message could be "increased maize silage may also result in additional N inputs/ha, additional cows, additional urine patches, and despite reduced urinary N concentrations more total urinary N excreted".

Table 2: Annual nitrogen (N) inputs, outputs and conversion efficiencies for four Resource Efficient Dairying farmlets with varying maize silage inputs and milksolids /ha (mean of 3 years, 2002-2005)

Farmlet	kgMS/ha	N input (kg/ha)	N conversion efficiency (%)	N leaching (kg/ha)
Control	1151	270	30	42
Low supplement	1493	320	34	48
Moderate supplement	2122	418	37	67
High supplement	2839	606	34	113

Low supplement= 5 t maize silage DM/ha
Moderate supplement = 10 t maize silage DM/ha
High supplement = 20 t maize silage DM/ha

Conclusion:

Greater understanding of the farm management changes that are important in managing nutrient loss is required throughout the dairy farming community. Our view is that N surplus is the measure that farmers can influence the most through reducing N inputs and improving N conversion efficiency. While research continues to improve this understanding, farmers and their advisors can start by checking the impact of their feed supply/feed demand balance on N inputs and N surplus using the CSR and kgMS/kgN ratios described. It's possible that improvements can be made in this balance which results in N inputs being withdrawn or better utilised, resulting in a lower N surplus for a farm. This should be checked before significant changes are made to the type of feed (N input) used in an effort to improve N conversion efficiency. A risk is that seeking to improve the efficiency of the farm system through focussing on single indicators could create a system change that increases N loss and is detrimental to both the business and the environment.

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