The Mitigation of Nutrient Loss from New Zealand Agriculture:
Separating the Probable from the Possible

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Abstract

Pastoral farming contributes significantly to the New Zealand economy but can have adverse environmental affects. Nitrogen and phosphorus leaching into water ways are known to affect the health of aquatic wildlife and can have health implications for humans. Nutrient leaching can be reduced by mitigation. Understanding the effectiveness and cost of mitigation is critical to informed farmer and policy maker responses to these challenges.

In this paper we combine existing research with expert knowledge to construct a picture of what nitrogen and phosphorus mitigation is likely to be possible, at a national level, over the next eight years. We distinguish between mitigation that is probable (likely to be implemented given current trends), and mitigation that is possible (while technologically feasible, is unlikely to be implemented given current trends).

JEL codes

Q53, Q57

Keywords

Beef, dairy, mitigation, nitrogen, phosphorus, sheep

Contents

1. Introduction

Pastoral farming contributes significantly to the New Zealand economy but frequently has adverse environmental affects. Nitrogen and phosphorus leaching are associated with reduced water clarity and increased algal growth. Eutrophication of water ways is known to affect the health of aquatic wildlife and can have health implications for humans.

Nutrient leaching can be reduced by mitigation: changes in land management practices, improvements in farm production efficiency, reductions in land-use intensity and land use change. Understanding the effectiveness and cost of mitigation is critical to informed farmer and policy maker responses to these challenges.

In this paper we combine existing research with expect knowledge to construct a picture of what nitrogen (N) and phosphorus (P) mitigation is likely to be possible, at a national level, over the next eight years.[1] Mitigation is separated into two classes: Type 1 mitigation is that which we think is probable (i.e. likely to be implemented given current trends). This includes mitigation that is in line with industry, landowner or regional council goals. Type 2 mitigation is that which we think is possible (i.e. while technologically feasible, is unlikely to be implemented given current trends). This is frequently more costly mitigation that might only be carried out under significant regulatory pressure.

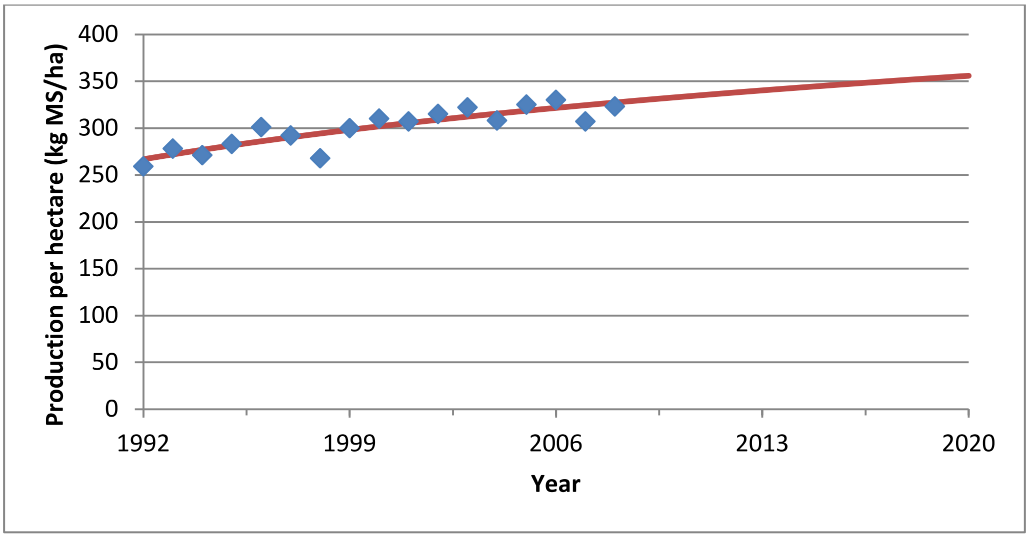
The paper is set out as follows: Mitigation on dairy farms in considered in section 2, and on sheep/beef farms in section 3. Section 4 concludes. Where we are aware of possible approaches to modelling or quantifying mitigation, these are noted in the text.

2. Mitigation on Dairy Farms

We consider dairy farms under the assumption that current improvements in production per hectare will continue, though at a decreasing rate. Figure 1 gives an estimate of this trend at a national level. This section aims to give a picture of likely mitigation outcomes; these will be driven by increased implementation of best practice in line with the potential for mitigation identified by research and industry goals.

[1] This paper arises from a series of conversations held in August 2011, looking forward to the year 2020.

Figure 1: National trend in dairy production per hectare

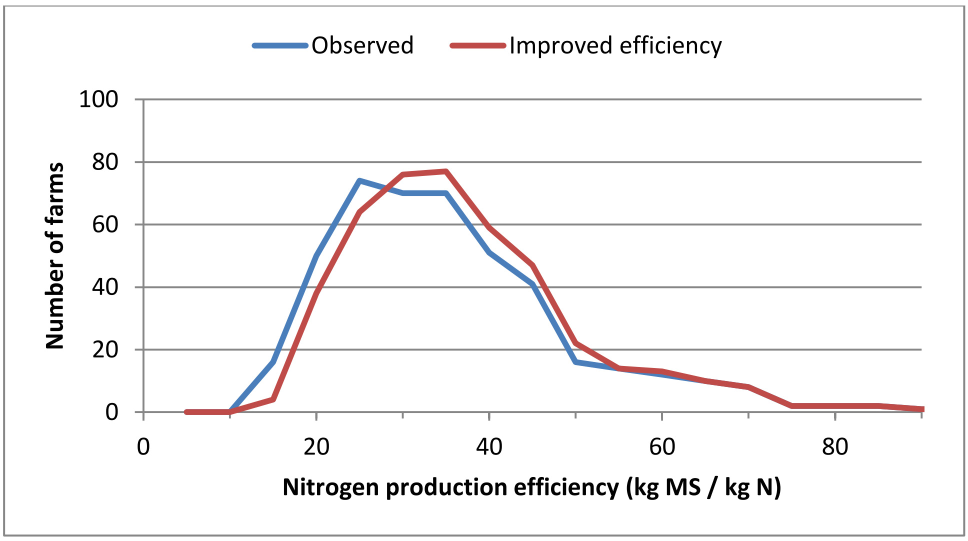


2.1. Nitrogen leaching on dairy farms

There is anecdotal evidence that farms vary in their N production efficiency (kg product per kg N leached) for the same level of production. Understanding the causes of this variation will help explain how farmers can improve. This is in line with industry goals and a number of commercial reports on case study farms have already been done to illustrate this. Unfortunately many of these studies appear to be somewhat 'ad hoc' and are not publically available.

Figure 2, from Anastasiadis and Kerr (2012), demonstrates improvements in N production efficiency, where the least efficient farmers become more like the average farmer, after controlling for exogenous environmental factors.

Figure 2: The distribution of nitrogen production efficiency

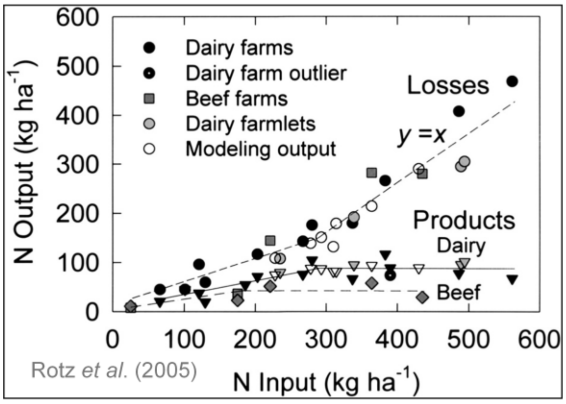


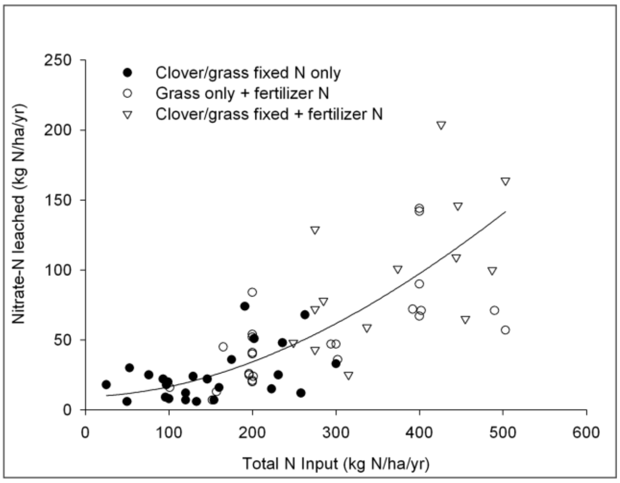
Any gain in N production efficiency will be realized progressively over time. As farmers intensify by increasing farm inputs they will, in general, become less N efficient. There is a limit to the extent that farmers can intensify via increases in inputs. At some point a change in farming system will be necessary. (de Klein et al. (2010) shows that a change in farming system will change N losses, especially in relation to the intensity of production and N inputs.

We expect that it will be these more substantial changes that will drive significant gains in efficiency. They are likely to be associated with the greater use of supplementary feed and increasing use of feed or wintering pads to reduce the number of urine patches and associated leaching losses.

There will be limits as to the possible gains from improvements in efficiency.[2] Figure 3 demonstrates that as N inputs (which are strongly associated with production) increase the quantity of N leached likewise increases. The left hand graph shows a collection of European studies and is drawn from Rotz et al. (2005), while the right hand graph is drawn from New Zealand studies and is drawn from Ledgard et al. (2009). Breaking this relationship will require a fundamental change in our farming system.

Figure 3: The relationship between nitrogen inputs and leaching





Pre-experimental modeling undertaken as a part of the Pastoral 21 (Phase II) program[3] of work has developed hypotheses for testing that suggest that a 30% reduction in N leaching in absolute terms is technically feasible for farming systems typical of key dairy production areas (Manawatu, Waikato, Canterbury and Southland) by adopting mitigation practices and management activities already available to farmers. This also factors in a production increase of

[2] There is a limit to the increases in production per cow with a pasture eaten *in situ* farming system, and beyond some point New Zealand will need to consider a cut and carry type system.

[3] Pastoral 21 is a joint venture funded by DairyNZ, Fonterra, Beef and Lamb New Zealand, Dairy Companies Association of New Zealand and the Ministry of Science & Innovation. The collaborating research organizations include AgResearch, DairyNZ, Landcare Research, Lincoln University/Telford Rural Polytechnic, Massey University, NIWA, On-farm Research and Plant & Food Research.

more than 20 percent (P21 Environment, 2011). Similar work by Clark et al. (2011) suggests farm profitability can be maintained while reducing leaching by 20% per hectare.

While these are working hypotheses they provide a good starting point for estimating the likelihood of success. Our sense is that this work has been done on a single farm. So it has not yet been scaled up and only considers the technical feasibility. There will be lags in the realization of these gains as farmers will need time to raise the required capital and may only replace existing capital as it nears the end of its useful life. There are also limits in our national resources (for example: the supply of skilled expertise required to install feed pads is finite).

Several studies (Ridler et al., 2010) (Anderson and Ridler, 2010) (Beukes et al., 2010) suggest that some farms are overstocked (their marginal stock unit has negative marginal returns) so they could increase profit and production by lowering their stocking rate. This may be due to the focus in the industry on production per hectare through high stocking rates or pressure from banks or processors to increase volume of production. The absence of a capital gains tax may also be motivating higher stocking rates as farmers have incentives to invest in capital that allows higher stocking rates in order to increase the sale value of their property.

There has been growing interest in recent years in shifting from increasing production per hectare through higher stocking rates to a management approach. This would entail reduced stocking rates and strategic use of supplements to enhance production both per cow and per hectare (Salles et al., 2003).

In identifying mitigation potential over the next eight years, we avoid offering a too detailed analysis as this would add spurious accuracy. Our approach is therefore to say that if Pastoral 21 modeling is giving fairly strong indications of what can be achieved (albeit, still to be tested in the field), then this is a good starting point for our assumptions. While Pastoral 21 aims to test that this can be implemented at a farm level within 6 years, scaling this up will have to take into account implementation, etc, as described earlier.

We classify the following activities as type 1 N mitigation for dairy farms:

- From improvements in production efficiency N losses per hectare from farms will remain close to their current levels. The gains in productivity will be distributed more towards the less efficient farms. This includes the effect of improvements in the genetic merit of stock.
- New farms in each region will be more N efficient from the start as when they are set up (by nature of acquiring resource consent) they will have best practice. Hence their production efficiency will be in the top quintile for farms in their region.
- Stocking rates and production per hectare will continue to increase following current trends.

We classify the following activities as type 2 N mitigation for dairy farms:

- There will be a move away from over stocking. Stocking rates will decrease by 5 percent, with production per animal increases such that production per hectare remains relatively unchanged.
- There will be an additional 10 percent reduction in N leaching per hectare for farms beyond what can be accomplished via type 1 mitigation. This will be delivered by a suite of mitigation activities which will differ for farms around the country and within regions (as farms are unique). This suite will include feed / stand-off / wintering pads, DCDs, herd homes, wetlands and fencing.

With our mitigation activities for type 2 mitigation, we have taken the view that there is no merit in being too prescriptive around how the suite of mitigation activities will be carried out. We know that the key management activities will revolve around variations in N fertilizer and feed management, stock management, standing animals off, and DCD use (de Kleim and Monaghan, 2011). We recognize that different mitigations will be more appropriate in different conditions. For example: wetlands will be more appropriate for surface drained, rather than freely drained soils; large effects of DCD have been reported in the south due to colder winter temperatures (Monaghan et al., 2009). The choice of mitigations and how they are implemented are the focus of the P21 program of work.

2.2. Phosphorus leaching on dairy farms

Compared with N leaching, where losses are linked directly to production levels, and hence mitigation commonly affects production, there is considerable scope for reducing P losses through the implementation of best management practices that are semi-independent of production. These include stream fencing, riparian boundaries, and effluent systems. Maintaining Olsen P in the optimal range through the use of testing and less soluble P fertilizer products (Monaghan, 2010), and practices that limit soil erosion to waterways (Parfitt et al., 2007) (Parfitt, 2009) are also recommended.

The dairy clean streams accord provides a framework to promote sustainable dairy farming in New Zealand (Fonterra et al., 2009). It specifies the management requirements for waterways, effluent and wetlands on dairy farms. Compliance with the accord is reported each year. The fencing of waterways is estimated to reduce P loss by 0.5 kg per hectare, and the introduction of appropriate effluent management is estimated to reduce P loss by 1 kg per hectare (Parfitt, 2009).

We classify the following activities as type 1 P mitigation for dairy farms:

- All farms in all regions will have compliance with the clean streams accord.

We classify the following activities as type 2 P mitigation for dairy farms:

- Farms on sedimentary soil would use wintering pads. This would result in a 15 – 30 percent reduction in P loss.

Further mitigation of P is possible, but this requires greater attention to the individual characteristics of the catchment (rainfall, soil type, slope) and the farm infrastructure and design. For example: around 20 percent of older North Island dairy farms on sedimentary soils would observe a 7 – 37 percent reduction in P loss from maintaining good Olsen P soil health. See also Monaghan (2010) and Monaghan et al. (2010).

3. Mitigation on Sheep/Beef Farms

Unlike dairy farming, where most farms operate in very similar ways, there is significant variation in sheep/beef farming operations. Sheep/beef farms differ in their stocking practices and frequently specialize in different parts of the animals' lifecycle, with some farms specializing in animal breading, while others finish the animals for slaughter. They also have the potential to graze other stock, such as deer or dairy heifers. The heterogeneity in sheep/beef farming practices makes it difficult to identify specific mitigation practices that are appropriate for the industry as a whole.

3.1. Nitrogen leaching on sheep/beef farms

In recent years the sheep/beef industry has continued to increase production levels with a major emphasis on production per animal, including improvements in fecundity, growth rates and age of slaughter. This has occurred despite competition from other land uses, including: dairy, lifestyle properties and plantation forestry, which has seen more productive and versatile land converted out of sheep/beef farming. It follows, that the actual gains in production per hectare are higher than are reported.[4]

Due to differences in the management of sheep/beef herds and dairy herds, many of the mitigation technologies that can be applied to dairy farms are not feasible on sheep/beef farms. For example, as animals do not regularly spend extended periods of time gathered together by the farmer, stand-off pads are not an effective form of mitigation.

We classify the following activities as type 1 N mitigation for sheep/beef farms:

[4] The significance of this improvement can be observed by considering Greenhouse gas emissions. The emissions from sheep/beef farms have been increasing even as the land in sheep/beef farming has been decreasing. We do not have equivalent data for N leaching.

- From improvements in production efficiency N mitigation will match intensification so N losses per hectare will remain close to their current levels. This includes the effect of improvements in the genetic merit of stock.

3.2. Phosphorus leaching on sheep/beef farms

Phosphorus loss on sheep/beef farms is strongly associated with soil erosion. In response to this regional councils and the government have put in place soil conservation plans and hill country erosion initiatives (Greer and Trost, 2009), continuing the work of catchment boards that go back to the 1950's. They aim to encourage land stability by the conversion of land to tree-pasture systems, plantation forestry and, through managed retirement, back to native vegetation (Jones et al., 2008). In contrast, the main driver for pastoral farmers to plant trees is to provide shelter for their livestock and to protect them against extreme weather events.

Dymond and Shepherd (2007) use the Land Use Capability framework (LUC) to identify land with high or severe erosion risk. LUC is a tool that is used to assess land's capability for sustained production, and the physical limitations of the land (Lynn et al., 2009). It is the basis for land evaluation and planning throughout most of New Zealand and has been used in various forms since the 1950s. In recent years it has seen significant use on-farm as a component of farm plans and it underpins level 3 of the Beef & Lamb NZ Land and Environment Planning tool kit[5] available to all sheep and beef producers.

We classify the following activities as type 1 P mitigation for sheep/beef farms:

- Mitigation that takes place under soil conservation plans will act to offset increases in P loss that would otherwise arise from increases in production intensity.

We classify the following activities as type 2 P mitigation for sheep/beef farms:

- Erosion vulnerable areas will be targeted for tree planting and conversion to tree-pasture systems. This will result in a 2 percent reduction in P loss per hectare per year (Parfitt, 2009).

Further reductions in P loss are possible with the conversion of land away from sheep/beef and into forestry or native scrub. However, as sheep/beef land may also be converted to dairy farming, changes in land use are better treated separately rather than as a form of mitigation.

[5] www.beeflambnz.com/farm/tools-resources/land-and-environment-planning-toolkit/ accessed December 2011

4. Discussion and Conclusions

Research into ways to reduce nutrient loss from agricultural activities is ongoing. New technologies are frequently proposed and tested. Different farm management strategies are frequently modelled or trialled. Given the available information, we have attempted to identify what mitigation is probable and what mitigation will be possible over the next eight years.

Given current regulatory pressures, and the rate at which new technologies and management practices are disseminating, we classify the following mitigation as probable: On dairy farms production efficiency will improve, maintaining N loss per hectare close to current levels, and all farms will be compliant with the clean streams accord. On sheep/beef farms improvements in production efficiency and mitigation under soil conservation plans will match increases in farming intensity, maintaining N and P loss per hectare close to current levels respectively.

While further mitigation appears possible it is unlikely to be realized other the next eight years. We classify the following mitigation as possible: On dairy farms the focus will shift to production per animal, decreasing stocking rates while maintaining production. More costly technologies will be adopted depending on the individual characteristics of each farm. On sheep/beef farms erosion vulnerable areas will be converted to tree-pasture systems. We do not identify any further N mitigation for sheep/beef farms.

It should be noted that results produced by OVERSEER[6] already include some of the mitigation discussed in this paper. OVERSEER assumes farms are compliant with regulation, including resource consents and the Clean Streams Accord, and that farm managers follow best practice. Hence all streams are fenced, dairy effluent is correctly managed, fertilizer application follows the Fertilizer Industry Code of Practice, etc. Because of this, care must be taken when applying the results from this paper to avoid double counting.

[6] OVERSEER is a farm management tool developed by AgResearch to help farmers maximise the productivity of their land (AgResearch, 2009). It also calculates nutrients lost to the environment, which has drawn the attention of regulators and researchers.

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