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MODELLING DAIRY FARM SYSTEMS: PROCESSES, PREDICAMENTS AND POSSIBILITIES

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Abstract

All you need to know, and more, about farm systems modelling. This paper will guide you through the process of modelling nutrient mitigation to demonstrate how dairy farm systems can meet potential nutrient regulations. It also identifies some of the pitfalls and challenges of mitigation modelling and explores the possibilities for the future. Farm systems modelling is becoming a necessity as regional councils seek to understand the economic consequences of setting water quality limits under the Government's National Policy Statement on Freshwater. As there is potential for environmental regulation to significantly impact farm systems in New Zealand, it is important to understand how to model farm impacts in a robust way. Farm systems modelling relatively simply estimates the impacts of a change on farm while retaining sufficient detail. There is currently no comprehensive model that incorporates a farm's economic performance, nutrient pathways and biological feasibility. Therefore, farm systems modelling is a complex, multi-model, iterative process with no single solution.

Introduction

The National Policy Statement for Freshwater Management (NPSFM) directs regional councils to maintain or improve the quality of freshwater resources in New Zealand. To meet requirements of the NPSFM, some regional councils are setting regulations on nutrient losses from agricultural land uses. The Resource Management Act (RMA) (1991) requires regional councils to evaluate of the efficiency and effectiveness of the policies under a regional plan change and outline methods used to achieve objectives. In particular, Section 32 in the RMA requires an assessment of the benefits and costs of a proposed policy. Currently regional councils are attempting to understand and quantify the costs of nutrient loss regulations to farmers. Farm systems modelling can help with this quantification.

The purpose of farm systems modelling is to examine how a change to one aspect of a farm system, in this case reducing nutrient loss, may impact the rest of the system. Models are used as physical measurement of nutrient loss at a farm or paddock scale is currently unfeasible as it is time consuming and costly (Addiscott, 1995; Oenema, Kros & De Vries, 2003). The aim of farm systems modelling in this context is to construct abatement cost curves which describe the cost of achieving a given level of nutrient loss mitigation for a farm (Doole, 2012). These curves are widely used because of their clear and concise explanation of both abatement and cost dimensions and have been used in the analysis of policies for water pollution (including Hart & Brady, 2002 & Beaumont & Tinch, 2004). This paper will use an example dairy farm to discuss the process and some of the common challenges in farm systems modelling.

Background

Economic and nutrient loss changes are both required to create an abatement curve, and a biophysical model is crucial to ensure feed supply and demand are balanced at each point on the abatement curve. A nutrient budgeting tool estimates the effects of various management changes on nutrient loss, while biophysical farm systems and economic models ensure a feasible farm system is modelled (feed demand supply are balanced) and estimate the impact of farm system and management changes on farm profit. There is not a model in New Zealand that incorporates the biophysical farm system, economic performance and nutrient pathways of a farm.

Overseer is one tool that can be used to calculate nutrient losses from a farm system. It is an agricultural management tool that uses a budgeting approach to assist examination of nutrient use and movements within a farm (MPI, FANZ & AgResearch, 2013). Overseer has been widely used for calculating nutrient losses from rural land enterprises in New Zealand (for example; Dymond, Ausseil, Parfitt, Herzig & McDowell 2013; Parfitt et al., 2012; Matthew, Horne & Baker, 2010). The key assumptions, limitations and structure of the Overseer model are discussed in various publications, such as Ledgard, Penno and Sprosen (1999), Wheeler et al., (2003) and Wheeler, Ledgard, Monaghan, McDowell and de Klein (2006). Validation has shown this model to provide a reasonably accurate description of nitrogen leaching loads arising from New Zealand farming systems (Thomas, Ledgard & Francis, 2005; Wheeler, van der Weerden & Shepherd, 2010). However, Ledgard (2014) noted that while many studies are in agreement on nitrogen estimates, there are few studies available against which to compare estimates of phosphorus losses. Overseer requires farm productivity and farm inputs to be entered by the user. These quantities are usually known for existing farms or can be estimated for hypothetical farms using farm system models such as Farmax (Marshall, McCall & Johns, 1991; Bryant et al., 2010).

Farmax is a simulation model which predicts the effects of farm system changes on production and economic variables (McCall, 2012). It enables the biophysical requirements of the farm system to be estimated, in particular feed supply and demand. There are alternative farm systems models that could be used instead of Farmax, including optimisation models. However, optimisation models do not directly relate to reality due to an assumed change in farm management and they do not explicitly consider farm heterogeneity, which is inherent in rural land uses.

Farmax and Overseer have been widely used to create abatement cost curves for pastoral farm systems in New Zealand (for example Vibart et al., 2015a; 2015b; Kaye-Blake et al., 2014). These models should always be used concurrently to ensure a farm's feed supply and demand is balanced. Models should also be used in the most recent version to ensure the most current science is used. Data input standards should be followed and any assumptions must be noted. Models are not able to capture all facets of reality and there are potential mitigation options that are not able to be implemented in Overseer, such as detention bunds. In addition to this, Overseer assumes best practice and so there are some changes on farms as they move to meet this assumption, which could lead to improvements in water quality, but no reduction in Overseer.

Dairy farms across New Zealand are heterogeneous and therefore, an average farm cannot be used to approximate the costs of regulation. Using real case study farms for analysing the effects of mitigating nutrient loss will allow more of the variation inherent in farms to be captured. The variation in biophysical and farm systems characteristics of farms in a region should be considered when selecting case study farms as a sub sample of the population. Farm data should be smoothed to represent a reasonably typical season as Overseer is designed to model a long term steady state (MPI, FANZ & AgResearch, 2015).

An example farm is used to illustrate the modelling process, it is described in Table 1.

Table 1: Example farm

Effective hectares	255	Off pasture structures	No
Peak cows milked	720	Irrigation	No
Milksolids per cow	423	Crop	12 hectare (swedes)
Replacement rate	24% (raised off farm)	Effluent area	41% effective platform
Nitrogen fertiliser	126 kg N/ha/year	Phosphorus fertiliser	31 kg P/ha/year
Wintering	90% off farm in June and July	Imported supplements	336tDM (9% feed offered per hectare)
Soils	Imperfectly drained	Rainfall	1,100 mm/year

Nutrient mitigation strategies will have differing costs and effectiveness based on the farm they are applied on. Mitigation strategies are seldom applied in isolation and each needs to be considered in a whole farm context. In addition, mitigation strategies should be targeted to a particular nutrient, as determined by the catchment priorities, although some mitigation strategies do reduce both nitrogen and phosphorus losses. The mitigation strategies used should represent those possible with the current levels of technology and science. However, there are other mitigations which could be applied on farm that are currently unable to be estimated in the available models, for example constructing lanes and tracks to ensure no runoff from these reaches water.

Mitigations that impact on pasture production or consumption must be presented as a set of interdependent mitigations. This is because the mitigations must represent a feasible farm system and energy supply and demand need to balance. For example, a reduction in fertiliser cannot be measured in isolation as this will reduce the feed supply, it must be measured with either an associated increased in alternative feed supply (e.g. imported supplements) or a reduction in feed demand (e.g. less cows milked).

Processes

While the broad mitigation modelling process is generally similar for farms, there will be subtle differences in the mitigation strategies applied to each farm due to their individual characteristics. When choosing mitigation strategies it is practical to target the most cost-effective mitigations first, however it should be noted that all farmers have a complex set of drivers and may choose an alternative mitigation strategy. Choice of mitigation is also likely to depend on the required level of mitigation. For example, a farm considering a 10% reduction in nitrogen leaching may choose a different strategy to one that is required to reduce nitrogen leaching by 30%.

Mitigation strategies can be broadly categorised as management changes within the current farm system (stage one mitigation strategies), and then mitigations which will change the wider farm system (stage two mitigation strategies). This paper focuses primarily on stage one mitigations although at higher mitigation levels such as for a reduction of 40%, there could be significant changes to a farm system through less inputs like supplementary feed. While mitigation strategies are presented in a linear sequence for this paper, the mitigation process is actually iterative and each step is often a combination of a few mitigations to keep the farm balanced. Furthermore, farmers often choose and prioritise mitigation strategies based on personal goals, objectives and their capability to implement the mitigation in addition to cost-effectiveness.

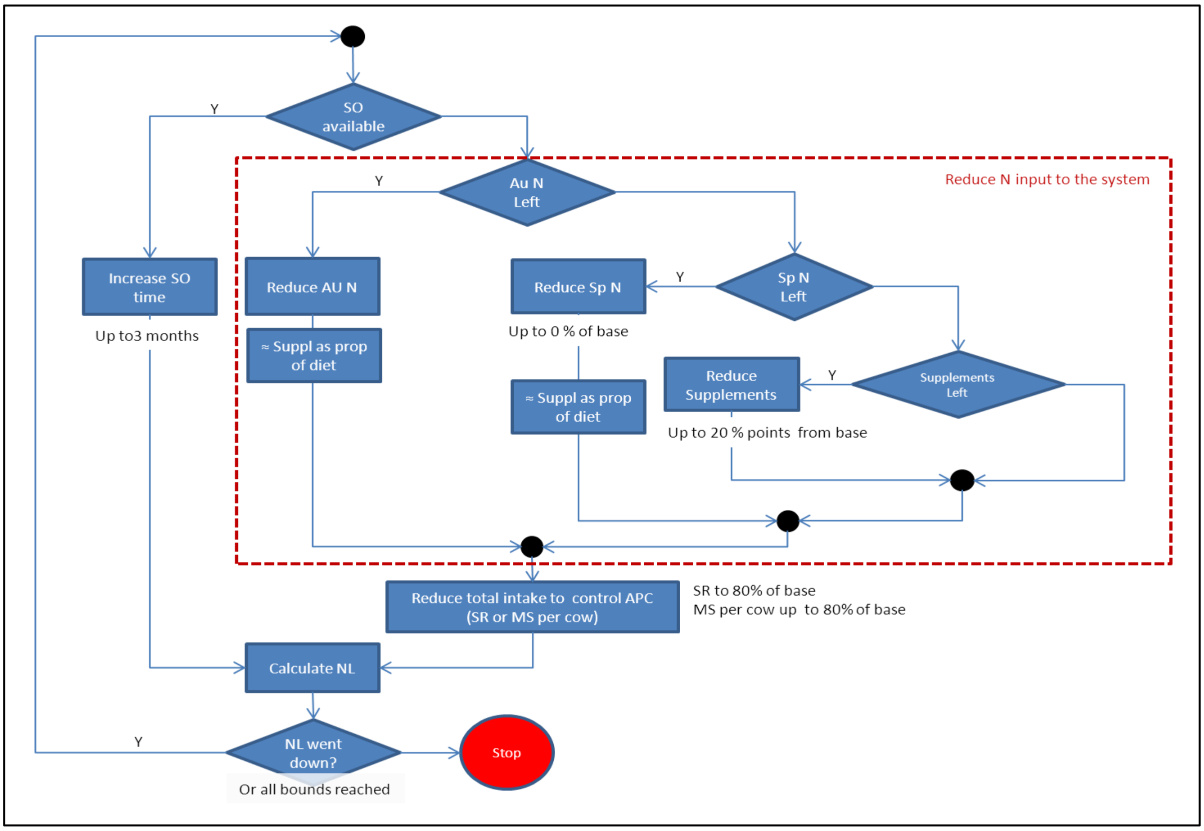
Stage 1.0	Within system changes: a process in which reductions in farm inputs are sequentially applied on the base farm. These changes are applied to the existing farm system.
Stage 2.0	System change: significant changes to the farm system or significant capital investment. Includes (but not limited to) barns, wetland construction, changes in wintering practices and significant changes in effluent storage and disposal.

Nitrogen mitigation

The nitrogen mitigation strategies that are broadly followed when applying stage one mitigation strategies to each case study farm are illustrated in Figure 1. The process for choosing nitrogen mitigation options (Figure 1) can also be described as:

1. Optimising the use of an existing off-pasture structure if the farm has one.
2. Reduce and then remove autumn nitrogen fertiliser applications.
3. Reduce and then remove spring nitrogen fertiliser applications.
4. Reduce imported supplements (up to a 20% reduction from the base).
5. Reduce stocking rate (up to 20% reduction of cow numbers from the base) and balance feed supply and demand.

Figure 1: Flow diagram of stage one nitrogen mitigation options
Note: Legend = Au N: autumn applications of nitrogen fertiliser, Sp N: spring applications of nitrogen fertiliser, SO: stand-off pad, NL: nitrogen leaching, SR: stocking rate, MS: milksolids, APC: average pasture cover



Increasing time spent off pasture on an existing structure allows for increased capture of urine and controlled dispersal of effluent at appropriate times. The extent that this mitigation option can be utilised depends on the characteristics of the existing facilities and must consider factors such as animal welfare.

Farms with a high risk of nitrogen leaching from effluent disposal can increase this area. The availability of paddocks suitable for effluent disposal limits this option. If the effluent block has a different fertiliser program to the non-effluent block this should be adjusted to reflect the change in nutrients applied to pasture.

Imported feed with a high nitrogen content can be replaced with low nitrogen content alternatives, if available. This option needs to consider the dry matter and energy intake of the cows and ensure feed requirements are still being met.

Nitrogen fertiliser application rates and timing can be adjusted to minimise the risk of nitrogen leaching. The total amount of nitrogen fertiliser used can also be reduced and high risk applications should be targeted first. For example, autumn applications should be targeted before spring applications. A review of research in Ledgard (2016) on pastoral nitrogen fertiliser use showed that pasture growth and nitrogen uptake increases with added nitrogen (except in urine patches) up to rates above 400 kgN/ha/year. Therefore, any reduction in nitrogen fertiliser (where the total applied is less than 400 kgN/ha/year) will reduce pasture production and therefore feed supply.

If a farm utilises a crop area, crops with a lower nitrogen leaching risk factor can be considered as a mitigation option if the alternative crop fits into the farming system. When considering this option, the growing conditions and the suitability of alternative crop types need to be taken into account. The cropping area can also be reduced but this must be balanced with a reduction in feed demand or an increase in alternative feed supply.

Following these mitigation options, the proportion of purchased feed in the diet can be reduced. A standard rule is up to 20% relative to the original scenario because any further than this is likely to require a farmer to change their management style and system considerably and they may not have the skills for the alternative system.

All these steps (except the increased time on a stand-off facility) reduce feed supply, this must be offset by reducing the feed demand (through stocking rate) to achieve appropriate pasture covers and avoid feed gaps, or by increasing alternative feed supplies.

For the case study farm the following mitigation options were applied:

1. Nitrogen fertiliser application was reduced by removing the May application on the effluent block and by reducing the non-effluent block nitrogen fertiliser application by 9 kgN/ha in November, by 5 kgN/ha in March and 3 kgN/ha in May. The swedes crop area was reduced to 7.8 hectares from 8 hectares and more baleage was made (18t DM). Cow numbers were reduced by 20 to match feed supply.
2. In addition to the above mitigation, nitrogen fertiliser was reduced by removing the May application on the non-effluent block and reducing the April application rate on the effluent block by 8 kgN/ha. The swedes crop area was reduced to 7.6 hectares and more baleage (15t DM) was made on farm. Cow numbers were reduced by 20 to match feed supply.

3. In addition to the above mitigation steps, nitrogen fertiliser was reduced by removing effluent block applications in April and December and reducing the application rates by 8 kgN/ha in March and 17 kgN/ha in April on the non-effluent block. The swedes crop area was reduced to 7.3 hectares and more baleage (15t DM) was made from the reduced crop area. Cow numbers were reduced by 22 to match feed supply.
4. In addition to the above mitigation steps, the March and April nitrogen fertiliser was removed on the non-effluent block, and in September the application rate was reduced by 17 kgN/ha. On the effluent block the September application rate was reduced by 9 kgN/ha and the March, October and November applications were removed. The swedes crop area was reduced to 7.0 hectare and cow numbers were reduced by 25.

For the case study farm, these four mitigation steps allowed a reduction in nitrogen leaching by 38%. There was an associated reduction in operating profit of 24% and production of 12%. The case study farm did not have irrigation, an off-pasture structure or an associated support block so some mitigations that may be applicable to other farms were not used in this case study. Phosphorus loss also reduced by 5% when using these mitigation strategies. These results are shown in Table 2. They are also shown in Figure 3.

Table 2: Nitrogen mitigation results

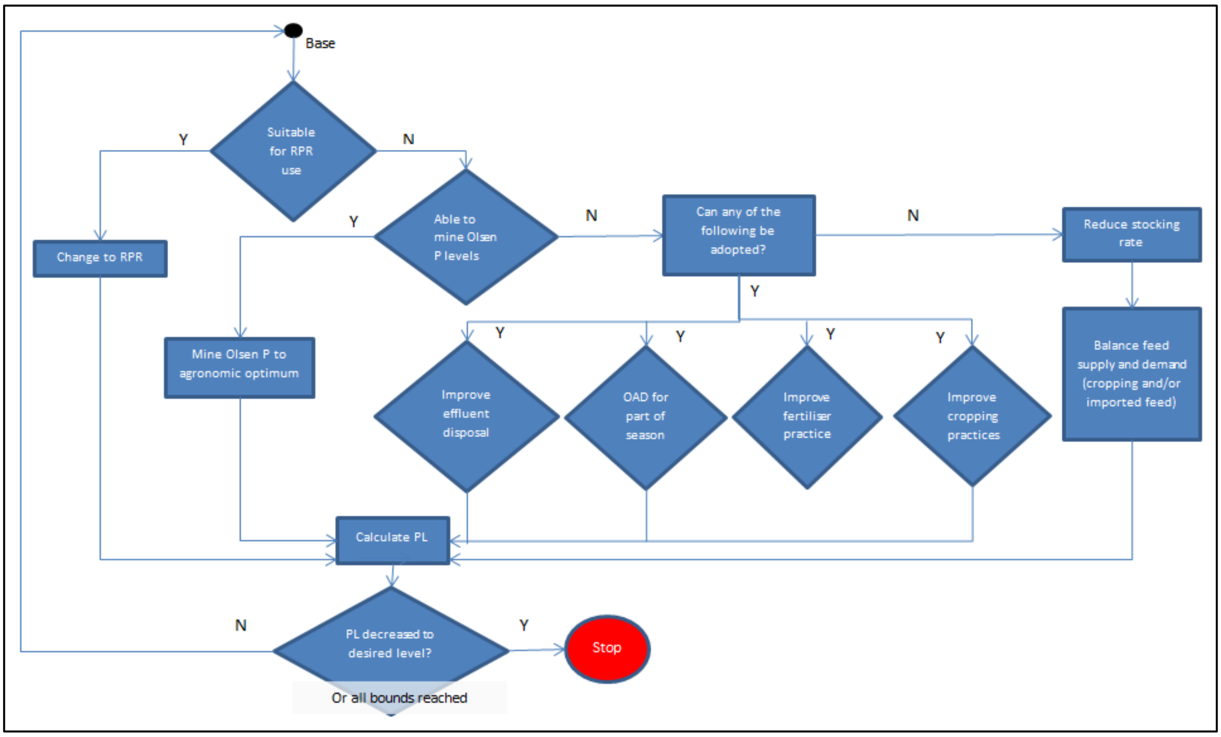
		Absolutes				**Percentage Change**			
Measure	Base	N.1	N.2	N.3	N.4	N.1	N.2	N.3	N.4
N leaching (kg N/ ha)	36	33	29	25	22	-9	-18	-30	-38
P loss (kg P/ ha)	1.25	1.24	1.23	1.21	1.20	-1	-2	-3	-5
Peak cows milked	720	700	680	658	633	-3	-6	-9	-12
Stocking rate (cows/ha)	2.8	2.7	2.7	2.6	2.5	-3	-6	-9	-12
N fertiliser applied (kg/ha)	126	112	98	70	36	-11	-22	-44	-71
P fertiliser applied (kg/ha)	35	35	35	35	35	0	0	0	0
Production (kg MS/ha)	1,194	1,160	1,126	1,093	1,051	-3	-6	-8	-12
Operating Profit ($/ ha)	2,347	2,230	2,106	1,943	1,783	-5	-10	-17	-24

Phosphorus mitigation

Phosphorus mitigation employs the same two stage process as nitrogen mitigation, with de-intensification followed by system changes. Figure 2 shows the overall process that this study followed when applying stage one phosphorus mitigation strategies to each case study farm. The process for choosing phosphorus mitigation options (Figure 2) can also be described as:

1. Swap any phosphorus fertiliser for reactive phosphate rock (RPR) if the farm is suitable.
2. If Olsen P levels are above the agronomic optimum reduce them to this.
3. Identify key areas of risk that are unlikely to impact significantly on production and address where appropriate, this includes effluent and cropping practices.
4. Identify key areas of risk that may impact significantly on production and address where appropriate, this includes the use of once a day milking (OAD) for part of the season and decreasing cropping areas.
5. Reduce stocking rate (up to 20% reduction of cow numbers from the base) and balance the feed supply and demand.

Figure 2: Flow diagram of stage one phosphorus mitigation options
Note: Legend = RPR: Reactive Phosphate Rock fertiliser, PL: phosphorus loss, OAD: once a day.



Using (RPR) instead of superphosphate fertilisers can be a relatively cheap mitigation tool. However, RPR is not a suitable alternative to other phosphate fertilisers for every farm. Sinclair, Dyson and Shannon (1990) provide guidance to determine which farms are suitable for RPR: RPR can be used when the annual rainfall is above 800 mm, soil pH is less than 6 and phosphate retention is lower than 95%. Plant available phosphorus is released at a slower rate from RPR than superphosphate; for it to be used with no negative impact on pasture production it should be used in areas where Olsen P levels are above the agronomic optimum.

Other factors to consider when using RPR include the impact on soil sulphur and acidity levels. The timing of fertiliser applications will also impact phosphorus losses. As long as fertiliser is applied when runoff is unlikely then the runoff from a high water-soluble phosphate fertiliser (e.g. superphosphate) can be similar to that from low water-soluble phosphate fertilisers (e.g. RPR) (McDowell & Catto, 2005).

Soils with high Olsen P values are at greater risk of phosphorus loss, therefore reducing Olsen P levels will reduce the phosphorus losses from a farming system (McDowell, Monaghan & Carey, 2003). If Olsen P levels are above the agronomic optimum and are reduced to this level, there will be a minimal negative impact on pasture production, while reducing Olsen P levels below agronomic optimum will reduce pasture production (Roberts & Morton, 1999). Overseer provides a steady state for a year therefore it does not capture the time taken to reduce Olsen P levels, which can take years (Monaghan et al., 2007).

On some farms phosphate fertiliser application practices can be improved. This includes changing applications to months when the risk of runoff is lower and splitting large applications into multiple smaller ones. If effluent disposal is a high risk for a farm then this can be mitigated through increasing effluent area and reduced application rates. Whether this can be implemented depends on the farm characteristics. OAD may also help reduce phosphorus loss, however, this will impact on production and feed demand and these will need to be accounted for.

Cropping practices can be improved on some farms, including the use of cultivation methods that disturb the soil less, reducing the time left fallow (accounting for soil and weather conditions) and changing crop types. The cropping area of the highest risk crops (in terms of phosphorus loss) can be reduced. As with nitrogen mitigation options, all these need to be balanced for energy supply and demand.

For the case study farm the mitigation options were as below:

1. Change phosphorous fertiliser to RPR on the effluent block.
2. In addition to the previous mitigation, the Olsen P was reduced on the effluent block from 36 to 30. Fertiliser application was reduced from capital and maintenance to just maintenance on the effluent block.
3. In addition to the previous mitigation, the swede crop was reduced from 8 hectares to 7.6 hectares and additional baleage (33t DM) was made. Cow numbers were reduced by 40 to match feed supply and were milked OAD two weeks before drying off.
4. In addition to the previous mitigation, the swede crop was removed and replaced by feeding more baleage. The herd was also on OAD for half of the season.

For the case study farm, these mitigation steps allowed them to reduce phosphorus loss by 13%. There was an associated reduction in operating profit of 51% and production of 20%. The case study farm had Olsen P levels at the agronomic optimum on the non-effluent block and therefore these were not reduced and RPR was not considered on this block. Nitrogen leaching also reduced significantly (47%) when using these mitigation strategies, however, the reduction in nitrogen leaching did not start until the third mitigation strategy. These results are shown in Table 3. They are also shown in Figure 3.

Table 3: Phosphorus mitigation results

		Absolutes				**Percentage Change**			
Measure	Base	P.1	P.2	P.3	P.4	P.1	P.2	P.3	P.4
N leaching (kg N/ ha)	36	36	36	29	19	0	0	-19	-47
P loss (kg P/ ha)	1.25	1.24	1.22	1.21	1.10	-2	-3	-4	-13
Peak cows milked	720	720	720	680	633	0	0	-6	-12
Stocking rate (cows/ha)	2.8	2.8	2.8	2.7	2.5	0	0	-6	-12
N fertiliser applied (kg/ha)	126	126	126	98	37	0	0	-22	-71
P fertiliser applied (kg/ha)	35	35	33	31	27	0	0	0	-13
Production (kg MS/ha)	1,194	1,194	1,194	1,126	901	0	0	-6	-20
Operating Profit ($/ ha)	2,347	2,324	2,324	2,071	1,143	-1	-1	-12	-51

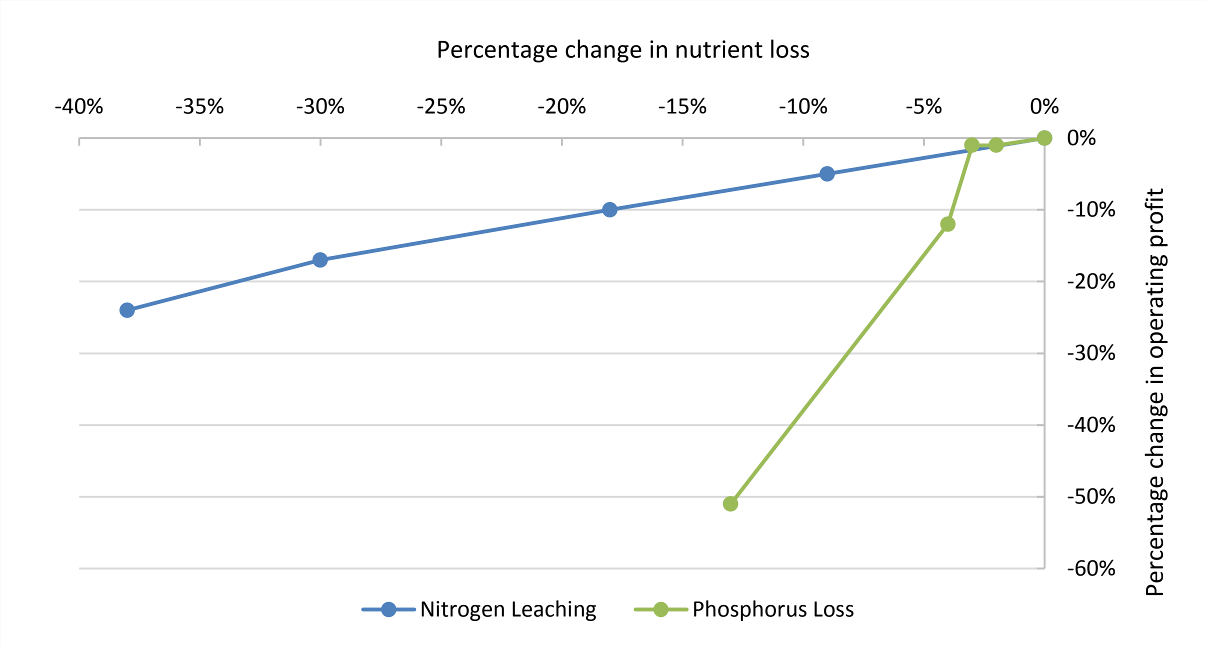


Figure 3: Abatement curve for example farm.

Predicaments

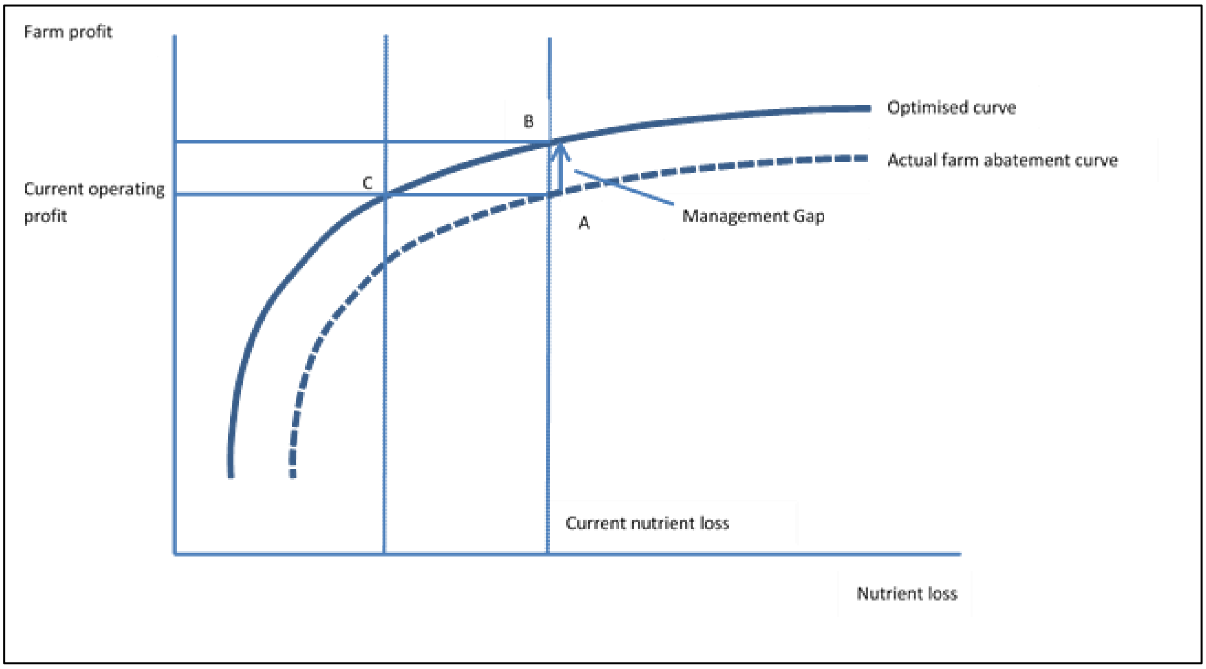
Farm systems modelling is not without its challenges. Models simplify reality and therefore by definition there will be aspects of reality that are missed in farm systems modelling. For example, they do not encompass all characteristics of human decision making. Farm systems modelling often has multiple solutions depending on the underlying assumptions used. Because farm systems modelling is now being used in a policy planning context, it is important to understand some of the assumptions and the challenges that can lead to different outcomes in modelling.

One of the most debated challenges facing farm systems modellers is whether farmers can be more efficient with their use of current resources. This is commonly seen as a farmer producing more from the same, or fewer, resources (more units of output per unit of input). It is important to understand that this is a rational decision and if farmers could do this, it would be rational for them to have already done so. However, it is assumed that farmers are producing at their best already given a range of obvious, and not so obvious, constraints. This concept is related to a production possibility frontier, where a rational producer will produce at their limit of their production possibility frontier given a set level of resources (including inputs, technology, skill and time). To move beyond this production possibility frontier a producer must move their frontier out through investing in, for example, better technology or improving their skills, with all of these investments costing, either money or time.

In terms of farm systems modelling this is often described as a management gap and is illustrated by Figure 4. A mitigation curve can be described by a number of parallel curves, with the leftmost curve being an optimum curve representing full management capability, perfect knowledge and full use of optimal resources, including technology (optimised curve in Figure 4). The current farm situation (Point A in Figure 4) is a result of farmer experience, skill and resources. The gap between this optimised curve and the lower actual curve is a management gap. In other words the lower curve represents a different level of management capability (Figure 4). A proxy for this production possibility frontier in dairy farm systems modelling is milksolids production per cow. Holding this constant ensures the farmer remains on their existing management curve. To move from this curve some investment could need to be made, for example, using a farm consultant.

If the farmer currently had the skill to create a more efficient farm business (e.g. increase milksolids production per cow for the same set of inputs), they would be on the optimised curve. This management gap is shown as between point A to point B on Figure 4, but equally this could be moving from point A to anywhere on the optimised curve depending on what is being optimised. For example, point B represented more profit for the same nutrient loss, while point C represents less nutrient loss for the same profit, both points are optimised relative to point A and would require a higher level of management capability. While farmers can increase their skill level, the time and cost of this would vary for each farmer and this is unable to be captured with any degree of accuracy in modelling. Therefore, holding milksolids production per cow constant is an important proxy for farmers maintaining the same skill level when using farm systems modelling in the policy planning process. An exception to this was when cows were shifted to a different type of milking interval where production per cow is likely to change due to the change in milking interval rather than the change in farmer skill.

Figure 4: Example mitigation curves showing management gap



It is also important to understand when to stop modelling a farm system. Specifically, farm systems modelling is limited in its ability to capture land use change as there is a significant challenge in determining what land use would be preferred. Therefore, mitigation modelling should stop when land use change would be likely to occur. This is when a farm reaches the point where land is no longer required to satisfy feed demand; there is a pasture surplus that is either sold each season or stored indefinitely. While pasture can be harvested and sold, the economic return of this is likely to be lower than an alternative land use, especially if a significant proportion of farms are harvesting and selling pasture regularly.

This paper has provided a process for mitigating nutrient loss based on the lowest cost options. In reality there are many factors which influence which mitigations are applied on farm, for example, the skills of farm management, the level of debt or the life stage of the farmer. It is not possible to model the impact of all these factors, which is not to say they are not important, but rather, this complexity is challenging to capture in a model. Using farm systems modelling as a tool with the decision makers in the room is likely to lead to a more comprehensive result. However, when modelling is used in the policy planning process it is difficult to capture all variables, therefore, it often seeks to find the cheapest way to implement a proposed policy. The specific regulation each farmer faces will also likely impact on the choice of mitigations, with relatively more severe regulations likely to prompt system changes rather than modifications within system.

In addition to trying to simplify mitigation selection to the most cost-effective mitigation, there are challenges in trying to understand decision making in response to specific mitigations. For example, if a farm was to reduce its nitrogen fertiliser use, will the farmer import additional feed or reduce stocking rate? Often farmers themselves do not know the answer to these questions and it will depend on factors such as milk price, weather and input prices.

The use of prices in farm systems modelling is very important, as well as making the price assumptions clear. Both input and output prices can be very volatile and will influence farmer behaviour. Overseer operates at a steady state and does not account for seasonal climatic differences, therefore using standardised prices will be more consistent with this than using volatile seasonal prices. If the farm systems modelling is being used to inform the policy planning process, using standard prices to match the steady state in Overseer is applicable, however it is important to consider the impact of different prices on the ability of farmers to afford mitigation, particularly those that are capital intensive and funded by debt which incurs interest. If farm systems modelling is being used to inform farm management using actual prices may be more applicable. Some costs in the farm systems modelling are variable, some are fixed and some are likely to be 'sticky' where they vary in steps. An example of sticky costs is labour; changes in labour requirements for a dairy farm are non-linear and are best treated as a fixed cost unless cow numbers reduce considerably. The assumptions are about which costs are sticky, variable or fixed should be consistent across farms being modelled.

Not only do physical changes on farm needs to be considered in context of the whole farm system, but financial changes need to as well. For example, if effluent area is increased, additional costs need to be considered, including extra compliance costs and additional electricity for pumping. The costs beyond the farm gate also must be considered, for example, when altering imported supplements, supplement price may change if there is a change in demand across a large enough proportion of farms. While there is often not enough information to understand what these flow-on costs may be, or to estimate them with any accuracy, it is important to be clear and transparent in what assumptions have been made.

One of the limitations of Farmax is that it does not account for changes in capital costs if making substantial changes to a farm system (Allen, 2012). Therefore, incorporating capital changes needs to be done outside of the models. This includes the capital freed up from sales (e.g. of cows and milk company shares) and that spent on mitigations (e.g. fencing, improving effluent or irrigation systems). Additionally, how these capital expenditures will be financed must be considered, for example, if it is all borrowed, and if so, at what interest rate.

Possibilities

Despite the challenges involved with farm systems modelling it has made large improvements in recent years, not least due to improvements in the models available for use. Models simplify reality and there will always be factors that are not able to be captured and assumptions are therefore implicit in them. The possibilities for farm systems modelling range from improvements in the models, improvements in processes and further areas of research.

There is scope to integrate models to remove the use of multiple models in the construction of abatement cost curves. Currently farm systems modelling requires the use of at least two models and transferring information between the them allows for human error. Integrating models to remove this risk would mean any nutrient loss modelling would be considered in a farm systems context with a more automatic check for biophysical feasibility.

One area for further research is social research on mitigation preferences. Research into this would help validate the assumption of using the lowest cost mitigation option, or set up criteria to help choose an alternative mitigation strategy for each farm based on the farmers' preferences. This still needs to be transparent for modelling and is able to be replicated across multiple farms being modelled. Currently this is done through discussions with each individual farmer and is time consuming and not transparent.

Currently there is no ability to model mitigations over time, for example reducing Olsen P levels is a valid mitigation option but in the real world takes time, while it is instantaneous in the models. Being able to model changes over time, allows the impact of on farm change to be captured more accurately and also allows changes to be implemented incrementally rather than sudden system changes. It is however, necessary to approach this with caution as the model currently assumes a farm in steady state.

At present the available farm systems models measure nutrient losses to the root zone. They do not measure the nutrients that end up in water as they do not account for attenuation. While accounting for attenuation is complex, it would help to bridge the gap between modelling and what is happening in reality.

There is a range of possibilities as to where farm system modelling can be used in science and policy development. Many regional councils are requiring farm environment plans (FEPs) to capture how farmers are mitigating nutrient losses, as a result they are capturing a large amount of farm information. This farm information can be used to undertake farm systems modelling at a catchment scale to understand what on farm changes could be used to deliver required water quality outcomes. For example, could edge of field mitigations, and/or critical source areas, achieve desired reductions in nutrient loss. This is similar to the modelling currently undertaken to estimate the impact of proposed policies, however as more information is recorded it could be used in developing more robust catchment level models. It could also be used to predict how effective FEPs will be by modelling the agreed upon actions.

Summary

Dairy farm systems modelling is the use of models to estimate the impact of a change on farm. Farm systems modelling which estimates the impact of reducing nutrient loss on farms should use models that capture nutrient loss changes, financial impacts and ensures the farm is a viable farm system with energy supply and demand in balance. Overseer and Farmax are widely used in conjunction for farm systems modelling in New Zealand. While there is no one right answer for farm systems modelling it is important to keep energy supply and demand in balance. It is necessary to capture the economic costs of changes on farm, including those that require farmers to change their skill levels. Farm systems modelling is a very useful tool for policy makers as they must estimate the costs of proposed policies. It does not cover all the costs and benefits that must be considered in policy decisions and it does have limitations, however, it is still a valuable tool that provides information for the decision making process. Farm systems modelling is likely to become more widely used as farmers' face regulation and some are required to decide how they can mitigate nutrient losses.

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