A WHOLE FARM MODELLING APPROACH TO EVALUATE THE ECONOMIC VIABILITY OF A DAIRY FARM IN A SENSITIVE CATCHMENT

Trevor Sulzberger, Tom Phillips, Nicola Shadbolt, Barrie Ridler and Roy McCallum

Institute of Agriculture & Environment, Massey University

The Horizons One Plan recognises the significant impact that nutrient discharges from agricultural activities can have on water quality and regulates existing intensive farming activities for individual farms including dairy in targeted catchments. This is achieved by allocating nitrogen leaching allowances based on Land Use Capability class (LUC). Existing dairy farms in target water management sub-zones will either meet nitrogen (N) leaching targets (Limits), according to the Land Use Capability (LUC) of the farms or, where they cannot, then a consent will be granted subject to a reduction in nutrient loss from farm land.

The Grazing Systems Limited Linear Program (GSL LP) is a bio-economic model in that resources have economic values that drive optimisation, and provides an opportunity to distinguish the changes that are required to optimise operating surplus, this is where marginal cost equals marginal revenue (MC=MR) and to minimise N-loss of the farming system.

The results showed that six of the nine runs out performed the base system with farm surplus and eight out of nine runs showed lower N-loss than the 20 year N-loss limit, with run five giving the highest profit and run ten the lowest N-loss. Run five reduced cow numbers by 23% to 2.2 cows/ha, removed imported supplements, N fertiliser and 15 ha of winter Oats. The results showed run five increased profits by 14% and decreased N-loss by 43% over the base system; this would make the farm meet the 20 year set limit imposed by the One Plan by 39% (N-loss).

The research highlights that the farm system needs to de-intensify, reduce stocking rate, remove or reduce imported supplements and remove or reduce nitrogen fertiliser, thus increasing profitably of the farm system and reducing the environmental impact.

This study found that the GSL LP whole farm modelling tool to be very effective when used with Overseer®, to identify profitable options for reducing N-loss off the case study farm.

KEYWORDS: *Dairy farm, sensitive catchment, whole farm modelling, linear programming, mitigation strategies.*

Introduction

In 2007, Horizons Regional Council which manages Manawatu, Rangitikei and Wanganui river catchments, proposed a legislation called One Plan (Horizon, 2013). Horizons One Plan reflect a move towards catchment-based water management that seeks to manage the effects of all land uses and activities within that catchment (Parfitt et al., 2013). The One Plan regulates existing intensive farming activities for individual farms including dairy in targeted catchments (sensitive catchment zones, water management sub-zones), this is achieved by allocating nitrogen leaching allowances based on Land Use Capability class (LUC). Existing dairy farms in target water management sub-zones will either meet nitrogen (N) leaching targets (Limits), according to the Land Use Capability (LUC) of the farms or where they cannot then consent will be granted subject to a reduction in nutrient loss from farm land (Bell et al., 2013b).

The purpose of this study is determine if it is possible for a dairy farm in a sensitive catchment to have acceptable N leaching and make a profit using a whole-farm modelling approach.

Materials and Methods

A single case study farm has been selected to represent a dairy farm in a sensitive catchment. Detailed physical and financial information was supplied by the farmer and other sources; information available included DairyBase, supplying physical and financial information, virtual climate data from NIWA's web site and soil information provided by a detail soil and landscape capability survey at the paddock level, this was undertaken earlier in 2014 by a trained Soil Pedologist. This was entered into Overseer® V6.1.3 nutrient budget model to develop the base file.

The case study farm borders the Rangitikei River and is in the Coastal Rangitikei catchment. The milking platform is 238.3 ha or 217 ha with a prominently Friesian herd, at peak 620 cows are milked producing approximately 275,124 kg MS each year, equating to 443.75 kg MS/cow or 1,268 kg MS/ha, stocking rate is 2.86 cows/ha. In winter half the herd is removed from the farm for six to eight weeks during June and July with all excess stock and replacement grazed off farm.

The mean rainfall is 880 mm per annum with a mean temperature of 13.5°C with potential evapotranspiration (PET) of 1024 mm per annum and PET seasonal variation of low. Cropping consists of 25 ha of Chicory and clover mix and 15 ha of winter Oats with 220 tonnes palm kernel extract (PKE) and 240 tonnes maize silage to supplement pasture deficits.

Nitrogen fertiliser is applied with four equal application of 25 kg N/ha over the whole farm during April, August, September and October while the crops get an initial application when sown of 40 kg N/ha.The effluent system is a sump and pump system with an effluent application area of 38 ha and irrigation covering approximately 98 ha, 55 ha from central pivot and 43 ha from K-line pods. The farm has 12 different soil types; they are mainly silt, silt loams, sandy loams and sand, with drainage status of well drained, moderately well drained, and imperfectly drained to poorly drained.

The permissible N-loss limits were calculated using farm scale maps on a 1:6,000 scale. With ten different LUC units recorded on this case study dairy farm, the data was then used to calculate the permissible N-loss, results show year one permissible N-Loss limits of 26.9 kg N/ha/year, year five 24.3 kg N/ha/year, year ten 22.1 and year twenty 21.2 kg N/ha/year.

To examine the economic performance of a range of development options or system changes for a case study dairy farm, annual whole-farm budgets will be developed using the Grazing Systems Limited Linear Program (GSL) for both the biophysical and economic modelling provide an in-depth analysis of a whole farm business (Armstrong et al., 2010; Heard et al., 2012; Malcolm et al., 2005a; Malcolm et al., 2005b).

The combination of a whole farm system model and Overseer® provides a decision-making tool that leads to a complete picture which should then lead to better decisions for the stakeholder as opposed to any one of these tools in isolation.

The GSL optimisation model was set up to optimise profit, this was achieved by optimising/restricting stocking rate, cow numbers, cow age, N excreted (Nx), N fertiliser, supplements, pasture by discarding or cutting for silage, wintering off, cropping area.
The model comprises a feed supply and a feed requirement component, with feed management activities linking supply and consumption. The year is divided into 26 periods, allowing management decisions to be made every 2 weeks.

Farm Gross Margins is defined as the difference between returns from milk sales and working expenses (costs). Working expenses relate to direct costs of production and exclude overheads and financial costs not normally quantified to specific activities of daily farm production. Working expenses is converted into a per cow cost while resources that influenced the optimisation is independently allocated as per unit increment when required, this included fertiliser, purchase of off-farm feed, cropping, grazing, conservation of silage. The analysis is based on a whole farm forecast, modelled covering the next 12 month period, for this reason depreciation, family income, taxation, capital items and loan (principle and interest) are not included in this analysis.

Over the last few years we have seen record paid-out for Milk solids (MS), this season (2014-2015) there has been a sharp drop, therefore a payout of $6.00 kg/MS has been assumed, with PKE set at $350 per tonne.

Results
To evaluate the robustness of the calculated N-loss using Overseer®, three consultants Overseer® files have been obtained representing the case study farm. Consultant 1, with farm data dated 2013, Consultant 2 with farm data dated 2013 and Consultant 3, completed recently using 2013-2014 seasonal farm data and up to date farm soil mapping.

Table 1: Consultants Overseer® Data

Consultant	No. Blocks	Irrigated	Effluent	Pasture	Total area	Effective area	N loss to water
	Productive	ha	ha	ha	ha	ha	kg N/ha/yr
1	4	131.5	40	54.7	232	226	25
2	4	110	40	68	230	218	32
3	11	98	38	86	238	217	23

A case study farm using 2013-2014 seasonal data was used and formed the basis to develop a base system within the GSL. From this, a further nine runs could then be compared to the base to see how the farm performs financially and environmentally. Consultant 3 Overseer® data formed the bases to develop N-loss of the case study farm.

The permissible One Plan N-loss limits for the cases study farm outlines the N-loss limits targets at specific time periods. The farm already meets year one N-limits of 26.9 kg N/ha/year and year five N-limits of 24.3 kg N/ha/year with the current farm N-loss of 23 kg N/ha/year. However the farm needs to reduce N-loss limits to meet the year 10 limits of 22.1 kg N/ha/year a reduction of 0.9 kg N/ha/year and year 20 limits of 21.2 kg N/ha/year a reduction of 1.8 kg N/ha/year.

To show how the farm would perform over each run, the GSL LP data is plotted, this allowed a comparison of each run using Figure 1 and Figure 2. The One Plan permissible N-Loss of the farm has been set at the 20 year limit, 21.2 kg N/ha//year. The milk solid production per cow went from 433 kg MS/cow and stabilised around the 456 kg MS/cow to 457 kg MS/cow for the rest of the runs.

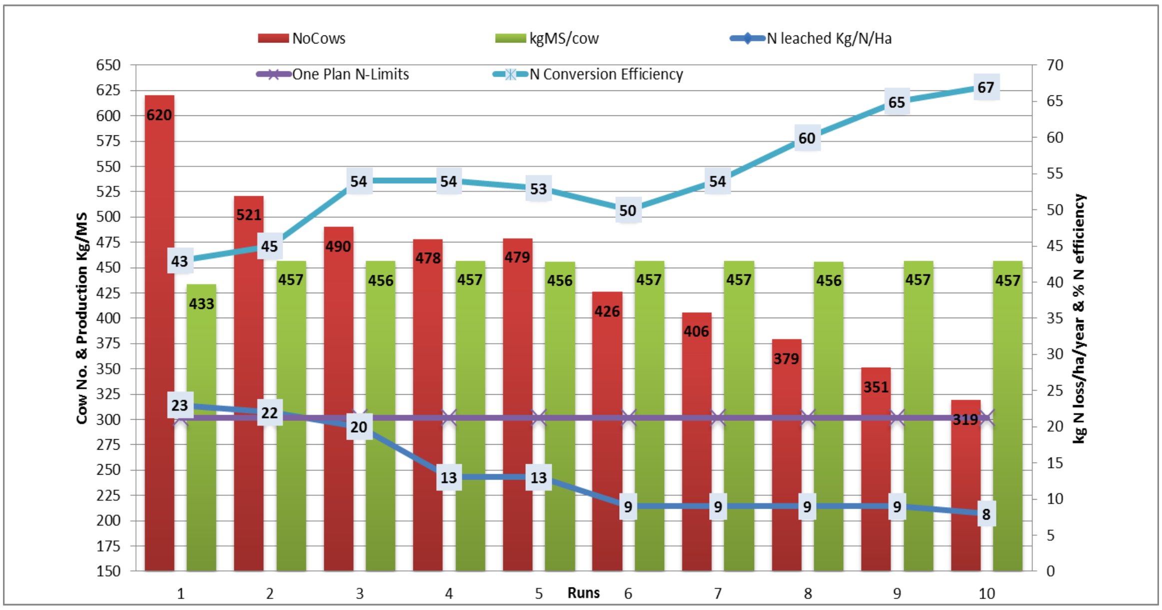

Figure 1: GSL plotted runs with comparison of N leaching, cow numbers and production and N efficiency

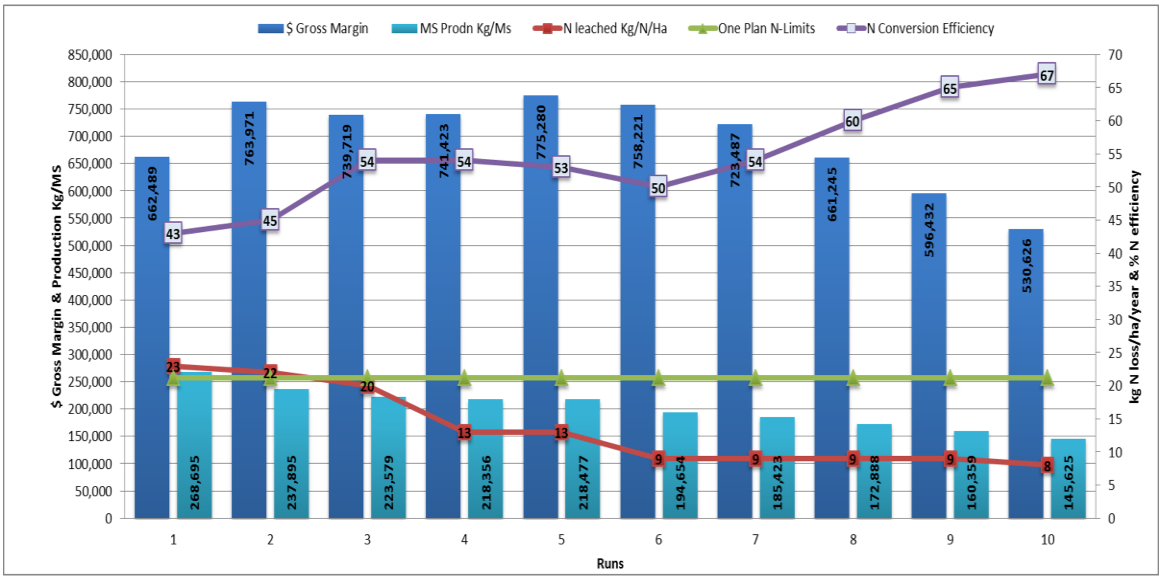

Figure 2: GSL plotted runs with comparison of N leaching, N efficiency and cash surplus

The completion of the ten runs demonstrated that six out of ten runs provided a higher surplus and lower N-loss across the whole farm with run five providing the highest surplus of all runs. For this reason run five has been selected to perform a comparison with different milk solid payouts.

Comparison with changes in milk solid payout

The comparison was performed using a range of forecast milk solid payouts, based a range of milk solid payout over the last ten years (Table 2), this included four dollars, six dollars and eight dollars. A sensitivity analysis was not appropriate for this analysis as it cannot optimise and allocate resources based on marginal returns. For this reason the GSL LP was used to perform this analysis.

Table 2: Ten year milk solid payout

Season	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015
$ kg MS	4.10	4.46	7.66	5.20	6.37	7.90	6.40	6.16	8.50	5.65

The base run (one) and run five has been used with a change in PKE price to reflect the correlation that has been seen with milk prices over the last few seasons. The base run was run twice, this was to reflect the current 620 cows and then to optimise cows, also nitrogen fertiliser was restricted to a range of 0 kg N/ha to 25 kg N/ha, supplements import limits have been opened up to 2,000 tonnes. The base system did not have a constraint on N excreted (Nx), while run five had a maximum N excreted of 76,183. Each run demonstrates how a change in the forecast milk solid payout impacts on the whole farm system, financially and physically. The changes to the whole farm system was then modelled using Overseer® and plotted to see the correlation to the farm operating surplus over individual runs (Figure 3).

The analysis demonstrates that some form of mitigation constraints need to be implemented in the model to achieve reduced N-loss across the whole farm system. In comparison to the base run there have been no costings for an increase/decrease in labour units on any of these runs and no costings for any new infrastructure that might be required if the herd increases above the base system.

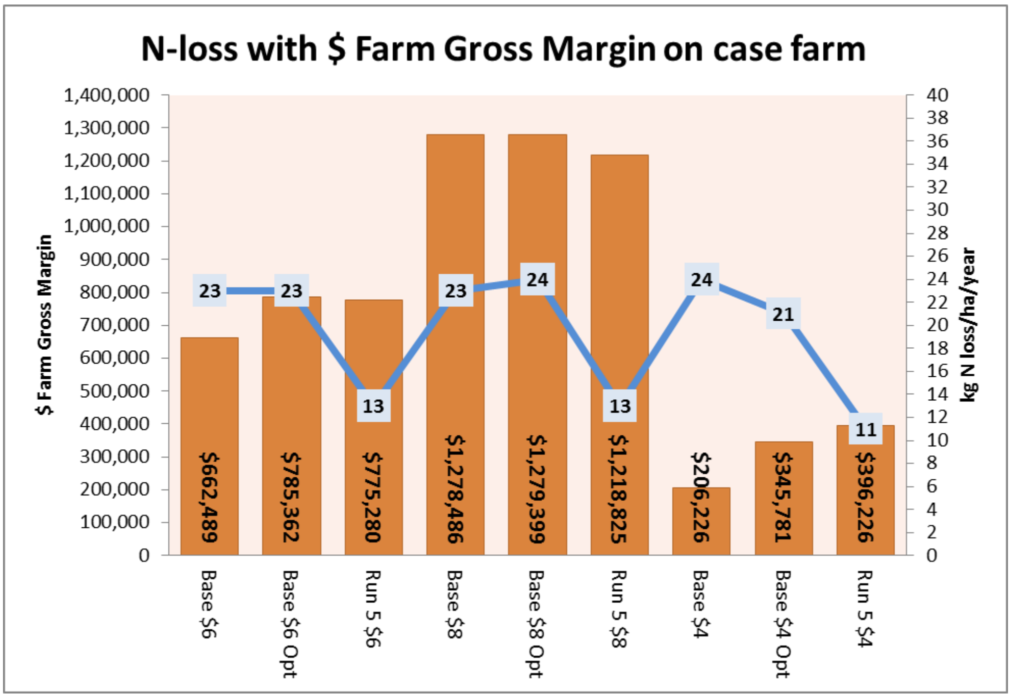

Figure 3: GSL Comparison with different MS Payout

Discussion

Modelling approach

Dairy farmers face important issues related to improving efficiency, lowering costs, and increasing productivity while being cognizant of issues related to the environment, animal welfare, and food safety. The complex interrelationship between a large number of factors in a dairy system makes it difficult to determine the costs and benefits of implementing various management or technological alternatives (Shalloo et al., 2004). Systems modelling involves representing what seem to be the key features of a relevant system in mathematical "models", and then using these models to make inferences about the system. There are a range of modelling approaches based on different forms of mathematical representation and methods of analysis. In addition, some important issues that influence decision making by farmers, such as practical skill levels, family goals, cultural constraints, habits, changing personal worldviews, values, and interests, are difficult to represent in a computer model (Woodward et al., 2008).

The capability of simulating whole dairy farm systems is a challenge that has long been recognised (Cabrera et al., 2006). The complexity of dairy farms that include livestock, waste, feed, crops, and their interactions, justifies the creation of a whole-farm model, integrating several disciplines and modelling approaches, in order to better analyse these systems (Herrero et al., 2000). However, currently there are few tools available for predicting how dairy farm systems will respond to management changes from environmental and economic perspectives. Those tools that are available are typically applied in isolation, with the net result that a double bottom line analysis (environmental and economic) is seldom considered (Monaghan et al., 2004).

Optimisation Models

Optimisation models are a key tool for the analysis of emerging policies, prices, and technologies within grazing systems. Optimisation allows the efficient identification of profitable system configurations, which can be time consuming if manual trial-and-error is used, particularly in complex farming systems (Doole et al., 2013c).

Deterministic farm models generally use mathematical programming and do not have a random number generator, this is often based on Linear programming (LP) (Janssen & van Ittersum, 2007). Linear programming represents the farm as a linear combination of so-called ‘activities’. An activity is a coherent set of operations with corresponding inputs and outputs, resulting in e.g. the delivery of a marketable product, the restoration of soil fertility, or the production of feedstuffs for on-farm use (Ten Berge et al., 2000).

Linear programming based models optimise, however only gives one answer, this can be a devise alternative management choices that maximise (minimise) an objective function according to a set of restrictions (Hardaker et al., 2004) and have been widely used in analysis of farming systems, since 1958 (Cabrera et al., 2005). The discipline of this type of modelling is that the systems and the individual components that make up each system must be clearly defined (Ridler et al., 2001).

Grazing Systems Limited

The Grazing Systems Limited (GSL) Model is a Linear Program model for pastoral farm systems developed by Barrie Ridler. It optimises animal production needs against dry matter feeds (energy) – pasture, crops and supplements. It is a bio-economic model in that resources have economic values that drive optimisation (Riden, 2009). The GSL LP optimisation model allowed selected resources to be constrained, primarily cow number and production per cow, but it allowed the addition of other resources such as supplementary feeds, nitrogen and grazing off. The model depended primarily on relationships involving feed energy and its cost (Anderson & Ridler, 2010). The ability to substitute use and management of specific resources as part of the optimisation process provides the difference between this and other more deterministic simulation methods. The use of GSL LP is highly educational to those involved, it is not restricted to thinking inside the square and will often provide answers that are sensible but not necessarily intuitive (Riden, 2009).

When used as a modelling tool GSL generally takes an established model representing an optimised farm system and varies a single input parameter about the optimal –typically herd size but it can also be herd structure, calving dates, animal or pasture production, or management decisions on culling or drying off/sales. This provides data to build the system production function, and marginal cost and/or revenue curve (Riden, 2009).

The production level where operating surplus is maximised (marginal cost equals marginal revenue - MC=MR) is simple to determine. Setting production at the operating surplus maximising point (MC=MR) on a production function is common wisdom and infers allocation efficiency. That there are a wide range of possible production functions for the same farm should be no surprise given the complexity of pastoral farming and the diversity of farm managers and farm management system (Riden, 2009). It is also assumed that except in unusual circumstances, no rational manager would continue to use the input or resource at a level beyond the point where MR = MC, the profit-maximising point. Critically, this is also the point of optimal or efficient resource allocation. Calculation of a ratio such as the average revenue or a Gross Margin does not indicate when that profit-maximising 'tipping point' has been reached (Ridler et al., 2010).

Marginal decision making

In the dairy industry, it is almost always much easier to focus on the income side rather than to try to decrease expenses. However, farmers can dilute their fixed costs by increasing production, MS/cow or increasing stocking rate. When facing an economic choice, farmers should base their analysis on the marginal impact of the decision, not on the farm's average performance. Any economic estimates that involved increase milk production needs to account for the increase feed costs. These must be calculated using marginal costs, not average feed costs (Eicker, 2006).

Averages can be a useful measure of a farm's status, but it is only one measure. When making specific management decisions, averages can be misleading sources of information. Averages themselves may not accurately reflect the farm's real status, as averages are vulnerable to several types of error, significant lag or bias; averages also are deficient in characterising a farm because they, of necessity, express only the central point on a distribution. Averages can be particularly dangerous when used in making economic decisions. Economic decisions based on averages can be seductively appealing; at first glance they can seem like "common sense". In fact, farmers often make decisions based on such "common sense". Often, these common sense decisions are wrong, and very costly (Eicker, 2006).

Many dairy farmers forego very significant profit opportunities in the false pursuit of reducing the costs of inputs. By focusing on the costs of inputs and not the inputs' marginal impact on revenue (milk) and therefore profit, many dairy producers box themselves into a cycle of poor investment decisions, poor profitability, and a poor lifestyle (Eicker, 2006).

The law of diminishing marginal returns dictates that as more of an input is added to the fixed resources of the farm, the addition to output eventually declines (called diminishing marginal product). The effect of diminishing marginal product is to cause average production per unit of input to decline. The profit maximising rule for the use of inputs is to use inputs up to the level where marginal cost (MC) from an extra unit of input nearly equals the marginal return (MR) (Figure 4). This level of input use will be somewhere between the level of input use where the average product of the input (total product/total input) is maximum and where the total production reaches a maximum and the marginal product of an extra unit of the input becomes negative. Between these two levels of input use – where average product is maximum and marginal product is zero, any level of technical efficiency (total output/total input) could be the most profitable, depending on the prices of the input and the output (Melsen, Armstrong, Ho, Malcolm, & Doyle, 2006).

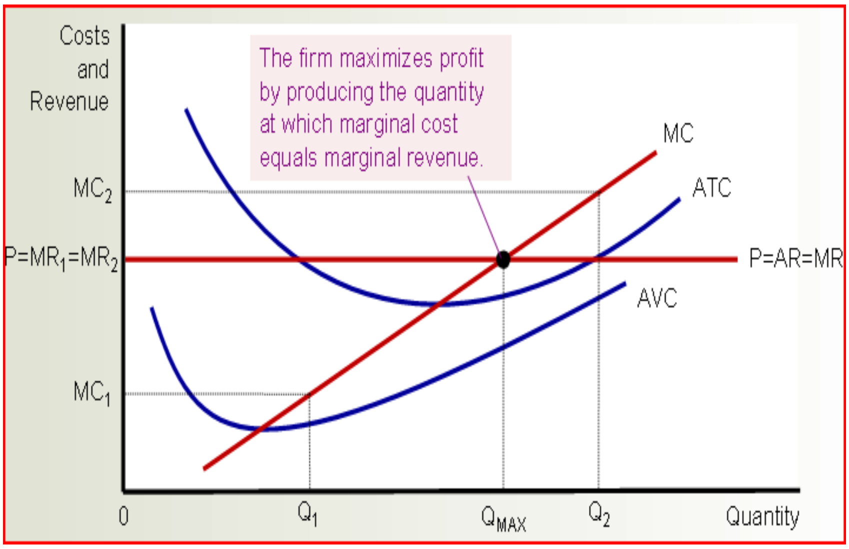

Figure 4: Marginal cost curve (Gans, King, & Mankiw, 2011)

Figure 4 shows the marginal-cost curve (MC), the average-total-cost curve (ATC) and the average-variable cost curve (AVC). It also shows the market price (P), which equals marginal revenue (MR) and average revenue (AR). At the quantity Q_1, marginal revenue MR_1, exceeds marginal cost MC_1, so rising production increases profit. At the quantity Q_2, marginal costs MC_2 is above marginal revenue MR_2, so reducing production increases profit. The profit-maximising quantity Q_{max} is found when the horizontal price line intersects the marginal-cost curve (Gans et al., 2011).

Whole farm modelling approach

New Zealand has an average stocking rate of 2.83 cows/ha, the case study farm has a stocking rate of 2.9 cows/ha, with high supplements and farm resources requirements.

With the current farm N-loss of 23 kg N/ha/year, and with the use of GSL LP optimisation model, not all mitigation options would be required. There was no additional expenditure on infrastructure; when an effluent storage system was included in Overseer®, N-loss was unchanged, a feed pad or standoff shelter also was not considered, due to the capital expenditure and the current N-loss of the farm.

There are numerous ways a farmer could reduce N-loss. For example, a standoff facility with duration-controlled grazing, as advocated by Christensen et al., (2011), reduced NO_3^--N leaching by more than 50%. However, no financial analysis is provided by Christensen et al., (2011) of the costs associated with this N-loss. De Klein & Monaghan, (2005) suggests monetary benefits do not necessary flow from such investments.

To provide a standoff shelter, including infrastructure on the case study farm would cost approximately $1,125 per cow, with 620 cows, $697,500 and effluent system, $125,000 total cost of $822,500 would need to be spent. The GSL LP run five by comparison achieved a reduction of 43% in N-loss, an increase in surplus of $112,791, plus in the first year the proceeds of shares & cow of $543,036, a total surplus of $655,827 above the base system.

It was difficult to measure the impact of fertiliser application rates and timing in this GSL analysis. In most runs N fertiliser was completely removed, the focus was on improving nitrogen use efficiency by both plants and livestock. As described by Groot et al., (2003), Ledgard, (1991) and Stout & Jung, (1992), fertiliser was a factor in N-loss and long-term N losses can be reduced by improving N use efficiency by both plants and livestock also with changing fertiliser application rates and timing.

The GSL LP optimisation model eliminates inputs in order of their non-acceptance on an economic or environmental consequence basis according to the constraint data applied, not on the type of supplement, protein or carbohydrates in the diet. The farm produced sufficient pasture at a cost lower than maize silage or PKE, this results in the removal of supplements and an increased reliance on pasture with each run. The GSL LP optimisation model demonstrated in accordance with Edwards et al., (2007) and in contrast to Dijkstra et al., (2011) diet based strategies are not always required to significantly reduce N-loss.

The GSL LP optimisation model was set up to optimise profit, this was achieved by optimising/restricting stocking rate, cow numbers, cow age, N excreted (Nx), N fertiliser, supplements, pasture by discarding or cutting for silage, wintering off, cropping area, this whole farm approach as advocated by Cardenas et al., (2011) reduced N-loss by as much as 65% in run ten. It also confirmed LP as a tool for model optimisation (Doole et al., 2013).

It is difficult to compare and contrast other models against the GSL LP optimisation model. To compare the GSL LP optimisation model to UDDER or Farmax® Dairy Pro you would have to totally constrain GSL LP to give the desired answer, this also applies in reverse, trying to compare UDDER or Farmax® Dairy Pro to GSL LP optimisation model as explained by McCall, (2012).

A point emphasised by Eicker, (2006), Melsen et al., (2006), Monaghan et al., (2004), Riden, (2009) and Ridler et al., (2010), UDDER and Farmax® Dairy Pro are simulation models that will always average the additional costs and benefits over the entire farm's resources over the 12 month period. This is in contrast to the GSL LP optimisation model as it uses margins, each year is divided into 26 periods, allowing management decisions to be made every 2 weeks, where each cost/benefit change to each additional and/or subtracted unit is applies.

Averages as mentioned by Eicker, (2006) can be particularly dangerous when used in making economic decisions, any economic estimate that involve an increase and/or decrease in milk production needs to account for the increase and/or decrease in feed costs, this must be calculated using marginal costs, so any specific final financial answer can be found from many different mixes of resources which means it is impossible to identify exactly the same mix of resources (Anderson & Ridler, 2010; Eicker, 2006; Riden, 2009; Ridler et al., 2010).

Optimisation models are an effective way to analyse many different scenarios, with the aim to reduce N-leaching while increasing profit per hectare (Bell, 2013; Bowler & McCarthy, 2013; McCall, 2012; Riden, 2009). Optimisation models can perform many iterations quickly by changing a single input to determine the outcome, this can then be compared to the next. This allows efficient identification of profitable systems and can be time consuming if a manual trial-and-error approach is used (Bell, 2013; Doole et al., 2013c; McCall, 2012; Riden, 2009).

In contrast to UDDER and Farmax® Dairy Pro, the GSL LP optimisation model provides the user the ability to run initial scenarios, this can then be used to restrict inputs and/or optimise resources. Not only does the GSL LP optimise a single run, it also provides a snapshot where each run can then be compared (production levels, expenses and surplus) based on resources used. This provides an opportunity to distinguish the changes that are required to maximise operating surplus. This is where marginal cost equals marginal revenue (MC=MR) and to minimise N-loss of the farming system (McCall, 2012; Riden, 2009). This has been demonstrated with the case study, run five, producing the highest profit of all the 10 runs, while reducing N loss to 13 kg N/ha/year, surpassing the 20 year N-loss limits by 11.2 kg N/ha/year.

In the same catchment and similar farm type Bowler & McCarthy, (2013) demonstrated using a combination of Farmax® Dairy Pro and Overseer® to evaluate opportunities of using existing resources more efficiently, demonstrated N-loss reduction of 16% and operating profit increase of 0.6% ($23/ha). In parallel using GSL LP optimisation model on the case study farm, run five resulted in a N-loss reduction of 43% and a surplus increase of 14% ($520/ha). This demonstrates the strength of a whole farm optimisation model set up to optimise profit, while some models fine tune system runs, others rely on manual trial-and-error (Doole et al., 2013c; McCall, 2012).

The Overseer® nutrient model provided the environmental information in the form of N-leaching and nitrogen conversion efficiency (NCE) for each run on the case study farm. The base run had a N-loss of 23 kg N/ha/year and a NCE of 43% as the N-loss decreased the NCE increased with run five N-loss of 13 Kg N/ha/year and NCE of 53%, so as nitrogen conversion efficiency (NCE) increases, nitrogen leaching loss decreases.

A whole farm modelling approach using GSL LP optimising model provides information on the physical and economic impact of each run, while Overseer® provides the environmental impact of each run. The whole farm modelling in combination with Overseer® provides the stakeholder with an invaluable insight into how a physical system change will affect the economic viability and provide the environmental impact of the farming system, as demonstrated by Bowler & McCarthy, (2013), Wedderburn et al., (2011), Monaghan et al., (2004), Bell, (2013), McCall, (2012). The same approach was used at Massey No.1 dairy unit, to develop a whole farm system that was both profitable and environmentally robust.

The case study farm is rated in DairyBase as a production system three, with 10% to 20% of imported feed to extend lactation. The runs produced using GSL LP give the stakeholder a snapshot of options, these are not all the runs that can be performed; this is only the first step. The stakeholder has the ability to clarify runs that could potentially be used; make further runs or drill down on a selected run, this allows price comparisons, risk analysis, uncertainty or other potential variation of interest to be performed as requested by the farmer. The next step is to select a run (option) and perform an in-depth analysis; this could be financial, managerial, social, environmental or a combination. Botterill & Mazur, (2004) and Hardaker et al., (2004) states that imperfect knowledge about alternative outcomes creates uncertainty so improving knowledge through multiple runs will improve that knowledge so you can actually feel better informed.

Run five was only selected based on its highest surplus and responsible N-loss over the case study farm, not because it suits the stakeholder’s ability, skills, ideology, constraints or resources.

High-input systems can have greater variability because of additional complexity and more decisions required on a daily basis (Kloeten, 2014). This case study farm is a system three farm. Removing imported supplements and fertiliser reduces the complexity but it will require greater pasture management, monitoring, measuring and grazing skills (system two farm). These are learnt farmer skills and cannot be assumed. There are always going to be trade-offs when you have environmental objectives (Dake, Mackay, & Manderson, 2005).

Conclusion

The objectives of this study were to gain an in-depth understanding of how the One Plan imposes limits on nutrient losses and how mitigation strategies will affect the economic viability of a dairy farm in a sensitive catchment. A case study farm in a sensitive catchment was considered the most appropriate method for achieving this objective and the combined GSL and Overseer® modelling approach was adopted. In this chapter, the main research findings are described and the implications of this research discussed and opportunities for future research outlined.

Foremost, grassland-based agricultural production is the most important component of livestock production systems in New Zealand because of the competitive economic advantage of grazed grass. This study found that GSL LP whole farm modelling tool to be very effective when used with Overseer®, to identify profitable options for reducing N-loss off the case study farm.

This was observed.

- Most of the analysis in mitigating N-loss currently completed has focused on single issue or solution and in most cases without any financial analysis on the impact on the farm system.
- Some whole farm models use averages, the selected whole farm model for this case study farm used margins in its calculations.
- That whole farm management system analysis requires many iterations to get a useful picture. The selected whole farm model for the case study farm optimises its outputs on selected constraints giving greater accuracy and a more reliable outcome for both financial and environmental analysis.

- Some whole farm models are better at fine tuning than others.
- The case study farm system needs to de-intensify, reduce stocking rate, remove or reduce imported supplements and remove or reduce nitrogen fertiliser to increase the farm surplus and reduce the environmental impact.
- Overseer® should not be used in isolation of whole farm modelling tools. A better result is obtained if the two tools are used together.

This would suggest that.

This would suggest that it is possible for a dairy farm in a sensitive catchment to have acceptable N leaching and make a profit.

LESS COWS, MORE PROFIT, BETTER ENVIRONMENT

References

Anderson, W. J., & Ridler, B. J. (2010). Application of resource allocation optimisation to provide profitable options for dairy production systems. *PROCEEDINGS- NEW ZEALAND SOCIETY OF ANIMAL PRODUCTION, 70*, 291-295.

Armstrong, D., Tarrant, K. A., Ho, C. K. M., Malcolm, L. R., & Wales, W. J. (2010). Evaluating development options for a rain-fed dairy farm in Gippsland. *Animal Production Science, 50*(6), 363-370. doi: http://dx.doi.org/10.1071/AN10009

Bell, B., Brook, B., McDonald, G., Fairgray, D., & Smith, N. (2013b). Cost Benefit and Economic Impact Analysis of the Horizons One Plan. New Zealand: Nimmo-Bell & Company LTD.

Cabrera, V. E., Breuer, N. E., Hildebrand, P. E., & Letson, D. (2005). The dynamic North Florida dairy farm model: A user-friendly computerized tool for increasing profits while minimizing N leaching under varying climatic conditions. *Computers and Electronics in Agriculture, 49*(2), 286-308. doi: http://dx.doi.org/10.1016/j.compag.2005.07.001

Cabrera, V. E., Hildebrand, P. E., Jones, J. W., Letson, D., & de Vries, A. (2006). An integrated North Florida dairy farm model to reduce environmental impacts under seasonal climate variability. *Agriculture, ecosystems & environment, 113*(1), 82-97.

Dake, C., Mackay, A., & Manderson, A. (2005). *Optimal trade-offs between financial and environmental risks in pastoral farming.* Paper presented at the MODSIM 2005 International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand.

Doole, G. J., Romera, A. J., & Adler, A. A. (2013c). An optimization model of a New Zealand dairy farm. *Journal of Dairy Science, 96*(4), 2147-2160. doi: http://dx.doi.org/10.3168/jds.2012-5488

Eicker, S. (2006). *Marginal thinking: making money on a dairy farm.* Paper presented at the Advances in dairy technology: proceedings of the... Western Canadian Dairy Seminar.

Gans, J., King, S., & Mankiw, N. G. (2011). *Principles of microeconomics*: Cengage Learning.

Hardaker, J. B., Huirne, R. B. M., & Anderson, J. R. (2004). *Coping with risk in agriculture [electronic resource]*: CABI.

Heard, J. W., Leddin, C. M., Armstrong, D. P., Ho, C. K. M., Tarrant, K. A., Malcolm, B., & Wales, W. J. (2012). The impact of system changes to a dairy farm in south-west Victoria: risk and increasing profitability. *Animal Production Science, 52*(7), 557-565. doi: http://dx.doi.org/10.1071/AN11291

Herrero, M., Fawcett, R. H., Silveira, V., Busqué, J., Bernués, A., & Dent, J. B. (2000). Modelling the growth and utilisation of kikuyu grass (Pennisetum clandestinum) under grazing. 1. Model definition and parameterisation. *Agricultural Systems, 65*(2), 73-97. doi: http://dx.doi.org/10.1016/S0308-521X(00)00028-7

Horizon. (2013). Proposed One Plan 2013, from http://www.horizons.govt.nz/about-us/publications/about-us-publications/one-plan/proposed-one-plan/

Janssen, S., & van Ittersum, M. K. (2007). Assessing farm innovations and responses to policies: A review of bio-economic farm models. *Agricultural Systems, 94*(3), 622-636. doi: http://dx.doi.org/10.1016/j.agsy.2007.03.001

Malcolm, B., Ho, C. K. M., Armstrong, D. P., Doyle, P. T., Tarrant, K. A., Heard, J. W., . . . Wales, W. J. (2005a). Dairy Directions: a decade of whole farm analysis of dairy systems. *Australasian Agribusiness Review, 20*.

Malcolm, B., Malcolm, L. R., Makeham, J., & Wright, V. (2005b). *The farming game: agricultural management and marketing*: Cambridge University Press.

Melsen, M. G., Armstrong, D. P., Ho, C. K., Malcolm, B., & Doyle, P. T. (2006). Case-study forty-year historical analysis of production and resource use on northern Victoria dairy farming. *AFBM Journal, 3*(1).

Monaghan, R. M., Smeaton, D., Hyslop, M. G., Stevens, D. R., De Klein, C. A. M., Smith, L. C., . . . Thorrold, B. S. (2004). *A desktop evaluation of the environmental and economic performance of model dairy farming systems within four New Zealand catchments*. Paper presented at the Proceedings of the New Zealand Grassland Association.

Parfitt, R. L., Frelat, M., Dymond, J. R., Clark, M., & Roygard, J. (2013). Sources of phosphorus in two subcatchments of the Manawatu River, and discussion of mitigation measures to reduce the phosphorus load. *New Zealand Journal of Agricultural Research, 56*(3), 187-202. doi: 10.1080/00288233.2013.799497

Riden, C. (2009). NZ Dairy Farms - Optimising Resource Allocation. http://www.agprodecon.org/node/99#Management%20Changes

Ridler, B., Anderson, W., & Fraser, P. (2010). *Milk, money, muck and metrics: inefficient resource allocation by New Zealand dairy farmers.* Paper presented at the 2010 Conference, August 26-27, 2010, Nelson, New Zealand.

Ridler, B., Rendel, J., & Baker, A. (2001). *Driving innovation: Application of Linear Programming to improving farm systems.* Paper presented at the PROCEEDINGS OF THE CONFERENCE-NEW ZEALAND GRASSLAND ASSOCIATION.

Shalloo, L., Dillon, P., Rath, M., & Wallace, M. (2004). Description and Validation of the Moorepark Dairy System Model. *Journal of Dairy Science, 87*(6), 1945-1959. doi: http://dx.doi.org/10.3168/jds.S0022-0302(04)73353-6

Ten Berge, H. F. M., Van Ittersum, M. K., Rossing, W. A. H., Van de Ven, G. W. J., & Schans, J. (2000). Farming options for The Netherlands explored by multi-objective modelling. *European Journal of Agronomy, 13*(2–3), 263-277. doi: http://dx.doi.org/10.1016/S1161-0301(00)00078-2