The feasibility of nutrient leaching reductions (N leaching) within the constraints of minimum impact on the profitability and production of three dairy farms in the Horizons Region

A Report for

horizons regional council

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An in-depth analysis of Horizons Farms including discussion on model structure as related to marginal economics and the costs of nitrogen abatement costs with respect to selected soils and climate.

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Executive Summary

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 consent may be granted subject to a reduction in nutrient loss from farm land.

The program Overseer® which is a nutrient budget program is used to calculate estimated nutrient discharges from individual properties.

The Enviro-Economic Model (EEM 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, where marginal cost equals marginal revenue (MC=MR) and to minimise N-loss from the farming system.

The use of “Synthetic farms” provided data of less value in understanding how to minimise the economic impact of N leach for the farms’ of the Region than the data associated with a real farm.

After initial N leach reduction and an associated improvement in profit as resources were allocated more efficiently, the modelling found an increasingly rapid decrease in profit as N leach constraints were forced below a critical level. It is therefore imperative that each farm’s actual N leach be assessed based on the best soil and farm system’s data (individual farms).

Although some management options were included to improve overall systems efficiencies and also final $surplus at the required N leach levels, with the leachable soil type chosen, achieving the required N leach levels without large reductions in $surplus could not be achieved.

The analysis also shows that there is NO average cost of N abatement and that, depending on the resources and efficiencies of use, there is NO curvilinear line that will describe N abatement costs.

Some variation in the synthetic farm system and soil type illustrated that the extent of $surplus outcome is strongly influenced by factors specific to each farm. For example, previous work for Horizons has shown that whereas many of the current Industry recommendations increase economic risk and achieve little N leach reduction, efficient use of a farm’s resources will reduce N leaching and improve profit.

When this farm management message is adopted and implemented by farmers, the overall N leach of dairy farms throughout the Horizon Region will decline.

Profits will rise, debt can be repaid, and more money will therefore stay within New Zealand and the local community.

The lack of knowledgeable extension and the extensive use of industry models which are incapable of identifying marginal change are currently an impediment. Indeed, the past 15 years of increasing industry debt and water quality degradation show that the current agricultural “model” of intensification/productionism has not worked except to provide a (fleeting) perception of tax free capital gain.

Identifying the point where profit becomes loss is critical for the farm, the environment and the well-being of the local community.

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, Frelat, Dymond, Clark, & Roygard, 2013). The One Plan recognises the significant impact that nutrient discharges from agricultural activities can have on water quality and the growing scepticism that voluntary measures to mitigate nutrient discharges, whilst well intended, will not significantly reduce nutrient discharges without having measurable and enforceable standards in a regional plan.

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 may be granted subject to a reduction in nutrient loss from farm land. The nitrogen leaching allowances for each land use class are presented in Table 1. (Table 14.2 One Plan – 2014).

Table 1: Cumulative nitrogen leaching maximum by Land Use Capability Class (Table 14.2 One Plan – 2014).

	LUC I	LUC II	LUC III	LUC IV	LUC V	LUC VI	LUC VII	LUC VIII
Year 1 (kg of N/ha/year)	**30**	**27**	**24**	**18**	**16**	**15**	**8**	**2**
Year 5 (kg of N/ha/year)	**27**	**25**	**21**	**16**	**13**	**10**	**6**	**2**
Year 10 (kg of N/ha/year)	**26**	**22**	**19**	**14**	**13**	**10**	**6**	**2**
Year 20 (kg of N/ha/year)	**25**	**21**	**18**	**13**	**12**	**10**	**6**	**2**

The program Overseer® which is a nutrient budget program has been used to calculate estimated nutrient discharges from individual properties.

The purpose of this study is to determine if it is possible for a dairy farm in a sensitive catchment to meet the year 1, 5, 10 and 20 cumulative nitrogen leaching maximums (CNLM's) in Table 14.2 of the One Plan, while remaining profitable and viable using a whole-farm modelling approach.

Discussion

Modelling approach

Dairy farmers face important issues related to improving efficiency, lowering costs, and increasing productivity while being cognisant 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, Dillon, Rath, & Wallace, 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).

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, Romera, & Adler, 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, Van Ittersum, Rossing, Van de Ven, & Schans, 2000).
Linear programming based models optimise and provide an outcome answer which will assist to devise alternative management choices that maximise (minimise) an objective function according to a set of restrictions (Hardaker, Huirne, & Anderson, 2004). Such models in various forms have been widely used in the analysis of farming systems since 1958 (Cabrera, Breuer, Hildebrand, & Letson, 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 (B. Ridler, Rendel, & Baker, 2001).

Enviro-Economic Model

Enviro-Economic Model (EEM) structure. (Enhanced version of the previously used Grazing Systems Limited (GSL) Model.) The EEM Model is a model developed for pastoral farm systems by Barrie Ridler using the expertise of a New Zealand firm that specialises in systems work (Systems Software and Instrumentation Ssi). EEM uses LP as a part of a full systems analysis process which 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 EEM LP optimisation model allowed selected resources to be constrained, primarily cow number and production per cow, but allows addition of resources such as bought in feeds (BiF), nitrogen and grazing off. The model depends primarily on relationships involving feed energy and its cost (Anderson & Ridler, 2010). ***The ability of the EEM to substitute use and management of specific resources using marginal analysis integrated with an optimisation process provides the difference between this and other more deterministic simulation methods***.

The use of EEM 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, EEM LP generally takes an established model representing a farm system and begins a process of varying single input parameters about the optimal –such as herd size but including options of herd structure, calving dates, animal or pasture production, varying feed sources or decisions on calving dates culling, drying off/sales. All these are related to marginal costs and returns.

This provides data to build the system production function, and marginal cost and/or revenue curve (Riden, 2009). It constitutes an "orientation" phase for the system.

The production level where operating surplus is maximised (marginal cost equals marginal revenue - MC=MR) is simple to determine for LP. Setting production at the operating surplus maximising point (MC=MR) on a production function 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 systems (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*. *Yet this is what is happening in the dairy industry in New Zealand*.** Critically, MR=MC is the point of optimal or efficient resource allocation. Calculation of a ratio such as the average revenue or a Gross Margin cannot indicate when that profit-maximising 'tipping point' has been reached (B. Ridler, Anderson, & Fraser, 2010). Input/Output models cannot determine where this point is.

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 attributable fixed costs by increasing production/ha, 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 involve increasing milk production need to account for the increase in all costs associated with that objective, not just 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 are 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" yet these common-sense decisions are wrong, and often very costly (Eicker, 2006) both for the farm and environment.

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 1). 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).

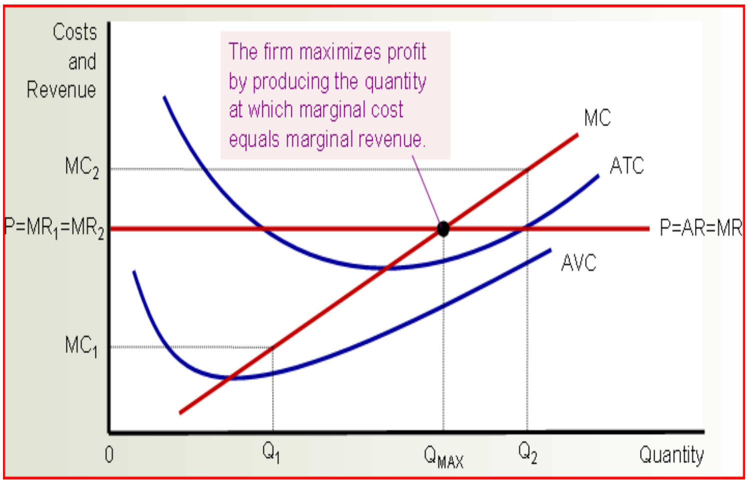


Figure 1: Marginal cost curve (Gans, King, & Mankiw, 2011)

Figure 1 shows the marginal-cost line (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 (Gans et al., 2011).

A useful starting point is considering a simple 'accounting' view of profit ($P**)**, which conceptualises profit as a residual; or what is 'left over' when total cost (TC) is subtracted from total revenue (TR).
This can be expressed thus:

$P = TR - TC (or 'profit equals what you earned less what you spent to earn it')
Economics goes a step further and distinguishes between a firm that 'makes a profit' versus one that is 'profit maximising'; with **marginal analysis** being the key to determining the latter.

In microeconomics, the term 'marginal' simply means 'one more' or 'one less' - so 'marginal cost (MC) is simply the cost associated with producing one additional unit of output, whereas 'marginal revenue[1]' is the revenue generated from selling that same one additional unit of output.
The standard assumption is firms will maximise profits, which occurs when marginal costs equals marginal revenue: or 'when the last dollar *spent* equals the last dollar *earned'*. Maximum Profit is where Marginal Cost = Marginal Revenue or MC=MR.

At this point the marginal (or extra) profit from producing one additional output is **zero** - implying no further gains can be made.

[1] For the mathematically inclined, MC and MR are merely the first derivative of TC and TR.

The result is akin to a 'tipping point', where:

- if marginal cost is *<u>less</u>* than marginal revenue then it is profitable to *<u>increase</u>* production and thereby *<u>increase</u>* profitability (as the last dollar spent is less than last dollar earned - so 'add cows'); however
- if marginal cost is *<u>greater</u>* than marginal revenue then it is profitable to *<u>decrease</u>* production to *<u>restore</u>* profitability (as the last dollar spent is more than the last dollar earned - so 'reduce cows').

Marginal analysis is especially useful when making decisions to increase or decrease production - which is something dairy farmers do all the time.

The fundamental problem with an output or production-based objective (Benchmarks and Production Ratios report) is *there is no consideration given to profit maximisation* - with the result typically being systemic overstocking. This implies a farm essentially has 'two herds': the first is the profit maximising herd (so makes money); whereas the additional cows make up a 'parasitic' herd that generates net costs (and thereby *<u>reduces</u>* the profitability of the entire farm).

Any additional cows (total or per ha.) above the point where MC=MR are the "parasitic herd".
They are eroding the profit made by the cows up to the point where MR=MC.
Profitability per ha at different production levels is represented in Figure 2 as the number of cows (and production per ha.) increases past a certain point, the costs of milking each extra cow compared to the additional return, increase at an increasing rate.

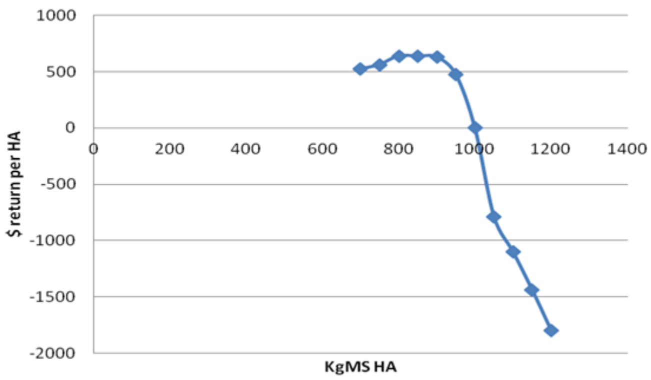


Figure 2: Profit/Loss per HA

- this means that when calculating any step-wise change to input or output, averages are incapable of distinguishing when MC=MR.
- When stepwise reductions are required (such as decreases in N leaching), the cost vs. return for each step must be known to define the cost of each additional reduction in N leach required.

In reality, very few farmers or consultants actually employ any type of profit maximising analysis.
Without this ability they are incapable of profit maximising or accurately costing N abatement. For example, Farm Working Expenses (FWE) is basically a total cost/total revenue approach with average cost analogous to FWE. However, on its own FWE is merely a point estimate - so while FWE can confirm whether a profit is made (or not), unless you have _all_ the FWEs for each level of production for the specific farm in question, it is impossible to profit maximise.

All systems are ultimately bound by diminishing marginal returns (which occurs when at least one input is fixed - so that becomes the system constraint) If land area is fixed then that becomes the constraint within a pastoral farming system. Beyond constant returns one has diseconomies of scale due to decreasing marginal returns, so it is *marginal costs* - rather than *average costs* - that are critical. This is illustrated in Figure 3.

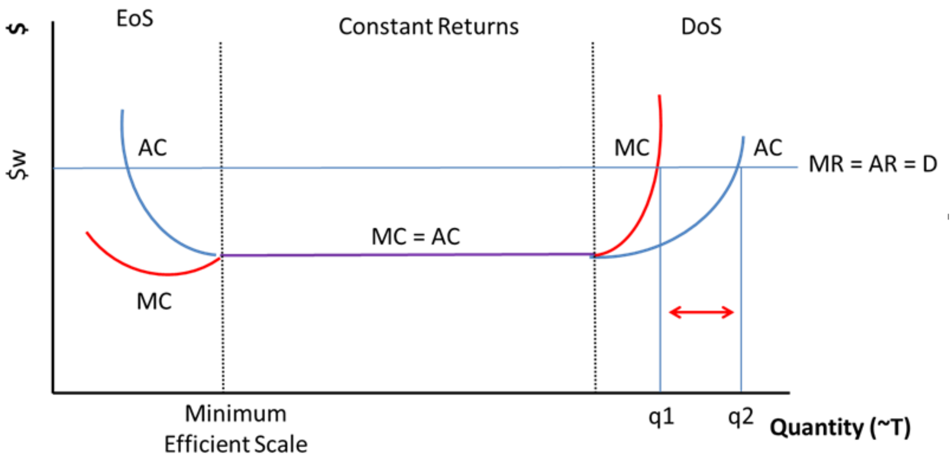


Figure 3: NZ Dairy Industry

Figure 3 assumes a constant world price for dairy commodities - labelled $w. With a constant price over the production range the result is marginal revenue and average revenue (AR) are identical, and together form the demand curve (labelled D).
A firm's supply curve is merely its marginal cost curve (which is why a supply curve slopes upwards - this is due to diminishing marginal returns) but, as noted above, most farms produce based on average costs; which is represented by quantity q2. However, the profit maximising output is where marginal costs match marginal revenue - and this is represented by point q1.
The difference between q1 and q2 is the cost to the farm (or industry) of parasitic cows.
In summary, from an economic perspective all that is required to optimise a system is a thorough understanding of profit maximisation; but one cannot profit maximise without knowing a farm's *marginal cost and marginal revenue*.

It is of little value to know only the average costs and returns as using such data will lead to overproduction which in turn produces higher nutrient output and greater N leaching but at an increasing rate of profit erosion as the parasitic cows erode the profits of the “optimal” herd.

Marginal analysis allows the last “profitable” or MC=MR cow to be identified and the impact on profit that each additional parasitic cow will have.

The explanation above regarding diminishing marginal returns, profit maximisation and the concept of a parasitic herd is an excellent introduction into understanding how the Enviro-Economic Model (EEM LP – an enhanced version of the original GSL model) is fundamentally different from other farm models (such as *Farmax* or the *Whole Farm Model*). In simple terms, EEM LP can combine environmental constraints within an economic model that uses linear programming (LP) techniques to undertake marginal analysis. EEM LP can thereby ascertain both where a farm 'is' (i.e. what is the base case) but also where a farm can 'be' (i.e. its individual point of profit maximisation - or alternatively, loss minimisation).

A real strength of LP is its ability to handle constraints: for example, to profit maximise subject to a nitrogen (N) leaching constraint by 'crunching' alternative resource combinations. For example, in terms of energy production the application of N and the purchase of BiF (“Bought in Feeds”) are substitutes - albeit with significantly different cost structures. However, the entire issue of energy production becomes irrelevant if an alternative strategy: reducing stocking rates - is also considered.

In essence, once a constraint is identified, EEM LP will calculate the least cost method of addressing that constraint subject to an overall objective of profit maximisation - and in doing so will 'de-clutter' the analysis by seamlessly eliminating a myriad of inferior outcomes.

The analytical power of EEM LP becomes apparent when one considers the use of benchmarks within the dairy industry. The rationale for benchmarks is simple: given an inability to maximise numerous variables subject to one or multiple constraints on a 'farm by farm' basis, the simplifying assumption is made that farms are, on the whole, homogenous in nature (and can be represented by synthetic data).

They are not of course homogenous but this assumption is critical for most models as it permits the application of simple benchmarks (e.g. comparative analysis such as kgMS/HA, kgMS/cow, cows/HA, milk production targets, per cow production targets, production at X percentile etc.) that are - at best - irrelevant (as they do not provide the information farmers require to make informed decisions) and - at worst - misleading or erroneous (as the averaging processes masks useful farm specific information).

In comparison, EEM LP can analyse a farm 'as is' to provide a base case from which alternative strategies can be considered.

For example, in the original analyses of the synthetic material provided for each farm, Run 1 is the base and may be followed by the standardised application of existing industry 'wisdom'. This is essentially a standard template approach to farming where stock numbers are held constant and an energy deficit that was previously filled by the application of N is substituted via the purchase of BiF ("Bought in Feed").

This approach will invariably lead to a significant decrease in farm profitability compared to the base case, as it assumes that every cow removed from such analyses under current farm models, will be at a cost. From a public policy perspective, this implies that N abatement cannot be achieved without imposing significant economic harm on farmers.

In comparison, with the EEM LP, the templated prescription is progressively abandoned, and other resource options are considered (i.e. grazing off, reducing feed inputs which reduces stock numbers, altering replacement rates - which also impacts by improving per cow production and therefore both feed and economic efficiencies, optimising stock numbers) - albeit within the overall objective of profit maximisation.

Efficient resource re-allocation via EEM LP not only significantly reduces N leaching (more so than the industry solutions), but results in an ***increase in profitability*** compared to the base case. However, there is a warning here: each farm has an N 'tipping point' after which further reductions can make the farm in question economically infeasible.

The public policy implications of these findings are also stark: compared to status quo it is possible for almost all dairy farmers to make substantial reductions in N leaching at little or no economic cost - indeed, in most cases, farmers would be better off.

However, for such "win/win" outcomes to occur each farmer needs to know what the specific combination of changes necessary are to profit maximise.

Moreover, in the absence of such knowledge policy makers run the risk of:

- Imposing significant - and unnecessary - economic harm on farmers
- 'Locking in' the status quo e.g. allocations which provide a 'license to pollute' whilst at the same time penalising efficient farmers who would get comparatively smaller allocations.

Some may find it "counterintuitive" or more bluntly "wrong" that the model can waste so much feed (up to 300,000 kgDM or 15%) and reduce herd number by 22% before the new $surplus falls below the current farm. What must be understood is that many of the Base farm inputs are actually *losing* money, this has been explained previously with regard to MC vs. MR of inputs vs outputs. With MS price at $6.40 and the cheapest current input costing 28 cents/ kg of wet weight (which by the time they are stored, transported, fed out, utilised and adjusted to MJME equivalent pasture are costing about 45 cents/kg utilised DM Refer Appendix 3 for full explanation of calculation) such bought in feeds (BiF) are fed at a marginal cost greater than the returns from that cow MC>MR).

However, all this does not alter the Overseer® N leach readings as shown in the Tables Farm 1 where only 1 kg N leach/ha reduction has occurred despite a 22% drop in herd size and feed eaten.

Any soil appears to reach a "basement level" of N leach and despite less feed being consumed, the cost of reducing N leach will increase at an increasing rate.

With the highly leachable soil chosen for the synthetic farm options the marginal cost per kgN abated can reach as high as $934 /kgN leach /ha. (Runs 4 and Run 10 on Farm 1) **yet only $155/kgN leach /ha for the same decrease in N leach** (25 kgN to 24 kgN leach) for a differing use of resources (Run 6 and Run 7 on Farm 1)

This illustrates the problem of imposing low N leaching caps without identifying what the *marginal impact* on a specific farm will be.

Current industry models cannot distinguish least cost marginal abatement strategies.

OVERSEER®

The Overseer® nutrient budgets program is a decision support model to help users develop nutrient budgets (Wheeler et al., 2003). A nutrient budget is a table of inputs and outputs of a nutrient, into and from a particular physical identity (AgResearch., MPI., & FANZ., 2013). It calculates a nutrient budget for a farm and for management blocks within the farm, taking into account inputs and outputs and internal cycling of nutrients around the farm (Figure 4) (Cichota & Snow, 2009; Wheeler et al., 2003; Wheeler, Ledgard, Monaghan, McDowell, & De Klein, 2006).

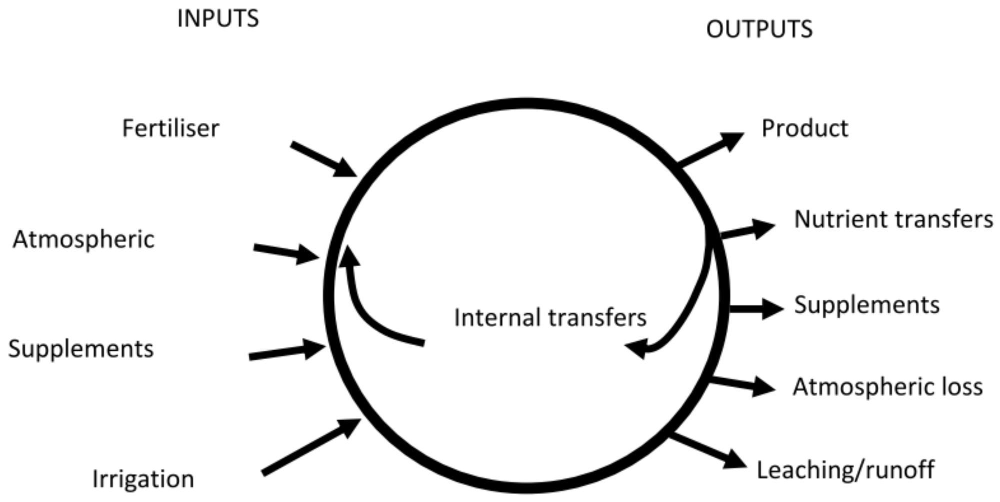


Figure 4: A diagrammatic example of a nutrient budget (AgResearch. et al., 2013).

Overseer® ground rules

When the model is used as a component in developing nutrient management plans, an understanding of the model is helpful. Like all models, the quality of the input data is important. The Overseer® model requires actual farm data, as assumptions are made about farm efficiency. The main assumptions (Table 2) underpinning the model are that: it uses long-term annual averages, i.e. the model assumes a "steady state"; the system is in quasi-equilibrium (inputs commensurate with production levels on the farm); users supply actual and reasonable inputs; and management practice implemented on the farm follows good practice (Shepherd, Wheeler, Selbie, Buckthought, & Freeman, 2013). This is done to reduce the number of inputs, and to use data that most users have or where suitable defaults are available. For example, the model uses estimates of farm productivity to calculate animal intake, rather than estimates of pasture production, utilisation, and grazing management. Using this model structure does have implications when using the model to look at mitigation options (Wheeler, Ledgard, & Monaghan, 2007).

Table 2: The key assumptions used in Overseer® are: (Wheeler & Shepard, 2013, p. 4)

Assumption	Notes
Quasi-equilibrium	The model assumes that inputs and farm management practices described are in quasi-equilibrium with the farm productivity.
Long-term average	For a given farm system, the nutrient budget estimates the long-term annual average outputs if the management system described remained in place.
Actual and reasonable inputs	The model assumes that inputs including animal productivity are correct. There is no checking on whether an inputted farm system is practicable, possible or viable.
Mitigations	The quasi-equilibrium and actual and reasonable assumptions means that any management changes or mitigation changes must also include changes in animal productivity
Management practices	Assumes 'good management practices' have been implemented on the farm

The model assumes that Good Management Practices (GMP) are followed, especially for storage and application of effluent, fertiliser, and irrigation. Under GMP, there are a number of practices that farmers could adopt to improve water quality. For example, if fertiliser or effluent are applied, Overseer® assumes the stated rate is applied evenly at the time stated i.e., there is no 'poor management' that would result in 'large' discharges. GMP reflects complying with supplier regulations and local government law, such as those in the Fertiliser Code of Practice, Best Management Practices (BMP) and Regional Council guidelines on effluent management (Everest, 2013; Park, 2014; Paterson, Brocksopp, & van Reenen, 2014; Wheeler & Shepard, 2013). Research has demonstrated that the use of GMP such as deferred irrigation (pond storage during periods of high soil moisture) and low application rate/intensity technology has been effective in decreasing or avoiding the direct losses of Farm Dairy Effluent (FDE) from land application (Everest, 2013; Longhurst, Houlbrooke, & Laurenson, 2013).

It is reasonable to assume that, in the absence of full regulation, the practices adopted will initially be those that have low cost or little impact on farm profitability, or, are those required under supply agreements with processing companies (Bell, Brook, McDonald, Fairgray, & Smith, 2013b).

When these practices are not being followed, the model is likely to underestimate nutrient losses. Thus, in developing plans, a method is required to identify these breeches, and in most cases these should be remedied first as they are usually easiest to do (Wheeler et al., 2007).

The model uses long-term annual average input data and loss predictions. The variation between years in nutrient flows and losses, as affected by climatic variability, are encompassed within the long-term annual average. This reduces the need for specific daily climate data and a large amount of extra detail in the model, which is more appropriate for detailed research models or those used by expert users. In most cases, the user does not need to specify within-year nutrient management information, although some model components account for the effects of timing on management practices (e.g. timing of fertiliser use, animal winter management and fodder crop management). Many of the effects of poor timing of application or placement of fertiliser or effluent are covered by BMP recommendations (Wheeler et al., 2007).

Overseer® Best Practice Data Input Standards

The ground rules listed above are a set of guidelines to assist expert users to define data inputs that consistently achieve the most accurate nutrient budget of a farm for nutrient management purposes. In 2013, the Overseer® owners (Ministry for Primary industry (MPI), Fertiliser Association of New Zealand (FANZ) and AgResearch) brought together a Stakeholders Advisory Group (SAG) to scope out the need for, and requirements of an input user guide. The new input user guide, called "Best Practice Data Input Standards" was finalised in late August 2013 and published on the Overseer® websites in December 2013, since updated April 2014 and the latest November 2016. The purpose of providing a 'Best Practice Data Input Standards' is to reduce inconsistencies between different users when operating Overseer® to model individual farm systems (Roberts & Watkins, 2014).

Verification and validation

Verification is the general process used to decide whether a method in question is capable of producing accurate and reliable data. Validation is an experimental process involving external corroboration by other laboratories (internal or external) or methods or the use of reference materials to evaluate the suitability of methodology. Neither principle addresses the relevance, applicability, usefulness, or legality of an environmental measurement. The reliability and acceptability of environmental analytical measurements depend upon rigorous completion of all the requirements stipulated in a well-de-fined protocol (Keith et al., 1983).

Precision describes the degree to which data generated from replicate or repetitive measurements differ from one another. Statistically this concept is referred to as dispersion. Accuracy refers to the correctness of the data. Unfortunately, in spite of its importance, there is no general agreement as to how accuracy is evaluated. Inaccuracy results from imprecision (random error) and bias (systematic error) in the measurement process, high precision does not imply high accuracy and vice versa. Unless the true value is known, or can be assumed, accuracy cannot be evaluated. Bias can only be estimated from the results of measurements of samples of known composition (Keith et al., 1983).

Overseer® operates at a block level, blocks are set up within the property, usually according to variations in soil type and/or management history of the farm. The primary aim of Overseer® is to calculate a long-term average nutrient balances and nutrient loss estimates at both the block and property level. With this, Overseer® has evolved from a decision support system designed for on-farm fertiliser and nutrient management advice to a tool being used to implement regional policy and regulations in relation to nutrient losses from agriculture. Horizon Regional Council requires the development of a farm environmental plan for the consent process. However, for detailed farm nutrient management and development of management measures, each farm must have constructed a robust individual farm Overseer® nutrient budget model, that must be prepared by or validated by a suitably qualified person. Therefore, all users of Overseer® must appreciate its limitations and must have a good understanding of the uncertainties in Overseer® estimates (GHD, 2009; Stafford & Peyroux, 2013; Williams et al., 2011).

The main inputs that have the most influence on nutrient loss estimates in Overseer® are those that influence the size of source of a nutrient (e.g., stocking rate, fertiliser inputs), and those that influence the transport of a nutrient (e.g., soil, drainage, slope for P). Drainage is a key driver of N (and P) losses and it is therefore important to recognise that this calculation is sensitive to climate inputs, predominately rainfall, potential evapotranspiration, soil characteristics that affect available water capacity such as soil order, texture, sand or stony subsoils, and the depth to those subsoils, and

irrigation rate and method, and (less important) crop cover (Wheeler & Shepard, 2013).
The challenge continually is being able to model the transfer and fate of nutrients around the farm system whilst maintaining a level of user input that is practical and achievable (Shepherd & Wheeler, 2010). Amongst other outputs, Overseer® calculates the long-term annual average N leaching from the management block(s) and the farm. Thus, the model has to respond to the full range of inputs that Overseer® has (e.g. stocking rate, soil type, and rainfall) and it has to be driven by parameters that the user knows, or suitable defaults need to be available (Wheeler, Cichota, Snow, & Shepherd, 2011). Therefore, there are differences between measured and modelled values, for example N leaching, are an expression of the certainty/uncertainty arising from attempting to model complex biological processes with a minimum set of readily available farm data inputs (Williams et al., 2011). Further uncertainty are associated with the accuracy and appropriateness of data inputs, as Overseer® users must have access to good quality farm data that accurately reflect management practices on farm (Williams et al., 2011).
Clear protocols are now available “Best Practice Data Input Standards” to ensure a consistent and fair approach is taken across farm systems. However, setting up a farm system in Overseer® still requires a reasonable amount of interpretation and judgement by the user. The major limitation to improving precision can be potential differences in inputs entered by users. For example, model parameters such as soil properties, weather and/or climatic data always contain errors. Some of these may be “human error” or mistakes, and it is important to minimise this type of error (Shepherd et al., 2013; Wheeler, Shepherd, Freeman, & Selbie, 2014).

When interpreting a model’s predictive abilities, it is important to know whether the model has been calibrated. This is the process of adjusting model parameter values to maximise the agreement between a given set of data and the model outputs (Refsgaard, 2001; Trucano, Swiler, Igusa, Oberkampf, & Pilch, 2006). The next step in the application of a model like Overseer® is to validate the model to provide a method of assessing the confidence that can be had in the modelled outputs (i.e., testing to see how well the model outputs fit a set of data (Jorgensen, 2006)).
It is also important to appreciate that the uncertainty will increase significantly the more a situation moves from the information used to develop and calibrate a model such as Overseer® (Wheeler & Shepard, 2013). This is illustrated in Figure 5.

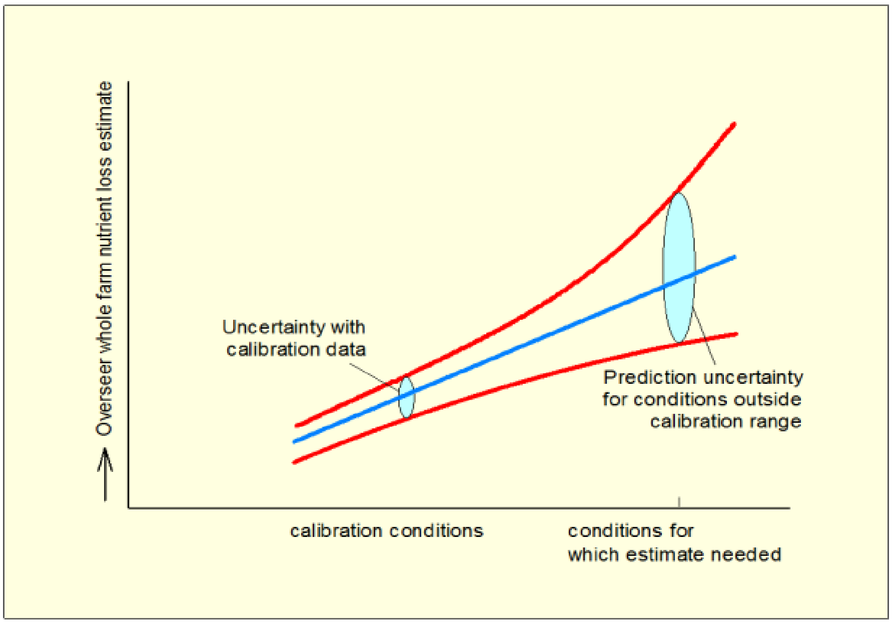


Figure 5: An illustration of the changes to model uncertainty as the conditions move from those used for calibration: based on (Loucks, Van Beek, Stedinger, Dijkman, & Villars, 2005).

Overseer® can only be calibrated and/or validated against measured data where trials have been carried out. Calibrate and/or validate is limited by the range of soils, climates and time to undertake these field trials, it would be extremely resource intensive to test all combinations of soils, climate and regional variation. For instance, no N leaching trials have been undertaken in Northland, on peat soils or under high rainfall (>1200mm /yr) (Wheeler & Shepard, 2013). More data for calibration/validation data will be required to decrease any uncertainty, most notably for, clay and shallow and light textured soil types; and locations with high (>1200 mm) rainfall (Shepherd et al., 2013).

Policy makers should consider the accuracy of Overseer® and the uncertainty associated with the inputs and outputs from the model. Placing Overseer® into a policy setting where the outputs are regarded as a fixed and absolute number where legal challenges and experts could be drawn in to discussion over the appropriateness or otherwise of input variables used in any given farm situation (Edmeades, Metherell, Rahn, & Thorburn, 2013).

Soils mapping

The need for reliable soil information to develop farm environmental plan for the Horizon Regional Council consent process has never been greater. There is, however, uncertainty about what soil information is required to meet the needs of both councils and the farming industry – in terms of the appropriate scale and types of soil attribute information required, as well as the information accuracy and uncertainty appropriate to the resolution (scale) of farm management (Carrick, Hainsworth, Lilburne, & Fraser, 2014).

Soil survey in New Zealand from 1938 to 2001 has resulted in a set of soil maps of varying quality at varying scales. By the end of 2001, the whole country was covered by 1:253,440 scale soil maps. In addition, just over 50% of the country is covered by more detailed maps

(with scales ranging from 1:126,720 through to 1:10,000) (Lilburne, Hewitt, & Webb, 2012).

Soil information is available from a range of sources, produced using a variety of methods, and varies in the degree of fitness for purpose. Farm soil maps may be provided at any nominal scale, with no quality indication as regards the accuracy or uncertainty of the mapping. The level of detail needed to resolve the soil pattern in areas with significant risk of leaching or runoff depends upon the nature of soil variability (Carrick et al., 2014). In a highly variable floodplain we would expect significant improvement in the accuracy of leaching and runoff predictions with soil maps at finer scales, with 1:10,000 map scale often suggested as an appropriate standard (Manderson & Palmer, 2006).

Soil maps are often confused with single-attribute mapping; e.g. the use of detailed electromagnetic induction survey to predict soil water holding capacity. Extrapolation of single-attribute maps beyond their original purpose may be inappropriate; e.g. the use of a soil water holding capacity map for farm dairy effluent system design, which is strongly affected by a number of other soil attributes such as soil drainage, infiltration rate, subsoil permeability and bypass flow vulnerability. Likewise, soil survey can be confused with other farm-scale assessment, such as land-use capability (LUC) mapping or farm plan assessment. Soil information is a crucial underpinning component of these assessments, rather than a direct derivative (Carrick et al., 2014).

S-map is the new digital soil spatial database that aims to provide a seamless digital 1:50,000 scale (or better) soil map coverage for New Zealand. S-map has being created as part of the government-funded Spatial Information programme run by Landcare Research (Landcare-Research., 2014). S-map is not just a map but, rather, is an integrated and dynamic soil information system. The S-map system has been designed to accommodate soil data at any scale, and be adaptable to both changing soil science knowledge and end-user needs. Up to now, soil data generation has been funded by regional councils, with priority to meet regional and catchment-level policy needs, and to digitise the historical soil surveys. As a result the resolution of the spatial soil data (soil maps) is mostly 1:50,000 scale, although there are finer-resolution data in some areas (Carrick et al., 2014).

There are a number of key S-map development initiatives at each level of the information system that can support farm-scale mapping. The flexibility of the factsheet generator allows the information provided on the soil factsheets to be customised to meet end-user needs; e.g. the development of a factsheet page for each soil type, with targeted soil information for inputs into Overseer® Nutrient Budget Model (Carrick et al., 2014). The S-map database, due to underlying scale limitations, at a scale of 1:50,000, this resolution may be too coarse to be useful and then there is the lack of on-farm verification, there is still likely to be reliability issues in this database, especially when applied at paddock-scale or sub paddock scale management (Stafford & Peyroux, 2013). Carrick et al., (2014), defines quality for soil mapping, a scale of 1:50,000 is classed as poor quality, while farm-scale soil map at 1:10,000 is of good quality and premium quality if farm-scale soil map can demonstrate high confidence (e.g. ± 10% variance in area of each soil type).

Materials and Methods

The modelling for these farms is based on made up or synthetic data to reflect what a Dairy farm may look like in a sensitive catchment. However, it cannot be assumed that any other farm within a sensitive catchment will exhibit any of these characteristics. A farm will exhibit differences in terms of soils, LUC classification, N-loss limits, management style, resources, infrastructure, land area, climate, herd makeup and many other attributes. This will be demonstrated later in the report.

The “synthetic” farm data used for this work depicted a combination of poor quality pastures (below 10 MJME January to March), highly leachable soils (allophanic brown) in a rainfall of 1100-1280 mm/year and cows with varying milk solids production. We have been in communication with a Soil Pedologist, and was advised that there are over 20 primary soils in the Tararua Region of which not all of the soils on a typical dairy farm can be classed as highly leachable, so unless a farm scale soil map has been completed on each dairy farm, the soil characteristics used on these “synthetic” dairy farms cannot be classed as typical.

The methodology used to address the question of “what opportunity do the sample farms’ have to achieve required N leaching reductions” was one of viewing the value of each input compared to the cost (including any peripheral costs associated with the use of that input; i.e. what is each additional cow costing in terms of feed costs and general expenses associated with that specific cow.) *Marginal Analysis* as described earlier.

Existing industry approaches to N-mitigation provide relatively modest reductions in leaching, albeit at the cost of imposing significant economic harm on farmers. This is completely unnecessary.

The starting point matters - in that most farms are overstocked so are therefore carrying a 'parasitic herd' as the additional cows are requiring above the feed limit defined by the point where MC>MR.

The difference in outcome between industry approaches and the EEM approach is simply that the EEM approach identifies and eliminates the parasitic herd - and therein lies the ability to reduce negative externalities (such as N leaching and GHG emissions) whilst also improving farm profitability. This implies that the marginal cost of abatement is either positive or zero over the initial part of the desired abatement range.

Based on previous case studies of dairy farms provided within the Horizon's region, it is possible for New Zealand dairy farmers to make significant reductions in N leaching at little or no economic cost compared to the status quo.

However, beyond a farm specific point of N leaching constraints, a 'tipping point' can be identified where further N reductions make the farm financially unviable (NB: these findings are entirely consistent with previous GSL and EEM analysis generally).

The soil data presented for the synthetic farms is highly leachable and cannot viably reach the required limits for N reduction limits set by the 20-year period. However, considerable reductions can be achieved rapidly and at little cost in the initial N reduction phase.

Some alterations to combine different farm system changes such as stock type, pastures, pasture management options and “new technologies” (such as “Spikey) may provide some further room to reduce N leach before the more drastic steps of “retiring” areas of land at considerable economic cost are required.

Detailed Points

- All farms could allocate resources more efficiently: but these changes are dependent on the opportunity for marginal increases in efficiency vs. the marginal N leach reduction required.
    - N leach limits create differing levels of constraint that are more dependent on soils and climatic influences than efficiency of resource use.
    - The imposition of set “caps” on farms fails to acknowledge the distinction between efficient and inefficient resource allocation.
    - Overseer® does not appear to reflect potential N leach reductions once a certain “basement” level of N leach reduction has been achieved (about 24 kgN/ha for the scenarios presented). This varies with soil type with highly leachable soils obviously exhibiting this more than lower leaching soils. See discussion page 35.

- There are options for mitigation which will ***reduce N leach and reduce profit*** (i.e. the current industry-based approaches) and others that will ***reduce N leach but improve profit*** (i.e. those identified by previous GSL and EEM analyses based on profit maximisation).
    - Current industry recommendations for reducing N may reduce N leach but also unnecessarily reduce profit (Refer Appendix - Run Data Tables).
    - EEM resource allocation progressively reduces N leaching with least impact on profit.
    - Reducing herd number, improving herd and per animal efficiencies by increasing per animal production, reducing actual lactation days, grazing off, adopting systems that require no additional N fertiliser, no cropping and some move towards alternatives to ryegrass farming and the management requirements that this entails, provide the best options if available and acceptable.
    - Farmer objectives are all important but under the restrictions that will be required for N leach limits, a far more knowledgeable dialogue with farmers and support groups (including the "vested interest" salespeople who drive the agricultural industry) will be an imperative requirement.
    - **Acceptability may not be a factor for these synthetic farm systems as they all have combinations of soil type and rainfall that combine to make dairying unacceptable both financially and environmentally with current costs, prices and N leach caps.**
    -
- Depending on response rate, nitrogen provides the best and cheapest additional feed when applied correctly (date and rate); however, Overseer® penalises nitrogen applications at the times when most economic benefit can be extracted (spring and autumn).

    - On all soil types, as Overseer® approaches a lower limit of N leach, the N leach reduction "curve" flattens.

    - **This can increase the marginal cost of any additional N leach reduction required to a point where the farm system becomes unviable.**

    - This may require a change in stock type or perhaps a "hybrid" system of dairy and beef.

    - Beyond this point, reversion to sheep (buy/sell) and some beef (buy/sell) may be an option.

    - Many intensified farms are less profitable than they appear due to unrecognised non-cash costs (depreciation), maintenance costs associated with intensification (infrastructure and machinery), and costs that are now "fixed variable costs" due to use of new infrastructure (insurance, labour, interest, feeds) i.e. the *additional* costs associated with intensification that are ignored as a part of the intensification process.

- Because of this, no attempt to build capital intensive barns requiring additional machinery and effluent handling facilities was undertaken as an option for these farm systems (Anderson & Ridler, 2017).

- Use of marginal analysis will prevent this level of intensification on the basis of economics but the industry suffers from the fact that averages dominate thinking and averages encourage more production. Knowledge or understanding of marginal analysis is almost non-existent due to the inability for most models to distinguish when to cease adding resources.

- Marginal analysis identifies such intensification as being unprofitable. Gross Margin and cash budgets average costs equally across all production income. The marginal cost associated with specific actions are therefore hidden within all-encompassing accounting "categories".

    - This makes any reliance on Gross Margins, averages, benchmarks and ratios fraught with misinterpretation and leads to erroneous "causal relationships" when used for analysing between systems, mitigating nutrient loads or as a basis for policy decisions.
    - If the concept of marginal analysis was more widely understood both farmers' profits and the environment would benefit.

- Existing debt levels impact by altering the point at which resource use reaches a 'tipping point" with reduced profits. Optimisation techniques provide a means to distinguish how critical each debt level may be for any resource combination. N leaching caps impose an added constraint which supersedes that of maximising profit.

Project Objectives

Service description: Overview

The work is to understand feasibility of nutrient leaching reduction (N-loss), by comparing analyses of 3 "synthetic" farms ("Synthetic" is a term that describes a set of artificial, rather than real, data consisting of specified soils, animal numbers, productions, crop, pasture, (quality and quantity) bought in feeds and use of nitrogen, in an attempt to represent differing farm systems). This follows the agricultural industries propensity to simplify data to use for comparative purposes by way of averages, ratios, Gross Margins and benchmarks. (This approach has already been commented upon [page 8])

These data have been constructed to describe responses to different system changes and changes in assumptions (e.g. basic mitigation techniques such as effluent area and management, use of nitrogen, use of bought in feed, herd number, pasture and crop use, debt, product price scenarios), within the constraints of minimum impacts on:

(a) Farms' profitability, and
(b) Farm production

What opportunity do the sample farms have, to achieve N leaching reductions?
More specifically: modelling of 3 synthetic farm study examples.
Objective 1.0 –Initialise and optimise each farm to illustrate the marginal and overall response to progressive decreases in nitrate leaching values.

> Based on the knowledge gained from the initial runs, the contractor will modify the underlying assumptions in order to test the sensitivity of results to various assumptions.

Objective 1.1 – sensitivity testing around the optimum. The contractor will also test a range of costs and milk solids prices for a range of scenarios to provide an understanding of what remains achievable and affordable for farmers under more recent dairy price scenarios.

> This will provide additional insight into the impact of constraining N leach under differing product price and cost scenarios.
>
> The impact of debt on such scenarios will also be explored in order to better describe the impact the required N leach reductions will have on final farm profit.

Analysis

To investigate ways to reduce N loss whilst retaining profitability.

The relevant Farm details are contained within the following Tables.
The base farm data, as supplied, has been used to construct the farm within the Enviro-Economic Model (EEM) structure. (This is an enhanced version of the previously used GSL model.)
Although some financial data provided contained basic errors, **the farm systems analyses, and base resources remain relevant between EEM runs for all 3 farms.**
Each Table provides not only a number of related resource use options but also provides a structured farm implementation strategy that can be understood by scanning across rows and down columns.

NOTE: All data balances. Marginal changes can be tracked to provide the changes in the resource use that have been selected by the EE model to provide a “best fit” between economic results and the environmental constraints imposed (decreasing N leach). These changes track across rows of the Tables to provide all the data needed to understand the changes made and the impact these have had to final $surplus.

The process by which the model alters resource use should therefore be transparent. The emphasis is *NOT* to “reduce cows” (as some commentator’s state) but to remove inputs that have MC>MR. When these are removed (mostly the BiF) cow number is reduced as a *consequence* rather being the *driver* of N leaching reduction. So the key difference provided by the EEM is that of quantitatively assessing the marginal value of each resource rather than guesstimating how Overseer® will react to various policies.

The Table figures therefore provide a guide as to the least cost means to reduce N leach as they illustrate the effect each marginal change in resources has on the $surplus figure. This $surplus is comparable between each “Run” or optional resource use applied.

“$surplus” is not strictly a “Gross Margin” (GM) as in calculating the figure, the model has selected resources where the MC/MR provides the best result possible and has therefore rejected the least profitable options as part of this same process.

This is a more refined approach than using averaged gross figures for each resource category, altering the resource mix in a specified manner then comparing that financial result (GM) with the previous figure (GM) to see if it is a better answer.

Using LP as the final analysis system in the Enviro-Economic Model (see page 10) provides the ability for many economic vs environmental iterations between and across all resource possibilities that refine a single comparative “Gross Margin” to a more precise “$surplus” figure.

This then precludes the need to apply mitigations in any prescribed “order”.

Although:

Riparian planting.

Remove all winter cropping.

Remove winter applications of nitrogen (they are normally unprofitable anyway due to low responses and high N leaching that occurs when N is not used by the plants).

Remove nitrogen applications from effluent area.

Extend effluent area and improve spreading system.

Winter cows off farm, are all obvious first steps to reduce N leach.

Some of these are improve the economic viability of the constrained system and the EEM will select them primarily for that reason.

This emphasises again that there are “win/win” options on all farms and why $surplus can be improved as N leach is constrained on all these 3 farms.

All the Runs are based on the same resources but with constraints either being removed (for optimisation) or applied (for N leaching reductions).

Each column and row can be mathematically linked to the Base farm data and farm system through the relationships (animals and feeds) associated with resource allocation. By comparing between Columns and Rows, the extent and type of resource changes can be accurately tracked to provide validation for each change.

Each farm is different and optional computer model runs have been completed on these resource-linked synthetic farm systems to analyse various management options. For each Farm, run “Base” uses data for each individual farm as supplied in files provided by Horizons Regional Council. These did include estimations of pasture growth, quality and utilisation data and response rates of kg DM grown per kg N applied to ALL nitrogen applications at ALL periods applied.

The EE model process generates data from equations used within the model, all of which require to be balanced (the “orientation phase” where poor data matches, incorrect data or poor systems construction can also be detected).
This orientation phase differs from other models used in Agriculture where incorrect data and system imbalances can remain undetected until actual farm implementation is attempted.
It should also be noted that EEM works on a 2 weekly time periods which eliminates the errors such as timeliness of feeds or crops which can occur with longer periods

Farm 1. Farm description

Climate data

The case study farm is situated approximately 70 km from the coast. The mean rainfall is 1271 mm per annum with a mean temperature of 12.4°C with potential evapotranspiration (PET) of 882 mm per annum and PET seasonal variation of low.

Land and production

The milking platform is 200 ha. The herd is predominantly Friesian Jersey Cross with an average weight of 450 kg, at peak 460 cows are milked producing approximately 144,883 kg MS each year, equating to 315 kg MS/cow or 724 kg MS/ha, stocking rate is 2.3 cows/ha. In winter the herd is removed from the farm for eight weeks during June and July with all excess stock and replacement grazed off farm.

Soil resources

The farm has two different soil types Table 3, with three LUC classification. Its purpose is for determining farm scale soil and the LUC resources for calculating nitrogen loss limits. The farm has not been mapped by a trained Soil Pedologist and there is limited soil data available around the location of this farm.

Table 3: Soil types and area Farm 1

LUC	No.				Whole farm
Class	Block	Type	Soil		Area (ha)
LUC Class III	1	Effluent	Dannevirke	Flat	30
LUC Class III	2	Milking Platform	Dannevirke	Flat	100
LUC Class II	3	Milking Platform	Dannevirke	Flat	40
LUC Class IV	4	Milking Platform	Matamau	Rolling	30
					0
Totals					**200**

The permissible N-loss limits were calculated using Table 4, results show year one permissible N-Loss limits of 23 kg N/ha/year through to, year twenty at 17 kg N/ha/year.

Table 4: Permissible N-Loss limits for Dairy Unit for Farm 1

Land Use Capability	Table 14.2 N Leaching Limites (KgN/ha)				LUC Area (Ha)		
(LCU)	Year 1	Year5	Year 10	Year 20	Platform	Run-Off	Totals
LUC Class I	30	27	26	25	0	0	0
LUC Class II	27	25	22	21	30	0	30
LUC Class III	24	21	19	18	117.5	0	117.5
LUC Class IV	18	16	14	13	52.5	0	52.5
LUC Class V	16	13	13	12	0	0	0
LUC Class VI	15	10	10	10	0	0	0
LUC Class VII	8	6	6	6	0	0	0
LUC Class VIII	2	2	2	2	0	0	0
Farm Area (Ha)					200	0	200
Farm Leaching Tarkets (KgN/ha	**23**	**20**	**18**	**17**			

Results

Whole farm modelling approach

Introduction

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 decision-making tool EEM LP has been chosen as the whole farm model. The main reason for using the optimising model EEM LP was the potential to maximize profit by determining optimal resource allocation using constraints and then perform as many snap shots as required to compare and contrast the differences in performance economically and environmentally (See Tables Farm Run Data pages 67-72).

Farm operating surplus ($surplus) 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 are converted into a per cow cost while resources that influenced the optimisation are independently allocated as per unit increment when required, 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 are as per Farmax file. Taxation, capital items and loan (principle and interest) are not included in this analysis.

The model comprises a feed supply and a feed requirement component, with feed management activities linking energy supply and consumption. The year is divided into 26 periods, allowing management decisions to be made every 2 weeks.

EEM Scenarios Explained

Run 1

Base farm. All figures may not exactly equate due to probable variations in MJME for bought in feeds, utilisations and 2 weekly data (EEM) vs monthly data.

[NOTE: the issue of MJME is important. It is not accurately known for any feeds at the time they are fed but plays an important part in relative contribution to MC/MR calculations and when intake limits are reaching constraint points. EEM contains all MJME data (and $ cost/kgDM which of course calculates through to $/ MJME within the EEM) as a best estimate for every food source able to be substituted or rejected within the marginal analysis process. This means that comparisons between various models for feed grown or consumed will be influenced by specific MJME data.]

Run 2:

The following steps are taken in conjunction with Run 2 onwards as the logical first adjustments for any farm dairy system requiring immediate reductions in N leaching:

Riparian planting

Remove any winter cropping (none for SC farm but summer turnip increased by EEM to 10 ha. Time to sow and re-sow altered from 15 Oct to 30 May to 15 Oct to March 30 (to ensure no bare winter ground and also to provide more quality feed for cows IF pasture MJME drops as low as 9.7 MJME/kgDM as stated in Parminter model)

Remove all winter applications of nitrogen.

Model applies only 15 kgN/ha August 10th. (This is an optimisation feature when the model N use (time and amount) is no longer constrained and provides a “best fit” economic use of N rather than a guess as to what N to use and when.)

Remove nitrogen applications from effluent area.

Model applies no autumn nitrogen (Economic solution but also Environmentally sound).

Model finds it break-even profitable to graze all R 2yr heifers and cows OFF FARM ($13.50 and $24 per week + transport costs. Again, a model decision based on MC/MR but also *environmentally* sound. In later runs when the equivalent N leach constraints are applied in EEM, the model is forced to reject use of N even when it may be *economic* to do so.)
Extend effluent area (30 ha of the 200ha. total) and improve spreading system.

Run 2 therefore incorporates some of the more appropriate N leaching mitigation protocols that have been suggested by industry.
But also included for Run 2 is the ability of the EEM to adjust herd number and inputs to better fit the reductions in feed grown with less nitrogen application.
This results in the many small alterations to the farm system as shown in the appendix Table 12 page 67 comparing Run 1 with Run 2.
Total N use reduces.
Crop area increases to 10 ha. (to improve overall energy available for the months of January, February and March when pastures have poor MJME/kgDM levels).
Herd number decreases from 460 (275 for 120 ha adjusted for 200ha) to 450 cows.
No bought in hay. (This is expensive and lower MJME/kgDM)
Costs reduce (less cows and associated costs, less rearing and grazing costs, no hay bought and fed so reduced machinery and time, less nitrogen bought and applied).
Milksolids production decreases but as per cow production is low at 316kgMS/cow, the decrease in costs associated with those additional cows ensures the associated changes in marginal cost vs. marginal return (MC vs. MR) provides higher $surplus.
A “win/win” as N leach decreases as well.

Run 3:

No cropping. This required an increase in MJME of pasture through January, February and March as noted above to ensure cows retained condition and milked as expected. These revised (or higher) MJME figures would seem appropriate for a dairy farm with the PGR figures and rainfall supplied over this period of the year.
Nitrogen applications ceased.
Herd number again reduced which again reduces costs

Run 4:

Lower herd numbers (now reduced to 430 cows) means a reduction in replacement rate with better young stock growth and performance (in-calf rate and 1st lactation production per animal) can be achieved.
The model is adjusted for a better LW for all stock in terms of higher body condition score.
This also provides a more mature herd profile with fewer younger compared to mature cows and even without increasing mature cow MS, overall average production of the herd increases. (Ridler & Anderson, 2014*b*)
The calving date remains at 10 August and dry off date is again April 30th.
Although Overseer® does not reduce N leach, profit increases due to the better efficiencies of feed produced and converted to milk (fewer young stock reared and grazed, higher production per cow reducing the influence of fixed costs per kgMS produced.)

Run 5, 6, 7.

These runs use the higher MS cows but the EEM is used to constrain feed and crude protein use to reduce N leach as derived by Overseer®.

The higher production per cow and reduced costs of less cows allows for a measured decline in $surplus but all the pasture being grown can no longer be used.

As this situation is likely across the Region (and perhaps in neighbouring regions such as HBRC) no profitable market for this feed may be available in the short term.

A comment has been requested about how Run 13 was achieved.

The steps taken by the EEM are in Table 13 and have been defined in explanations above.

It should be noted that all Runs are related (and are consistent between the different systems adapted for Farms 1-3. All have similar soils, pasture quality, quantity cow weights and replacement rates, with only per cow production and some systems changes occurring).

Runs 1 to 7 are explained above.

Runs 8 and 9 investigate any Overseer change for a bull substitution for milking cows. In this case Overseer actually increased N leach despite less crude protein being eaten

From these runs onwards, there are no opportunities left to reduce feeds where MC>MR.

Thus feed (crude protein) and cows must now be removed where MC<MR or where MR>MC and this of course reduces $surplus.

This means the only option left to decrease N leach is to reduce feed eaten with a concomitant decrease in cow number and $surplus.

Despite these reductions in crude protein (as explained in another comment) Overseer reduces N leach from 24, 23 ,22 kgN leach per hectare then suddenly in Run 13 reduces to 16 kgN leach/ha.

The amounts of feed not used, feed used, and cows grazed off with resultant N leach figures are all in the Table 13 page 70.

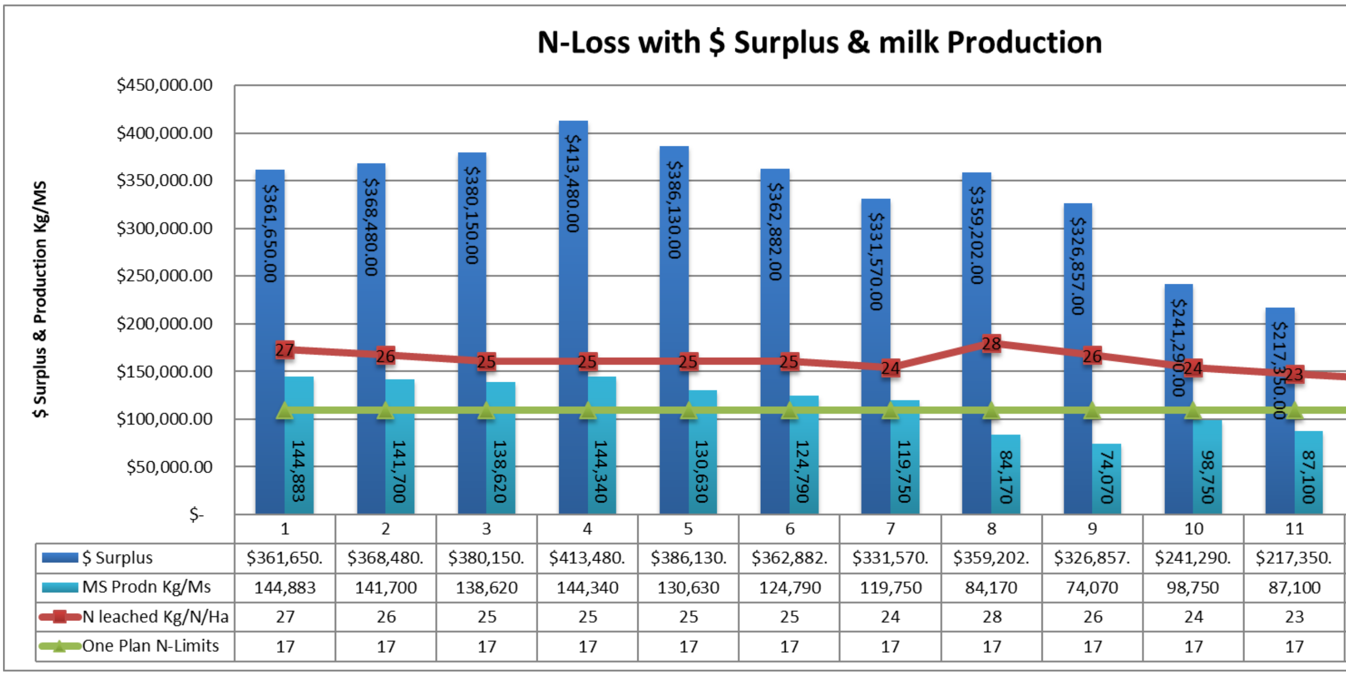
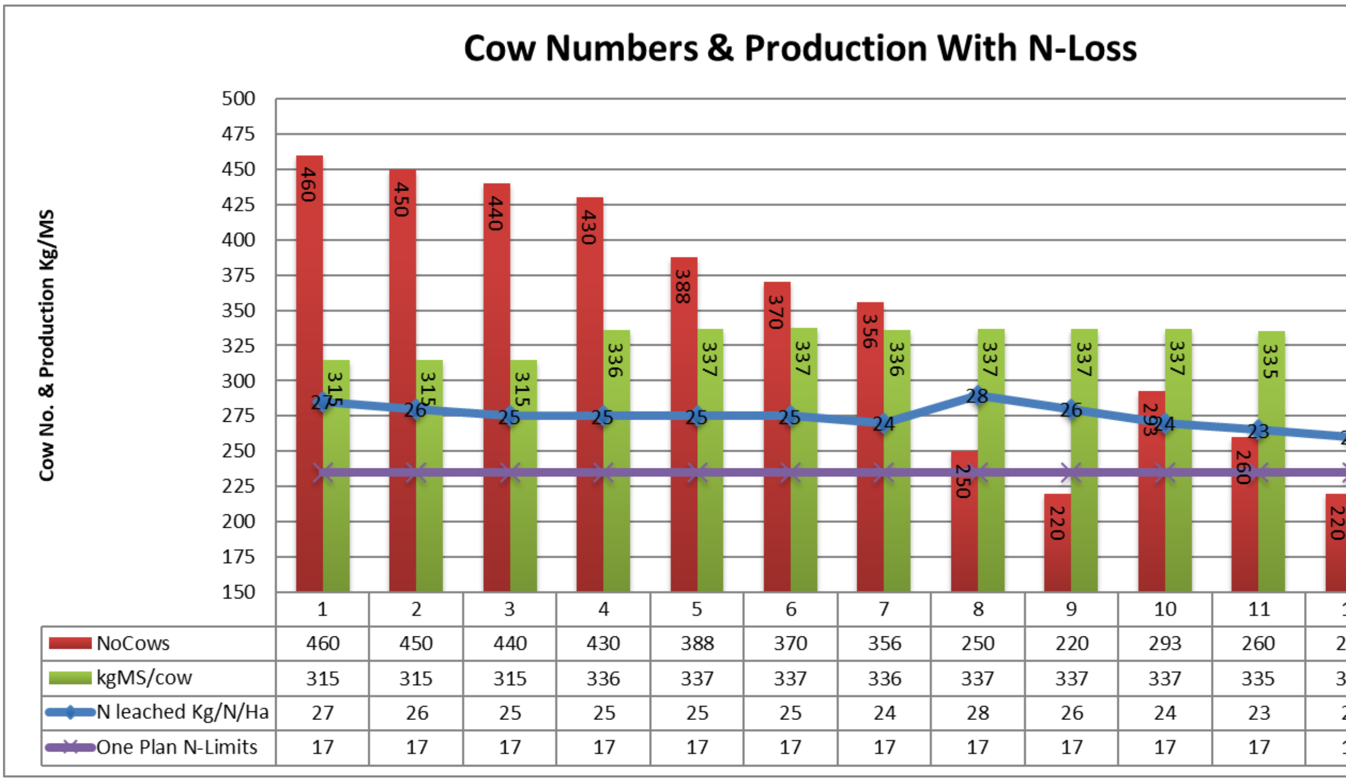


Figure 6: Plotted runs with comparison of N leaching and cash surplus



	1	2	3	4	5	6	7	8	9	10	11
NoCows	460	450	440	430	388	370	356	250	220	293	260
kgMS/cow	315	315	315	336	337	337	336	337	337	337	335
N leached Kg/N/Ha	27	26	25	25	25	25	24	28	26	24	23
One Plan N-Limits	17	17	17	17	17	17	17	17	17	17	17

Figure 7: Plotted runs with comparison of N leaching, cow numbers and production

Summary

The completion of the thirteen runs demonstrated that five out of thirteen runs provided a higher surplus and lower N-loss across the whole farm, with run four providing the highest surplus of all runs. Due to the type of soils selected for this synthetic farm it was impossible to maintain the same level of $ surplus as the original base run (For full Farm run data refer to Appendix under Farms pages 67 and 68).

$Surplus increased by +$51,830 for the first 2 kgN/ha leached but despite reductions in all inputs and herd numbers, Overseer® did not reduce N leach further until Run 7 when $surplus was less than Base (-$29,880). Trying to reduce N leach further was difficult as it had reached the point described earlier as “basement level” where the Overseer® program resists N leach reduction.

The next kgN reduction was Run 11 (-$144,480 from Base) then Run 12 (-$186,843 from Base) yet Overseer® then reduced N leach from 22kgN /ha to 16 (-$193,040 from Base) for Run 13.

So, cost per kgN abatement varies from +$130 kgN leach /ha to -$150; -$722; -$934 then -$965 if individually *averaged* comparing Base to a specific Run.

Cost per *additional* N leach/ha varied by +$260; -$150; -$722; -$934 then -$161 kg N/ha leach abatement for Run 13 due to a sudden (and unexpected) 6 kgN/ha decrease in N leach.

(The same marginal vs. average calculations can be analysed for each of the farms.)
This shows that there is NO average cost of N abatement and that depending on the resources and efficiencies of use, there is NO average curvilinear line that will describe N abatement costs.
Refer to Appendix Table 12 & Table 13 Runs Base 1 to Run 13 pages 67 and 68.
Herd number in Run 1 was 460 cows producing at 315 MS/cow and total 144,883 kgMS.
To reduce the N leach the EEM has been successively constrained for the output of an N leach equivalent designated as N excreted. You will note the Overseer® N leach follows a similar progressive decline until N leach of about 24/25. (Overseer® is not accurate enough to really distinguish between N leach at this level.)
But then despite reducing herd numbers in steps from 460 down to 293 cows (Run 10 with all the associated decreases in pasture (crude protein) eaten (Base Farm total eaten 1,991,000 kgDM @ 10.5 MJME adjusted equivalent; Run 10 eaten 1,392,400 kgDM) Overseer® N leach remains at 24. This means that the synthetic data chosen (main influence is soil) for this farm has extremely high leaching characteristics.
The model was therefore constrained further (despite Run 10 "discarding" 600,000 kgDM i.e. not able to use for stock feed on this farm) **and in Run 13, herd number had been more than halved to only 200 cows producing at 334 kgMS/cow.**
It is important to note the per cow production in any calculation of this type.
Although a cow producing 334kgMS/cow will eat more than a 316kgMS/cow the kgDM consumed/kgMS declines and so should N leach/kgMS produced.
By Run 13 with only 200 cows, N leach is just below that required and from the Table it can be seen by looking across the Run rows, when and by how much herd number, N use (0 for this run); BiF (bought in feeds), cropping, supplements made are all reduced. However, due to these reductions, less of the feed grown can now be eaten ("Discard" row) and by Run 13, 1,130,000 kgDM cannot be used.
It may seem perverse that the EEM grazes cows OFF farm in Run 13 when so much feed is wasted. But this is where the Environmental influence on the EEM (output constraint) takes precedence over the Economics as **N leach is now the dominant influence** (and has been since Run 4/5 when the $profit began to fall.)
So, all the information to track what has happened and when is contained in the Tables. From this data it should be possible to "connect the dots" as to why each Run differs.

Discussion – Farm 1

Changes from the original farm system

This was originally a "Self-Contained Dairy Farm" (SC) of 120 hectares.

To allow some comparisons between each of the "synthetic" farms, which will all be constrained to similar levels as N leach constraints apply, all data for this farm were increased as if it were 200 ha milking 460 cows vs. 120 ha milking 275 cows. This required an increase of the original figures.

The data in the Profit and Loss account provided for SC has been entered incorrectly in the document provided. It seems a "cut and paste" error was made. This was corrected after some investigation.

Per cow production within the EE model was slightly higher than original data as were sales from livestock. This increased Total Revenue by about 4.5% compared to the Parminter model.

Specific costs such as grazing charges, feed out costs and application costs for nitrogen were not specified. However, the costs used within the EE model were within 1% of the total costs for the Parminter data.

The data supplied for pasture quality was very low in the summer months, yet the pasture growth data remained reasonable. The MJME/kgDM were adjusted upward in Runs 4 onwards. January, February and March increased from 9.9, 9.7 and 9.9 MJME/kgDM to a more likely 10.5, 10.3, 10.5 MJME/kgDM as **management improved**.

- (Refer to page 26 for these but as a **comment has been asked for**, briefly:

  Reducing herd number improves herd and per animal efficiencies provided certain criteria are understood and the reasons for them explained; improve rearing standards (which will reduce need for higher replacement rates which will lead to higher average production per cow in the herd) and overall consistency and level of feeding to ensure higher efficiency of animal production, grazing off, adopting systems that require no additional N fertiliser, no cropping and some move towards alternatives to ryegrass farming and the management requirements that this entails, that of monitoring feed levels and being prepared to harvest and conserve surplus's rather than imposing grazing controls at times of peak milk production. This means that "standards" such as "grazing at 3 leaf stage" no longer apply as this can lead to underfeeding cows. The emphasis should be to monitor, look ahead, understand what your system is, what the important constraints and efficiencies are and how to ensure that occurs.

  Similar recommendations were provided to the Lincoln University Dairy Farm LUDF advisory board in 2010 when the earlier version of the EEM was used to provide their "Precision Farming" management system. This has proved to be highly successful in reducing N leach and improving $surplus as predicted in the full systems report provided to them. Despite many industry critics stating that "farmers should not try this at home", numerous farmers are now adopting these simple recommendations based on EEM analyses to restructure their farm systems by identifying and overcoming simple constraints).

There has been no attempt to "mitigate" N leaching through use of self-containment feed pads or barn structures. If N leach restrictions of 17 kgN/ha are required, such capital investments will reduce the ability of the farm to survive due to added debt and associated running costs. It is therefore not logical to invest heavily in such systems until such options can be shown to be viable in practically reducing N leach to these levels. Although some figures from Overseer® may indicate reductions in N leach of this magnitude may be possible, the complexities of managing combinations of such on/off, cut and carry, slurry and effluent disposal systems with the associated costs that include added interest, depreciation and R&M costs associated with them, is unlikely to prove viable. (Anderson & Ridler, 2017).

Farm 1 *Run Data*

Table 12 and 13 (Appendix) introduces the possibility of using the Enviro-Economic Model LP capability to introduce options of mixed systems which may provide an option as N leach constraints restrict "pure" dairy systems.
Managers are unlikely to want to change systems of farming markedly. Therefore, the change to a dairy/beef mix may be more acceptable than milking sheep or goats, planting forestry or retiring otherwise reasonable contour land.
As these are 'synthetic" farms, the possibility of selecting poorer contour or access land or the lower LUC land areas within the farm boundaries would be another exercise in synthesising options.
Obviously, many real farms have areas where the costs of maintaining poorer performing production opportunities can be weighed against the decrease in overall N leach vs. $surplus retiring them may present. Some may decide selected areas for "retirement" may be advisable.
The EEM was set up to allow inclusion of a bull beef rear, grow, sale (17-18 months 285-295 kg CW at schedule prices of $3.86; $4.35 and $5.10/kg CW. Current price at 10/11/2017 is $5.20/kg CW but expected to ease as demand for grinding beef declines on world markets).

The resulting economic and leaching outcomes are summarised in Farm 1 *Run Data*

Table 12/13 Runs 8 and 9 (Appendix).
These include inputs required to produce an N leach figure from the Overseer® program. There was again a disappointing response from Overseer® with an increase in N leach (+4 N leach to 28 kgN) despite consuming almost the same kgDM as Run 8.

Overseer® input notes:
This farm is an increase in size from 120ha to 200 ha. All other data have been increased in equal proportions. Blocks in the Overseer® file should be increased in a like manner. **This then provides comparable figures between all 3 synthetic farms**.

Effluent areas received NO nitrogen after Base.
Run 2: 170ha received 1 x 15 kg urea/ha August

No urea all subsequent Runs from 3 to 7.
Effluent area increased to Overseer® specs after Run 2.
Crop was used and re-sown earlier (March 1 – 20th)
NO crop after Run 2.
Herd calving altered to 10 August and dry by 30 March.
Herd LW increased to reflect better CS that enables higher peak milk and shorter lactation.
Option of OAD milking from November onwards for Runs 5, 6, and 7.

Some points regarding calculations for this farm:

As the pasture MJME was very low (3 months under 10 MJME/kgDM) the cow intake limits for the cows were adjusted upwards (more because of the smaller younger animals which were also under energy limitations of 10.4 MJME/kgDM from beginning of November) to allow animals to eat sufficient for the required MS production, travel and LWG loss. At 9.7 MJME/kgDM, intake limits are reported in literature to be < 3%.
When the turnip crop was removed (Run 3 onwards) quality feed for the herd became a major issue over this 3-month period.
Therefore, the lactation curve was altered to once a day when turnips were removed otherwise intake limits would have needed to be raised to impractical levels.

MJME/kgDM pasture for the "bull" runs were increased on the basis that pasture qualities were improved due to more flexible grazing management options. If Overseer® is working only on kgDM, the extra energy may appear as extra pasture. PGR were not altered.
In past work looking at bulls replacing proportion of herd (Rachel Mudge and Alison Dewes) Overseer® *decreased* N leach when bulls were introduced. This makes sense as the bulls are lower LW / intake in winter and are gone before April in second year.

The bulls were on farm at 86kgLW 2 November and except for one run were sold 22 March at 542 kgLW / 287kgCW average. Also, as MJME increases in pasture, less "kgDM" are required to produce product of course. This extra MJME may be associated with small increases in CP%.
The LWG profile of the bulls was varied a little for pasture quality but was an efficient system which helps reduce MJME /kgCW.

Farm 2 - Low Intensity 200 ha dairy farm.

Farm description

Climate data

The case study farm is situated approximately 70 km from the coast. The mean rainfall is 1271 mm per annum with a mean temperature of 12.4°C with potential evapotranspiration (PET) of 882 mm per annum and PET seasonal variation of low.

Land and production

The milking platform is 150 ha with a run-off of 50 ha. The herd is prominently Friesian Cross with an average weight of 439 kg, at peak 403 cows are milked producing approximately 144,230 kg MS each year, equating to 358 kg MS/cow or 721 kg MS/ha, stocking rate is 2.02 cows/ha. In winter the herd is removed from the farm for eight weeks during June and July with all excess stock and replacement grazed off farm.

Soil resources

The farm has three different soil types Table 5, with three LUC classification. Its purpose is for determining farm scale soil and the LUC resources for calculating nitrogen loss limits. The farm has not been mapped by a trained Soil Pedologist and there is limited soil data available around the location of this farm.

Table 5: Soil types and area Farm 2

LUC	No.				Whole farm
Class	Block	Type	Soil		Area (ha)
LUC Class III	1	Effluent	Dannevirke	Flat	50
LUC Class III	2	Milking Platform	Dannevirke	Flat	47.5
LUC Class II	3	Milking Platform	Dannevirke	Flat	30
LUC Class IV	4	Milking Platform	Matamau	Rolling	22.5
LUC Class III	5	Run Off	Kopua	Flat	20
LUC Class VI	6	Run Off	Matamau	Rolling	30
					0
					0
Totals					**200**

The permissible N-loss limits were calculated using Table 6, results show year one permissible N-Loss limits of 23 kg N/ha/year through to, year twenty at 17 kg N/ha/year.

Table 6: Permissible N-Loss limits for Dairy Unit for Farm 2

Land Use Capability	Table 14.2 N Leaching Limites (KgN/ha)				LUC Area (Ha)		
(LCU)	Year 1	Year5	Year 10	Year 20	Platform	Run-Off	Totals
LUC Class I	30	27	26	25	0	0	0
LUC Class II	27	25	22	21	30	0	30
LUC Class III	24	21	19	18	117.5	0	117.5
LUC Class IV	18	16	14	13	52.5	0	52.5
LUC Class V	16	13	13	12	0	0	0
LUC Class VI	15	10	10	10	0	0	0
LUC Class VII	8	6	6	6	0	0	0
LUC Class VIII	2	2	2	2	0	0	0
Farm Area (Ha)					200	0	200
Farm Leaching Tarkets (KgN/ha	**23**	**20**	**18**	**17**			

Results

EEM Scenarios Explained

(For discussion on how to understand Table results and link to steps taken to limit N leach refer to page 35 but note that discard increases to 740,000kg DM, herd number therefore drops to 207 cows and $surplus to $189,870. This loss can be reduced if some basic changes to the farm system are implemented as described for Farm 3)

Run 1

Effluent area was taken as 50 ha for nitrogen application.

Nitrogen was spread on whole farm as per synthetic farm. See Table.

Run 2

NO nitrogen applied at all Run 2.

The resulting feed deficit forced the model to purchase the only feed offered in this Run initially, all maize silage at 8% crude protein, 10.3 MJME/kgDM and a cost of 33 cents */kgDM* to illustrate the economic loss this option causes.

This run was to investigate the economic comparison of this option.

The model found this to be infeasible as at the times the maize silage replaced nitrogen boosted pasture at 11.8 MJME/kgDM in early lactation (when the winter crop ground was still not back in full pasture production) and through January/February (when presumably the December nitrogen boost was still occurring). The lower energy available in the maize silage compared to intake limits required means overall energy balances were negative (as per energy requirements of ruminant’s data and DairyNZ information. Also refer to: DairyNZ Feedright booklet page 14).

11 MJME/kgDM feed was therefore required. This was costed at 35 cents/kgDM.

This option of replacing N with lower crude protein feed therefore resulted in less profit, a reduction in N leach figures (due more to no nitrogen being used than the lower CP% of the feed) and higher costs in time and extra use of machinery.

Run 3

Run 3 onwards allowed the EEM to reduce herd number to better match feeds and energy required.
The model increased area of high MJME turnip crop to 12 ha, reduced herd number by about 40 cows (and associated replacements) reduced N use to 15 kgN/ha in December but still retained 40 kgN/ha in autumn to ensure APC retained through winter and early spring.
All summer Crop was used and re-sown earlier (March 1 – 20th).
Herd calving altered to 1 August and dry by 30 March.
All resources altered as per the Table summary for Run 3.

Runs 4

Run 4 constrained the N leach potential output from the EEM. Run 4 is therefore close to optimum herd size but only due to the specific constraints, resources and quantities provided. The N leach constraint for example, means no nitrogen is now used.

Run 5

Run 4 constrained the N leach potential output from the EEM and reduces herd size below economic optimum. 12 ha of summer crop is still grown to ensure energy levels in the diet but the need for winter crop is being phased out as total stock are reduced.

No N Runs 5 and 6.
All stock grazed on "runoff" and some wintered there plus milking area as per plan of synthetic farm.
Note summer crop increased to 12 ha Run 3-5 (more energy) but winter crop reduced.
No crops at all Run 6 due to further N leach restrictions. This sharp decrease in energy available from January to March (no high MJME crop) results in changing the herd from original 403 cows averaging 360 MS/cow to 300 cows going onto OAD end of December and MS dropping to average 334 MS/cow.
This has the dual effect of reducing both the economics and N leach for the farm. As a consequence of this lower stock number, more feed is grown than can be allowed to be eaten (N leach constraint) and this is "discarded".
Discard could be seen as sale off farm or taking some area from pasture into trees. This in itself is not an easy transition to manage as the area of "discard" varies with seasonal feed grown and required.
The EEM treats "discard" as a small cost.

Some other option needs to be investigated and this is done while modelling the 3rd synthetic farm: the "Moderate Intensity Dairy Farm (MI)."
Farm 2 results are demonstrated in Figure 8 & Figure 9.

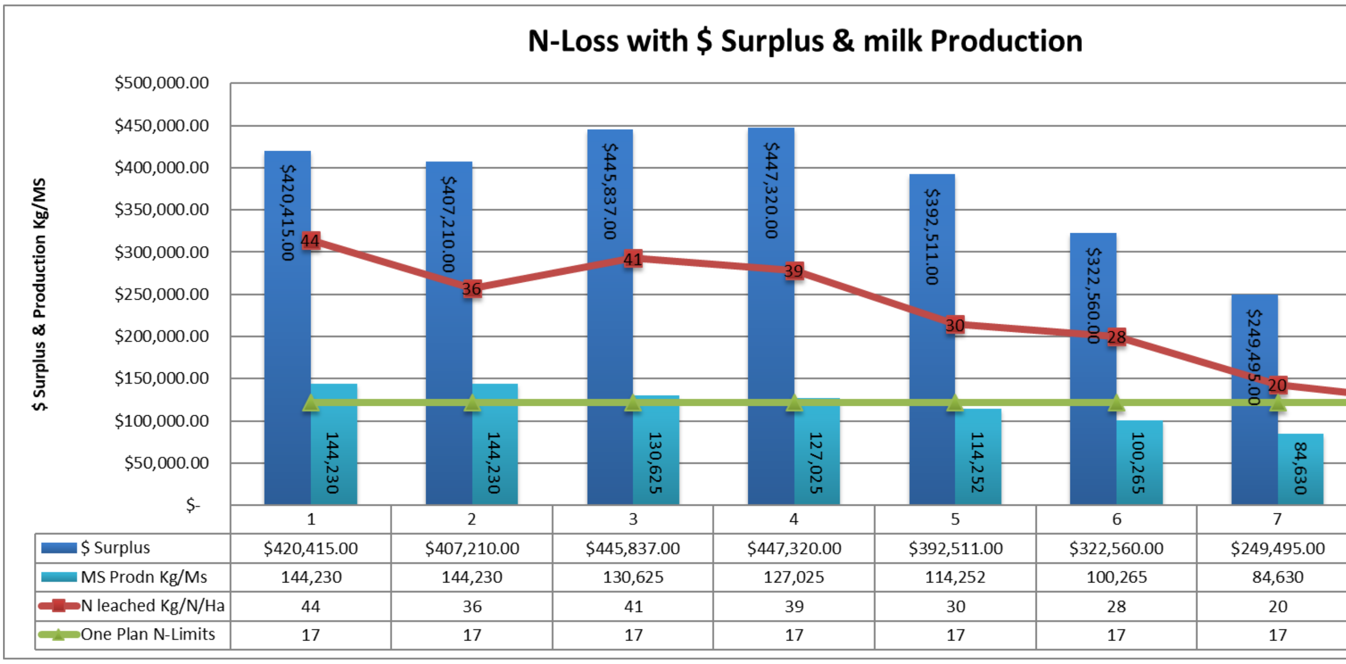


Figure 8: Farm 2 - Plotted runs with comparison of N leaching and cash surplus

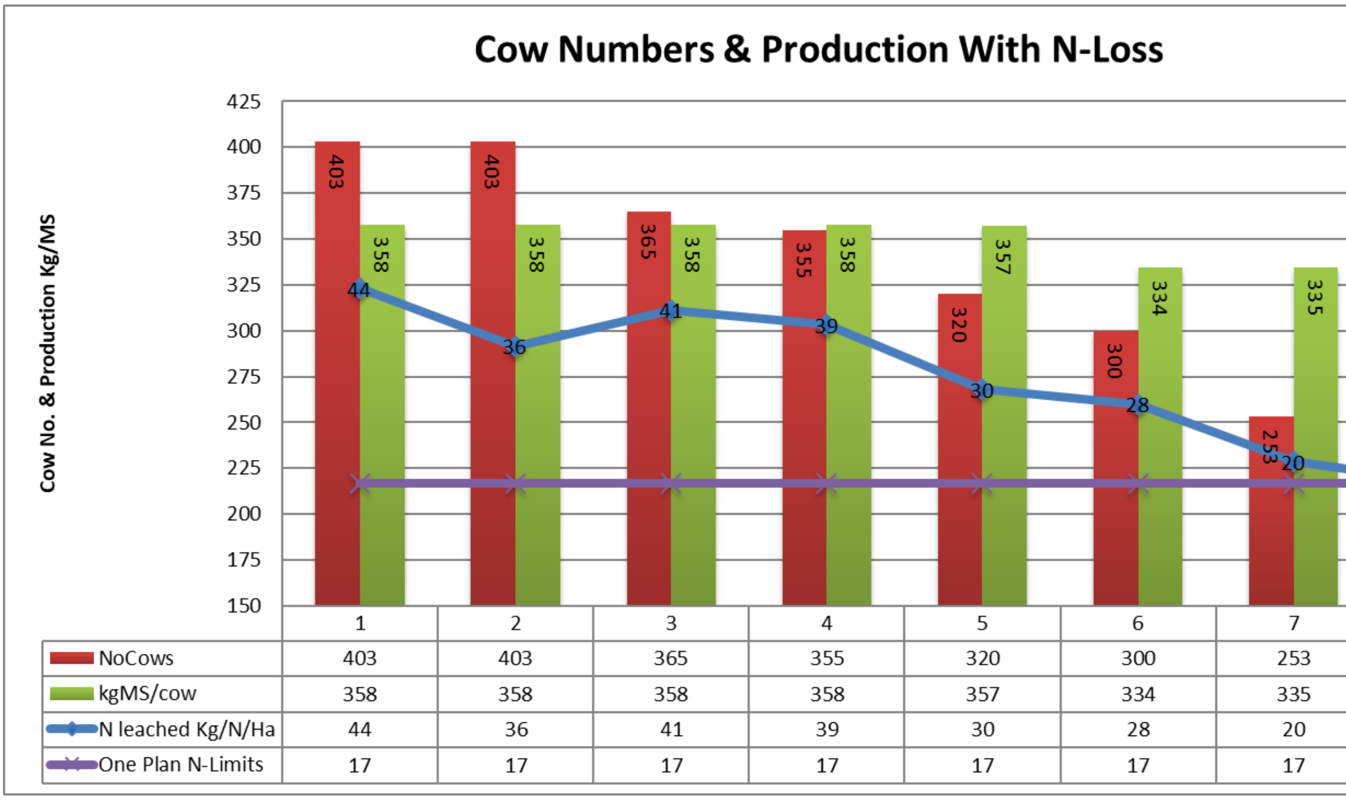


Figure 9: Farm 2 - Plotted runs with comparison of N leaching, cow numbers and production

Summary

The completion of the eight runs demonstrated that two out of eight runs provided a higher surplus and lower N-loss across the whole farm, with run four providing the

highest surplus of all runs. Due to the type of soils selected for this synthetic farm it was impossible to maintain the same level of $ surplus as the original base run.
(For full Farm run data refer to Appendix under Farms).

Discussion – Farm 2

The approach taken in this series of runs was firstly to **adopt some industry protocols in terms of replacing Nitrogen with bought in low protein feeds (maize silage) for Run 2 to illustrate the change to N leach (due mainly to no Nitrogen use) but a decrease in $surplus.**
Then to revert back to allowing the EEM to choose the best enviro vs economic options for N leach abatement.
This again resulted in reducing herd numbers along with all the additional costs associated with fewer cows (although "lumpy inputs of labour, machinery and true fixed costs remained the same.)
Using N at most economically strategic times (response of N at times when feed is required most and MC vs. MR for feeds offered decided by the LP process within the EEM) and allowing the model to decide most economic use of cropping (summer and winter).
Emphasis was therefore more on *economic* outcomes for Runs 3 and 4 (when N leach increased) but reverted to constraining the model to assess reductions of N leach at least cost (Runs 5 and 6).
However, it became difficult to balance energy required to that being offered when the summer crop of turnips was removed in Run 6 (12.0-12.4 MJME/kgDM) and a combination of OAD milking and forced reduction in MS /cow over January to March were required.
Despite the model increasing summer turnip to 12 ha (even with a reduction in herd number Run 3), the need for at least 11 MJME feed was required from Run 2 onwards. This applied to the younger lower LW animals and also depends on distance walked.
Energy required for walking in undulating terrain is between 4 MJME and 5 MJME per km walked. As the synthetic farm has only moderate pasture growth and quality per hectare, this forces longer distances to walk and forage than higher growth rate farms where energy is more "concentrated" both within the pasture and within the farm area being walked.
At this level of feed quality, all these will impose an increasing constraint on possible increases in milk solids production per animal.
These are all an indicator of the very poor-quality feed over the January to March period in the synthetic farm data and the requirements of younger milking animals for some periods of the spring. Yet pasture growth rates remained at a reasonably high level for summer (24-28 kgDM/ha/day) which should also mean higher MJME than those specified (9.7 – 9.9 MJME/kgDM).

Research has shown that intake limits vary from <4% of bodyweight for higher quality feeds (>11.5 MJME/kgDM) to a level of 3.3% or less of bodyweight for feeds at or below 10 MJME/kgDM.

This would indicate that, despite some LW loss and lower MS production from the synthetic herd over this period of low quality pasture, energy requirements for the milking cows will be difficult to meet.

(This issue will be addressed with some optional pastures for the 3rd synthetic farm "Moderate Intensity").

As the EEM had some difficulty matching sufficient energy grown from pasture or bought in with feeds with that energy required for maintenance, walking, production (and lesser requirements for pregnancy), the model altered the amounts and types of feed sources being offered (within the model framework) to best fit each circumstance as increasing N leach constraints were imposed.

Some walking was assumed within the EEM but LW and MS production was close to that of the synthesised farm although the feeds offered varied.

The EEM found some requirement for added energy (mainly for 2 year and 3 year old animals in October when APC was low) in the initial runs. Removing the higher energy turnip crop (as N constraint increased) exacerbated the summer energy deficit.

These are all symptoms of a farm with poor basic "resources" in terms of pasture qualities, species and perhaps management expertise.

Farm 3 - Moderate Intensity Dairy Farm. (MI).

Farm description

Climate data

The case study farm is situated approximately 70 km from the coast. The mean rainfall is 1271 mm per annum with a mean temperature of 12.4°C with potential evapotranspiration (PET) of 882 mm per annum and PET seasonal variation of low.

Land and production

The milking platform is 150 ha with a run-off of 50 ha. The herd is prominently Friesian Cross with an average weight of 439 kg, at peak 480 cows are milked producing approximately 194,220 kg MS each year, equating to 405 kg MS/cow or 971 kg MS/ha, stocking rate is 2.40 cows/ha. In winter the herd is removed from the farm for eight weeks during June and July with all excess stock and replacement grazed off farm.

Soil resources

The farm has three different soil types Table 7, with three LUC classification. Its purpose is for determining farm scale soil and the LUC resources for calculating nitrogen loss limits. The farm has not been mapped by a trained Soil Pedologist and there is limited soil data available around the location of this farm.

Table 7: Soil types and area Farm 3

LUC	No.				Whole farm
Class	Block	Type	Soil		Area (ha)
LUC Class III	1	Effluent	Dannevirke	Flat	40
LUC Class III	2	Milking Platform	Dannevirke	Flat	57.5
LUC Class II	3	Milking Platform	Dannevirke	Flat	30
LUC Class IV	4	Milking Platform	Matamau	Rolling	22.5
LUC Class III	5	Run Off	Kopua	Flat	20
LUC Class VI	6	Run Off	Matamau	Rolling	30
					0
					0
Totals					**200**

The permissible N-loss limits were calculated using Table 8, results show year one permissible N-Loss limits of 23 kg N/ha/year through to, year twenty at 17 kg N/ha/year.

Table 8: Permissible N-Loss limits for Dairy Unit for Farm 3

Land Use Capability	Table 14.2 N Leaching Limites (KgN/ha)				LUC Area (Ha)		
(LCU)	Year 1	Year5	Year 10	Year 20	Platform	Run-Off	Totals
LUC Class I	30	27	26	25	0	0	0
LUC Class II	27	25	22	21	30	0	30
LUC Class III	24	21	19	18	117.5	0	117.5
LUC Class IV	18	16	14	13	52.5	0	52.5
LUC Class V	16	13	13	12	0	0	0
LUC Class VI	15	10	10	10	0	0	0
LUC Class VII	8	6	6	6	0	0	0
LUC Class VIII	2	2	2	2	0	0	0
Farm Area (Ha)					200	0	200
Farm Leaching Tarkets (KgN/ha	**23**	**20**	**18**	**17**			

Results

Whole farm modelling approach

EEM Scenarios for Farm 3:

(For discussion on how to refer to Farm Table results and determine what changed, refer to previous explanations, notes below and Tables 16 and 17 pages 71 and 72.)
160 ha plus 40 ha effluent.

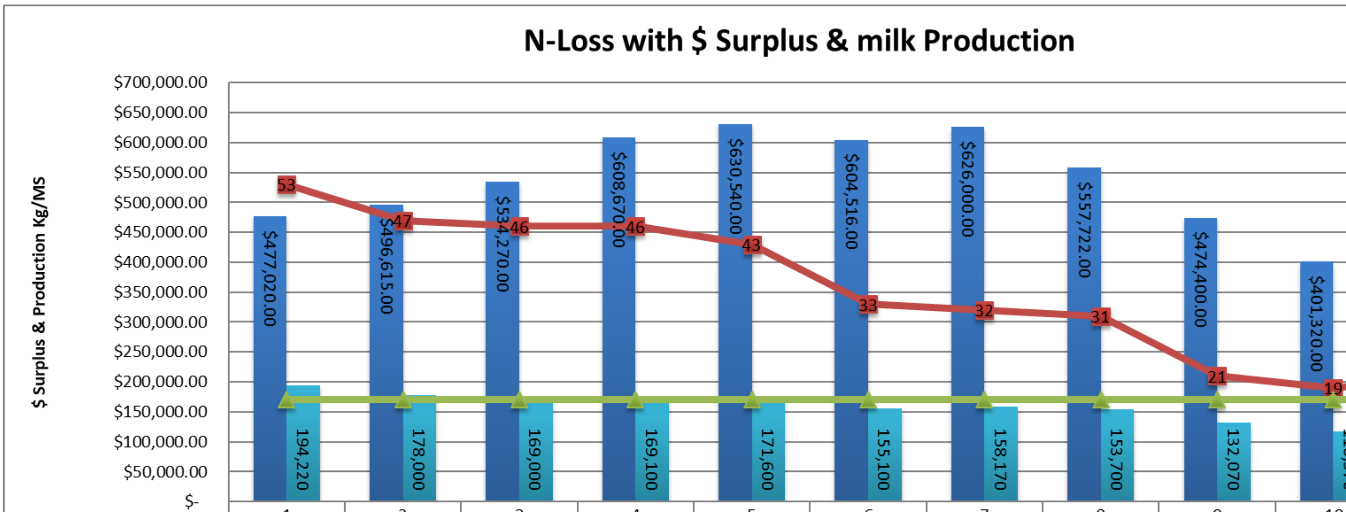
The 40 ha is progressively changed over to different pasture (Prairie + Caucasian or similar hybrid) as cropping ceases (Refer to later (next page 46 and 48) for discussion of this).

This pasture change allows retention of better quality despite lax grazing, which does actually suit these species (Prairie Grass and Caucasian hybrid clovers) anyway.
Nitrogen 160 ha : Run 1 July, Sept, October, Dec, March, May @ 30kgN/ha
Nitrogen 40 ha Run 1 Aug, Oct, Apr @ 46 kgN/ha
Nitrogen 160 ha Run 2 Sept, Oct, Dec, Mar, April @ 25 kgN/ha
None on 40 ha just effluent N.
Nitrogen Run 3, 4, 5 Same as above
Runs 6-8 no nitrogen applied.
Crop phased out.
Run 1 11ha Turnip/11 ha winter
Run 2 14ha turnip resown March. + 11ha winter
Run 3 14+ 11
Run 4 14 ha turnip
Run 5 14 ha turnip
Runs 6,7,8 no crop.
Weaner heifers grazed on until Run 4 then ALL grazed off 5-8.
68 R2yr heifers grazed off in all runs until Run 8 when ALL R2yrs grazed off.

No weaners or cows grazed off Runs 1-6 but supplement fed off paddock.
The EEM selected when and what bought in feeds to cease using and the crop area and grazing off options based initially on MC vs. MC then on reduction in N leach.
Hay was actually so expensive /MJME that the EEM would not use it until the price was dropped below 30 cents per kg 10.5 MJME DM with at least 85% utilisation.
Very good silage at 33 cents 10.6MJME and PKE at 28 cents/kg 10.8MJME were preferred.
Concentrates were required to balance energy required for these higher producing cows until the increasing area of “better” pastures (11.8-12.2MJME/kgDM) were introduced.

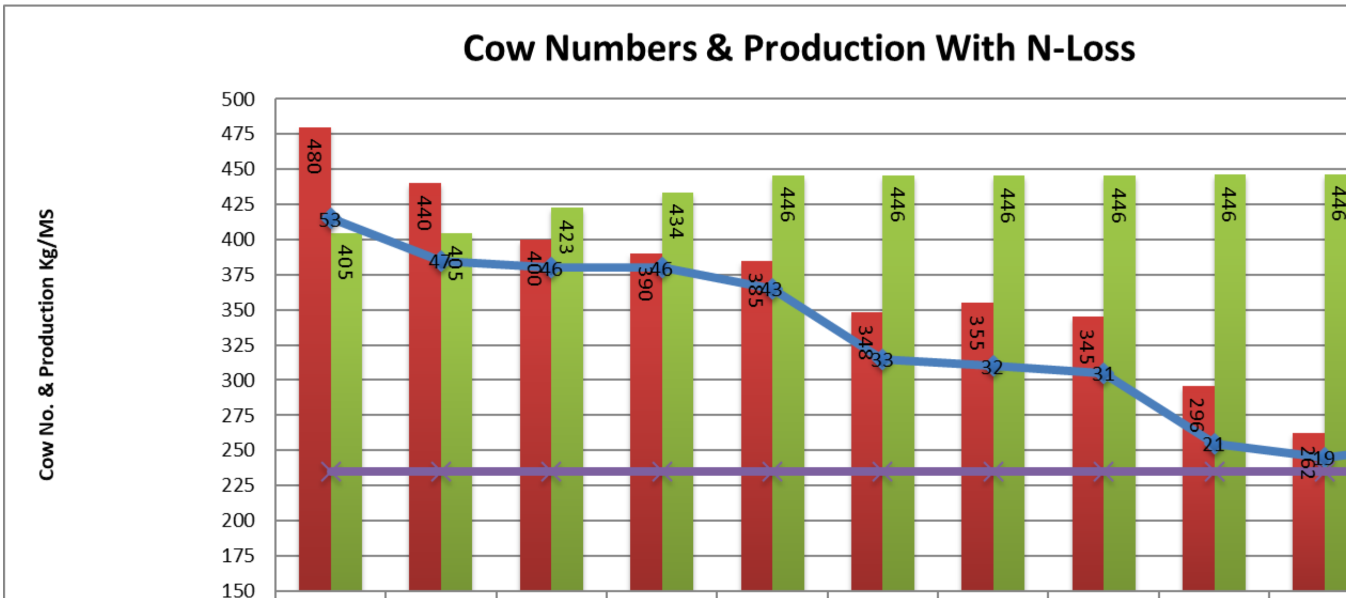
It may seem odd that the EEM grazes animals OFF despite having to discard feed, but that is the environmental constraint overriding the economics to reduce N leach.

This area of better feed also allowed the reduced herd number to produce at a higher MS/cow which helps economics but it is uncertain how Overseer® copes with better quality feed and more efficient milk production from increasing production per cow.



	1	2	3	4	5	6	7	8	9	10
$ Surplus	$477,020.00	$496,615.00	$534,270.00	$608,670.00	$630,540.00	$604,516.00	$626,000.00	$557,722.00	$474,400.00	$401,32
MS Prodn Kg/Ms	194,220	178,000	169,000	169,100	171,600	155,100	158,170	153,700	132,070	116,9
N leached Kg/N/Ha	53	47	46	46	43	33	32	31	21	19
One Plan N-Limits	17	17	17	17	17	17	17	17	17	17

Figure 10: Farm 3 - Plotted runs with comparison of N leaching and cash surplus



	1	2	3	4	5	6	7	8	9	10
NoCows	480	440	400	390	385	348	355	345	296	262
kgMS/cow	405	405	423	434	446	446	446	446	446	446
N leached Kg/N/Ha	53	47	46	46	43	33	32	31	21	19
One Plan N-Limits	17	17	17	17	17	17	17	17	17	17

Figure 11: Farm 3 - Plotted runs with comparison of N leaching, cow numbers and production

Summary

The completion of the eleven runs demonstrated that seven out of eleven runs provided a higher surplus and lower N-loss across the whole farm, with run four providing the highest surplus of all runs. Due to the type of soils selected for this synthetic farm it was unable to maintain the same level of $ surplus as the original base run (For full Farm run data refer to Appendix under Farms).

An important point to note is that with much the same basic resources as Farm 1, but more efficient system (higher MS/cow; proportion of better quality and more flexible management options type of pasture) the N leach limit could be reached at higher $surplus for Farm 3 than the less efficient Farms 1 and Farm 2. (Explained next page.)

Discussion – Farm 3

Again, this farm was altered in terms of the area. Reduced from 250 ha to the 200 ha of the other synthetic farms for better comparisons.
All other per ha data remained as reported for this MI unless otherwise adjusted as the EEM enviro constraints were used to reduce N leach at least cost. Therefore, the N leach decreases downward in a structured manner.

The Medium Intensity dairy farm has figures of just over 400kgMS/cow. This imposes even more severe energy requirements on the poor basic pasture resource.
Because of this, over the period when crops are phased out, a change to pasture species was undertaken.
Due to the need for infrequent and lax grazing as herd numbers decrease to meet lower N leach figures, Matua Prairie Grass was introduced with a Caucasian hybrid clover or a lucerne mix. This depends on the actual characteristics of the climate range for the synthetic farm.
These new forages are grown in the 40 ha effluent area as the cropping regime is phased out. This provides higher nutrients overall and supplies added nitrogen for the Prairie Grass.
Matua plus either Caucasian or lucerne allows both good dry summer growth rates of higher quality feeds and an ability to sustain better production without requiring lower grazing levels and higher utilisations to retain “quality” or the need to import higher MJME feeds at increasing cost to buy, feed out and utilise efficiently (feed bins, feed pad plus bins or a barn).
The Barn costs as per DairyNZ data are about $2,000/cow depending on level of feeding, cleaning systems and retention facilities required for effluent. As the effluent is also more “solid”, alterations to effluent disposal systems may also add to capital involved.
Using a barn efficiently is also practically quite difficult in terms of time in versus out, walking to and through paddocks for intermittent rationed pasture feeding and times. These all impose greater stress on races, machinery, staff and organisation. Additional risk and inability to borrow is also a practical consideration after several years of lower payout and the likelihood that these payouts will remain in a narrow band into the future given the improvement in the efficiencies and lower feed costs of competing countries.

Such a mix of summer and strong winter growing forages will at some time be recognised within Overseer® as being a very efficient user of nitrogen (either from the clover or the lucerne) throughout the year but especially over winter.
Lucerne was used to establish the productive soils now present in the Waikite Valley and Rerewhakaaitu areas near Rotorua and may suit the poor summer quality characteristics of the synthetic farms.

The approach to investigate alternative forages was taken rather than borrowing more money to build a barn with the requirement to increase the quantity, quality *and cost* of bought in feeds plus the associated increases in depreciation and running costs for buildings and additional machinery. This commits a large capital expenditure (and higher "fixed variable costs" that must now be paid as they are all associated with the additional costs the barn creates) for a farm with a poor capability for profitable dairy farming.
Although the quantity of pasture grown had increased from the self-contained and low intensity dairy farms, little change to pasture quality had been made in the data for this Moderate Intensity farm. (MJME/kgDM levels of <10 for 3 summer months and <10.5 MJME/kgDM for a further 3 months. This means that for 6 months of the year in its current state, this farm exhibits feed qualities that are poorer than most sheep and beef farms). Hence the need for high quality pasture and high cost feeds if increasing MS production to 434 kgMS/cow is desired to improve profit.

Similar to the other two farms, the EEM was adjusted to model the Base MI synthetic farm.
Although the MJME were supplied, as were estimates of the Pasture Growth Rates and Nitrogen responses, this process is not exact.
Bought in Feeds (BiF) vary in MJME, utilisation and cost. Estimates on pasture utilisation were also supplied on a monthly basis. As the EEM works on 2 week periods, there may be some variations to the full year figures.

The method for modelling the MI was to begin with the Base Farm, then progressively allow the model to assess the least cost N abatement.
The model chooses to decrease BiF and herd number. This reduces BiF amount and farm costs, not only for the BiF but also the costs associated with its use (tractor, labour, machinery) and the costs associated with the cows that are effectively eating this BiF (e.g. costs of breeding, health, proportions of shed, labour, power, rearing replacements, grazing.)
At some stage (normally at the discretion of the manager) "lumpy inputs" such as labour units, tractor, machinery, may also be removed.

As the alternative forages were introduced via re-grassing summer crop areas, production per cow was increased (401; 405; 422; 434; 446 kgMS/cow) due to the higher MJME quality and the ability to graze such forages laxly without impacting quality. This laxer grazing also allows a higher intake of the better quality feed and more flexibility to overcome pasture feed peaks.
There is also an added benefit in that there will be less LW loss over the critical periods leading up to and over mating. This will lead to a lower replacement rate which in turn alters the herd age structure and the potential to lift the overall *average* production per cow. As this results in a more mature herd, the ability to graze some of the existing pastures harder at critical times will also lead to some improvement in the overall quality of these pastures too.

However, the *overriding* requirement in the work "**is demonstrate reductions in N leach to meet the cumulative leaching maximums in One Plan Table 14.2**".
The EEM model follows this process by progressively eliminating any inputs where marginal cost is greater than marginal return (MC>MR which is a profitable option), then those inputs where MC=MR.
If further N leach reduction is required, this will be at a cost as now the MR>MC inputs are removed (at a loss) then inputs where MR is much greater than the MC (MR>>MC) are removed at an increasing loss.
This process can be used to demonstrate "Nitrogen abatement " for any farm.

As all the farms have been reduced to 200 ha, and are now below the current stock capacity for the pastures grown, the options left are:

a) To reduce feed consumed by "discarding" feed or retiring areas to plantings.
b) To change the stock policy away from dairy.
c) To invest large capital sums in structures and machinery to capture and spread dung and urine over wider areas.

The problem presented from the preceding farm systems analysis is that within Overseer®, the specified characteristics of the synthetic farms make it difficult to shift N leaching below a critical level. (This peculiar circumstance has been noted in previous work for Horizons. It was referred to as "Overseer® reaching a 'basement level' of N leach from which it becomes extremely difficult to reduce N leach any further.")
Specific combination of soils and climate combine in a manner that presents difficulties in generating any further leaching reductions. This is the "tipping point" where the additional cost of further Nitrogen leaching reduction increases at an increasing rate because any resources now removed to reduce crude protein have been those whose

use within the farm system have been very profitable i.e. their contribution to the system has been critical to keep it running efficiently.

This farm has not reached the N leach level required. However, the final run would remove cows from the farm and graze off to achieve the required reduction.
The higher production per cow (mainly brought about by lowering replacement rate) shows how more efficient use of feeds (more into milk compared to maintenance compared to earlier herd structures Farms 1 and 2) provides a consistent increase in the economics of the farm.

Discussion – Soils & LUC N-loss

How does soil types and LUC N-loss limits affect the outcome of this study?

There are approximately 24 dominant soil types for dairy farming in the Taranua area. The three farms used up to 3 soil types with Dannevirke silt loam being the dominant land area used, this soil is well drained so will leach N to a high degree than a poorly drained soil type.

The soil types were altered from those of Farm 1 in the following Table 9, this reflects a mixture of poorly and well drained soils that can occur in a dairy farm in the Tararua catchment.

Table 9: Changed soil types used in Farm 1

LUC	No.				Whole farr	iry platfor	unoff bloc
Class	Block	Type	Soil		Area (ha)	Area (ha)	
LUC Class	1	Effluent	Kairanga	Flat	30		
LUC Class	2	Milking Platform	Tukituki	Flat	100	94.4	7.5
LUC Class	3	Milking Platform	Kairanga	Flat	40		34.8
LUC Class	4	Milking Platform	Takaoau	Rolling	30		7.9
					0		
Totals					**200**	94.4	50.2

We can keep with the original LUC N-loss limits as in **Error! Reference source not found.**, or we could change the area (ha) in one or more LUC classes which will change the N-loss reduction needed as in Table 11. We see an increase in N-loss limits from 23 KgN/ha to 25 KgN/ha in the first year and an increase in N-loss limits from 17 KgN/ha to 19 KgN/ha in the second year.

Table 10: LUC N-loss limits Farm 1

Land Use Capability	Table 14.2 N Leaching Limites (KgN/ha)				LUC Area (Ha)		
(LCU)	Year 1	Year5	Year 10	Year 20	Platform	Run-Off	Totals
LUC Class I	30	27	26	25	0	0	0
LUC Class II	27	25	22	21	30	0	30
LUC Class III	24	21	19	18	117.5	0	117.5
LUC Class IV	18	16	14	13	52.5	0	52.5
LUC Class V	16	13	13	12	0	0	0
LUC Class VI	15	10	10	10	0	0	0
LUC Class VII	8	6	6	6	0	0	0
LUC Class VIII	2	2	2	2	0	0	0
Farm Area (Ha)					200	0	200
Farm Leaching Tarkets (KgN/ha	23	20	18	17			

Table 11: LUC N-loss limits changes in Farm 1

Land Use Capability	Table 14.2 N Leaching Limites (KgN/ha)				LUC Area (Ha)			
(LCU)	Year 1	Year5	Year 10	Year 20	Platform		Run-Off	Totals
LUC Class I	30	27	26	25	0		0	0
LUC Class II	27	25	22	21	82.5		0	82.5
LUC Class III	24	21	19	18	117.5		0	117.5
LUC Class IV	18	16	14	13	0		0	0
LUC Class V	16	13	13	12	0		0	0
LUC Class VI	15	10	10	10	0		0	0
LUC Class VII	8	6	6	6	0		0	0
LUC Class VIII	2	2	2	2	0		0	0
Farm Area (Ha)					200		0	200
Farm Leaching Tarkets (KgN/ha	25	23	20	19				

We now have a different farm based only on soil changes and an increase on LUC N-loss which in reality is highly likely on a nearby farm.

One would assume that when only the soil types are changed, we would see the same trends that was observed in Farm 1, Figure 6: Plotted runs with comparison of N leaching and cash surplus and Figure 7.

The new Farm 1 changes are shown in Figure 12 and Figure 13.

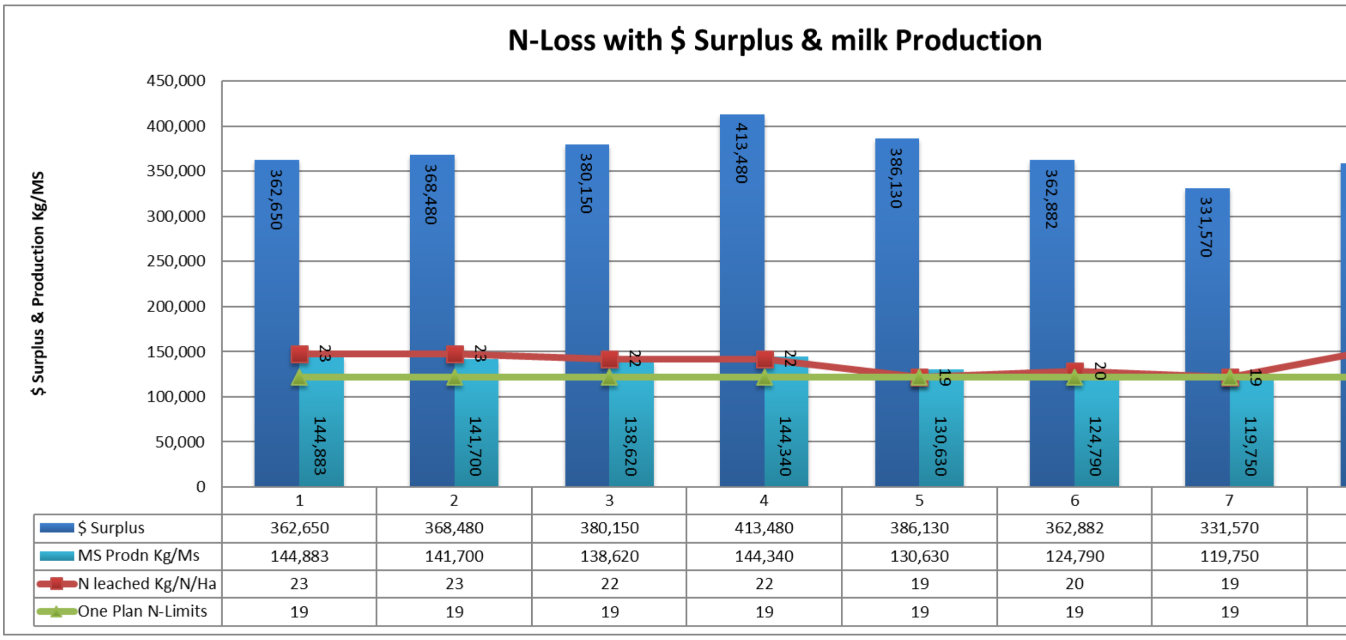
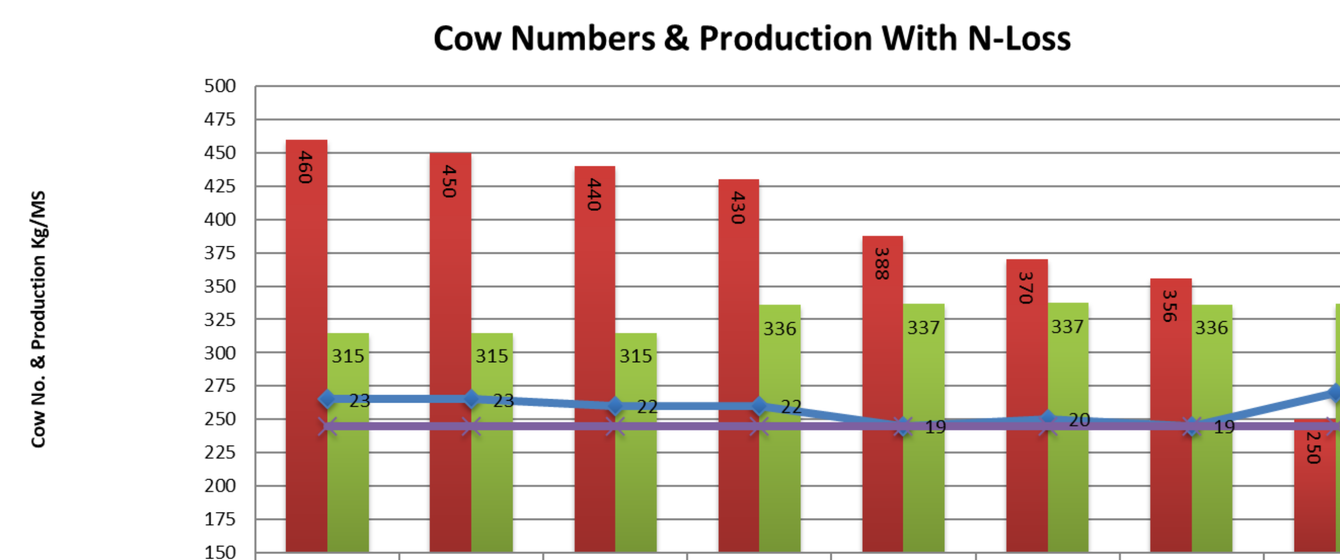


Figure 12: Plotted runs with comparison of N leaching and cash surplus on changed Farm 1

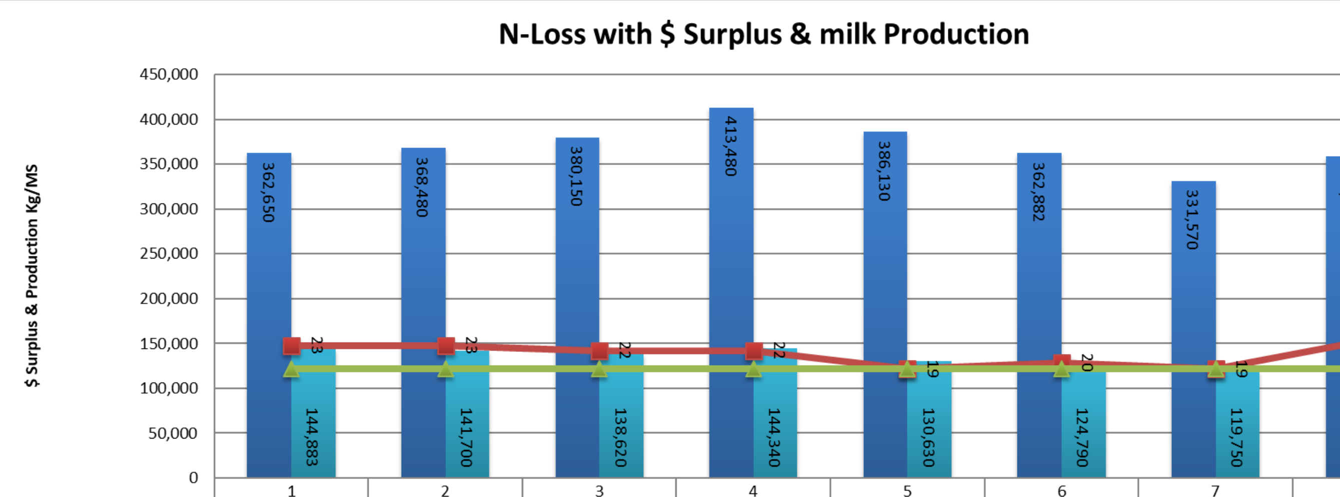


	1	2	3	4	5	6	7	8
NoCows	460	450	440	430	388	370	356	25
kgMS/cow	315	315	315	336	337	337	336	33
N leached Kg/N/Ha	23	23	22	22	19	20	19	2
One Plan N-Limits	19	19	19	19	19	19	19	1

Figure 13: Plotted runs with comparison of N leaching, cow numbers and production on changed Farm 1

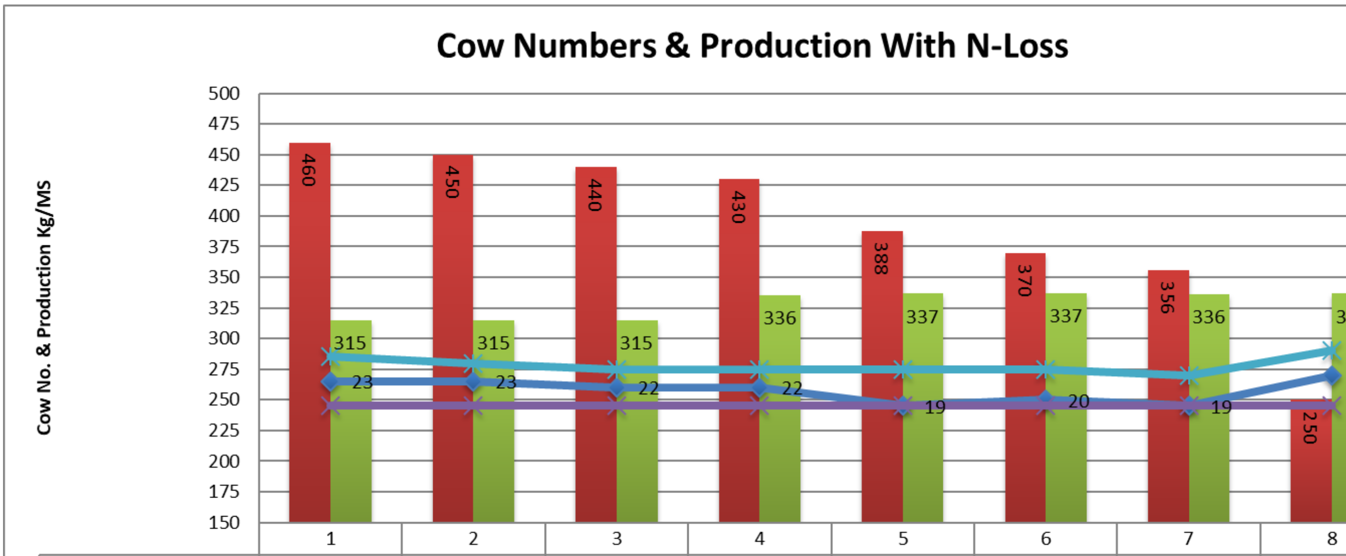
In the original Farm 1 analysis, the farm is unlikely to be financially viable and reach the 20-year N-loss limits.

This cannot be said with the soil changed in Farm 1. We now have two runs on the limit, now we have a reduction in surplus of $2,448 while Run 5 increases the surplus in comparison to the base by $24,480. This is demonstrated in Figure 14 and Figure 15.



	1	2	3	4	5	6	7
$ Surplus	362,650	368,480	380,150	413,480	386,130	362,882	331,570
MS Prodn Kg/Ms	144,883	141,700	138,620	144,340	130,630	124,790	119,750
N leached Kg/N/Ha	23	23	22	22	19	20	19
One Plan N-Limits	19	19	19	19	19	19	19

Figure 14: Plotted runs with comparison of N leaching and cash surplus with N-loss of old farm 1



	1	2	3	4	5	6	7	8
NoCows	460	450	440	430	388	370	356	250
kgMS/cow	315	315	315	336	337	337	336	337
N leached Kg/N/Ha	23	23	22	22	19	20	19	24
One Plan N-Limits	19	19	19	19	19	19	19	19
N leached OLD	27	26	25	25	25	25	24	28

Figure 15: Plotted runs with comparison of N leaching, cow numbers and production with N-loss of old farm 1

Summary

The need for reliable soil information to develop farm environmental plan and to evaluate by modelling the economic viability of a farm system in a sensitive catchment has never been greater.

Soil survey in New Zealand from 1938 to 2001 has resulted in a set of soil maps of varying quality at varying scales. By the end of 2001, the whole country was covered by 1:253,440 scale soil maps. Farm soil maps may be provided at any nominal scale, with no quality indication as regards the accuracy or uncertainty of the mapping.

S-map is the new digital soil spatial database that aims to provide a seamless digital 1:50,000 scale (or better) soil map coverage for New Zealand. S-map has been created as part of the government-funded Spatial Information programme run by Landcare Research (Landcare-Research., 2014).

The S-map system has been designed to accommodate soil data at any scale, and be adaptable to both changing soil science knowledge and end-user needs. The S-map database, due to underlying scale limitations, at a scale of 1:50,000, this resolution may be too coarse to be useful. However, quality for soil mapping, a scale of 1:50,000 is classed as poor quality, while farm-scale soil map at 1:10,000 or lower is of good quality and premium quality.

Below Figure 16: S-Map demonstrates coverage in deeper colour while there is a large percentage that is currently unavailable. Figure 17: S-Maps - Sorry - there is no S-map data yet for this location.

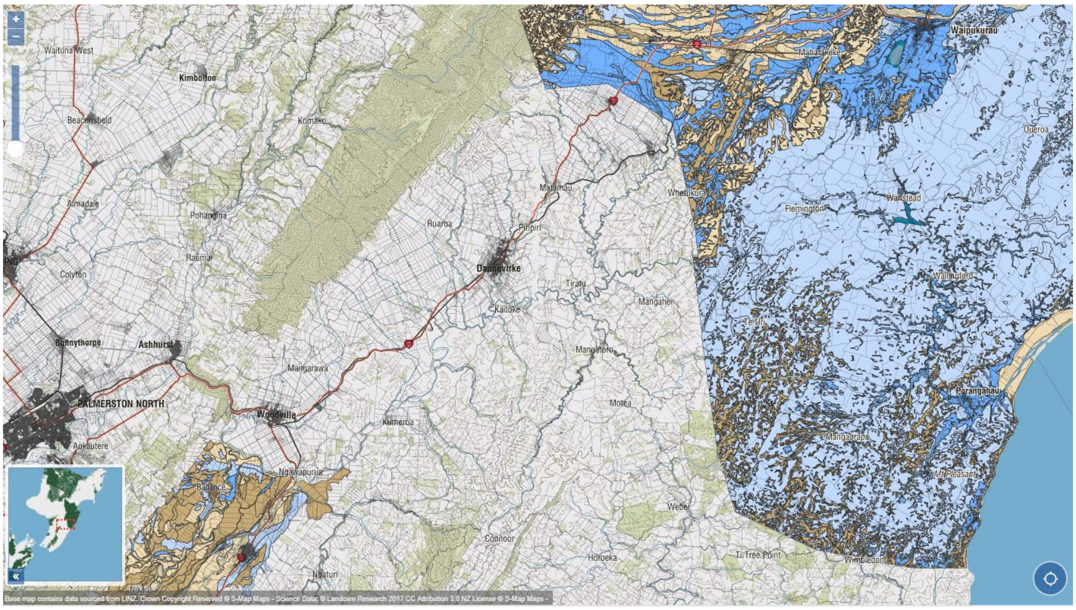


Figure 16: S-Map demonstrates coverage in deeper colour

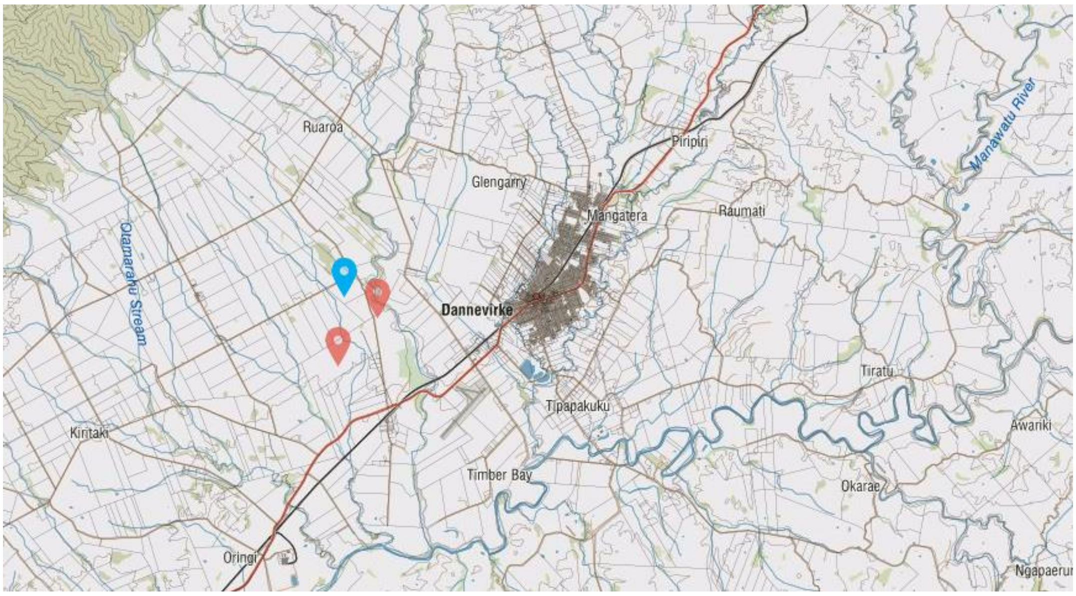


Figure 17: S-Maps - Sorry - there is no S-map data yet for this location.

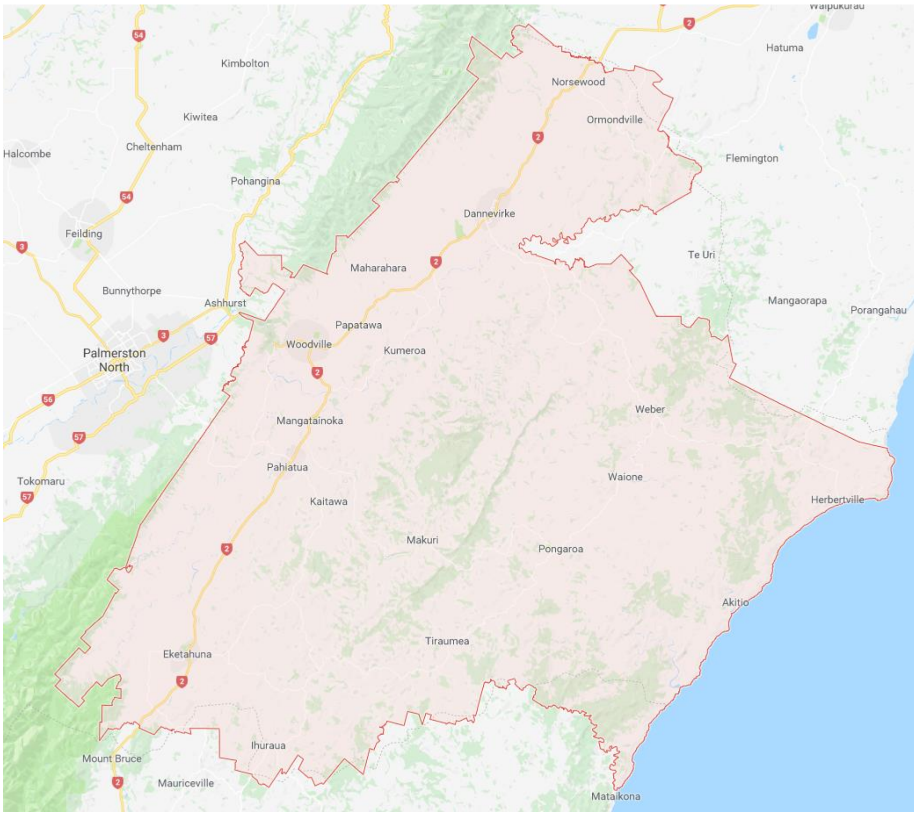


Figure 18: Taranua District is an area near the south-east corner of New Zealand's North Island

Taranua District covers a very large area of which only a very small proportion has formally been mapped by a trained Soil Pedologist mainly in the Ekatahuna district.

A detailed soil and landscape capability survey at the paddock level mapped by a trained Soil Pedologist will produce a map of a 1:6,000 scale is recommended to give any farmer a real chance of obtaining a real N-loss figure along with the correct LUC N-loss amount.

A whole farm modelling approach using EEM and Overseer® can then be used to accurately ascertain how a farm will perform in a sensitive catchment.

Conclusion

Introduction

The objectives of this report 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. Three case study farms in a sensitive catchment were considered the most appropriate method for achieving this objective and the combined EEM and Overseer® modelling approach was adopted.

Main *findings*

All three farms presented are highly leachable and cannot viably reach the required limits for N reduction limits set by the 20-year period.

However, considerable reductions can be achieved rapidly and at little cost in the initial N reduction phase.

There are options for mitigation which will ***reduce N leach and reduce profit*** (i.e. the current industry based approaches) and others that will ***reduce N leach but improve profit.*** **(**Win/Win is possible.**)**

The concept of using “Synthetic Farms” to provide a base for informed debate or decisions is flawed as resources (soils, climate, animals, plants, production, production systems and costs) are farm specific.

As has been shown within this report (soils and more efficient production systems), small variations in soil definition and resource use will produce markedly differing opportunities or constraints to profit when a defined N leach constraint must be reached.

This emphasises that each farm must be individually assessed to ensure proportionate N reductions are as accurately known (as current technology allows) and enable flexible systems changes to be explored and implemented by management.

An objective quantitative approach can reveal systems with greater synergy and enable higher levels of efficiency at lower levels of N leach.

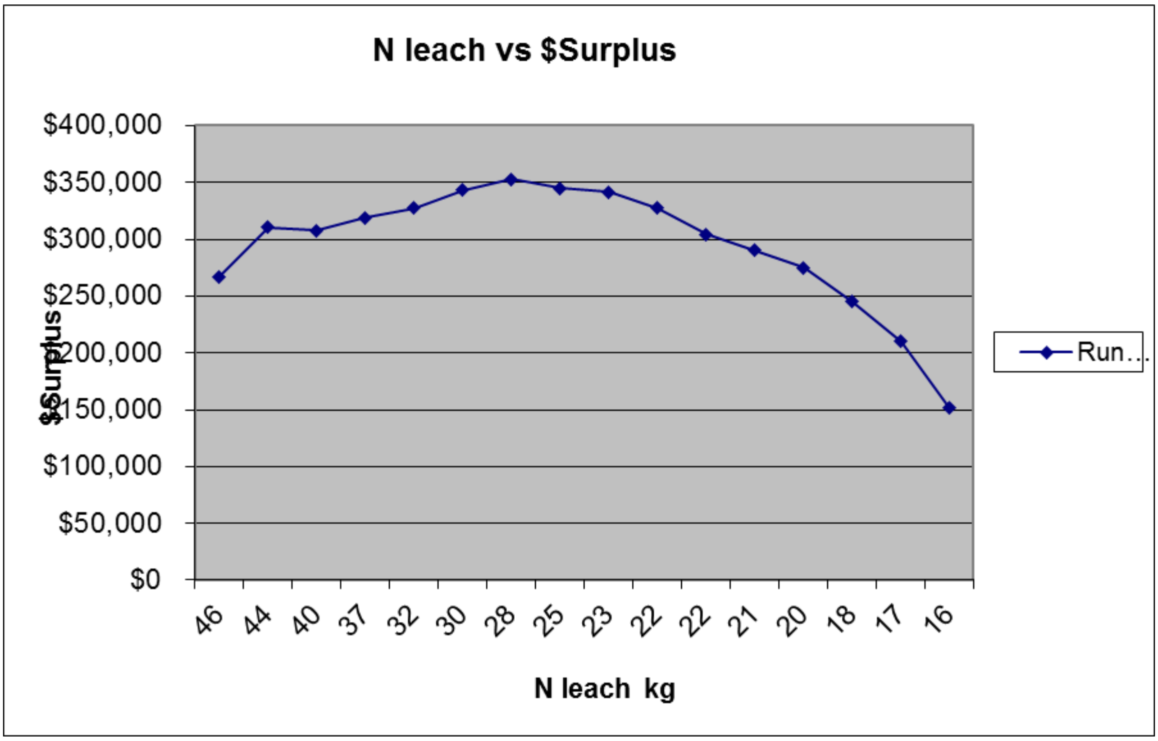
Such farm systems provide more profit at a given N leach level whereas other less knowledgeable combinations cannot.

The reality is that once a critical point is reached, even efficient systems using resources in an optimum manner will not be able to achieve the low N leach levels demanded due to the specific combinations of soil, climate and management stock policies that apply.

There is no “average cost per kg N abatement”. The profit or cost will increase as the marginal cost vs marginal return alters. This is due to the removal of those inputs where MC>MR (i.e. where profit will therefore increase) then the removal of those inputs where MC=MR (i.e. the point of maximum profit); then those inputs where MC<MR (i.e. reduction in profit) and then moving to an escalating rate of $profit loss

as MC<<MR (i.e. where more and more higher profit earning resources are required to be removed to reduce N leach further.)

The cost of N leach abatement is a figure that varies for each farm and farm system. It may show a line of $profit vs N leach as below (an actual farm) although the Synthetic farms (due to mainly the influence of the soils chosen) indicates far more abrupt (and difficult to explain) changes within Overseer®.



Effect on $profit of a change in MS price:

A sensitivity analysis to examine $surplus changes as MS varied found that the EEM selected the same resources and quantities (and therefore no change to costs).

This means that at a milksolids price of up to $8.50/kgMS, $surplus will increase equal to the additional increase in the MS price x the total MS produced.

At >$8.50, the EEM may select to purchase more feed and run more cows but only where the MS/cow exceeds 420MS/cow and only if purchased feed and other costs do not increase.

This seems unlikely to occur should the MS price rise above $7/kgMS.

Such increases will exceed the N leach limit even though a small additional profit may occur.

Effect of debt on overall $profit:

If it can be assumed that the Farm 1 is valued at $35/kgMS ($5 million) plus $0.75 million (stock, machinery) and an interest rate of 6% (no O/D) and there is 35% debt on the farm, interest alone will be $120,750/year.

This sum should be deducted from each Run $surplus for the Farm 1.

Presuming on this average basis of value per kgMS and additional stock carried, this figure will rise for Farm 2 and Farm 3 leaving little surplus for debt repayment or unforeseen events as N leach for the synthetic farms reduces towards the figure required.

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Appendices

Three graphs to illustrate intensification of pasture systems:

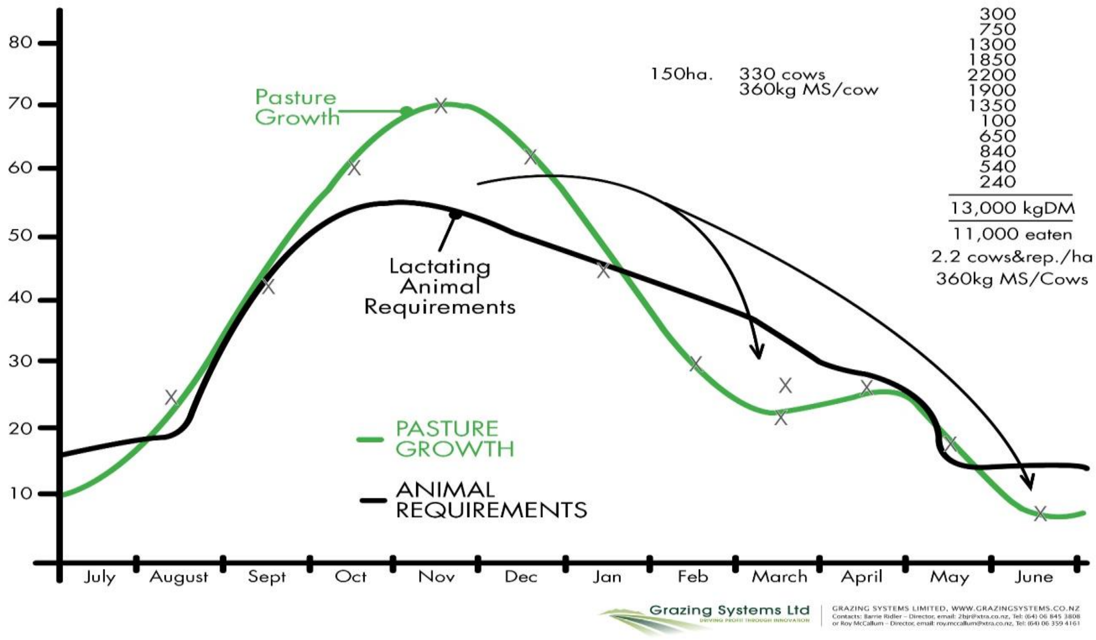

Figure 19 All pasture self-contained

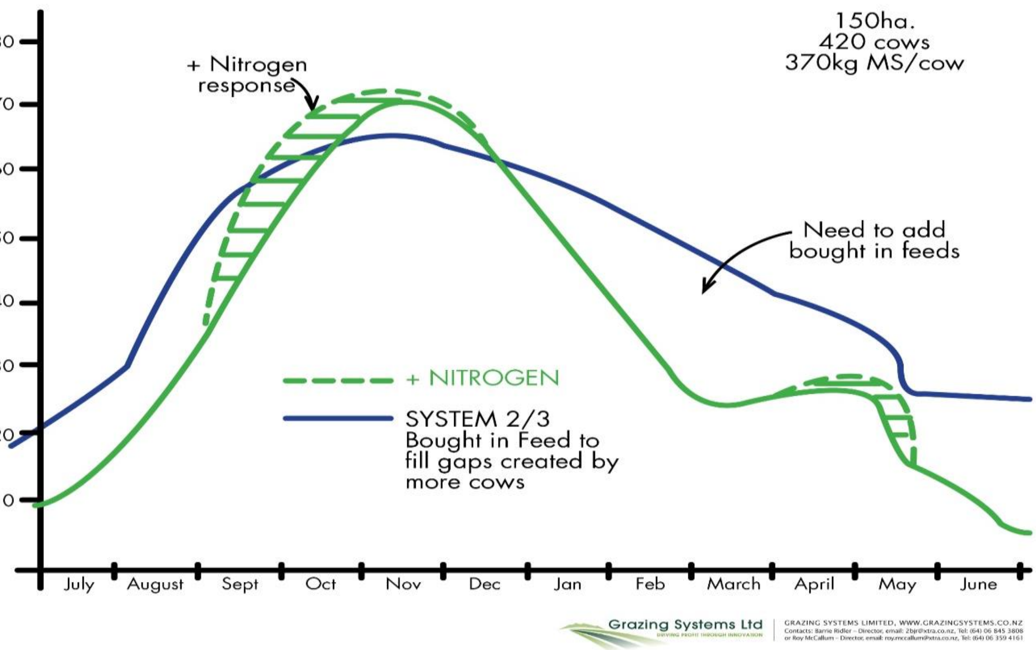

Figure 20 Increased intensification. Now more feed required (blue line) than basic farm pasture growth (green line) can produce so buy in feeds for much of year.

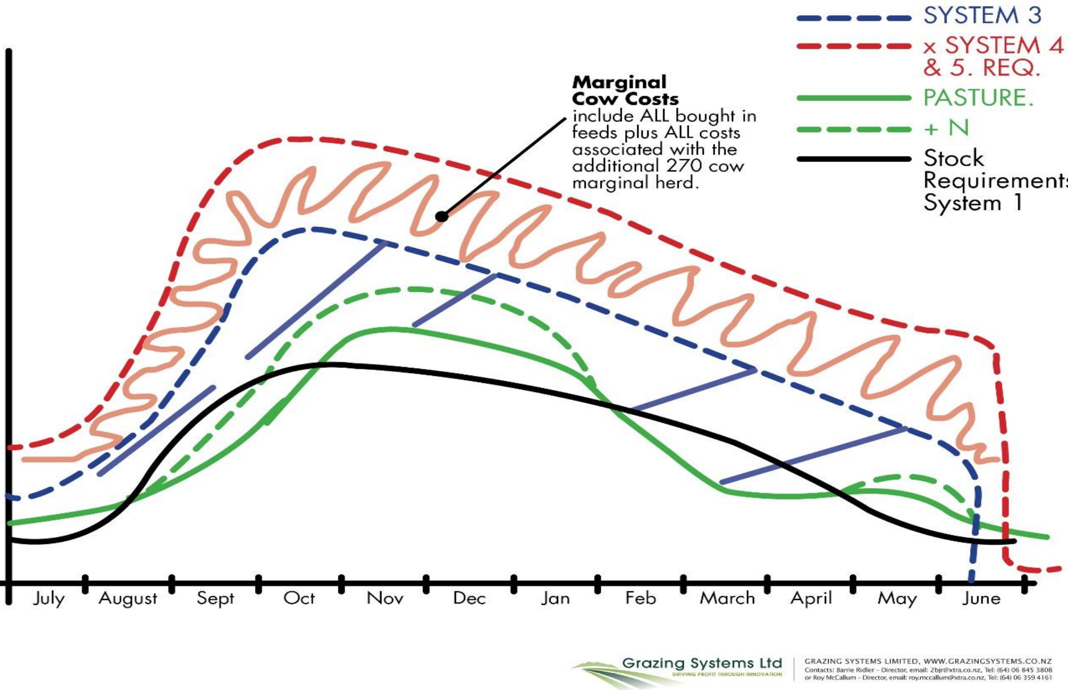

Figure 21 Now intensified and 600 cows at higher MS per cow require bought in feeds (BIF) throughout the full year.

Real costs of BIF (Bought In Feed)

Simple mathematical calculation of true cost of bought-in feed vs pasture.
The important point is to be able to identify when **supplementary feed** (to fill in genuine feed gaps when feed demand is balanced with production required) becomes **bought-in feed** (when additional animals are supported solely from bought-in feed or **BiF**).

1 kg of bought-in feed example:

Most farmers (and many advisors) use the actual purchase price of **BiF** to perform a simple margin over feed cost (MOFC) comparison. This is incorrect. Buy-in cost 28 cents per kg off truck but may be 90% DM (PKE type products and many concentrates), but:

- To feed 1 kg of say 11MJME feed means a cost of 3– 8 cents /kg wet weight depending on where fed (labour, machinery costs), which implies 31-36 cents /kg 'wet weight'.
- Utilised at 85% (higher if barn/feed pad but feed out costs higher as costs of silos, in-shed feeding infrastructure)
- This brings the consumed cost to 36.5 cents/kg wet weight fed.

- At 90% DM, this brings cost per kgDM consumed to **40.5** cents
- BIF substituting for pasture at 11.5 MJME/kgDM requires 6.5% more BIF than pasture.
- This adds another 3 cents to the comparative costs of bought in feed vs. pasture eaten.
- Total cost of about **43 cents/kg pasture equivalent** being substituted.

If this is a true supplement that fills in genuine feed gaps only and meets required production targets, this 43 cents /kgDM cost should now be used for calculations.

However, if there are more cows being run than pasture growth allows, the **additional cows** can be viewed as consuming a complete feed intake of **all BiF** (NB: an optimisation model such as GSL identifies the tipping point where supplements become **BiF**).

If this is the case, the simple calculation takes on another dimension as ALL costs associated with the additional cows must now be attributed to those cows.

- A 400 kgMS cow (quite efficient by NZ standards) with a replacement rate of 25% requires about 6000kg of 11.5 MJME DM to sustain its full herd contribution (Milk + part replacement) each year.
- Simplistically, if all bought in feed is used the feed cost is 6000 x $0.43 = $2,580.
- It may be simple to think that $2,580/400kgMS = $6.45/kgMS price covers this, but this is wrong.
- There are also all the additional costs that are incurred by that additional animal.
- These include not only the feed costs but the costs of rearing a replacement (8 weeks), animal health, AI, proportion of animal management costs (shed, labour) interest costs on actual cow and shares but also added infrastructural costs if enough extra cows are milked to require them.
- These add at least a minimum $500 of additional costs (more with infrastructure) which now requires a $3080/400 kgMS
- Break-even product price is now $7.70 /kgMS but also brings extra risks, stress and requires better management ability.

The tipping point (where marginal costs exceed marginal return) is critical when assessing where to attribute costs. Averages, benchmarks and ratios used in Input/Output (I/O) models cannot identify this tipping point as no marginal analysis is possible because substitution of resources that show negative diminishing marginal values are unable to be identified within the I/O model format.

Such costs are averaged equally across all production income in the account structured databases and the costs associated with specific actions are also hidden within all-encompassing accounting “categories” (such as Fuels and Oil; Repairs and Maintenance – Machinery; Dairy Shed, Supplementary Feeds...). This makes any reliance on averages, benchmarks and ratios fraught with misinterpretation and erroneous “causal relationships”.

This calculation allows the marginal cost of additional cows to be established. However, this calculation also depends on the kg milk solids per cow. As per cow performance increases, so the efficiency of feed improves (as less maintenance “fixed cost” feed relative to that used for milk solids (“variable feed”.)

In the following diagram, choose the level of per cow production that seems possible for a farm and this will indicate the kgDM required. If ALL this feed is for an additional cow compared to what pasture can supply, use the BiF cost of feed calculation to find the cost of feed to compare with MS produced. If the cow is additional to what the pasture can supply, add per cow costs to this figure to find a milksolid price that must be achieved to breakeven.

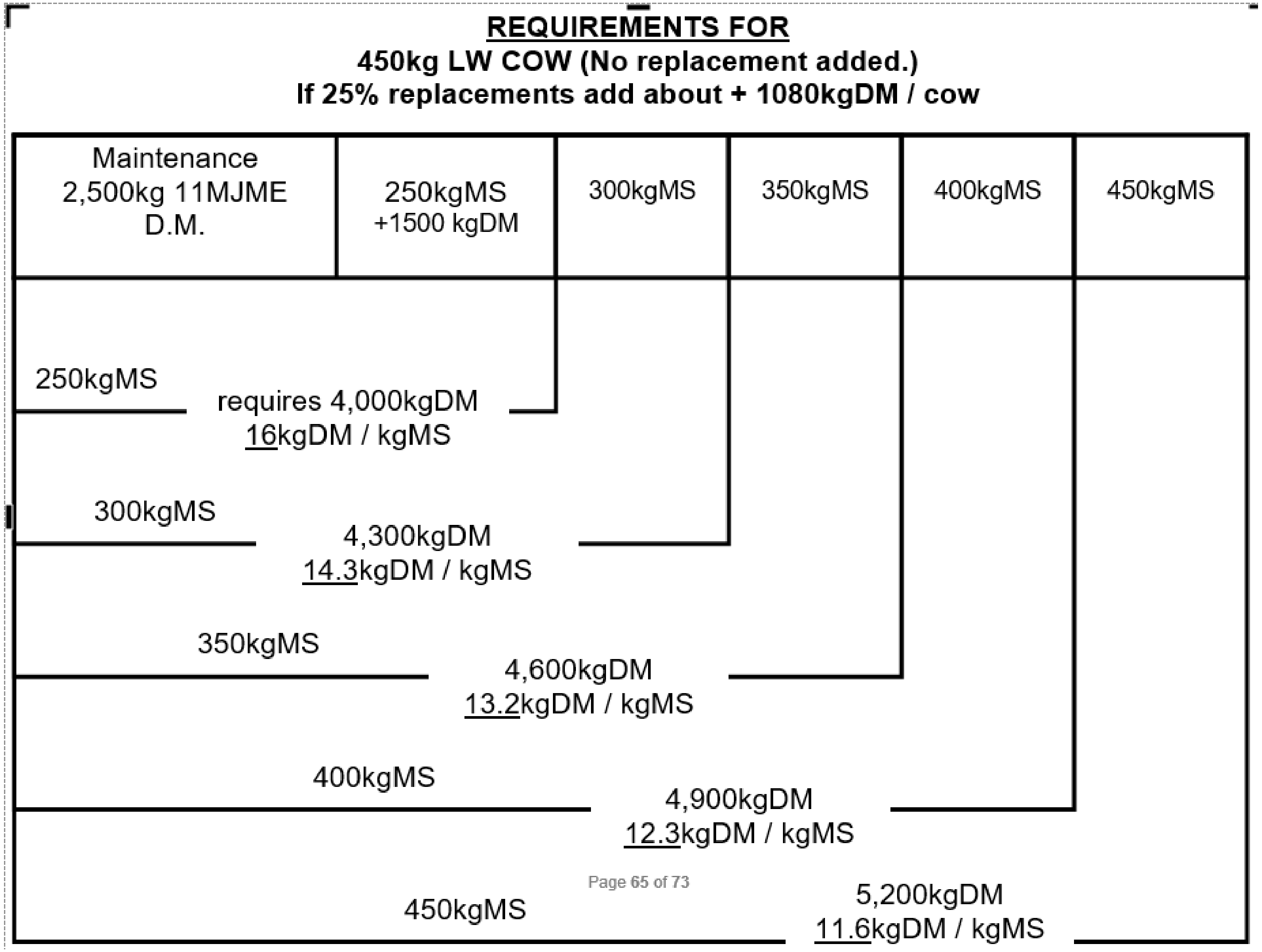

Figure 22: Requirements for 450kg LW cows

Farm 1 Run Data

Table 12: Farm 1. 200ha (170ha + 30 ha Effluent) Economic and N leach outcomes.

Run no.	**1. Base**	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Run 6**	**Run 7**
No. Cows	460	450	440	430	388	370	356
kgMS/cow	315	315	315	335	335	335	335
KgN/hatotal	Aug15kgN 200ha	Aug15kgN 170ha	0	0	0	0	0
Supplmade	123,000	130,000	100,000	110,00	24,000	0	0
discard	0	0	0	0	137,000	190,000	326,000
Total BIF	20,000	0	0	0	0	0	0
MSprodn	144,883	141,700	138,620	144,340	130,630	124,790	119,750
Bull sales	0	0	0	0	0	0	0
Date kill	-	-	-	-	-	-	-
$Income	1,014,050	991,900	970,200	988,648	894,706	854,716	820,000
$costs	652,400	623,420	590,050	575,168	508,576	491,834	488,430
$Surplus	**361,650**	**368,480**	**380,150**	**413,480**	**386,130**	**362,880**	**331,570**
Summer crop area	10ha	10ha	0	0	0	0	0
R1yr graze off	0	0	0	0	0	0	0
R2yr graze off 12 months	All	All	All	All	All	All	All
Herd graze off 8 weeks	All	All	All	All	All	All	All
N excreted	61,100	60,800	60,550	60,400	57,500	55,000	52,500
Total '000 kgDM use	1,991	1,968	1,929	1,929	1,803	1,716	1,642
N leached kg/Ha~	**27**	**26**	**25**	**25**	**25**	**25**	**24**
Change in $/kgNleach	**Compare To Base**	**-$ / kgNleach**	**-$ / kgN**	**-$ / kgN**	**+$ / kgN**	**+$ / kgN**	**+$ / kgN**
		+6830	**+18,500**	**+51,830**	**+24,480**	**+1,230**	**-29,880**
$/ additional kg N leached/ ha		**(+6830) $34.15**	**(+18500) $92.50**				**(-81710) $408**

Table 13: Farm 1. 200ha (170ha + 30 ha Effluent) Economic and N leach outcomes.

Run no.	**1. Base**	**Run 8**	**Run 9**	**Run 10**	**Run 11**	**Run 12**	**Run 13**
No. Cows	460	250	220	293	260	220	200
kgMS/cow	315	335	337	337	336	334	334
KgN/hatotal	Aug15kgN 200ha	0	0	0	0	0	0
Supplmade	123,000	15,000	34,000				
discard	0	330,000	300,000	600,000	775,000	930,000	1,130,000
Total BIF	20,000	0	0	+0	0	0	0
MSprodn	144,883	84,170	74,070	98,750	87,100	73,450	67,336
Bull sales	**0**	**150**	**180**	0	0	0	0
Date kill	-	22 March	22 March	-	-	-	-
Income($6.40 &$4.35/kgCW)	1,014,050	763,892	698,388	676400	596800	503070	461210
$costs	652,400	404,690	371,531	435110	379450	328202	292600
$Surplus	**361,650**	**359,202**	**326,857**	**241290**	**217350**	**174868**	**168610**
Summer crop area	10ha	0	0	0	0	0	0
R1yr graze off	0	48	0	All	All	0	0
R2yr graze off 12 months	All	45	0	0	0	0	All
Herd graze off 8 weeks	All	None	105	110	80	0	All
N excreted	61,100	52,500	52,500	45000	40000	35000	30000
Total '000 kgDM use	1,991	1,651	1,657	1,392	1,254	1,102	951
N leached kg/Ha~	**27**	**28**	**26**	**24**	**23**	**22**	**16**
		-2448	**-34794**	**-120360**	**-144480**	**-186840**	**-193040**

Farm 2 - Run Data

Farm 2 “Low Intensity” synthesised Dairy Farm. (200ha.)

Table 14: Farm 2. 200ha (160ha + 40 ha “RunOff”/Effluent) Economic and N leach outcomes.

Run no.	**1. Base**	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Run 6**
No. Cows	403	403	365	355	320	300
kgMS/cow	360	360	360	360	360	335
R 2yr replace	93	93	84	82	74	68
KgN/ha	Aug/Dec/ April 40kgN/ha 150ha	0	Dec 15kgN/ha 150ha	0	0	0
kgN/ha	Aug/April 40kgN/ha 40ha effluent	0	April 2x40kg N/ ha 200 ha	April 2x40kgN /ha 200ha	0	0
Supplmade	0	0	0	0	0	0
discard	0	0	0	0	90,000	180,000
Total BIF kgDM	276,000	180,000 11MJME	68,000 11MJME	45,000 11MJME	26,000 11MJME	0
Concentrate 13MJME	5,000	5,000	5,000	9,000	12,000	5,900
MSprodn	144,230	144,230	130,625	127,025	114,525	100,265
$Income	976,410	976,410	884,343	859,940	775,314	681,310
$costs	555,995	569,200	438,506	412,620	382,803	358,750
$Surplus	**420,415**	**407,210**	**445,837**	**447,320**	**392,511**	**322,560**
Summer crop	9ha	9ha	12 ha	12 ha	12 ha	0
Winter crop	9 ha	9 ha	8 ha	3 ha	0	0
R1yr graze off	0	0	0	0	0	0
R2yr graze off	0	0	0	0	0	0
Herd graze off	0	0	0	0	0	0
N excreted	60,545	56,835	56,264	55,382	50,000	47,500
Total ‘000 kgDM use	2,110	2,031	1,861	1,814	1,632	1,516
N leached kg/Ha~	**44**	**36**	**41**	**39**	**30**	**28**

Table 15: Farm 2. LI 200ha (160ha + 40 ha "RunOff"/Effluent) Economic and N leach outcomes.

Run no.	**7**	**8**
No. Cows	253	207
kgMS/cow	360	360
R 2yr replace	58	48
KgN/ha	0	0
kgN/ha	0	0
Supplmade	0	0
discard	465,000	740,000
Total BIF kgDM	0	0
Concentrate 13MJME	0	0
MSprodn	84,630	69,310
$Income	575060	470970
$costs	325,565	281,100
$Surplus	**249,495**	**189,870**
Summer crop	0	0
Winter crop	0	0
R1yr graze off	0	0
R2yr graze off	0	0
Herd graze off	0	0
N excreted	40,000	32,500
Total '000 kgDM use	1283	1052
N leached kg/Ha~	**20**	**17**

Farm 3 : Run Data

Farm 3. MI 200ha (160ha + 40 ha Effluent) Economic and N leach outcomes

Table 16: Farm 2. 200ha (160ha + 40 ha Effluent) Economic and N leach outcomes.

Run no.	**1. Base**	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Run 6**	**Run 7**	**Run 8**
No. Cows	480	440	400	390	385	348	355	345
kgMS/cow	405	405	422	434	446	446	446	446
kgN/ha 160ha	6x30	5x25	5x25	5x25	5x25	0	0	0
kgN/ha 40ha	3x46	0	0	0	0	0	0	0
Supplmade	0	0	0	0	0	0	0	0
discard	0	0	0	0	0	0	0	240000
PKE buy tonne	283	283	144	0	0	0	0	0
Past Sil buy T	250	40	0	0	0	0	0	0
Hay buy T	44	44	0	0	0	0	0	0
concentratesT	21	19.7	7	0	0	0	0	0
MSprodn	194220	178000	169000	169100	171600	155100	158170	153700
$Income	1305330	1196555	1134270	1134250	1149200	1038668	1059350	1029825
$costs	828310	699940	600000	525580	518660	434152	433350	472103
$Surplus	**477020**	**496615**	**534270**	**608670**	**630540**	**604516**	**626000**	**557722**
Summer crop area	11	14	14	14	14	0	0	0
Winter crop	11	11	11	0	0	0	0	
R1yr graze off	0	0	0	0	0	0	0	0
R2yr graze off 12 months	68	68	68	68	68	68	68	68
Herd graze off 8 weeks	0	0	0	0	0	0	All	All
N excreted	64400	60900	57210	56400	56400	51660	52440	48000
Total '000 kgDM use	2314	2103	1902	1853	1853	1683	1712	1458
N leached kg/Ha~	**53**	**47**	**46**	**46**	**43**	**33**	**32**	**31**

Table 17 Farm 3. MI 200ha (160ha + 40 ha “RunOff”/Effluent) Economic and N leach outcomes.

Run no.	**9**	**10**	**11**
No. Cows	296	262	200
kgMS/cow	446	446	446
R 2yr replace	68	60	46
KgN/ha	0	0	0
kgN/ha	0	0	0
Supplmade	0	0	0
discard	439000	643000	838000
Total BIF kgDM	0	0	0
Concentrate 13MJME	0	0	0
MSprodn	132,070	116,970	89,150
$Income	884,430	783,330	597,057
$costs	410,030	382,010	281,610
$Surplus	**474,400**	**401,320**	**315,447**
Summer crop	0	0	0
Winter crop	0	0	0
R1yr graze off	0	0	0
R2yr graze off	All	All	0
Herd graze off	All	All	0
N excreted	40,000	35,000	30,000
Total ‘000 kgDM use	1306	1153	1003
N leached kg/Ha~	**21**	**19**	**21**