GSL DIAGNOSTIC
DRIVING PROFIT THROUGH INNOVATION

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

A Report for

horizons
regional council

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An additional in-depth analysis of Horizons Farms with emphasis and discussion on model structure as related to marginal economics and ability to determine nitrogen abatement costs.

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Peter Fraser.

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Technical Forward

Explanation of marginality and profit maximisation

This report makes extensive reference to marginal analysis - so it is vital the reader has a working understanding of the concepts employed - otherwise large sections of the report will sound - at best - counterintuitive and - at worst - 'just plain wrong'.

A useful starting point is considering a simple 'accounting' view of profit (π), 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:

π **= 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 more 'widget' (i.e. a widget is some type of good or service), whereas 'marginal revenue[1]' is the revenue generated from selling one more widget.

Widgets are made by 'firms' (where a dairy farm is analogous to a firm if the widget in question is milk). 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*'.

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

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

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

A practical example neatly illustrates the theory.

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

Let's assume a hypothetical farm is currently producing 900 kgMS HA (which is a little under the national average). The farmer is therefore considering increasing production; so is targeting 1100 kgMS HA production over the same land area via greater intensification. As planning figures, let's assume:

- Farm gate milk price is $5 kgMS
- Fixed costs (FC) are $4 kgMS
- Variable costs (VC) range from 20 cents to $2.50 kgMS depending on intensity
- Current farm working expenses [FWE] are $4.50 kgMS
- Whilst the farm is currently doing 950 kgMS HA, the possible range is 700 kgMS HA - 1,200 kgMS HA.

The results are summarised in the table below.

Table A: *Hypothetical farm profitability analysis*

KgMS HA	FC $	VC $	AC $	TC per HA $	MC $	TR $	MR $	π per HA $	M π $
700	4.00	0.25	4.25	2975.00	-	3500	-	525.00	-
750	4.00	0.25	4.25	3187.50	212.50	3750	250	562.50	37.50
800	4.00	0.20	4.20	3360.00	172.50	4000	250	640.00	77.50
850	4.00	0.25	4.25	3612.50	**252.50**	4250	**250**	637.50	-2.50
900	4.00	0.30	4.30	3870.00	277.50	4500	250	630.00	-7.50
950	4.00	0.50	4.50	4275.00	**385.00**	4750	**250**	475.00	-155.00
1000	4.00	1.00	5.00	5000.00	725.00	5000	250	0	-475.00
1050	4.00	1.75	5.75	6037.50	1037.50	5250	250	-787.50	-787.50
1100	4.00	2.00	6.00	6600.00	**562.50**	5500	**250**	-1100.00	-212.50
1150	4.00	2.25	6.25	7187.50	587.50	5750	250	-1437.50	-337.50
1200	4.00	6.50	6.50	7800.00	612.50	6000	250	-1800.00	-562.50

Colour code

Profit maximising output

Actual or targeted production

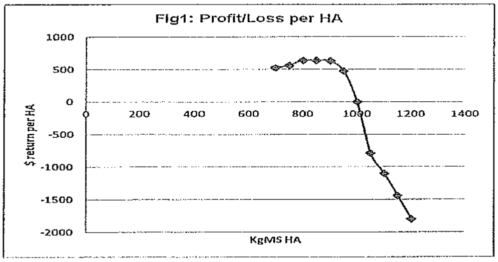
Loss making production

The table illustrates the following:

- At an expected milk price of $5 kgMS, any level of production above 1000 kgMS HA will be unprofitable - so that targeted expansion should be abandoned
- Current production of 950 kgMS HA, whilst profitable, is not optimal - as MC is greater than MR - so the farm will benefit from *reducing* production.
- Profit maximising production is almost exactly 850 kgMS HA, so in this case a 21% drop in production leads to a 34% increase in profitability
- The column denoting profit per HA achieves a maximum before reaching a 'tipping point' and declining; whereas the marginal profit approaches zero at the maximum - and is negative thereafter.

The fundamental problem with an output or production based objective 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 second is a 'parasitic' herd that generates net costs (and thereby <u>*reduces*</u> the profitability of the entire farm).

In the example above, the cows producing the marginal 100 kgMS per HA (between 850 and 950 kgMS HA) are the parasitic herd. Profitability per HA at different production levels is represented in figure 1 (below).



A counter argument is often expressed thus: 'well, that's fine when the milk price is down, but more intensive farms will make plenty of money when the milk price is higher'. As table B shows, this is also flawed thinking. In table B the milk price assumption is increased to $6.00 kgMS but the cost structure remains unchanged. As can be seen:

- the 1100 kgMS production target is now at breakeven (compared to an $1100 HA loss) so is still nowhere near optimal
- the existing 950 kgMS level of production has improved; but is also not optimal - as profit maximisation is closer to 900 kgMS HA (so at 950 kgMS the farmer is just starting to rebuild a parasitic herd)
- A 20% increase in milk price only resulted in only a 6% increase in output from the previous optimum (and a 5% reduction from status quo).

Table B: *Revised farm analysis*

KgMS HA	FC $	VC $	AC $	TC per HA $	MC $	TR $	MR $	π per HA $	M π $
700	4.00	0.25	4.25	2975.00	-	4200	-	1225.00	-
750	4.00	0.25	4.25	3187.50	212.50	4500	300	1312.50	87.50
800	4.00	0.20	4.20	3360.00	172.50	4800	300	1440.00	127.50
850	4.00	0.25	4.25	3612.50	252.50	5100	300	1487.50	47.50
900	4.00	0.30	4.30	3870.00	**277.50**	5400	**300**	1530.00	42.50
950	4.00	0.50	4.50	4275.00	385.00	5700	300	1425.00	-95.00
1000	4.00	1.00	5.00	5000.00	725.00	6000	300	1000.00	-425.00
1050	4.00	1.75	5.75	6037.50	1037.50	6300	300	262.50	-737.50
1100	4.00	2.00	6.00	6600.00	562.50	6600	300	0	-252.50
1150	4.00	2.25	6.25	7187.50	587.50	6900	300	-287.50	-287.50
1200	4.00	6.50	6.50	7800.00	612.50	7200	300	-600.00	-312.50

In reality, it is not possible with a biological system like a farm to obtain the level of precision outlined in the tables - but one can closely approximate. However, very few farmers actually employ any type of profit maximising analysis - and models like Farmax (and the plethora of industry benchmarks) are incapable of profit maximising as they are based on averages, whereas markets clear 'at the margin'. 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.

A further reason why profit maximising analysis is almost never employed is many farmers erroneously assume that higher production must equate to higher profitability - so the result, is essence, is a form of 'output maximisation' ('productionism') rather than profit maximisation.

The productionist assumption of 'more production means more profit' only occurs if there are economies of scale (EoS) where a farm is struggling to achieve minimum efficient scale. In this case average costs are falling - so all a farmer needs to do is keep expanding until average costs stabilise (at which point there are constant returns to scale - or if an additional 20% of resources are added then widget production should likewise increase by 20%).

However, all systems are ultimately bound by diminishing marginal returns (which occurs when at least one input is fixed - so that becomes the system constraint). For example, the number of cows, the amount of fertiliser applied, and volumes of bought in feed (BiF) can all be increased; but 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 2.

Figure 2: NZ Dairy Industry – Scale economies over time

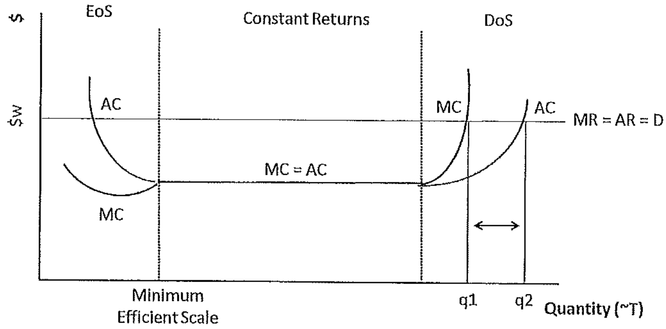


Figure 2 assumes a constant world price for dairy commodities - labelled $w. With a constant price over the production range the result is marginal revenue and average revenue (AR) are identical, and together form the demand curve (labelled D).

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 profit maximisation; but one cannot profit maximise without knowing a farm's marginal cost and marginal revenue.

Overview of GSL and explanation of why it is different

The explanation above regarding diminishing marginal returns, profit maximisation and the concept of a parasitic herd is an excellent segue into understanding how GSL is fundamentally different from other farm models (such as *Farmax* or the *Whole Farm Model*). In simple terms, GSL is an economic model that uses linear programming (LP) techniques[2] to undertake marginal analysis. GSL 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 Y or 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 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 GSL 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 GSL 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 (so are akin to standardised multisite processes such as a McDonald's Restaurant). This assumption is critical 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).

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2 Linear programming is defined as a mathematical technique used in computer modelling (simulation) to find the best possible solution in allocating limited resources. An example of LP is solving the best assignment of 70 people to 70 jobs. The computing power required to test all the permutations to select the best assignment combination is vast; the number of possible configurations exceeds the number of particles in the observable universe. However, it takes only a moment to find the optimum solution by posing the problem as a linear program. The theory behind linear programming it that it drastically reduces the number of possible solutions that must be checked (see: https://en.wikipedia.org/wiki/Linear_programming).

In comparison, GSL can analyse a farm 'as is' to provide a base case that alternative strategies can be considered. For example, in the material that follows for farm 1, run 1 is the base case whereas runs 2 and 3 are the application of existing industry 'wisdom'. This is essentially a standard template or 'cookie-cutter' 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.

In all farms assessed, this approach led to a significant decrease in farm profitability compared to the base case, with a marginal cost of N abatement of up to $1,225 per kg/HA. From a public policy perspective, this implies that N abatement cannot be achieved without imposing significant economic harm on farmers.

In comparison, in runs 4-7 the templated prescription is progressively abandoned and other resource options are considered (i.e. grazing off, reducing stock numbers, optimising stock numbers) - albeit within the overall objective of profit maximisation.

In stark contrast with runs 2 and 3, resource re-allocation via GSL not only significantly reduced 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 had an N 'tipping point' where further reductions made the farm in question economically infeasible.

The public policy implications of these findings are also stark: compared to status quo is it 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* (implying a Pareto-safe policy outcome - and positioning farmers for any future move to bring agriculture in the emissions trading scheme [ETS]).

However, for a Pareto safe outcome to occur each farmer needs to know what his or her base case is, and what are the specific combination of changes necessary 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 (via grand parented allocations providing a 'license to pollute') whilst at the same time penalising efficient farmers (who would get comparatively small allocations) whilst rewarding gross polluters (who would get large allocations).

Summary

Executive Summary

1. 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.

2. The starting point matters - in that all farms surveyed were overstocked so are therefore carrying a 'parasitic herd'. The difference in outcome between industry approaches and GSL is simply that GSL 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 a key part of the desired abatement range.

3. Based on five case studies of dairy farms 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 - though beyond certain levels a 'tipping point' emerged where further N reductions made the farm financially unviable (NB: these findings are entirely consistent with GSL analysis generally).

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.

- 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 GSL based on profit maximisation).
    - Current industry recommendations for reducing N may reduce N leach but reduce profit (Refer Tables 1A and 1B Farm 1 analyses; 72 ha).
    - GSL model resource allocation progressively reduces N leaching with least impact on profit (Compare model Runs Farm 1 Runs B-H).
    - Reducing herd number, grazing off and no winter cropping provide the best options if available and acceptable.
        - Acceptability may not be a factor for some of the farms as they 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 (Example Farm 4.).

- Several of these farms have intensified (or plan to intensify) and will incur large decreases in overall profit and increased N leaching. These increases are possible due to soil and rainfall interacting "favourably" with Overseer criteria (Farms 2 and 3).

  - Much of the decrease in profit is 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 costs associated with intensification.
  - Use of marginal analysis may have prevented this level of intensification where in one case, almost $3.5 million of added capital has been spent for a net increase of about 50,000kgMS (about $70/kg additional MS.)

    A better investment may have been to buy more land.

  - Such intensification is not only unprofitable, it also increases Nitrates to soil.

- 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 (Appendices 3, 4 and 5 provide the means for understanding this concept) 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.

- A more co-ordinated National approach that encompasses N leaching "bands" and associated CO_2 emissions combined with specific resource input taxes (bought in feeds, fertilisers, additional fuel) will penalise the less efficient producers proportionately more than efficient producers, create an overall more profitable agricultural industry and provide funds for the environmental improvement now required.

Five farms were selected from a short list of dairy farms in the Horizons Regional Council area which provide insight of these points.

Project Objectives

Service description: Overview

The work is to understand feasibility of nutrient leaching reduction (N leaching), by modelling a small sample of farms' responses to different system changes and changes in assumptions (e.g. 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 5 case 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.

Conclusions

The Opening Summary lists the important points.

- Sensitivity analysis indicates that the "optimal" resource use and $surplus provided by these farms at current $4.50/kgMS and input prices will prevail until a price of over $7 /kg MS is paid.
- This depends on the production of milk-solids per cow achieved. Higher per cow production and efficient management in terms of cost structures allows better profits and may allow use of BIF at about $7.
- The marginal benefit from BIF even at this price will be small and may not warrant the extra risk and management expertise.
- Emphasis must go back to profitable farming. This will involve efficient resource use which will reduce inputs and in turn reduce detrimental environmental legacies.
- Farmers need reassurance that pasture farming is not difficult but also may not always appear "perfect" in terms of perception of what pastures should look like at all times.

For any "message" to be understood well enough to be implemented requires farmers to participate in, not just "perceive" what is being put forward. The same applies to those who are making rules. Those rules need to be carefully thought through after all avenues of knowledge have been investigated. This may seem to make the conclusions that can then be taken from such work, a simple exercise.

The problem with this however is that often maligned quote offered by Donald Rumsfeld: "There are known knowns. These are things we know that we know. There are known unknowns. That is to say, there are things that we know we don't know. But there are also unknown unknowns. These are things we don't know we don't know". Donald Rumsfeld.

This report has conducted analyses, some simple and some very complex, in order to expand the knowledge on what the outcomes may be from making resource allocation changes to complex systems. However the final analysis relies on Overseer which is a computer model that deals more with 'known knowns' but is used to make decisions on what are still at best known unknowns, but that also include unknown unknowns. The data used within Overseer® is merely an averaged snapshot of what a particular farm system may have resembled at one point in time. The subsequent calculations then rely upon ratios and extrapolations to provide a guide to future outcomes.

The GSL model provides the opportunity to delve deeper into what, how and why each resource contributes to a farm system and to provide a range of outcomes. These outcomes are dependent upon the relationships and resource constraints that may apply. The GSL model itself may choose pathways and resources that simpler input/output model (I/O models) are incapable of detecting. I/O provides a single option whose parameters require to be changed each time a new solution is sought. Even the "optimisation" routine in such models is limited.

The iterations undertaken as the final step Linear Programming by the GSL model ensures the best resource allocation will emerge from the large range of options offered from the initial data functions. Both specified input and output constraints can be used to ensure logical progression of outcomes towards a specified goal. In this project's case, this was to find the best economic solutions to decreasing N leach.

The GSL model is therefore capable of pushing past perception and providing deeper understanding of what may be possible. This is getting to know what the unknowns may look and perform like. But this still leaves the unknown of how best to firstly present such new concepts and ideas and secondly how to manage our way through that change.

The good news is that New Zealand farming was very close to managing the changes required in the years from 1958 (McMeekan: From Grass to Milk) to about 1986 when the "more production through intensification" wave began.

The past four to five years, management at the Lincoln University Dairy Farm combined with the work by Chris Glassey of DairyNZ should be reviving this simplification; but that work does not yet include the production economics backing to clinch the argument (despite GSL being used to initiate the 2011 changes at LUDF).

Useful references include:

- Pellow, R; Lee, S; Metherell, A; McCallum, R; Moir, J; Roberts, A; Wheeler, D. 2015: Assessing the impact of input choices within Overseer ® (V6) on the modelled N losses to water for Lincoln University Dairy Farm (LUDF) *Occasional Report No. 26.* Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand.
- Glassey, C.B; Roach, C.G.; Lee, J.M; Clark, D.A. 2013: The impact of farming without nitrogen fertiliser for ten years on pasture yield and composition, milksolids production and profitability; a research farmlet comparison. *Proceedings of the New Zealand Grasslands Association* **75**: 71-78.
- Glassey, C.B.; Pinxterhuis, I. 2015: Nutrient Management. Stocking rate: more is not always better. Presentation by DairyNZ., Hamilton, NZ. *Pers comm.*

This report attempts to tie this (economics, implementation, environment) together with an emphasis on reducing N leach at least cost while providing a number of "asides" to examine and explain why many of the current perceptions about production, efficiency and economics are not fallacious. An additional message is that by presuming some of the 'known unknowns', regulations should not be enforcing rules that condemn efficient farmers to relinquish farming while inefficient farmers continue to waste resources.

Appendices

Three graphs to illustrate intensification of pasture systems:

Figure 1 All pasture self contained

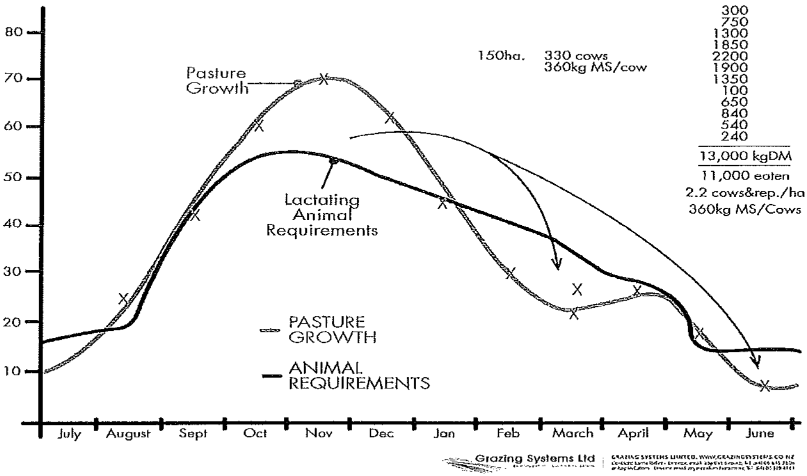


Figure 2 Increased intensification. Now more feed required (blue line) than basic farm pasture growth (green line) can produce so buy in feeds for much of year.

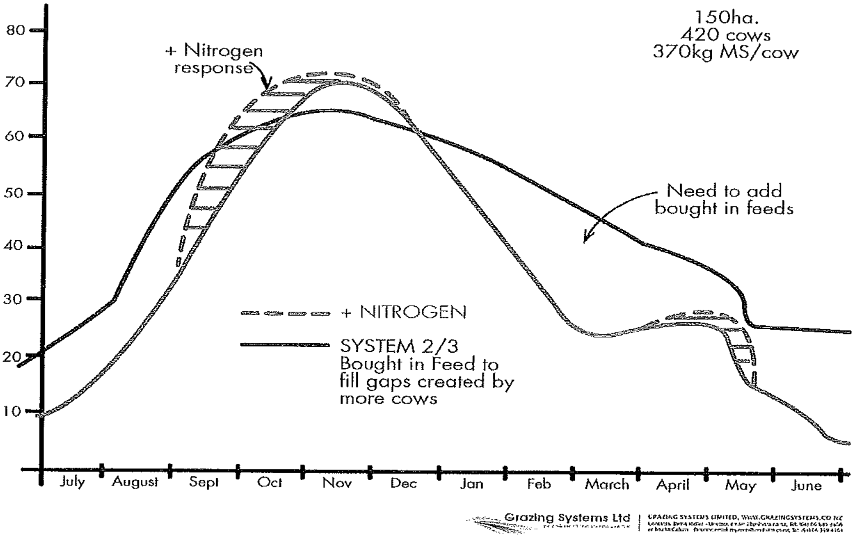
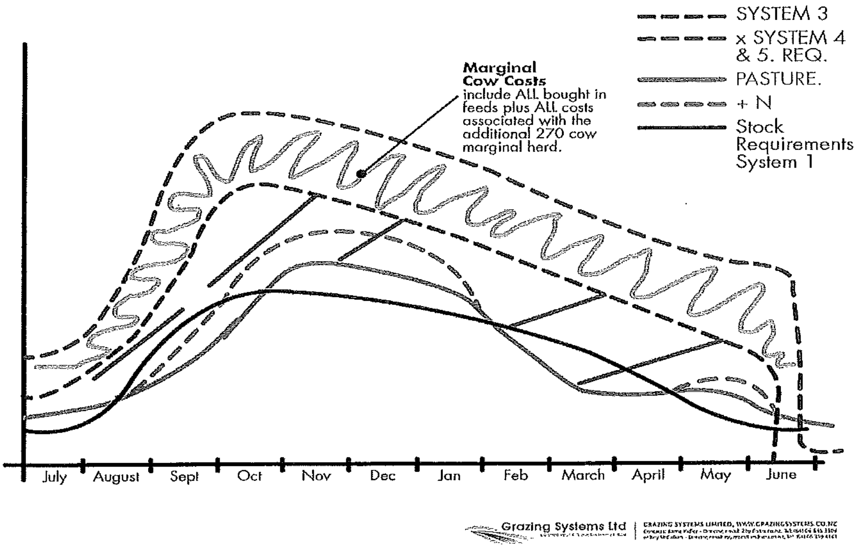


Figure 3 Now intensified and 600 cows at higher MS per cow require bought in feeds (BIF) throughout the full year.



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.

REQUIREMENTS FOR

450kg LW COW (No replacement added.)

If 25% replacements add about + 1080kgDM / cow

Maintenance 2,500kg 11MJME D.M.	250kgMS +1500 kgDM	300kgMS	350kgMS	400kgMS	450kgMS

250kgMS requires 4,000kgDM
16kgDM / kgMS

300kgMS 4,300kgDM
14.3kgDM / kgMS

350kgMS 4,600kgDM
13.2kgDM / kgMS

400kgMS 4,900kgDM
12.3kgDM / kgMS

450kgMS 5,200kgDM