An Economic Evaluation of High Nitrogen Fertiliser Rates at Limestone Downs

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Contents

Executive Summary

Increased nitrogen application has potential to achieve "step change" in forage production and productivity of hill country properties. This paper reports the results of a financial evaluation of high rates of nitrogen at Limestone Downs where the farms management have experienced difficulty in meeting sheep and cattle feed requirements in late winter and spring.

High rates of nitrogen (250kg N/ha in split dressings) were applied from June to September and pasture responses measured by Agresearch®. In the first year of the study large (19 kg DM/kg N) responses were achieved to applied N, and in the second year 11 kg DM/kg N within 90 days of application.

The financial performance of the system was evaluated by monitoring of the whole farm system using the simulation model Stockpol®. Evaluations were completed across a four-year period, including two years prior to the application of high nitrogen rates, the transition year and for the new farm system operating at a sustainable level.

Changes to the farm system increased feed demand in late winter and early spring to coincide with the period of increased forage production. Increases in sheep meat and beef production of approximately 10% were achieved. The annual benefit was $46,000, an increase in the annual property gross margin of only 3%, but a return on additional nitrogen expenditure of approximately 30%. The financial response was reduced by the margins on cattle in the adjusted trading system and might be conservative.

The evaluation confirms that large increases in hill farm production are possible as a result of increased N fertiliser application. As a consequence increased nitrogen fertiliser use appears to be a likely strategy for hill farmers to increase profitability. However, significant changes to the farm system are required in order to utilise additional feed and without this improved profitability cannot be assured. Variability in the pasture response to nitrogen and management systems to cope with this variation and to manage environmental risks warrants further investigation.

1.0 Introduction

Increased nitrogen fertiliser usage by sheep and beef cattle farmers has been identified as having the potential to significantly increase the production potential of hill farms, Lambert et al 2003. Whereas nitrogen fertliser has historically been used tactically to meet temporary feed deficits arising through seasonal variation in pasture supply, farmers are now contemplating large-scale strategic applications to increase forage production on an annual basis.

Whilst the potential to increase forage production has been measured in a range of situations, the profitability of whole farm systems dependent upon strategic nitrogen applications has not been well defined. For example, Lambert et al (2005) report the results of an economic evaluation on Manawatu Hill Country but results looked only at stocking rates in spring and the ability of the system to support proposed stocking rates year round was not considered. Gillingham et al (2004) calculated economic returns to a long-term field trial on dry hill country but notes that results may differ for other conditions.

This paper presents the results of an economic evaluation of high nitrogen fertiliser rates at Limestone Downs Station in the Western Waikato. The properties management has experienced difficulty in meeting animal feed requirements in late winter and early springy and had identified nitrogen fertiliser as a potential means of meeting this feed deficit to achieve earlier sale dates and improve utilisation of late spring pasture growth.

1.1 Nitrogen in New Zealand Grazing systems

Pasture plants require more nitrogen (N) for growth than any other nutrient. For example McNaught (1969) calculated that a mixed grass clover pasture yielding 10,000 kg DM/ha has an annual nutrient requirement of 450 kg of N but only 57 kg phosphorus and 39 kg sulphur.

Not only do pasture systems require more N but the recycling of N through the farm system is less efficient than for other nutrients. This is because nitrogen becomes concentrated in urine in a water-soluble form that is susceptible to losses via leaching and volatilisation.

1.2 The nitrogen cycle

The nitrogen cycle describes the storage and transfer of nitrogen in its various forms within the soil. An understanding of this cycle is useful in developing systems that rely on fertiliser nitrogen.

Unimproved soils contain relatively little nitrogen but under grazing conditions the concentration of nitrogen in topsoil accumulates to high levels. The largest N component is in soil organic matter, Jackman(1964) estimated between 7660 and 16,140 kg N/ha in the top 29 cm of soil, depending upon the soil and environmental conditions. Some 2-3% of this pool is mineralised annually, however this generally meets less than half of the N requirement of grass swards for maximum production (Carran, 1978).

Rhizobia in nodules on the roots of legumes fix atmospheric nitrogen that is utilised for growth in the host plant. Hoglund et al (1979) measured annual nitrogen fixation under rotational sheep grazing at between 107 to 380 kg N/ha. This nitrogen is transferred to companion grasses in two main ways; firstly, grazing and return as dung and urine is the major source N transfer as only a small proportion of nitrogen consumed is retained in the animal, (finishing animals typically retain only 5%)

whereas estimates of the concentration of N in urine are very high, the equivalent of 484 kg N/ha and 970 kg N/ha of fertiliser nitrogen for sheep and cattle respectively and secondly, through decay of nodules and root tissue and the senescence of legume herbage not consumed by stock. This is an important means of N transfer between clovers and soil N and estimates of underground transfer typically range from 60 to 100 kg N/ha/year Walker et al (1954) and Sears et al (1953).

Nitrogen in plant material or dung is broken down by soil microorganisms and incorporated in the soil organic matter (organic N). By contrast urine contains ammonia and urea that are immediately available to plants.

1.3 Seasonal variations in Nitrogen cycling and availability

Provided other conditions for growth are suitable legumes will fix nitrogen when soil nitrogen is insufficient to meet their needs. N fixation efficiency tends to be high in late winter and early spring, when soil mineralisation is low and when grasses that have initiated their growth earlier have a competitive advantage over legumes in the uptake of nitrogen (Jackman and Mouat, 1972).

In summer soil mineral nitrogen will often accumulate when soil moisture limits grass growth, and clovers will often meet their requirements from soil mineral nitrogen. Autumn conditions will vary depending upon rainfall and soil moisture. Where organic matter has accumulated then available soil nitrogen may be utilised by microorganisms as they digest accumulated organic matter following autumn rains. This N is subsequently released when the available food source is utilised and the microbial population dies back to equilibrium releasing accumulated N and creating an "autumn flush" of pasture growth. A transition to spring conditions then occurs over winter as surplus N is utilised.

2.0 Pasture responses to applied nitrogen

A large number of nitrogen response trials have been conducted to determine the efficiency of response to applied nitrogen. O'Connor(1981) reports the results of 405 experiments conducted in autumn and spring at various sites across NZ. Points arising from these experiments were.

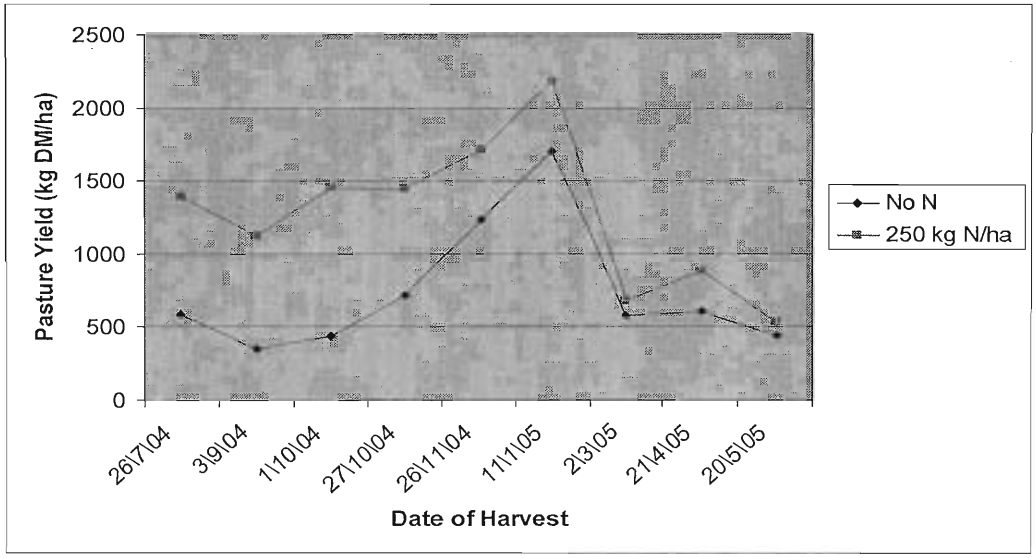
1. As the rate of application increased from 25 to 100 kg N/ha the efficiency of response decreased.
2. Responses in spring were larger and more consistent than responses in autumn reflecting the seasonal variations in soil mineral nitrogen,
3. As pasture growth rate increased the efficiency of response increased.
4. As pasture growth rate increased the duration of response decreased, that is the response was achieved more quickly.
5. There were large regional differences in response. These were believed to occur as a result of local climatic conditions.
6. Changes in botanical composition in response to nitrogen application were measured as the percentage of total yield. Results showed the total yield of clover did not necessarily decrease but typically reduced as a percentage as the proportion of ryegrass increased.

Ball et al (1981) summarise nitrogen response studies on New Zealand hill country. They report responses variables that show a similar pattern to flat land sites, but responses are often larger and persist longer, particularly under grazing. These larger responses are thought to be due to the more chronic level of nitrogen deficiency on many hill soils.

2.1 Limestone Downs 2004/05

Pasture responses to Nitrogen applications over winter and early spring were measured at Limestone Downs in the Western Waikato. AgResearch were contracted to measure pasture production and nitrate leaching arising from the application of 250 kg N/ha applied in autumn and late winter and the results reported by Burgraff and Lambert (2005). The applications were to an area of coastal hill country, but monitoring areas were generally typical of the range of contours present on the farm. Pasture production results are summarised in Figure 1.

Figure 1: Pasture growth with and without N fertiliser application



At Limestone Downs, 100kg N/ha (as urea) was applied by plane (using GIS/GPS technology) to around 500 ha of the farm in early June (9th) and a further 150 kg N/ha was applied on August 10th 2004. Three large representative paddocks in the same area of the farm were left as control paddocks and received no N. An additional 4.7 tonnes DM/ha was grown from June 04 to May 05 where N had been applied, relative to the Control paddocks (Figure 1). This equates to an average efficiency of response of 19 kg DM/kg N applied. The marginal cost of producing the extra feed was 5.8 c/kg DM, as the applied cost of the fertiliser was $1.10/kg N.

Very small responses continued to be recorded until May of the following year, with 4kg DM/kg N being recorded after November. Thus 15 kg DM/kg N was received during the main period of spring fed deficit.

Reponses were greatest on easy versus steep slopes and on Northerly versus Southerly aspects. There were no significant changes to botanical composition (grass versus clover).

The responses measured here are similar to those reported by Lambert et al (2003) of 18 to 22 kg DM/kg N on hill country at Ballantrae in Southern Hawkes Bay. These responses were measured over two years to annual applications of 400 kg N/ha annually as eight split dressings of 50 kgN/ha.

The application of N fertiliser at Limestone Downs increased N leaching from 13 to 42 kg N/ha and while this is a considerable increase much of this will be due to the fact that the 500ha was grazed by a high proportion of cattle. These losses are still

considerably lower than the 30 and 65 kg N/ha measured under Waikato dairy pastures stocked at 3.3 cows/ha with 0 and 200 kg N/ha applied respectively.

2.2 Limestone Downs 2005/06

Pasture monitoring continued in 2005 following applications of 100 kg N as Urea in June and August to the monitored area. Responses to 30 October are summarised in table 1.

Table 1 Pasture responses to nitrogen 2005

Date of cut	8/7	1/8	13/9	19/10	14/11
Response kg DM/kg N	3.0	5.3	6.7	9.0	10.3
Growth of N paddocks	1265	611	1319	1554	1318
Growth non N paddocks	961	382	507	1273	1050

The rate of response in the first 60 days of application was lower than in year 1. Whilst continued pasture cuts were to be made beyond the period reported here a reduced total level of response was expected. In addition any further response would fall outside of the main feed deficit period. The absence of any rate trials means that it is not possible to determine if the system might have been saturated with N and an equivalent response might have been achieved to a lower rate.

3.0 Method of economic evaluation

Despite the desirability of conducting farm-based trials these impose a number of limitations on a commercial property. The potential for experimental bias means that a number of replicates need to established greatly increasing the resources required and trials need to extend for several years to measure all the potential forms of improvement arising from a pasture response to nitrogen e.g. carry over effects of ewe live weight.

Pasture responses to applied nitrogen can be extrapolated through the use of feed budgets to predict the benefits to applied nitrogen to determine the economic and management implications. In this situation the impact of nitrogen is determined by monitoring the performance of the farm over time. The main limitation is that there is no scientific control against which the new system can be measured. The response is measured against the estimated performance of the property in the absence of nitrogen. This creates the potential for experimental bias in that factors other than the application of nitrogen may have occurred between years that would influence the results.

The benefits of the modelling approach are that pasture response data can be extrapolated to a whole farm situation more quickly and that a range of past present and future scenarios may be evaluated. For these reasons, this is the method adopted in the present investigation.

3.1 The case farm

Limestone Downs is a large-scale sheep and beef cattle farm situated in the Franklin District some 10 km South of Port Waikato. The property has been in common ownership since 1929 and since 1981 has been farmed with the objective of applying intensive management techniques to the management of a large property. The farm is considered to be "well developed" by hill country standards.

The property comprises a grazing area of approximately 2700 ha in mixed grass and white clover pasture. Contour is generally easy to medium hill country with some steeper slopes. Annual rainfall is 1100 mm and is generally well distributed but is

subject to dry summers and wet winters. Ten cm soil temperatures average 18 C in summer and 8 C in winter.

Soils are predominantly Mairoa ash over Limestone and buried mudstone subsoil. The ash influence generally declines with increasing contour where the ash mantle has been subject to erosion. Average five year soil tests are summarised below:

	pH	P	K	S
5 year average	5.7	20	15	6

These results are in the optimum economic range as defined by the "Sapphire" model used by Ravensdown Fertiliser Co-operative staff. At this level maintenance applications of major nutrients; phosphate, sulphur, and Lime (calcium) are recommended to maintain soil fertility levels.

Coinciding with the new farm policy an all weather airstrip was installed to allow nitrogen to be applied at any time.

3.2 Livestock and production

Livestock wintered on the property since 2002 are detailed in the following table.

	Pre nitrogen		**Post nitrogen**	
	2002	**2003**	**2004**	**2005**
Ewes	11119	9253	9959	8841
2 tooth ewes	3712	3659	3204	3929
Ewe Hoggets	1794	2123		
Mated ewe hoggets	2000	3000	5777	6341
Other sheep	351	586	398	496
Total sheep	**18976**	**18621**	**19338**	**19607**
Autumn born calves				343
R 2yr steers	294	303	297	250
R 1yr Steers	304	297	259	260
R 2yr bulls	231	287	236	210
R 1yr bulls Spr	794	690	315	
R 1yr bulls Aut	235	335	698	1037
Total	**1861**	**1934**	**2003**	**2122**

3.3 Policy description

The current livestock policies employed on the farm are;

The Sheep policy breeding ewes lambing from early August, female replacements are bred and non-replacement lambs sold prime and store from weaning till mating. Male lambs are sold either store or finished for slaughter. Replacement lambs are mated as hoggets at 8-9m months and lamb from mid September. Sheep breed is a Romney East Friesian composite.

Cattle policy is purchasing Friesian bulls calves at 3-4 months of age form June till September and farming them to slaughter at 15-20 months. In addition Autumn born Friesian X Hereford steers calves are purchased and sold at 24-36 months.

Changes in the farm policy that occurred in response to increased nitrogen application were:

1. Ewe hoggets replacements numbers increased and all ewe hoggets mated.
2. Lambing potential had been increased through the introduction of exotic sheep breeds (predominantly East Friesian and Finn).

3. The purchase of 100 kg Autumn born bull calves from June to September as opposed to spring born calves from November to January.
4. The purchase of Autumn born steer calves from June to September as opposed to Spring born calves in November/December. 2 year steers were previously sold store in early spring to alleviate a feed deficit.
5. Ewe live weight and lamb weaning weight have increased.

The effect of these policy changes is to increase pasture demand over winter and spring as a result of the earlier purchase of replacement bull and steer calves and the higher live weight of these animals the following year. Sheep feed demand has increased with higher lambing percentage and mating additional ewe hoggets, previously mated as 2 tooths.

3.4 Evaluation of high nitrogen policy

The economic impact of the nitrogen application has been evaluated by monitoring the performance of the whole farm system. Response variables and measurement were as follows:

1. Pasture cover is measured monthly using a rising plate meter.
2. The live weight profile of replacement stock was derived from farm data. The weights are estimated monthly by the farm manager and verified periodically by sample weights. Sale weights are from meat packer carcass weights or liveweights for store stock.
3. Nitrogen responses were based on measurements by AgResearch®.

This data was used to model the farm system using Stockpol ®. Stockpol® is a simulation model of a pasture based sheep and cattle farm developed by New Zealand Agresearch® and operated on a personal computer(PC). Within the program Animal liveweights and production variables are entered monthly. This data is then used to determine feed consumption, and together with changes in average pasture cover is able to determine pasture growth. Financial benefits are measured as gross margins that assume costs other than animal health, nitrogen and feed costs are fixed and charge for interest on capital in livestock. All models were based on a June to June year to coincide with the financial year of the farm and to provide separation between the pre and post nitrogen systems.

3.5 Stockpol® analysis

This chapter provides a discussion of the models that were constructed and their performance. The stockpo®l model was established for the farm using historical data of production levels and pasture covers. Four models describing the actual performance of the farm over the period July 2002 to June 2006 were constructed as follows:

1. 2002/03 model of the pre nitrogen production system, "03actual"
2. 2003/04 model of the pre nitrogen production system, "04actual"
3. 2004/05 model of the high N (N+) system using actual farm data and N response data from field plots, "05actualN".
4. 2005/06 model of the high N system. This model uses actual data to October 2005 and is then estimated.

3.6 Discussion of models of actual farm system

The annual pattern of feed demand and average pasture cover arising from these four models is depicted in Figures 2 and 3. The first two years show the performance of the farm prior to high nitrogen input and then two years following adoption of the high nitrogen regime.

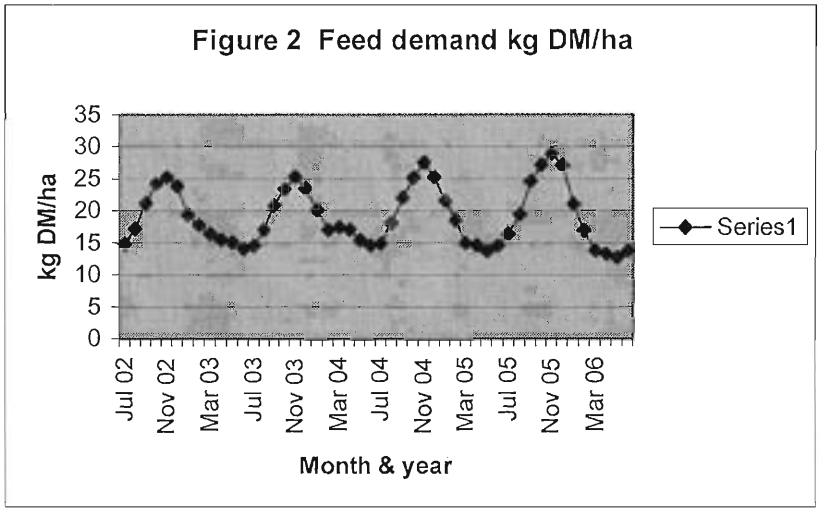
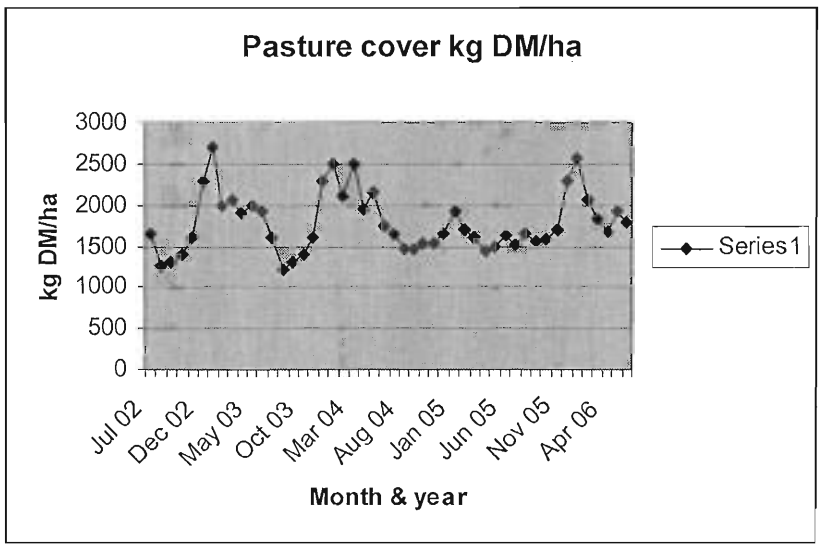


Figure 2 shows the increased pattern of feed demand (consumption) from July through January arising from the adjusted livestock policy. Earlier sale of non replacement stock reduces feed demand in autumn and early winter. Earlier purchase of replacement stock and higher performance increases demand from late winter to early summer.

Pasture cover across the four year period is shown in figure3. Observations arising from this are:

1. In the first two years (July 2002 through June 2004) pasture cover drops below 1500 kg DM/ha for an extended period in late winter and early spring and is a constraint to stock performance.



2. A feed surplus occurs following weaning in mid to late November, when pasture cover exceeds 2500 kg DM/ha.
3. The first two years show a relatively consistent pattern of pasture cover and performance. The "spike" in March 04 coincides with an exceptional rainfall event that affected most of the North Island.

4. The period from July 2004 through June 2006 represents the period of high nitrogen application. Nitrogen application maintains pasture cover at a higher level over winter, despite the higher feed demand.
5. The size of the pasture surplus in spring is reduced. However, pasture growth rates without nitrogen were lower in the spring of 2004 than for the two preceding years.
6. Pasture cover declines more rapidly in autumn because of the higher feed demand and greater utilisation of the spring pasture surplus.
7. Although not shown in the figure the model predicts that pasture quality over spring will improve as a result of higher pasture utilisation.

3.7 Long term comparison of high and low nitrogen systems

In this section models of the farm system have been constructed in the "long term mode" of the Stockpol® to depict a sustainable farm system where stock numbers and production remain constant, for both the high and low nitrogen policies. In this mode the program ensures that the opening and closing pasture covers are adequate to maintain farm performance from year to year.

The low nitrogen system has been prepared based on the stock numbers and performance of 03actual and 04actual models. The high nitrogen system represents a continuation of the system established in the 2004/05 and 2005/06 seasons. Both models assume the same base pasture growth rates as derived from the 03actual and 04actual models. In this way any difference in pasture growth is a result of either; nitrogen application or differences in pasture growth arising from differences in pasture cover as calculated by the model (these were generally small).

Average stock numbers used in the comparison are as follows:

	SQ N-	**SQ N+**
Ewes	9800	9000
2 tooth ewes	3702	4357
Ewe Hoggets		
Mated ewe hoggets	5345	6000
Other sheep		
Total sheep	**18847**	**19357**
Autumn born calves		330*
R 2yr autumn steers		320
R 1yr autumn Steers		315
R 2yr spring born steers	315	
R 1yr spring born steers	320	
R 2yr bulls	297	
R 1yr bulls spr	700	
R 1yr bulls Aut		1050
Total	**1896**	**2035**

* autumn born calves are only on the farm for 10-30 day prior to 30 June.

The comparison is based on the following assumptions:

1. Stock numbers and policies as above.
2. Lambing percentage was derived for the high N policy by developing an equilibrium ewe liveweight and then applying the farms average lamb scanning index (3.0) and survival index (2.5) to this. This derived a lambing % on average 8% higher than for the no nitrogen model. This seemed to be consistent with observed results in the 2005/06 sample scanning where

results were 8% ahead of the previous year. By comparison anecdotal evidence suggests other local properties were lower following a dry autumn affecting mating weights.

3. Cattle performance was based on actual performance in the 2004/05 year and year to date performance for the 2005/06 season.
4. Liveweight gains were adjusted to utilise available feed.
5. An average nitrogen response of 10kg DM/kg N for all applications and a response duration of 90 days.

3.9 Results

Detailed summaries of the output of the two models are included in the appendix. A comparison of the pasture cover profiles and livestock feed demand of the alternative systems is depicted in figures 4 and 5 below.

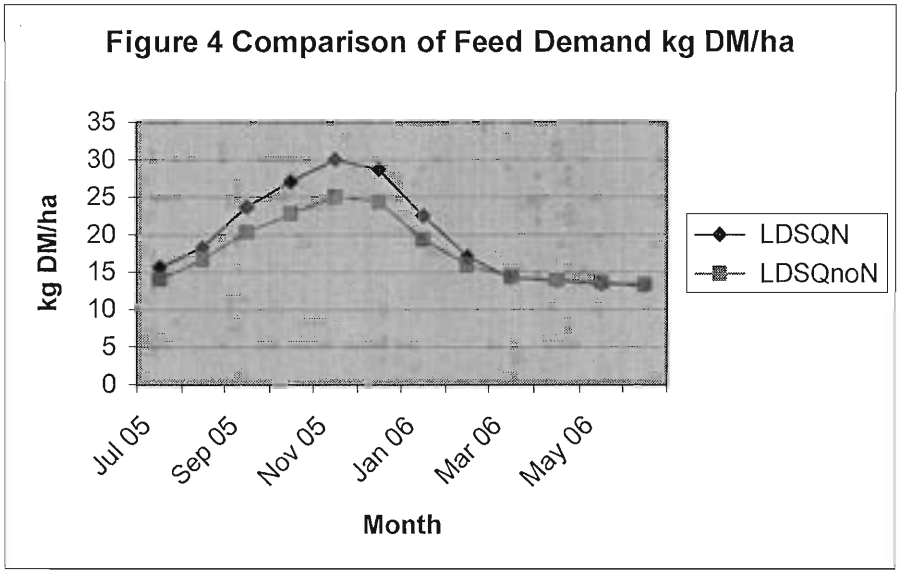
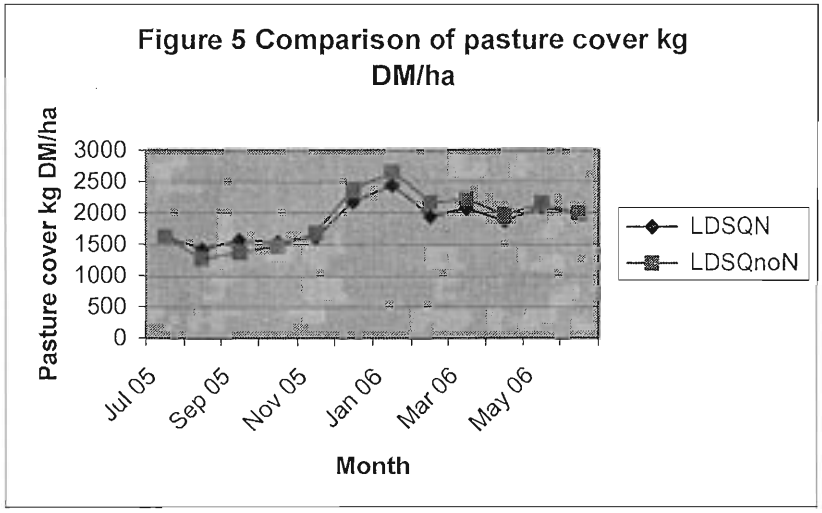


Figure 4 shows the higher feed demand of the N system from June till February. This demand coincides with; the earlier purchase of replacement calves; farming of adult cattle that are six months older and heavier; and, the higher lambing percentage and liveweight of ewes in spring.



A comparison of pasture cover in figure 4 shows that despite the higher feed demand, nitrogen application in June and August maintains pasture cover at a higher level over winter and early spring. The higher feed demand then achieves higher utilisation of the late spring pasture surplus. Higher pasture utilisation in spring leads to a lower pasture cover being carried into summer and autumn with associated pasture quality benefits.

A comparison of financial performance is shown in table 2. Points arising from this comparison are:

1. The Stockpol analysis shows a 90,000 kg increase in sheep liveweight production. This is associated with an increase in income of 17%.
2. Net cattle liveweight production also increases by approximately 90,000kg. However, this results in an increase in revenue of only 3%. Closer analysis suggests that this is a result of an increase in the relative cost of replacement autumn born calves.
3. The gross margin increase is $48,916. This assumes no other increases in fixed costs, which is consistent with observations on farm.
4. There is additional nitrogen application of 109,059 kg. The break-even cost of this additional nitrogen is $1.73 per kg N. The current cost used in the model is $1.29/kg N applied.
5. An increased response of 1kg DM/kg N would improve profitability by $12,800 assuming that a reduced amount of nitrogen could be applied.
6. Pasture production increased by 460 kg DM/ha in response to nitrogen application. Feed consumption increased by 728 kg DM/ha. This was possible because more of the spring pasture surplus was able to be consumed.

Table 3 Comparison of financial returns

			LDSQnoN	LDSQN	Difference
Net production sheep kg liveweight			672995	763315	90320
Revenue	Sheep	Sales - Purchases	949970	1114366	164396
		Wool	252987	273631	20644
		Capital Value Change			0
		Total Sheep	1203415	1387908	184493
Net production cattle kg liveweight			555803	641974	86171
	Beef	Sales - Purchases	570855	589357	18502
		Capital Value Change			
		Total Beef	570855	589357	18502
	Total Revenue		1774270	1977266	202996
Expenditure	Crop & Feed	Nitrogen	58050	198737	140687
		Total Crop & Feed	58050	198737	140687
	Stock Costs	Animal Health	121197	118500	-2697
		Shearing	139242	136515	-2727
		Total Stock Costs	260439	255015	-5424
	Interest on Capital		226085	245226	19141
	Total Expenditure		544574	698979	154405
Gross Margin			1229696	1278287	48591
Gross Margin / ha			496	516	20

3.10 Discussion

High rates of nitrogen application resulted in large but variable pasture growth responses between years. Significant changes to the farming system were made to harvest the additional feed produced. These changes increased stocking rate and feed demand in late winter and early spring, coinciding with the period of increased feed production from nitrogen. Nitrogen application allowed pasture cover to be maintained at a higher level during this period and supported higher levels of animal performance.

The carry over of livestock from one season to the next meant that the changes to the farm system took some time to implement. This transition will continue beyond the two-year period of analysis because of the ongoing impact of replacement ewe hogget and ewe liveweights on the performance of the flock.

Higher utilisation of late spring pasture surplus led to a lower pasture cover being carried into summer and improved pasture quality. Early sale of non-replacement stock meant that "finishing" these animals was less exposed to variability in summer pasture growth rates.

Despite the nitrogen system producing quite large increases in cattle liveweight production these were not fully reflected in profitability. This was because the higher cost of autumn born calves was not adequately compensated by the price premium for selling stock earlier in the production season as 18-20 month animals. This highlights the difficulty in developing systems that profitably utilise additional feed. Despite this management were satisfied with the benefits and believed that the model may underestimate the price differential between spring and summer prices (and this will vary between seasons).

Where farmers use nitrogen in a tactical manner to fill temporary feed deficits then it is possible to use a marginal cost approach. For example, from feed tables it can be

calculated that increasing the average daily liveweight gain for a 300 kg steer from 0.25 kg LWG to 0.5 kg LWG per day will increase the daily feed requirement from 4.8 kg DM/day to 5.7 kg DM/day, thus the feed conversion efficiency increases from 19.2 kg DM/kg LWG to 11.4 kg DM/kg LWG. Utilising additional feed to increase production from existing stock will generally be the most efficient method of increasing production and probably confirms why many farmers utilise it in this manner. In the present study most of the increase in output was achieved by increasing per head performance as opposed to increasing stocking rate. This would be expected to improve the economic returns.

On sheep and cattle farms nitrogen is often applied to meet specific feed deficits, for example, ewes post lambing. In these situations timing can be critical to provide feed for the targeted stock class. By contrast systems that depend upon high rates of nitrogen produce feed consumed by a wider range of livestock classes over a longer period. In these situations applications should be made early to ensure that the required feed is available.

Dependence on nitrogen requires a reliable means of application. On hill country this requires access to an all weather airstrip or preparedness to use helicopter application. Although the later will often significantly increase application costs.

One of the key management difficulty arising from this investigation is the variability in the pasture response to N. From the Limestone Downs data and from earlier research factors that would improve the pasture response to nitrogen are:

1. Application to a larger area at a lower rate.
2. Application to more northerly aspects.
3. Application to easier contoured areas.

Application to a larger area would also be expected to reduce the potential for nitrate leaching. The application of smaller amounts more often may increase the reliability of response, but also increases the costs of application. There is the added difficulty that it is not possible to determine the level of response until some time after application.

Production systems that are able to cope with variation in the pasture response to N should be considered when developing nitrogen dependent systems. These are likely to include a higher component of trading stock. Trading stock allow feed demand to be varied by adjusting the time of sale. Breeding stock sales will often need to be managed around breeding activities particularly in the spring when calving and lambing occurs.

The results of this investigation suggest that at present levels of economic return hill farmers will make increasing use of applied N. Management practices to protect the environment from potential harmful effects of additional nitrogen should therefore be investigated and codes of practice developed for hill farmers.

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Appendix 1

Summary of Stockpol® output for status quo system with low nitrogen

Stock Reconciliation for Sheep

LDSQnoN:Plan

Mob	Aged from	Open	Wean	Die	Buy	Sell	Transfer In	Transfer Out	Close
Ewes 6yr		2300		345		1500	1845		2300
MA Ewes		7500		500		290	2635	1845	7500
Ewes 2th	Ewe Hoggets	3702		279		788		2635	
Ewe Hoggets	Ewe Lambs1	5345				1643			3702
Ewe Lambs1			10066			2921		1800	5345
Mixed Lambs			10066	205		11661	1800		
Killers	Mixed Lambs								
Total		18847	20132	1329	0	18803	6280	6280	18847

Mob	31 Jul	31 Aug	30 Sep	31 Oct	30 Nov	31 Dec	31 Jan	28 Feb	31 Mar	30 Apr	31 May	30 Jun
Ewes 6yr	2272	2246	2219	2193	2167	2141	2749	2428	2396	2364	2332	2300
MA Ewes	7457	7415	7372	7329	7287	7244	5356	7848	7628	7586	7543	7500
Ewes 2th	3660	3620	3581	3546	3511	3477	2653					
Ewe Hoggets	5345	5237	4113	4113	4087	3702	3702	3702	3702	3702	3702	3702
Ewe Lambs1					5459	7810	5345	5345	5345	5345	5345	5345
Mixed Lambs					7060	3872	4988	2991	1366	642	642	
Killers												

Weight Reconciliation for Sheep

LDSQnoN:Plan

Live Weight (total kg)	Open	Wean		Die	Buy	Sell	Transfer		Close	Net Lwt
		In	Out				In	Out		Prod.
Ewes 5yr	126500		87492	18149		85263	101633		126529	71151
MA Ewes	420000		237383	27916		14327	134534	101633	419975	218783
Ewes 2th	192331		119120	13948		46211		134432		107432
Ewe Hoggets	221109		69235			76763			192534	117424
Ewe Lambs		239164				67427		44292	221109	93663
Mixed Lambs		274066		6829		382958	44351			64542
Rigers										
Total	959940	513229	513229	66841	0	672950	280518	280356	960147	672995

Sales for Sheep

LDSQnoN:Plan

Date	Mob	To	Number	Avg. kg	$ Per kg	$ Per Head	$ Total	Fwt/hd
16 Jul 05	Ewe Lambs1	store	0					
31 Aug 05	Ewe Hoggets	works	108	18.6	4.44	82.69	6921	0.52
30 Sep 05	Ewe Hoggets	store	1124	45.9	1.70	77.97	87638	0.82
30 Nov 05	Ewe Hoggets	works	26	23.9	3.56	85.00	2210	2.32
15 Dec 05	Mixed Lambs	works	202	17.9	3.83	68.58	13854	1.17
14 Dec 05	Mixed Lambs	store	948	21.6	1.62	35.04	33216	0.65
15 Dec 05	Mixed Lambs	store	117	23.4	1.62	37.89	4433	0.71
15 Dec 05	Mixed Lambs	works	81	15.5	3.81	59.14	4790	1.14
16 Dec 05	Mixed Lambs	store	1124	24.7	1.62	40.13	45105	0.76
21 Dec 05	Mixed Lambs	works	160	15.6	3.81	59.31	9489	0.02
21 Dec 05	Mixed Lambs	works	60	16.0	3.81	61.06	3664	0.02
24 Dec 05	Mixed Lambs	store	25	25.4	1.62	41.16	1029	0.03
29 Dec 05	Mixed Lambs	works	145	15.3	3.81	58.38	8466	0.09
29 Dec 05	Mixed Lambs	store	1000	27.2	1.62	44.04	44042	0.07
30 Dec 05	Mixed Lambs	store	800	28.4	1.62	46.07	36858	0.08
31 Dec 05	Ewe Hoggets	store	385	49.4	1.47	72.61	27955	2.62
31 Dec 05	Mixed Lambs	store	877	29.6	1.62	47.98	42077	0.10
05 Jan 06	Mixed Lambs	works	550	16.6	3.58	59.53	32742	0.35
05 Jan 06	Mixed Lambs	store	84	18.1	1.51	27.32	2295	0.17
10 Jan 06	Ewes 2th	store	788	58.6	1.18	69.16	54500	2.59
11 Jan 06	Mixed Lambs	works	116	15.3	3.57	54.80	6357	0.39
14 Jan 06	Mixed Lambs	works	540	15.0	3.57	53.49	28886	0.41
16 Jan 06	Mixed Lambs	works	49	8.6	2.77	23.80	1166	0.25
24 Jan 06	Ewes 5yr	store	1090	61.0	0.89	54.36	59252	0.81
26 Jan 06	Ewes 5yr	store	121	38.3	1.18	45.22	5472	0.53
31 Jan 06	Ewe Lambs1	store	2921	23.1	1.44	33.18	96915	0.13
10 Feb 06	Mixed Lambs	works	503	15.9	3.46	55.19	27761	0.56
10 Feb 06	Mixed Lambs	works	44	16.4	3.47	56.98	2507	0.58
16 Feb 06	Ewes 5yr	works	220	21.2	1.94	41.00	9020	1.03
16 Feb 06	Ewes 5yr	store	69	41.8	0.72	30.00	2070	0.85
16 Feb 06	Mixed Lambs	works	520	16.1	3.46	55.79	29009	0.60
22 Feb 06	Mixed Lambs	works	210	15.8	3.46	54.51	11447	0.64
28 Feb 06	MA Ewes	works	114	16.8	2.44	41.00	4674	1.65
28 Feb 06	Mixed Lambs	works	545	15.9	3.46	54.98	29965	0.68
10 Mar 06	Mixed Lambs	works	550	15.7	3.34	52.42	28829	0.73
10 Mar 06	Mixed Lambs	works	240	16.2	3.35	54.11	12987	0.75
16 Mar 06	Mixed Lambs	works	50	11.6	2.65	30.71	1535	0.56
17 Mar 06	MA Ewes	store	176	55.0	0.91	50.00	8800	2.50
22 Mar 06	Mixed Lambs	works	550	15.7	3.34	52.40	28819	0.79
23 Mar 06	Mixed Lambs	works	205	14.7	3.34	49.02	10049	0.75
30 Apr 06	Mixed Lambs	works	724	16.2	3.39	54.80	39678	1.11
15 Jun 06	Mixed Lambs	works	0					0.01
16 Jun 06	Mixed Lambs	works	642	17.6	3.67	64.62	41488	1.54
Total			18803				949970	0.69

Financial Report for Sheep

LDSQnoN:Plan

			Number	kg/hd	$/kg	$/hd	$ Total	c/kg DM
Revenue	Stock	Store Sales	11649	34.1	1.39	47.36	551657	
		Works Sales	7154	38.6	1.44	55.68	398312	
		less Purchases	0				0	
		Total					**949970**	9.2
	Grazing		0				0	
	Wool		35052	2.7	2.65	7.22	252987	
	Change in Capital Value						458	
	Total Revenue						**1203415**	11.6
Expenditure	Animal Health		21437			4.10	87912	
	Shearing		35052			3.97	139242	
	Interest on Capital						138750	
	Total Expenditure						**365904**	3.5
Gross Margin							**837511**	8.1

Stock Reconciliation for Beef2

LDSQnoN:Plan

Mob	Aged from	Open	Wean	Die	Buy	Sell	Transfer In	Transfer Out	Close
Autumn bulls 05	Autumn bulls 06				330				330
Autumn bulls 06									
Autumn bulls 04	Autumn bulls 05	330		12		318			
Spring calves 05					700				700
1-Year Bulls	Spring calves 05	700		3		400			297
2 Year Bulls	1-Year Bulls	297		7		290			
Steer Calves -> 1 Year Steers1	Steer Calves 06			13	300				287
1 Year Steers	Steer Calves -> 1 Year Steers1	287		5					282
2 Year Steers	1 Year Steers	282				282			
Steer Calves 06									
Total		1896	0	40	1330	1290	0	0	1896

Mob	31 Jul	31 Aug	30 Sep	31 Oct	30 Nov	31 Dec	31 Jan	28 Feb	31 Mar	30 Apr	31 May	30 Jun
Autumn bulls 05	150	300	330	330	330	330	330	330	330	330	330	330
Autumn bulls 06												
Autumn bulls 04	328	326	325	323	321	219	118					
Spring calves 05					350	700	700	700	700	700	700	700
1-Year Bulls	700	699	699	699	698	698	647	547	447	397	347	297
2 Year Bulls	296	295	293	215	114	11	11					
Steer Calves -> 1 Year Steers1				48	147	245	294	293	291	290	288	287
1 Year Steers	287	286	286	285	285	284	284	284	283	283	282	282
2 Year Steers	282	282	182	182	182	182	132	132	82	42		
Steer Calves 06												

Weight Reconciliation for Beef2

LDSQnoN:Plan

Live Weight (total kg)	Open	Wean		Die	Buy	Sell	Transfer		Close	Net Lwt
		In	Out				In	Out		Prod.
Autumn bulls 05					36305				112588	76283
Autumn bulls 06										
Autumn bulls 04	112588			5003		174589				62001
Spring calves 05					73500				165690	92190
1 Year Bulls	165690			1082		204614			144250	183174
2 Year Bulls	144250			3707		173127				28877
Steer Calves > 1 Year				2009	33900				59276	25376
1 Year Steers	59276			1507					111195	51919
2 Year Steers	111195					147178				35983
Steer Calves 06										
Total	593000	0	0	13307	143705	699509	0	0	593000	555803

Financial Report for Beef2

LDSQnoN:Plan

			Number	kg/hd	$/kg	$/hd	$ Total	c/kg DM
Revenue	Stock	Store Sales	100	467.5	1.87	876.60	87660	
		Works Sales	1190	548.5	1.54	843.41	1003653	
		less Purchases	1330	108.0	3.62	391.32	520457	
		Total					**570855**	**9.8**
	Grazing		0				0	
	Change in Capital Value						0	
	Total Revenue						**570855**	**9.8**
Exp.	Animal Health		2257			14.74	33271	
	Interest on Capital						87335	
	Total Expenditure						**120606**	**2.1**
Gross Margin							**450249**	**7.7**

Appendix 2

Summary of Stockpol® output for Status quo system with high nitrogen

Stock Reconciliation for Sheep

LDSQN:Plan

Mob	Aged from	Open	Wean	Die	Buy	Sell	Transfer In	Transfer Out	Close
MA Ewes		9000		1010		2280	3290		9000
Ewes 2th	Ewe Hoggets	4357		279		788		3290	
Ewe Hoggets	Ewe Lambs1	6000				1643			4357
Ewe Lambs			11000			4655		345	6000
Mixed Lambs			11003	205		11143	345		
Killers	Mixed Lambs								
Total		**19357**	**22003**	**1494**	**0**	**20509**	**3635**	**3635**	**19357**

Mob	31 Jul	31 Aug	30 Sep	31 Oct	30 Nov	31 Dec	31 Jan	28 Feb	31 Mar	30 Apr	31 May	30 Jun
MA Ewes	8768	8685	8603	8520	8414	8288	6728	9560	9286	9191	9095	9000
Ewes 2th	4315	4275	4236	4201	4166	4132	3308					
Ewe Hoggets	6000	5892	5568	5568	5542	5157	4357	4357	4357	4357	4357	4357
Ewe Lambs1					6372	9240	6000	6000	6000	6000	6000	6000
Mixed Lambs					6373	3703	4470	3295	1670	946		
Killers												

Weight Reconciliation for Sheep

LDSQN:Plan

Live Weight (total kg)	Open	Wean		Die	Buy	Sell	Transfer		Close	Net Lwt
		In	Out				In	Out		Prod.
MA Ewes	522000		351691	60063		130132	175898		521853	305777
Ewes 2th	230293		150968	14528		47691		176004		144371
Ewe Hoggets	253699		85127			87149			230359	148936
Ewe Lambs		273869				114941		9632	253699	104403
Mixed Lambs		313917		7228		383359	9614			59828
Killers										
Total	1005992	587786	587786	81819	0	763273	185512	185636	1005910	763315

Financial Report for Sheep

LDSQN:Plan

			Number	kg/hd	$/kg	$/hd	$ Total	c/kg DM
Revenue	Stock	Store Sales	13258	35.8	1.43	51.39	681270	
		Works Sales	7251	39.7	1.50	59.73	433097	
		less Purchases	0				0	
		Total					**1114366**	**9.7**
	Grazing		0				0	
	Wool		39599	2.6	2.63	6.91	273631	
	Change in Capital Value						-89	
	Total Revenue						**1387908**	**12.1**
Expenditure	Animal Health		22250			4.01	89234	
	Shearing		39599			3.45	136515	
	Interest on Capital						151482	
	Total Expenditure						**377232**	**3.3**
Gross Margin							**1010677**	**8.8**

Sales for Sheep

LDSQN:Plan

Date	Moh	To	Number	Avg. kg	$ Per kg	$ Per Head	$ Total	Fwt/hd
16 Jul 05	Ewe Lambs1	store	0					
31 Jul 05	MA Ewes	store	148	60.7	1.58	96.16	14232	0.30
31 Aug 05	Ewe Hoggets	works	108	18.6	4.44	82.60	8921	0.52
30 Sep 05	Ewe Hoggets	store	324	47.6	1.64	77.97	25262	0.82
30 Nov 05	MA Ewes	store	24	59.5	2.06	122.78	2947	1.92
30 Nov 05	Ewe Hoggets	works	26	24.5	3.47	85.00	2210	2.36
21 Dec 05	Mixed Lambs	works	1000	16.2	3.82	61.80	61803	0.02
21 Dec 05	Mixed Lambs	works	59	15.3	3.81	58.38	3445	0.02
24 Dec 05	Mixed Lambs	store	25	16.7	1.62	27.00	675	0.02
29 Dec 05	Mixed Lambs	works	146	15.2	3.81	57.75	8373	0.09
29 Dec 05	Mixed Lambs	store	2633	25.8	1.62	41.82	110110	0.06
30 Dec 05	Mixed Lambs	store	800	29.2	1.62	47.42	37937	0.08
31 Dec 05	MA Ewes	store	44	59.0	2.10	123.94	5453	0.49
31 Dec 05	Ewe Hoggets	store	385	50.2	1.45	72.61	27955	2.66
31 Dec 05	Mixed Lambs	store	877	30.5	1.62	49.39	43313	0.10
05 Jan 06	Mixed Lambs	store	84	18.7	1.51	28.27	2374	0.20
05 Jan 06	Mixed Lambs	works	550	16.2	3.58	58.15	31994	0.38
10 Jan 06	MA Ewes	store	1495	59.2	1.18	69.85	104420	0.69
10 Jan 06	Ewes 2th	store	788	60.5	1.18	71.38	56245	2.64
11 Jan 06	Mixed Lambs	works	116	14.9	3.57	53.24	6176	0.42
14 Jan 06	Mixed Lambs	works	540	14.8	3.57	52.68	28449	0.45
16 Jan 06	Mixed Lambs	works	49	9.0	2.78	24.95	1223	0.28
31 Jan 06	Ewe Hoggets	store	800	57.5	1.66	95.42	76335	3.78
31 Jan 06	Ewe Lambs1	store	4655	24.7	1.44	35.49	165210	0.14
16 Feb 06	Mixed Lambs	works	245	16.7	4.00	66.75	16354	0.69
22 Feb 06	Mixed Lambs	works	210	16.6	3.86	64.02	13444	0.71
28 Feb 06	MA Ewes	works	393	19.1	2.14	41.00	16113	1.72
28 Feb 06	Mixed Lambs	works	545	16.7	4.06	68.00	37060	0.75
10 Mar 06	Mixed Lambs	works	550	16.6	3.35	55.65	30612	0.61
10 Mar 06	Mixed Lambs	works	240	17.0	3.35	57.04	13690	0.82
16 Mar 06	Mixed Lambs	works	50	12.1	3.52	42.50	2125	0.60
17 Mar 06	MA Ewes	store	176	58.8	0.85	50.00	8800	2.47
22 Mar 06	Mixed Lambs	works	550	15.7	4.16	65.27	35899	0.89
23 Mar 06	Mixed Lambs	works	205	16.3	4.15	67.59	13856	0.87
30 Apr 06	Mixed Lambs	works	724	17.6	3.40	59.78	43281	1.23
31 May 06	Mixed Lambs	works	946	17.1	3.59	61.40	58080	1.44
15 Jun 06	Mixed Lambs	works	0					
16 Jun 06	Mixed Lambs	works	0					
Total			20509				1114366	0.71

Stock Reconciliation for Beef2

LDSQN:Plan

Mob	Aged from	Open	Wean	Die	Buy	Sell	Transfer In	Transfer Out	Close
Autumn bulls 05	Autumn bulls 06	300			750				1050
Autumn bulls 06					300				300
Autumn bulls 04	Autumn bulls 05	1050		35		1015			
Spring calves 05					250				250
1-Year Bulls	Spring calves 05	250		3					247
2 Year Bulls	1-Year Bulls	247				247			
Steer Calves -> 1 Year Steers1	Steer Calves 06	50		15	210				245
1 Year Steers	Steer Calves -> 1 Year Steers1	245		5					240
2 Year Steers	1 Year Steers	240				240			
Steer Calves 06					50				50
Total		**2382**	**0**	**58**	**1560**	**1502**	**0**	**0**	**2382**

Mob	31 Jul	31 Aug	30 Sep	31 Oct	30 Nov	31 Dec	31 Jan	28 Feb	31 Mar	30 Apr	31 May	30 Jun
Autumn bulls 05	550	920	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050
Autumn bulls 06												300
Autumn bulls 04	1045	1041	1036	1032	1027	1023	496	264	63			
Spring calves 05										100	250	250
1-Year Bulls	250	249	249	249	248	248	247	247	247	247	247	247
2 Year Bulls	247	247	247	197	97							
Steer Calves -> 1 Year Steers1	110	159	208	256	255	253	252	251	249	248	246	245
1 Year Steers	245	244	244	243	243	242	242	242	241	241	240	240
2 Year Steers	240	240	240	240	240	190	140	90	40			
Steer Calves 06												50

Weight Reconciliation for Beef2

LDSQN:Plan

Live Weight (total kg)	Open	Wean In	Wean Out	Die	Buy	Sell	Transfer In	Transfer Out	Close	Net Lwt Prod
Autumn bulls 05	34380				83679				362141	244081
Autumn bulls 06					31500				34380	2880
Autumn bulls 04	362141			15637		599916				237776
Spring calves 05					42500				53450	10950
1 Year Bulls	53450			1005					120561	67111
2 Year Bulls	120561					154311				33750
Steer Calves -> 1 Year	5783			3112	26886				67501	34832
1 Year Steers	67501			1852					111189	43688
2 Year Steers	111189					147964				36775
Steer Calves 06					5500				5783	283
Total	755004	0	0	21607	190066	902191	0	0	755004	712125

Sales for Beef2

LDSQN:Plan

Date	Mob	To	Number	Avg kg	$ Per kg	$ Per Head	$ Total
31 Oct 05	2 Year Bulls	works	50	334	3.22	1077.38	53869
30 Nov 05	2 Year Bulls	works	100	329	3.11	1021.38	102138
31 Dec 05	2 Year Bulls	works	97	327	3.04	993.30	96350
31 Dec 05	2 Year Bulls	works	0				
31 Dec 05	2 Year Steers	store	50	665	1.78	1186.23	59312
25 Jan 06	Autumn bulls 04	works	402	295	2.72	801.00	322002
26 Jan 06	Autumn bulls 04	works	40	280	2.68	750.65	30026
27 Jan 06	Autumn bulls 04	works	40	297	2.72	807.32	32293
31 Jan 06	Autumn bulls 04	works	40	283	2.66	757.35	30294
31 Jan 06	2 Year Steers	works	50	336	3.06	1029.80	51490
09 Feb 06	Autumn bulls 04	works	40	298	3.02	901.00	36040
10 Feb 06	Autumn bulls 04	works	40	309	3.10	957.63	38305
16 Feb 06	Autumn bulls 04	works	40	322	3.13	1007.90	40316
17 Feb 06	Autumn bulls 04	works	30	323	3.13	1010.60	30318
17 Feb 06	2 Year Bulls	works	0			1010.00	
22 Feb 06	Autumn bulls 04	works	40	309	3.04	938.72	37549
24 Feb 06	Autumn bulls 04	works	40	279	2.97	827.37	33095
28 Feb 06	2 Year Steers	works	50	324	3.01	974.37	48719
01 Mar 06	Autumn bulls 04	works	40	313	2.99	935.60	37424
02 Mar 06	Autumn bulls 04	works	40	273	2.87	784.00	31360
04 Mar 06	Autumn bulls 04	works	41	276	2.87	791.60	32464
15 Mar 06	Autumn bulls 04	works	48	289	3.01	869.45	41734
16 Mar 06	Autumn bulls 04	works	16	292	2.77	809.00	12944
16 Mar 06	2 Year Steers	works	50	312	3.01	937.29	46864
31 Mar 06	Autumn bulls 04	works	16	273	2.95	809.00	12944
27 Apr 06	2 Year Steers	works	40	287	2.95	847.20	33888
30 Apr 06	Autumn bulls 04	works	62	297	2.80	830.71	51504
Total			1502				1343240

Financial Report for Beef2

LDSQN:Plan

			Number	kg/hd	$/kg	$/hd	$ Total	c/kg DM
Revenue	Stock	Store Sales	50	664.9	1.78	1186.23	59312	
		Works Sales	1452	598.4	1.48	884.25	1283929	
		less Purchases	1560	121.8	3.47	422.50	659093	
		Total					684148	9.3
	Grazing		0				0	
	Change in Capital Value						0	
	Total Revenue						684148	9.3
Exp.	Animal Health		2658			12.31	32718	
	Interest on Capital						107996	
	Total Expenditure						140714	1.9
Gross Margin							543434	7.4