Analysing the implications of increased nitrogen application on greenhouse gas emissions and productivity of New Zealand sheep and beef farms

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Abstract
New Zealand's goal to double agricultural exports as well as meet Kyoto protocol commitments is a challenge. New Zealand sheep and beef farmers have been advised that applying more nitrogen fertiliser is the cheapest way to boost productivity. However, an increase in nitrogen fertiliser application results in greenhouse gas emissions increasing. This study analysed the implications of increased nitrogen fertiliser application on productivity and greenhouse gas emissions for New Zealand sheep and beef farms. Three scenarios were modelled to use the additional pasture production achieved from the different rates of nitrogen fertiliser and compared with a base model sheep and beef farm. These scenarios were (1) better feeding livestock to increase end live weight, (2) increasing stocking rate and (3) better feeding livestock to reduce the number of grazing days. The model farm was based on weighted average of all sheep and beef farms in New Zealand (Class 9). Simulations were then run with the different rates of nitrogen fertiliser ranging from 20 to 100kgN/ha/yr through each scenario.

Consistent with the hypotheses, the efficiency of utilisation of extra grass production is an important determinant of the ratio of product output to GHG emissions. For scenario 1 and 2, productivity increased with the ratio of profit to kg of GHG emissions increasing. In scenario 1, the profit per kg of GHG emissions increased 27% in simulation 1 from the base model farm. This occurred when nitrogen fertiliser was increased to 20 kg/N/ha/yr from 5.6 kg/N/ha/yr. The ratio increased 0.6% for scenario 2 for the same change in nitrogen fertiliser. In scenario 3, the ratio of profit to kg of GHG emissions decreased 9% for the same change in nitrogen fertiliser. In all scenarios, GHG emissions increased.

When N fertiliser is increased, productivity increased, greenhouse gas emissions could not be reduced and the proposed emissions trading scheme will have little impact on profitability.

Strategic use of N could improve hill-country resilience. With an increase in strategic N fertiliser application, livestock can be better fed; thus, increased live weight and reducing the number of grazing days.

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Contents

1.0 Introduction

Approximately 44% of farms in New Zealand are sheep and beef farms (Beef + Lamb, 2015). These farms are mostly located in hill country where pasture does not grow to its full potential. This causes a limitation to pasture production that is normally alleviated by enhancing legume growth and symbiotic N fixation through management practices such as applying P fertiliser. Increasing N fertiliser is being recommended to grow more grass, hence increasing production (Lambert, Mackey, Ganesh & Upsdell, 2014). N fertiliser achieves this by filling feed deficits that occur in the different seasons (Lambert, 2009). Research by Rich (1984) showed that N fertiliser use was linked to increased stocking rates and higher incomes. Therefore, resulting in an increase in productivity. However, there is a corresponding increase in greenhouse gas emissions as a result of increased stocking rates (Bolan *et al.*, 2004, de Klein *et al.* 2001).

Greenhouse gas (GHG) emissions from the agriculture sector make up 48% of New Zealand's total emissions (Ministry for the Environment, 2015). Therefore, to meet New Zealand's original Kyoto commitments to halve GHG emissions to 1990 levels by 2050, big emissions reductions are needed in the agriculture sector. This almost directly conflicts with New Zealand's goal to double agricultural exports by 2025 from 2012 levels (Ministry for Primary Industries, 2015), presenting a unique challenge to increase productivity while decreasing GHG emissions.

There are many implications for greenhouse gas emissions and productivity as a result of an increase in N fertiliser. These are both positive and negative. When compared to other feed supply solutions such as baled silage, hay bales, bulk PKE, bagged dairy mix and off farm grazing, nitrogen is the most cost effective option for feed as it is the cheapest per kilogram of dry matter (Gillatt, 2014) (Table A.1). The rate of nitrogen applied in Gillatt's (2014) calculation was 30kg/ha, which increased pasture growth enabled farmers to hold stock levels when the feed situation is tight resulting in better financial results.

A positive implication for productivity is the increase in pasture growth as a result of the increase in N fertiliser application. Trials on a hill country farm in southern Hawkes Bay (Lambert *et al.*, 2003) consisting of eight split dressings of N fertiliser at a rate of 50 kg/ha (400kgN/ha/annum), resulted in an increase from 9.2 t DM/ha to 19.4 t DM/ha of pasture production over the year. In Invermay, South Otago, Lambert (2009) also reflected this increase in pasture production as a result of N fertiliser. Results showed pasture production increased from 12.7 t DM/ha in the no N control plots to 21 t DM/ha when between 300 and 400 kgN/ha/annum was applied.

However, 400 kgN/ha/annum is a very high rate of N fertiliser and does not reflect current practices with the average sheep and beef farm applying only 5.6 kgN/ha/annum (Beef + Lamb, 2014). Research (Lambert, 2009) also indicates application rates above 100-200 kgN/ha/annum results in large detrimental effects on the environment through increased nitrate leaching.

These trials demonstrate that N fertiliser is an effective method to increase pasture production, however, there are potential negative implications. To consume the additional pasture growth, stocking rates are increased. This leads to increased concentration of N rich urine patches that exceed N uptake capacity of pasture causing volatilisation of N into atmosphere in the form of nitrous oxide (N_2O) emissions (Taghizadeh-Toosi, 2011). N_2O emissions are a potent GHG with a global warming potential rating of 298 over a 100 year life span (IPCC, 2013). This means N_2O has 298 times greater global warming effect than one tonne of carbon dioxide.

Increased stocking rates also causes an increase in methane (CH_4) emissions as a result of more ruminating livestock. CH_4 has a global warming potential of 25 CO_2-eq (IPCC, 2013).

This research will analyse the implications of an increase in N fertiliser application on GHG emissions and productivity for New Zealand sheep and beef farms.

2.0 Methodology

2.1 Model Farm

A model farm was created based on the weighted average of all sheep and beef farms in New Zealand (Class 9) (Beef + Lamb, 2014). This farm does not represent any class of farm within the industry but gives an indication of a typical sheep and beef farm. The farm was made up of 635 effective hectares and 4062 stock units which consisted of:

- Sheep
- Bull beef
- Beef
- Dairy grazing

These enterprises were based on 2013 to 2014 figures. Lambing percentage was 125.4% and calving percentage 82.7%. The farm was split into three categories with 127 hectares rolling, 254 hectares easy hill and 254 hectares hard hill (R Vibart, pers. comm. 12 January 2015). Cash crops were grown on the rolling hills. Pasture quality was medium on the rolling hills and was low on the easy to hard hill. One application of 28 kgN/ha/month was applied on the rolling hill block in September. This meant 5.6 kgN/ha was applied annually on the whole farm.

2.2 OVERSEER®

OVERSEER® is a model that is used to develop on-farm nutrient budgets (OVERSEER, 2015). This tool is mainly used by farmers and their advisors to assess nutrient use and movements within the farm to optimise production and environmental outcomes. The nutrients losses that are estimated within this model are N leaching/run-off, P run-off and greenhouse gas emissions. The greenhouse gas emissions included are; methane, nitrous oxide and carbon dioxide. This model is a tool for informing policy as well as implementation.

OVERSEER® was used by running the Class 9 base model sheep and beef farm through it to obtain greenhouse gas emission outputs. This gave the base greenhouse gas emissions that were used to determine increases or decreases in GHG emissions from different simulations run with deviations in N fertiliser application.

2.3 Farmax Pro

Farmax Pro is a whole-farm decision support model that determines the production and economic outcomes of managerial decisions based on stock and farm information as well as pasture growth (Farmax, 2015). This program is used by rural consultants, farm owners and farm managers as well as other rural professionals. It has the ability to create different scenarios and compare differences as well as strategic and tactical modelling.

This model was used to generate pasture growth outputs from the increase in N fertiliser which were then transferred into the Microsoft Excel spread sheets to calculate dry matter to live weight gains and dry matter to stock unit increases. Farmax Pro did not adjust live weight gains in proportion to the increase in pasture made available; these were calculated separately and then transferred back into Farmax Pro to determine profit changes. This process was carried out for each simulation.

2.4 Microsoft Excel

N fertiliser application was increased in Farmax Pro and OVERSEER® at varying rates. This led to an increase in pasture cover in Farmax Pro. To quantify this increase, two Microsoft Excel spread sheets was used to run final simulations. These two spread sheets represented two different scenarios which were (1) better fed livestock or (2) higher stocking rate.

The spread sheet calculated the difference in kilograms of dry matter for the year between the model farm and each scenario. This difference was then allocated on a stock unit basis between sheep and beef livestock. The intention here was to calculate live weight gains by stock from consuming the increased pasture available as a result of the increase in N fertiliser.

Increased pasture was allocated to the sheep enterprise based on stock unit values. This assumed the lambs (rising hoggets) consume 17.6% of the pasture. The sheep enterprise consumes 63% of the total pasture grown as determined by the stock unit ratio of sheep to beef.

Eq.1

$$Lamb\ pasture\ consumption = \frac{SU\ of\ mob\ (hoggets)}{(\sum SU\ of\ all\ mobs)} = \frac{0.7}{1 + 0.7 + 0.8} = 0.28 = 0.28 \times 0.63 = 0.176$$

This allocated pasture figure was then divided by the number of days lambs were grazing then divided by the number of total lambs. This gave the extra kilograms of dry matter per head available each day.

Eq.2

$$extra\ kgDM\ per\ head\ per\ day = \frac{(0.176\ \times P)}{(n_l \times n_d)}$$

Where: $P = Increase\ in\ pasture\ production\ for\ the\ period\ in\ which\ the\ lambs\ were\ grazing$

$n_l = Number\ of\ lambs$

$n_d = Number\ of\ days\ lambs\ grazing\ pasture$

Research from Ceres Farm (2012) indicated that for every 0.2 increase in kilograms of dry matter per day resulted in a 50 gram increase in live weight[1]. This finding was added in to the calculation to give live weight grams per head per day.

Eq.3

$$Live\ weight\ grams\ per\ head\ per\ day = kgDM_{h/d}\ \times C$$

Where: $kgDM_{h/d} = Extra\ kilograms\ of\ dry\ matter\ per\ head\ per\ day$

$C = Conversion\ of\ dry\ matter\ to\ weight\ (250)$

Live weight grams were then multiplied by the number of days and lambs then converted into total kilograms of live weight.

[1] Ceres Farm have been breeding sheep for 40 years in the Waikato to optimise their profitability through good growth and fleece weights

Eq.4

$$Total\ kilograms\ live\ weight = \frac{(LWgrams_{h/d} \times n_d \times n_l)}{1000}$$

Where: $LWgrams_{h/d} = live\ weight\ grams\ per\ head\ per\ day$

$n_l = Number\ of\ lambs$

$n_d = Number\ of\ days\ lambs\ grazing\ pasture$

Live weight growth was converted into carcass weight growth (dressing out) as this is how the revenue is calculated. Research by Stevens and Turner (1994) indicated that on medium quality pasture for every 100 grams of live weight gain, 45 grams converts to carcass weight gain; on low quality pasture, 35 grams is converted. This figure was multiplied by the average lamb price from Farmax Pro of $4.58 per kilogram to calculate total additional potential revenue that will be received.

Eq.5

$$Additional\ potential\ revenue = TotalLW_{kg} \times d_o \times p$$

Where: $TotalLW_{kg} = Total\ kilograms\ of\ live\ weight$

$d_o = dressing\ out\ percentage\ (average\ of\ 0.35\ and\ 0.45 = 0.4)$

$p = average\ lamb\ price\ as\ determined\ by\ Farmax\ Pro$ ($4.58)

A similar process was followed for the beef enterprise; however, the pasture allocation and dry matter to live weight to carcass weight equation was different. Pasture was allocated based on cattle equivalent stock units (Beef + Lamb, 2015).

Eq.6

$$Pasture\ allocation\ for\ beef\ enterprise = \frac{SU\ of\ mob}{(\sum SU\ of\ all\ mobs)} \times 0.37$$

Where: $0.37 = beef\ to\ sheep\ ratio\ as\ determined\ by\ stock\ units$

Note: Cattle equivalent SU table for beef enterprise is in Table A.36.

Research (Morris, 2003) indicated that for R1 (rising one year old - between weaning and one year old) cattle, for every kilogram extra of dry matter, live weight gain will be 357 grams per day. For R2 (rising two year old – between yearling and two year old) cattle and above, the live weight gain is 238 grams per day for every kilogram of dry matter. This is the same as Eq.3 where C equals 357 and 238.

This report used average dressing out percentages (Muir & Thomson, 2008); the steer beef percentage was 53.3 per cent and 53.7 per cent for bull beef. This gave the carcass weight figure which was multiplied by the average beef price from Farmax Pro of $3.29 per kilogram to calculate additional revenue from the increased pasture growth. This equation is the same as Eq.5 where d_o equals 0.533 and 0.537 and p equals $3.29.

Another Excel spread sheet was created to convert the increased pasture growth into additional stock units that could be added to consume the extra pasture. This sheet was based on the previous dry matter to live weight gain sheet by using the same allocation methods to each enterprise. However, kilograms of extra dry matter available were converted into the number of extra livestock that could be added to consume extra pasture.

Dry matter intake (DMI) values for sheep were sourced from research by Oregon State University (n.d.). Ewes DMI was 2 percent body weight for maintenance and 3.5 per cent during lactation. The average of 2.75 per cent was used (Subcommittee on Beef Cattle Nutrition, 2000). The values for dairy were sourced from Wheeler (1996). The average weights came from the base farm within Farmax Pro. DMI for all livestock are in Table A.2.

The extra pasture available to each livestock category was divided by their DMI values (see Eq.2 for calculation of extra pasture available). This gave the extra livestock numbers that were then put through a stock unit calculator to convert stock numbers to stock units. The stock unit values were based on Beef + Lamb NZ standard values (2015). This gave the final additional stock units that could be added to consume the additional pasture produced from the increase in N fertiliser.

These stock units were then added into Farmax Pro and OVERSEER® to calculate changes in profit and greenhouse gas emissions.

3.5 Simulations

Three different scenarios were simulated with different rates of N fertiliser: 20, 35, 50, 75 or 100 kgN/ha/annum. Note that 75 and 100kg/ha/annum were purely experimental and do not reflect commercial use within the sheep and beef industry (refer to introduction).

Simulation 1: Increase N fertiliser to 20kg/ha/annum

The first simulation involved a September N fertiliser application of 33 kg/ha/month and added two more applications at the same rate in November and March all on the rolling block. This resulted in a pasture production increase of 437kg/ha over the year from the base model.

Simulation 2: Increase N fertiliser to 35kg/ha/annum

The second simulation involved a September N fertiliser application of 44 kg/ha/month and added three more applications at the same rate in November, March and May all on the rolling block. Pasture production increased by 1055kg/ha over the year from the base model.

Simulation 3: Increase N fertiliser to 50kg/ha/annum

The third simulation involved a September N fertiliser application of 52 kg/ha/month and added three more applications at the same rate in November, March and May all on the rolling block. One application in September was added to the easy hill block at a rate of 21 kg/ha/month. This resulted in a pasture production increase of 1456kg/ha over the year from the base model.

Simulation 4: Increase N fertiliser to 75kg/ha/annum

The fourth simulation involved a September N fertiliser application of 60 kg/ha/month and added four more applications at the same rate in July, November, March and May all on the rolling block. One application in September was added to the easy hill block at a rate of 38 kg/ha/month. This resulted in a pasture production increase of 2242kg/ha per annum from the base model.

Simulation 5: Increase N fertiliser to 100 kg/ha/annum

The final simulation involved a September N fertiliser application of 70 kg/ha/month and added four more applications at the same rate in July, November, March and May all on the rolling block. Two applications in September and March were added to the easy hill block at a rate of

40 kg/ha/month. This resulted in a pasture production increase of 3280 kg/ha over the year from the base model. This rate is extremely high and is only hypothetical.

The three scenarios were:

Scenario 1: Improve the feed for the same number of livestock for the same period of time as the base model farm; hence, increasing end live weight.

Scenario 2: Increase stocking rate to consume additional pasture produced.

Scenario 3: Improve the feed for the same amount of livestock until they reach the same end live weight as the base model farm; hence, reducing the number of days livestock are grazing pasture.

3.0 Results

3.1 Scenario 1

Better Fed Livestock – Increasing end live weight

With better fed livestock the profit increased $30,370 from the base model farm. However, there was a 2.3% increase in N_2O and CO_2 emissions of 78kg CO_2 equivalents per hectare from the base model farm. CH_4 remained the same as livestock numbers did not change from the base model farm.

In the second simulation profit increased $73,785 which is a 141% increase on simulation #1 on the back of a 75% increase in N fertiliser. This came at the expense of a 4.5% increase in N_2O and CO_2 emissions from simulation #1 and a 6.9% increase from the base model farm. CH_4 remained the same as livestock numbers did not change from the base model farm.

Profit increased $98,085 in simulation #3. This is a 33% increase in profit from a 43% increase in N fertiliser from simulation #2. N_2O and CO_2 emissions increased 4.4% from simulation #2 and an 11.6% increase from the base model farm. CH_4 remained the same as livestock numbers did not change from the base model farm.

Simulations #4 and #5 were not recorded as pasture production exceeded the potential consumption by livestock as determined by Farmax Pro.

Table 3.1.1

		Simulations		
	Base Farm	**1**	**2**	**3**
Farm Profit Before Tax ($)	102,600	132,970	176,385	200,685
Total GHG Emissions (kg/CO_2 equivalents)	3,443	3,521	3,679	3,841
Profit/ kg GHG	29.80	37.77	47.94	52.25

Note: more in depth breakdown of table components in Tables A.3 to A.11.

3.2 Scenario 2

Increase Stocking Rate

The extra pasture growth resulted in stock units increasing by 440. This is a 10.8% increase from the base model farm. Total GHG emissions increased 10.5% and farm profit increased 11.0% from the base model farm. Methane had the largest increase of 212kg CO_2 eq/ha as a result of the higher stocking rate.

In simulation 2, the extra stock units increased to 1,069 from the base model farm and a 143% increase from simulation #1. Profit increased 30% and total GHG emissions increased 26% from the base model farm.

The third simulation resulted in stock units increasing to 1,485, which is up 39% from simulation 2. This corresponded with a 6% increase in profit and 9% increase in GHG emissions from simulation 2. CH_4 and N_2O emissions both increased greatly as a result of more livestock ruminating and increased N fertiliser application.

Extra stocking units totalled 2,303 in simulation 4 which is a 55% increase on simulation #3 and 57% increase on the base model farm. Profit increased 60% and GHG emissions increased 58% from the base model farm.

The final simulation resulted in the stocking rate increasing by 3,405 stock units which is a 48% increase on simulation #4 and an 84% increase on the base model farm. Profit increased 91% and GHG emissions increased 70% from the base model farm.

Table 3.2.1

				Simulations		
	Base Farm	**1**	**2**	**3**	**4**	**5**
Farm Profit Before Tax ($)	102,600	113,988	133,713	141,946	163,847	195,689
Total GHG Emissions (kg/CO_2 equivalents)	3,443	3,804	4,327	4,714	5,434	5,854
Profit/ kg GHG	29.80	29.97	30.90	30.11	30.15	33.43

Note: more in depth breakdown of table components in Tables A.12 to A.26.

3.3 Scenario 3
Better Fed Livestock – Reducing Grazing Days

In simulation 1, profit decreased 7.1% from the base model farm and GHG emissions increased 1.7%. With the reduced number of grazing days there was a reduction in methane emissions as livestock were ruminating for a shorter period of time. However, this reduction was less than the increase in N_2O and CO_2 emissions due to the increase in N fertiliser application.

Profit decreased 16 per cent in the second simulation and GHG emissions increased 0.5% from the base model farm. CH_4 emissions decreased substantially but could not be offset by N_2O and CO_2 emissions.

Profit decreased 26% in simulation #3 from the base model farm with only a 1% increase in GHG emissions. CH_4 emissions contributed the most to reductions as a result of reduced number of days livestock were ruminating because end live weight gains were achieved on average 112 days faster than the base model farm.

Table 3.3.1

			Simulations	
	Base Farm	**1**	**2**	**3**
Farm Profit Before Tax ($)	102,600	95,298	85,769	75,719

Total GHG Emissions (kg/CO_2 equivalents)	3,443	3,503	3,461	3,479
Profit/ kg GHG	29.80	27.21	24.78	21.76

Note: more in depth breakdown of table components in Tables A.27 to A.35

4.0 Discussion

In all scenarios increases in N fertiliser application resulted in increased GHG emissions. Research (Wolken, 2009) expressed the difficulty in decreasing GHG emissions in the sheep and beef sector as farms are characterised by a large effective area and low intensity. Mitigation options such as feed and wintering pads are not available. Although Wolken's research was not primarily focused on mitigating GHG emissions, the most effective strategy achieved only a 3.7 per cent reduction in overall GHG emissions. Wolken also indicated that none of his mitigation strategies would assist in meeting New Zealand's Kyoto commitments.

Productivity increased in two of the three scenarios with increases in profit and production. These scenarios were better fed livestock and increased stocking rates.

4.1 Scenario 1: Better Fed Livestock – Increasing end live weight

The major assumptions for this scenario were that livestock were not being fed to their full potential and any extra pasture consumed would go towards growth as maintenance had already been covered in the base model farm. Farmax Pro backed up these assumptions as it calculates the potential feed demand and the current feed demand which showed all livestock classes had room to be fed more. Current demand was also broken up into maintenance and growth figures.

Better fed livestock was not simulated in simulations 4 and 5 as the increased pasture growth exceeded the potential feed demand of livestock as determined by Farmax Pro.

This scenario delivered the largest increases in profit from the base model farm compared to the two other scenarios. Increasing the N fertiliser rate from 5.6kgN/ha/annum to 20kgN/ha/annum resulted in a 21.6 per cent increase in profit from the base model farm. When increased to 50kgN/ha/annum, profit increased 95.6 per cent from the base model farm.

GHG emissions increased at a much lower rate than profit as a result of the increased application of N fertiliser. In all simulations CH_4 remained the same as the livestock numbers remained constant.

4.2 Scenario 2: Increase Stocking Rate

The general trend throughout all simulations was that profit and GHG emissions more or less increased by the same levels when the stocking rate increased. For 20kgN/ha/annum, profit increased 11.0 per cent and GHG emissions increased 10.5 per cent from the base model farm. When increased to 100kgN/ha/annum, profit increased 91 per cent and GHG emissions increased 70 per cent. This scenario had the largest increases in GHG emissions and is not favourable with New Zealand's emission reduction targets. However, production is being increased as a result of more stock units and therefore meets New Zealand's goal to double agricultural exports by 2025.

4.3 Scenario 3: Better Fed Livestock – Reduce Grazing Days

For all the simulations, reducing grazing days resulted in reductions in profit and minor increases in GHG emissions. The premiums received for reaching end live weights faster and early processing did not cover the additional N fertiliser costs that were incurred when increasing application rates.

Benefits to reduced grazing days include less susceptibility to droughts which are becoming more frequent in sheep and beef hill country as a result of climate perturbation (Willman, 2014). This reduction is because livestock have already reached their target live weight gains before the drought occurs. Pasture is also not over grazed resulting in greater autumn and winter response times.

4.4 Effect of an Emissions Trading Scheme

Currently NZU's (NZ carbon credits) are trading at $6.60NZD per tonne of carbon (CommTrade, 2015). New Zealand's proposed ETS scheme makes farmers pay for 10 per cent of total emissions and the Government pays for the remaining 90 per cent with the Government decreasing their share every year creating an incentive to decrease GHG emissions. For the base model sheep and beef farm, this equates to $1442.96 which is 1.4 per cent of total profit (3443CO_2eqkg/ha*635ha/1000*$6.60*0.1). Therefore, during the early stages of ETS implementation, the cost is minimal but in the long term this will increase with the long term problem of having limited strategies to reduce GHG emissions in sheep and beef farming.

5.0 Conclusions

New Zealand's goal to double primary exports by 2025 from 2012 levels is an ambitious goal. Increases in N fertiliser application will assist New Zealand reaching this goal as demonstrated by the increases in production and profitability in the scenarios simulated. However, GHG emissions were unable to be reduced in all the scenarios which conflicts with New Zealand's international Kyoto commitments. Even though increased application of N fertiliser cannot decrease GHG emissions, productivity can also be enhanced through increased resilience against climate perturbation for sheep and beef farms. Also, the proposed ETS scheme will have little initial effect on sheep and beef profitability.

There is scope for further research into combining multiple scenarios such as better feeding livestock to increase end live weight as well as reducing grazing days. These scenarios could then include GHG mitigation options that also require additional research.

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7.0 Appendices

Table A.1 Table of the costs of different feed supply solutions (Rural News, 2014)

Feed Supply Solutions	Unit Cost*	Cost per kgDM
Baled Silage	$85/bale	$0.44
Hay bales	$90/bale	$0.56
Bulk PKE	$310/tonne	$0.34
Bagged dairy mix	$440/tonne	$0.51
Off farm grazing	$12 cow/week	$0.51
Nitrogen	$790/tonne	$0.14-$0.21 (depending on response rate)

Table A.2

Sheep	Average Weight (kg)	DMI (% of BW)	DMI (kg/DM/h/d)
Lambs	40	4.3	1.72
Hoggets	55	3.5	1.93
Ewes	64	2.75	1.76
Beef			
Beef Cows	464	2.26	10.4846
Heifer Calves	178	3.12	5.5536
Steer Calves	201	3.03	6.0903
1 Year Heifers	225	1.89	4.2525
1 Year Steers	244	2.89	7.0516
2 Year Steer	286	2.76	7.8936
Bull Calves	185	3.12	5.7720
1 Year Bulls	404	2.44	9.8576
2 Year Bulls	548	2.27	12.4396
Dairy			
Dairy Grazers	438	2.6	11.308

Better Fed Livestock – Increasing End Live Weight

Simulation 1

Table A.3

Microsoft Excel Output: Better Fed Livestock - Conversion of extra pasture growth from N fertiliser to carcass weight and dollars

	KgDM/head/day	Carcass Weight grams/h/day	Total $ Worth
Lambs	0.0663	6.6282	$8922.66
Weaner Bull Calves	1.0123	194.08	$11047.76
1-Year Bulls	0.7233	92.452	$9769.87
2-Year Bulls	1.2008	153.47	$9769.57
Weaner Steer Calves	0.6774	128.89	$1526.62
1-Year Steers	0.6508	82.559	$2181.10
2-Year Steers	0.6171	78.283	$876.19
Total			44093.77

Table A.4

Farmax Pro Outputs ($)

	Base Farm	Simulation #1	Difference
Farm Profit Before Tax ($)	$102600	$88876 Plus Table 3.1.1 Total =132970	30370

Table A.5

OVERSEER® Outputs (kg CO_2 equivalents per hectare)

	Base Farm	Simulation #1	Difference
Methane (CH_4)	2333	2333	0
Nitrous Oxide (N_2O)	894	921	27
Carbon Dioxide (CO_2)	216	267	51
Total GHG Emissions	3443	3521	78

Simluation 2

Table A.6

Microsoft Excel Output: Better Fed Livestock – Conversion of extra pasture growth from N fertiliser to carcass weight and dollars

	KgDM/head/day	Carcass Weight grams/h/day	Total $ Worth
Lambs	0.1326	13.256	$17845.32
Weaner Bull Calves	2.4441	468.55	$26671.37
1-Year Bulls	1.7464	223.20	$23586.29
2-Year Bulls	2.8989	370.50	$23586.29
Weaner Steer Calves	1.3645	259.65	$3075.26
1-Year Steers	1.5712	199.31	$5265.57
2-Year Steers	1.6645	211.15	$2363.28
Total			$102393.38

Table A.7

Farmax Pro Outputs ($)

	Base Farm	Simulation #2	Difference
Farm Profit Before Tax ($)	$102600	$73992 Plus Table 3.2.1 Total =176385	73785

Table A.8

OVERSEER® Outputs (kg CO_2 equivalents per hectare)

	Base Farm	Simulation #2	Difference
Methane (CH_4)	2333	2333	0
Nitrous Oxide (N_2O)	894	1023	129
Carbon Dioxide (CO_2)	216	323	107
Total GHG Emissions	3443	3679	236

Simulation 3

Table A.9

Microsoft Excel Output: Better Fed Livestock – Conversion of extra pasture growth from N fertiliser to carcass weight and dollars

	KgDM/head/day	Carcass Weight grams/h/day	Total $ Worth
Lambs	0.1819	18.190	$24486.79
Weaner Bull Calves	3.3730	646.64	$36809.02
1-Year Bulls	2.4102	308.03	$32551.31
2-Year Bulls	4.0001	511.32	$32551.31
Weaner Steer Calves	1.7163	326.57	$3867.92
1-Year Steers	2.1684	275.07	$7266.99
2-Year Steers	2.4390	309.39	$3462.88
Total			$140996.22

Table A.10

Farmax Pro Outputs ($)

	Base Farm	Simulation #3	Difference
Farm Profit Before Tax ($)	$102600	$59689 Plus Table 3.3.1 Total =200685	98085

Table A.11

OVERSEER® Outputs (kg CO_2 equivalents per hectare)

	Base Farm	Simulation #3	Difference
Methane (CH_4)	2333	2333	0
Nitrous Oxide (N_2O)	894	1129	235
Carbon Dioxide (CO_2)	216	379	163
Total GHG Emissions	3443	3841	398

Scenario: Increase Stocking Rate

Simulation 1

Table A.12

Microsoft Excel Output: Increase Stocking Rate - Conversion of extra pasture growth from N fertiliser to stocking rate

	Extra Stock Numbers (rounded down)	Extra Stock Numbers converted to Stock Units
Sheep	225	225
Cattle	44	215.7
Total	269	440 (rounded down)

Table A.13

Farmax Pro Outputs ($)

	Base Farm	Simulation #1	Difference
Farm Profit Before Tax ($)	$102600	$113988	$11388

Table A.14

OVERSEER® Outputs (kg CO_2 equivalents per hectare)

	Base Farm	Simulation #1	Difference
Methane (CH_4)	2333	2545	212
Nitrous Oxide (N_2O)	894	990	96
Carbon Dioxide (CO_2)	216	269	53
Total GHG Emissions	3443	3804	361

Simulation 2

Table A.15

Microsoft Excel Output: Increase Stocking Rate - Conversion of extra pasture growth from N fertiliser to stocking rate

	Extra Stock Numbers (rounded down)	Extra Stock Numbers converted to Stock Units
Sheep	545	545.0
Cattle	107	524.8
Total	652	1069 (rounded down)

Table A.16

Farmax Pro Outputs

	Base Farm	Simulation #2	Difference
Farm Profit Before Tax ($)	102600	133713	31113

Table A.17

OVERSEER® Outputs (kg CO_2 equivalents per hectare)

	Base Farm	Simulation #2	Difference
Methane (CH_4)	2333	2813	480
Nitrous Oxide (N_2O)	894	1186	292
Carbon Dioxide (CO_2)	216	328	112
Total GHG Emissions	3443	4327	884

Simulation 3

Table A.18

Microsoft Excel Output: Increase Stocking Rate - Conversion of extra pasture growth from N fertiliser to stocking rate

	Extra Stock Numbers (rounded down)	**Extra Stock Numbers converted to Stock Units**
Sheep	752	752
Cattle	149	733.5
Total	901	1485 (rounded down)

Table A.19

Farmax Pro Outputs

	Base Farm	**Simulation #3**	**Difference**
Farm Profit Before Tax ($)	102600	141946	39346

Table A.20

OVERSEER® Outputs (kg CO_2 equivalents per hectare)

	Base Farm	**Simulation #3**	**Difference**
Methane (CH_4)	2333	2976	643
Nitrous Oxide (N_2O)	894	1353	459
Carbon Dioxide (CO_2)	216	385	169
Total GHG Emissions	3443	4714	1271

Simulation 4

Table A.21

Microsoft Excel Output: Increase Stocking Rate - Conversion of extra pasture growth from N fertiliser to stocking rate

	Extra Stock Numbers (rounded down)	**Extra Stock Numbers converted to Stock Units**
Sheep	1158	1158
Cattle	232	1145
Total	1390	2303 (rounded down)

Table A.22

Farmax Pro Outputs

	Base Farm	**Simulation #4**	**Difference**
Farm Profit Before Tax ($)	102600	163847	61247

Table A.23

OVERSEER® Outputs (kg CO_2 equivalents per hectare)

	Base Farm	**Simulation #4**	**Difference**
Methane (CH_4)	2333	3243	910
Nitrous Oxide (N_2O)	894	1710	816
Carbon Dioxide (CO_2)	216	481	265
Total GHG Emissions	3443	5434	1991

Simulation 5

Table A.24

Microsoft Excel Output: Increase Stocking Rate - Conversion of extra pasture growth from N fertiliser to stocking rate

	Extra Stock Numbers (rounded down)	Extra Stock Numbers converted to Stock Units
Sheep	1695	1695.0
Cattle	348	1710.1
Total	2043	3405 (rounded down)

Table A.25

Farmax Pro Outputs

	Base Farm	Simulation #5	Difference
Farm Profit Before Tax ($)	102600	195689	93089

Table A.26

OVERSEER® Outputs (kg CO_2 equivalents per hectare)

	Base Farm	Simulation #5	Difference
Methane (CH_4)	2333	3404	1071
Nitrous Oxide (N_2O)	894	1865	971
Carbon Dioxide (CO_2)	216	585	369
Total GHG Emissions	3443	5854	2411

Scenario: Better Fed Livestock – Reducing Grazing Days

Simulation 1

Table A.27

Farmax Pro Outputs

	Base Farm	Simulation #1	Difference
Farm Profit Before Tax ($)	102600	95298	-7302

Table A.28

OVERSEER® Outputs (kg CO_2 equivalents per hectare)

	Base Farm	Simulation #1	Difference
Methane (CH_4)	2333	2307	-26
Nitrous Oxide (N_2O)	894	929	35
Carbon Dioxide (CO_2)	216	267	51
Total GHG Emissions	3443	3503	60

Table A.29

Days to Reach End Live Weight

		Bull Calves	1-Year Bulls	2-Year Bulls	Steer Calves	1-Year Steers	2-Year Steers	Lambs
Base Model Farm	Average Growth (kg/d)	0.6875	0.875	0.875	0.16	0.175	0.1875	0.09
	Days to reach end LW	205	243	113	125	251	229	130
Simulation 1	Average Growth (kg/d)	1.0489	1.0472	1.1608	0.4018	0.3299	0.3344	0.1066
	Days to reach end LW	134	203	85	47	133	129	110
Difference in days		71	40	28	78	118	100	20

Simulation 2

Table A.30

Farmax Pro Outputs

	Base Farm	Simulation #2	Difference
Farm Profit Before Tax ($)	102600	85769	-16831

Table A.31

OVERSEER® Outputs (kg CO_2 equivalents per hectare)

	Base Farm	Simulation #2	Difference
Methane (CH_4)	2333	2187	-146
Nitrous Oxide (N_2O)	894	953	59
Carbon Dioxide (CO_2)	216	321	105
Total GHG Emissions	3443	3461	18

Table A.32

Days to Reach End Live Weight

		Bull Calves	1-Year Bulls	2-Year Bulls	Steer Calves	1-Year Steers	2-Year Steers	Lambs
Base Model Farm	Average Growth (kg/d)	0.6875	0.8750	0.8750	0.1600	0.1750	0.1875	0.0900
	Days to reach end LW	205	243	113	125	251	229	130
Simulation #2	Average Growth (kg/d)	1.5600	1.2906	1.5649	0.6471	0.5490	0.5837	0.1230
	Days to reach end LW	90	165	63	29	80	74	95
Difference in days		115	78	50	96	171	155	35

Simulation 3

Table A.33

Farmax Pro Outputs

	Base Farm	Simulation #3	Difference
Farm Profit Before Tax ($)	102600	75719	-26881

Table A.34

OVERSEER® Outputs (kg CO_2 equivalents per hectare)

	Base Farm	Simulation #3	Difference
Methane (CH_4)	2333	2107	-226
Nitrous Oxide (N_2O)	894	996	102
Carbon Dioxide (CO_2)	216	376	160
Total GHG Emissions	3443	3479	36

Table A.35

Days to Reach End Live Weight

		Bull Calves	1-Year Bulls	2-Year Bulls	Steer Calves	1-Year Steers	2-Year Steers	Lambs
Base Model Farm	Average Growth (kg/d)	0.6875	0.875	0.875	0.16	0.175	0.1875	0.09
	Days to reach end LW	205	243	113	125	251	229	130
Simulation #3	Average Growth (kg/d)	1.8917	1.4486	1.8272	0.7727	0.6911	0.7680	0.136
	Days to reach end LW	75	147	54	25	64	56	86
Difference in days		130	96	59	100	187	173	44

Table A.36

Cattle Equivalent Stock Units (SU) for Beef Enterprise

Mob	SU
Bull Calves	0.8
1-year bulls	1.0
2-year bulls	1.0
Dairy cows grazing	0.8
Beef cows	1.0
Heifers	0.6
1-year heifers	0.8
1-year steers	0.9
2-year steers	1.0
Steers weaner	0.8