Laggan Grazing Demonstration

Results: 2015- 2017

Conducted at Shannon Arnall's, "Carinya", Laggan

Beginning January 2015

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Background

This on-farm demonstration began following the 2011 Crookwell Flock Ewe competition. Shannon Arnall had recently purchased a new block of 'native' country and was keen to increase profitability in the most cost-effective way. After several discussions with Phil Graham (NSW DPI) it was decided that a simple nutrient subtractive trial would be a good way to get a better handle on which nutrients are limiting pasture growth at 'Carinya', Laggan.

Part A: Nutrient Subtractive Trial

A nutrient subtractive trial is a simple way to identify which nutrients are limiting growth. This works by applying all nutrients to a measured area/plot ('All Nutrient') and then systematically removing a single nutrient from subsequent plots and comparing pasture growth. For example, the '**- P**' plot is all nutrients excluding phosphorus (Figure 1). The nutrient trial commenced in July 2013 on a native perennial based pasture containing some legume.

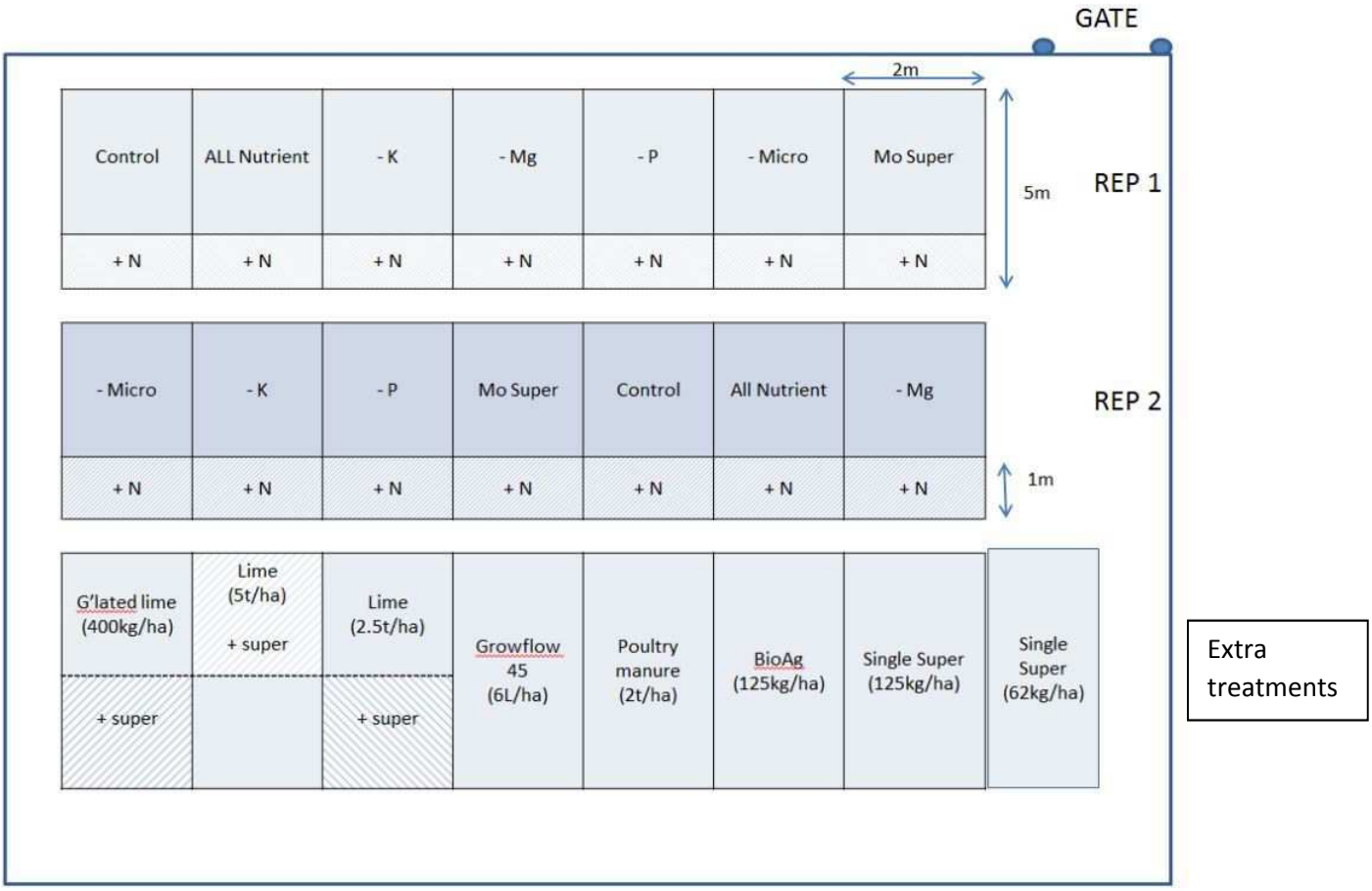

Figure 1: Nutrient subtractive trial layout at Carinya, Laggan*

*The only nutrient that cannot easily be 'removed' is sulfur. This is because most of the nutrients are applied in a sulfate form (e.g. magnesium is applied as Magnesium Sulfate). The '- Micro' treatment consisted of All Nutrients minus the micronutrients Copper, Zinc, Molybdenum and Boron.

Nutrient subtractive trial – timeline of events

4 July 2013

- Rep 1 and Rep 2 established and nutrients applied

17 April 2014

- Top up nutrients applied to Rep 1 and 2
- Shannon was also interested in a range of other products. The 'extra' treatments were also applied on 17 April

2 April 2015

- Top up nutrients applied to all treatments (except 125kg Molybdenum Super on the lime treatments and the BioAg Superb treatment– see below)

14 April 2015

- It was decided that half of the 3 x lime treatments should receive 125kg/ha of Mo single super. This was done on 14 April 2015.
- 125kg/ha of BioAg Superb treatment was also applied on the 14 April.

2015 Results

Herbage mass (kg DM/ha) was measured using a pasture probe (GrassMaster II) on 18 November 2015. Results for the two replicate plots were averaged and are presented in Figure 2. Note this data has not been statistically analysed.

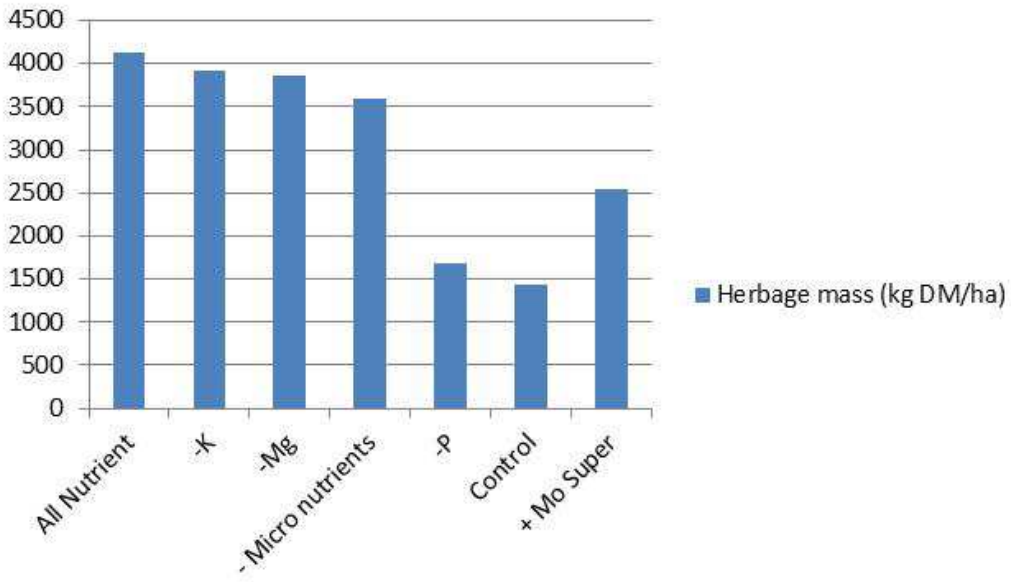

Figure 2: 2015 results from the nutrient subtractive trial at 'Carinya', Laggan.

Part B: Grazing Demonstration

The nutrient trial showed that phosphorus (P) is the major nutrient limiting pasture growth (Figure 2). However, the question then became: ***what level of production can be achieved under commercial grazing conditions, and does it pay to put fertiliser and/or lime out in a wool operation?***

To answer this question, an area near the nutrient trial consisting of similar pasture was fenced to create three, 7 hectare paddocks (Figure 3). The selected treatments were:

- **Paddock 1: Lime + single superphosphate** – fertiliser applied annually to increase soil P to a targeted level and fine agricultural lime (calcium carbonate) applied as a one off application to the native pasture to reduce soil acidity (pH).
- **Paddock 2: Control** (no fertiliser or lime): a native pasture of low soil fertility.
- **Paddock 3: Single superphosphate:** fertiliser applied annually to the native pasture to increase soil P to a targeted level.

Single superphosphate was selected as it is one of the most cost-effective ways of applying phosphorus to a grazing system. This has been proven in a long-term fertiliser trial at Bookham (Native Pasture & Alternative Fertiliser Project, Binalong/Bookham 2009 – 2014, unpublished data). Superphosphate also provides adequate amounts of sulfur (S) – another key nutrient that is often deficient in tableland soils. Lime was also chosen to be applied across one of the treatments to investigate its economic viability in a native pasture based grazing system.

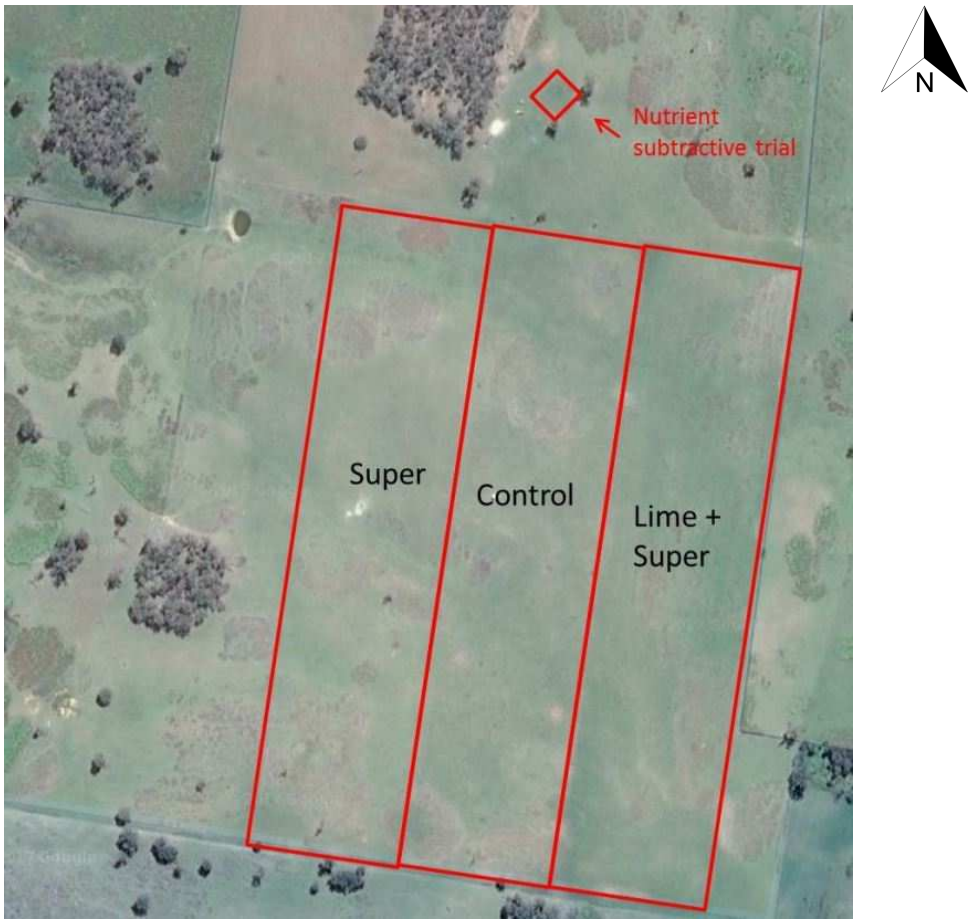

Figure 3: Aerial view of the Laggan Grazing Demonstration

About the site

"Carinya" is a 606 ha property located 18km north of Crookwell. The landscape is gently undulating with an altitude of around 980-1000m. Long-term average annual rainfall is 860mm with slight winter dominance.

From a pasture perspective the site could be described as a very good, dense native-based perennial pasture with the main species being Weeping grass (*Microleana stipoides*), Wallaby grass (*Austrodanthonia spp*.), subterranean clover (*Trifolium subterraneum*), native/naturalised legume species and annual grasses.

The soil is an acidic, brown Kurosol (Australian Soil Classification) with a topsoil pH ($CaCl_2$) of around 4.0 – 4.1 and 40% aluminium (Al). Soil testing to a depth of 20 cm has shown Al % increases to 50 to 66%. Soil texture changes with depth, with a grey brown silty loam 'A Horizon' (0-25cm) sitting over a moderately structured light clay subsoil (Figure 4).

The geology of this site means that the soil has very low inherent fertility. Prior to the paddocks being used for the demonstration they had not received any form of fertiliser for at least 13 years. Baseline soil testing showed that soil P was low, with Colwell P levels sitting around 10mg/kg. The site has a Phosphorus Buffering Index (PBI) of between 110 to 120 indicating the critical Colwell P level to be around 35 mg/kg.

Figure 4: Soil profile from the Laggan Grazing Demo site. Note the colour change in the profile where the soil changes from a silty loam top soil to a light clay subsoil.

What information is being collected?

- **Pasture growth rates:** pasture growth rates (kg DM/ha) are being collected on a monthly basis using a pasture probe (GrassMaster II). Refer to Appendix 1.
- **Pasture composition:** a botanical analysis is done each spring using the 'End Point Evaluation' technique. This assessment will help identify if there are any major changes in pasture composition across the treatments over time (see Appendix 2).
- **Soil nutrient levels, pH and soil carbon:** baseline soil testing occurred in December 2014 prior to any treatments being applied. This data is summarised in Table 1 below. Soil tests are taken annually in late spring to a depth of 10 cm to monitor changes over time. See Appendix 3 for the latest soil test results.

Table 1: Baseline soil test results for the three treatments

	pH ($CaCl_2$)	Aluminium %	PBI L/kg	Phos (Colwell) mg/kg	Sulfur mg/kg	Potassium cmol(+)/kg	CEC cmol(+)/kg	Total Carbon %
Lime + Super	4.1	38	120	11	5.4	0.64	4.7	4.7
Control	4.0	38	120	9.4	4.8	0.63	4.5	5.0
Super	4.0	45	110	8.8	3.7	0.4	4.0	4.0

- **Lime movement:** the movement of surface applied lime down through the soil profile will be measured annually in incremental segments to a depth of 20 cm. Complete soil cores were taken in December 2014 down to a depth of 20 cm and cut into four 2.5 cm segments down to a 10 cm depth and then cut into two 5 cm segments down to 20 cm. The same sampling protocol is used annually to monitor changes in pH and Al%. Lime movement is being monitored in autumn to ensure a better chance of receiving enough moisture at depth in order to take soil cores.
- **Livestock data:** wethers are weighed regularly so that similar body weights are maintained across the treatments. If body weight is kept the same then wool characteristics will be similar, allowing a fair economic assessment of treatments.
- **Wool data:** wethers are shorn annually in December. Un-skirted fleeces from each animal are weighed and tested (via OFDA 2000) for a range of wool characteristics including micron and staple length. These measurements are then used to calculate an average fleece price for each treatment on a $/head basis using wool prices at the time of shearing (obtained from AWEX weekly wool report).

Results and discussion

Merino wethers were shorn in December 2014 and allocated to all three treatments on 14 January 2015. The control paddock was allocated 35 wethers (5 wethers/ha) and the two treatment paddocks received 45 wethers (6.4 wethers/ha).

Fertiliser and lime applications that have been applied to date are shown in Table 2. The application of fertiliser had an immediate impact, with the fertilised paddocks growing more pasture and sustaining higher stocking rates than the control. It is important to note that the fertilised paddocks have shown a large increase in the amount of legume present (refer to Appendix 2 for botanical composition data). As such, the increase in stocking rate has been a function of both increased pasture quantity and quality.

Table 2: Fertiliser and soil ameliorant applications

Year	Month	Lime + Super	Super
2015	January	2.5t/ha of lime	
	February	125kg/ha Mo Single Superphosphate	125kg/ha Mo Single Superphosphate
2016	March	125kg/ha Single Superphosphate	125kg/ha Single Superphosphate
2017	March	160kg/ha Single Superphosphate	160kg/ha Single Superphosphate

Higher stocking rates have resulted in the fertilised paddocks cutting more wool per hectare. When averaged over the first three years, annual wool income has increased by $126/ha (Super treatment) to $168/ha (Lime + Super treatment) above the Control treatment (Table 3).

Putting out fertiliser and running a higher stocking rate also generated additional income through increased stock sales. Valuing the wethers at the start and end of the each year (after shearing) means that we can calculate meat income per hectare for the three treatments. As shown in Table 3, when averaged over the first three years livestock sales generated an extra $60/ha (Super treatment) to $103/ha (Super + Lime treatment).

Table 3: Livestock and economic data across treatments for the first three years of the Laggan Grazing Demonstration. Figures reported are average annual results from 2015 – 2017.

	Lime + Super	Control	Super
Wethers/ha*	7.66	5.37	7.56
Wool cut (kg wool/ha, clean)	27.25	17.86	25.05
Wool income ($/ha/yr)	493.44	325.46	451.79
Meat income ($/ha/yr)	198.73	95.46	155.33
Total income ($/ha/yr)	692.17	420.92	607.12
Total costs ($/ha/yr)	200.88	85.02	173.37
Operating profit ($/ha/yr)	**491.29**	**335.90**	**433.75**
Difference to control ($/ha profit/yr)	**+ 155.39**		**+ 97.85**

*adjusted stocked rate which takes grazing area lost to bracken fern into account. A handheld GPS unit was to map out the amount of bracken fern in all treatments (see Appendix 5 for further details)

When all the costs are taken into account (i.e. the costs of fertiliser as well as additional variable costs of running more stock), the super treatment has on average increased net profit by **$98/ha/yr** and the Lime + Super treatment by **$155/ha/yr** (above the Control treatment). The economic difference between the treatments was amplified in 2017 on the back of an extremely strong wool market, climbing to a record high in January 2018 (Figure 5).

The results to date clearly demonstrate that fertilising country not only pays in 'average' seasons, but it enables you to capitalise on opportunities to a much greater degree when they come around. While the fertilised treatments have generated higher financial returns in all years since the start of the demonstration, the differences between treatments were magnified in 2017 as a result of the wool market. As shown in Figure 6, gross margins on fertilised paddocks far exceeded the control, returning between $650 and $740/ha.

Refer to Appendix 6 and 7 for a full breakdown of the economic analysis and comparison between treatments.

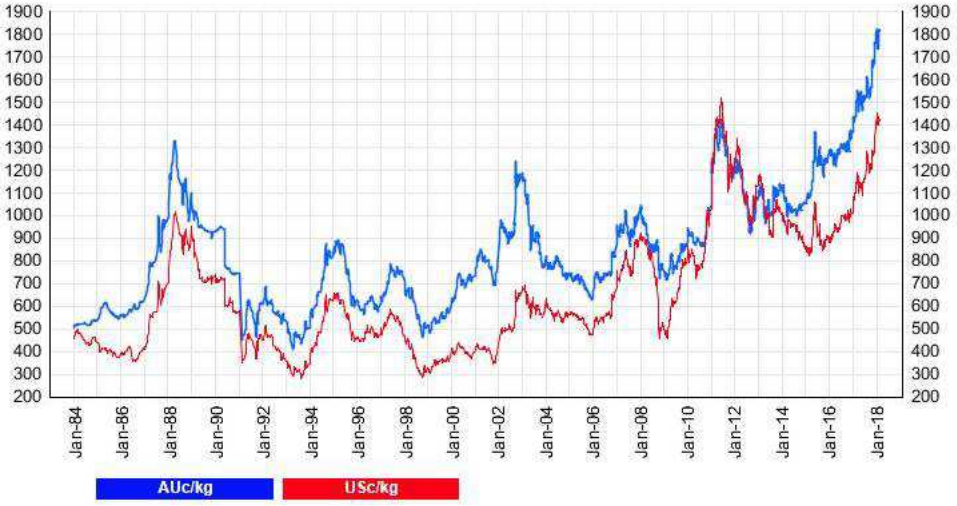

Figure 5: Australian Wool Exchange Eastern Market Indicator (1984 – 2018)

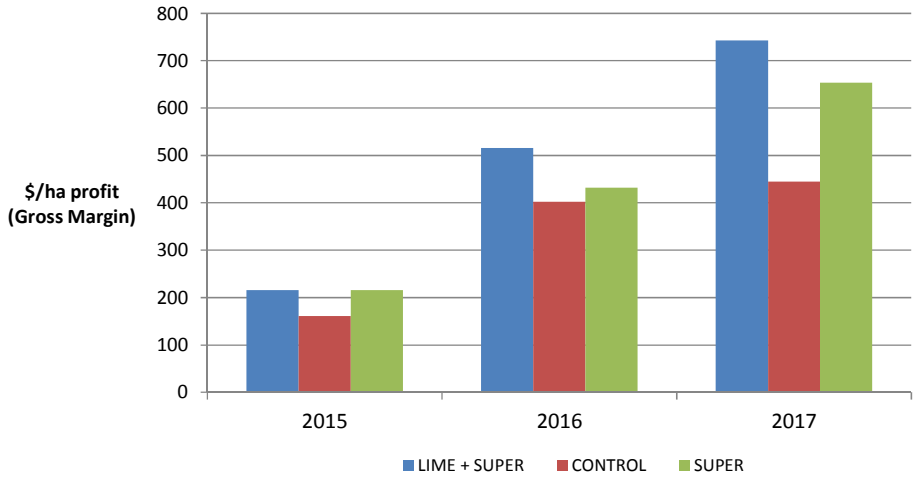

Figure 6: Gross margin comparison between treatments ($/ha profit)

Looking at the above results one could assume that putting out lime has a clear economic advantage. This is particularly interesting as the soil testing results (May 2016) showed that after 16 months the lime had only had an impact on soil pH and aluminium in the top 2.5cm of soil. Since May 2016 the impact of lime has not progressed any further down the profile (further details on the lime movement are detailed in Appendix 4).

Similar studies at Binalong, NSW found that surface applied lime resulted in a slight increase in pasture production in the first two years following application, but this effect was short lived (Leech 2006). Time will tell if the same effect is observed at this site. Nevertheless, the work to date is showing that there is a clear economic advantage from applying fertiliser and addressing P and S deficiencies providing that the additional pasture grown is utilised.

A cautionary note regarding the financial results…

Calculations showed that in 2015 the super only treatment had almost 2 ha completely removed from the system due to bracken fern. This was much more than the other two treatments. Appendix 5 shows the adjusted stocking rate once the bracken fern is taken into account for both 2015 and 2016. All economic results presented are based on the adjusted stocking rate in each of the three paddocks. It's worth noting however that assessing the impact of the bracken is difficult and the scale of the demonstration means the results are quite sensitive to this assessment. It is therefore important to view these results as 'preliminary' at this stage. Data collected over the next 3-4 years will be important in verifying the economic differences recorded to date.

While applying fertiliser has resulted in increased production, it is worth noting that P and S levels have only increased marginally to date. However, this is not overly surprising given the relatively modest rates of application and the Phosphorus Buffering Capacity of this soil (PBI between 110 to 120). The other point to note is that the last three years have been relatively good seasons (especially 2017) and hence a lot of the nutrients that have been applied would have been utilised by the plants for growth. While soil testing provides a guide to the level of nutrients that are readily plant available, it does not measure the total amount of nutrients in the soil.

It is also worth noting that sulfur levels have returned to more 'normal' levels after the extremely wet conditions experienced during 2016. This can be seen by comparing sulfur levels across years. Sulfur levels at the end of 2016 (30 Nov 2016 results) were undetectable in two out of the three paddocks, highlighting the mobile nature of this particular element. Sulfur levels above 8mg/kg are considered to be adequate for plant growth (i.e. not limiting production).

Comments from years

2015

- Significant rainfall in January resulted in wethers grazing around 1000kg of DM/ha (green) at the start of the demonstration, however dry conditions in February and March meant that pastures dried out quickly and the amount of green leaf started to disappear. The site received good rainfall and growth in April but May growth rates were very low – possibly due to lack of nitrogen as a result of the previous summer rainfall.
- Winter was particularly tough with the district receiving in excess of 30cm of snow in mid July. The negative pasture growth rates associated with July are a result of frost burning the leaves and shifting green material into the 'dead' pool.
- Although there was good soil moisture at the end of winter, lack of rainfall in September and October meant that the top soil dried out, restricting pasture growth. This is reflected in very modest pasture growth rates for these months.
- In looking at the data there is no doubt that the super paddock started with less herbage mass and this trend carried through for the remainder of the year. This was exacerbated by the fact that the super paddock had almost 2 ha completely removed from the system due to bracken fern. This was much more than the other two treatments. Appendix 5 shows the adjusted stocking rate once the bracken fern is taken into account.

- Wethers from all three treatments were shorn on 10 December 2015. Individual fleeces were weighed and tested (via OFDA 2000) for a range of wool characteristics including micron and staple length. This information was then used to calculate a full economic comparison (Appendix 6).

2016

- Weighing off shears in December 2015 showed that the wethers from the Lime + Super paddock had put on more weight and were approximately 6kg heavier than the other two paddocks. In hindsight, this was probably due to:
  - differences in pasture quality: the Lime + Super paddock had better legume content than the other two paddocks (Appendix 1)
  - stocking rate: due to the impact of the bracken fern, the Lime + Super paddock carried a slightly lower stocking rate compared to the Super paddock (7.26 vs 8.77 wethers/ha).
- In an effort to try and correct differences in body weight, effective stocking rate and pasture quantity, stocking rate was increased to 48 wethers in the Lime + Super paddock and reduced to 42 wethers in the super paddock. This adjustment effectively cancelled out the additional bracken in the Super treatment.
- In consultation with the landholder it was decided that the stocking rate in the Lime + Super treatment should be further increased to 53 wethers help cover the extra cost of the lime (Appendix 5).
- A second application of 125kg/ha was applied on 12 March 2016. Following a dry start to autumn, the season broke on 9 May with around 60mm falling over five days. Good soil moisture combined with warmer than average temperatures meant that pastures responded quickly.
- Despite good growth in May, extremely wet and overcast conditions meant that pastures and livestock did it tough during winter. The wet winter was immediately followed by the wettest September on record and above average rainfall in October. Cold temperatures however meant that spring growth was slow – it wasn't until late November that the pasture exceeded 1000kg DM/ha and pasture started to get ahead of the stock.
- Wethers from all three treatments were shorn on 13 December. Individual fleeces were weighed and tested. Despite running a slightly higher stocking rate, wethers from the Lime + Super paddock cut more wool per head and were heavier when compared to the super only paddock.

2017

- The wethers that were introduced at the start of the grazing demonstration (January 2015) were sold in February 2017 and replaced with a new team of 18-month-old wethers (spring 2015 drop). These wethers were tagged and allocated at random to one of the three paddocks. The average entry weights were 35.9kg (Lime + Super); 35.6kg (Super) and 36.9kg (Control). Single super was spread on 15 March at 160kg/ha.
- Unlike large parts of NSW, graziers in the Crookwell region experienced a good season where the timing of key rainfall events proved to be just as important as the amount. Excellent rainfall in March provided a solid early break to the season with Crookwell recording 114mm, all of which fell in the second half of the month. Pastures responded quickly to the moisture and warm conditions and there was a big germination of clover, especially in the fertilised paddocks.
- After a strong start to the growing season, pasture growth during winter was heavily restricted by exceptionally dry conditions (NSW recorded its 10th driest winter on record) and cold nights. The

frequent and large number of heavy frosts hit pastures hard and by the end of winter pasture levels in general had declined and were sitting somewhere around the long-term average (Figure 7).

- Dry conditions extended into September with annual grasses quickly putting up a seed head. Good rain in late September and early October provided valuable moisture for the perennials, however the end result was a spring that didn't produce a lot of bulk but enough rain to keep pastures green and extend out the growing season.
- Herbage mass (kg of dry matter/ha, green) and wether liveweight data where very similar between treatments up until the start of winter. After this point, wethers in the fertilised treatments started to pull away from the control (Figure 8), even though the amount of pasture in the paddocks remained similar (Figure 7). This trend continued for the remainder of the year. The differences in liveweight was a result of a greater amount of sub-clover in the fertilised paddocks.

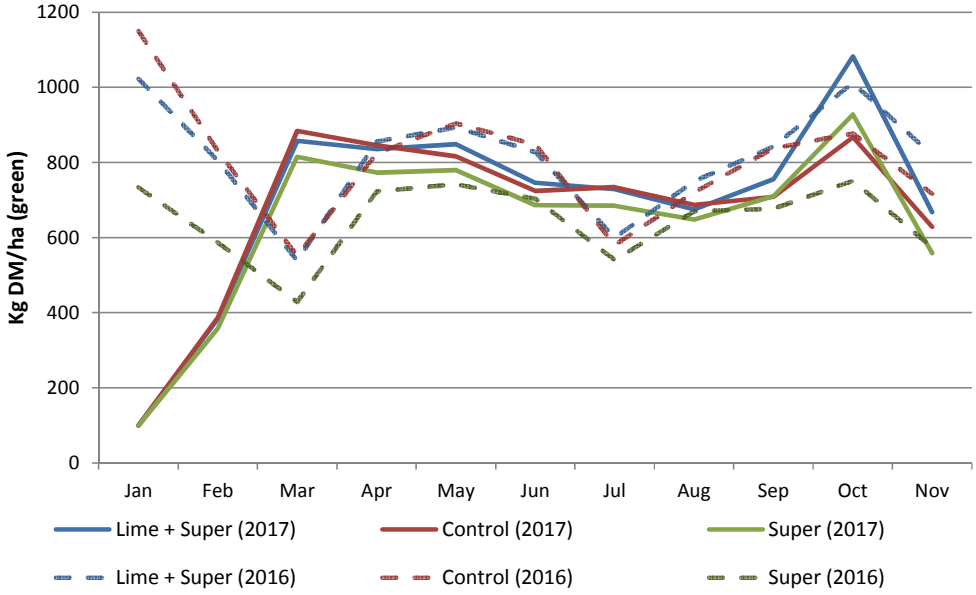

Figure 7: Laggan Grazing Demonstration end of month herbage mass – green component (kg/DM/ha) for 2016 and 2017

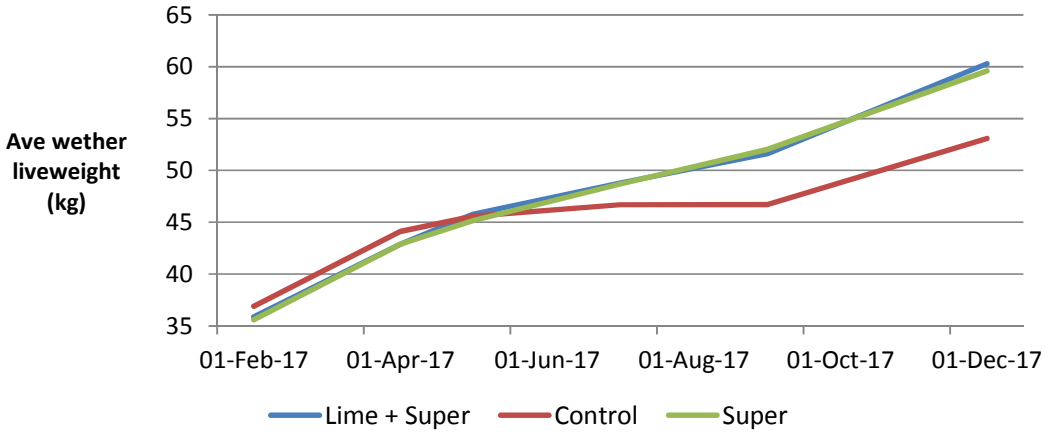

Figure 8: Laggan Grazing Demonstration – 2017 average wether liveweight

The Bookham grazing demonstration

- A similar study was conducted over a 13 year period at 'Kia-Ora', Bookham, NSW. The Bookham Grazing Demonstration (520m elevation) showed that applying single superphosphate resulted in a 2-fold increase in stocking rate, generating an additional $79/ha in profit (Appendix 8). When comparing the two demonstrations it is important to note that the Bookham work did not take the meat component into account.

References

Leech FJ, (2006). Profitability of liming and fertilising native pastures in the Yass district. In 'Proceedings of the Grasslands Society of NSW Inc - 21st Annual Conference'. pp130-131.

Acknowledgments

Thanks to Shannon Arnall of "Carinya" for hosting the project and for his ongoing assistance and support

Appendix 1: Pasture growth rates

Laggan Grazing Demonstration - Average Monthly Pasture Growth Rates (kg DM/ha/day)

Year	Treatment	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2017	Super + lime	green	18	23	8	10	5	6	5	12	21	-6	green
	Control	green	12	22	4	5	3	5	3	6	12	-2	green
	Super	green	16	22	6	8	4	6	4	10	16	-5	green
2016	Super + lime	nc	-8	2	2	17	7	6	7	13	4	29	nc
	Control	nc	-8	0	2	15	5	5	4	9	2	19	nc
	Super	nc	-5	2	2	15	6	5	6	10	4	25	nc
2015	Super + lime	nc	2	-1	19	3	5	-2	11	11	16	3	nc
	Control	nc	-3	-3	15	4	4	-4	9	10	8	2	nc
	Super	nc	5	4	19	2	7	2	11	10	13	7	nc

nc = not collected

green = pasture contained a green component, but the amount of green was not measured

Appendix 2: Botanical Composition

Botanical composition is assessed each spring using the 'End Point Evaluation' technique. This measurement is taken to see if there are significant changes in the composition of the pasture over time. In other words, is there an increase, decrease or no change of certain species as a result of treatment and/or management?

Botanical composition of the three treatments at 'Carinya' *

Species	Pdk 1: Lime + Super			Pdk 2: Control			Pdk 3: Super		
	2015	2016	2017^	2015	2016	2017^	2015	2016	2017^
Microlaena	40	38	39	52	47	49	43	45	45
Danthonia	22	15	13	25	25	17	23	20	9
Yorkshire Fog	1			0.5					
Annual Grasses	6	9		0.5	6		5	8	
Legumes	19	27	11	8	10	2	13	20	5
Weeds	5	4	9	2	3	7	1	1	6
Bare ground	1	3	2	2	2	3	2	3	3
Litter	5	4	26	10	7	22	13	3	32
Other	1								

*Numbers indicate the percentage of species present in the pasture sward

^ The 2017 botanical composition was delayed and done much later in the season compared to previous years. As such, a lot of the 'litter' that was recorded was sub clover (and other plant material including microlaena and danthonia) that had senesced due to drying conditions.

Appendix 3: 0-10cm soil test results (summary)

Treatment	pH ($CaCl_2$)	Al %	Colwell P mg/kg	Sulfur mg/kg	Potassium cmol(+)/kg	CEC cmol(+)/kg	Total Carbon %
2014 (baseline, sampled 10 Dec)							
Paddock 1 (Lime + Super)	4.1	38	11.0	5.4	0.64	4.7	4.7
Paddock 2 Control)	4.0	38	9.4	4.8	0.63	4.5	5.0
Paddock 3 (Super)	4.0	45	8.8	3.7	0.4	4.0	4.0
2015 (sampled 26 Nov)							
Paddock 1 (Lime + Super)	4.2	17	11.0	4.3	0.47	5.7	4.0
Paddock 2 Control)	3.8	38	9.9	4.6	0.68	5.0	4.3
Paddock 3 (Super)	3.8	46	9.4	4.9	0.36	4.4	4.1
2016 (sampled 30 Nov)							
Paddock 1 (Lime + Super)	4.3	18	8.9	<2	0.45	4.5	4.1
Paddock 2 Control)	4.0	39	7.4	<2	0.51	6.1	4.3
Paddock 3 (Super)	3.9	46	8.9	2.4	0.38	5.0	3.9
2017 (sampled 13 Dec)							
Paddock 1 (Lime + Super)	4.2	26	11.0	5.1	7.3	6.0	4.5
Paddock 2 Control)	3.9	46	9.8	4.3	11.0	5.1	4.6
Paddock 3 (Super)	3.9	45	13.0	7.1	9.2	4.9	4.8

Note: Baseline soil testing showed a PBI in the range of 100 to 120 across the demonstration site.

Appendix 4: Lime movement results

Soil pH ($CaCl_2$) profiles

PADDOCK 1: Lime + Super							
Depth (cm)	2014	2016	2017	2018	2019	2020	2021
0 - 2.5	4.2	**5.0**	**5.1**				
2.5 - 5	4.1	3.9	4.2				
5 - 7.5	4.0	3.8	4.0				
7.5 - 10	4.0	3.8	4.0				
10 - 15	4.0	3.8	4.0				
15 - 20	4.1	3.8	4.0				

PADDOCK 2: Control							
Depth (cm)	2014	2016	2017	2018	2019	2020	2021
0 - 2.5	4.3	4.0	4.2				
2.5 - 5	4	3.8	4.1				
5 - 7.5	4.0	3.8	4.0				
7.5 - 10	4.0	3.8	4.1				
10 - 15	4.1	3.8	4.1				
15 - 20	4.1	3.7	4.1				

PADDOCK 3: Super							
Depth (cm)	2014	2016	2017	2018	2019	2020	2021
0 - 2.5	4.2	4.0	4.1				
2.5 - 5	4	3.8	4.0				
5 - 7.5	4.0	3.8	4.0				
7.5 - 10	4.0	3.8	4.0				
10 - 15	4.1	3.8	4.1				
15 - 20	4.1	3.9	4.1				

Soil aluminium (% of CEC)

PADDOCK 1: Lime + Super							
Depth (cm)	2014	2016	2017	2018	2019	2020	2021
0 - 2.5	16	**0**	**0**				
2.5 - 5	34	29	23				
5 - 7.5	42	41	36				
7.5 - 10	50	48	44				
10 - 15	52	50	50				
15 - 20	55	55	58				

PADDOCK 2: Control							
Depth (cm)	2014	2016	2017	2018	2019	2020	2021
0 - 2.5	12	18	21				
2.5 - 5	35	36	37				
5 - 7.5	42	44	41				
7.5 - 10	46	48	43				
10 - 15	52	52	47				
15 - 20	57	54	48				

PADDOCK 3: Super							
Depth (cm)	2014	2016	2017	2018	2019	2020	2021
0 - 2.5	16	18	21				
2.5 - 5	41	39	39				
5 - 7.5	48	46	46				
7.5 - 10	52	52	49				
10 - 15	62	61	56				
15 - 20	66	63	61				

Key: **"Lime Effect"** >0.3 unit change

Reduced Al% to < 5%

Appendix 5: Stocking rates across years

The table below shows the stocking rates across all treatments. Wethers are weighed and stocking rates are adjusted accordingly to try and maintain similar liveweights across the treatments. If liveweight is kept the same then wool characteristics will be similar, allowing a fair economic assessment of treatments.

Paddocks are assessed for bracken (*Pteridium esculentum*) each spring to account for differences in the amount of bracken across treatments and therefore effective grazing area. Each 'patch' of bracken is measured using a handheld GPS unit and then visually assessed in terms of its impact on grazing (i.e. a patch containing 100% bracken is rated as having zero grazing value and hence removed from the overall grazing area). The table below shows the adjusted stocking rate once the bracken fern is taken into account.

The number of weathers grazing each paddock and the adjusted stocking rate*

	2015			2016			2017		
Month	**Super + Lime**	**Control**	**Super**	**Super + Lime**	**Control**	**Super**	**Super + Lime**	**Control**	**Super**
Jan	45	35	45	53	35	42	53	35	40
Feb	45	35	45	53	35	42	55	35	40
Mar	45	35	45	53	35	42	55	35	40
Apr	45	35	45	53	35	42	55	35	40
May	45	35	45	53	35	42	55	35	40
Jun	45	35	45	53	35	42	55	35	40
Jul	45	35	45	53	35	38	55	35	40
Aug	45	35	45	53	35	38	55	35	40
Sep	45	35	45	53	35	38	55	35	40
Oct	45	35	45	53	35	38	55	35	40
Nov	45	35	45	53	35	38	55	35	40
Dec	45	35	45	53	35	38	55	35	40
No. of wethers/paddock (averaged over 12 months)	**45**	**35**	**45**	**53**	**35**	**40**	**55**	**35**	**40**
Paddock size (ha)	7.02	6.98	6.97	7.02	6.98	6.97	7.02	6.98	6.97
Total area affected by bracken fern	**0.82**	**0.66**	**1.84**	**0.27**	**0.51**	**1.22**	**0.03**	**0.20**	**1.22**
Adjusted area	6.2	6.32	5.13	6.75	6.47	5.75	6.75	6.47	5.75
Stocking rate (wethers/ha)	6.41	5.01	6.46	7.55	5.01	5.74	7.55	5.01	5.74
Adjusted stocking rate (wethers/ha)	7.26	5.54	8.77	7.85	5.41	6.96	7.87	5.17	6.96

*adjusted stocked rate which takes grazing area lost to bracken fern into account. A handheld GPS unit was to map out the amount of bracken fern in all treatments

Appendix 6: Wether production and financial comparison – 2015 to 2017

2015

Wool income				
		LIME + SUPER	CONTROL	SUPER
Production				
Area of paddock	ha	6.20	6.32	5.13
Number of wethers	per paddock	45	35	45
Stocking rate	per ha	7.3	5.5	8.8
GFW (kg)	per head	4.7	4.5	4.4
Clean wool (kg)	per head	3.3	3.2	3.0
Micron	average	18.0	18.4	17.6
Wool Price (Dec 2016)	cents/kg clean	1500	1470	1514
Clean Wool (kg)	per ha	24.0	17.5	26.7
Wool income ($/HA):		359.71	257.09	404.71
Meat income				
Livestock value as of Jan '15				
Average Liveweight	kg	45.0	45.0	45.0
Purchase price	c/kg cwt	300	300	300
Livestock value/hd	$/hd	52.7	52.7	52.7
Livestock value/ha	$/ha	382.1	291.6	461.8
Livestock value as of Dec '15				
Average liveweight off shears	kg	49.8	43.0	44.3
Mutton price	c/kg cwt	300	300	300
Livestock value/hd	$/hd	58.3	50.3	51.8
Livestock value/ha	$/ha	422.9	278.6	454.7
Meat income ($/HA):		40.76	-12.96	-7.18
TOTAL INCOME ($/HA)		400.47	244.13	397.52
Costs				
Variable Costs	$/ha			
Animal health ($3.50/hd)		25.40	19.38	30.70
Wool harvesting ($9.00/hd)		65.32	49.84	78.95
Selling costs (5.5% of wool income)		19.78	14.14	22.26
Fertiliser costs	$/ha	74	0	50
Feeding costs	$/hd	0	0	0
TOTAL COSTS ($/ha)		184.51	83.36	181.91
PROFIT				
$/ha		215.96	160.76	215.62
Difference (to control)		55.20		54.85

Fertiliser costs: 2015 (ex GST)	
Superphosphate	
Price/t (delivered)	344
Price/ha (125kg/ha @ $344/t	43
Spreading cost/ha	7
Total cost/ha	50

2016

Wool income				
		LIME + SUPER	CONTROL	SUPER
Production				
Area of paddock	ha	6.75	6.47	5.75
Number of wethers	per paddock	53	35	40
Stocking rate	per ha	7.9	5.4	7.0
GFW (kg)	per head	4.4	4.4	3.9
Clean wool (kg)	per head	3.2	3.2	2.9
Micron	average	18.0	18.3	17.4
Wool Price (Dec 2016)	cents/kg clean	1710	1689	1750
Clean Wool (kg)	per ha	25.1	17.3	20.2
Wool income ($/HA):		429.65	292.38	353.04
Meat income				
Livestock value as of Dec '15				
Average Liveweight	kg	49.8	43.0	44.3
Purchase price	c/kg cwt	300	300	300
Livestock value/hd	$/hd	58.3	50.3	51.8
Livestock value/ha	$/ha	457.5	272.2	360.6
Livestock value as of Feb '17				
Average liveweight off shears	kg	53.0	48.5	48.2
Mutton price	c/kg cwt	413	413	413
Livestock value/hd	$/hd	94.1	86.1	85.6
Livestock value/ha	$/ha	739.0	465.9	595.5
Meat income ($/HA):		281.54	193.78	234.90
TOTAL INCOME ($/HA)		711.19	486.15	587.95
Costs				
Variable Costs	$/ha			
Animal health ($3.50/hd)		27.48	18.93	24.35
Wool harvesting ($9.00/hd)		70.67	48.69	62.61
Selling costs (4% of wool income)		23.63	16.08	19.42
Fertiliser costs	$/ha	74	0	50
Feeding costs	$/hd	0	0	0
TOTAL COSTS ($/ha)		195.78	83.70	156.37
PROFIT				
$/ha		515.42	402.45	431.57
Difference (to control)		112.96		29.12

Fertiliser costs: 2016 (ex GST)	
Superphosphate	
Price/t (delivered)	344
Price/ha (125kg/ha @ $344/t	43
Spreading cost/ha	7
Total cost/ha	50

2017

Wool income		LIME + SUPER	CONTROL	SUPER
Production				
Area of paddock	ha	6.99	6.78	5.75
Number of wethers	per paddock	55	35	40
Stocking rate	per ha	7.9	5.2	7.0
GFW (kg)	per head	5.8	5.1	5.7
Clean wool (kg)	per head	4.2	3.6	4.1
Micron	average	17.8	17.3	17.9
Wool Price (Dec 2017)	cents/kg clean	2116	2272	2116
Clean Wool (kg)	per ha	32.7	18.8	28.2
Wool income ($/HA):		690.95	426.92	597.63
Meat income				
Livestock value as of Feb '17				
Average Liveweight	kg	35.9	36.9	35.6
Purchase price	c/kg cwt	500	500	500
Livestock value/hd	$/hd	70.0	72.0	69.4
Livestock value/ha	$/ha	550.8	371.4	482.9
Livestock value as of Dec '17				
Average liveweight off shears	kg	54.9	48.4	54.3
Mutton price	c/kg cwt	444	444	444
Livestock value/hd	$/hd	104.8	92.4	103.7
Livestock value/ha	$/ha	824.7	477.0	721.2
Meat income ($/HA):		273.90	105.57	238.26
TOTAL INCOME ($/HA)		964.85	532.49	835.89
Costs				
Variable Costs	$/ha			
Animal health ($3.50/hd)		27.54	18.07	24.35
Wool harvesting ($9.00/hd)		70.82	46.46	62.61
Selling costs (4% of wool income)		38.00	23.48	32.87
Fertiliser costs	$/ha	86	0	62
Feeding costs	$/hd	0	0	0
TOTAL COSTS ($/ha)		222.36	88.01	181.83
PROFIT				
$/ha		742.50	444.48	654.06
Difference (to control)		298.01		209.58

Fertiliser costs: 2017 (ex GST)	
Superphosphate	
Price/t (delivered)	344
Price/ha (160kg/ha @ $344/t)	55
Spreading cost/ha	7
Total cost/ha	62

Lime costs:

Lime	
Price/t	$45
Freight/t	$16
Spreading cost/t	$19
Total cost/t (spread)	$80
Spreading rate (t/ha)	2.5
Total cost/ha	**$200**
Life of application (yrs)	$10
Annual cost/ha/yr	$20
plus interest @ 6%	$4.00
Total annual cost/ha	**$24.00**

Appendix 7: Wether production and financial data across years

	2015	2016	2017	2018	2019	2020	2021
Lime + Super							
Wethers/ha*	7.3	7.6	7.9				
GFW (ave kg/hd)	4.7	4.4	5.8				
Micron (ave)	18.0	18.0	17.8				
Wool cut (kg wool/ha, clean)	24.0	24.6	32.7				
Wool income ($/ha/yr)	395.71	394.68	690.95				
Meat income ($/ha/yr)	40.76	161.15	273.90				
Total income ($/ha/yr)	400.47	555.83	964.85				
Total costs ($/ha/yr)**	169.23	173.89	222.36				
Operating profit ($/ha/yr)	231.24	381.94	742.50				
Difference to control ($/ha profit/yr)	+58.32	+91.23	+298.01				
Control							
Wethers/ha*	5.5	5.4	5.2				
GFW (ave kg/hd)	4.5	4.4	5.1				
Micron (ave)	18.4	18.3	17.3				
Wool cut (kg wool/ha, clean)	17.5	17.3	18.8				
Wool income ($/ha/yr)	257.09	292.38	426.92				
Meat income ($/ha/yr)	-12.96	187.32	105.57				
Total income ($/ha/yr)	244.13	479.70	532.49				
Total costs ($/ha/yr)	71.20	71.20	88.01				
Operating profit ($/ha/yr)	172.93	408.49	444.48				
Super							
Wethers/ha*	8.8	7.9	7.0				
GFW (ave kg/hd)	4.4	3.9	5.7				
Micron (ave)	17.6	17.4	17.9				
Wool cut (kg wool/ha, clean)	26.7	23.5	28.2				
Wool income ($/ha/yr)	404.71	378.88	597.63				
Meat income ($/ha/yr)	-7.18	113.86	238.26				
Total income ($/ha/yr)	397.52	492.74	835.89				
Total costs ($/ha/yr)	162.68	151.66	181.83				
Operating profit ($/ha/yr)	234.84	341.07	654.06				
Difference to control ($/ha profit/yr)	+61.92	+50.36	209.58				

* Paddock areas were adjusted to take into account grazing area lost to bracken fern (i.e. some paddocks had more bracken fern than others. A handheld GPS unit was to map out the amount of bracken fern in all treatments.

** The cost of applying lime ($25/ha) is presented as an annualised cost. This cost is based on lime delivered at 'Carinya' plus spreading costs and interest (6% p.a.) over a 10 year period (all prices GST exclusive). The annualised cost of lime ($25/ha) is then added to the cost of single superphosphate ($60/ha), bringing the total to $85/ha.

Appendix 8: Results from the Bookham Grazing Demonstration

13 Year wether production data from the Grazing Demonstration at 'Kia-Ora', Bookham NSW.

SUPER	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	13 YEAR AVGE
Stocking Rate / ha	11.05	10.70	11.20	12.80	13.20	14.00	14.90	14.90	14.60	12.60	14.50	15.10	15.10	13.43
Total Clean Wool kg/ha	35.30	39.90	41.30	39.90	43.60	50.20	53.60	56.00	43.50	31.60	34.00	41.50	35.40	41.98
Total Wool Income $/ha	462.43	251.37	255.73	374.66	218.44	347.43	701.41	574.56	581.16	285.35	311.58	341.13	415.95	393.93
Total Cost $/ha	258.32	225.97	217.28	248.73	251.09	228.96	281.51	297.64	289.89	392.99	344.11	333.48	321.06	283.92
Profit $/ha	204.11	25.40	38.45	125.93	-7.33	136.01	419.90	276.92	291.27	-107.64	-32.53	7.65	94.89	113.31
Difference Super-No Super $/ha Profit	94.90	5.07	23.86	72.04	15.24	124.31	287.63	209.04	123.67	-41.65	-9.65	40.67	78.82	**78.76**
Cost of Production c/kg Clean	7.32	5.66	5.26	6.23	5.76	4.56	5.25	5.32	6.66	12.44	10.12	8.03	9.07	7.05
NO SUPER	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	13 YEAR AVGE
Stocking Rate / ha	6.30	6.30	6.30	6.30	6.30	6.30	6.10	6.10	6.30	6.10	5.80	5.30	5.80	6.10
Total Clean Wool kg/ha	19.50	22.90	22.20	19.50	19.50	23.80	22.90	22.50	22.10	15.60	15.60	15.50	14.10	19.67
Total Wool Income $/ha	253.50	151.83	138.46	191.30	116.22	149.94	288.08	225.00	333.05	158.50	151.32	122.76	178.08	189.08
Total Cost $/ha	144.29	131.50	123.87	137.41	138.79	138.24	155.81	157.12	165.45	224.49	174.20	155.78	162.01	154.53
Profit $/ha	109.21	20.33	14.59	53.89	-22.57	11.70	132.27	67.88	167.60	-65.99	-22.88	-33.02	16.07	34.54
Cost of Production c/kg Clean	7.40	5.74	5.58	7.05	7.12	5.81	6.80	6.98	7.49	14.39	11.16	10.05	11.49	8.23