Laggan Grazing Demonstration – observations and key lessons after six years

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Abstract: *A grazing demonstration was established at Laggan NSW to measure the production response and economic advantage of applying fertiliser and lime to a native pasture of low soil fertility. The grazing demonstration commenced in 2015 and consists of three treatments: single superphosphate (SS); lime + single superphosphate (L+S); and a control (Cont). Lime was surface applied as one-off application (2.5 t/ha) at the start of the demonstration. The demonstration site is set stocked with Merino wethers. Wethers are regularly weighed and stocking rates adjusted to achieve similar average body weight across treatments. The financial performance of each treatment is based on wool returns plus meat income when wethers are sold. The application of fertiliser had an immediate impact, with the fertilised paddocks growing more pasture and sustaining higher stocking rates. Economic data from the first six years shows that when P and S are applied at this site, average stocking rates can be increased by 2 wethers/ha (143%), lifting overall profitability by around $100/ha/year. While the effect of lime on soil pH was limited to the top 2.5 cm of soil, lime appears to have had a positive effect on legume production at this site. L+S increased stocking rate by 2.9 wethers/ha (163%) and profitability by a $181/ha. With current commodity prices and high returns for livestock the data shows that adding lime to native pastures is likely to be profitable. However, applying lime is still a considerable up-front cost to the producer and any potential benefit will only be realised if deficiencies of major nutrients are addressed.*

Key words: native pastures, phosphorus, lime response, livestock production

Introduction

Australia's grazing industries were originally established on the natural grassy ecosystems found by the early explorers in the early 1800s. Native pasture species continue to play an important role in supporting livestock production throughout New South Wales, occupying several million hectares (Langford *et al*. 2004).

Although native pastures have long been associated with 'low input, low output' systems, we know that this is not always the case. A long-term grazing demonstration in the Bookham NSW district has shown that pasture production and long-term stocking rates can be doubled when major nutrient deficiencies are addressed (Graham 2012).

A long-term grazing demonstration was established in the Laggan area (14 km NNE of Crookwell NSW) to assess the economics of fertilising native pastures in the Crookwell region, which is approximately twice the elevation of Bookham (Laggan demonstration site ~1000 m; Bookham demonstration site ~ 520 m). The demonstration was also set up to assess the impact of applying lime on pasture production and overall economics. Adding a lime treatment to the demonstration was of particular interest as lime is commonly applied to the surface of established pastures (both native and introduced).

Methods

Site description

The demonstration site is located at "Carinya", Laggan NSW. The local topography is gently undulating, elevated terrain with broad ridgelines and long gently to moderately graded hillslopes (5–8%), draining to shallow depressions and drainage lines. Altitude at the demonstration site ranges from 976 m to 1008 m. Long-term average median rainfall is 868 mm with slight winter dominance (Crookwell Post Office; Bureau of Meteorology weather station 070025).

The pasture is a dense native-based perennial grass pasture with Weeping Grass (*Microlaena stipoides*) and Wallaby Grass (*Austrodanthonia* spp.) being the dominant species. The pasture also contains subterranean clover (*Trifolium* subterraneumn), native/naturalised legume species and annual grasses.

The soil is an acidic, brown Kurosol (Australian Soil Classification). Soil texture changes with depth, with a grey brown silty loam 'A Horizon' (0–25 cm) sitting over a moderately structured light clay subsoil. Soil pH in the top 10 cm is 4.0–4.1 ($CaCl_2$) with exchangeable aluminium (Al) at 40 % of Cation Exchange Capacity. Deeper soil testing at the site shows that Al % increases to 50–66 % at 20 cm.

Prior to the demonstration the site had not received any form of fertiliser for at least 13 years. Baseline soil testing showed Colwell P levels sitting around 10 mg/kg and a Phosphorus Buffering Index (PBI) between 110–120 (Table 1).

Design, treatments and sampling

During 2014 a paddock at "Carinya" was sub-divided to create three paddocks, each approximately 7 hectares in size. A reticulation system was installed to provide water to all three paddocks via troughs and baseline soil sampling was carried out.

Lime was surface applied as a one-off application (2.5 t/ha) in January 2015 and superphosphate was also applied to create the following treatments:

- Paddock 1: Lime + Single superphosphate (L+S)
- Paddock 2: Control (Cont)
- Paddock 3: Single superphosphate (SS)

In January 2015, 125 Merino wethers were weighed and randomly allocated across the three treatments. Treatments are continuously grazed by Merino wethers to simplify management. Wethers are weighed every 4–6 weeks and stocking rate is adjusted so that a similar average body weight and wool characteristics are maintained across treatments. The financial performance of each treatment is based on wool returns plus meat income when wethers are sold.

Herbage mass (kg DM/ha) measurements are taken at the end of each month using a capacitance probe (Grassmaster II). Average daily pasture consumption rates by livestock for the month are estimated using the GrazFeed decision support tool. Together, these measurements are entered into the fodder budgeting program PRO Plus to calculate average daily pasture growth rates for the month (kg DM/ha/day). A botanical composition analysis is done each spring using the 'Rod Point' technique (Little and Frensham 1993), with 200 observations recorded in each paddock

Annual soil tests are taken in late spring in each paddock along fixed transects to a depth of 10 cm to monitor soil nutrient levels, pH and soil carbon. The movement of surface applied lime down through the soil profile is also measured annually along a set 100 m transect and assessed in incremental segments to a depth of 20 cm. The top 10 cm is cut into four 2.5 cm segments. The remaining 10–20 cm section is cut into 5 cm segments. This sampling procedure is conducted in each of the three paddocks in autumn to monitor changes in pH and Al.

Wethers are shorn annually in December. Unskirted fleeces from each animal are weighed and fibre diameter is tested on site using Optical Fibre Diameter Analyser (OFDA) technology. Micron and fleece weight measurements are used to calculate an average fleece price for each treatment on a $/head basis using wool prices at the time of shearing (obtained from the

Table 1. Baseline soil test results sampled in December 2014 (0–10 cm) for the three treatments at the Laggan Grazing Demonstration.

Treatment	pH ($CaCl_2$)	Exchangeable Aluminium (%)	PBI (L/kg)	Colwell P (mg/kg)	Sulphur (mg/kg)	Total Carbon (%)
Lime + Super	4.1	38	120	11	5.4	4.7
Control	4.0	38	120	9.4	4.8	5.0
Super	4.0	45	110	8.8	3.7	4.0

Australian Wool Exchange weekly report).

Wethers are weighed upon entry into the grazing demonstration (15–18 months of age) and at the end of each shearing to calculate annual changes in meat value as well as total meat income for the period the wethers are grazing the demonstration.

Results and discussion

Soil nutrients and soil carbon

Despite annual applications of single superphosphate, soil Colwell phosphorus (P) levels in the two fertilised paddocks (L+S and SS) remained static for the first three years (2015–2017) of the demonstration (Figure 1). However, this is not surprising given the modest rates of superphosphate application and the PBI of the soil. It is important to note that during this period the fertilised paddocks were growing more pasture and supporting higher stocking rates. These results suggest that the rates applied were only sufficient to address maintenance P requirements and not enough to build soil Colwell P levels. When using moderate rates of fertiliser, pasture, livestock production and carrying capacity are a better means of assessing the response to fertiliser inputs rather than changes in soil test values.

It wasn't until the end of the 2018 season where a significant rise in soil Colwell P levels were observed. This was driven by an increase in fertiliser application rates and drought. The lack of moisture during a drought heavily restricts pasture growth and nutrients often accumulate in the soil. While this trend can be seen in all treatments, it occurs to a much greater degree in the fertilised paddocks. This seasonal effect can also be seen in the soil sulphur (S) results (Figure 2).

Although the same rates of fertiliser were applied to both the L+S and SS paddocks in the first five years, by the end of 2019 soil Colwell P levels in the SS paddock are much higher than the L+S paddock. This can be explained by the fact that the L+S paddock has consistently grown more pasture and supported a higher stocking rate. As such, more nutrients have been used by the plants for growth, which in turn leads to a lower level of residual nutrients in the soil. This effect can also be seen with S (Figure 2).

Exceptional growing conditions in 2020 saw a significant decline in residual P and S levels in all three paddocks. These nutrients haven't disappeared out of the system, but rather are 'tied up' in undecomposed plant material either standing, on the ground or in root material. This highlights the impact that the season can have on soil test results e.g. elevated readings after a dry period and lower than normal readings following a good season.

Soil test results can vary significantly from year-to-year depending on the amount of fertiliser applied, seasonal conditions and when samples are taken. For these reasons, annual soil testing is recommended to identify trends and check the appropriateness of fertiliser application rates (Simpson *et al*. 2009).

Baseline 0–10 cm soil testing at the end of 2014 showed that total soil carbon levels measured by Dumas combustion were already high at this site, ranging between 4.0–5.0 % (Table 1). After six years of monitoring there is no clear treatment effect on soil carbon levels. The measured changes appear more related to seasonal conditions than treatment (Figure 3). Given the high initial soil carbon levels measured, it is possible that this site is very close to its upper soil carbon threshold. The high starting point also means that modest gains in soil carbon may be difficult to detect.

Soil pH

Soil testing to 20 cm shows that the lime has only had an impact in the top 2.5 cm of soil, lifting pH ($CaCl_2$) from 4.2 to 5.0 (Table 2) and reducing aluminium from 16 % to 0 % (Table 3). This was achieved within the first 16 months of application. Since May 2016 the impact of lime has not progressed any further down the profile.

While the purpose of applying lime is to alter the soil chemistry to a large proportion of the soil, history shows that getting lime into the soil to depth is a major challenge and difficult to predict. Research findings over the last 40 years have ranged from no movement to deep and

Table 2: Impact of lime on soil pH ($CaCl_2$) in the L+S paddock at the Laggan Grazing Demonstration over the period 2014 to 2020.

Depth (cm)	2014	2016	2017	2018	2019	2020
0–2.5	4.2	5.0	5.1	4.9	4.7	4.7
2.5–5	4.1	3.9	4.2	4.1	4.0	4.0
5–7.5	4.0	3.8	4.0	4.0	4.0	4.0
7.5–10	4.0	3.8	4.0	4.0	3.9	3.9
10–15	4.0	3.8	4.0	4.0	4.0	4.0
15–20	4.1	3.8	4.0	4.1	4.0	4.0

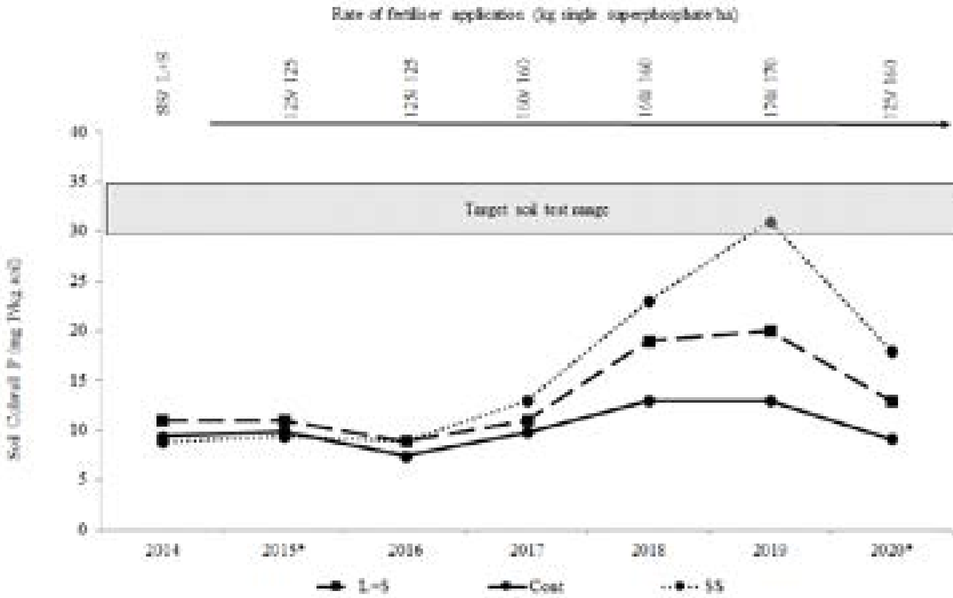

Figure 1: Fertiliser application history and annual soil Colwell P levels on the Laggan Grazing Demonstration for the period 2014 to 2020 (* indicates the years in which superphosphate was applied with molybdenum).

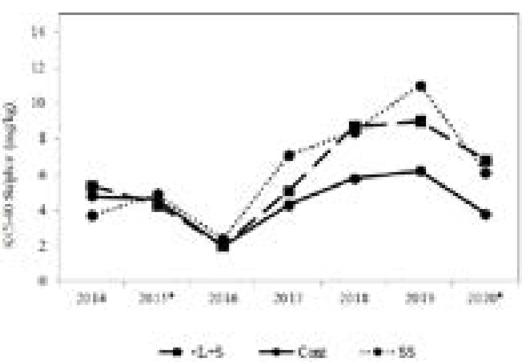

Figure 2: Annual soil S levels (KCl-40) on Laggan Grazing Demonstration from 2014 to 2020.

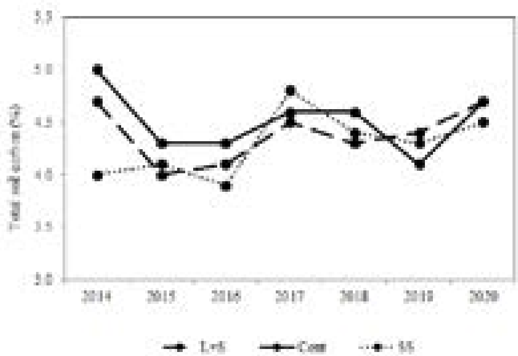

Figure 3: Annual Total Soil Carbon % (Dumas Combustion method) on Laggan Grazing Demonstration from 2014 to 2020.

Table 3: Impact of lime on soil aluminium (Al % of CEC) in the L+S paddock at the Laggan Grazing Demonstration over the period 2014 to 2020.

Depth (cm)	2014	2016	2017	2018	2019	2020
0–2.5	16	0	0	1	3	3
2.5–5	34	29	23	29	25	25
5–7.5	42	41	36	40	39	39
7.5–10	50	48	44	46	42	42
10–15	52	50	50	50	46	46
15–20	55	55	58	52	50	50

rapid penetration into the soil (Scott *et al.* 2000). Local work done on the Southern Tablelands has shown variable results from topdressing lime, with lime movement varying from 5 cm to 20 cm. Several factors influence lime movement, including soil type, soil buffering capacity, the amount of lime applied and rainfall.

The relatively high total soil carbon levels measured (>4.0 % in the 0–10 cm sample) could explain why 2.5 t/ha of lime has not been able to alter soil chemistry below 2.5 cm at this particular site. Higher rates of lime would be required to achieve deeper penetration. A long-term trial at Sutton NSW (on a soil with very similar pH and Al levels) was able to achieve a pH change down to a maximum depth of 17.5 cm (Norton *et al.* 2018), however much higher rates were used (7.72 t/ha).

Pasture production, livestock and economics

The application of fertiliser had an immediate impact, with the fertilised paddocks growing more pasture and sustaining higher stocking rates than the Control (Table 4). Over the first 6 years, stocking rates have averaged:

- Control: 4.6 wethers/ha
- SS: 6.6 wethers/ha
- L+S: 7.5 wethers/ha

These results show that when P and S is applied at this site, stocking rates on average have increased by 2 wethers/ha above the Control (Control 4.6 wethers/ha cf. SS 6.6 wethers/ha). The surface application of lime at 2.5 t/ha has increased stocking rate by a further 0.9 wethers/ha above the SS treatment. The biggest increase in livestock production has come from addressing both P and S deficiencies, with lime lifting production to a lesser degree. It is worth noting that the L+S paddock has a slight easterly aspect which could be providing some advantage over the SS and Control paddocks which both have a slight westerly aspect). Further work is required to verify the true production advantage that has been observed as a result of topdressing lime at this site. A small plot trial at the site prior to the start of the grazing demonstration did not show a visual response in pasture production to the application of 2.5 t/ha of surface applied lime.

Higher stocking rates have resulted in the fertilised paddocks (SS and L+S) cutting more wool per hectare. When averaged over the six years, annual wool production has increased from 16.9 kg/ha (clean) in the Control paddock to 24.7 kg/ha in the SS paddock and 29.3 kg/ha in the L+S paddock. Higher stocking rates in the fertilised paddocks also generated more meat income per hectare.

An economic comparison shows that SS has on average increased net profit by $99/ha above the Control. The L+S treatment has increased net profit to a far greater extent, boosting returns by $181 /ha (Table 4). While the difference in stocking rate between the SS and L+S paddock is relatively small (average of 0.9 wethers /ha), the 2015–20 period has coincided with exceptionally strong wool and mutton markets. When markets are favourable, small increases in carrying capacity can make a big difference to the bottom line.

The increase in stocking rate and economic return in the fertilised paddocks has been a result of both increased pasture growth (Figure 4) and pasture quality. As expected, the application of P immediately stimulated the legume component in the fertilised paddocks, especially in the L+S treatment. This was particularly evident in 2018 and 2019 where the L+S paddock recorded 45–49 % legume in spring. This was more than double the amount of legume recorded in the SS paddock (19–20 %). As a further comparison in 2018 and 2019, the Control paddock recorded 3–7 % legume in spring. Legume has performed poorly in the Control paddock due to low soil fertility (Table 5). It is important to note that legume must be present in the pasture in order to achieve a production response to P. This site had some background legume within the pasture which quickly responded when P (and S) was applied.

At this particular site the surface application of lime appears to have had a positive effect on the presence of legume in the pasture (Table 5) and its performance, despite the lime only having an impact on the top 2.5 cm of soil (Table 2). A replicated experiment at Sutton NSW on a soil with similar pH and aluminium levels also measured a legume response to surface applied lime (Norton *et al.* 2020), although noting much higher rates of lime were used.

A review by Scott *et al.* (2000) highlights that pasture yield response to lime is highly variable and hard to predict. Some studies have reported no measurable yield increase while others have reported large increases in response to lime. It is worth noting the majority of pasture research over the years involving lime has been done on introduced perennial pastures (e.g. lucerne, phalaris and cocksfoot) and the lime has been incorporated via cultivation.

Table 4: Livestock and economic data comparison across treatments (averaged annual results over period 2015–2020) at Laggan Grazing Demonstration.

	L+S	Cont	SS
Wethers/ha	7.5	4.6	6.6
Wool cut (kg wool/ha, clean)	29.3	16.9	24.7
Wool income ($/ha/yr)	533	316	453
Meat income ($/ha/yr)	200	86	149
Total income ($/ha/yr)	732	402	602
Total costs ($/ha/yr)	245	96	197
Profit ($/ha/yr)	487	306	405
Difference to control ($/ha profit/yr)	+ 181		+ 99

Table 5: Botanical composition of the L+S, SS and Control treatments at the Laggan Grazing Demonstration. Numbers indicate the average percentage of each species in the sward for the first six years (2015–2020).

Species	L+S	Cont	SS
Microlaena	28	47	37
Wallaby grass	13	21	15
Annual grasses	7	3	5
Legumes	37	7	23
Weeds	4	3	2
Bare ground	3	7	7
Litter	9	13	13

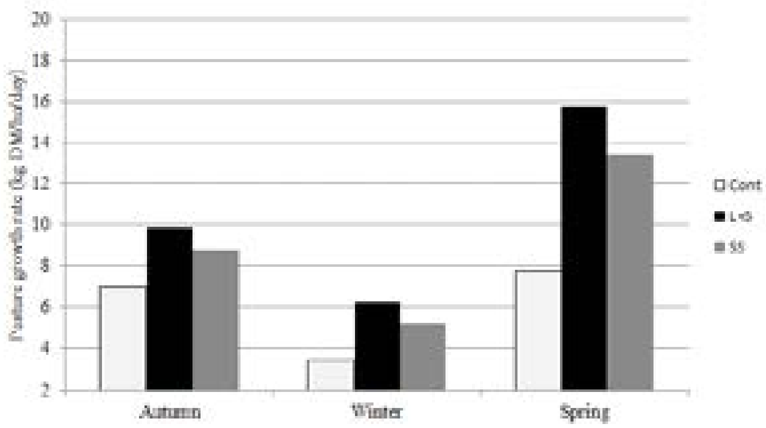

Figure 4: Average pasture growth rates (kg/ha/day) in Autumn, Winter and Spring for the L+S, SS and Control treatments measured over the period 2015–2020 on the Laggan Grazing Demonstration.

While few studies have investigated the impact of topdressing lime on native perennial grass-based pastures (Scott *et al.* 2000), a long-term grazing demonstration at Binalong NSW reported an average increase of 2.4 wethers/ha in response to surface applied lime, applied as a one-off application at 2.5 t/ha (Leech 2006). At the time of the Binalong demonstration (1999–2004) the data suggested that liming native based perennial pastures in the Yass district was – a secondary economic benefit with the largest gains in stocking rate being achieved by addressing key soil nutrient constraints i.e. P, S, Molybdenum.

In contrast, this demonstration shows a strong economic advantage of liming which is being driven by high commodity prices. Livestock returns have improved dramatically since the early 2000s, with gross margins currently sitting around $60/DSE compared with $16/DSE in 2007, representing an increase of 284%. In the same period the cost of applying lime has only increased by 21% (Francis 2021). The cost to apply lime in this demonstration ($200/ha) was annualised over a 10-year period which equates to $24/ha/yr (assuming an interest rate of 6%). With current commodity prices and high returns for livestock the data shows that small increases in production from lime are likely to be profitable. However, any potential benefit from adding lime will only be realised if major nutrient deficiencies are addressed (Peoples *et al.* 1995).

Annual monitoring of pasture composition shows that all three paddocks have maintained a very strong native perennial grass base. This is despite three drought years (2017–2019) occurring during the first 6 years (2015–2020). Pasture stability is just as important as any production increase. Native pasture species have adapted to shallow acidic soils and maintaining their presence across the landscape is important. Sowing introduced pasture species into these soils is expensive and successful establishment comes with considerable risk. Persistence of these introduced species can also be variable.

Conclusions

A grazing demonstration was established in the Crookwell NSW region to measure the production increase and economic advantage of applying fertiliser and lime to a native pasture of low fertility.

The native pastures at this site responded to the addition of fertiliser (P &S), and in particular the legume component. While the increase in pasture production is evident across all seasons, the additional growth in autumn and winter is of greatest value as this is the period of minimum feed availability and sets the annual stocking rate (Scott *et al.* 2000).

As with any pasture improvement strategy, in order to realise an economic advantage, stocking rate must be increased to utilise the extra pasture grown. Data collected from the first six years of the demonstration showed that when P and S is applied at this site, average stocking rates can be increased by two wethers/ha, or 143%. This increase in stocking rate translated into more wool and meat produced per hectare, lifting profitability by almost $100/ha/year.

While the benefits of surface applied lime in undisturbed soils have seldom been demonstrated, at this site lime appears to have had a positive effect on pasture production, especially the legume component. As a result, lime has increased stocking rate by 0.9 wethers/ha and overall profitability by $82/ha above the fertiliser only treatment (SS). With current commodity prices and high returns for livestock the data shows that small increases in production from lime are likely to be profitable. However, applying lime is still a considerable up-front cost to the producer and any potential benefit will only be realised if major nutrient deficiencies are addressed.

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