Final report

PDS Is fertilising pastures economically worthwhile?

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Abstract

Poor sown pasture vigour underpinned by chronically low levels of key soil nutrients is limiting productivity on many grazing properties in the southern Brigalow Belt region in Queensland. Fertilising pastures is not common practice for beef producers in this region and they were interested in investigating if it was economically worthwhile to adopt this practice and what sort of application strategies would suit their local environment.

Paired paddock comparisons of fertilised and unfertilised paddocks were used across four properties to demonstrate how strategic fertilising based on regular soil testing can improve long-term pasture productivity. Data collected from all the sites monitored changes in soil nutrients, pasture yield, pasture composition and the diet quality of pasture. Fertiliser application rates and costs were tracked and used to do a benefit cost analysis of the practice.

This project demonstrated that even at maintenance levels and during dry years, fertiliser application significantly increases the quantity of plant biomass produced. Average pasture yield in the fertilised paddocks was consistently double that of the unfertilised paddocks and the diet quality (protein, energy and digestibility) was also consistently better, regardless of season. The benefit cost analysis demonstrated that fertilising was an economically worthwhile investment with a benefit to cost ratio of 2.2:1 using 2018-2021 input costs.

Executive summary

Background

Poor sown pasture vigour is limiting property productivity on many grazing properties in the southern Brigalow Belt region in Queensland. Symptoms of nutrient "rundown" and poorer than expected pasture yields indicate that there is untapped potential to strategically use fertiliser to correct these issues and boost business productivity by increasing both kilograms of beef turned off per hectare and per head.

Fertilising pastures is not common practice in this region and graziers were interested in investigating if it is economically worthwhile to adopt this practice and what sort of application strategies would suit their local environment.

Objectives

The key objectives of this project were:

1. Use paired paddock comparisons across four properties to demonstrate how strategic fertilising can improve long-term pasture productivity via increased growing season pasture yield and improved diet quality.

2. Conduct a benefit-cost analysis to clearly demonstrate the economic value of fertilising existing sown pastures to red meat producers compared to doing nothing (good grazing management alone).

3. Increase competency of producers how to initiate and manage a successful pasture fertilising program.

4. Communicate the results of this project to red meat producers and agronomists in similar environments.

Methodology

Soil, pasture and diet quality data was collected from paired paddock comparisons to compare the differences between fertilised and unfertilised sown pastures on four different properties. Trial paddocks were fertilised annually just prior to or at the start of the growing season with products and rates guided by dry season soil test results and forecast growing season conditions.

Applied fertiliser rates, incurred costs on the treated paddocks and the resulting yields were used to create a benefit cost model to analyse if there was a financial benefit in adopting the practice compared to the control (unfertilised) paddocks.

Paddock progress was monitored by a core observer group and broad results from the project were extended to producers and agronomists via field walks, a webinar, Beef Up Forum presentation and Feedback Magazine article.

Results/key findings

In this demonstration the most obvious response to the applied fertiliser was the significant increase in quantity and quality of plant biomass produced. Average pasture yield in the fertilised paddocks was consistently double that of the unfertilised paddocks and the diet quality was also consistently better, regardless of season. Whilst the soil nutrient levels did not significantly change or improve during the trial period as a response to the fertiliser, the soil's output in terms of nutrient removal as a response of the dry matter production have removed from 1.8 to 3 times more nutrients (nitrogen, phosphorus and potassium) than the control areas.

Sown pasture fertilising appears to be economically worthwhile in the western Darling Downs, particularly when applied to pastures on deep, high water holding capacity soils exhibiting symptoms of nutrient rundown. A simple benefit cost model was used to test the value of the investment and found that in each scenario tested, the activity was worthwhile as it cleared the economic hurdles for good investment. Using prices paid during, the benefit cost analysis showed that the Net Present value of the fertiliser investment after 10 years would be $52,130, internal rate of return 35%, it would take four years to break even and the benefit to cost ratio was 2.2:1.

The poorest return was achieved when the model was tested with the current extremely high fertiliser prices. The result was that the investment only just broke even but was still positive. Taking a longer-term view, it is thought that even with these high prices, it is still a worthwhile activity long-term.

Co-operators observed that good grazing management, timeliness of fertiliser application and following the full fertilising program underpinned the success of the investment. If these weren't closely followed, the result was clearly diminished.

The project generated a lot of interest from both producers and agronomists. A mid-project webinar to review the interim results attracted 85 registrations. The trial co-operators have expanded their fertilising programs to other paddocks on their property and a couple have invested in fertiliser spreaders. Other interested producers are holding off venturing into a pasture fertilising program in the due to record high fertiliser prices and lack of data to demonstrate if it will pay off with such high input costs.

Benefits to industry

The southern Brigalow Belt covers an area of 27,196,933 ha and is historically the location of some of the most productive cattle country in Australia. Given that a lot of this country, is now exhibiting nutrient "rundown" symptoms, there is huge potential to increase business productivity by addressing soil fertility problems.

Strategic fertilising of existing sown pastures provides a mechanism to do this without taking paddocks out of production for extended periods of time and leaving soil bare to plant new pasture or forage crops.

The economic analysis of this demonstration has shown that there are clear economic and soil health benefits to graziers with rundown sown pastures in this region to invest in a soil testing and fertilising program. Potential benefits include:

- The ability to increase the scale of operation by increasing the pasture yield and therefore carrying capacity of existing paddocks without the need to buy more land
- Improved liveweight gain and reduced turnoff age due to better diet quality
- Better pasture composition, land condition and long-term carrying capacity

Fertilised perennial tropical pastures provide a sustainable and cost-effective alternative to summer forage crops because they can produce similar yields and diet quality when provided with the same nutrients, but with lower input costs (seed, herbicide, diesel, etc.). In dry years they provide ground cover and feed where fodder crop paddocks may be left bare.

Future research and recommendations

Widespread recognition and adoption of pasture fertilising as a sound business investment in the Queensland's southern Brigalow Belt will require investment in research and development to quantify predicted pasture and animal performance for different application strategies. In particular:

- Nutrient response curves for a variety of different pasture species, locations around Queensland and for key limiting nutrients
- Animal production data (LWG/age to turnoff)
- Application strategies suitable for the different environments and tropical pasture communities (timing of application, nutrient placement, product choice, etc.)

It will also require local upskilling of support professionals, such as agronomists, in soil test interpretation and fertiliser program development for grazed tropical pastures.

This research should also consider the consequences of nutrient use from an environmental context. Recommendations for best practice use of fertiliser on pastures in environmentally sensitive areas such as the reef catchments and the impact it would have on landscape-scale carbon accounting would be useful. Investigation into novel strategies and product sources to correct soil nutrient deficiencies and imbalances in this environment should be incorporated into any future research in this area.

PDS key data summary table

Project Aim: To clearly demonstrate the economic value of fertilising existing sown pastures to red meat producers compared to doing nothing (good grazing management alone) measured as additional kilograms of beef per hectare and per AE.			
	Comments		**Unit**
Production efficiency benefit (impact) Pasture productivity – kg DM/ha Stocking rate – DSE, AE or LSU/ha	Average dry matter increase across trial sites as a result of fertilising and corresponding extra AEs per hectare as a result of the additional growth. (Average growth was typically double that of the control paddocks, regardless of season)	+3500 +0.58	Kg DM/ha AE/ha
Number of core participants engaged in project		4	
Number of observer participants engaged in project		121	
Core group no. ha		17491	
Observer group no. ha		10649	
Core group no. cattle		4179	hd cattle
Observer group no. cattle		2710	hd cattle
% change in knowledge, skill & confidence – core	*E.g. Grow fodder crops to finish lambs on*	28%	
% practice change adoption – core	*E.g. Grow fodder crops to finish lambs on*	43%	

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1. Background

The southern Brigalow Belt bioregion in Queensland covers an area of 27,196,933 ha and is historically the location of some of the most productive cattle country in Australia. Poor sown pasture vigour is limiting property productivity on many grazing properties in the southern Brigalow Belt.

This project focuses on the western Darling Downs in this bioregion which was opened-up for grazing in the 1840s. Its fertile land has been intensively grazed and farmed ever since; the region producing a quarter of the state's agricultural output. Much of the grazing country was broken up into smaller soldier settlement farming and dairy blocks which were pushed beyond their productive limits to provide enough income to support a family. Overgrazing and long-term fodder and grain production without adequate fertilising has resulted in a lot of unproductive cropping country being converted to unproductive pasture. In the western areas broadscale brigalow scrub clearing began in earnest in the 1950s and like the abandoned farming country, the paddocks sown to introduce grass species have been gradually declining in productivity ever since.

Fertilising pastures has historically been dismissed as uneconomic for graziers in broadscale sub-tropical pastoral holdings, particularly in northern Australia. Farmers in the region have adopted sophisticated soil testing and fertilising regimes, but graziers haven't and most agronomists in the region have specialist crop management skills, but not pasture and there is little support for graziers who want to develop a pasture fertilising program.

A review commissioned by MLA in 2014 (B.NBP.0768 Fertilising for yield and quality in grass pastures and forage crops – Scoping study) negated this theory, but there have been few trials conducted in Queensland that have collected production data to demonstrate the economic benefits to red meat producers. Graziers in this region are interested to explore strategies and economic benefits in applying fertiliser to sown pastures.

2. Objectives

By May 2022, using paired paddock comparisons across four properties:

1. Demonstrate how strategic fertilising can improve long-term pasture productivity via:
   a. At least 25% (starting land condition B) to 55% (starting land condition C) increase in average growing season pasture yield (kg DM/ha) and long-term carrying capacity (AE/ha) within three years. ***ACHIEVED***
   b. Improved pasture quality (up to 30% increase in pasture crude protein measured via plant tissue analysis) ***18-25% INCREASE***
   c. Improved diet quality (up to 20% increase in annual diet quality measured via fNIRS) ***8-19% INCREASE***

2. Conduct a cost-benefit analysis to clearly demonstrate the economic value of fertilising existing sown pastures to red meat producers compared to doing nothing (good grazing management alone). This will be measured as additional Adult Equivalents per hectare. ***ACHIEVED***

3. All 14 core members and additional 15 observer members know:
   a. the production benefits of addressing soil nutrient imbalances,
   b. how to initiate a successful pasture fertilising program

c. key principles to managing grazing pressure to encourage and maintain good pasture condition

4. Eight of the 14 core group members have started soil testing rundown pasture paddocks with a plan to act to optimise pasture productivity. ***PARTIALLY ACHIEVED - MORE SOIL TESTING BEING UNDERTAKEN***

5. Communication materials will be produced to publicise the outcomes of the PDS to producers in similar environments. ***ACHIEVED***

3. Demonstration Site Design

3.1 Methodology

3.1.1 Soil sampling

A full (0-60cm) soil profile assessment was done at the start and end of the project.

Soil tests are to determine:
1. Existing nutrient levels in a plant available form
2. Some slow release/long term availability – BSES-P, C:N, C:P, etc.
3. A current biological indicator of soil health – root proliferation, Active carbon test, etc.

Soil sampling positions were either on a transect or point method and according to the following depths:
1. 0 – 10 cm: tested for: pH, O.C.%, E.C. and E.C. (se), chlorides, nitrogen, P(Colwell), potassium, sulphur, calcium, magnesium, sodium, aluminium, zinc, copper, manganese and iron and total N, P and S and active carbon.
2. Subsurface samples (10 – 30 cm) tested for: pH, E.C. and E.C. (se), chlorides, nitrogen, P (Colwell), BSES-P, potassium, sulphur, calcium, magnesium, sodium and aluminium and Total N.
3. Subsurface samples (30 – 60 cm) tested for: pH, E.C. and E.C. (se), chlorides, nitrogen, P (Colwell), BSES-P, potassium, sulphur, calcium, magnesium, sodium and aluminium.

Soil sampling was GPS monitored and conducted as a base line sampling and pre and post season. Biannual tests to identify change against the baseline assessments and to determine amelioration drawdown over the course of the project.

Each trial paddock was paired with a neighbouring control paddock which hasn't been fertilised and which is of a similar land type (e.g. both paddocks cleared softwood scrub). The control areas were monitored and measured at the same time and using the same methodology as trial paddocks.

Two, 3m x 3m grazing exclosures (fenced areas excluded from grazing animals) were erected in the trial and control paddocks. This is the area that cumulative pasture yield was measured in the paddock each Autumn. The exclosure in the trial paddock were removed each time the paddock is fertilised so that the area excluded from grazing is fertilised as well. The exclosure in the control paddock will remain standing until the end of the project (i.e. doesn't need removing while fertilising, as per the trial paddock).

3.1.2 Fertiliser application

Fertiliser products and rates were selected for solubility and dissolution characteristics and applied at a rate to maintain soil nutrient levels not capital application rates. Seasonal fertiliser recommendations devised for each trial paddock based on annual non-growing season soil test results and forecast growing season conditions. When conditions were dry, rates were tempered to align with the likely growth achievable in a water-limited environment. These rates were increased and more minor nutrients addressed as rainfall and subsoil moisture improved.

Non-volatile fertiliser such as single superphosphate was applied during the non-growing season while volatile fertiliser such as urea was applied after the season had broken and the plants were actively growing. Where possible, urea was applied as close as possible prior to a rain event.

3.1.3 Pasture condition

Pasture condition was assessed at the start and end of the project using a standard A, B, C or D land condition assessment and modified Botanal* methodology. A land condition assessment based on Grazing Land Management EDGE methodology comprises a combined rating for soil condition and pasture condition. Key assessment criteria are:

A condition has all the following features:

- good coverage of perennial grasses dominated by those species considered to be 3P grasses for that land type; little bare ground (<30%) in most years
- few weeds and no significant infestations
- good soil condition, no erosion, good surface condition

B condition has at least one or more of the following, otherwise similar to A:

- some decline of 3P grasses; increase in other species (annuals, less favoured grasses, weeds) and/or bare ground (more than 30% but less than 50% in most years)
- some decline in soil condition; some signs of previous erosion and current signs of erosion risk.

Poor or C condition has one or more of the following, otherwise similar to B:

- general decline of 3P grasses; large amounts of annuals, less favoured species and/or bare ground (>50% in most years)
- obvious signs of past erosion and/or susceptibility currently high.

D condition has one or more of the following features:

- general lack of any perennial grasses or forbs
- severe erosion or scalding, resulting in hostile environment for plant growth.

3.1.4 Forage condition

Forage condition, or the condition of pasture in terms of its feed value, was assessed via an annual assessment of growing season pasture yield (kg/DM/ha) and diet quality.

Cumulative pasture yield (kg DM/ha) was measured annually at the end of the growing season (April/May) in the grazing exclosures (3x3m areas of pasture excluded from grazing). These

* The Botanal procedure assessed species composition, species frequency, proportion of total dry matter yield attributed to each species, and ground cover. Pasture in the trial and control paddocks were assessed in a 0.5m x 0.5m quadrat a minimum of 30 times spread out over 4 transects in each paddock.

exclosures were 'zeroed' (mowed down) at the end of the non-growing season (September) so that only new season growth was measured each year.

Diet quality was assessed via two different methods. The first was via leaf tissue analysis and the second via dung sample analysis. Leaf tissue analysis provided a direct indication of the level of uptake of fertiliser in the fertilised paddocks while dung samples showed how much impact the fertilised pasture would likely be having on animal performance relative to the control paddocks based on their diet selection.

The leaf samples were collected annually during phase 2 of growth just prior to the monitored grazing period. One kilogram of randomly sampled leaf was collected from the fertilised and control areas from each property and analysed using Near InfraRed Spectrometry and wet chemistry analysis. The analysis provided estimates of the levels of key nutrients (N/P/K/S) within the leaf tissue sample and the relative feed value (protein, energy and digestibility) of the pasture.
One-off dry season samples were also collected from the fertilised and control paddocks in 2020 to review if there was a difference in diet quality while the pasture was in its dormant phase.

Dung samples were collected during the growing season monitored grazing period to measure dietary Crude Protein, digestibility, and phosphorus levels using NIRS analysis. The samples were collected 2 weeks after the animals started grazing the trial and control paddocks. This was to ensure the dung is representative of the focus paddocks and not the paddocks they were previously grazing. Dung samples were collected from about 10-20 fresh dung pats and dried before packaging and analysis. Diet quality data can be used to predict animal performance in the absence of reliable liveweight figures.

3.1.5 Grazing management

The project collected production data from two grazing periods (growing season and non-growing season) each year. Producers aimed to utilise approximately 10-15% of useful pasture during our monitored grazing periods in the treatment and control paddocks. A rotational forage budget (as used in Grazing Land Management EDGE) was used to calculate grazing days and manage grazing pressure during these periods and minimum residual of 1000-1500kg/ha was set for the co-operators to maintain in the paddocks throughout the dry season. Early wet season spelling was applied to all the trial paddocks to ensure pasture plants had ample opportunity to maximise plant health.

3.1.6 Animal performance data

Liveweights were initially collected, where possible, when animals went into and out of the trial paddocks for the monitored grazing periods.

3.2 Economic analysis

The data collated during this process will be used to generate a cost/benefit analysis of the value of fertilising pastures in the Darling Downs region. Based on the data collected the following economic indicators will be generated from this project:

- Gross margin/ha, and
- Gross margin/animal unit (AE).

3.3 Extension and communication

Extension and communication from this project were focused on a local level. The aim was to get neighbours and local agronomists aware of the trial and give them an opportunity to track its progress. Activities that were planned as part of this project were:

- Annual field walk
- Reference group meetings
- Case studies/news article
- Producer guides/fact sheets

3.4 Monitoring and evaluation

The monitoring and evaluation for this project required:

- Clear identification of practices and metrics being demonstrated and measured
- Collection of data on producer numbers and animals, and area potentially impacted by the project
- Entrance surveys of producers to benchmark current knowledge and skills in relation to the subject
- Benchmark current practices in relation to the subject
- Exit surveys of producers to enable assessment of changes in:
    - Reactions (perceptions, enthusiasm etc.) as a result of the project
    - Knowledge, Attitudes, Skills and Aspirations
    - Practices
- Review of the extent of and impact from communication / extension activities outside of the PDS project participants

4 Results

4.1 Demonstration site results

4.1.1 Seasonal conditions

The during the first 18 months of the project the cooperating properties (core producers) endured very dry conditions. 2019 had the second lowest rainfall on record for the district and rain that did fall, fell at the very start and the very end of the growing season with in-season rainfall to sustain high rates of pasture growth. The average rainfall across the trial properties in 2019 was 223mm and the range was 152mm to 287mm. Long-term average rainfall for the district is 660.4mm. Fertilising was only partially completed in 2019 for this reason. Rainfall improved in 2020, ranging from 416.5mm to 594mm on the trial properties, however 78% of the rain fell in two major rain events in January/February and December. Rainfall total and distribution improved significantly and rose above the long-term average for all properties in 2021 as the project finished.

Rainfall was highly variable across the cooperating properties which meant that monitored grazing periods and data collection happened at different times depending on when and how much rain fell. This was to ensure that data was collected at the same phase of growth, regardless of timing of rain.

4.1.2 Soil results

4.1.2.1 Baseline paddock description and fertilising program applied

4.1.2.1.1 "Inverlochy"

The site at "Inverlochy" was a contoured area with a variable slope and soil type ranging from reddish brown sandy clay loams to a black light or medium clay loam under what was originally softwood and brigalow scrub. The area selected for the trial was more of the black light or medium clay and contained within a set of contours to reduce variability. An electric fence was used to split the paddock and one half was treated with fertiliser and the other was left as an unfertilised control area.

The site was managed well through the trial period with fertiliser products applied timely and often with local rain events post application to assist with incorporation.

Initial base line soil sampling suggests that the soil fertility in the field sampled was low in nitrogen, phosphorus, sulphur and zinc. During the demonstration soil potassium levels were declining, in response potassium was included in the fertiliser recommendation.

Fertiliser was applied in a timely manner; around September/October, to an established Gatton panic, Rhodes grass, Bisset creeping bluegrass, Premier digitaria and desmanthus mixed pasture.

Fertilising program at "Inverlochy" was:

- 2018 – 100kg/ha urea + 50kg/ha Granulock Z Supreme, spread
- 2019 – 50kg/ha urea + 50kg/ha Starter Z, spread
- 2020 – 100kg/ha urea + 100kg/ha Granulock Z + 100kg/ha Muriate of Potash

4.1.2.1.2 "Oakland"

The two trial sites at "Oakland" i.e. Fertilised and Control, had different soil properties, even though adjacent. The fertilised paddock comprised of a dark reddish brown sandy clay loam and pre-clearing transitioned from spotted gum into softwood scrub and slightly less fertile than the control paddock. The control paddock was a dark brown fine sandy clay loam and was originally softwood scrub pre-clearing. These differences were reflected in their production and analysis.

Fertiliser was applied in a timely manner; around September/October, to an established creeping bluegrass pasture.

Fertilising program at "Oakland" was:

- 2018 – 50kg/ha urea + 50kg/ha Granulock Z Supreme, spread early December prior to rain
- 2019 – 50kg/ha urea + 50kg/ha Starter Z, spread late September
- 2020 – 70kg/ha urea + 150kg/ha Granulock Z + 150kg/ha Muriate of Potash

4.1.2.1.3 "Diamondy"

The trial paddock at "Diamondy" was on alluvial poplar box flats and had fine sandy clay loam textured soil. The control area was a strip in the treated area so soil types should be similar. The base line soil samples indicate that the soils fertility was reasonably satisfactory with more than satisfactory micronutrients and phosphorus and potassium levels, in fact the only essential nutrient that was low was sulphur. The calcium % was also lower and magnesium % higher than desired but the actual calcium and magnesium levels were satisfactory.

Fertilising program at "Diamondy" was:

- 2018 – 100kg/ha Single Superphosphate, spread late January 2019
- 2019 – 100kg/ha urea, spread early March
- 2020 – No fertiliser applied

Not all recommended fertiliser was applied to this site due to poor seasonal conditions and lack of manpower to do the job.

4.1.2.1.4 "Jolimont"

"Jolimont" only came on board with the project in 2019 after another co-operator pulled out of the project.

The trial area was a dark grayish brown fine sandy clay loam, and the treated area was generally of a higher fertility than the control area.

Fertilising program at "Jolimont" was:

- 2019 – 100kg/ha Single Superphosphate spread onto dry pasture in late December and urea direct drilled into green paddock at the start of February 2020
- 2020 – 250kg/ha SuPerfect Pot spread onto dry pasture late September 2020, too dry to apply urea
- 2021 – 100kg/ha Urea applied <u>after</u> trial results collated in September 2021 as the property remained too dry over the growing season to fertilise then

4.1.2.2 End of trial soil results

In this demonstration the most obvious response to the applied fertiliser was the significant increase in quality and quantity of plant biomass produced. Whilst the soil nutrient levels may have not significantly changed/improve as a response to the fertiliser and if anything, more nutrient was removed in the fertilised paddocks due to what is believed to be an invigorated nutrient cycling system, the soil's output in terms of nutrient removal as a response of the dry matter production have removed from 1.8 to 3 times more nutrients (nitrogen, phosphorus and potassium) than the control areas. The soil fertiliser applied is simply an input (like mineralisation) that is related to the corresponding output in both the short and long-term depending on the input. A process catalysed by increasingly better seasonal conditions in terms of amount and frequency of rainfall.

Figure 1: Organic Carbon % - Fertilised paddocks (0-10cm)

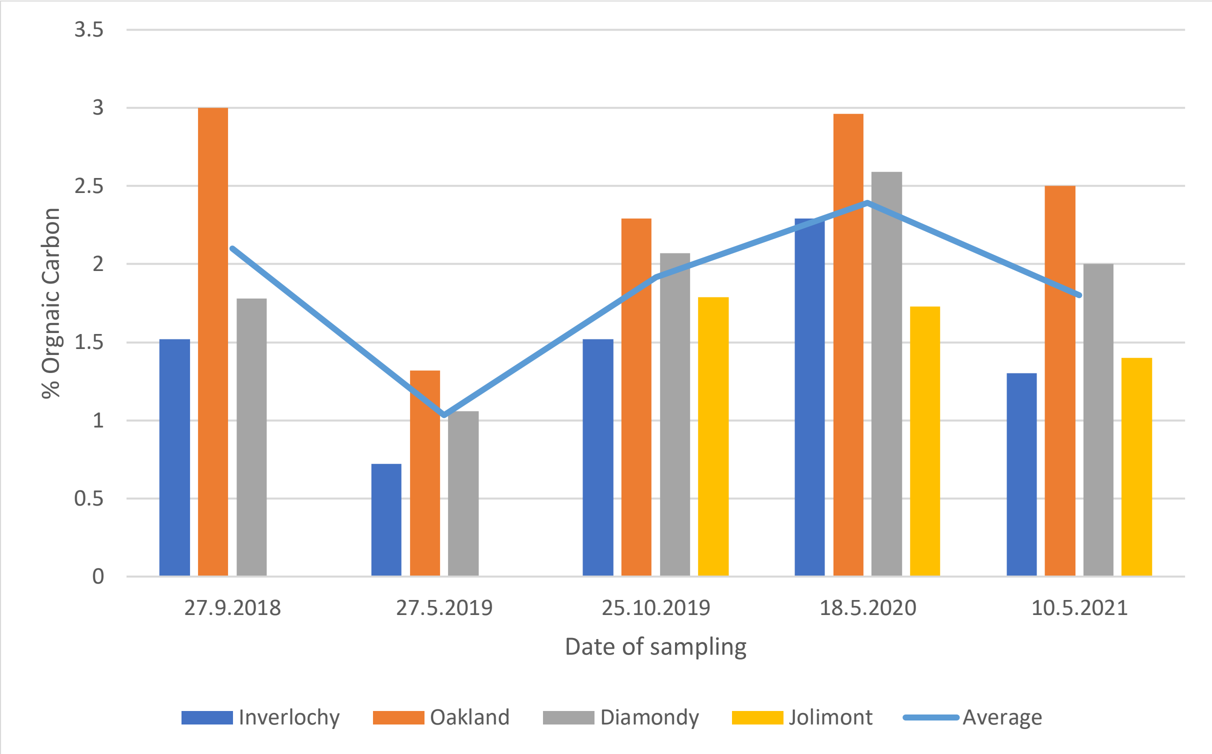
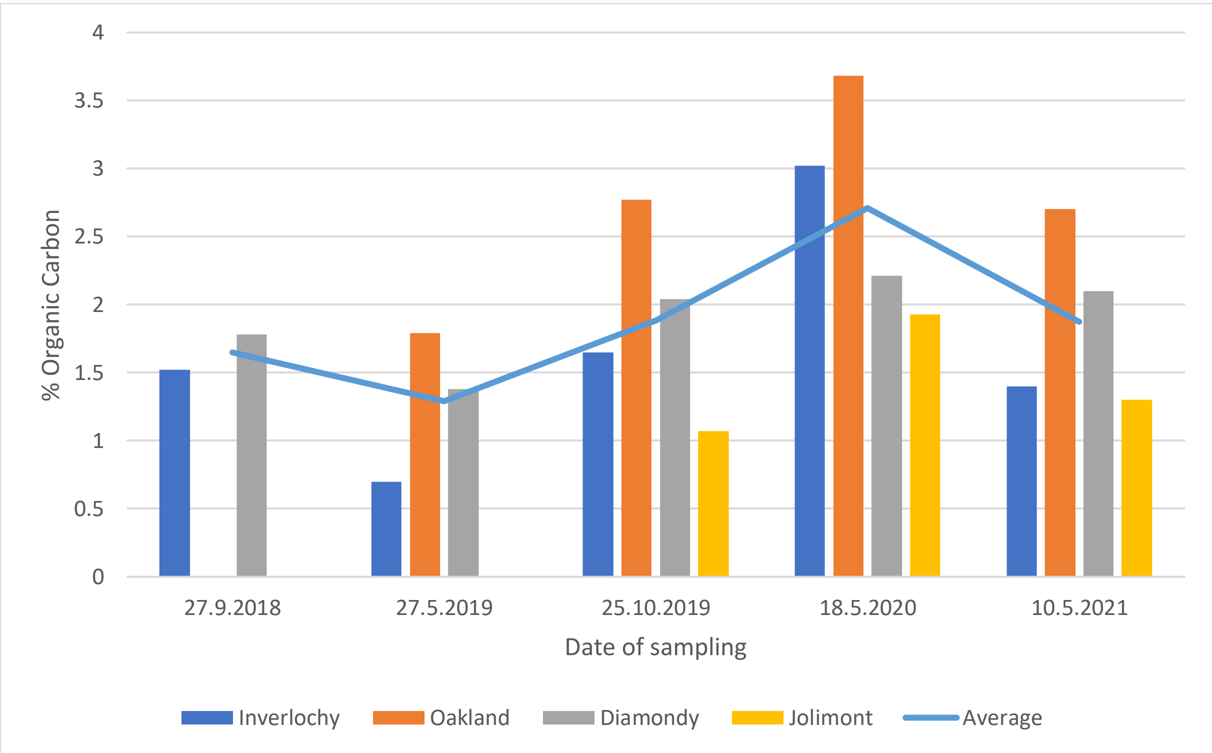


Figure 2: Organic Carbon % - Control paddocks (0-10cm)



A key observation from the soil results was that the variation is soil carbon seemed to be irrespective of treatment and was highly influenced by seasonal conditions (Fig. 1 and 2).

The total carbon would be expected to change slowly over time, so what is being seen is the variations seen from the susceptible pools as a response to environmental changes, microbial and plant demands.

The Total Nitrogen (Fig. 3 and 4) measures all of the nitrogen in the soil; both in the organic and the inorganic (ammonia, nitrate and nitrite) forms.

Figure 3: Total N % - Fertilised paddocks (0-10cm)

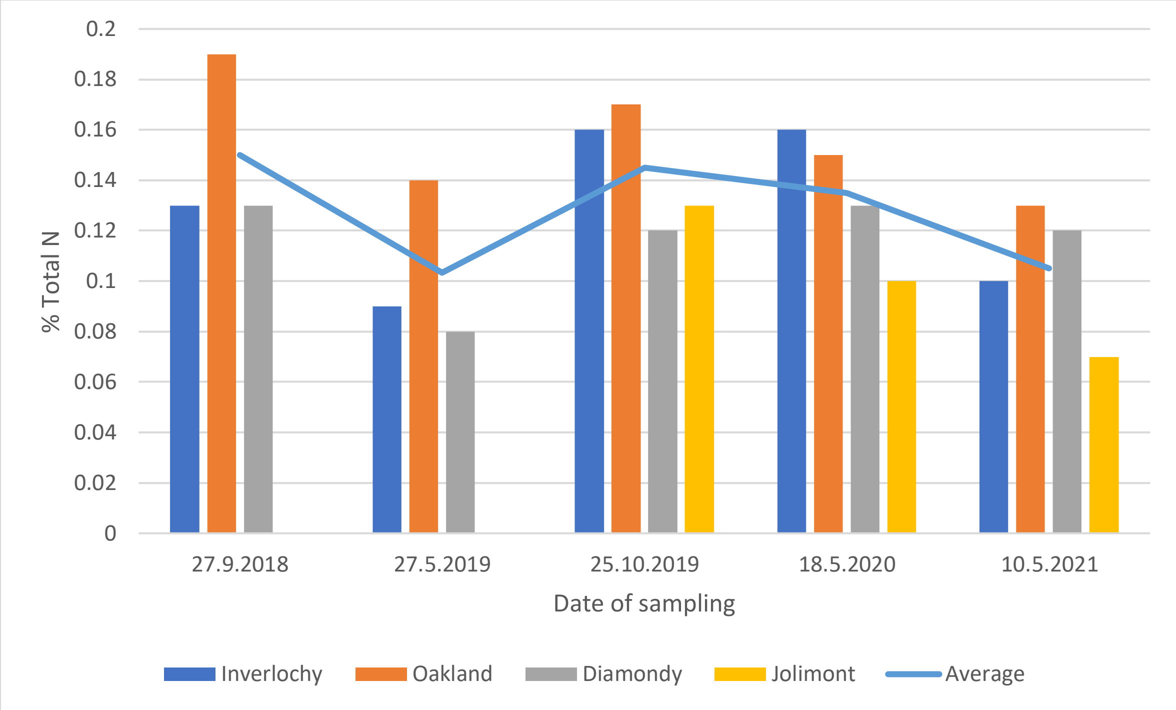
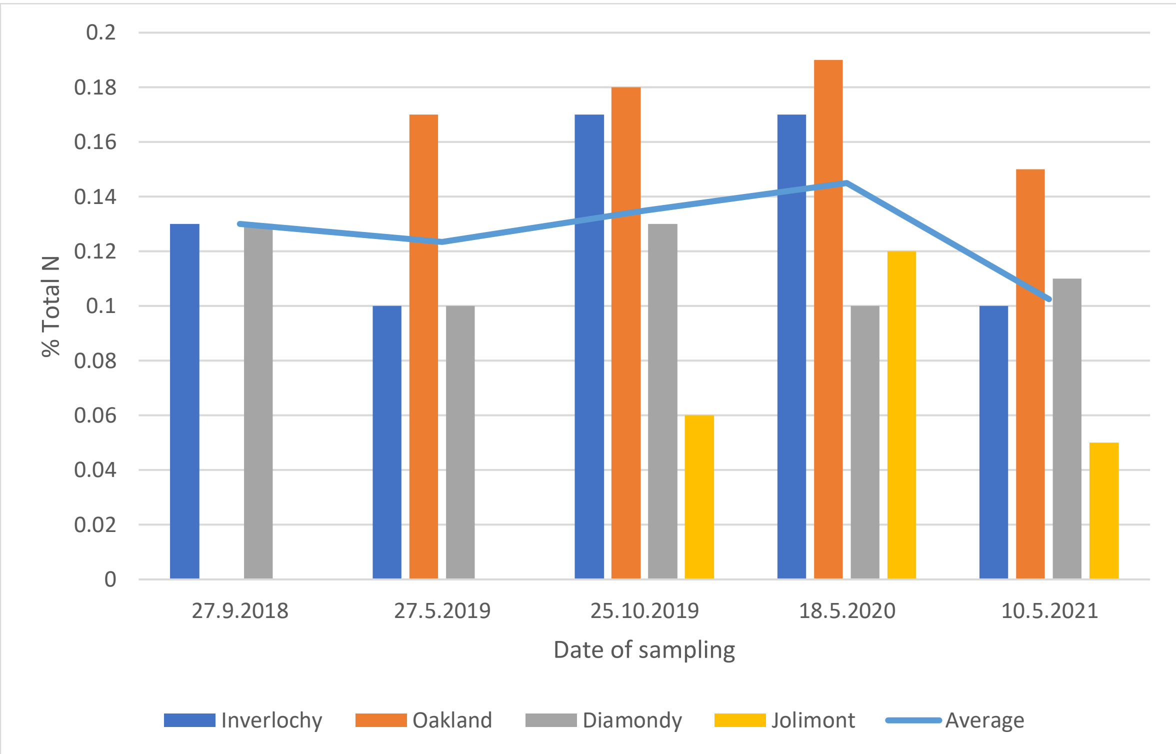


Figure 4: Total N % - Control paddocks (0-10cm)



Most of the total nitrogen is held in the organic phase and not plant available, hence the levels remain fairly even especially when compared to the nitrate-nitrogen levels (Fig. 5 and 6). The consistently higher control site levels would be due to the site being a different soil to the treated site.

Figure 5: Nitrate N - Fertilised paddocks (0-10cm)

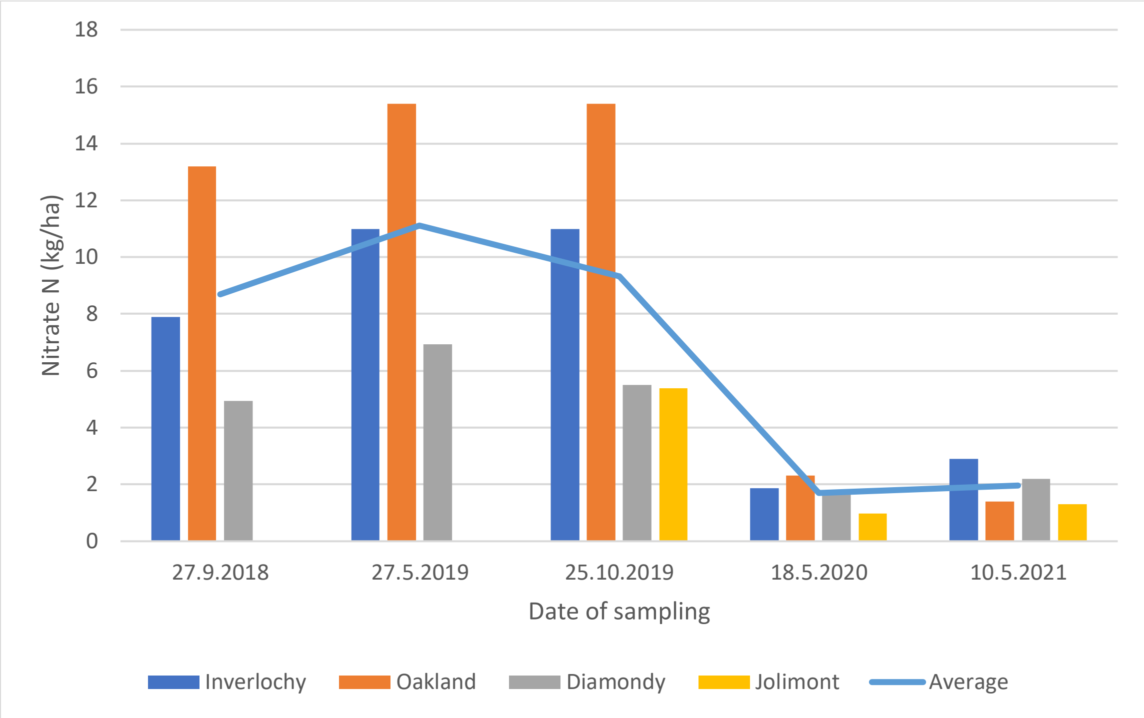
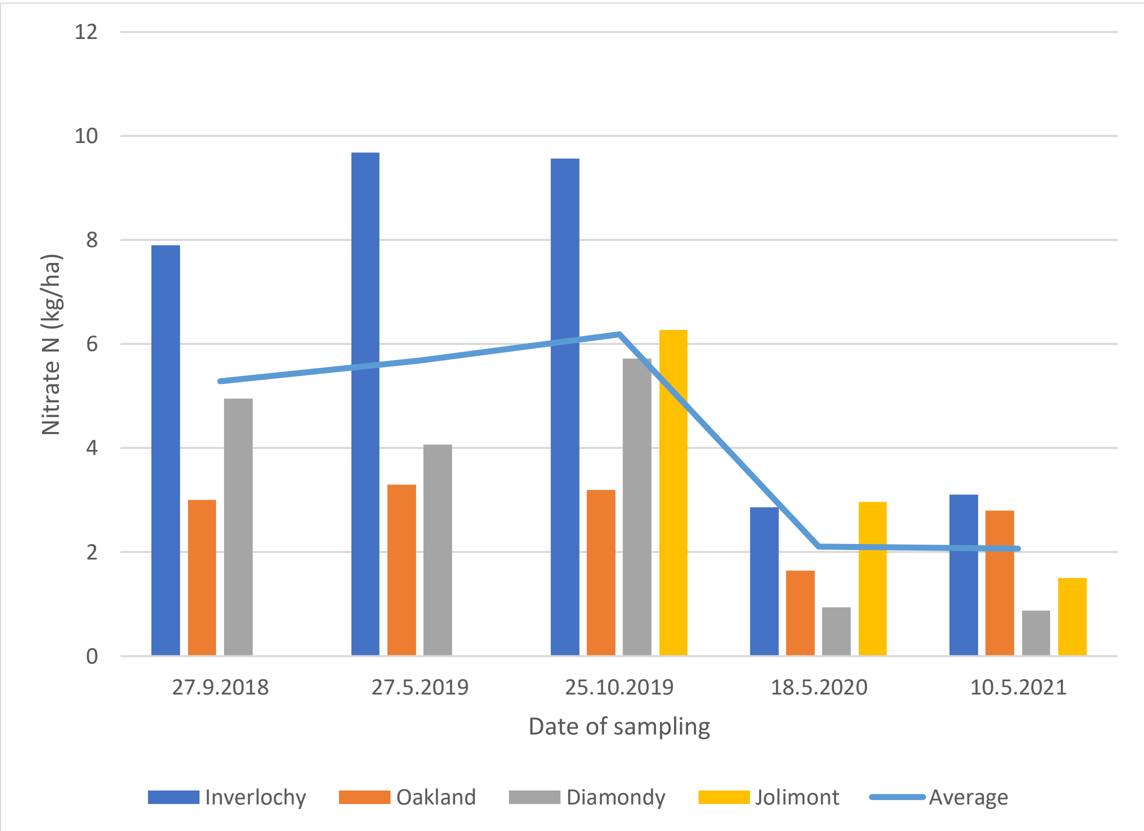


Figure 6: Nitrate N - Control paddocks (0-10cm)



Whilst the nitrate-N results themselves don't portray the total picture, they show that the pastures were able to respond to applied fertiliser nitrogen during better seasons and produce far greater biomass production than the control areas. The nitrate-N levels at "Diamondy" at the conclusion of the trial were at yield limiting levels. Fertiliser was not applied to the “Diamondy” paddock in the 2020/2021 growing season.

In each sample the C:N ratio is within the desirable range to promote decomposition or organic matter and the mineralisation of plant nutrients (Fig. 8 and 9). The ratios increased slightly throughout the term representing the increased carbon recycled from the dry matter production with the treated area in each case being slightly lower and therefore mineralising at a greater rate in the soil.

Figure 8: Carbon to Nitrogen ratio – Fertilised paddocks (0-10cm)

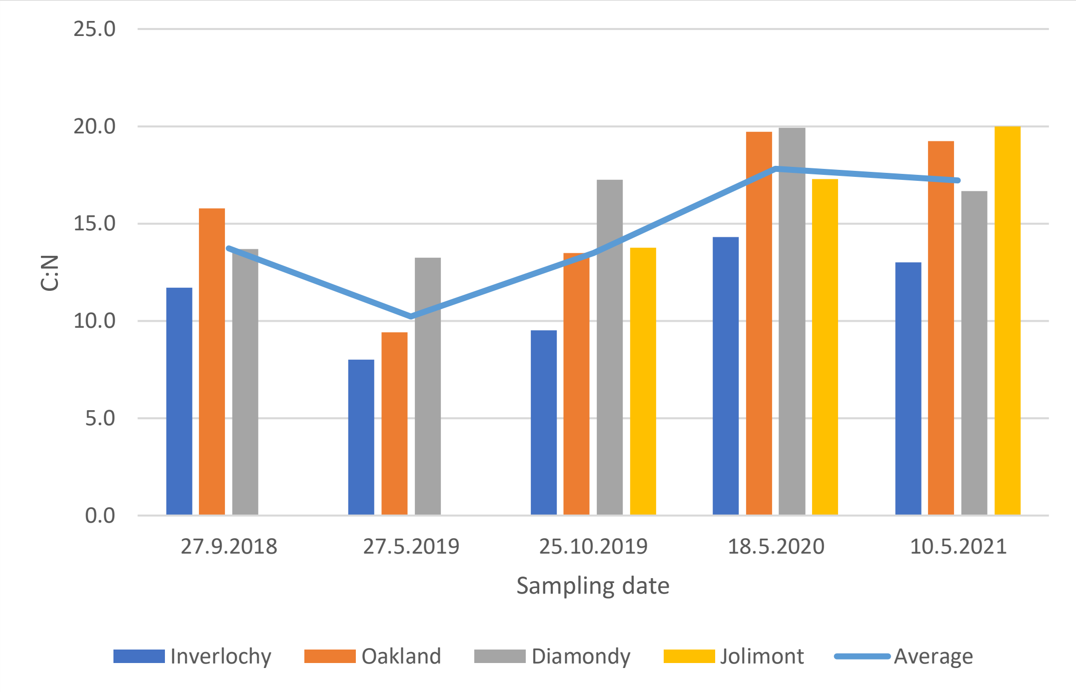
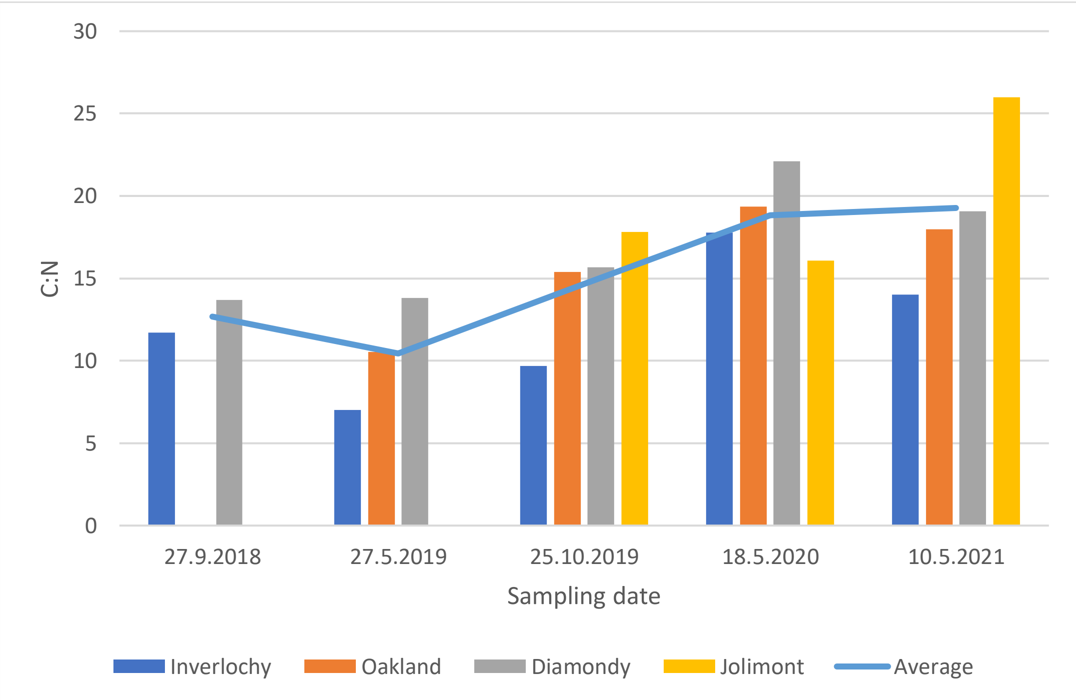


Figure 9: Carbon to Nitrogen ratio – Control paddocks (0-10cm)



The Phosphorus (Colwell) (Fig. 10 and 11) is the plant available phosphorus and will contribute to the Total Phosphorus. As a proportion over time the percentage of Available P to Total P decreased due to soluble P becoming insoluble P and increased removal of soil available P due to increased dry matter yields.

Figure 10: Phosphorus (Colwell) mg/kg – Fertilised paddocks (0-10cm)

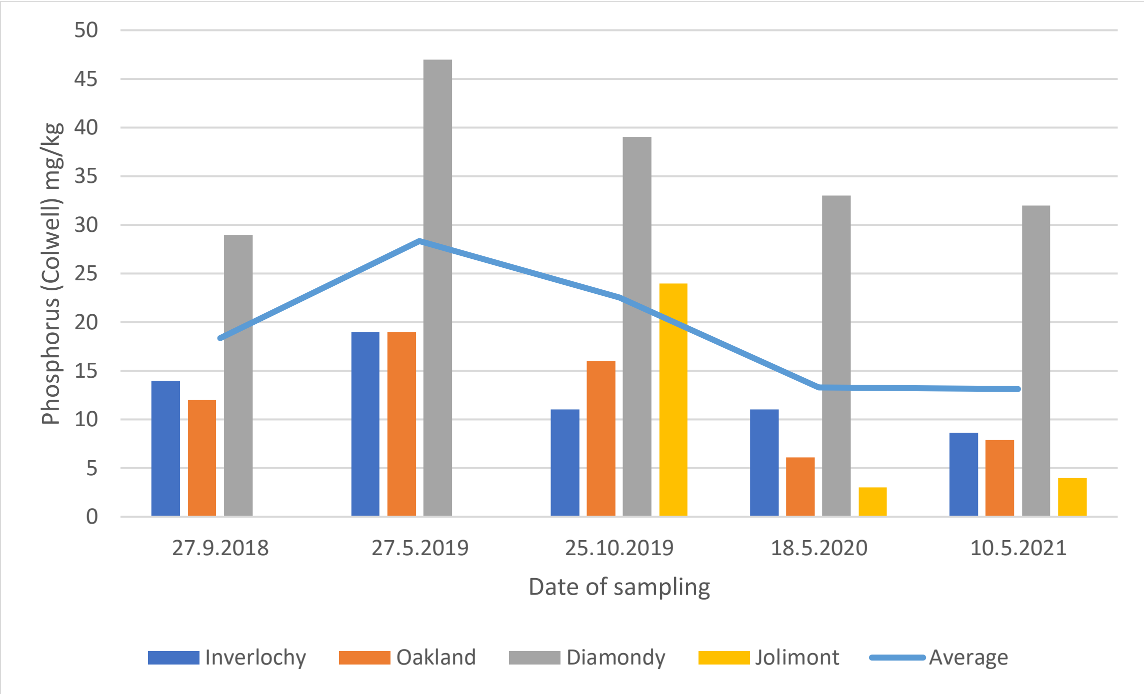
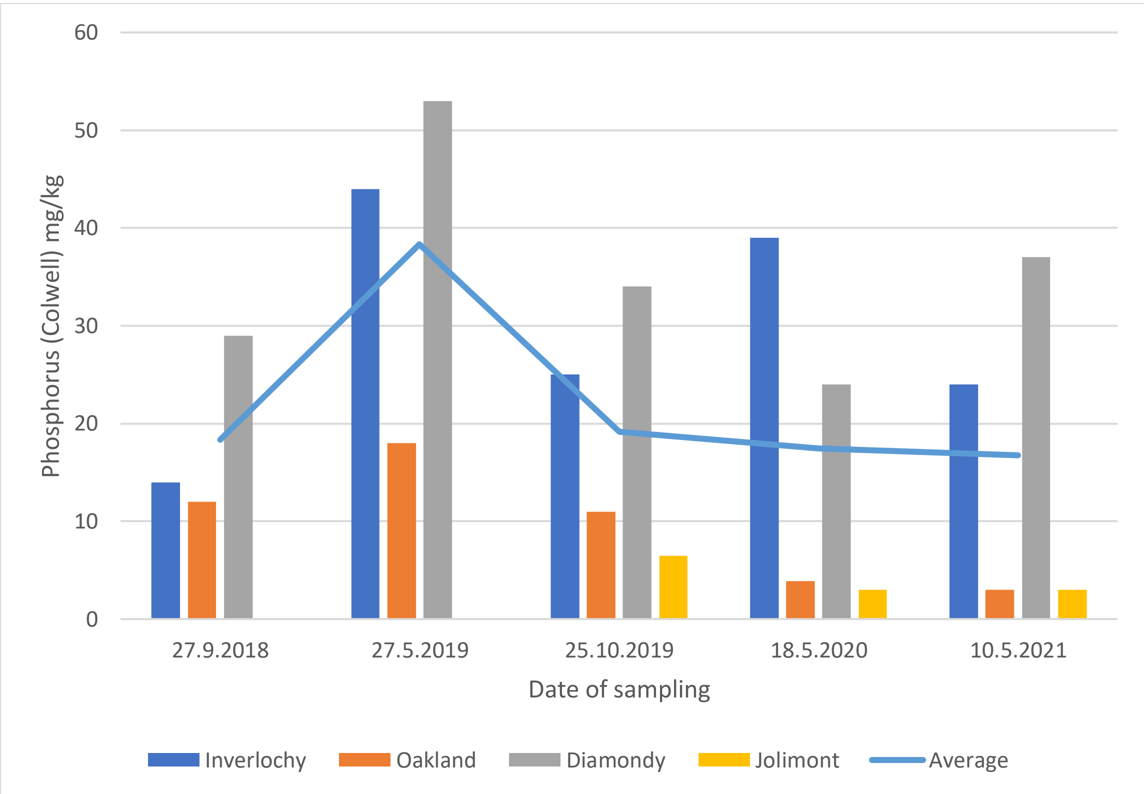


Figure 11: Phosphorus (Colwell) mg/kg – Control paddocks (0-10cm)



At "Inverlochy" the phosphorus (Colwell) was higher in the control than the treated areas. This trend can only be explained in terms of site differences and additional removal of soil phosphorus (14 kg P/ha in treated area following 2021 production) due to the increased dry matter production in the treated area. Amounts of phosphorus applied with the fertiliser for the treated area was applied on a commercial basis as for maintenance levels not for capital improvement. The average phosphorus (Colwell) levels remain unchanged from the initial base line sample with the average across the project time still at 14.27 mg/kg which is slightly lower that desired for Rhodes grass pasture; satisfactory levels would be from 15 to 20 mg/kg.

Soil phosphorus (Colwell) levels at "Jolimont" remained low during the trial in both treated and control areas. The levels in both areas are at yield limiting levels and fertiliser phosphorus application rates were for maintenance only not including any capital applications at this point; if capital applications were included then the fertiliser phosphorus application rate (not product) would be in the order of 37 kg P/ha.

Figure 12: Available Potassium mg/kg – Fertilised paddocks (0-10cm)

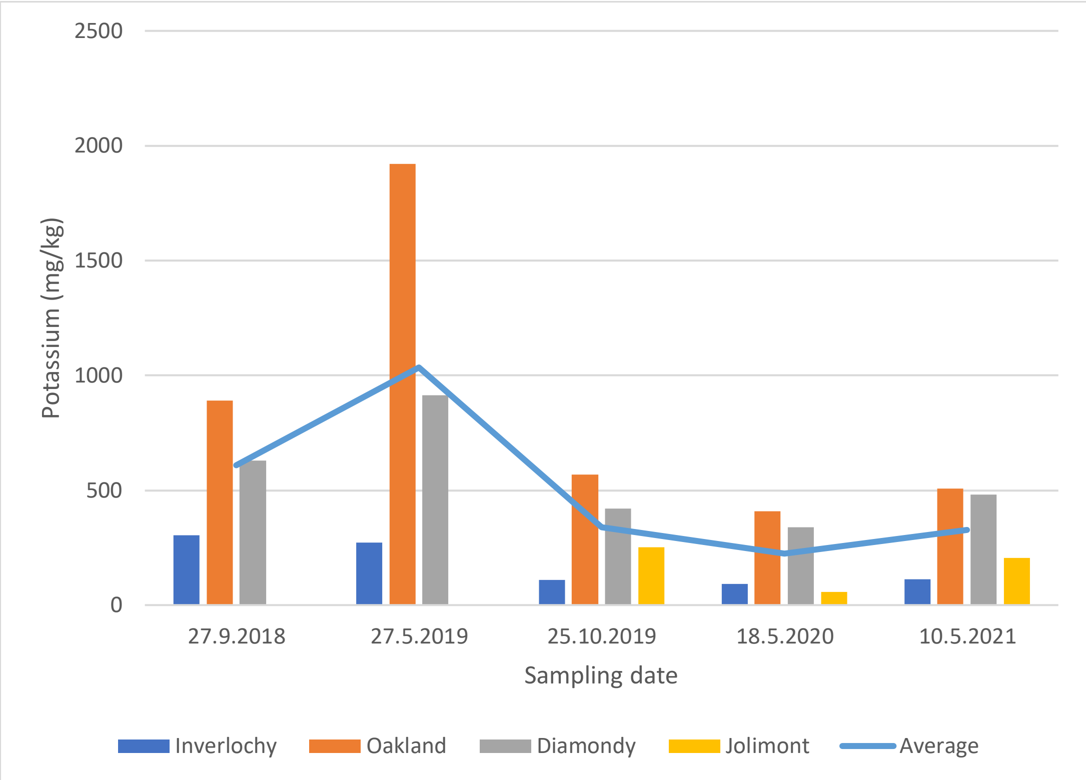
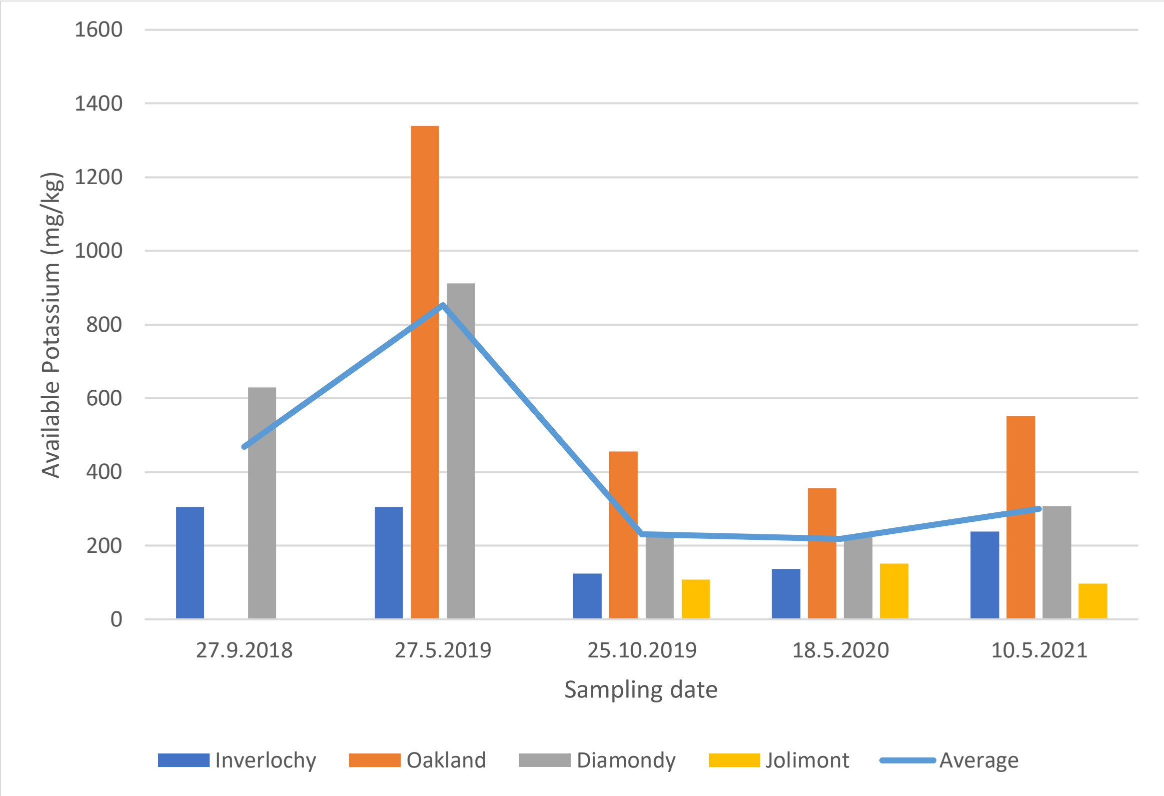


Figure 13: Available Potassium mg/kg – Control paddocks (0-10cm)



Plant available potassium (Fig. 12 and 13) in the soil is part of the Total Potassium (not measured), the initial and following soil levels of potassium were not limiting to pasture production even in the 18/5/2020 soil samples which were taken prior to a dramatic dry matter yield increase. Fertiliser potassium (75 kg K/ha) was applied on the 29/10/2020 to the "Oakland" and "Inverlochy" trial sites which still showed a soil potassium increase even after the next high yielding year 2021 and corresponding removal rates (around 15 – 18 kg K/t DM). The level of soil potassium increase after the potassium fertiliser application would not be as positive if the soil potassium levels had become deficient prior to application (minimum soil potassium benchmark levels for grass pasture would be 120 mg/kg).

The available soil potassium levels have basically responded to the seasonal conditions, soil moisture and dry matter production. Applications of potassium in the initial fertiliser recommendation was not necessary as base line levels were at satisfactory or luxury levels. As dry matter production increased the potassium removal increased accordingly. It is doubtful whether there would have been any loss of potassium due to leaching from seasonal rainfall.

Apart from the traditional soil chemistry being monitored across the term of the trial the "Active Carbon" was also monitored in the top 10 cm. The active carbon test measured in the units - mg/kg is a small portion of the total organic matter pool and a well correlated indicator of soil organic carbon which is more sensitive to the subtle changes (production levels, soil microbial biomass, seasonal changes, tillage and management) in the short term.

This portion of soil carbon will have a rapid turnover as it is being utilised by the soil microbial decomposers as an energy source, and as a result, can be an early detector of soil degradation. There will be a much closer relationship and correlation using the active carbon assessment when relating to soil quality properties - microbial biomass, plant biomass, aggregate stability, than using the total carbon or organic carbon.

Active carbon expressed as a % of the organic carbon varied considerably across all sites in this case due to seasonal conditions, soil types and dry matter production as there was no tillage involved. “Inverlochy” consistently had the highest readings in the treated area which would be due to this soil type i.e. heavier soil texture (more clay) and greater cation exchange capacities.

4.1.2.3 Nutrient changes at depth

Soil sampling at the commencement and end of the trial measured soil depths 0 – 10 cm, 10 – 30 cm and 30 – 60 cm with all other soil tests in between being 0 – 10 cm. Trends were found in each site for nutrients at depth for potassium and the calcium to magnesium ratio. In the “Oakland” and “Diamondy” sites especially there was an increase in the calcium to magnesium ratio at each soil depth.

In contrast there was a general but significant decrease of plant available potassium at each depth but predominantly in the 0 – 10 and 10 – 30 cm depths at all sites. Even though there had been some fertiliser potassium applications for “Oakland” and “Inverlochy” during the trial period there was still a significant reduction in plant available potassium. Fertiliser applications of potassium (synthetic or organic) will be essential after such large dry matter yields and removal of soil potassium.

The phosphorus (Colwell) increased in all strata’s in “Diamondy” site whilst the others remained constant, the fertiliser application rate would not be responsible for the increase at each depth.

4.1.2.4 Other benefits

Other less tangible benefits from the applied fertiliser were improved soil health, significant root proliferation and flow on to soil structure/porosity, potential carbon inputs from nutrient cycling and the greater level of nutrients mineralised.

4.1.3 Pasture condition

4.1.3.1 Species composition

Three years is a short period of time to see a significant species composition change in a paddock without some form of seeding. A general trend in all paddocks was that there was less weedy grass such as barnyard grass (Echinochloa spp.) and liverseed grass (Urochloa panicoides) and broadleaf weeds such as Gomphrena (Gomphrena celosioides) and Maynes pest (Verbena aristigera) present in the fertilised areas than the unfertilised areas. For example, one property had a reduction from 10.7% to 2.5% and another 12.4% to 2.4% weedy annual species as a proportion of the pasture composition.

In general, sown pasture species were more prevalent at the end of the trial comparted to the start. At one property there was an increase in Gatton panic from 8.8% to 49.2% of composition in the fertilised paddock by the end of the project at Inverlochy. While not as large, this trend was also observed in the control paddocks, likely assisted by a wetter final growing season and a tightened grazing management regime which allowed for longer early growing season rest periods.

There was a noticeable ‘do nothing’ effect of low soil nutrient availability in some of the control paddocks. At “Diamondy” the Rhodes grass population decreased from 80% to 31.3% in the unfertilised areas by the end of the project. The undesirable native, pitted bluegrass (Bothriochloa decipiens) had taken over as the dominant species in the unfertilised areas and made up 33.9% of the pasture by the end of the trial.

4.1.3.2 Land condition

Most of the paddocks selected for the trial were in at least fair (B) condition but with distinct nitrogen rundown symptoms such as yellowing of the leaves, lower than expected yields and poor amounts of seed produced. At the end of the project, all of the fertilised paddocks had improved to A land condition. An increase in undesirable species resulted in two of the control paddocks dropping to C condition, one had remained in B condition and the other had improved to A condition.

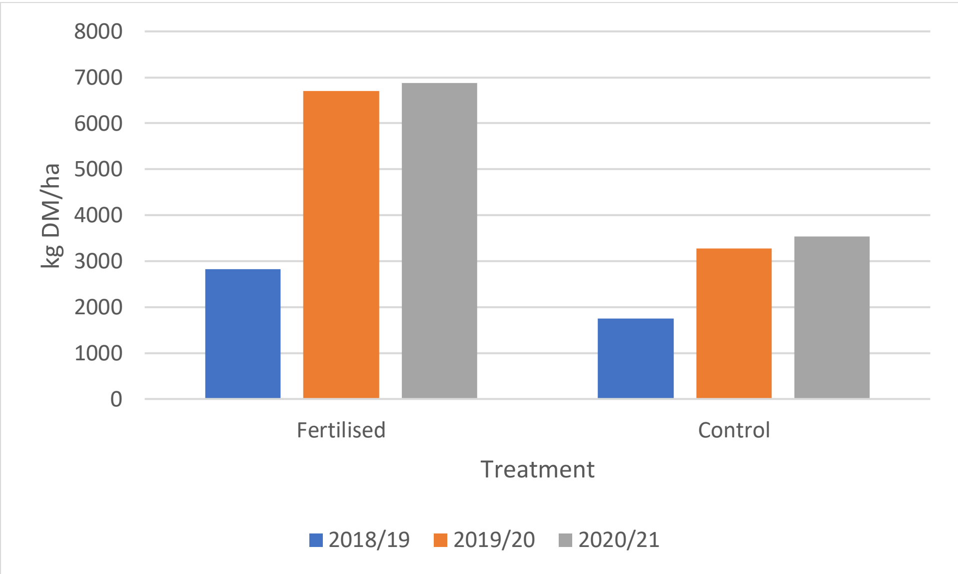
Extended wet season spelling periods and a wet final year of the project made it difficult to clearly attribute the improvement in land condition in the fertilised paddocks to fertilising alone. It is likely it was a combination of better management practices that contributed to the land condition improvement. It was clear, however, that lack of nutrient in a couple of the paddocks was the likely cause of a drop in land condition. These paddocks were rapidly encroached by undesirable species while the fertilised paddocks improved in composition. This supports the argument the 'do nothing' option may not be an option if you want to retain sown pasture species in some land types.

4.1.4 Forage condition

4.1.4.1 Pasture yield

The most consistent result achieved in this project was that regardless of seasonal conditions and location, pasture yield in the fertilised paddocks was always approximately double that of the control paddocks. As growing season rainfall increased and nutrient availability increased, so did the yield in the fertilised paddocks (Fig. 14).

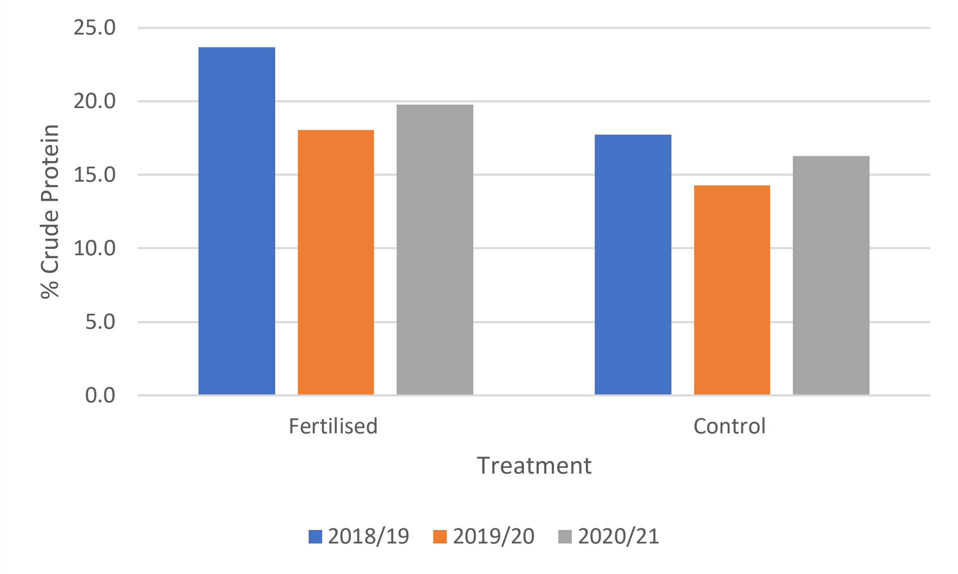
Figure 14: Average end of growing season pasture yield across properties



4.1.4.2 Diet quality

Improved diet quality, most notably as improved Crude Protein (CP) levels, was measured in both the pasture tissue samples and the dung analysis from the fertilised pastures (Fig. 15).

Figure 15: Average % CP across properties taken from phase 2 growth leaf tissues samples

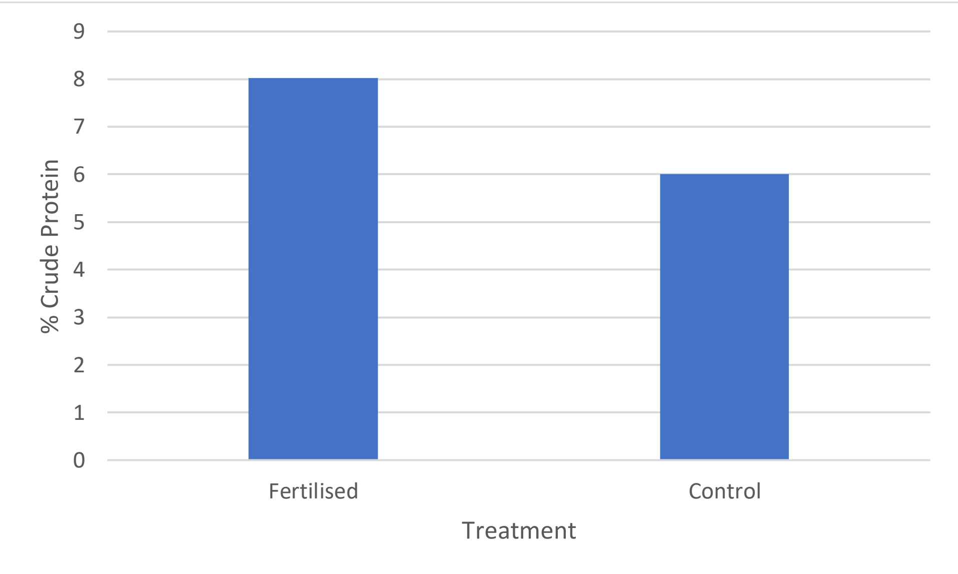


The average difference between the fertilised paddocks and the control paddocks each year of the trial was:

- 2019 – 25%
- 2020 – 21%
- 2021 – 18%

A difference was also observed during the dry season when plants were dormant in phase 4 of growth. Fig. 16 illustrates the average difference in CP levels between the fertilised and unfertilised sites.

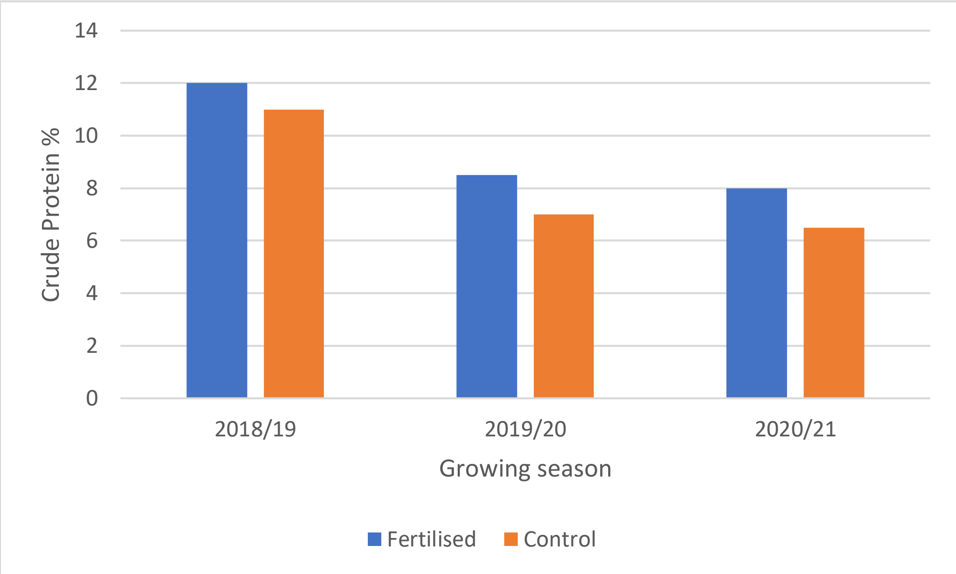
Figure 16: Average Phase 4 % CP across properties taken from phase 4 growth leaf tissues samples in 2020



Tropical pastures translocate nutrients from the shoot system into the crown and roots during the dry season as part of their dormancy mechanism. The nutrient value of tropical grasses in winter is always low and insufficient to maintain weight without supplementation or green herbage. While only a snapshot in time, these results show that fertilised pastures are likely to have better nutritive value in the dry season as well as the growing season.

The crude protein levels in the leaf tissue were significantly higher than the crude protein levels analysed in the dung samples. This can be partially explained by animals' ability to select out a diet that could include other forage then grass leaf. The animals would have inadvertently consumed other plant parts (e.g. stem) and other plant species such as legumes and broadleaf plants in the paddock as well. It was also suggested by the dietary NIRS expert that lab that did the leaf tissue analysis may have had equipment calibrated for temperate pastures and not tropical pastures.

Figure 17: Average % Dietary CP assessed via faecal NIRS of animals grazing phase 2 pasture



The average difference in % Dietary CP between the fertilised paddocks and the control paddocks each year of the trial was (Fig. 17):

- 2019 – 8%
- 2020 – 18%
- 2021 – 19%

Cattle grazing a diet with a minimum of 8% CP and digestibility above 57% would likely be gaining weight, however, in the control areas where dietary CP got down to 6.5% breeders would likely be losing weight.

4.1.5 Animal performance data

Dry conditions meant that grazing periods in the first year were short and the data collated was highly variable (ranging between 0.75 and 5kg/hd/day). This level of variability could not be explained, even considering gut fill variations. In addition to dubious results, one property had animals in the trial go down with 3-day sickness, another had their scales break during weighing. It was decided that due to the short, monitored grazing period (2 weeks), defendable liveweight gain data couldn't be collated for the project.

4.2 Economic analysis

4.2.1 Benefit Cost Analysis

A simple benefit cost model was developed to test the economic worth of fertilising pasture in the Western Downs region based on the data collected in this demonstration trial. The model examined the likely benefits attained by growing more pasture as a result of fertilising over a 10-year period compared to the average productivity likely to be achieved over that timeframe for the same paddock if it was left as is. The results are specific to the set of assumptions tested and will change under a different set of circumstances. It is important that in making on-property investment decisions producers do their own analysis for their unique circumstances.

4.2.2 Assumptions

The underlying assumptions in the model were based on data collected from the demonstration property, "Inverlochy":

- Cleared brigalow softwood scrub on a dark brown medium clay soil
- Rundown mixed pasture comprising of Gatton panic, Rhodes, Premier digitaria, Bisset creeping blue and desmanthus
- 100ha paddock
- 1 AE would consume an average of 2,738kg DM/year
- Average liveweight gain for the enterprise is 130kg/AE/year (averaged across all classes of animals)
- Income per kg of liveweight is $3
- Fertiliser application rates are $15/ha
- Discount rate is 8%
- Long-term average pasture yield of unfertilised sown pasture is 3,000kg DM/ha
- Modelled average annual pasture yield in fertilised paddocks ranges from 9,000kg DM/ha to 3900kg DM/ha depending on seasonal conditions and nutrient availability.
- Fertiliser is applied at optimum time based on soil test results, seasonal conditions and agronomist recommendations

4.2.3 Models

There were 6 different scenarios tested with a benefit cost model.

4.2.3.1 Model 1 - 4-year fertilising program with no follow-up maintenance, 2018-2021 fertiliser prices

This model mapped out the exact fertilising program and prices paid for fertiliser during the demonstration. Optimum yield was achieved in the third and fourth year and then it was assumed that productivity would decline over the remaining 6 years without maintenance fertiliser. The fertiliser applied to the modelled property was:

- Year 1 - 100kg/ha urea + 50kg/ha Granulock Supreme Z
- Year 2 - 50kg urea + 50kg Granulock Z (dry year)
- Year 3 - 100kg/ha urea + 100kg/ha Granulock Z + 100kg/ha Muriate of Potash
- Year 4 - 100kg/ha urea

- Years 5 to 10 – None

Fertiliser prices (ex GST) paid during project (2018-2021), considered moderate at the time:

- Urea - $629/t
- Granulock Z - $827/t
- Muriate of Potash - $751/t

The result of this benefit cost analysis was:

- Net Present Value $52,130 *(Hurdle = Positive)*
- Internal Rate of Return 35% *(Hurdle = 15%)*
- Years to Break Even 4 *(Hurdle = <7)*
- Benefit to Cost Ratio 2.2:1 *(Hurdle = 3:1)*

In years when fertiliser prices are low or even moderate (prices paid during 2018-2021 were considered moderate) fertilising rundown pastures on good country is well worth the investment.

4.2.3.2 4-year fertilising program with no follow-up maintenance, projected fertiliser prices

This model replicated the first one but used the assumption that all the fertilisers used would cost $1000 per tonne (ex GST) to assess the value of the exercise with prices thought to reflect the level they may sit at in the medium term.

- Net Present Value $39,920
- Internal Rate of Return 22%
- Years to Break Even 5
- Benefit to Cost Ratio 1.7:1

As input costs rise, the benefit received from fertilising declines when pasture yield doesn't increase as well. Using these projected prices, it is still a worthwhile exercise.

4.2.3.3 4-year fertilising program with no follow-up maintenance, record high fertiliser prices (today's prices)

This model replicates the first one as well but uses today's high fertiliser prices. This model reviews if there is any financial benefit from fertilising with these prices.

Fertiliser prices paid (ex GST):

- Urea - $1550/t
- Granulock Z - $1645/t
- Muriate of Potash - $1525/t

The result of this benefit cost analysis was:

- Net Present Value $9,022
- Internal Rate of Return 10%
- Years to Break Even 8
- Benefit to cost ratio 1.1:1

This option barely breaks even and there would likely be more profitable ways to spend your money short-term. However, given that it is a rare high rainfall year where the pasture has enough soil moisture to fully benefit from extra nutrient supplied, it may still be a worthwhile exercise, paying back in the longer-term. The extra organic matter produced would eventually be returned to the soil to boost soil organic matter reserves and provide a sink of nutrient to eventually be drawn upon to grow new organic matter.

4.2.3.4 10-year maintenance fertilising programs based on decadal rainfall patterns from 1992-2021 and using projected fertiliser prices

Three models were developed to test the effect order of seasonal conditions would have on the profitability of a maintenance fertilising program on the Western Downs. Assumptions for each 10-year model were:

- High rainfall years (>700mm) a full fertilising program would be completed, 100kg/ha urea and 250kg/ha SuPerfect + Pot 1&1 (green shaded years),
- Very dry years (<462mm, 10th percentile) no fertiliser would be applied (red years),
- Average years (462mm to 700mm) only urea (100kg/ha) would be applied (orange years), and
- All fertilisers projected to be $1000/t

In practice, the pattern of rainfall throughout the year would dictate if these rules could be met, however, for modelling purposes, they provide a trigger to change yield achieved and fertiliser application rates.

Below is an overview of the rainfall pattern that occurred in each decade and the corresponding fertilising program and benefit cost analysis for each based on the outlined model assumptions.

Decade 1

Table 1: Decade 1 rainfall pattern and corresponding fertilising program.

Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Fertilising program	None	Maint.	None	Full	Maint.	Maint.	Full	Maint.	Maint.	Maint.

Benefit cost analysis:

- Net Present Value $21,694
- Internal Rate of Return 20%
- Years to Break Even 1
- Benefit to Cost Ratio 1.2:1

Decade 2

Table 2: Decade 2 rainfall pattern and corresponding fertilising program.

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Fertilising program	Maint.	Maint.	Maint.	None	Maint.	Maint.	Maint.	Maint.	Full	Full

Benefit cost analysis:

- Net present value $28,643
- Internal Rate of Return 25%
- Years to Break Even 1
- Benefit to Cost Ratio 1.3:1

Decade 3

Table 3: Decade 3 rainfall pattern and corresponding fertilising program.

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Fertilising program	Maint.	Maint.	Maint.	Full*	Maint.	Maint.	Maint.	None	Maint.	Full

**An extra full fertilising program was added to the fourth year of the last decade because it is likely key limiting nutrients such as phosphorus and potassium would start to limit growth if maintenance applications of urea have been applied consistently over several average rainfall years.*

Benefit cost analysis:

- Net present value $21,052
- Internal Rate of Return 18%
- Years to Break Even 1
- Benefit to Cost Ratio 1.2:1

Based on the results from the three analysed decades, maintenance fertilising on the example property appears to be a long-term worthwhile exercise, regardless of seasonal patterns. Strictly speaking, a true benefit cost analysis doesn't look at repeated applications so the benefit to cost ratio is expected to be lower in a maintenance program than a one-off program.

4.2.4 Likely benefits not considered in the models

There are a couple of benefits of fertilising that were observed in the project but not specifically accounted for in the economic model. These benefits include:

- Fertilised pasture staying green for up to a month longer than the control paddocks, and
- Better diet quality in the fertilised pasture and therefore annual liveweight gain likely to be higher in these paddocks.

Both observations would likely reduce time to turnoff and potentially improve the kilograms of beef produced per hectare and the gross margin of the operation.

4.3 Extension and communication

Covid restrictions (2019-2020) had a significant impact on the face-to-face delivery of planned field walks throughout the project and alternative means of extension had to be employed. Extension of this project has been focused on a local level focusing on community connections to spread the word.

4.3.1 Field walks

Two open field walks were conducted at the start and the end of the project. A mid-project field walk had to be changed to a webinar due to Covid group gathering restrictions at the time.

A PDS paddock tour of all four demonstration sites (field day) was conducted on 14th June 2021. 22 people attended the tour, including 6 local agronomists. Despite being less than the targeted 30 people, we were happy with the result given the uncertainty with events going ahead with random Covid lockdowns and numerous potential participants we engaged in planting winter crop at the time.

The field day in June was the first time the demonstration sites have been visited by local agronomists. Feedback was excellent and one of the senior agronomists followed up with an email commenting "How do we get more producers to these events? Every cattle producer in the district would have benefited from being there."

Image: Twitter post by Russ Wood regarding the field day.

4.3.2 Case Study/Article

An article template was submitted MLA on 23/5/22 profiling the project to develop an article for Feedback magazine and to develop a case study on one of the co-operating producers who managed a trial site.

4.3.3 Producer guides/Fact sheets

Results and producer interest from this PDS project have been the impetus for the customisation of the PayDirt Profitable Grazing Systems program for northern Australia. The customisation was completed by project coordinator, Jill Alexander and project agronomist, David Hall.

The practical learnings and recommendations from the project were embedded in the Profitable Grazing Systems program "PayDirt North" which was customised for Queensland by the professional support team on this project. The package was piloted with the core PDS producer group.

Support tools that were created for PayDirt North include:

- Producer manual and trainer's manual
- Series of 4 videos about assessing whether pastures are good contenders for fertilising and soil testing protocols
- Information sheets embedded in the supporting manuals include:
    - Sown pasture nitrogen rundown rating assessment guide

  - What to ask for in a soil test
  - Soil testing protocol
  - Ranges of nutrient limits for Rhodes grass (for interpreting soil tests)
  - How much fertiliser to apply
- Fertiliser Cost-Benefit Calculator

4.3.4 Reference group meetings

Reference group meetings were held on:

- 14th June 2019 at "Oakland" 10 producers attended the meeting.
- 17th July 2020 at "Inverlochy", 11 producers and one private agronomist attended the meeting.
- 16th July 2021 at "Inverlochy", (run in conjunction with first pilot PayDirt session)

4.3.5 Webinar

A mid-project overview was completed via webinar on the 18th of June 2020. 82 people registered for the webinar and 35 joined the webinar live.

4.3.6 Goondiwindi Beef Up Forum

A presentation about the results from this project was given to a crowd of 70 producers and industry professionals at the Goondiwindi Beef Up Forum on the 27th of May 2022.

4.4 Monitoring and evaluation

4.4.1 KASA results

The members of the Diamondy Pasture Productivity Group changed between the start and end of the project due to death and change of circumstance. As a result, several post-project responses were missing from the final data set and a couple of new members contributed feedback sheets instead. Field walk participants were not asked to complete KASA assessments due to the one-off nature of their participation.

The Knowledge and Skills Assessment results showed that the knowledge and skills of the participants improved from an average of 4.5 out of 10 at the start of the project to 7.3 out of 10 at the end of the project. The average knowledge scores out of 10 improved from 67% to 85% correct. Confidence improved from an average of 4.6 out of 10 at the start of the project to 7.4 out of 10 by the end.

At the start of the project only one person said it was normal for them to soil test pastures and no-one said it was normal to fertilise pastures. 30% said they rarely or never soil tested pastures and 40% said they rarely or never fertilised pastures. By the end of the project 57% said it was now normal to soil test pastures and 43% said that it was now normal to fertilise pastures. The rest of the respondents were at least sometimes soil testing and fertilising pastures.

4.4.2 General feedback

- Lots of inquiries about how to do soil tests and who reliable agronomists are to conduct and interpret soil tests done on pastures in the region.

- Co-operators have expanded their fertilising to other paddocks on their properties.
- 2 co-operators have purchased their own fertiliser spreaders and one is doing contracting with the spreader he purchased. The primary reason given for this was the yield benefit they have observed in their project paddocks and the results influenced by the timeliness of application of fertiliser.
- Trial co-operators are much more conscious about resting paddocks during the growing season and retaining pasture stubble in the paddock. Two have expressed remorse over grazing paddocks for longer than recommended during the growing season as it has set back the progress that they have made in their trial paddocks. The co-operator who has been most vigilant managing grazing pressure has commented on how hard it is to get water in his dam now that his paddocks are yielding so much grass in summer.
- Record high fertiliser prices have made a lot of interested graziers hesitant to start a pasture fertilising program at the moment.

5 Conclusion

5.1 Key Findings

In this demonstration the most apparent response to the applied fertiliser was the significant increase in quantity and quality of plant biomass produced. Average pasture yield in the fertilised paddocks was consistently double that of the unfertilised paddocks and the diet quality was also consistently better, regardless of season, facilitated by the increased supply of plant available nutrients. Essentially what went into the soil (nutrient) went out in the form of plant organic matter.

Sown pasture fertilising appears to be economically worthwhile in the western Darling Downs, particularly when applied to pastures on deep, high water holding capacity soils exhibiting symptoms of nutrient rundown. A simple benefit cost model was used to test the value of the investment and found that in each scenario tested, the activity was worthwhile as it cleared the economic hurdles for good investment. The poorest return was achieved when the model was tested with the current extremely high fertiliser prices. The result was that the investment only just broke even but was still positive. Taking a longer-term view, it is thought that even with these high prices, it is still a worthwhile activity long-term.

Co-operators observed that good grazing management, timeliness of application and following the full fertilising program underpinned the success of the investment. If these weren't closely followed, the result was clearly diminished.

The project generated a lot of interest from both producers and agronomists. A mid-project webinar to review the interim results attracted 85 registrations. The trial co-operators have expanded their fertilising programs to other paddocks on their property and invested in fertiliser spreaders. Other interested producers are holding off venturing into a pasture fertilising program in the due to record high fertiliser prices and lack of data to demonstrate if it will pay off with such high input costs.

A key challenge to seeing this practice get more widely adopted in this region is the lack of current research data on pasture and grazing animal response to fertilising. While results from this trial were positive, it was at the end of the day only a demonstration trial and rigorous replicated data is required to give the broader population of red meat producers the confidence to adopt the practice.

5.2 Benefits to industry

The economic analysis of this demonstration has shown that there are clear economic and soil health benefits to graziers with rundown sown pastures in this region to invest in a soil testing and fertilising program. Potential benefits include:

- Ability to improve scale of operation by increasing the pasture yield and therefore carrying capacity of existing paddocks without the need to buy more land
- Improve liveweight gain and reduce turnoff age by improving diet quality
- Better pasture composition, land condition and long-term carrying capacity
- Increased scale of operation without the need to buy more land

Fertilised perennial tropical pastures provide a sustainable and cost-effective alternative to summer forage crops because they can produce similar yields and diet quality when provided with the same nutrients, but with lower input costs (seed, herbicide, diesel, etc.). In dry years they provide ground cover and feed where fodder crop paddocks may be left bare.

6 References

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