



Grassland Society of NSW Inc.

Renewed focus on livestock systems for resilience – the swing back to forages

Proceedings of the 31st Conference
of the Grassland Society of NSW Inc.

GUNNEDAH TOWN HALL, 3-4 JULY 2019



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Edited by Sean Murphy, Suzanne Boschma and Marja Simpson

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Grassland Society of NSW Inc.

**A unique blend of people with a common interest in developing
our most important resource – our Grasslands**

The Grassland Society of NSW was formed in March 1985. The Society now has about 300 members and associates, 75% of whom are farmers and graziers. The balance are agricultural scientists, farm advisers, consultants and executives or representatives of organisations concerned with fertilisers, seeds, chemicals and machinery.

The aims of the Society are to advance the investigation of problems affecting grasslands husbandry and to encourage the adoption into practice of results of research and practical experience. The Society now holds a biennial conference, publishes a quarterly newsletter, holds field days, and has established regional branches throughout the State.

Membership is open to any person or company interested in grassland management and the aims of the Society.

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Preface

On behalf of the Grassland Society of NSW Inc., it gives me great pleasure to extend a very warm welcome to all members and non-members attending this, the 31st Conference of our Society. Conducted 'biennially', our conference returns to Gunnedah 15 years after the very successful 2004 conference. This year, with most of NSW remaining in a drought that is persisting for far too long, the focus on forage and livestock is more critical. Stock numbers are generally being reduced everywhere and finding fodder for the stock retained is getting very difficult, and expensive. Growing feed is so much cheaper, but there is just that 'minor' hurdle of H₂O!! As autumn rolls into winter, several good fronts have brought useful rainfall to much of southern, central and western NSW. I do hope, for all concerned in agriculture, that the pattern continues and results in a wet winter. Cross your fingers.

Our Society deems that the sharing of conference locations is a very strong attribute, which attempts to widely disseminate findings from the current research and extension work. In addition, the Society over the past six years has conducted in excess of 25 Pasture Updates for Meat & Livestock Australia, with the total attendance now approaching 1500 people. Many attendees returned at least once, and some travelled more than 200 km to attend. Such is the interest in pastures, fodder and livestock enterprises, and I have no doubt that this year's conference will continue that theme.

Change is inevitable; whether it be the seasons, climate or market conditions. Therefore, it is critical that we make the effort to expose ourselves to what researchers, consultants, agronomists and other producers have to offer. Implementing new ideas may not be instantly possible, but just hearing and seeing new things will often challenge us. 'Would that work at home?', or 'I wonder if...?' are questions people often ask themselves after seeing or hearing of the successes of others. The conference this year, with its theme 'Renewed focus on livestock systems for resilience – the swing back to forages'

will challenge us all. The presentations cover attributes of climate change and variability, the plant/animal production system and economics, and are complemented by the bus tours. I encourage everyone to ask questions and learn from the experiences of others.

Our sponsors are an integral part of our Society. They continue to provide great assistance, both financial and in-kind, and it is their involvement that makes possible many of the Society's activities. I am fully aware that the commercial world is getting tougher. To our conference and Society sponsors for 2019–20, I would sincerely like to thank each and every one of you for your contribution. I encourage all conference delegates to visit the commercial displays and take the time to talk with the representatives. Their product knowledge and the resources they have available may just be the key you need to achieve improvements in your own business.

To the conference organising committee, thank you. The enthusiasm and skills that you brought to this year's event are greatly appreciated. I would also like to thank the employers of the conference organising committee, as it is their time that has contributed to the conference program. Many hours of voluntary work have come together for the benefit of all delegates, and for that we are grateful. I wish all delegates the very best for the conference as it is provided for your learning and enjoyment. While the conference is our Society's pinnacle event, I encourage 'non-member' delegates to consider joining to reap the year-round rewards on offer. Should you have any ideas, comments or concerns, I would encourage you to share them with a member of the organising committee. Your feedback is always welcome and our Society can only improve on the back of people's collective input.

Enjoy your time here.

David Harbison, President

Conference Program

WEDNESDAY 3 JULY – SMITHHURST THEATRE, TOWN HALL, GUNNEDAH	
DAY ONE	
Time	Topic and Speaker
8.00 am	Registrations
9.00–10.00 am	<p>Welcome and Welcome to Country David Harbison, President, Grassland Society of NSW Wade Natty, representing the Gunnedah Aboriginal Community</p> <p>Conference opening Jock Laurie, Land & Water Commissioner, NSW Drought Coordinator</p>
9.30 am	<p>SESSION 1 – Overview</p> <ul style="list-style-type: none"> • <i>Climate Change and Variability</i> – Prof. Mark Howden, Director, Climate Change Institute, Australian National University – by Skype
10.00 am	Trade Displays and Morning Tea
10.30 am –12 noon	<p>SESSION 2 – Economics – Producers changing – the swing to forages</p> <ul style="list-style-type: none"> • <i>Pathways to a profitable grazing business</i> - Simon Fritsch, Director, AgriPath, Tamworth • <i>Producer perspective</i> – David Maxwell, Producer, Spring Plains • <i>Poisoning of lambs on mature Bambatsi panic pasture</i> – Shaun Slattery, North West Local Land Services, Narrabri
12.30–5.45 pm	<p>Bus Tours Depart Town Hall to visit farms in the following localities:</p> <p>Tour A – Carroll / Tamworth district Stuart Swain, Carroll – Beef Tamworth Effluent Re-Use Farm, Westdale – Forage</p> <p>Tour B – Boggabri / Narrabri district Alastair Donaldson, Boggabri – Silage Assoc. Prof. Guy Roth, Narrabri – The University of Sydney, Plant Breeding Institute</p>
6.15–6.45 pm	<p>Grassland Society of NSW Annual General Meeting Baxter Room, Gunnedah Services & Bowling Club, 313 Conadilly Street, Gunnedah</p>
7.00 for 7.30 pm	<p>Conference Dinner & Entertainment Gunnedah Services & Bowling Club, Auditorium, 2nd Floor, 313 Conadilly Street, Gunnedah <i>Social License to Operate</i>. After dinner speaker Greg Mills, General Manager, GoAhead Business Solutions, Moree</p>

THURSDAY 4 JULY – SMITHHURST THEATRE, TOWN HALL, GUNNEDAH	
DAY TWO	
Time	Topic and Speaker
8.30–11.00 am	SESSION 3 – <i>Livestock Production Systems</i> <ul style="list-style-type: none"> • <i>Dairy cut and carry</i> – Hayden Hollis, Agronomist, Landmark, Tamworth • <i>Beef systems</i> – Jason Catts, Stud and Commercial Producer, Kenebri • <i>Sheep systems</i> – Justin and Lorroi Kirkby, Stud and Commercial Producers, Gravesend
11.00	Trade Displays and Morning Tea
11.30 am – 1.45 pm	SESSION 4 – <i>Livestock Nutrition and Genetics</i> <ul style="list-style-type: none"> • <i>Plant genetics – The Pipeline for Improvement</i> – Dr Noel Cogan, Research Leader, AgriBio Center, La Trobe University • <i>Balancing livestock genetics and nutrition</i> – Dr Jason Trompf, Livestock Consultant and Producer • <i>Drought opportunities – Producer Panel: Q&A</i>
1.45–2.15 pm	Conference Close and Lunch



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Sessional Papers

Damned if I do, damned if I don't: striving for higher grazing returns with fodder crops in northern NSW

S Fritsch

AgriPath, Tamworth, NSW 2340: simon@agripath.com.au

Abstract: Long-term returns on assets managed data collected across NSW and Victoria indicate that north of Dubbo livestock returns are inferior to those of farming. In northern NSW, feed quality and quantity are major issues for livestock producers. Rapid cycles of growth and deterioration of feed quality mean that a producer's capacity to finish livestock on pastures remains a large challenge. Returns on grazing assets in northern NSW are inferior to southern grazing assets. Top performing producers in northern NSW utilise higher percentages of fodder crops and pasture improvement in managing for this, but it can come at a high cost, particularly in years where fodder crops do not perform well due to dry conditions.

Key words: farm performance, return on operating asset, fodder crop, improved pasture, stocking rate, feed cost

Introduction

The modern successful farming business is focused on excellent production systems that complement the climate and natural assets available to the business. The capacity of a business to generate returns from its asset base is best measured using return on asset managed for the asset class. This allows for a meaningful comparison of business performance within regions and across different asset classes.

Return on assets managed

Data from Agripath's 'Profit Focus' program collected from southern NSW and Victoria, indicate that in most mixed farming environments business returns from livestock compare well to the alternative land use of farming (Fig. 1). The top performers consistently produce long-term returns on assets managed (ROAM) of greater than 6%, while average performance is ~3.5%. This suggests that land is priced relative to its productive potential and both livestock and farming production systems can generate returns that are competitive. North of Dubbo is an entirely different story with livestock returns vastly inferior to those of farming. Average long-term ROAM for livestock assets is less than 2% for the North West, North West Slopes, and Liverpool Plains regions. This compares with average long-term

farming returns of 4–5%. The best performing dryland farming assets have returned >6% ROAM averaged over five years, whereas the best grazing businesses have averaged 3.5%. The Northern Tablelands has also struggled to produce competitive asset returns for the value of the land.

One of the main reasons that ROAM for livestock enterprises tend to be lower is due to asset valuation. The farming country in the North West is valued based on its productive capacity from farming, hence average returns are running at the same pace as commercial interest rates. Livestock assets are valued at roughly 50% of the farming value and are not reflecting the productive capacity of these assets. On the Northern Tablelands, the data indicate that only the top quartile of the dataset are operating at levels that match the cost of finance and are therefore setting the price for land in that region (Fig. 1). Improved livestock returns have also led to increased pricing with average asset values in the dataset rising from \$603/dry sheep equivalent (DSE) in 2014 to \$871/DSE in 2018.

Challenges to a profitable grazing business in northern NSW

A simple response to rising asset value is to conclude that grazing land in the region is overvalued, which is true. However, there are also several unique characteristics of the region that make it particularly difficult to build a profitable grazing business.

Rainfall. It can rain at any time of the year and generally, that means that producers who have a mixture of winter and summer-growing pastures have six weeks of feed in all but the coldest months. If it hasn't rained within six weeks it's dry and by 12 weeks, it's a drought. Average winter rainfall is, for most of the area, less than 200 mm and temperatures quickly rise in September and October to reduce the contribution of winter-growing species.

Growing season. Grass can grow extremely fast, ~100 kg dry matter (DM)/day, in the warmer months, and it will often very quickly use the available moisture. Feed quality rapidly drops and dry standing feed quality is further reduced from rainfall events that don't materially contribute to additional feed. Compare this with the distinct growing season of southern or northern systems. The southern growing season is defined by an autumn break and a spring finish, is relatively reliable and produces high-quality feed. North of the border in Queensland, where buffel grass and Mitchel grass pastures

are defined by summer rainfall systems, winter rainfall is low, but this helps maintain dry feed quality. While these descriptions are a simplification, the reliable growing seasons do allow for robust livestock systems to be operated.

Species. The dominant pasture type across northern NSW is native/naturalised grass pastures. Grass species such as plains grass on the heavier soils, Coolatai and redgrass on the red soils, can out-compete other species but are dormant and of poor quality through the winter months. Native grass pastures often lack legumes and other forbs, apart from native medic that if unfertilised is a low contributor to feed quality. Tropical perennial grasses (e.g. digit grass) have been a recent useful addition but they are expensive to establish and provide feed at the same time as our native grasses and only offer a quantity not quality feed bridge into the winter months. The region lacks a high-quality winter growing perennial grass that performs consistently. Fescue and phalaris only persist in regions of the slopes and plains with higher

Return by Asset Class, 2014-2018

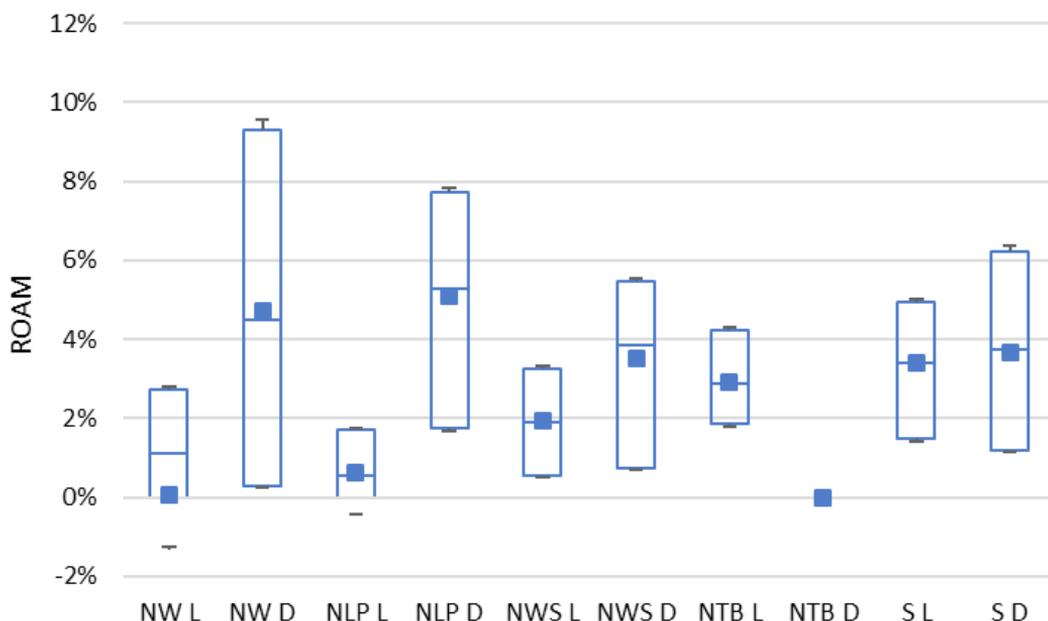


Figure 1. Long-term average return on assets managed (ROAM, % ■) for livestock (L) and dryland farming (D) assets by region; North West (NW), Namoi and Liverpool Plains (NLP), North West Slopes (NWS), Northern Tablelands (NTB), and Southern NSW and Victoria (S). The boxes show the interquartile range (i.e. ROAM for 25% to 75% of properties); middle bar is the median and the whiskers show the maximum and minimum ROAM values.

rainfall and superior soil type. Lucerne pasture can have issues with low ground cover and bloat so is not as widely sown as recommended.

Soil types. Heavy Vertosol soils need a lot of rain to get a forage rapidly growing. The red Chromosol soils, however, which were originally farmed are often missing an A-horizon. This means that they can have poor infiltration and low moisture-holding capacity.

Management responses to unique characteristics

As managers, our ability to deal with the unique characteristics of our region holds the key to generating industry competitive returns of >5% ROAM.

Management responses used by producers to deal with these challenging characteristics include the following strategies:

- Fodder crops to provide the quality and quantity of feed to meet the animal requirement in winter;
- Supplement poor quality grass with non-protein nitrogen to increase utilisation;
- Fertilise to promote the growth of subterranean clover and medic to improve feed quality;
- Lucerne for quality;
- Tropical perennial grasses to improve feed supply and increase stocking rate; and
- Grain-assist to improve weight gains.

The North West Slopes and Liverpool Plains datasets were analysed for the impact of these strategies by comparing the average pasture feed splits for different producers (Fig. 2). Top-performing producers have based their superior performance on improving greater than 75% of their farm area with fertiliser (45%), fodder crops (12.3%) and improved pastures (lucerne, tropical grasses and other pastures, 17.5%). Average farms in the region have improved around 60% of their farm area, but with substantially less improved and semi-improved (fertilised) pasture compared with the top performers. Top producers have a slightly lower reliance on fodder crops, but this has been replaced with more improved pastures.

The proportion of farm area improved had a resultant impact on producer stocking rate, as

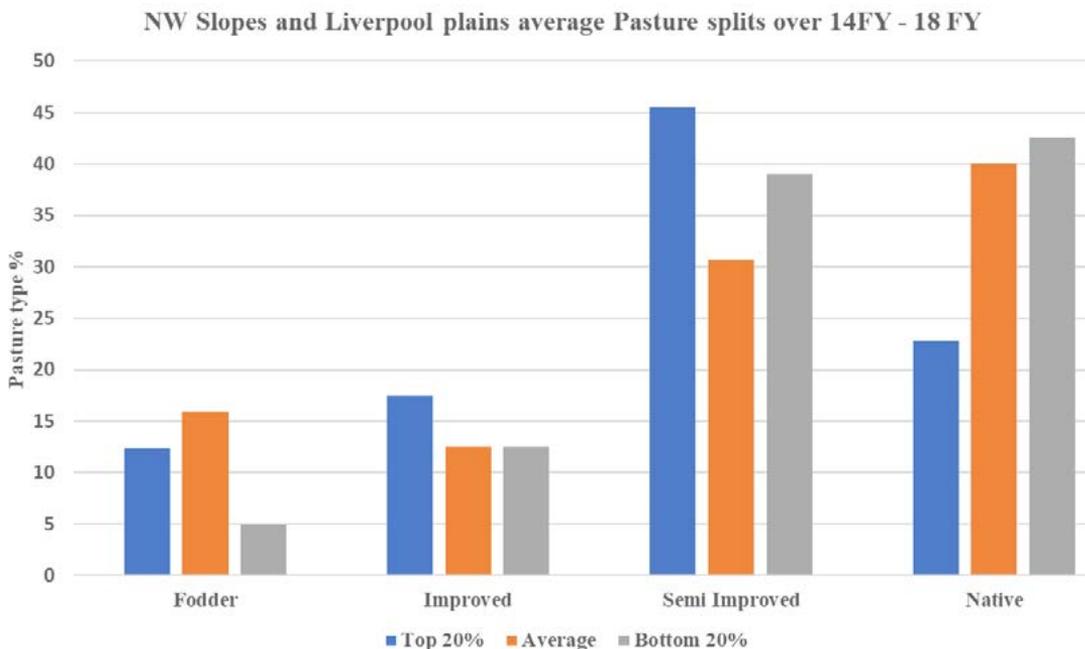


Figure 2. Long-term (5 years) average pasture splits for producers in the top 20%, average and bottom 20% of performers combined for the North West Slopes and Liverpool Plains.

measured by DSE/ha (Table 1). Top performers, who have more than 75% of the land improved, had a long-term average stocking rate of 7.1 DSE/ha or 1.3 DSE/ha/100 mm (Table 1). The poorest performing farms, with under 60% of the land improved, had an average stocking rate of 4.8 DSE/ha or 0.67 DSE/ha/100 mm. The contribution of each pasture type to the additional stocking rate was difficult to quantify. Experience suggests that fodder crops and improved pastures add significantly to the business’s capacity to finish livestock and improve the winter carrying capacity. Semi-improved pastures assist in increased carrying capacity year-round due to improved feed quantity and quality, and this, in turn, is reflected in animal performance.

Enterprise performance

The long-term gross margin per DSE for each livestock enterprise run by producers in the dataset illustrates substantial differences (Fig. 3). Top performers achieved superior enterprise performance compared to their peers. This is due to the combination of genetics, husbandry and the contribution that fodder crops and improved pastures make to their businesses, which supports higher stocking rates and better animal performance.

Growing winter fodder crops and improved pastures does come at a cost, albeit at a cheaper price per kg of DM compared with retained fodder and grain or feed bought in. Average long-term feed costs for beef breeding producers

Table 1. Impact of proportion (%) of native pasture on long-term (5 years) average stocking rate (DSE/ha) and stocking rate (DSE) per 100 mm of rainfall for producers in North West Slopes and Liverpool Plains NSW.

Producer group	Proportion of native (%)	DSE/ha	DSE/ha/100 mm
Top 20%	23	7.1	1.30
Average	40	5.5	0.95
Bottom 20%	43	4.8	0.67

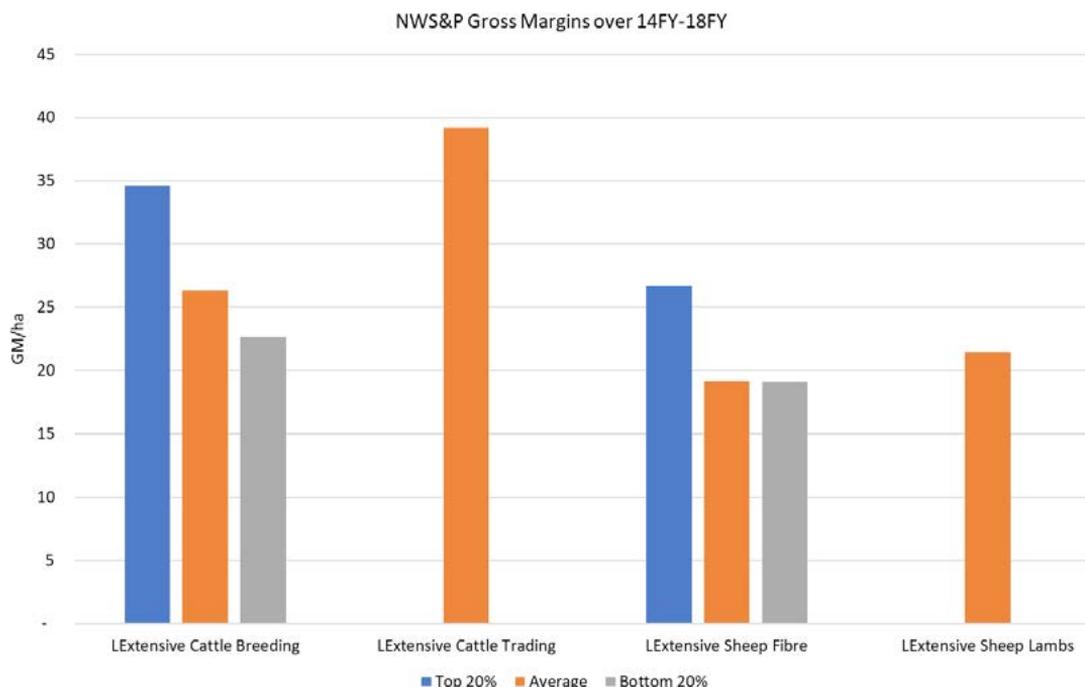


Figure 3. Long-term (5 years) average gross margins per ha (GM \$/ha) for different livestock enterprises of producers in the top 20%, average and bottom 20% of performers in the North West Slopes and Plains of NSW.

on the North West Slopes and Liverpool Plains are summarised in Figure 4. The chart clearly shows the significant increase in spending on fodder crops and pastures by top performers. These are the two cheapest forms of feed and add significantly to the overall performance of the enterprise.

For many producers, poorer performances are in part due to lower investment in the pasture base. This is often reflected by reduced proceeds from stock sales as livestock are often sold unfinished.

The challenges listed above are largely addressed by having a greater area of fodder crop and improved pastures. The subsequent challenge is, however, that feed related costs make up 42% of the direct costs for top producers. This cost structure works well in years with good rainfall that supports fallow moisture retention in fodder crop country, the early planting of winter fodder crops and adequate in-crop rainfall to sustain growth. Fodder crops can often be grazed 3–4 times during a grazing season and therefore achieve excellent utilisation. In poor years, fodder crops tend to be grazed significantly less, either through the late establishment and or

poor in-crop rainfall to sustain growth and can, therefore, become a large cost to the enterprise.

Conclusions

In northern NSW, winter fodder crops are necessary because without them it is difficult to meet the production targets essential to achieve good enterprise returns. Top performing producers in northern NSW utilise higher percentages of fodder crops and pasture improvement in managing for this, but it can come at a high cost, particularly in years where fodder crops do not perform well due to dry conditions. Hence, striving for higher grazing returns with fodder crops in northern NSW is a case of 'damned if I do, damned if I don't'.

Acknowledgments

Agripath thank the participants of our New England Tablelands, North West Slopes and Liverpool Plains, North West NSW and Southern NSW benchmarking groups, who without their data this information would not be possible. Agripath also thank and acknowledge Newsome Agriculture for its contribution to the datasets.

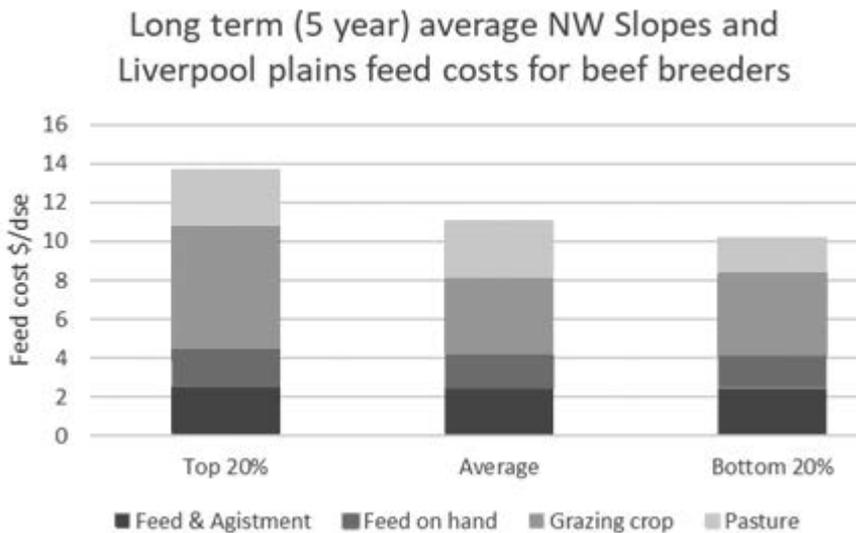


Figure 4. Long-term (5 years) average feed costs (\$/DSE) for producers in the top 20%, average and bottom 20% of beef breeders in the North West Slopes and Liverpool Plains region.

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Producer's perspective: the swing to forages

D Maxwell and T Maxwell

“Mountain View” and “Glenarden”, Wee Waa, NSW 2388: david@candw.com.au

Abstract: *David and Tracy run a 1597 ha sheep and dryland cropping business, split into two blocks, north and north west of Wee Waa in northern NSW. The soils are dominated by deep black cracking clays with intermittent red soil ridges. Over the past five years, excluding the current drought, they have run up to 1300 Dorper ewes across the two blocks. They have the capacity to farm 705 ha, of which 317 ha is developed for flood irrigation. The forage base includes 105 ha of old man saltbush, 202 ha of tropical perennial grass, and 690 ha of native pasture country. A nagging ‘gut feeling’ inspired David to closely analyse their trading figures, which suggested the farming enterprise was not as profitable as they thought. Now, with an expanding forage base of tropical grasses, the Maxwell’s are seeing some handy returns from their Dorper enterprise. However, along the way, they have learnt some painful and valuable lessons about grazing management. Does it mean they will stop cropping? The short answer is no, but it comes down to particular circumstances, scale, land types, capital position, labour capacity and climate variability.*

Key words: tropical grass, cropping, Dorper, old man saltbush

Introduction

My wife Tracy and I run a sheep and dryland cropping farm on 1597 ha split into two blocks, “Mountain View” 829 ha 12.5 km directly north of Wee Waa and “Glenarden” 766 ha 60 km north-west of Wee Waa. In addition to this, we have three kids and I work as a full-time partner of a 50+ staff accounting firm. Needless to say, I am quite time poor so our farm has to be labour efficient and cash positive. Capital gain is nice but we have two elderly parents to support so the business has to generate positive cashflow.

Farm description

Soils and landscape

On “Mountain View” the soil types are a 75/25 mix of deep black cracking clays with intermittent red ridges. Most paddocks will have a mix of both soil types. On “Glenarden” the mix would be closer to 50/50 with some heavy belts of belah timber.

Climate

The long-term average annual rainfall is approximately 525 to 550 mm, which is neither winter nor summer dominant. However, the value would be significantly less than that if we took an average of the recent 10 years. Basically, the rain stopped in about November 2016 and

we haven’t had a single day rainfall total greater than 45 mm since. In 2017 we received 370 mm and in 2018 we received just 289 mm, but since November 2018 we have received 56.5 mm.

We seem to be receiving rain in clusters of events over a few weeks and then it disappears for periods ranging anywhere between 2–4 months. We primarily rely on cap & pipe water at “Glenarden” and bore water at “Mountain View”; any dams that we have ran dry several months ago.

Livestock

When we purchased our first part of “Mountain View” from my parents we ran a Merino x Border Leicester first-cross operation. We started trading steers, but found that their performance on the saltbush was poor. In approximately 2006 we started running Dorper sheep. The shift to Dorpers was driven largely on their ability to handle tougher conditions. Being a full-shedding breed and given my full-time workload, I did not have to worry about flies, lice, shearing and crutching, which were all important considerations. The Local Land Service (LLS) recommended stocking rate is approximately 2.5 DSE/ha. We have tried as best we can to only keep the stock on our grazing land, but in dry times we will let them graze stubble on the cropping land. Ignoring the current drought, in the last five years, our business mix has 1300 Dorper ewes spread relatively evenly between the two blocks.

Drought strategies

Until recently we had 415 t of grain storage capacity; a 200 t grain shed and 215 t silo. In March 2019, we added further capacity with a 344 t silo. The aim is to fill them the next time we get a crop and keep them full. We also make our own hay, which we keep in our two haysheds and under hay caps. We use wheaten hay for weaning and barley stubble in the feedlot.

The planting of deep-rooted perennials such as old man saltbush, Bambatsi panic, Gatton panic, Premier digit and Bisset creeping bluegrass is also a significant part of our drought management strategy. We have also divided our paddocks into several small paddocks, which we are able to lock up, confine our stock to just a few sacrifice paddocks and destock until it rains. The idea is that when it does rain we have sufficient ground cover on our saved paddocks to respond more quickly to the rain event.

We have a five-cell feedlot to ensure that we can always sell a finished lamb. These cells can be turned into a drought lot for our ewes if necessary.

Due to my working off-farm, we don't have access to any form of drought assistance. Therefore, we have to always be prepared for drought and we try to make ourselves as drought proof as possible. There is more we would do but that all takes capital. With low-interest loans, there is much more we could do and we would be a lot further down the track by now.

Pastures and/or forages for livestock

To fill our feed gaps in the past we have tried to grow fodder crops ranging from dual-purpose wheat, forage barley, to millet and pastures like vetch and lucerne, but with very mixed success. There were some good wins but more often than not and the nett result was a short grazing window. Typically, there would be a dry spell followed by a good rainfall event that resulted in going from no feed to so much feed we couldn't stock it heavily enough. In turn, it would run to seed, which meant we had to quickly de-stock. Added to this, the seed was relatively expensive and with a long fallow lock-up period over summer, we were going back to a higher cost

structure of cropping. We needed a crop that provided a sustained and reliable feed supply from a rain event, even if it came at the cost of surrendering maximum production.

In 2002 we planted 65 ha of old man saltbush at "Mountain View" and 40 ha at "Glenarden" in a configuration of twin rows 1 m apart and then a 5 m space then two more rows. We planned to sow perennial grasses between the rows after the saltbush was established (as advised) but there was a bit of a mix up at planting and the gap between the rows became quite variable anywhere between 3 to 5 m, which made it hard to get a planter in. We later tried spreading grass seed, but nothing really established. Subsequently, we ended up with a stand that was just too thick and we have never been able to get a perennial to establish between the rows. So we have adapted with the use of barley straw and some grain supplementation. Prior to planting saltbush, we were running approximately 1 ewe/ha, but the saltbush has significantly increased our stocking capacity and gives us the flexibility to rest or graze paddocks. In the past, we have been able to run 700 ewes and small lambs on the 65 ha of saltbush for at least 12 weeks with only the addition of some barley straw as a supplement.

Our native pastures were hit and miss; if we have a decent winter our country grows a lot of burr medic and wild turnip, annual phalaris and annual ryegrass which is good feed up until it goes rank. As for summer pasture, we were heavily relying on the annuals of barnyard and liverseed grass, yellow vine, windmill grass, couch grass, button grass and a lot of black roly poly.

Cropping

"Mountain View" is in the middle of the dryland cropping and irrigation district of Wee Waa, we currently crop 705 ha, of which 317 ha was developed for flood irrigation.

For the past 16 years, we have run a zero-till cropping operation growing wheat, barley, chickpeas and faba beans in rotation under the guidance of one of the districts leading agronomists. We contracted the planting and the harvesting, which resulted in a slightly higher cost structure. We weren't cutting corners.

The Review: Does one size rule fit all?

On a spreadsheet, nothing beats cropping from the viewpoint of enterprise profit margin. In my district, it is just accepted by the banks, the agronomists, accountants, benchmarkers and chemical companies that if you want to make money, the “universal truth” is, you must crop. Livestock are only an acceptable side-line if they do not interfere with the cropping.

I knew all this, for after all, it is a “universal truth”, but for several years I had a “gut feeling” that the reality and the theory just weren’t aligning. For the record, accountants have the worst books; it took me about five wet weekends in a row in 2016 to sit down and actually work through our past eight years of trading figures to confirm my “gut feeling” was in fact correct.

In eight years of cropping, we made just three profits; since then it had only gotten worse. Including 2019, our farming had delivered profits in four of 11 years. In theory, we were doing everything right, but our scale and a “hot week” here and a “dry spell” there has sapped our profitability. Together with the fact we were also farming some paddocks that contained a real mix of soil types, it was clear the ‘spreadsheet’ didn’t allow for the variability and scale efficiencies.

The sheep operation, on the other hand, kept plugging along just nicely. The operation has a low-cost structure and a medium output, which has allowed us to see through the ups and downs and still turn a profit. Over the last six years, it has proven to be a reliable medium output operation. We have lambed every eight months with a weaning rate of around 112–120%. The 4-year average (2014–2017) price has been around \$140 per lamb, and the average price through 2018 and 2019 is considerably better again. And there is still plenty of room for improvement.

Decision time: it was clear that something had to change

The numbers dictated that something had to change and the answer wasn’t to double down on cropping! If we were going to expand our

stock numbers, the next decision was how do we expand – fodder crop v. perennial crop?

As stated earlier our experience with fodder crops was not delivering a reliable feed supply around which we could organise our grazing system. Due to the recent growing seasons and our smaller scale, fodder crops were relatively expensive. We were achieving a reasonably short grazing window considering the time that was spent on preparing the paddock. To be fair I do think that Dorpers probably do better on the harder feed but generally, it wasn’t so much about the quality of the feed. Rather, it was the length of the grazing window the fodder crop gave us and this was largely dictated by rain or lack of it.

The problem we were finding was that we got a big dump of rain and then nothing for a while. We believe that perennial grass allows us to better retain a greater proportion of the bigger rainfall events compared with fallow paddocks.

What to plant?

Old man saltbush is fantastic in measured doses. It has a three-tiered root system that can reach down to 5 m deep and up to 3 m across, which makes it a reliable drought-proof feed source. Its high protein, low carbohydrate and high salt levels make it great forage as part of a mixed diet, but it definitely needs a metabolisable energy source, such as perennial grass forage, with it.

Native perennial grasses were an option but just didn’t produce enough biomass to make them a viable alternative. Tropical perennial grasses seemed to fit the bill. They appealed to us because they were considered a drought-proof plant that had good water use efficiency, which led to large palatable biomass and long growing season.

So in December 2016, we decided to plant tropical grasses in 130 ha of our least profitable farming paddocks, one common factor was that they all had red ridges in them. We did it all by the textbook (Harris et al. 2014). We chose a blend of Bambatsi and Gatton panic, Floren bluegrass, Premier digit and Bisset creeping bluegrass. With a large rain event on the way, we sowed 10 mm deep into stubble. However,

the rain event that was there only days before, disappeared for 3 months. But, we eventually got up 10 ha, all in the last corner planted. We figured out that the 10 ha came up when the press wheels were pushed down a little harder, and the deeper planting seemingly was the success with our heavy soils.

In December 2017, we re-planted the remaining 120 ha, but this time we planted 25 mm deep and the germination was excellent, with up to 12+ plants per m². We didn't realise it at the time, but approximately 90% of the grass was Bambatsi or Gatton panic. We didn't care as there was just so much feed we couldn't believe it.

In December 2017, we also planted a further 72 ha of the same mix as before. We again sowed 25 mm deep, and again achieved very good germination of Bambatsi and Gatton panic with <10% of Floren bluegrass, Premier digit and Bisset creeping bluegrass.

The sea of grass: how do we graze it?

Being time poor, managing lots of little paddocks and moving livestock every few days just wasn't an option. Initially, we lambed down a mob of 325 scanned in lamb ewes in a 66 ha paddock for about 10 weeks. During this time we had about three reasonable rainfall events. At lamb marking, we only marked 102% of lambs and took out 86 dry ewes. We were a bit disappointed and blamed the vendor of the ewes (my brother-in-law) for selling us rubbish!

At the same time, we had ewes and weaner size lambs in another 40 ha paddock. They stayed for about five weeks but only grazed a 100 m wide strip between the water trough and the trees. It wasn't until I was driving my father around the paddock, a week after 37 mm of rain, that we noticed about 10 lambs were dead along the strip between the trough and the tress. There were also several lambs huddled under shrubs and trees.

We had a problem and its name was saponin toxicity (Slattery 2019). The fresh shoots of the panic varieties are particularly toxic for the first two weeks after a rain event. Mature sheep seem to be able to handle the toxicity or avoid grazing the shoots, but anything under about 12 months of age seems to be very vulnerable.

We lost approximately 30 to 40 lambs out of this event alone.

Saponins, which are particularly nasty toxins, affect the liver and the most obvious clinical sign is photosensitisation. Once they were affected, there was very little we could do with them other than locking them up in a dark place, feed them some grain and hay and hope for the best. All the experts advised us that this was a "one in twenty" event and to get it first time out was just plain unlucky.

In order to reduce the risk of more saponin poisoning, we decided to change our paddock sizes to no more than 20 ha each. We ran the whole flock together in one mob and moved them out of these paddocks immediately after rain. Our logic was that we would move the sheep into a paddock with larger and more mature plants, thereby reducing the percentage of fresh shoot for them to graze on. This plan worked well for the next 6–8 months as it didn't rain much.

In March 2018 we were hit again, this time we lost approximately 140 lambs and again we were told that this time we were "incredibly unlucky" as this was unheard of. Quite a few phone calls later and talking to other experts we found that by feeding lambs on panics within 2 weeks after the rain we were going to kill young sheep every time; 1 in 20 was really 1 in 1. In hindsight, we were actually hit three times with saponin poisoning; the first time we didn't know about it as we hadn't yet marked the lambs.

What have we learnt?

- We need a new grazing system. Our current plan is to remove all sheep from tropical pastures as soon as it rains. We put them on the saltbush for 3–4 weeks (to be safe) and then put them back and monitor them closely.
- We need to plant more improved pastures, but next time I think we will avoid the panics and reduce our sowing depth. If we manage to get these pastures up we will keep these for any stock under 12 months of age. The only problem with our new plan is that it just hasn't rained for about two years.
- When planting more saltbush stands, establish

the grasses first and plant the saltbush in twin rows approximately 20 m apart.

- When in doubt lock the lambs up in the feedlot pens until we can get the safe pastures established.

Do the numbers still stack up?

The short answer is yes. In a 20 ha paddock, we ran 800 ewes and 900 4–5-month-old lambs for five weeks and no saponin poisoning. We just need to be vigilant and have alternative grazing options available after rain events.

The LLS rate our area at 2.5 DSE/ha. Our aim is to run >2.5 ewes/ha (which we have already achieved), lambing every eight months with a minimum marking rate of 100%. At a sale price of \$140/lamb (i.e. our 5-year average minimum price), taking out approximately 40% for costs (including fixed costs but not feedlot costs), our resulting net profit margin is approximately \$311/ha. That matches a good wheat crop.

Unfortunately, since November 2018 at “Mountain View”, we have had 56 mm of rain and our ewe numbers have dropped from 700 to 460 and we have 200 maiden ewes. In spite of the lack of rain we are still generating a reasonable cash profit. The fact that for the last two years our lambs have averaged in excess of \$190/head just gives us a bit more room in our figures.

Should we put it all down to grass and stop cropping?

The short answer is no. In a good season, cropping in the Wee Waa district does work. Generally, it is the one enterprise that can deliver significant bursts of profit that can be used to retire debt. Interestingly we have found that our worst farming paddocks are in fact our best paddocks for grass, while our better farming paddocks have struggled.

No two farms are the same and what best suits your particular farming business depends on many factors such as your scale, land types (breakdown to individual paddocks), capital position, labour capacity and climate variability, so there is no “one size fits all”. In our situation, it is clear that we need to take our cropping from our primary enterprise to our opportunity

enterprise. The sheep need to become our primary enterprise as that suits our situation. However, it might not necessarily be the same for your mix of enterprises.

The future

At “Mountain View” we plan to establish a further 200 ha of tropical grasses. This will leave us with approximately 275 ha of cropping country, which we will try to keep in a simple rotation of faba beans and barley or dual-purpose wheat. After filling our silos and hay sheds, anything leftover can be sold.

At “Glenarden” we hope to start planting tropical grasses but we have a few hurdles to clear there first. If we can get everything developed as planned we aim to run approximately 2200 ewes, selling approximately 3300 lambs a year, but all this depends on rain.

Conclusions

What have we learnt? A lot of things. The first is don’t fall victim to your hubris because a big paddock of grass isn’t always your friend.

Know and manage your costs and your risks as best you can. Too many people try to manage their income and lose sight of the costs. Unfortunately, in agriculture, there are many factors that affect the income that we can’t control. Always be on the lookout for ways to improve as it is much cheaper to learn from someone else’s mistakes than from your own.

Acknowledgments

There are many people to thank for their inputs that have helped us on this journey, so for fear of missing someone, we simply say thank you all. Thank you to the Grassland Society of NSW for inviting us to share our story.

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Integration of on-farm silage systems for enhanced beef cattle production

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Abstract: *With increasing climate variation, livestock producers are required to safeguard their enterprises to stay viable. On-farm silage systems that harvest fodder crops are becoming more relied upon as a management practice to manage seasonal variability, reduce overgrazing of pasture and decrease the age of turnoff, whilst increasing live weight gains of cattle. This paper is a producer's account of the benefits of developing an on-farm silage system, from growing the fodder through to feeding it to livestock and the enhancements to profitability and environment it brings.*

Key words: silage, profit, opportunity, sustainability

Introduction

Futuraity Shorthorns is a beef seedstock and cattle trading business. The seedstock section supplies live animals and genetics throughout Australia and internationally. The cattle trading operation is an opportunity-based business that is flexible by design to allow variations in stocking rate.

The farming operations are in north-western NSW with “Glen Ayr” and adjoining holdings totalling 2550 ha located near Kenebri in the Warrumbungle Shire and on “Raeburn” consisting of 1520 ha located 30 km east of Coonamble in the Coonamble Shire. The properties have been purchased over a 20 year period by Jason and Kylie Catts and operated by Jason and Kylie and two full-time employees.

Farm description

Soils, landscape and climate

Soil types are quite varied ranging from sandy loams, red clays and self-mulching basalt. The topography of the land consists of slightly undulating to open plains country, with areas of scattered timber. The annual average rainfall is 600 mm with a slight summer dominant distribution.

Livestock

The seed stock business consists of 400–500 registered breeding females with the aim to produce 100 bulls for sale annually. Steers and cull heifers are taken through to export feeder weights. The cattle trading business focuses on

lighter weight cattle grown on to export feeder weights or finished for domestic or grass-fed markets. Numbers are dependent on available paddock feed or stored fodder, this allows for flexibility of stocking rate.

Pastures and/or forages for livestock

All properties have a mixture of native, subtropical and lucerne-based pastures. Both winter and summer forages are grown for grazing with 400 ha of oats or forage barley grown in the winter and 250 ha of sorghum or cowpea grown in the summer. Excess is chopped for silage.

Cropping

Cereal and pulse crops (240 ha) are grown in winter for silage and grain production for on-farm use. The cropping program is designed to produce fodder as well as to set up favourable agronomic outcomes when establishing perennial pastures.

Drought strategies

Like many producers, drought strategies are continually evolving in our operation. To date we have implemented the following:

- 500 head drought mitigation/opportunity feedlot; and
- 3000 t silage bunker capacity to be increased to 4500 t fresh chopped.

This allows flexibility in stocking rates, by running at 70% of stocking rate with breeder cattle and using trading cattle to increase stocking when fodder supply allows. Also, this enables us to store high levels of moisture in the fallow farming country prior to planting to increase the likelihood of successful cropping outcomes.

Goals or business objectives

Supply genetics to beef producers that add value and profit to the beef cattle supply chain. Further, reduce the effects of variable climatic conditions on forage supply. Reduce farm debt.

The swing back to forages

Over the past ten years, Futurity Shorthorns has developed a silage system by direct chopping forage crops to make pit silage to use as part of our annual management of livestock. The benefits of integrating on-farm silage production have been wide-reaching and added a lot of value to many sections of the business.

Agronomic

When direct chopping cereal crops for silage, in our case, there have been several agronomic improvements that stem from cleaning and early harvest. As crops are chopped four to six weeks earlier than if the crop was to be taken through to grain, the chopping process cleans most weeds from the field prior to weeds seeding and allows an earlier start to a fallow period for moisture storage. This early finish to the cereal crop chopped for silage can allow for a sooner subsequent crop or at least better starting moisture than if the crop was to be taken through for grain or hay. In cases where lucerne is undersown in the cereal crop, the early finish of the cover crop once chopped for silage allows more favourable establishment conditions due to reduced weed competition and less draw on subsoil moisture.

Hay-silage comparison

There is little doubt that a mixture of hay and silage feeding is appropriate for most operations although there are some tangible cost savings, improvements in feed quality and proficiency in feed delivery that have led us to include silage as our major component when feeding cattle. As silage is chopped near its peak nutritional value and with reduced losses through the drying and harvesting process, silages are generally higher in digestibility, crude protein, metabolisable energy value and palatability than hay cut from the same crop.

When we compare the cost of making hay versus silage there are some cost-savings on

a dry matter base. A common price for silage chopped, carted to the pit, rolled and the cost of plastic to cover is \$26/t. The average dry matter (DM) for cereal crops direct chopped for silage is generally 40%, which results in a cost of approximately \$64/t DM.

Common hay baling costs \$37.50/bale including cutting and raking. With the hay having a dry matter content of 90% brings the cost to \$68.75/t for 600kg bales. Plus \$5 cartage back to the stack gives a total of \$73.75/t DM.

When you take into consideration superior nutritional value, reduced harvest cost and a lot lower risk of crop damage during harvest, directly chopped silage stacks up well. Chopped silage has the advantage of not needing processing when fed through a mixing wagon compared to hay that requires processing. Silage greatly reduces mixing time and wear and tear on machinery. Although, a bale of hay is more mobile than a pit of silage. When the feeding of larger numbers of cattle in confined spaces is required to protect ground cover, silage offers greater time savings.

Environment

Due to operating a seedstock business, we are unable to sell all the stock when drought conditions occur due to not being able to replace them with like quality. Protection of ground cover and pastures are imperative for the sustainability of our country. A well planned on-farm silage system allows weaning of calves at any age and have them moving forward. If conditions deteriorate, breeding stock can be fed in a mitigation feedlot or finished for slaughter, thereby saving pastures from overgrazing and erosion of soil.

Increased profits from silage feeding

I would like to share a few key concepts that by having an on-farm silage system allows producers to do.

Take advantage of highs in the market. Every year there are highs and lows in the market (Fig. 1). By not being totally reliant on the weather for production, producers can have sale stock hitting the market in peak periods or purchase in a soft market.

If there is insufficient paddock feed in the autumn, calves can be weaned early and then by using silage based diets calves are able to gain 1–1.5 kg/day post-weaning until fodder crops are ready to graze. Producers can take advantage of higher prices in late winter-early spring preceding the spring turn-off cattle. This practice greatly reduces the age of turn-off and reduces stocking rates without reducing kilograms of turn-off.

Take advantage of lows in the market. Most years at the start of winter the weaner market is depressed (Fig. 1). Having silage systems in place allows for the purchase of stock at much-reduced rates. Silage based diets can supply high average daily gain (e.g. Table 1) and low cost of gain. Thus making the feeding component of cattle trading profitable even without an upside in the trade, but combining both can bring substantial rewards.

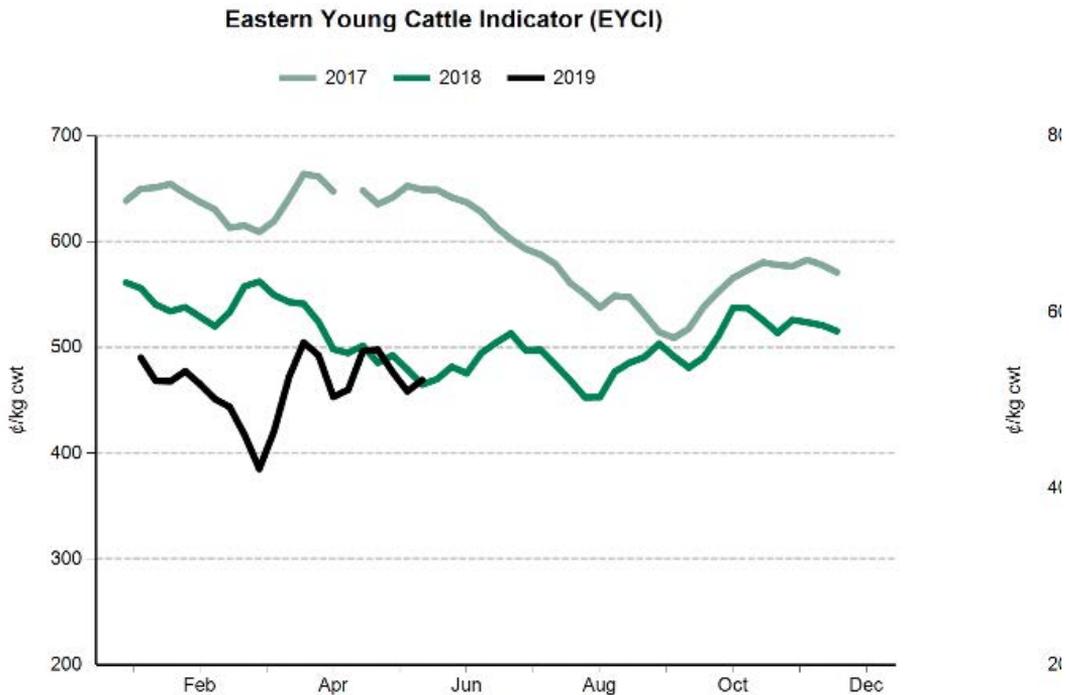


Figure 1. Eastern young cattle indicator demonstrating annual market trends (source: MLA 2019).

Table 1. Steer live weight gain and feed conversion were better on diets based on silage produced from ryegrass/subclover pasture with various levels of concentrate (source: Kaiser *et al.* 2004 adapted from Jacobs and Zorrillo-Rios 1994).

Concentrate in diet (% liveweight)*	Hay (5.6 t DM/ha)			Silage (5.0 t DM/ha)		
	0.5	1.0	1.5	0.5	1.0	1.5
DM intake (kg/day)						
Forage	4.36	3.86	2.82	4.99	4.26	3.58
Concentrate	1.39	2.90	4.47	1.45	2.94	4.39
Total	5.75	6.76	7.29	6.44	7.20	7.97
Liveweight gain						
kg/day	0.33	0.63	0.88	0.81	1.09	1.20
kg/t feed DM	57	93	121	126	151	151

* Concentrate comprised 67% barley, 30% lupins and 3% minerals.

Have the herd ready for breeding. Feeding post-weaned heifers a silage ration ensures they maintain good growth rates and retained heifers reach adequate weights prior to their joining date.

Conclusions

On-farm silage harvest offers agronomic advantages by the way of earlier moisture conservation and reducing weed burden. There are savings in direct chopping silage over hay as well as the increased nutritional value of the fodder and less weather risk during crop harvest. By having the option to rapidly reduce stocking rates in paddocks, a silage system allows protection of ground cover and ultimately reduces soil loss or erosion. Crops or pastures offer lower-risk production. However, by having the option of feeding silage-based diets to young cattle either, bred or purchased, when the season

requires can allow producers to take serious market advantages.

Acknowledgments

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Turning traditional cropping farmland into productive grasslands using tropical grasses, multispecies pasture cropping and saltbush

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Abstract: *This paper is about transitioning traditional farming country and degraded native pastures back to healthy productive grasslands. There are several methods that can be utilized including multispecies cover cropping, multispecies pasture cropping and the establishment of tropical grasses. There are many challenges that are faced along the way, but the rewards and the benefits of a healthier ecosystem by swinging back to forages, far outweigh these.*

Key words: soil health, soil biology, groundcover, rainfall use efficiency, Dorpers

Introduction

After the purchase of a small farm in 2004 and the neighbour's farm in 2008, we were the owners of 890 ha of Gravesend farming country, 50 km east of Moree. Both farms were rundown with poor soil health due to constant ploughing, use of chemicals, lack of groundcover and nutritional grasses. Grain cash crops were originally grown, but good profits were usually thwarted by the weather. Our main business was Amarula Dorper Stud, so our objective was to swing our bare soil back to grass. We did try letting nature take its course through grazing, but the country was too degraded, and this method was very slow. We then introduced tropical grasses on farmland and started pasture cropping in the native grassland. Trees and saltbush were the next steps. Inadvertently we began to regenerate soil health and armour the soil for increased rainfall use efficiency and ultimately profitability.

Farm description

- Glenavon has an area of 890 ha and is located 50 km east of Moree, just south of the Gwydir River.
- Our annual average rainfall is 650 mm, usually a summer dominant rainfall with the remaining months providing generally even falls. Summer rain tends to be more variable than winter rain due to the incidence of thunderstorms in summer. The last three years have been very below average and getting worse as the drought continues. Year to date

average is usually 310 mm. Our year to date rainfall to June this year has been 97 mm.

- Water access for livestock is excellent with a very good source of bore water that is piped to all 42 paddocks, with a portable trough system. The average paddock size is 15–20 ha. There are dams in some paddocks, but we do not have to rely on these. Our sheep prefer clean bore water.
- There are three soil types ranging from 60% black basalt, 30% red and 10% sandy loam, on a slightly undulating landscape.

Livestock

Amarula Dorper Stud was established in 2000 and is our main livestock enterprise. We breed Dorper and White Dorper sheep. We are currently running 800 stud ewes plus lambs and 300 young rams. Our moderately-sized, easy doing Dorpers are bred to cope in harsh conditions and be resilient to nutritional hardship. They are foragers and will eat bushes and shrubs and if managed properly can improve the species of plants within a pasture.

In the face of increasing climate variability, it is essential to have sheep which can both capitalise on good seasonal conditions but still perform under challenging ones. The Dorper can deposit and then utilise its body reserves when needed and utilise low-quality foods. This increases production rates from fewer inputs but also improves the survival and welfare of animals when faced with the harsh conditions of droughts in Australia. The less seasonal mating of Dorpers also allows producers more flexibility in matching the feed requirements

of the reproducing ewe to feed availability and allows mating systems to be altered according to seasonal conditions.

Pastures and/or forages for livestock

Tropical grasses. First established in 2008, we now have 250 ha of perennial tropical grasses including Premier digit, Bambatsi, green panic, Bisset and hatch creeping bluegrass, Floren bluegrass, and Rhodes grass. To improve the legume content of these tropicals, we have added clovers and medics with the hardiest being snail medics, rose clover and winter dormant old variety lucerne (Flairdale). We are seeing the native glycines flourish. Recently, we have successfully established perennial tropical legumes (*Desmanthus*) into our tropical grasses.

Native pasture. Our dominant grasslands are native pastures, with varying nutritional quality, including native bluegrasses, redgrass, plains grass, wallaby grass, to name a few. With our farming practices, we have seen native species including grasses, herbs, legumes and other plants returning.

Transitional farming country. We are using our new innovative farming practices on 150 ha to cover crop and turn this into productive grasslands.

Saltbush. We have established saltbush (along with tropical pastures) to increase drought tolerance, increase soil health, shade, shelter and water quality. It is a very drought tolerant plant that can provide green leaf through the driest periods and especially the autumn/winter feed gap. It improves biodiversity and environmental sustainability. Dorpers thrive on saltbush.

Grazing management of these pastures is through rotational grazing strategies. This improves the flexibility of movement, increases the health of animals, the health of plants and soils and decreases the need for drenching.

Cropping

Conventional cropping methods have been used in the past, with oats being grown for fodder very successfully. But after attending a field day with speakers Colin Seis and Judy Earle in 2006, our quest began to implement new farming

methods. We now use no synthetic fertilisers or chemicals.

Pasture cropping. This is done with a single crop species, usually, oats, into a perennial grass base improves soil structure, soil carbon, nutrient cycling and more efficient use of water while producing good crops for forage. This technique has increased our perennial grass species diversity and density while decreasing farming costs and increasing soil health.

Multi-species pasture cropping. This was experimented with when Justin discovered Gabe Brown and Ray Archuleta. This farming system mimics the native pastures where there is diversity, not a monoculture. We now use at least 10 or more different groups of plant species that produce good quality forage and have a range of different root systems. This includes broadleaves, grasses, fibrous and taproots, legumes, flowering plants and others to diversify our fodder cropping system. The greater the diversity of plants the greater diversity of microbes and the more robust and healthier the soil ecosystem.

Multi-species cover cropping. This is essential to rebuild soil health in degraded farming paddocks. The use of multi-species cover cropping will armour the soil, build soil health, organic matter and soil microbes. Once this is established, we can establish our tropical grasses and legumes. We have now eliminated the use of synthetic fertilizers for five plus years and chemical sprays for the last three years. All these methods grow more nutritious forage for our Dorpers. The intention is to split paddocks further, using temporary fences and solar powered gates, to increase the production of live-weight per ha. Livestock are integrated into this system to forage and trample excess herbage into groundcover. In our system, there is no such thing as a weed. We utilise our Dorpers to clean up our farming paddocks to remove spray resistant plants such as fleabane, barnyard grass and others.

Drought strategies

Our main drought strategy is to adjust our stocking in response to the 'rolling rainfall total'

and not rely on the average rainfall. There is no such thing as average. Our climate is getting hotter and dryer. As the 'rolling rainfall total' begins to decrease and forage reserves start to become depleted, destocking becomes the tool to maintain groundcover and conserve fodder in the paddock. Prior to the drought, we were running over 2000 Dorpers and 100 cows and calves. In early 2018 we started a destocking program, which has seen a steady decrease in our livestock numbers. This is to preserve our groundcover for a quick recovery when it does rain. Other drought strategies include early weaning and feedlotting, confined paddock feeding in sacrifice paddocks and more and more saltbush in the future.

Goals or business objectives

Out of adversity, comes opportunity. With the prolonged drought our end goals have changed with profit not production being our main driver. You don't have to be the biggest or the best and produce the most. It is all to do with profit at the end of the day.

Our short-term goal is to make it through this drought and maintaining groundcover and grass. This gives the land the ability to recover and regenerate quickly once the rain decides to fall. We also can take advantage of smaller falls as you need to maintain water infiltration and not let it all run away.

Our medium-term goal is to establish more saltbush in our native pasture country, for more resilience to drought, but also improved biodiversity and increased fodder reserves within the paddock. Also, to continue regenerating degraded pasture and establishing more tropical grasses, increasing organic matter and soil carbon.

Our long-term goal is to have all our land covered by biodiverse grasslands (either native or introduced tropical) along with more trees and saltbush established back on all our land. This leads to better guardianship of our natural resources and producing healthy highly nutritious food and livestock.

The swing back to forages

When we bought our farm in 2004, we were still following conventional farming methods

of cropping with oats for fodder and wheat or barley as cash crops. Our soil was very much degraded with a soil carbon of 0.7% and the native pasture was taken over by less nutritious and desirable plants such as wiregrasses, spear grasses and kerosene grass. Most of the soil was scalded bare and brittle. The catalyst for change began as we were not making money from our crops and we needed to improve our pastures for our livestock health. Along came Colin Seis, Judy Earle, Christine Jones, Bart Davidson, Gary McDouall to name a few and in the last four years Gabe Brown and Ray Archuleta. These people have made a huge impact on our swing back to forages and the methods we have adapted to our farm to make these changes.

The initial obstacles to establishing our tropical pastures were the cost of seed and preparation of the soil prior to planting. Luckily, we were successful in obtaining grants from the CMA for seed costs. The biggest obstacle of all with establishing any pasture is rain. In our opinion, the establishment of good tropicals comes down to luck. You can prepare efficiently, but if you don't get the rain and follow up rain, then it can fail. Luckily, we can easily fix our native pasture through the simple use of multi-species pasture cropping.

The biggest opportunity we see for swinging back to biodiverse grasslands is the increasing health of our soil. Better soil health and diverse ecologies build resiliency into our farming operation and improve productivity, but more importantly profitability. Better soil health, higher organic matter and hence carbon increases infiltration rates, increases the water-holding capacity of the soil and therefore ultimately drought proofs a property. Our methods of farming have made it possible to weather most dry periods, while still being productive. There will be other droughts and next time we will have built resiliency into our natural resources with our management practices.

The future

The future is exciting. We have just won the North West Landcare award for excellence in farming for 2019 and go to the State final in October. This

gives us acknowledgment that we are on the right path. Our journey into regenerating our soil, plants and land doesn't stop now. Yes, we have been successful using new farming techniques and sustainable agricultural practices with the positive outcomes of improved environment and profitability. However, we are still learning and educating ourselves to look for more efficient methods of establishing grasslands.

Conclusions

Swinging back to forages and grasslands has been the most important change and challenge to our farm. The drought has tested our farm, soil and vegetation. We have still been productive but have had to destock and feed grain to remaining Dorper Stud Ewes while they are lambing, to retain our ground cover and recovery ability of our ecosystem. We will continue our journey and learn from failures and trial better establishment methods of tropical and native grasslands in our transitional farming country. Ultimately, the end goal is leaving our grasslands and other natural resources better for future generations.

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Poisoning of lambs on mature Bambatsi panic (*Panicum coloratum*) pasture

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Abstract: In March 2018 the author investigated the deaths of 140 from 1400 Dorper lambs in the Wee Waa district of New South Wales. The deaths occurred after the lambs were introduced to tall, mature Bambatsi panic (*Panicum coloratum*) dominated pasture. The lambs had clinical signs, gross pathology and liver histopathology consistent with saponin toxicity. Photosensitisation was largely absent. Ewes also grazing the pasture were not affected. While the pasture was flowering at the time of the poisoning it is suggested that the lambs preferentially grazed new shoots from recent rain. Grazing management recommendations to avoid similar pasture circumstances were implemented with no further cases in the following 12 months. The lack of photosensitisation and age-related susceptibility is discussed.

Key words: saponins, photosensitisation

Introduction

Steroidal or lithogenic saponins are a relatively common plant toxin poisoning of ruminants in New South Wales (NSW). Common sources of saponins in NSW include *Panicum* and *Tribulus* spp. Regault (1990) reports a case in sheep grazing Bambatsi panic (*Panicum coloratum*) in the Goondiwindi region of Queensland. McKenzie (2002) lists both Bambatsi panic and Gatton panic (*Megathyrsus maximus*) as sources of saponins, and Bambatsi panic as an important species for poisoning. Both of these grass species are commonly sown in pasture mixes in northern NSW (Harris *et al.* 2014). Saponins cause crystal-associated cholangiohepatopathies and secondary photosensitisation. McKenzie (2002) indicated poisoning commonly involves young ruminants, especially lambs grazing stressed pastures or crops.

This paper reports an investigation into saponin poisoning in black-headed Dorper lambs following introduction to mature Bambatsi panic dominated pasture on a property in the Wee Waa district of NSW in March 2018.

Pasture description

Two adjacent 30 ha paddocks were sown in March 2017 with a Bambatsi panic, Gatton panic and Premier digit grass (*Digitaria eriantha*) mix. Due to conditions at pasture establishment, by the time of poisoning, the pasture consisted of predominantly Bambatsi panic. A small area of *Tribulus* spp. was present in one paddock but largely absent in the other.

At the time of poisoning the pasture was mature, 40–70 cm high and setting seed. Examination of the paddocks showed heaviest grazing of the Gatton panic, followed by Bambatsi panic. The digit grass was least grazed. These observations suggest the sheep had preferentially grazed the Gatton panic, then the Bambatsi panic. In the one paddock where *Tribulus* spp. was present, this had been heavily grazed suggesting that it had also been selectively grazed by the sheep. Perhaps critically, at the time of introduction, there had been 40 mm of rain. As a result, all grasses were actively growing, and new green shoots developing. At the time of paddock inspection, this green regrowth from the base of the plants appeared to have been preferentially grazed. The older longer leaves were generally ungrazed.

Case presentation

The black-headed Dorper lambs were from two mobs, grazing the two adjacent paddocks. One mob consisted of 500 weaned lambs aged 4–8 months. The other mob consisted of 700 Dorper ewes and 900 unweaned lambs aged 4–8 months. The history and grazing management of both 30 ha paddocks was similar and both mobs were introduced to their respective paddocks on the same day.

Deaths were first noticed 10 days after introduction to the pasture with 24 dead lambs. When the deaths commenced was unclear, as the mobs had not been checked since introduction. However, the degree of carcass decomposition suggested the first deaths had occurred 5–8 days after introduction. The sheep were immediately removed from the pasture.

At 13 days after introduction 50 lambs had died and another 80–90 were clinically affected. By 20 days after introduction 90 lambs were dead and 40–50 clinically affected. Deaths continued for two months and eventually almost all clinically affected lambs died (c. 140 lambs). All dead or clinically affected lambs were in the initial clinically affected group. Both mobs of lambs were affected at similar rates. No ewes were observed with clinical signs.

A property investigation was undertaken when deaths were first observed. This included an examination of clinically affected lambs, an autopsy and paddock inspection. Treatment consisted of immediately removing all sheep from the paddocks and placing the lambs in a well-shaded paddock with only dry grasses. The ideal treatment of removing from any direct sunlight was not possible due to the absence of a suitable shed.

Clinically affected lambs showed lethargy, shade seeking and yellowing of mucous membranes. Photosensitisation was not a prominent feature (possibly related to protecting black skin).

The autopsy found extensive yellowing of all tissues and a swollen orange liver. Tissue samples were submitted to the NSW Department of Primary Industries State Veterinary Diagnostic Laboratory. Liver histopathology was consistent with saponin poisoning but pathognomic crystals were not identified. This was potentially due to slight autolysis of samples. No other possible causes of the clinical signs and gross pathology were identified.

Discussion

The classic reported conditions for saponin toxicity of Bambatsi and other panic pastures are grazing short pasture that is actively growing, especially if it subsequently becomes moisture stressed (McKenzie 2002). These were the circumstances for an earlier poisoning incident (10 dead, eight clinically affected from 220 Dorper lambs) that occurred on the same paddocks in December 2017. To manage the risk of future poisonings the owner elected to restrict future grazing by lambs to only mature pastures.

In contrast to these classical circumstances, the March poisonings outlined in this paper demonstrated that poisoning of lambs grazing flowering stands of Bambatsi panic was possible. The observations suggested poisoning can occur if the pasture was actively growing and lambs were able to preferentially graze regrowing shoots. It also demonstrated that poisoning can occur without the pasture showing visible signs of moisture stress.

The role of Gatton panic in this poisoning incident was difficult to quantify. While preferentially grazed, Gatton panic plants were less than one in 20 plants, and as such would have been a small part of the diet. McKenzie (2002) did not categorise Gatton panic as an important species for poisoning. In contrast, Bambatsi panic was categorised as an important species and it was the major component of the grasses observed to have been grazed.

To manage the risk of future poisonings on Bambatsi panic dominated pasture, the following measures were recommended:

- Only graze lambs on mature pasture that is not actively growing;
- Remove sheep from the pasture following rainfall;
- Initially, graze actively growing pasture with ewes to remove green shoots;
- Not grazing lambs until 2–3 weeks after any rain; and
- Grazing lambs at high stock densities to reduce the potential for lambs to preferentially graze any new green shoots.

These measures were successful in preventing poisonings for the following 12 months, but this coincided with severe drought conditions when there were few rainfall events.

The absence of photosensitisation as a prominent clinical sign in a case with significant mortalities was unusual but consistent with the current understanding of secondary photosensitisation as a result of hepatic damage from toxins. This finding suggests it is not photosensitisation that kills most lambs with saponin poisoning but rather liver damage. Moreover, in this case,

the black pigment covering the head of black-headed Dorpers most likely protected the lambs from photosensitisation.

Dowling and McKenzie (1993) summarise photosensitisation as the heightened sensitivity of the skin to sunlight. Secondary photosensitisation occurs when liver damage interferes with the liver's ability to deal with phylloerythrin, a breakdown product of chlorophyll. Phylloerythrin then escapes into the circulatory system and lodges in the skin making it sensitive to sunlight.

Seawright (1989) indicated that this sensitivity damages cellular membranes with enhanced capillary permeability, cell necrosis, vascular occlusion and acute inflammation. The areas of sheep most affected are the ears, eyelids, face lips and vulva. Reddening and oedema result, with rubbing and shade seeking. In lambs, ears droop and the muzzle is swollen. Necrosis of skin can be seen in severe cases.

Bourke (2011) indicated that severity of photosensitisation is not related to individual or species differences in metabolising the offending compounds. Rather tolerance is related to an animal's ability to prevent sunlight from reaching the blood vessels in its skin. Thus variation in tolerance is related to skin thickness, thickness and density of hair or wool coat and the degree of pigmentation in the skin.

The lambs, in this case, were black-headed Dorpers a breed with deep black pigmentation of the head and upper neck. This pigmentation likely prevented the most sensitive areas from being affected with the photosensitisation that is typical of saponin poisoning. However, shade seeking was a prominent feature of the affected lambs.

Further, death in secondary photosensitisation cases is not usually caused by the photosensitisation but rather the damage to the liver by the toxin (Seawright 1989). Thus in this case, while the lambs showed few signs of photosensitisation besides shade seeking, the underlying liver damage from the saponins was sufficient to cause death.

The susceptibility of lambs and the absence of poisoning in adult sheep with *Panicum* spp. was noted by Button *et al.* (1987). They also indicated that age-related susceptibility has been used as a management tool for grazing of *P. coloratum*. In contrast, in both the author's experience and Button *et al.* (1987) saponin poisoning from *Tribulus* spp. affects sheep of all ages.

The literature fails to explain this strong age-related susceptibility. In general, younger sheep are more susceptible to toxicities due to differences in ruminant metabolism and general resilience. However, this does not explain the strict immunity of adult animals to *Panicum* spp. poisoning. The selective grazing, in this case, raises the possibility that differences in grazing behaviour may contribute to this age-related susceptibility.

Overall the risk factors for poisoning, in this case, are likely to have been actively growing pasture, the potential for selective grazing of new shoots and grazing of lambs. The grazing management measures outlined earlier may be sufficient to manage these risks, and thus future poisonings on *Panicum* spp. dominated pastures.

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Contributed Papers

Novel graphs show extreme rainfall shortages

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Abstract: *I have used the record of monthly rainfalls from 1884 at Manilla, NSW to compile cumulative rainfall totals through a range of durations up to 360-months. Expressed as percentile values, these are classed as serious, severe, and extreme rainfall shortages. Two new kinds of graph show this information concisely and comprehensively, month by month. They reveal that the current drought has extreme, even record-breaking rainfall shortages. The third kind of graph shows the beginning and end of shortages. Extreme decade-long rainfall shortages occurred from 1910 to 1950, but not since.*

Key words: rainfall deficiency, driest-ever, Federation Drought, contour graph

Introduction

Since 1999, I have been keeping weather records at Manilla for my own projects and for newspaper reports. Manilla is north of Tamworth, NSW. Although this work is specific to Manilla, it is representative of the North-West Slopes and surrounding areas, currently in drought.

Based on the long record of the Manilla rain gauge, I have done analyses of rainfall, including the nature and progress of droughts. I found that I could describe droughts more comprehensively by using novel graphs that show rainfall shortage, which I have described in this paper. I publish these graphs on my blog “climatebysurly” so that farmers, graziers, and others in the district may be better informed. I explain every aspect of this work in my blog, as referenced below.

Analysis of rainfall at Manilla is vitiated by the failure to maintain an official rain gauge through the last four years. The rain gauge at Manilla Post Office, Station 055031 (Bureau of Meteorology 2016) was read continuously from 1884 to 26 March 2015. Since then, there has been an intermittent record, in part as Manilla (Museum) Station 055312 (Bureau of Meteorology 2018). Most readings since March 2015 are from my own rain gauge.

Methods

Cumulative rainfall totals for each month

Spreadsheet analysis. I prepare two tables using the spreadsheet application Excel (Speight 2019a). The rows in each table are serial months

containing more than 1600 in total. The columns in each table are headed by the selected number of months, n , as specified below. In the first table, I cumulate the rainfall totals. First, I add each month's rainfall total to that of the previous month for a 2-month total. I add the month before that to get a 3-month total, and so on. For every month, I get n -month rainfall totals from $n = 1$ up to $n = 360$. However, I calculate for only the following 25 values of n :

$n = 1, 2, 3, 4, 5, 6, 9, 12, 15, 18, 24, 30, 36, 42, 48, 60, 72, 84, 96, 108, 120, 144, 180, 240, 360$.

For the second table, I convert values from the first table to percentile values. Each value in this table represents the frequency of occurrence in the historical record of that rainfall total. A 12-month rainfall value that falls at the 5th percentile (for example) is lower than all but 5% of all 12-month totals in the record from January 1884 to March 2019. Importantly, each time a record is broken, the whole percentile table needs to be revised.

Graphs of the severity of rainfall shortage

I classify the percentile ranks of rainfall shortage, using the Bureau of Meteorology convention of Rainfall Deficiency (Bureau of Meteorology 2015). That is, ‘Serious Deficiency’ between the 10th and the 5th percentile, and ‘Severe Deficiency’ below the 5th percentile. I replace ‘Deficiency’ by the simpler term ‘Shortage’. I also classify as ‘Extreme Shortage’ those values that are below the 1st percentile.

I devised graphs of two types, *line graphs* (Speight 2019a) and *contour graphs* (Speight 2019b). In each *line graph* (Fig. 1) a heavy black line shows

the rainfall status for a chosen month and a thinner line for the previous month. The x-axis is not a date or time axis but shows the duration of rainfall shortages that have been calculated for the chosen month. The y-axis shows the percentile value of rainfall totals. On the graph, horizontal fields are labelled ‘Serious Shortage’, ‘Severe Shortage’ and ‘Extreme Shortage’. The 50th percentile line is labelled ‘Normal Rainfall’.

In each *contour graph* (Fig. 2), the x-axis shows the dates of sequential months in a selected part of the record. The y-axis shows the duration of rainfall shortage, increasing from 1-month at the top to 36-months at the bottom. Severity of shortage is shown by labelled, coloured or stippled zones, such as ‘Extreme Shortage’.

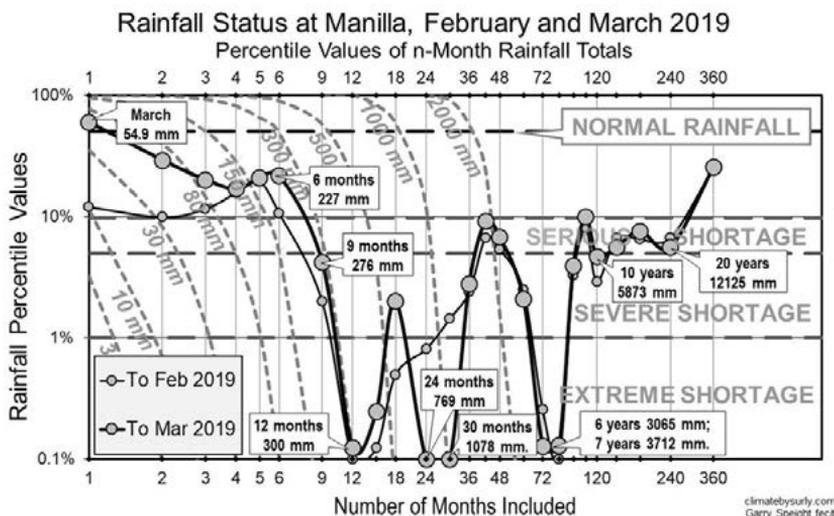


Figure 1. Line graphs showing rainfall status at February and March 2019. The x-axis is the duration of shortage and the y-axis is the percentile value. Labels show shortage percentile bands as ‘Serious’, ‘Severe’, or ‘Extreme’ as defined in the text.

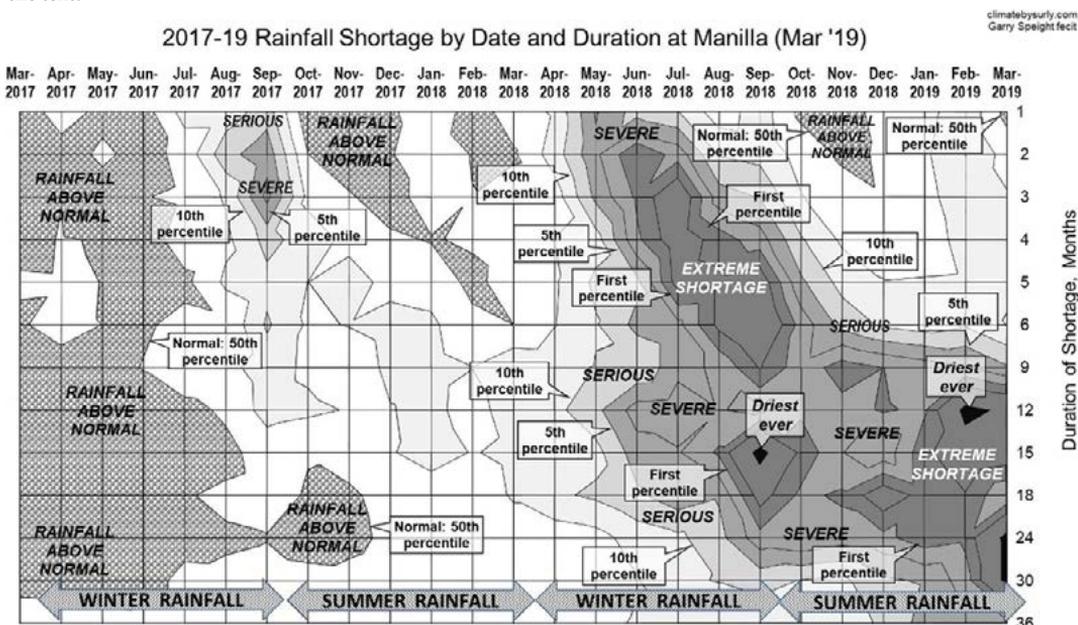


Figure 2. Contour graph showing the months from March 2017 to March 2019 on the x-axis, and duration of rainfall shortage on the y-axis. Severity of shortage is shown by layer tints and contours.

Identifying starting dates of shortages

Each tabulated rainfall shortage longer than 1-month must have begun earlier, but this is not explicit in the data or in the graphs described above. I developed further tables to extend each shortage back to the month when it began (Speight 2019c). I have new graphs to display the periods when rainfall shortages, as calculated for durations from 2 to 360-months, began and ended. Graphs may show the whole record (e.g. Fig. 3), or a part of the record in more detail (e.g. Fig. 4). Dashed lines labelled 'First Good Data' and 'Last Good Data' show the limits for determining true cumulative rainfall shortage. To the right of the second line, future

observations may make values more extreme.

Discussion

In this paper, I do not attempt an analysis of droughts. Instead, I offer several graphs of rainfall shortages at Manilla as examples of their potential to throw light on the subject if used more generally.

Data traces for February and March 2019 (Fig. 1) both show six extreme shortages at or near record levels for durations between 12 and 84-months. That is despite the fact that rainfall totals from 1 to 6-months were not serious shortages. The contour graph (Fig. 2) extends the display back through 25-months (i.e.

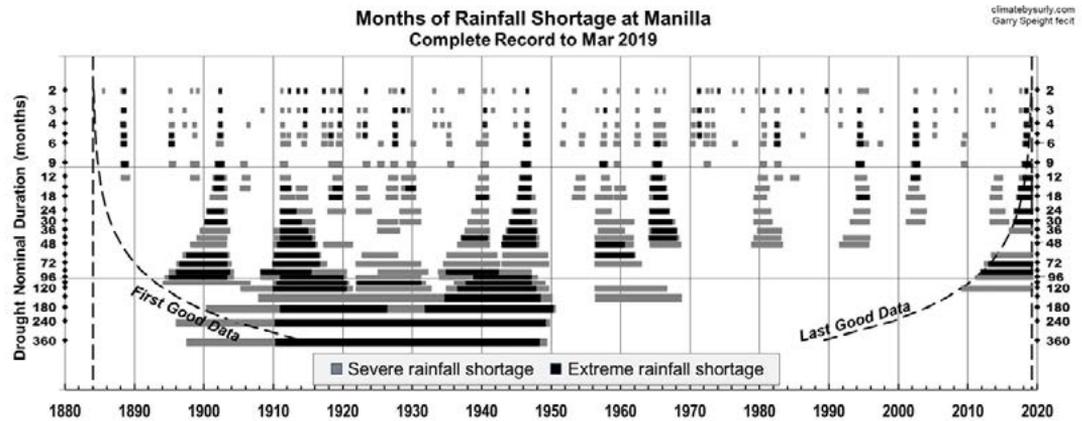


Figure 3. The complete record to March 2019 of severe and extreme rainfall shortage at Manilla. The y-axis is nominal duration from 2 to 360-months. Each period of shortage is plotted to show when it began and ended.

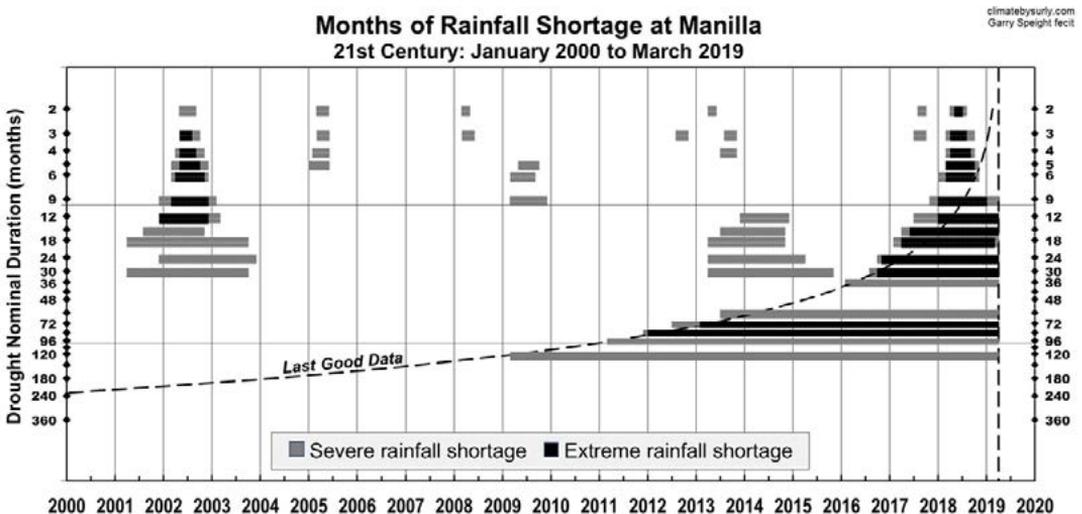


Figure 4. As Figure 3, with data plotted only from 2000 to date.

March 2017–March 2019) to show how rainfall shortages accumulated from month to month. The driest-ever 15-month total (400 mm) occurred in September 2018. The driest-ever 12-month total (271 mm) occurred in February 2019 as dry summer months succeeded very dry winter months.

In the complete history of Manilla's severe and extreme rainfall shortages (Fig. 3), the most striking feature is that decadal and longer extreme rainfall shortages occurred only between 1910 and 1950. This is not commonly known. Similarly, extreme shortages of 84-month (7-year) duration had been restricted to between 1895 and 1945, but we are currently experiencing them again now. This feature makes the drought of 2018 very like the Federation Drought of 1902.

The last 20 years of Manilla's severe and extreme rainfall shortages are shown in Figure 4. After the brief extreme rainfall shortage of 2002, the 15-year period from 2003 to 2017 was an unprecedented time without seasonal (i.e. <12-months) extreme rainfall shortages. Coping with water failure may have faded from memory. In retrospect, we can see that a 7-year (84-month) extreme shortage began in 2012 but could not be detected then (Speight 2019d).

Conclusions

These new graphs give context to the current drought on the North-West Slopes of NSW, revealing extreme rainfall shortages, some being of long duration, and records being broken. They provide food for thought.

Acknowledgments

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Could tropical species have potential in southern Australia? Defining the potential geographical distribution of Rhodes grass in current and future climates

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Abstract: *Grazing systems in southern Australia are currently based on temperate species. Increasing climate variability and changing spatial distribution of rainfall and temperatures are impacting on these grazing systems. Climate change predictions vary, but in general they indicate that in southern Australia temperatures will increase, annual rainfall will either remain the same or decline, and the rainfall distribution will shift from winter to summer dominance. This is predicted to result in a more pronounced summer-autumn feed gap. The integration of tropical pastures into grazing systems could contribute to filling this feed gap. As part of an ongoing study, the potential distributions of a range of tropical pasture species have been modelled under current and future climate scenarios. In this paper we present our preliminary results for Rhodes grass (*Chloris gayana* Kunth). These results suggest that the potential geographical extent of Rhodes grass is large. In the current climate Rhodes grass potentially extends along the eastern side of Australia, with distribution likely to extend into higher altitude environments under future climate projections.*

Key words: CLIMEX, global climate models, CSIRO-MK 3.0, MIROC-H

Introduction

Australia's climate has warmed since 1910 and particularly since 1950 (Climate Change in Australia 2018). Average temperatures are projected to further increase by 2050 potentially ranging from 0.8–1.8°C under a low emissions scenario and from 1.5–2.8°C under a high emissions scenario (Whetton 2011). Long-term average annual rainfall across Australia has increased slightly since 1900. A decline in winter rainfall has been observed for the south-west of Australia since the 1960s, and more recently, in the south-east of Australia, autumn and winter rainfall has been below average since 1990 (Climate Change in Australia 2018). Summer rainfall during the last three decades has increased in some parts of the Northern Grains Region of Australia (Simpson *et al.* 2018). Projections for annual rainfall are that for some regions there will be little change or a decline and that the rainfall distribution will shift from winter to summer dominance (Cullen *et al.* 2009). Therefore, the integration of summer-growing perennials into farming systems could

aid in overcoming the summer-autumn feed gap (Descheemaeker *et al.* 2014). Northern inland NSW was once considered to be a marginal environment for tropical species, but over recent years their persistence, productivity and ability to respond to summer rainfall has made them an important component of the feedbase (Harris *et al.* 2014; Boschma *et al.* 2017).

In 2018 a study commenced to define the potential geographical boundaries of a range of key tropical pasture species and show the extent where these species could persist in Australia in current and under future climate projections. In this paper we report preliminary results for the potential geographical boundary for Rhodes grass (*Chloris gayana* Kunth) in current and future climates as part of this ongoing study.

Methods

The CLIMEX software version 4.0.2 (Hearne Scientific Software Pty Ltd) was used to model the geographical distribution of tropical pasture species (Kriticos *et al.* 2015). This software has been used previously for modelling the distribution for a range of plant species including serrated tussock (*Nassella trichotoma*; Kriticos

et al. 2004), buffel grass (*Cenchrus ciliaris*; Lawson *et al.* 2004) and several bioenergy crops (Barney and DiTomaso 2011). CLIMEX is a species distribution model that uses parameters to define a species potential distribution. A series of temperature, moisture and light parameters describe the species growth response. Outside these settings growth does not occur and negative growth accumulates, which is described by four stress indices and their interactions. The stress indices are set to limit a species' survival in adverse seasonal climatic conditions. Together these growth and stress parameters are used to determine the geographical distribution.

The climatic data set, CliMond CM10_1975H_V1.2 (Kriticos *et al.* 2012), was used to model the climate. This raster dataset at an approximately 18 km² resolution, included the variables required for the CLIMEX software including monthly averages for minimum and maximum temperatures, rainfall and relative humidity. The current climate was based on monthly averages for 1961–1990. Climate projections for 2030 (2016–2045) were generated using the A1B emission scenario, also referred to as SRES scenarios, and two global climate models (GCMs), CSIRO-MK 3.0 and MIROC-H (Kriticos *et al.* 2012).

ArcGIS™ software Version 10.6.1 was used to generate the maps. Occurrence records for each species from Atlas of Living Australia (<https://www.ala.org.au/>) were also mapped to support the parameter fitting. The Ecoclimatic Index (EI) presented on each map integrates the annual growth and the stress indices into a single number between one and 100. This value describes the climatic suitability of a given location to support a permanent population of the species. Values of EI close to zero indicate that the location is not favourable for the long-term survival of the species. Ecoclimatic Index values of 100 are only achievable under constant and ideal conditions comparable to those in a growth cabinet (Kriticos *et al.* 2015). In this paper an EI < 10 was considered unfavourable for a species while an EI > 25 represented a highly favourable climate.

Rhodes grass is native to south and east Africa in areas from 660–2160 m elevation. It has become widely naturalised across a large area of Africa, the tropics and subtropics, and many other continents including Australia (Cook *et al.* 2005). The reported broad adaptation of the species is related to the range in intra-specific variation that exists within the species. Rhodes grasses can be both diploid ($2n = 20$) and tetraploid ($2n = 40$). In general the tetraploids are more 'tropical' and originated from lower latitudes ($\leq 20^\circ$) while the diploids are from more subtropical latitudes ($\geq 20^\circ$) (Loch 1983; Loch *et al.* 2004). The modelled distribution in this study is for diploid rather than tetraploid-types.

In the natural range of Rhodes grass, rainfall varies from 500–1500 mm/yr. It is generally sown in areas with annual rainfall ranging 700–1200 mm, but has been successful in areas with lower rainfall (Cook *et al.* 2005). It is considered to be relatively drought tolerant and able to survive dry periods (six months) (Loch and Harvey 1999; Cook *et al.* 2005). Rhodes grass grows on a wide range of soils from sand to heavy clay, alkaline and saline soils. Soil pH commonly ranges pH 5.5–7.5, but it can grow on soils as low as pH 4.5 and as high as pH 10 (Cook *et al.* 2005). Annual average temperatures for growth range 16.5–>26°C (Cook *et al.* 2005) and 17–22°C (Russell and Webb 1976). Optimal growth has been reported to occur at 30/26–40/29°C and 34/29°C day/night temperatures (Ivory 1976; Ivory and Whiteman 1978). Extreme temperatures for growth are 5 and 50°C. Some cultivars can survive sub-zero temperatures, but are killed by -10°C (Loch and Harvey 1999; Cook *et al.* 2005).

Results

Maps for the potential distribution of Rhodes grass in the current and future climates are presented in Figures 1 and 2. The species distribution in the current climate shows a wide adaptation from northern Australia, along the length of eastern Australia, around to South Australia. Rhodes grass is also suitable for areas from the Northern Agricultural Region in Western Australia to the south coast and east

of Esperance to Cape Arid National Park (Fig. 1). In southern inland NSW, Rhodes grass has potential west in longitude ranges 145–147°E, for example to Condobolin and Wagga Wagga (Fig. 1).

The potential distribution under two GCMs was modelled with results from one model presented here (Fig. 2). Using the MIROC-H map, the area suitable for Rhodes grass across northern Australia is predicted to decline. The area in southern Australia is predicted to increase, especially in the cooler, higher altitude areas such as the NSW Northern Tablelands, and from the Central Tablelands in NSW south to the southern end of the Dividing Range in Victoria, also Tasmania (Fig. 2).

Discussion

Initial results from this study show that the potential distribution of Rhodes grass extends across south eastern Australia and south

Western Australia. This wide adaptation supports reported literature. Distribution is currently restricted in higher elevation areas due to cold stress. Previous field evaluation and modelling studies conducted in a range of different locations across south eastern Australia have demonstrated the potential of tropical pastures as an alternative feed source (Bell *et al.* 2013; Descheemaeker *et al.* 2014). Our preliminary results are in agreement with those locations in terms of potential suitability. This map, and those of other key species modelled in this project including digit grass (*Digitaria eriantha* Steud.) were used to identify areas in marginal environments, such as southern NSW and tablelands regions, where widely adapted species could potentially be grown. Tropical grass evaluation experiments have commenced at a number of locations, including two sites in marginal areas. As part of this ongoing project relevant field data will be collected from these species evaluations and other experiments.

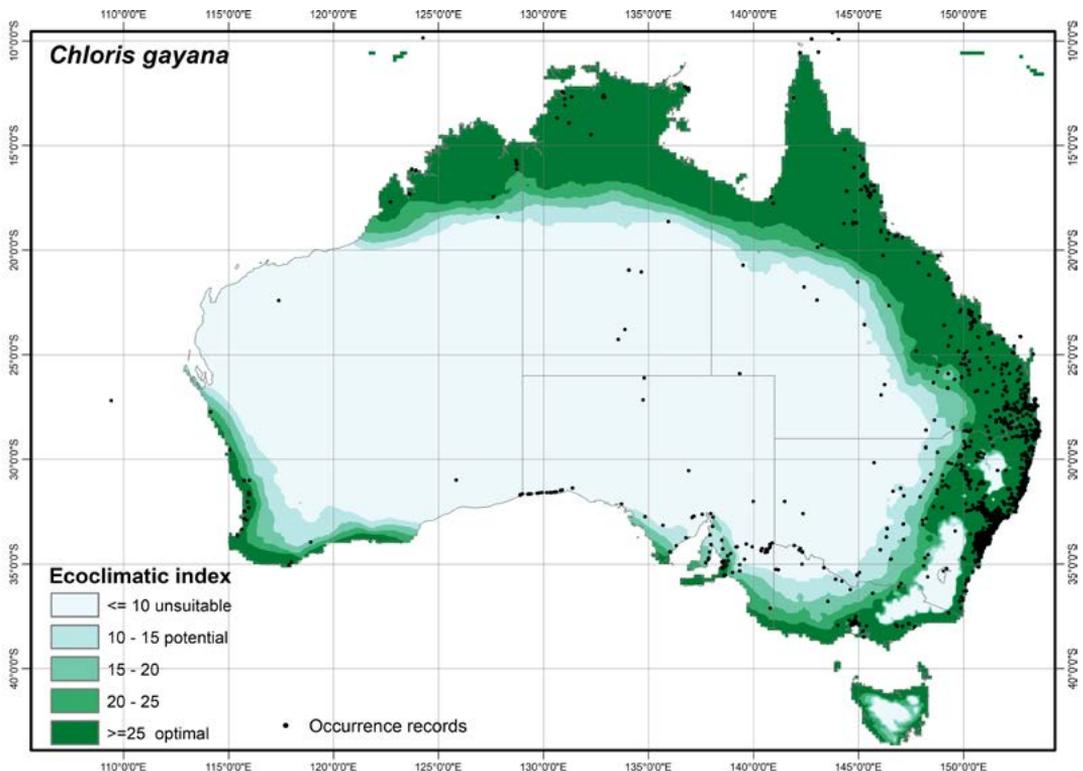


Figure 1. Potential distribution of Rhodes grass under the current climate. Dots represent *C. gayana* occurrence records from Atlas of Living Australia.

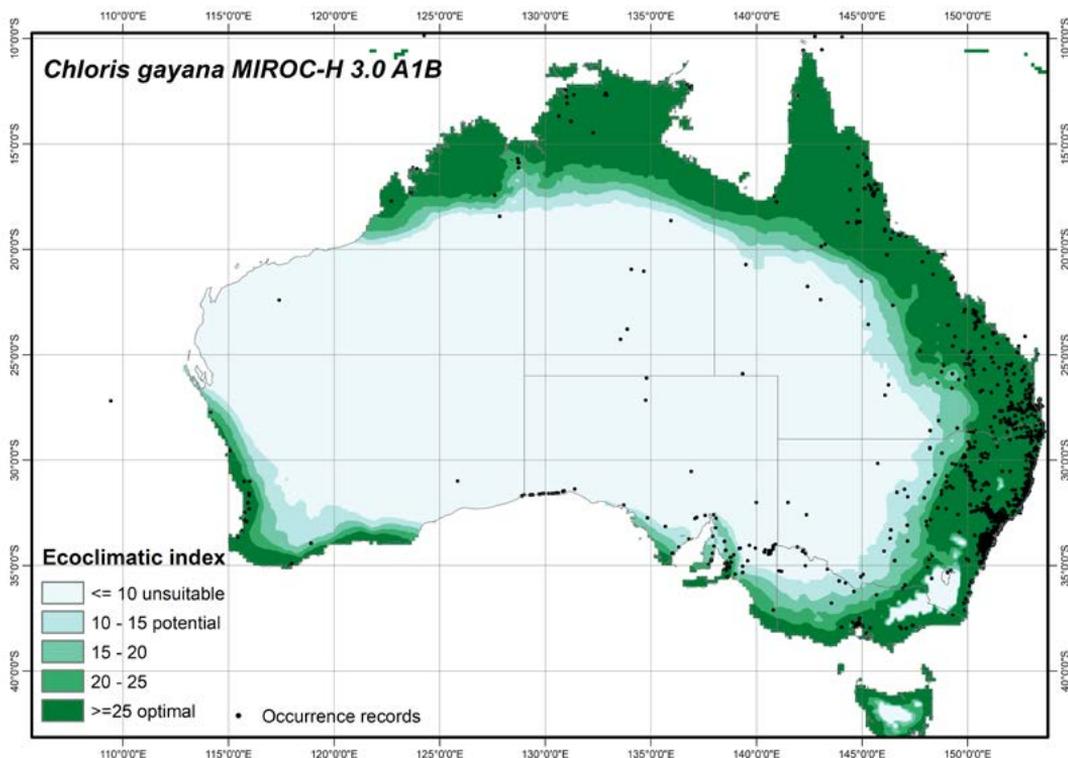


Figure 2. Projected potential distribution of Rhodes for 2030 using the MIROC-H 3.0 A1B climate projection. Dots represent *C. gayana* occurrence records from Atlas of Living Australia.

These data will be used to refine the model parameters and validate the distribution maps.

The preliminary species distributions modelled under a future climate suggest that the area suitable for Rhodes grass will increase especially in the higher elevation areas (Fig. 2). A comprehensive comparison of current and future distribution of each species will be conducted when the maps are finalised in the final year of the project.

Conclusions

Rhodes grass has potential to be a valuable pasture species in southern Australia – in both our current and projected climate. While this paper focussed on Rhodes grass, this is just one of a range of tropical pasture species that have been modelled. This is the first study to model the potential distribution under the current and a future climate for these key tropical pasture species for Australia. Spatial mapping using models such as CLIMEX can be effective to

enable predictions for locations and regions where experimental data are sparse.

Acknowledgments

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Harnessing producers' tropical grass experience to support potential new producers

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Abstract: *Climate projections together with farm systems modelling for southern Australia suggest conditions will reduce the length of the growing season of temperate species. This will result in an extended summer-autumn feed gap. Tropical species are a potential option to fill this gap. Research has commenced to identify the key enablers and constraints to trialling and 'successful' management of tropical grass based pastures. The approach is to conduct a series of workshops, initially with producers who have experience establishing and managing tropical grass pastures followed by a broader survey of experienced and inexperienced producers, and then semi-structured interviews with selected producers. This paper summarises the key findings from the first producer workshop held at Purllewaugh, NSW. Producers identified three critical success factors in establishing and managing tropical grasses: implementing a two to three year pre-sowing weed control program to reduce the summer grass seed bank; at sowing, ensuring that seed is sown shallow; and maintaining soil fertility with strategic applications of phosphorus, sulphur and nitrogen. Producers stressed the importance of service providers and producer networks in supporting them in their efforts to trial and manage tropical grasses. The experiential producer knowledge gathered in this research component will contribute to an extension package to support producers with an interest in trialling tropical grasses in the more southern areas of Australia.*

Key words: weeds, germination, fertiliser, practice, extension

Introduction

Across the slopes and plains of northern NSW tropical perennial grasses have been found to be highly productive, responsive to summer rainfall and nitrogen, and are able to rapidly recover after dry conditions. These grasses have become an important component of grazing systems in this geographic zone, largely replacing sown temperate grass pastures (Harris *et al.* 2014; Boschma *et al.* 2015, 2017; Murphy *et al.* 2019).

Australia's climate has warmed 1°C since 1910 with average temperatures in south-eastern Australia projected to increase further (CSIRO and BoM 2015, 2018). Furthermore, the rainfall in this region is projected to decline and the distribution to shift to a summer dominant pattern (CSIRO and BoM 2015, 2018). Farming systems modelling has demonstrated that under these projected climate conditions the growing season for temperate forage species will be reduced and, as a consequence, the summer-

autumn feed gap will be extended (Cullen *et al.* 2009; Moore and Ghahramani 2013). Under this scenario, integrating productive tropical species into the feedbase of southern Australian farming systems has the potential to reduce the risk of this projected feed gap.

A multi-disciplinary research program, "Increasing livestock production by integrating tropical pastures into farming systems" commenced in 2018. This program has been designed to increase the productivity of red meat production in southern Australia under a changing climate by introducing tropical pastures. The aim of one research component is to identify the key enablers and constraints to trialling and 'successful' management of tropical grass based pastures. The information will be used to inform the development of an extension package to support those producers in southern Australia intending to include tropical grass pastures in their feedbase.

In this component we are drawing upon the prior experience of those producers in northern and central NSW who have successfully

established and managed tropical grass based pastures. We are also testing the proposition with those producers in central and southern NSW that to date have not trialled or may have trialled a small area of tropical grasses. We are also capturing the knowledge of key service providers and NSW Department of Primary Industries researchers.

The research approach is to use a mix of qualitative and quantitative methods. It is proposed to conduct a series of five workshops with producers and some selected key informants (qualitative), a broader survey of both experienced and inexperienced producers (quantitative) and semi-structured interviews with selected producers (qualitative).

This paper describes the workshop approach and presents some findings from a recent workshop held at Purlawaugh in northern NSW. The participants in this workshop were producers with experience in successfully establishing and managing tropical pastures.

Workshop approach

Eleven producers were purposefully selected to participate in the workshop to obtain a diversity of experiences. Within the group, producers ran different enterprises on properties across different soil types and climatic conditions from Boggabri in the north, to Gilgandra and Coolah in the south. They also had different years of experience in establishing and managing tropical grasses. The producers were divided into two groups to provide a small group setting with near neighbours allocated to a different group. This provided the opportunity for each producer to describe their experiences, allowed time for clarification and discussion, and maximised data collection.

Within each group, producers were asked a series of key questions to draw out their knowledge and experience with tropical grass pastures. These questions included their first experience establishing tropical pastures, and their current establishment practice and grazing management. Producers also described the benefits and challenges with establishing and managing tropical grasses. Additionally, each

producer listed the three most important practical lessons they would pass on to producers considering including tropical grasses in their farming system.

Key findings

Although these producers had trialled and successfully managed tropical grasses, there was considerable diversity in their experience with establishment and management of these grasses on their property. Producer enterprises included growing out steers for feedlots, exporting live steers, breeders and traders, Merino sheep for wool and prime lambs.

Producers recognised the economic value of tropical grass pastures to their farm business in providing a long-term and low-cost feed base of high quality. They had been able to achieve a 'big' lift in productivity as a result of an increase in carrying capacity and/or improved wool quality. Other benefits identified included:

- Ability to control difficult weeds including spiny burr grass (*Cenchrus incertus*) and blue heliotrope (*Heliotropium amplexicaule*);
- Ability to persist, 'Sown once and you don't have to worry about it again' (producer);
- Drought tolerance, 'A resilient pasture that can bounce back after drought' (producer);
- Highly responsive to late spring, summer and early/mid-autumn rainfall events;
- Ability to provide erosion control; and
- Ability to improve soil health with their ability to root at depth.

Producers also recognised there were constraints, most notably, the high cost in establishing the pasture and issues relating to the commercial nature of seed supply. The main constraints identified included limited or inconsistent availability of seed, low germination and purity of seed, and the cost of coated seed.

Producers believed the pre-sowing 'clean-up' phase was critical to reduce the weed seed bank, especially of summer grass weeds. 'Impeccable weed control over three to four years prior to attempting establishment' (producer) is

essential to reduce the potential for grass weeds to emerge during establishment. Other critical establishment factors identified included:

- Matching species/cultivar to soil type;
- Checking germination and purity of the seed, *'Testing germination is important on all seed produced or bought'* (producer);
- Sowing in spring ahead of rain if subsoil moisture is available and ground temperature is between 16–18°C;
- Ensuring seed is sown shallow, *'Fine when [seed is] dropped on ground and press wheel following'* (producer);
- Soil test and correct for phosphorus, sulphur and nitrogen deficiency; and
- Be patient, especially in difficult years, *'Don't be concerned how establishment...looks for the first 12–24 months...often takes a few years to thicken up'* (producer).

To maintain a productive high quality pasture, producers believed it was important to keep the pasture 'short and green' by using a high stocking rate where possible. Key grazing management factors include:

- Duration: *'Eat a third, trample a third, leave a third'* (producer);
- Intensity: *'Don't overstock or overgraze'* (producer); and
- Interval: *'Many grasses are most valuable before getting long and rank'* (producer).

Other critical pasture management factors identified included:

- Allowing to flower and set seed prior to first grazing for persistence;
- Time to first grazing is highly variable, *'Could be three months or seven months depends on when the rain falls'* (producer);
- Managing excessive pasture growth by leaving as a standing haystack or slashing; and
- Applying phosphorus and sulphur in autumn and nitrogen in spring if required, *'The more*

you feed your grasses, the better they will feed your stock. That is, healthier grasses have far higher nutritional value' (producer);

Producers identified what they believed were the three most important practices that new producers should implement to achieve 'success'. These practices were to establish a weed-free seedbed, sow seed shallow, and maintain soil fertility.

Extension support was viewed by producers as crucial to their trialling and subsequent successful adoption of tropical grasses into their feedbase. Many producers emphasised the role of networks and respected individuals to support their efforts in trialling tropical grasses. As one producer explained *'Last 20 years swapping ideas with George A and agency staff. Importance of field days. Bob F was a huge influence. Networking. Getting together sharing information [about] what works and what doesn't work'*.

Conclusion

This workshop revealed how these selected producers have trialled, successfully managed and integrated tropical grasses into their feedbase. It also revealed that their initial testing was conducted within a framework which provided quality information and strong social networks, with respected producers promoting the agronomic and productivity benefits of these pastures. Even though establishment costs are high and the establishment phase can be prolonged, once the producer participants realised the economic gain that could be achieved they willingly expanded the area they had initially sown to tropical grasses. The experiential producer knowledge gathered in this research component will contribute to an information framework to support producers (and their service providers) with an interest in trialling grasses in the more southern areas of Australia.

Acknowledgments

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Evaluating seedling emergence, establishment and survival of tropical perennial grasses in Central West NSW

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Abstract: Seedling emergence, establishment and survival of five tropical grass species were investigated in Central West NSW. Seedling emergence was evaluated at six sowing times and was highest in spring and lowest in late autumn/early winter. Establishment and survival were assessed over three sowing dates and under irrigated and non-irrigated conditions. Like emergence, establishment was highest in spring. Irrigated plots showed higher establishment density than non-irrigated plots. The observed established plant density for all species over the three sowing times was in most cases greater than the desirable benchmark of 4–9 plants/m².

Key words: *Panicum coloratum*, *Cenchrus ciliaris*, *Chloris gayana*, *Digitaria eriantha*, *Megathyrsus maximus*

Introduction

Central West NSW has a low annual rainfall (400–600 mm) with a near even distribution across all seasons. During summer, temperatures are high and during winter, frosts are common. Increasing climate variability and changing weather patterns are projected to have a negative impact on feed availability and livestock production (Cullen *et al.* 2009). Utilising a range of pasture species including tropical perennial grasses is an option to fill the feed gap in this region. Tropical perennial grasses are able to produce large amounts of high quality feed in response to variable rainfall. However, the risk of establishment failure of tropical perennial grasses was identified as a major limitation to their widespread uptake in south-eastern Australia (Boschma *et al.* 2018). While some producers have successfully established tropical grass pastures in Central West NSW, the moisture and temperature requirements of the major tropical perennial grass species requires further investigation to improve the reliability of establishment and persistence. This information will be used to provide guidelines around optimum sowing times for tropical perennial grass species in Central West NSW.

Methods

Seedling emergence, establishment and survival of five tropical grasses were studied in two experiments. The studies were conducted at the

Trangie Agricultural Research Centre (31°59'45" S, 147°56'18" E, elevation 214 m above sea level) on a red Chromosol soil with pH_{Ca} 5.1 (0–10 cm) and about 20 frost days per annum.

Experiment 1

Seedling emergence was determined at six sowing times. The sowing times were 17 October 2016, 5 December 2016, 17 February 2017, 31 March 2017, 15 May 2017 and 26 June 2017. Each sowing time was a randomised complete block design with three replicates. The grasses were *Panicum coloratum* (Bambatsi panic) cv. Bambatsi; *Cenchrus ciliaris* (buffel grass) cv. Gayndah; *Chloris gayana* (Rhodes grass) cv. Katambora; *Digitaria eriantha* (digit grass) cv. Premier; and *Megathyrsus maximus* (panic grass) cv. Gatton. Emergence was recorded every three days for two weeks during which seed beds were kept moist at all times.

Experiment 2

An experiment to study establishment and survival was conducted in spring (October 2016), early-summer (January 2017) and late-summer (February 2017) under irrigated and non-irrigated conditions. Irrigated plots were watered fortnightly to simulate average monthly rainfall (23–39 mm). Seeds were sown by hand broadcast onto a prepared seedbed in plots (4 × 4 m) arranged in a randomised complete block design with three replicates. Grass seedlings were counted using two 0.5 × 0.5 m quadrats 8-weeks after sowing. Five plants from each plot were marked at the end of May 2017 and their winter survival was assessed when growth recommenced in spring.

Total number of seedling emergence and number of plants established data were analysed using linear mixed models of the form Count ~ Species + random(Rep) where: Count = number of seedlings emerged and number of plants established; species = grass species.

Results and Discussion

Across all species emergence was highest in October (34%) and lowest in June (0%). Bambatsi panic, Rhodes grass and buffel grass had significantly higher emergence than panic grass and digit grass in October and December while Rhodes grass had significantly higher emergence than all other species in March and May (Table 1). Since soil was kept moist throughout the 2-week period, any differences were likely to be due to soil temperature. The average weekly temperature during October, November and February were within the range described as suitable for tropical grass germination (Lodge and Harden 2009). However, there were three consecutive days with maximum temperatures over 44°C just after sowing in February that may have affected germination. In this experiment emergence of Rhodes grass seedlings was higher in the cooler autumn period than for all the

other species suggesting that there may be a wider sowing 'window' for this species.

In Experiment 2, irrigated plots seemed to have higher establishment density than the non-irrigated plots for all species except panic grass. There were no significant differences between grasses sown without irrigation in early-summer with plant densities ranging 6–25 plants/m² (Table 2). The observed differences in establishment between irrigated and non-irrigated plots were probably a result of a failure to germinate and/or seedling death post germination due to moisture stress. The observed number of established plants across all species and sowing times is considered greater than the desirable plant population (Moore *et al.* 2013; Boschma *et al.* 2019).

All of the established seedlings from the spring sown treatment survived the extended hot dry weather experienced in January and February, but growth was slow. However, the plants responded well to over 80 mm rainfall in mid-March. Over 90% of established seedlings from the early-summer sown grasses also survived, however, seedlings remained small and had a lower response to rainfall than those sown in spring.

Table 1. Field emergence percentage (%) of the five the tropical grasses. Values within a column followed by different letters are significantly different ($P = 0.05$).

Species	Emergence (%)					
	October	December	February	March	May	June
Bambatsi panic	50 b	44 c	12 a	12 b	2 a	0
Buffel grass	42 b	12 ab	18 a	6 ab	6 a	0
Rhodes grass	48 b	30 bc	6 a	26 c	26 b	0
Panic grass	16 a	4 a	8 a	0 a	2 a	0
Digit grass	14 a	2 a	0 a	2 a	2 a	0

Table 2. Established plant densities (plants/m²) of tropical grasses with and without irrigation. Values within a column followed by different letters are significantly different ($P = 0.05$).

Species	Sowing rate (kg/ha)	Spring sowing		Early-summer sowing		Late-summer sowing	
		Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated
Bambatsi panic	8	29 b	40 c	19 a	30 c	12 b	29 c
Buffel grass	12	5 a	14 a	6 a	14 ba	2 a	5 a
Rhodes grass	8	14 a	25 a	15 a	20 ba	7 b	13 b
Panic grass	12	28 b	29 a	25 a	22 b	14 b	18 b
Digit grass	12	11 a	22 a	11 a	11 a	11 b	15 b
Mean		17.4	26.0	15.2	19.4	9.2	16.0

Conclusions

Experiments in Central West NSW sought to study germination and emergence of a range of tropical perennial grasses. Once established the seedling growth and survival of the grass species were monitored. All species performed well both with and without irrigation, especially when sown in spring. These tropical perennial grass species could prove to be a viable resource for the region. However, more evaluation of their performance is required before firm recommendations can be made. Irrigation is unlikely to be a practical option for commercial enterprises in the region, however, including irrigation treatment in this study showed the potential of tropical grasses in seasons with rainfall that is near the long term average.

Acknowledgments

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Differences in soil water dynamics and herbage production between temperate and tropical pasture species for Central West NSW

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Abstract: *Tropical species have the potential to improve pasture productivity, especially in a changing climate, however little is known of their growth, productivity and persistence in Central West New South Wales. This study compared soil water use, rooting depth, herbage production and water use efficiency (WUE) for peak standing dry matter of six temperate and tropical pasture species established in pure swards. Perennial grass and legume species accessed soil water to depths >1.2 m within 12 months of establishment, while temperate annual legumes generally accessed water to approximately 1 m. Desmanthus (Desmanthus virgatus) especially cv. JCU2, barrel medic (Medicago truncatula) and woolly pod vetch (Vicia villosa) were productive in terms of herbage mass and WUE.*

Key words: extractable soil water, lucerne, *Medicago sativa*, digit grass, *Digitaria eriantha*

Introduction

The mixed farming region of Central West New South Wales (NSW) has medium rainfall (400–600 mm) with aseasonal distribution, but winter rainfall is generally more effective. Sown pastures in this area have traditionally consisted of temperate annual and perennial species, and both *Medicago truncatula* (barrel medic) and *M. sativa* (lucerne) are commonly sown. Over the last two decades there has been development of a range of new temperate annual legumes and cultivars that may be useful in this region. Recently, local producer interest in, and adoption of tropical perennial grasses has increased as these grasses have become widely sown in northern NSW due to their persistence, and ability to respond to summer rainfall and produce large quantities of forage (e.g. Boschma *et al.* 2015). The latest research in northern NSW is investigating the potential of tropical legumes (e.g. *Desmanthus* spp.). These tropical species may benefit pasture productivity, especially in a changing climate, which is predicted to become even more variable (e.g. Howden *et al.* 2008; Cullen *et al.* 2009), however, little is known of their growth, productivity and persistence in Central West NSW.

Information on seasonal soil water dynamics, rooting depths, peak growth periods and water use efficiency (WUE) are fundamental

traits to identify diverse forage options and underpin recommendations to producers. A field experiment was conducted to compare the relative performance of pure swards of a number of temperate and tropical pasture species. This paper describes several data sets including herbage production, soil water dynamics, plant rooting depth, water use and WUE.

Methods

A field experiment was conducted on a brown Chromosol soil (Isbell 1996) at the Trangie Agricultural Research Centre (31°59'45"S, 147°56'18"E; elevation 220 m) from spring 2014 to spring 2017. Mean annual rainfall at the site is 493 mm with no distinct seasonality.

The treatments consisted of two cultivars of the tropical legume desmanthus (*D. virgatus*) cvv. JCU2 (www.progardes.com.au) and Marc, three temperate legumes (lucerne cv. Venus, woolly pod vetch (*Vicia villosa*) cv. Haymaker and barrel medic cv. Caliph), tropical digit grass (*Digitaria eriantha*) cv. Premier and a control (bare ground) established in a modified randomised complete block design with three replications (total of 21 plots). The legumes were established by transplanting 6-week old seedlings as spaced plants (9 plants/m²) into 4 × 4 m plots; tropical legumes were planted in spring 2014 and temperate legumes in autumn 2015. Digit grass had persisted in an established plot sown 16 years prior and was located approximately 100 m from the legume treatments. The legume

plots were irrigated as required to ensure establishment of the experiment.

Standing herbage mass (kg DM/ha) in each plot was assessed at approximately 6-week intervals from June 2015 until April 2017 using a modified Ranked Set Sampling method of McIntyre (1952) described by El-Shaarawi and Esterby (1999). In each plot, 12 quadrats (0.5 × 0.5 m) were surveyed; eight of these quadrats were randomly located within 0.5 m of the perimeter of each plot and four were permanently marked in close proximity to a neutron probe access tube in the centre of each plot. Herbage mass in each quadrat was visually scored using a continuous scale (0–5). Plot herbage mass (kg DM/ha) was determined from one of the random quadrats, that represented the median (score = 3), which was cut to 10 mm, and dried at 80°C for 48 hours. Plant dry matter was not harvested or

removed from the plots following each herbage mass assessment.

Soil water content was estimated at 3-week intervals using a neutron moisture meter (CPN 503DR Hydroprobe; Boart Longyear Co., Martinez, CA, USA) calibrated for local conditions, in an aluminium access tube installed to 1.2 m depth in the centre of each plot. Maximum extractable soil water (MEW, mm) by the treatments was calculated from the greatest decline in stored soil water within the growing season of each species. The growing season was defined as a period when a species commenced regrowth until peak standing herbage mass was achieved. The duration of the growth period varied for each species and year (Table 1). Growth periods for lucerne were shorter and occurred at varying times of the year according to the availability of soil water. Plant rooting

Table 1. Length of the growing season (duration, weeks) and the maximum extractable soil water (MEW, mm), plant root depth (m), rainfall (mm), total water used (mm), herbage mass production (kg DM/ha) and water use efficiency (WUE, kg/DM/ha/mm) for each defined season for the treatments during the three experimental years.

Treatment	Duration (weeks)	MEW (mm)	Root depth (m)	Rainfall (mm)	Total water used (mm)	Herbage mass (kg DM/ha)	WUE (kg DM/ha/mm)
<i>2014–15</i>							
Digit grass	–	–	–	–	–	–	–
Desmanthus cv. JCU2	32	61	>1.20	362	355	1861	5.2
Desmanthus cv. Marc	32	69	>1.20	362	354	2022	5.7
Lucerne	27	–	–	251	293	1271	4.3
Barrel medic	23	–	–	174	225	4279	19.0
Woolly pod vetch	22	–	–	174	224	4040	18.0
<i>l.s.d.</i> , <i>P</i> = 0.05	–	4.6	–	–	17.7	742.0	2.96
<i>2015–16</i>							
Digit grass	31	89	>1.20	283	366	1694	4.6
Desmanthus cv. JCU2	29	71	>1.20	283	336	4356	13.0
Desmanthus cv. Marc	29	74	>1.20	283	340	3093	9.1
Lucerne	11	70	>1.20	250	197	1572	8.0
Barrel medic	20	70	1.15	416	397	3909	9.8
Woolly pod vetch	20	59	0.92	416	412	3655	8.9
<i>l.s.d.</i> , <i>P</i> = 0.05	–	17.4	–	–	16.1	1208.6	3.46
<i>2016–17</i>							
Digit grass	27	137	>1.20	297	358	1878	5.2
Desmanthus cv. JCU2	27	85	>1.20	297	353	10622	30.1
Desmanthus cv. Marc	27	86	>1.20	297	358	3565	10.0
Lucerne	6	84	>1.20	65	119	3649	30.7
Barrel medic	–	53	0.92	–	–	–	–
Woolly pod vetch	–	52	0.85	–	–	–	–
<i>l.s.d.</i> , <i>P</i> = 0.05	–	8.4	–	–	22.0	3003.4	9.82

depth was determined from changes in profile soil water content (Murphy and Lodge 2006). Peak herbage mass was divided by total water used (change in stored soil water plus rainfall; automatic weather station located 1 km from experimental site) to determine WUE (kg DM/ha/mm) for each treatment and growing season.

Results

Monthly rainfall during the experimental period was highly variable, with rainfall over the warmer months and in winter and spring of 2016 higher than long-term median. Highest mean maximum and lowest mean minimum daily temperatures were recorded in February (34.9–37.2°C, cf. 32.4°C LTA) and July (2.9–4.3°C, cf. 3.2°C LTA), respectively. Total frost occurrence ($\leq 2^\circ\text{C}$) was 38- and 35-d in 2015 and 2016 (cf. 37.7-d LTA), respectively, which frosted all tropical species.

Treatment values of MEW significantly differed ($P < 0.05$) in each year of the experiment. During the 2014–15 growing season desmanthus cv. Marc (69 mm) extracted more water than cv. JCU2 (61 mm) (Table 1). During the 2015–16 and 2016–17 growing season, digit grass extracted the most water and the annual legumes the least (Table 1). The other perennial species (i.e. desmanthus and lucerne) were intermediate. Plant rooting depth of the perennial species was always >1.2 m, while rooting depth for the annual legumes was <1.0 m, with exception of barrel medic in 2016 which had a rooting depth of 1.15 m (Table 1).

Total water use by treatments differed ($P < 0.05$) in each year of the experiment. In two of the three years, lucerne had the lowest total water use (197 and 119 mm, 2015–16 and 2016–17, respectively) due to its short growing season compared to the other species (Table 1). During the 2014–15 growing season the perennial species used more water than the annual legumes ($P < 0.05$), but in 2015–16 the reverse occurred due to double the amount of rainfall that occurred during the growing season of the annual legumes (416 cf. 174 mm).

Among the tropical species, desmanthus cv. JCU2 had greater herbage mass and digit grass

the least. The productivity of the desmanthus cultivars increased with each year of the experiment and was associated with recruitment (I. Toole, pers. comm.). Within the temperate species, the annual legumes were more productive than lucerne (Table 1) resulting in lucerne having significantly lower WUE; c. 25% of that for the annual legumes during the 2014–15 growing season. Data values for the 2015–16 growing season were less straight forward. The annual legumes had the highest total water use, but their herbage masses were intermediate to the desmanthus cultivars, resulting in WUE for the annual legumes and desmanthus cv. Marc being similar, but significantly less than desmanthus cv. JCU2 (Table 1). Digit grass had low herbage mass, resulting in the lowest WUE values (Table 1).

Discussion

The perennial species accessed soil water below 1.2 m, the depth of the access tubes, while the temperate annual species extracted water to a maximum depth of 1.15 m. The values for the perennial species broadly align with those from a range of studies conducted at Tamworth in northern NSW; vis. digit grass 1.0–1.3 m (Murphy *et al.* 2019), lucerne 1.2–1.6 m (Murphy *et al.* 2017, 2019) and desmanthus 1.4–1.8 m (Murphy *et al.* 2018). The values for the annual legumes were shallower than that found at Tamworth for subterranean clover (*Trifolium subterraneum*); vis. rooting depth of 1.2–1.4 m (S. Murphy, unpub. data). The ability of the perennial species to extract the soil water to depths >1.2 m indicates the importance of deep profile soil water for these species in this environment. Unfortunately, the total amount of soil water extracted was not quantified as the access tubes were too shallow (1.2 m).

No previous studies have examined the potential productivity of desmanthus in Central West NSW (medium rainfall environment). Herbage production of both cultivars of desmanthus increased each year that the study was conducted with cv. JCU2 producing more herbage with greater WUE than cv. Marc. Cultivar JCU2, one of a composite of five cultivars blended and sold as cv. Progardes (<https://www.progardes.com.au>),

also performed well on a brown Chromosol soil in northern NSW (Boschma *et al.* 2018a). Both desmanthus cultivars were selected for central and northern Queensland where rainfall is more summer dominant and frosts are fewer and less severe.

Both barrel medic and woolly pod vetch were productive legumes in this study, producing >3500 kg DM/ha each growing season in these non-defoliated stands. Both of these legumes also showed superior productivity and persistence compared to 14 other temperate annual legume species and cultivars in a co-located study (Boschma *et al.* 2018b). Both legumes were evaluated throughout the Central West decades ago and reported to have potential (e.g. Brownlee 1985; Meakins 1972), although only barrel medic is still widely sown. Lucerne productivity, both herbage mass and WUE, was underestimated in this study as it needs to be grazed to continue growth. In a five year study conducted at Trangie, lucerne cv. Trifecta grazed by sheep produced up to 4.9 t DM/ha per year (Bowman *et al.* 2002).

Digit grass reported only modest herbage production in this study; far below that reported in other studies. This is likely due to the stand not being defoliated and the growing season limited to 27–32 weeks as opposed to up to eight months (pending rainfall) and the fertility regime prior to the experiment. The digit grass stand was about 16 years old at the commencement of the experiment and had not received fertiliser for some years. Subsequently, digit grass showed consistently low rates of WUE (<5.5 kg DM/ha/mm); less than those reported for fertilised stands in northern NSW (33–34 kg DM/ha/mm [Murphy *et al.* 2019] and 6.5–11.4 kg DM/ha/mm [Boschma *et al.* 2019]).

This experiment has shown that in this medium rainfall environment the perennial species tested accessed soil water to depths of up to 1.2 m within 12 months of establishment, while temperate annual legumes generally accessed water down to about 1 m. Desmanthus was productive, especially cv. JCU 2, and increased productivity as the stand thickened. Similarly, barrel medic and woolly pod vetch were equally productive in these ungrazed stands.

Acknowledgments

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What is the optimal ratio of digit grass and lucerne in a mixed pasture?

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Abstract: *Tropical perennial grass and legume pasture mixes are productive forage options in northern inland NSW. Optimal sward density (plants/m²) to efficiently use resources is known to vary with annual rainfall. For the northern inland NSW region, this density for digit grass (*Digitaria eriantha*) ranges between 4 and 9 plants/m². Lucerne (*Medicago sativa*) is a favoured companion legume for digit grass, but it can dominate production. Therefore, the aim of this study is to determine the optimal ratio of digit grass and lucerne in a mixed pasture. In spring 2018 a replacement series field experiment, with five treatments comprising different proportions of digit grass and lucerne sown at 8 plants/m², was established at the Tamworth Agricultural Institute. Measures of total water use, total herbage production and proportion legume have begun. Early assessments through the hot and dry summer of 2018–19 have indicated that digit grass out-performed lucerne. Data collected over the period 2018–19 to 2021–22 will be used to determine the optimal ratio of grass to legume in this context.*

Key words: water use efficiency, stored soil water

Introduction

Tropical perennial grass pastures have many desirable characteristics as forage in northern inland NSW as they are highly productive, long-lived, and drought tolerant (Boschma *et al.* 2014). Digit grass (*Digitaria eriantha* cv. Premier) is suited to many soils in this region and it has been widely sown as either pure swards or the dominant species in mixes. Recent studies identified that the sward density for optimal production and hydrological performance of a digit grass pasture is 4–9 plants/m² (Boschma *et al.* 2019). All highly productive grass pastures require adequate nutrients, particularly nitrogen, to maintain growth (Havilah *et al.* 2006), and grass-legume mixtures are therefore desirable.

Lucerne (*Medicago sativa*) is well suited to this region and earlier studies have investigated the potential of digit grass-lucerne pasture mixes (e.g. Tow 1993). Following on from those studies, a more recent study (Murphy *et al.* 2018) investigated the effects of spatial arrangement on digit grass-lucerne mixes by varying sowing-row configuration (1:1, 3:3 or 6:6 alternating sowing rows of each species) while each species occupied 50% of the overall area sown. Almost regardless of the configuration, lucerne dominated total herbage mass contributing 69–73% of plant dry matter over the four years of

the study (Murphy *et al.* 2018). This occurred because lucerne established at a high density and was highly competitive at using stored soil water in spring before the digit grass commenced its growth, and the extent of this competition may have been due to the plant density of lucerne. A more even herbage distribution between the species may have been achieved with a lower plant density of lucerne. Therefore, the challenge is to identify the optimal ratio of digit grass-lucerne to prevent lucerne from out-competing digit grass for stored soil water, yet maintain overall production.

The replacement series experimental technique (de Wit 1960), involving two species sown in differing proportions, is an effective method of studying plant interactions at a constant total density (Boschma *et al.* 2010). The study described here uses five ratios of digit grass-lucerne in replacement series to identify the ratio that provides optimal dry matter production and efficient use of soil water. The study commenced in spring 2018 and will end in autumn 2022. This paper presents findings from the first summer after commencing the experiment.

Methods

Site and spaced plants

The experiment was initiated in spring 2018 at Tamworth Agricultural Institute (31°08'43"S, 150°58'06"E) on a brown Vertosol (Isbell

1996). In the two years prior to initiating the experiment, the site was planted to cover crops of forage oat (*Avena sativa*) and then field pea (*Pisum sativum*) during winter and fallowed during summer to accumulate stored soil water and control weeds.

A replacement series study (de Wit 1960) was designed with five treatments (Table 1). All treatments were established at 8 plants/m², but with differing ratios of digit grass and lucerne (vis. 8-0, 6-2, 4-4, 2-6, 0-8 plants/m² of digit grass and lucerne, respectively). Each treatment plot, 4 × 4 m, contained 128 plants and was replicated three times in a randomised complete block design. Seedlings of digit grass (cv. Premier) and lucerne (cv. Venus) were grown in a glasshouse as individual tubestock for 4–8 weeks before being transplanted into plots on 13–15 November 2018 in the defined proportions (Fig. 1a). Plots were irrigated on three occasions between 15 and 17 November (totalling 80 mm) to minimise transplant shock. Any sick or dead plants were replaced over the first four weeks. Total rainfall recorded at the Institute’s weather station (WaterNSW real-time data; weather station #419113) from transplanting to 1 February 2019 was 156 mm.

Soil water content and herbage mass

An aluminium access tube was installed in the centre of each plot to a depth of 1.9 m to enable volumetric soil water content to be estimated using a neutron moisture meter calibrated

for local soil conditions as per Boschma *et al.* (2019). Soil water content was estimated after transplanting (27 November 2018) and then at 3-week intervals by taking neutron counts over a 16-s period at 0.2 m intervals down the soil profile representing soil layers 0.2 m thick to 1.9 m (i.e. 0.1–0.3, 0.3–0.5, ..., 1.7–1.9 m). Total stored soil water for the profile (SSW, mm, 0–1.9 m) was calculated by summing values for each layer.

Herbage mass was assessed at 6- and then 9-weeks after transplanting by collecting all herbage above a height of 50 mm in a 1 × 1 m quadrat rotated through two of four locations adjacent to the access tube (e.g. Boschma *et al.* 2019). The herbage of digit grass and lucerne was cut separately and then oven dried at 80°C for 48 hr and plant dry matter (kg DM/ha) determined. After each assessment plots were mown to 50 mm height and the herbage removed.

Changes in soil water content and total herbage production were determined for the period 27 November 2018–1 February 2019. Water use efficiency (WUE, kg DM/ha/mm) of total herbage production was calculated by dividing total dry matter by total water use. Water use was determined by water balance (e.g. Murphy *et al.* 2018; Boschma *et al.* 2019). The least significant difference (l.s.d., *P* = 0.05) was used to identify differences between values of change in profile stored soil water, total water used, total herbage mass and water use efficiency.

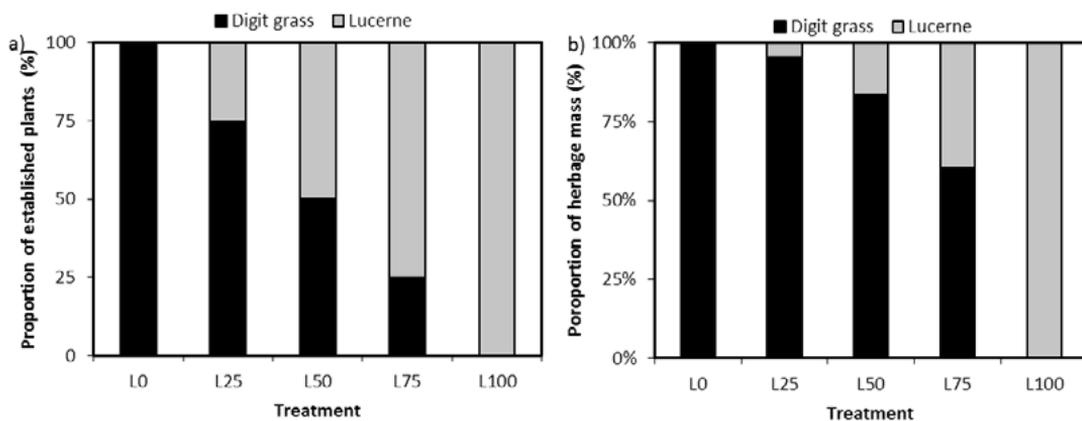


Figure 1. a) Proportions of digit grass and lucerne plants in five treatments established at 8 plants/m², and b) proportion of herbage mass (kg DM/ha) of digit grass and lucerne harvested from each of the treatments in summer 2018–19, which illustrates over-yielding of digit grass for this season.

Results

Summer 2018–19 experienced both above average daily temperatures and below average total rainfall. Following the commencement of the experiment, soil water content measures showed extraction to a depth > 1.0 m (Fig. 2), with the treatments extracting 87–103 mm, but differences were not significant ($P > 0.05$). Total water used during the period ranged between 323 and 339 mm for pure lucerne (L100) and pure digit grass (L0), respectively (Table 1).

Digit grass showed superior productivity during summer 2018–19; producing the most herbage of the five treatments as a pure sward (L0, $P < 0.05$, Table 1). It also outperformed its established proportion for the three treatments containing both species, e.g. digit grass represented 84% of total herbage in L50 (Table 1, Fig. 1). Total herbage production declined as the proportion of lucerne increased, with pure lucerne (L100) producing less ($P < 0.05$) than all other treatments (Table 1). Water use efficiency of total herbage production similarly declined from 11.5 to 4.9 kg DM/ha/mm with pure digit grass and lucerne plots having the highest and lowest ($P < 0.05$) efficiencies, respectively (Table 1).

Discussion

The data sets described in this paper provide a unique snapshot of the early development of these digit grass-lucerne pastures. While the assessed growth period was just 67 days, it has revealed some surprising insights. The soil water content data show that extraction took place in all treatments to depths of at least 1.0 m, which indicate that the drying front

progressed downwards at a rate of ~15 mm/day (i.e. 1000 mm divided by 67 days). Despite all treatments using similar amounts of soil water from the profile, there were large differences among values of herbage mass, which translated directly to significant differences in WUE.

The replacement series experimental approach (de Wit 1960) offers an effective method to study the competition between two species sown in a pasture sward (Boschma *et al.* 2010). The data presented here, obviously, are for only a short period following establishment and so only represent initial interactions. It is clear, however, that for this short period, neither species

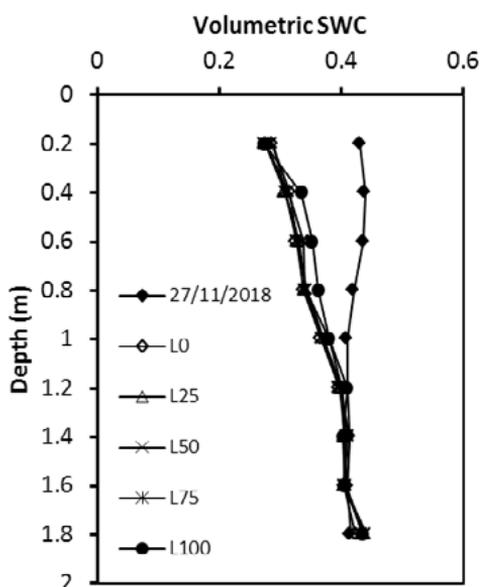


Figure 2. Changes in volumetric soil water content (SWC) of digit grass and lucerne treatments established at increasing proportion of lucerne from 27 November 2018 (mean of all treatments) to 1 February 2019.

Table 1. Effect of digit grass-lucerne treatments on change in stored soil water (SSW, mm), total water used (mm), herbage produced (kg DM/ha) and water use efficiency (WUE, kg DM/ha/mm) for the period 17 November 2018 –1 February 2019.

Treatment	Plants/m ²		Rainfall + Irrigation (mm)	Change in SSW (mm)	Total water used (mm)	Herbage (kg DM/ha)	WUE (kg DM/ha/mm)
	digit grass	lucerne					
L0	8	0	236	103	339	3904	11.5
L25	6	2	236	101	337	3590	10.6
L50	4	4	236	97	333	3218	9.7
L75	2	6	236	101	337	2674	7.9
L100	0	8	236	87	323	1596	4.9
l.s.d. $P = 0.05$			-	NS	NS	794.8	2.06

contributed to total herbage mass in direct proportion to its ratio in the mixture, with digit grass over-yielding and lucerne under-yielding. This outcome may be due to a couple of factors.

The tropical grass appeared to be unaffected by the hot and dry summer compared to the temperate legume. The high daily maximum temperatures experienced (mean maximum of 34.9°C) were above the reported optimum for lucerne growth (25–30°C; Moot *et al.* 2008), but within the reported range for growth of digit grass (25–40°C; Whitney and Green 1969). In the comparatively cooler autumn and in subsequent seasons the lucerne component of these mixtures may well perform more strongly as seen in earlier experiments (Murphy *et al.* 2019), where lucerne was shown to begin strong growth earlier in spring than digit grass.

Spring is known to be a less favourable time for sowing lucerne pastures and in a grass-legume mixture, sowing time can have a long-lasting impact on performance (S. Boschma pers. comm.). For such pastures, established plant density, and therefore subsequent production will tend to be dominated by the species sown closest to its preferred time of year, which in this experiment, was digit grass. In a previous experiment, where conditions for establishment were more suited to lucerne, it established well and subsequently dominated early spring growth, utilised soil moisture stored during winter, and so tended to dominate the stand through time, contributing 69–73% of herbage mass (Murphy *et al.* 2018).

The low WUE values for L100 and L75 (i.e. plant ratios dominated by lucerne) clearly articulate the relative underperformance in this establishment phase of these treatments compared with those having a high ratio of digit grass. It appears that WUE will be an ideal parameter to describe the effects of competition for soil water in these mixtures, as all treatments have had and will receive equal rainfall. This study will continue until the end of autumn 2022 and so provide data across seasons and years that will define the optimal ratio of digit grass and lucerne in mixed pastures in northern inland NSW.

Acknowledgments

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Sustainability and productivity of two mine rehabilitation sown pastures in the Hunter Valley

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Abstract: *This study set out to provide data on whether mine rehabilitation sown pastures in the Hunter Valley can be as sustainable and productive as native pastures from the same area. Two comparisons were made over three years from 2014 to 2017. Rehabilitation pastures were found to have similar levels to native pastures for ground cover and heavy metal contamination of soils, plants and livestock. However, species diversity was much lower in the rehabilitation pastures. Dry matter yields, percentage green and growth rates of rehabilitation pastures were all equal to or higher than for native pastures. The differences in feed quality were not so clear cut. The data from this study suggested that many measures of sustainability and production of rehabilitation pastures can be equal to or better than the original native pastures of the area. However, more comparisons are needed to confidently make generalisations and more work may be needed to boost the biodiversity of rehabilitation pastures if high biodiversity is regarded as a desirable feature of these pastures.*

Key words: sown-tropical pasture, pasture quality

Introduction

This study was initiated by the Upper Hunter Mining Dialogue (UHMD), which is a group comprising stakeholders from coal mining, agriculture, community and environment groups, local and state government. The UHMD needed to answer questions being raised by the community around the sustainability and profitability of mine land that had been rehabilitated to pastures, but they had very limited data to address these issues.

The aim of this study was to provide data on whether rehabilitated pastures can be as sustainable and productive as native pastures which were typically present before mining began. The study extended from 2014 to 2017 at two sites. It is acknowledged that this study looks at only one of many scenarios that are possible in mine rehabilitation and hence has considerable limitations.

Methods

Two study sites were identified near Singleton and Muswellbrook where mine land rehabilitated to sown pastures could be compared with adjacent native pastures. Sites consisted of two 20 ha paddocks for each pasture type at Singleton and three 10 ha paddocks for each pasture type at

Muswellbrook. Mine rehabilitation pastures had been sown to Rhodes grass (*Chloris gayana* cv. Pioneer), green panic (*Megathyrsus maximus*), lucerne (*Medicago sativa*), kikuyu (*Pennisetum clandestinum*), couch (*Cynodon dactylon*), medic (*Medicago* spp.) and white clover (*Trifolium repens*) in the 1980s (Singleton) and 1990s (Muswellbrook). Pastures persisting since the 1980s and 1990s were selected as an indicator of persistence and sustainability. All pastures had clumps of established trees which provided shade for stock.

Two groups of cattle were run at each site over three years: Group 1 from 2014–2016 and then Group 2 from 2016–2017. Initially, 10 Angus steers per pasture type were run at each site giving a stocking rate of 1 steer/4 ha at Singleton and 1 steer/3 ha at Muswellbrook. These rates were considered conservative for these areas. The number of steers on the Singleton rehabilitation pasture was increased to 15 (50% increase) in the second group in an attempt to increase pasture utilisation, which had been very low.

Grazing management was a simple rotation with cattle moved to a new paddock after being weighed every 12 weeks. At Muswellbrook, the second group of cattle were set stocked on the full 30 ha area for each pasture type due to problems with fencing and water supply. No supplementary feeding, fertiliser or mineral supplements were provided during the study.

Sustainability of the rehabilitation and native pasture systems were compared using heavy metal (arsenic, cadmium, lead) contamination of soils, plants and cattle, also species diversity and ground cover. Heavy metal contamination of soils (0–10 cm) was measured in 2016 using Analysis Systems. Heavy metal contamination of plants was measured every six weeks using inductively coupled plasma (ICP) analysis through the NSW Department of Primary Industries (DPI) Feed Quality Service laboratory. Heavy metal contamination of cattle was assessed using blood samples collected on the entry of cattle to the study sites and again on exit. These were analysed by NSW DPI Veterinary Diagnostic Laboratory and included analyses for phosphorous, selenium, copper, zinc, calcium, magnesium, sulphate, vitamin B12, arsenic, cadmium, lead and manganese. Pasture species compositions were intensively surveyed annually, with any extra species found during six weekly pasture monitoring added to the list. Ground cover percentage (%) was visually estimated in each quadrat used to estimate dry matter yield (see below).

Productivity of the rehabilitation and native pasture systems were compared using measurements of dry matter yield, percentage green (% green), growth and feed quality measurements. Dry matter yield and % green were estimated every 6-weeks using the BOTANAL relative yield method (Tothill *et al.* 1992); typically 150 or more 0.16 m² quadrats were used in each paddock. Pasture growth was estimated every 6 or 12-weeks using two exclusion cages per paddock: a 12-week period was used when the amount of new growth was extremely low at six weeks. Cages were placed on representative parts of each paddock and moved to a new site every 6-months: earlier if any damage to the pasture within the cages was observed. Feed quality samples were collected when undertaking BOTANAL field work: these were sorted into dead and green components and analysed by the NSW DPI Feed Quality Service laboratory. Near infrared (NIR) analysis was used for major feed quality components and ICP analysis for trace elements and heavy metals.

Results and Discussion

Sustainability

Soil, pasture and blood testing identified no heavy metal toxicities in any samples. All soil analyses were below the level of reporting for arsenic (<0.4 mg/kg), cadmium (\leq 0.2 mg/kg), lead (<2 mg/kg) and selenium (<4 mg/kg). Heavy metal concentrations for all pasture types were well below the maximum tolerable level for growing cattle (National Research Council 2005).

Rehabilitation pastures at Singleton and Muswellbrook contained a lower diversity of plant species (87 and 107 respectively) than the native pastures (144 and 174 respectively), but species numbers were still high and there was also a high percentage (43–49%) of native species in the sown areas. The abundance of native species in the rehabilitation areas may be due to survival of seed in the seedbank of the re-laid topsoil, transport by wind or animals from other areas and/or unrecorded sowing of native species in the forested areas. A broad diversity of plant species can be important for supplying diverse food sources and habitats for native animals, including soil fauna (Dorrough *et al.* 2008; Ruiz and Lavelle 2008). Whether the differences in plant species numbers and composition had an impact on the native fauna was outside the scope of this study, but may form a useful area for future investigation. It should also be noted that experience from other areas suggest that the diversity of native plant species may well increase over time with good pasture management and in the absence of fertiliser application (Leech and Keys 2003).

Ground cover was similar in both rehabilitation and native pastures and was maintained at desirable levels of \geq 90% (Lang and McDonald 2005) throughout the year. This is even though stocking rates were 50% higher on the Singleton sown pasture in the latter part of the study. Adequate levels of ground cover are important as it minimises run-off, reduces erosion, increases plant growth, aids soil health, assists in weed control and improves the quality of water entering dams, streams and rivers (Lang and McDonald 2005; Graham 2017). Pasture cover

is the preferred indicator of sustainability and stability on mine rehabilitated land as the soils are often very prone to erosion (Carroll *et al.* 2001; Grigg *et al.* 2000). Carroll *et al.* (2001) reported that >80% pasture cover is required to reduce erosion rates on steep slopes to negligible levels.

Productivity

Dry matter yields and % green were higher in the Singleton rehabilitation pastures than the native pasture throughout the study (Fig. 1). However, the rehabilitation pastures initially had higher yield and % green. Dry matter yields tended to increase over time in the rehabilitation pasture, but remain relatively steady in the native pastures. By comparison, there was no obvious difference in total dry matter yields or % green between sown and native areas at Muswellbrook. The carrying capacity at Muswellbrook of both the rehabilitation and native areas was very similar when based on pasture quantity alone.

Although not shown here, growth rates and the distribution of growth through the year in rehabilitation pastures was generally equal to or superior to the native pastures at both sites. This may be partly due to the greater growth rate

potential of the introduced pasture species and partly due to better soil fertility in the Singleton rehabilitation pasture. Soil Colwell phosphorous was greater than 30 mg/kg in the Singleton rehabilitation pastures and less than 10 mg/kg in all other pastures. Sulfur was also low in all pastures. This indicates that production was potentially limited by low phosphorous in three pastures and low sulfur in all pastures.

It is likely that rehabilitation pasture production could also have been higher if the pastures had been actively managed prior to the study to reduce the sizeable build-up of dead material. Silcock (1991) noted that only a small proportion of Rhodes grass pastures in ungrazed rehabilitation areas were actively growing. In part this is typically due to the build-up in dead material and consequent nitrogen immobilisation (Robbins *et al.* 1989; Robertson *et al.* 1993). Even with the introduction of cattle sizeable areas, especially at Singleton, retained a large dead biomass.

The message on pasture quality or feed value was more nuanced. Metabolisable energy of Singleton rehabilitation pastures declined during the study as biomass accumulated and plants

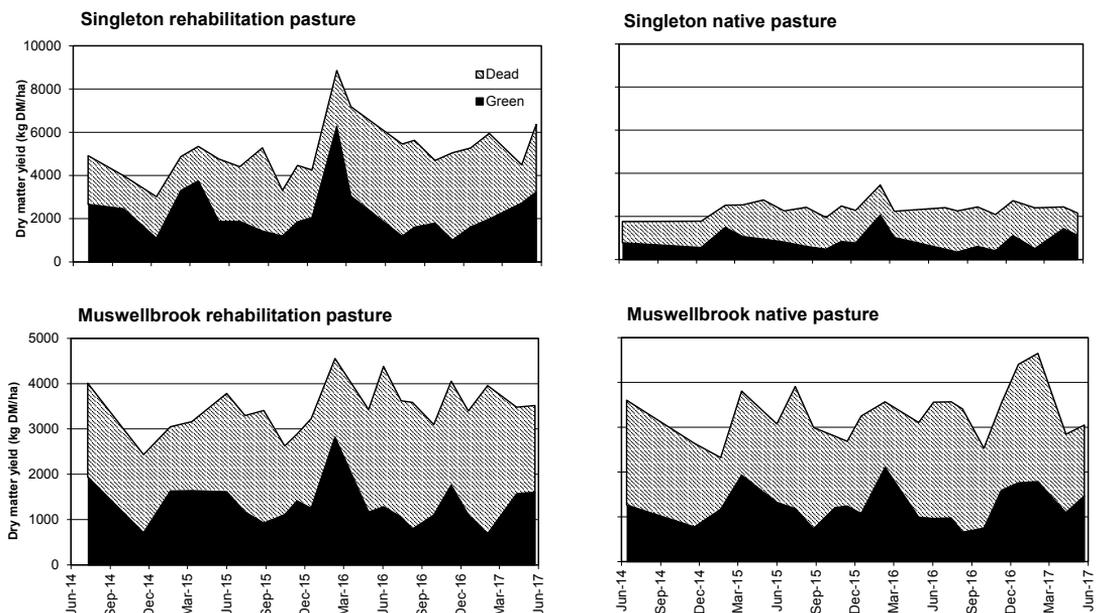


Figure 1. Green and dead pasture dry matter yields (kg DM/ha) for rehabilitation and native pastures at Singleton and Muswellbrook. Figures are averaged across paddocks within each area.

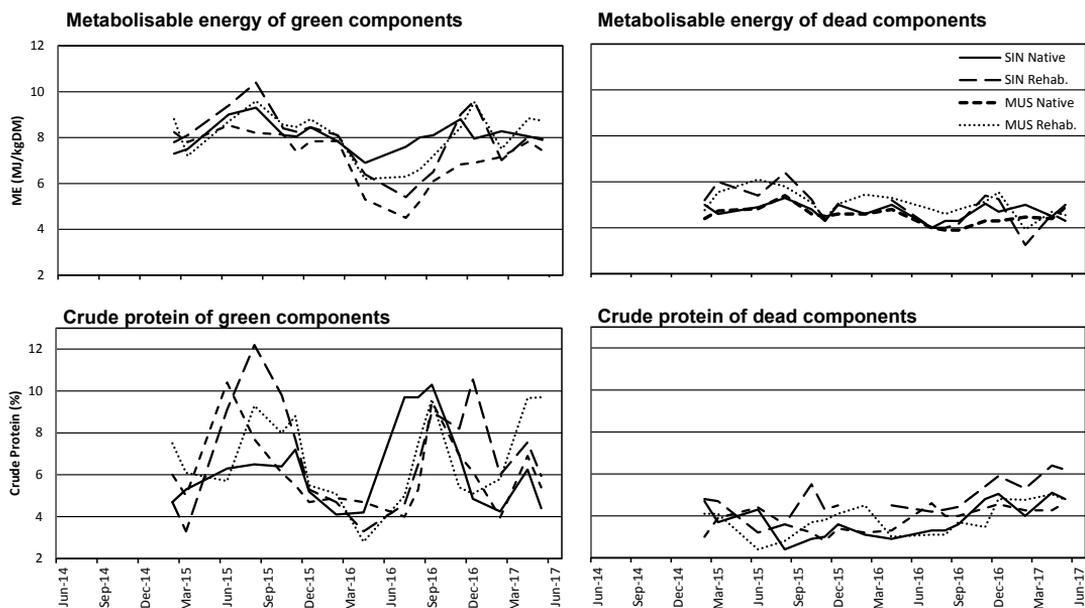


Figure 2. Metabolisable energy (ME, MJ/kg DM) and crude protein (%) of green and dead pasture components for rehabilitation and native pastures at Singleton (SIN) and Muswellbrook (MUS). Figures are averaged across paddocks within each pasture type.

became rank due to pasture growth exceeding cattle consumption (Fig. 2). Huxtable (1997) also noted that unless appropriate stocking rates are used Rhodes grass tends towards a monoculture and is of fairly low nutritive value to stock. The quality of Singleton native pastures appeared to improve as consumption exceeded pasture growth and a greater proportion of the pasture was of high feed value. In this case, lower green feed availability (often ≤ 1000 kg DM/ha) limited cattle weight gain.

Conclusion

Over the three years of this study, the rehabilitation and native pastures were found to have similar levels of ground cover and no toxic levels of heavy metals in the soils, plants and livestock. However, species diversity was much lower in the rehabilitation pastures. Dry matter yields, percentage green and growth rates of rehabilitation pastures were all equal to or higher than for native pastures. The data from this study suggest that many measures of sustainability and production of rehabilitation pastures can be equal to or better than the original native pastures of the area. However, to confidently make generalisations further

comparisons and work are warranted to boost the biodiversity of rehabilitation pastures if high biodiversity is regarded as a desirable feature of these pastures. Further information is available from the final report for Project C32053 ‘A study of sustainability and profitability of grazing land in the Upper Hunter NSW’ (Griffiths and Rose 2018)

Acknowledgments

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A comparison of beef production from native and mine rehabilitation sown pastures in the Hunter Valley

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Abstract: *This study compared the growth and value of steers grazing sown tropical grass pastures on rehabilitated mining land with steers grazing adjacent native pastures. Steers grazing on the sown pastures gained more weight, were fatter and worth more money than steers grazing on the native pastures.*

Key words: grazing management, weight gain, fat depth, gross margin, sown pasture, rehabilitated mine land

Introduction

This study was initiated by the Upper Hunter Mining Dialogue (UHMD), which is a group comprising stakeholders from coal mining, agriculture, community and environment groups, local and state government. The UHMD needed to answer questions being raised by the community around the sustainability and profitability of mine land which had been rehabilitated to pastures.

The aim of this study was to provide data on whether mine rehabilitation sown pastures can be as sustainable and productive as native pastures which were typically present before mining began. The study extended from 2014 to 2017. As this study looks at only one of many possible pasture scenarios it is not possible to make broad generalisations.

Methods

Two study sites were identified near Singleton and Muswellbrook where pastures sown to a mix of Rhodes grass (*Chloris gayana* cv. Pioneer), green panic (*Megathyrsus maximus*), lucerne (*Medicago sativa*), kikuyu (*Pennisetum clandestinum*), couch (*Cynodon dactylon*), medic (*Medicago* spp.) and white clover (*Trifolium repens*) were compared with adjacent native pastures. The Singleton site consisted of four 20 ha paddocks, two sown in the 1980s and two native. The Muswellbrook site consisted of six 10 ha paddocks, three sown in the late 1990s and three native.

Two groups of cattle were run at each site: Group 1 from 2014–2016 and then Group 2 from

2016–2017. Initially, (Group 1) 10 Angus steers per pasture type were run at each site giving a stocking rate of 1 steer/3 ha at Muswellbrook and 1 steer/4 ha at Singleton, which was considered conservative. At each site steers from a larger mob were randomly allocated to each treatment. For Group 2, the number of steers was increased to 15 (50% increase) at the Singleton rehabilitation site in an attempt at increasing pasture utilisation. Group 2 cattle at Muswellbrook were set stocked on the full 30 ha area for each pasture type due to problems with fencing and water supply.

Both sites were monitored from 2014 to 2017. Pastures were assessed every six weeks and cattle were weighed every 12 weeks. Grazing management was a simple rotation with cattle moved to a new paddock after weighing. A decision was taken that no supplementary feeding, fertiliser or mineral supplements would be provided during the study. All areas had clumps of established trees which provided shade for stock.

Steers were sold direct to abattoirs or scanned to measure fat cover allowing a reliable estimate of value.

Profitability of an enterprise can be measured in various ways and is influenced by production and cost structures (Anon 2017). This study focused on productivity at each site and gross margin analysis for each pasture type but does not include pasture establishment costs. Weight gains per head and per hectare were used to measure productivity.

Results and Discussion

Steers grazing the rehabilitation pastures gained more weight, were fatter and worth more money than steers grazing native pastures.

Cattle

Group 1 steers on rehabilitation pastures were heavier and fatter at exit than those on native pastures at both sites (Table 1); these differences were greater at Singleton (changes over time can be seen in Fig. 1). Cattle grazing rehabilitation pastures had superior weight gain to those grazing native pastures. Daily weight gain varied from 0.05 to 1.1 kg/head/day for Muswellbrook rehabilitation and -0.16 to 0.99 kg/head/day for Muswellbrook native pasture. Singleton rehabilitation varied from 0.18 to 1.3 kg/head/day and Singleton native 0.12 to 0.84 kg/head/day (Fig. 1). Fat score, which is a measure of stock condition, was recorded at final weighing for all cattle and showed that in each group cattle grazing rehabilitation pastures had better condition than those on the native pastures (Tables 1 and 2).

At Muswellbrook, differences in measured pasture availability were too small to explain the rehabilitation pasture weight gain advantage (Griffiths and Rose 2019). However, there was a notable difference in quality, with native pastures dominated by low quality wiregrass (*Aristida* spp.) and native Parramatta grass (*Sporobolus* spp.) whereas rehabilitation pastures were dominated by better quality Rhodes grass and green panic (Griffiths and Rose 2019).

At Singleton, rehabilitation pastures had much greater measured pasture availability and a

dominance of better quality Rhodes grass with some green panic. Native pastures, however, were dominated by low-quality grasses and this could all help explain the better performance of steers on the rehabilitation pastures. The performance of Group 2 steers (Table 2) and the factors affecting their performance were similar to Group 1. Group 2 steers on the rehabilitation pastures, however, showed greater weight gain per hectare than Group 1 steers (Fig. 1). This was because the rehabilitation pasture stocking rate had been increased by 50% in an attempt to reduce excessive pasture bulk. Although pasture availability had been reduced by the higher stocking rate, it had no detrimental effect on ground cover.

Economics

The main determinants of cattle value are weight, condition (fat score) and market prices. Group 1 cattle were 'finished' and were valued according to the Scone abattoir price grid at the time. Group 2 cattle were in 'store condition' and were valued using Singleton saleyard prices for store cattle at the time of analysis as reported in Table 3. In all cases the average value of cattle grazing the rehabilitation pastures was greater than those grazing the native pastures.

Gross margin (GM) is a standard indicator of enterprise profitability (Anon 2019). Group 1 cattle GM benefited from a rising cattle market at the time, while Group 2 used sale prices from

Table 1. Group 1 steer averages for weight gain per day, weight per head and condition (as measured by P8 fat depth) at exit from native and rehabilitation pastures at Muswellbrook and Singleton.

Site	Grazing days	Daily weight gain (kg/head/day)	Weight at exit (kg/head)	Average P8 fat depth (mm)
Muswellbrook native	557	0.45	537	5.3
Muswellbrook rehab.	557	0.53	586	7.0
Singleton native	553	0.46	611	9.3
Singleton rehab.	553	0.76	764	23.7

Table 2. Group 2 steer averages for weight gain per day, weight per head and condition (as measured by P8 fat depth) at exit from native and rehabilitation pastures at Muswellbrook and Singleton.

Site	Grazing days	Daily weight gain (kg/head/day)	Weight at exit (kg/head)	Average P8 fat depth (mm)
Muswellbrook native	441	0.46	456	3.6
Muswellbrook rehab.	441	0.62	529	6.2
Singleton native	293	0.45	381	2.4
Singleton rehab.	293	0.78	480	4.3

a falling market, which caused the GMs to be less than for Group 1. In all cases the GM for the cattle on rehabilitation pastures was greater than the GM for those on native pastures. Singleton Group 2 GM/ha is notable as it shows the combined effect of greater weight gain and greater stocking rate on the rehabilitation pastures.

Group 1 steers on rehabilitation pasture had a greater dollar value than steers on native pasture at exit from both sites (\$1822 v. \$1506 and \$2017 v. \$1560 per head for Muswellbrook and Singleton respectively). This comparison was based on actual carcase values for the Muswellbrook steers. Singleton steer values were

estimated based on expected dressing percentage from liveweights, P8 fat measurement and the relevant abattoir pricing grid as cattle were not sold till several months after exiting the study. Group 2 steers on rehabilitation pasture also had a greater dollar value than steers grazing native pasture at exit from the study, for both sites (\$1716 v. \$1505 for Muswellbrook and \$1559 v. \$1341 for Singleton; Tables 2 and 3).

For each site, rehabilitation pasture returned greater gross margin per steer, and hectare for both Group 1 and Group 2 steers (Tables 3 and 4). At Muswellbrook the rehabilitation pasture returned 33% higher gross margin for Group 1 and 28% for Group 2. At the Singleton site,

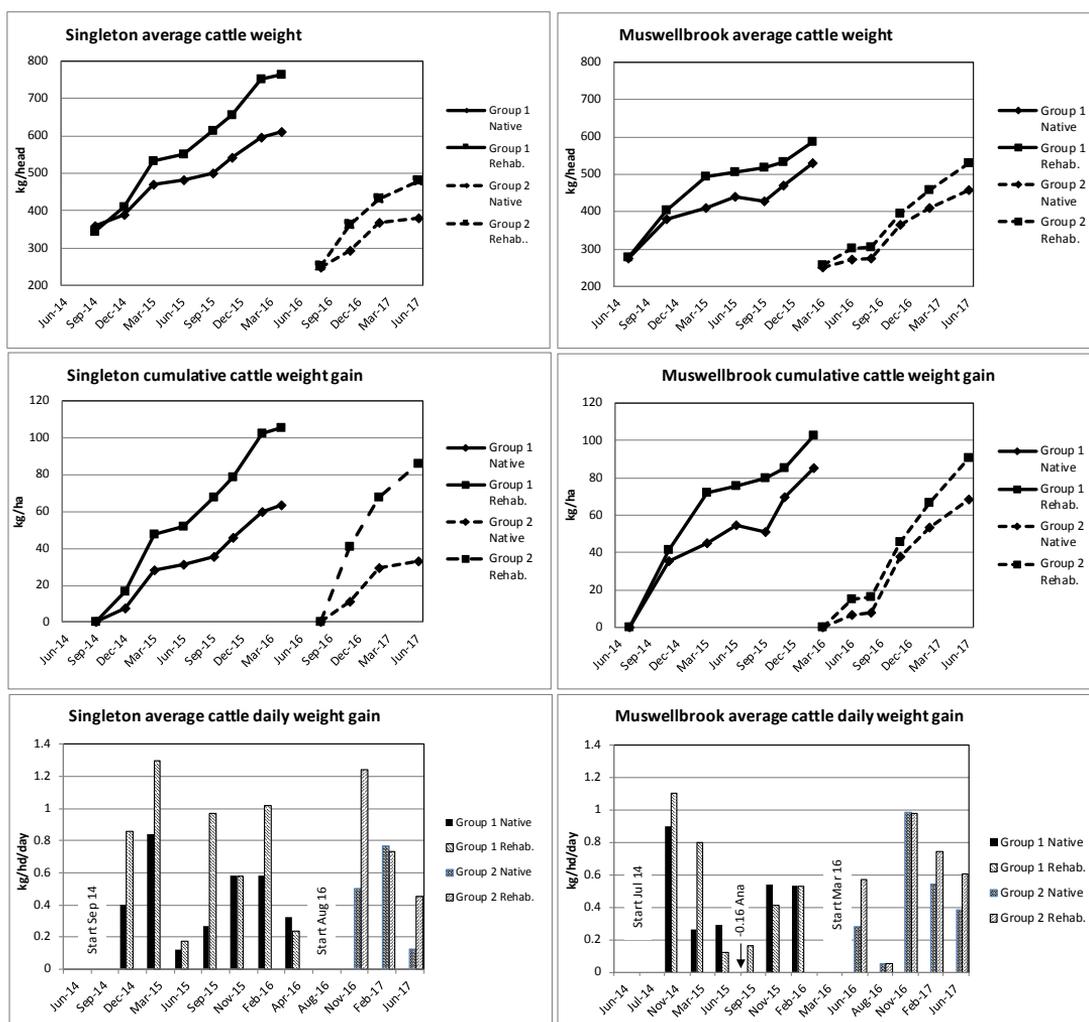


Figure 1. Average cattle weight (kg/head), cumulative weight gain (kg/ha), and daily weight gain (kg/head/day) over each measurement period for two groups of steers on native and rehabilitation pastures at Singleton and Muswellbrook.

Table 3. Purchase and sale prices of Group 1 and Group 2 steers at entry and exit from native and rehabilitation pastures at Muswellbrook and Singleton.

Site	Purchase Group 1 (c/kg LW)	Sale Group 1 (c/kg LW)	Purchase Group 2 (c/kg LW)	Sale Group 2 (c/kg LW)
Muswellbrook native	185	280	340	330
Muswellbrook rehab.	185	311	340	324
Singleton native	205	255	440	352
Singleton rehab.	205	264	440	325

Table 4: Gross margins (\$) for Group 1 and Group 2 steers for native and rehabilitation pastures at Muswellbrook and Singleton.

	Group 1		Group 2	
	Native	Rehab.	Native	Rehab.
<i>Muswellbrook</i>				
Gross Margin	8950	11928	5488	7034
Gross Margin/steer	895	1193	549	703
Gross Margin/ha	298	398	183	234
<i>Singleton</i>				
Gross Margin	7217	12021	1452	5190
Gross Margin/steer	722	1202	145	346
Gross Margin/ha	180	301	36	130

the sown pasture returned 67% and 258% more gross margin for Group 1 and Group 2, respectively. Singleton Group 2 steers on the rehabilitation pasture returned a significantly higher gross margin due to a higher stocking rate as well as weight gain per head: 15 steers on 40 ha as opposed to 10 steers on 40 ha for the native pasture. Gross margins for Group 2 for both sites were lower than Group 1 because prices for restocking cattle in 2016 increased to a greater extent than sale prices, resulting in tighter margins.

Conclusion

This project has provided quantitative data showing that steers grazing sown pastures grew faster, were heavier and worth more money than steers grazing native pastures. Further information is available from the final report for Project C32053 'A study of sustainability and profitability of grazing land in the Upper Hunter NSW' (Griffiths and Rose 2018).

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One size does not fit all – matching grazing strategies with plant growth stages

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Abstract: A glasshouse study was conducted to quantify the nutritive value of four tropical grasses at four growth stages. The grasses were digit grass (*Digitaria eriantha*) cv. Premier, Makarikari grass (*Panicum coloratum* var. *makarikariense*) cv. Bambatsi, Rhodes grass (*Chloris gayana*) cv. Katambora and panic grass (*Megathyrsus maximus*) cv. Gatton and the growth stages were 2-leaf, 4-leaf, 6-leaf and stem elongation. Makarikari grass developed the fastest and digit grass the slowest (38 and 52 days to stem elongation, respectively). Rhodes grass had the highest biomass at stem elongation. Nutritive value was highest at the earliest growth stage, declining as the tillers matured. Leaf per tiller number was used as a potential plant-based indicator of optimum time of grazing. The optimum growth stage for grazing and potentially fodder conservation was 4-leaf for Rhodes grass and digit grass. The optimum growth stage for Makarikari grass and panic grass was the 6-leaf growth stage. With field testing, this information could be a useful tool for producers to optimise pasture and stock production.

Key words: metabolisable energy, crude protein, acid detergent fibre, neutral detergent fibre, silage, Bambatsi panic

Introduction

The technique of using leaf number per tiller as a plant-based indicator to determine the optimum time for grazing was first described by Fulkerson and Slack (1994). They used it for irrigated perennial ryegrass (*Lolium perenne* L.) pastures. The advantage of leaf number is that it is a generic and readily identifiable trait (Fulkerson and Donaghy 2001). This technique has been extended to other temperate grass species used in the dairy industry such as cocksfoot (*Dactylis glomerata* L.; Rawnsley *et al.* 2002; Turner *et al.* 2006a) and prairie grass (*Bromus willdenowii* Kunth; Turner *et al.* 2006a,b). The technique has also been applied to two tropical grasses commonly used in dairy pastures including: kikuyu (*Pennisetum clandestinum* Hochst. ex Chiov; Reeves and Fulkerson 1996; Reeves *et al.* 1996; Fulkerson *et al.* 1999) and Rhodes grass (*Chloris gayana* Kunth; Pembleton *et al.* 2009). This plant-based indicator has been promoted within the dairy industry as a tool for producers to use to determine the optimum time for grazing.

Leaf number has been used to determine the optimum time for grazing and could also be

applied to dryland pastures. Tropical grasses are favoured pastures in the summer dominant rainfall zone because of their high productivity and persistence (Boschma *et al.* 2015, 2017). However, they are commonly underutilised (Boschma *et al.* 2014; Harris *et al.* 2014). This particularly occurs following periods of significant summer rainfall when growth rates are highest. This issue is complex and many factors need to be considered. Factors include paddock size, stock availability and highly variable production (e.g. Wilson and Minson 1980; Boschma *et al.* 2014; Harris *et al.* 2014). However, there is a lack of knowledge of the interaction between growth stages and nutritive value of tropical grass species that are commonly grown in dryland pastures. This information could also be useful to understand the optimum time to cut tropical grass pastures for fodder conservation. The aim of this study was to quantify tiller development and the associated nutritive value of a number of tropical perennial grasses used in dryland tropical grass pastures.

Materials and methods

An experiment was conducted between November 2012 and May 2013 in a temperature-controlled glasshouse at the University of New England, Armidale (30.487°S, 151.637°E),

Australia. The glasshouse was initially set at 25/20°C day (0600–1800 hr)/night (1800–0600 hr) and increased to 28/22°C day/night on 19 February 2013 for the balance of experiment.

In November 2012, 10 seeds of four tropical grass species were sown into pots (20 cm diameter, 20 cm deep) filled with a potting mixture of sand and peat (2:1 ratio). The grasses were digit grass (*Digitaria eriantha* Steud.) cv. Premier, Makarikari grass (*Panicum coloratum* L. var. *makarikiense*) cv. Bambatsi, Rhodes grass (*Chloris gayana* Kunth) cv. Katambora, and panic grass (*Megathyrsus maximus* (Jacq.) B.K. Simon & S.W.L. Jacobs) cv. Gatton. The pots were free draining and watered manually twice a day until emergence, then twice daily using an automatic irrigation system for the remainder of the experiment. Plants were thinned to 4 plants/pot on 30 November 2012 and further thinned to 2 plants/pot on 7 January 2013. All pots were fertilised with urea (46% N at 72.5 kg/ha), potassium phosphate (52% K, 34% P at 75 kg/ha) and potassium sulphate (41% K, 18% S at 34 kg/ha) on 8 January 2013. Urea (124 kg N/ha) was applied weekly from 1 April 2013 and further applications of the same rates of potassium phosphate and potassium sulphate as previously were applied on 1 April and 20 May 2013. The plants in pots were cut to about 5 cm on 18 January 2013.

The experiment commenced on 1 April 2013. We used a split-plot design with species as the main plot and growth stage harvest times as subplots, with three replicates. Growth stage harvest times were based on the number of emerged leaves produced per tiller: 2-leaf, 4-leaf, 6-leaf and stem elongation (presence of a node on the stem). Twelve pots of each species were selected and plants cut to 5 cm above the soil surface (except for panic grass, which was cut just below the first node which varied in height for each tiller). In total the experiment comprised 48 pots and concluded 27 May 2013.

Tillers of each species were inspected daily and the number of emerged leaves counted to determine if they were ready to harvest based on the average number of leaves per tiller. When the majority of inspected tillers of all plants of

a species within a treatment had reached the designated leaf stage, the date was recorded and all replicates of that species and treatment were harvested (i.e. three pots). Plants in each pot were cut to 5 cm and the harvested material dried at 60°C for 48 hours. The dried samples were weighed (g/pot) then ground through a 2 mm sieve and stored in airtight plastic containers. The samples were analysed for neutral detergent fibre (NDF, %), acid detergent fibre (ADF, %), crude protein (CP, %), and metabolisable energy (MJ/kg DM). Herbage samples from replicates of the 2- and 4-leaf growth stages were too small for analysis and the three replicates were bulked.

Biomass data were analysed by analysis of variance using RStudio, version 0.97.551 (RStudio Inc. 2009–2012). Replicate samples for the 2 and 4-leaf growth stage samples were combined so analyses could not be conducted, therefore means are presented for these treatments.

Results

The average number of days for each species to progress through the growth stages to stem elongation varied, as did the rate that they accumulated biomass (Table 1). Makarikari grass tillers developed the fastest, reaching stem elongation in 38 days. Significant biomass accumulation occurred in the last 14 days when the tiller growth stage progressed from 6-leaf to stem elongation ($P < 0.05$). Digit grass tillers were the slowest to develop (52 days). Also, digit grass had significant biomass accumulation through each growth stage then plateauing from 6-leaf to stem elongation. Panic grass also plateaued from 6-leaf to stem elongation. The tiller development of Rhodes grass was intermediate to Makarikari and digit grass taking an average of 43 days to reach stem elongation. The biomass of Rhodes grass increased significantly at each growth stage from 4-leaf to stem elongation, achieving the highest biomass of the grasses at stem elongation ($P < 0.05$) (Table 1).

Crude protein concentration was highly responsive to tiller development, being highest at the 2-leaf growth stage. However crude protein declined as the tillers developed to

be lowest at stem elongation (Fig. 1). Rhodes grass showed the greatest changes, declining sharply from 32 to 23% between the 2- and 4-leaf growth stages and further to 16.5% at stem elongation. In contrast, Makarikari grass had the smallest decline (27 to 17%) which was almost evenly distributed across the four growth stages observed. All grasses had similar crude protein levels at stem elongation. Metabolisable energy also declined with tiller development, but the changes were not as large. Most grasses had an average of 11.0 MJ/kg DM at the 2-leaf growth stage and declined to 7.9 MJ/kg DM at stem elongation (Fig. 1). Panic grass was the exception; it had the highest metabolisable energy at the 2-leaf growth stage and declined to a similar level as the other grasses at stem elongation. Acid detergent fibre and NDF concentration of all grasses tended to be lowest at the 2-leaf growth stage and increased as the tillers developed to stem elongation (Fig. 1).

Discussion

It is well reported that as grasses mature, herbage production increases while both digestibility and crude protein content decline (e.g. Wilson

1976; Wilson and Minson 1980; Pembleton *et al.* 2009). These changes result in selective grazing (Wilson and Minson 1980) and a decline in voluntary intake (Minson *et al.* 1993). This inverse relationship between herbage production and its nutritive value means that the optimum time to graze is a compromise of the two. Grazing management techniques based on growth stage to determine the optimum time of grazing can assist optimising livestock production by maximising nutritive value without compromising biomass production and pasture persistence. Field studies have determined the optimal time to graze kikuyu pasture is at the 4.5-leaf stage (Reeves and Fulkerson 1996; Reeves *et al.* 1996) which is a compromise between forage quantity and nutritive value. In kikuyu at growth stages later than 4.5 leaves/tiller, digestibility and crude protein levels declined associated with a declining leaf-stem ratio, and increasing dead material due to leaf senescence (Fulkerson *et al.* 1999). Similarly, for Rhodes grass (cv. Callide), the proportion of stem in the herbage increased when 4 leaves/tiller were present. The crude protein of the leaf fraction also decreased

Table 1. Average time (number of days regrowth), acid detergent fibre (%) and neutral detergent fibre (%) of tropical grasses at 2-leaf, 4-leaf, 6-leaf and stem elongation (SE) growth stages.

Grass species	Time (days)				Acid detergent fibre (%)				Neutral detergent fibre (%)			
	2-leaf	4-leaf	6-leaf	SE	2-leaf	4-leaf	6-leaf	SE	2-leaf	4-leaf	6-leaf	SE
Makarikari grass	5	13	24	38	28	27	30	34	61	61	59	67
Rhodes grass	5	19	24	43	29	35	37	40	56	67	68	72
Panic grass	7	17	30	40	21	26	35	37	47	61	63	73
Digit grass	5	21	34	52	33	35	35	38	68	70	67	71

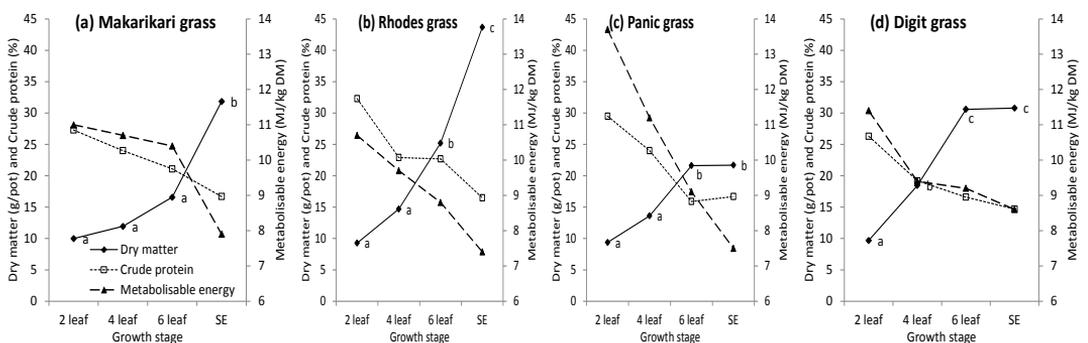


Figure 1. Biomass (dry matter, g/pot), crude protein (%) and metabolisable energy (MJ/kg DM) content of (a) Makarikari grass, (b) Rhodes grass, (c) panic grass and (d) digit grass at different growth stages. Biomass production values marked with the same letter within a grass species are similar (P = 0.05).

as the tiller matured. The greatest decline was observed between the 4- and 6-leaf harvest stages (Pembleton *et al.* 2009).

The principle of matching good nutritive value, primarily metabolisable energy, with good biomass can be applied to the grasses in this study. For good animal production, the grasses would need to be grazed at the 4-leaf (Rhodes grass and digit grass) or 6-leaf growth stage (Makarikari grass and panic grass) to achieve minimum metabolisable energy of 10 MJ/kg DM. Delaying grazing until the average tiller development was at stem elongation would result in metabolisable energy values <7.5 MJ ME/kg DM. This lower level is only suitable for maintenance. This 4- to 6-leaf growth stage target for grazing is consistent with previous studies (Reeves and Fulkerson 1996; Reeves *et al.* 1996; Pembleton *et al.* 2009). These growth stages are also relevant for fodder conservation. Tropical grasses can produce silage of medium forage value (i.e. metabolisable energy of 9–10 MJ/kg DM) (Kaiser *et al.* 2004). Extensive research has been conducted on silage production of kikuyu and is summarised in the Topfodder Successful Silage manual (Kaiser *et al.* 2004).

High rates of N were applied to this experiment and were reflected in the high crude protein values. This response in crude protein to increasing N application is well reported (Pembleton *et al.* 2009; Boschma *et al.* 2017), along with a positive, although small response in metabolisable energy. In a field study, average crude protein of tropical grasses (digit grass and Rhodes grass) fertilised with 300 kg N/ha increased by 12 percentage-units (11 to 23%) compared to the unfertilised grasses. Metabolisable energy also increased significantly, but only from 8.0 to 9.5 MJ/kg DM (Boschma *et al.* 2017).

Many actively growing fertilised tropical grasses will flower within six weeks of grazing/cutting in the field in northern inland NSW (S Boschma pers. comm.). This is a shorter timeframe than the regrowth of the grasses in this study. This delayed development could be due to a combination of rapidly shortening day length in April–May and cloudy days at the time of the experiment.

This glasshouse study has demonstrated that there is variation in tiller development and nutritive value between tropical grass species. Leaf number has potential to be used as a plant-based indicator to determine the optimum time to graze or cut pastures for hay or silage making. But one size does not fit all grazing strategies. To ensure both good metabolisable energy and biomass production Rhodes grass and digit grass pastures need to be grazed or cut when tillers are at the 4-leaf growth stage. Makarikari grass and panic grass can be cut or grazed slightly later at the 6-leaf growth stage. Field testing is required to confirm these results and assess the practicalities of harvesting short pastures.

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Effects of topdressed lime, superphosphate, sewage ash and stocking rate on subterranean clover production of a Southern Tablelands pasture

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Abstract: High levels of phosphorus (P) led to peak subterranean clover production for the first 4 years in a treatment with no lime and a low stocking rate although productivity subsequently declined to low levels, on soils with high levels of Al^{3+} , low pH_{Ca} and under the increasingly dry seasons of the mid-term Millennium Drought. Conversely where high P levels were combined with lime, productivity was high and remained stable over the longer term under the same seasonal conditions. This was associated with reduced soil Al^{3+} levels and higher pH_{Ca} after liming. At the low P rates (125 kg/ha superphosphate every 2–3 years, 5 t/ha sewage ash) legume productivity was constrained.

Key words: Acid soil amelioration, surface application, drought persistence

Introduction

On many fragile, non-arable soils grazing animal production from permanent pastures is a relatively sustainable form of agriculture. Legume productivity is pivotal to many of these extensive grazing systems as nitrogen (N) fixation is the primary source of N as well as providing high quality forage. Adequate phosphorus (P) is crucial to maintaining legume production (Richardson 1924) although questions regarding P use efficiency and methods of determining appropriate P levels remain. In addition the build-up of organic matter associated with these systems can acidify soils (Williams 1980), as can the removal of alkalinity due to agricultural production. Soil acidity constrains pasture productivity limiting production from grazing animals. It is estimated that there are 50 M ha throughout Australia with a $pH_{Ca} < 5.5$ and associated increase in soil aluminium (Al^{3+}). Many of these areas produce meat and wool, but many Australian farmers are uncertain of the benefits of liming. Research has concentrated on the effects of lime incorporated into the 0–10 cm soil profile. However, incorporation is only an option where land is arable. On the NSW Southern Tablelands, there are large areas of non-arable soils, acidic to depth where the only option to ameliorate acidity is to surface apply lime. Given these knowledge deficiencies in Australia a detailed study is justified of the

effects on subterranean clover production of different levels of lime, superphosphate, sewage ash and stocking rate over a time period long enough to ensure that the effects of lime will be acting to ameliorate the acid soil.

Materials and Methods

A replicated experiment continuously grazed by sheep was conducted (35.12° S, 149.27° E) near Sutton, NSW, Australia. The soils, predominately Chromosols with Leptic Rudosols (Isbell 1996) in higher areas, are mainly shallow (<0.20 to >1.5 m) and stony with texture contrast having brown loam topsoils overlying reddish to reddish brown light clays and clay loams. The climate of the area is warm temperate, with average annual rainfall of 660 mm. In autumn 1998, prior to lime application an initial spray to remove annual grasses and broadleaved weeds whilst retaining the established native perennial grasses was performed. Sowing occurred in May 1998 using a direct drill seeder at a row spacing of 30 cm so as to only minimally disturb the established native perennial grasses, whilst giving a reasonable density of introduced pasture species. The sown mix comprised *Trifolium subterraneum* (subterranean clover) cv. Goulburn and Seaton Park LF, *Dactylis glomerata* (cocksfoot) cv. Kara, *Phalaris aquatica* (phalaris) cv. Australian and Holdfast and *Lolium perenne* (perennial ryegrass) cv. Roper at 5.4, 2.6, 1.75, 1.75, 1.75 and 1.75 kg/ha respectively. All legume seed was inoculated and lime pelleted, with an additional treatment

of molybdenum trioxide at approximately 100 g/ha applied to the seed.

The soil was strongly acidic to depth with a pH_{Ca} ranging from 4.1 at the surface to 4.7 at 55 cm. In the 0–10 and 10–20 cm profiles Al^{3+} saturation was very high ranging from 30 to 48% of the effective cation exchange complex (ECEC). ECEC levels were low (4.6 cmol^+/kg) as were extractable P (9.7 mg/kg, Colwell) and total carbon (3%).

There were three treatment factors, P, lime and stocking rate, with different levels, replicated twice. All treatments received a P source either as superphosphate (0–9–0–11, N, P, potassium, sulphur), at a typical local application rate, P1, 125 kg/ha every 2 to 3 years, at a high, non-limiting rate, P2 (250 kg/ha/yr) or as sewage ash (P3). Four rates of lime were applied at experiment commencement: nil (L0); sufficient lime to increase pH_{Ca} in the 0–10 cm profile to 5.0 (L1); lime to increase pH_{Ca} in the 0–10 cm profile to 5.5 (L2) and sewage ash at 5 t/ha (L3). All lime applied was F70 superfine (70% <75 μm , neutralising value = 97 %). The single rate of 5 t/ha sewage ash (P3L3) contained 14% CaCO_3 by weight, 24% CaO and 4.5% MgO, calculated to have a neutralising value of 64%. This ash also contained 23% $\text{Ca}_3(\text{PO}_4)_2$.

The experiment was set stocked with wethers at two stocking rates, with the lower stocking rate (SR1) being 67% of the higher rate (SR2). The low P treatment was only stocked at SR1 whereas the high P treatment was stocked at both SR1 and SR2. Thus the treatments were combinations of three rates of P, four rates of lime and two stocking rates as follows: P1L0SR1, P1L1SR1, P2L0SR2, P2L0SR2, P2L1SR1, P2L1SR2, P2L2SR2, P2L2SR and P3L3SR2. Stocking rates were modified by seasonal conditions and consequent pasture growth rates. There were extremely dry periods, when pasture growth rates were so low that plots had to be destocked. Plot sizes for SR1 and SR2 were 1 and 0.67 ha respectively.

Herbage mass and botanical composition (as a percentage of herbage mass) were measured in each plot every six weeks, except after April 2002 when measurements were more sporadic

due to drought and funding constraints, using BOTANAL procedures (Tothill *et al.* 1992). In each plot, the pasture measurements were taken in 30 quadrats at 1 m intervals along two permanent transects chosen to sample the environmental variation. Sheep camping sites were avoided. Herbage mass was estimated directly as kg DM/ha. Statistical analyses using both splines for continuous data (1999–2002, 2005–2008) and a linear mixed model for discrete data (2003, 2004) were fitted using ASReml 3.0 (Gilmour *et al.* 2009).

Results and Discussion

While results here from 1999 to 2006 are presented, seasonal conditions close to average were only experienced during the first three years. From 2002, the area entered a period of below-average rainfall, with altered seasonal patterns during a climatic event which has come to be known as the Millennium Drought. Consequently, animals at times were fed with supplements, paddocks were de-stocked, and some measurements suspended with the effect that these changes altered stocking rate over the duration of the experiment.

The high P, nil lime, low stocking rate treatment, P2L0SR1, in the period between September 1999 and May 2003 was the most productive on 16 occasions and at the other three harvests was either second or third most productive (Table 1). However, from July 2004 its productivity fell so that at that time it was equal sixth, and at the two harvests after, December 2005 and February 2006, it was the least productive treatment. The subterranean clover in this treatment initially responded positively to the high P levels and low stocking rates. The subsequent decline is unlikely to be due to excessive competition from other pasture components because its corresponding high stocking rate treatment (P2L0SR2) also had relatively low productivity from July 2004 till experiment termination in 2008 (Dear *et al.* 2000). By contrast, the two high P, high lime treatments (P2L2SR1, P2L2SR2) as well as the high P, low lime, low stocking rate treatment (P2L1SR1) were highly productive with these treatments being in the most productive group at nine, 12 and seven occasions respectively of

the 23 harvests for which there were significant results between September 1999 and February 2006 (Table 1). Unlike P2L0SR1, these treatments did not decline in relative productivity over time. The level of soil Al^{3+} declined markedly and the soil pH_{Ca} increased after lime application in these treatments in contrast to the nil lime treatments (Norton *et al.* 2018). It is likely that the reduction in levels of toxic Al^{3+} is a key reason why the clover was more persistent and productive than under the nil lime treatments presumably because the clover roots were able to exploit more soil volume, a major advantage during drought. In contrast the low P treatments, P1L0SR1, P3L3SR2 and P1L1SR1, were in the

most productive groups on only four, four and one occasion respectively out of the 23 harvests with most occurring within the first two years after experiment commencement (Table 1). It is clear that P and lime were major drivers of legume productivity and persistence, and that within the P1 and sewage ash treatments, the low P levels reduced legume growth.

Conclusions

- The standard Southern Tablelands superphosphate rate, 125 kg/ha applied every two to three years is inadequate leading to subterranean clover pastures highly responsive to extra P.

Table 1. Harvest occasions when yields of subterranean clover biomass showed significant differences under nine treatment combinations of superphosphate (P1, P2), lime (L0, L1, L2), sewage ash (P3, L3) and stocking rate (SR1, SR2) from September 1999 to February 2006 at Sutton, NSW. Z scores ($P = 0.05$) show significant differences between data modelled with splines. (*1.s.d., $P = 0.05$ was used between discrete points.)

Harvest month	Treatment									Z score
	P1L0 SR1	P1L1 SR1	P2L0 SR1	P2L0 SR2	P2L1 SR1	P2L1 SR2	P2L2 SR1	P2L2 SR2	P3L3 SR2	
Sep 99	130	138	336	114	316	183	201	326	270	188
Oct 99	706	687	1011	622	968	689	838	870	835	226
Dec 99	359	344	762	292	709	392	528	626	793	321
Jun 00	241	30	299	137	59	126	160	192	240	211
Jul 00	325	61	387	197	96	192	215	272	314	210
Sep 00	415	50	481	255	89	265	249	377	286	234
Oct 00	1857	1321	1931	1562	1470	1560	1657	1696	1403	261
Dec 00	888	300	972	569	408	580	630	742	546	344
Jan 01	330	218	547	328	245	367	464	494	347	187
Mar 01	128	45	327	103	61	147	253	236	210	172
Apr 01	92	22	267	88	32	146	208	215	149	167
Jun 01	113	58	270	127	79	197	225	226	205	163
Jul 01	43	0	169	49	3	128	133	137	80	163
Sep 01	87	53	227	176	113	275	216	248	144	167
Oct 01	281	252	550	408	444	499	541	461	328	172
Jan 02	52	17	207	47	19	60	75	40	70	119
Mar 02	241	205	381	228	235	238	283	213	141	106
Apr 02	69	46	162	59	49	79	90	51	58	102
May 03	150	69	153	61	116	79	170	73	86	90*
Jun 04	24	46	88	150	189	70	83	71	81	131*
Jul 04	93	131	87	87	161	78	184	33	86	131*
Dec 05	169	313	34	343	432	593	398	266	315	370
Feb 06	49	248	15	181	224	207	135	125	261	153

- On acidic soils with high levels of exchangeable Al³⁺ the addition of lime in the presence of sufficient P improves subterranean clover production and persistence even under drought conditions.
- The addition of adequate P alone is not enough to maintain clover production on acidic soils with high exchangeable Al³⁺.

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Poultry litter as a fertiliser: 30 years of development

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Abstract: *Understanding and attitudes to the use of poultry litter as a fertiliser have changed over time. Testing and monitoring of both poultry litter and soils where it has been applied have contributed to changes in the way it is used. The answer to the question 'Is poultry litter a great resource or an environmental hazard?' is 'It can be both'. It is a great resource and management today aims to maximise the benefits and minimise any problems. Using poultry litter as a phosphorous fertiliser has reduced most of the overuse issues seen in the past. It is a variable product which contains most macro and micro nutrients plus carbon. These nutrients are not perfectly balanced but can provide a cost effective base for a fertiliser program to be supplemented with other fertilisers as required.*

Key words: chicken manure, soil fertility, pasture growth, pathogens, disease risk

In the beginning

When I began working with poultry litter (PL) in the Hunter Valley NSW in the 1980s it was mainly considered a waste disposal issue for the broiler (meat) chicken industry. The main concern was water pollution as it was often applied at excessive rates by poultry producers onto their own properties. At this time PL was mainly considered a nitrogen (N) fertiliser which contained other nutrients. There was no restriction on ruminant animal access to poultry litter in stock piles or when spread on paddocks. Repeated high applications as an N fertiliser led to a build-up of high levels of phosphorus (P) in soil and associated increased risk of P runoff. The latter is considered a contributing factor to blue-green algae developing in still water in hot weather (CSIRO 2019).

In the 1980s multi-batch litter was produced from an annual clean out of broiler sheds, with lime sometimes spread on litter between batches of chickens. This influenced soil test results in 1997 when soils from paddocks with a history of PL application were compared with nearby paddocks which had received superphosphate or nil fertiliser (Griffiths 2000b). Major findings from this comparison were the increase in average soil P levels from 37 to 360 ppm (Colwell) and average soil pH_{Ca} 4.7 compared to 5.3 where PL had been repeatedly applied.

At about the same time a range of PL from the Lower Hunter and Central Coast was tested for nutrients and trace elements. Nutrient analyses

of 22 single batch poultry litter samples showed average total nitrogen N = 4.9%, P = 1.8% and potassium (K) = 1.4%. These levels were the source commonly referred to in a number of publications including *Poultry Litter: A great resource or environmental hazard* (Griffiths 1998) and *Best Practice Guidelines for using poultry litter on pastures* (Griffiths 2000a). Although PL was alkaline due to its ammonia content, lime was not applied to single batch litter and so it did not have the same neutralising value as seen in later studies.

Management systems in broiler sheds changed after 1997 from naturally ventilated open-sided sheds to enclosed tunnel ventilated systems. This coincided with increased stocking rates, changes in type of material used for bedding and changes in diet. As reported in Griffiths (2015) a mix of 38 broiler, turkey and layer sheds were sampled in 2010 with the major change from 1997 analyses being a drop in average P content in broiler litter from 1.8 to 1.1% P. This reduction was mainly attributed to a change of diet with the introduction of phytase enzyme improving efficiency with less P being fed to and excreted by broiler chickens. Average P levels in turkey litter (1.7% P) and layer manure (2.2% P) remained similar to previous testing.

A knowledge of nutrient values in PL and the affect it had on soil test results led to recommendations that PL should primarily be used as a source of P rather than focusing on N. Comprehensive nutrient analysis of PL meant that application rates and costs could be compared with other fertilisers leading to greater appreciation of the fertiliser value of

PL and its application to a larger area by more producers. Effectively it meant reducing PL use in areas with a long history of PL application and applying it to new areas where soil tests showed P was needed. It was particularly cost effective when developing land that was deficient in most major nutrients and trace elements. In these situations it became known as 'half price fertiliser' due to its NPK value compared to other fertilisers. By focusing on soil testing and using PL as a P fertiliser most of the previous overuse issues could be avoided. Testing of PL has added to the understanding that it is an inherently variable product, which should be considered when sampling, testing, costing and using it as a fertiliser.

Some other changes

Over time understanding and attitudes have changed toward using PL as a fertiliser. While it is standard practice in some areas it is contentious in others especially where communities are not familiar with the product. In response, NSW Department of Primary Industries developed guidelines and training for producers, contractors and users to support the use of PL as 'a great resource not an environmental hazard'.

Pathogens and disease risk

Poultry litter is manure and can contain pathogens, so the poultry industry has developed guidelines to reduce disease risk within its industry. The grazing industries are more concerned about disease risk to grazing animals which has led to the adoption of two practice changes:

- The mandatory exclusion of grazing animals from PL dumps, storage sites and paddocks where PL has been spread for at least three weeks or until poultry residue is not present. This withholding period is considered sufficient to facilitate the environmental degradation and inactivation of pathogens due to sunlight and desiccation.
- Vaccination of cattle to protect them from botulism. Botulism is not common where PL is used on pastures but can be devastating if it occurs.

Poultry litter use in cropping areas

As poultry production has increased in inland grain producing areas such as Tamworth and Griffith, use of poultry litter as a fertiliser on crops has also increased. Applications of PL can have both positive and negative effects in cropping. Deep application of high rates of PL into sodic subsoils in the high rainfall cropping zone in Victoria was found to be profitable despite the very high cost (Lush 2013; Sale *et al.* 2015). However, excessive PL applications on crops can reduce grain yield by promoting vigorous early growth with associated increased water use and risk of lodging and/or moisture stress toward the end of the growing cycle (Rural Directions 2015).

Value adding poultry litter

To date most attempts to value add to poultry litter have increased costs to the end user but not increased returns to the poultry farmer. Pelleting provides convenience when handling and applying through standard machinery. But the nutrient content of pellets depends on the type of manure used, whether it is composted and if other nutrients are added. The pelleting process often means the cost of nutrients in the pelleted product is double that in the raw manure. End users must decide if convenience, reduced pathogen risk and any changes in nutrient balance provide good value.

Composting is used to reduce the volume of PL to be handled, reduce pathogen risk and provide a more stable product. Ideally PL will be mixed with straw or other carbon sources for efficient composting. It must also be turned and maintained at ideal moisture levels to achieve temperatures required to kill pathogens. The volume of PL will commonly halve when composted thereby reducing transport and application costs. However, the time and labour required for composting adds to the cost of production and composted PL has less N than raw PL. End users must decide if the reduced pathogen risk and any changes in nutrient content provide good value. Often PL will age in a storage area with associated changes in volume and nutrient content but this aged litter is not

turned and properly composted so still contains a pathogen risk.

Total trial contributes to understanding

A trial was established on a kikuyu (*Pennisetum clandestinum*)/ryegrass (*Lolium multiflorum*) pasture at the Tocal Agricultural Centre dairy in 2002. Initially the trial was used to measure N and P in runoff from three treatments with two replications. The treatments were (1) Litter – 15 m³ of PL applied annually, (2) BMP – 15m³ of PL applied every second year plus 100 kg/ha urea (46% N) every 3 months, (3) Fertiliser - applied equivalent NPK to Treatment 1 using di-ammonium phosphate (18% N, 20.2% P, 1.5% sulphur), urea and muriate of potash (50% K). After three years the runoff project was completed but the trial site was maintained for a further 12 years. Treatment 3 was changed to monthly applications of 100 kg/ha urea when the pasture was actively growing as high levels of P had accumulated. Pasture growth was measured using pasture cages and soil testing was continued.

As can be seen in Fig. 1 the site was high in P when the trial started due to the initial focus on monitoring nutrient runoff. There was variation across the three treatments but generally the annual PL applications more than doubled the P levels in the period 2002–16. The BMP treatment roughly maintained P levels, while P levels fell in Treatment 3 but still had adequate P despite applying only urea for 10 years. Subsequently, there was a drop in soil pH with the urea only treatment compared to the PL treatments (Fig. 2).

Pasture growth varied from year to year depending on seasonal conditions and management as can be seen in Fig. 3. Total pasture dry matter production for the duration of the trial (15 years) for each treatment was Litter (Treatment 1) 190 t DM/ha, BMP (Treatment 2) 202 t DM/ha and Fertiliser (Treatment 3) 203 t DM/ha. Considering all treatments had excessive P levels it is considered that pasture growth was mainly limited by water, when not irrigated, and N levels. As with past comparisons (Griffiths 2009) if current fertiliser costs were applied to these yields then PL would be very cost effective but this may vary depending on

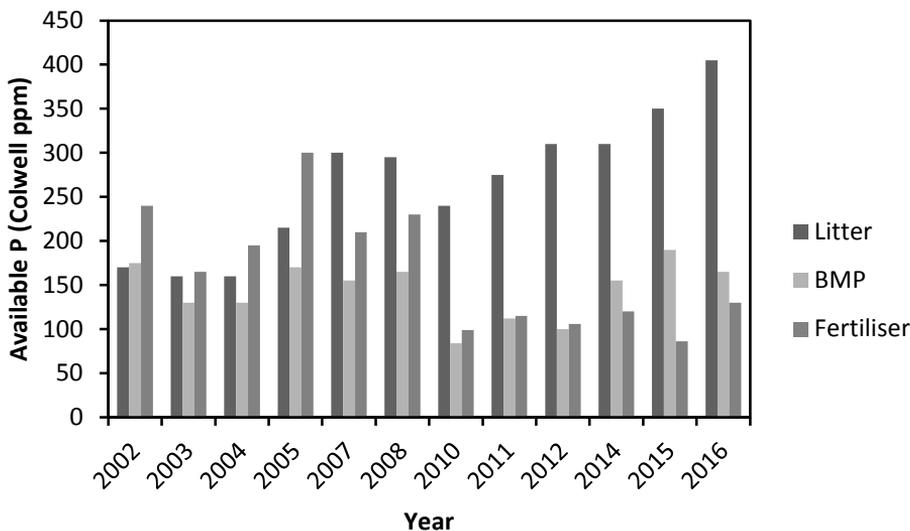


Figure 1. Changes in available soil phosphorus (P, Colwell, ppm, 0–10 cm) from three treatments in a poultry litter trial at Tocal Agricultural Centre.

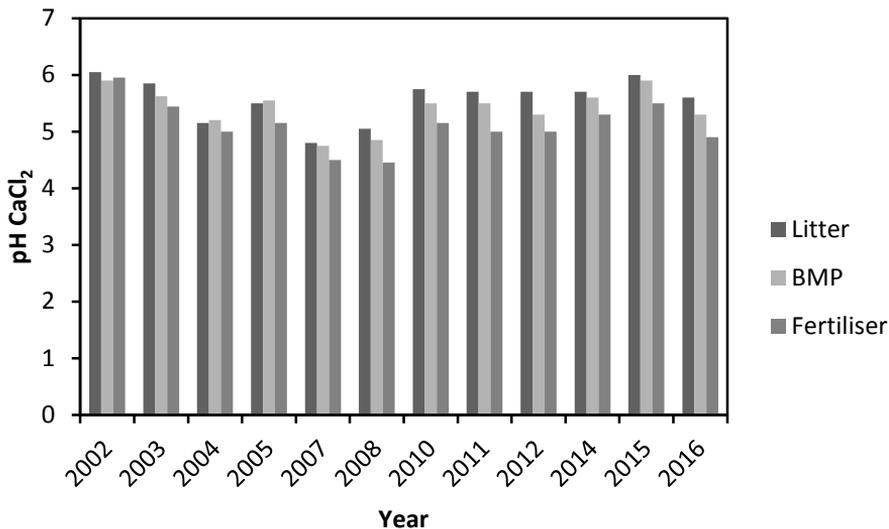


Figure 2. Changes in soil pH (CaCl₂, 0–10 cm) from three treatments in a poultry litter trial at Tocal Agricultural Centre.

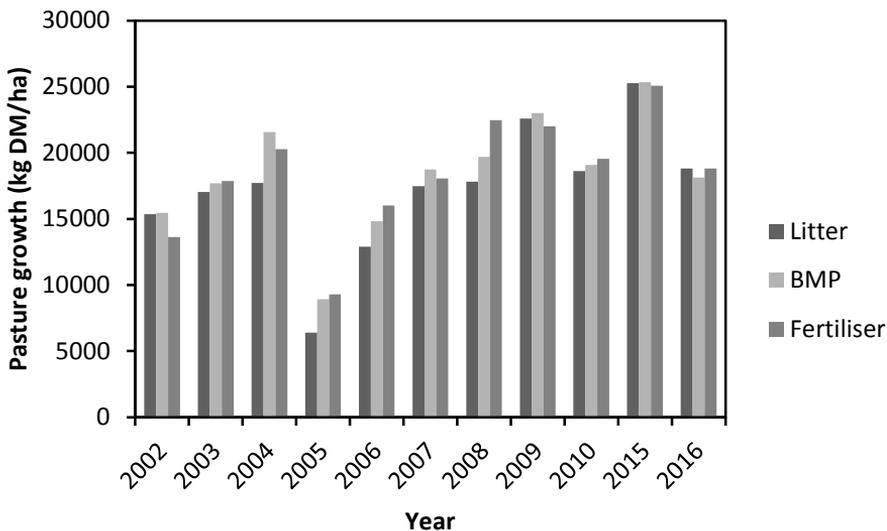


Figure 3. Annual pasture growth (kg DM/ha) from three treatments in a poultry litter trial at Tocal Agricultural Centre.

costs for PL and fertiliser from year to year. The PL would be much more cost effective in a situation where a P response was expected, remembering this site was already high in P.

The future

In future, PL will continue to be a valuable fertiliser resource if used wisely. It will be cheapest if used close to the source and if application rates are based on soil test results to ensure maximum benefit is obtained from the nutrients and organic matter it contains. The environment and neighbours must be considered when transporting, storing and applying PL to ensure that it can continue to be used sensibly and without prohibitive regulation.

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