final report

Project code: B.NBP.0768

Prepared by: David Lawrence, Stuart Buck, Brian Johnson, Gavin Peck

Department of Agriculture, Fisheries and Forestry

Date published: October 2014

ISBN: 9781740362757

PUBLISHED BY
Meat & Livestock Australia Limited
Locked Bag 991
NORTH SYDNEY NSW 2059

Fertilising for yield and quality in sown grass pastures and forage crops

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

Abstract

Sown pasture rundown and declining soil fertility for forage crops are too serious to ignore with losses in beef production of up to 50% across Queensland. The feasibility of using strategic applications of nitrogen (N) fertiliser to address these losses was assessed by analysing a series of scenarios using data drawn from published studies, local fertiliser trials and expert opinion. While N fertilser can dramatically increase productivity (growth, feed quality and beef production gains of over 200% in some scenarios), the estimated economic benefits, derived from paddock level enterprise budgets for a fattening operation, were much more modest. In the best-performing sown grass scenarios, average gross margins were doubled or tripled at the assumed fertiliser response rates, and internal rates of return of up to 11% were achieved. Using fertiliser on forage sorghum or oats was a much less attractive option and, under the paddock level analysis and assumptions used, forages struggled to be profitable even on fertile sites with no fertiliser input. The economics of nitrogen fertilising on grass pasture were sensitive to the assumed response rates in both pasture growth and liveweight gain. Consequently, targeted research is proposed to re-assess the responses used in this analysis, which are largely based on research 25-40 years ago when soils were generally more fertile and pastures less rundown.

Photo 1. Dramatic responses from 50-200 kg N/ha as Green Urea® were a catalyst to assess the feasibility of using nitrogen fertilisers for yield and quality in grass pastures and forages

Acknowledgements

The support of regional experts in sown pastures, soils, and dairy and beef nutrition, who gave freely of their time, is greatly appreciated. However, the authors would like to specifically acknowledge the time and effort of those experts who attended a two-day meeting to collate information and data, and/or contributed key data and interpretation of the subsequent results: Mike Bell, Chris Guppy, Mark Callow, Jack Fitzgerald, Roger Sneath, Sid Cook, Jo Owens, Maree Bowen and Suzanne Boschma. We especially acknowledge Fred Chudleigh for his recommendations on the economic approach, the data subsequently required, and the conduct of the economic analysis in-line with the limitations of a small scoping study. A full copy of the economic analysis is included in the appendix of this report. The support of Meat & Livestock Australia to conduct the study is greatly appreciated.

Executive summary

Sown grass pastures and forages can produce more feed of better quality than native pastures alone. However, their productivity declines over time. Sown pastures become 'rundown' from a lack of available nitrogen (N) as N becomes immobilised into organic matter under ageing swards; while forage crop productivity declines as soil organic matter levels and the subsequent supply of nutrients decrease with continued cultivation.

Fertilisers, especially those containing N, have the potential to recapture the initial high levels of production for both sown grass pastures and forages. This potential has been re-emphasised in recent farm trials that have typically increased dry matter production by up to 200% and lifted the absolute protein levels in the feed by an additional two to four percentage points (e.g. from 3-4% to 6-8%). These fertiliser responses are expected to become more dramatic as sown pastures and cultivations across southern and central Queensland become older, sparking renewed interest in the feasibility of using N fertilisers in these regions where most of the sown pastures and forages are grown.

The project assessed the feasibility of using N fertiliser on the rundown sown grass pastures and on the soils that support forage sorghum and oats in southern and central Queensland, specifically to:

- Better understand the growth and feed quality responses from applying nitrogen fertiliser to existing sown grass pastures, and both nitrogen and phosphorus fertilisers to forage sorghum and oats;
- Assess the likely economic returns and the conditions that determine the profitability of fertiliser use; and
- Identify significant information gaps and priorities for any further research, development and/or extension investment.

Likely on-farm impacts were developed into a series of possible scenarios for 'proof-of-concept'. Data was collated from published studies, results from local fertiliser trials and expert opinion. The resulting production outcomes were then assessed using paddock level enterprise budgets and discounted cash flow techniques. The economic analysis was based on a steer turnover/bullock production enterprise that purchased store steers and sold finished Ox to the meatworks. This method was considered the most appropriate way to filter the production responses and identify the level of response needed to improve the relative profitability of pasture and forage systems. Findings on the overall economic merit of the treatments analysed are therefore limited to how they compare in a relative sense to the base treatment. Extrapolation of the results to how the predicted responses may impact the economic performance of any farm business would be misleading. Whole farm analyses were not possible given the dose rate/response rate nature of data that was readily available for the scoping study, and were therefore seen as being outside the scope of this review.

Results

Pastures and forages have to be in good condition, quite productive and show a significant response in both stocking rate per hectare and growth rate per head, before any potential economic benefit to fertiliser can be expected for fattening enterprises that purchase all their stock. Adding fertiliser to a low output system does not appear viable.

The study concludes that fertiliser use on sown grasses is a better investment than fertilising forage sorghum or oats. The high costs associated with the production of annual forages and the low average margins makes the profitability of forages quite low, regardless of whether or not fertiliser is applied. Very high rates of response in both dry matter (DM) production and liveweight gain are required to make fertiliser applications on forage crops profitable.

Results from this study suggest that applying nitrogen fertilisers to rundown sown grass pastures can produce dramatic increases in dry matter yield and animal production. However, a relatively high and consistent response rate in both pasture yield and quality was required for the application of nitrogen fertiliser to be profitable. The analyses in this study found application of 100 kg N/ha was consistently more profitable than application of 50 kg N/ha. For the suggested 100 kg N/ha fertiliser rate:

- average gross margins in the year of application were calculated to increase by 121%-217% when dry matter yield responses of 40 kg DM/kg N (i.e. an additional 4000kg/ha) and an additional liveweight gain of 0.2 kg/AE/Day (i.e. an extra 70 kg AE/year) can be achieved; and

- an Internal Rate of Return of 11% is also possible for the same pasture growth response rate if potential carryover nitrogen responses were included in subsequent years, and the additional liveweight gain was more conservatively spread across two years (50 kg/AE in the first year and 20 kg/AE in the second year).

Recent trials and the reinvestigation of past research suggest that this 40 kg DM/kg N response rate is achievable on long-established pastures. However, the economic analyses also suggest that lower dry matter response rates and/or liveweight gain responses will likely fail to be profitable.

Conclusions and recommendations

This study highlights some of the challenges for intensifying the beef production systems based on sown pastures. The fertiliser scenarios suggest that it will be difficult to achieve attractive rates of return if the only benefit is increased carrying capacity. The opportunity cost of the extra investment in stock means that fertiliser use will need to also significantly increase the performance of individual animals.

Recent data from replicated and non-replicated on-farm trials suggests the pasture growth response required for nitrogen fertiliser to be profitable (40 kg DM/kg N) is achievable. However, there are insufficient data to assess the variability of these responses over a range of seasonal conditions. Further, there are few data on impacts of fertiliser on feed quality and liveweight gains per head. Consequently, further research is recommended to clarify:

- The pasture growth response to applied nitrogen fertiliser. Research is needed to clarify whether the expected rate of 40 kg DM/ha can be achieved consistently; and

- Liveweight gains per head from increased feed quality. This impact on liveweight gain is critical to the profitability of using fertilisers and needs clarification.

Therefore, additional research is needed before the potential for modest economic returns to applying N fertiliser on sown grass pastures can be confirmed.

Table of Contents

1 Background

Sown pastures are able to produce more feed, of better quality, for longer periods of time than native pastures alone (Quirk and McIvor 2005). Consequently, sown pastures have been widely used in the more favourable areas of northern Australia and continue to improve production and economic returns for the beef industry (Chudleigh and Bramwell 1996; Walker *et al*. 1997). This pasture development was part of a substantial investment in research, development and extension (RDE) from the 1970s that achieved impressive gains in productivity (Ash *et al*. 2013).

There are now approximately 12 million ha of sown pastures across northern Australia, with the majority in Queensland where they make a major contribution to the economy (Peck *et al*. 2011). Sown pastures and forages underpin \$1.3~\$1.4 billion per annum of beef production in the 'Mixed farming zone' of southern and central Queensland (DPI&F Prospects Update 2007-2012). This represents approximately 40% of Queensland's total beef output and typically matches the total annual value of Queensland's grain and cotton production.

However, rates of productivity improvement for beef (e.g. beef yield per animal) have slowed over the last decade and northern beef enterprises now face significant economic challenges, especially to remain viable (Ash *et al*. 2013). Return on assets may average less than 2% (McCosker *et al.* 2009) and options to intensify northern beef production systems are being considered (Watson *et al.* 2013).

Many of the sown pastures developed across southern and central Queensland since the 1970s are now 'rundown' and have suffered declines of approximately 50% in pasture productivity; declines caused by a lack of available soil nitrogen as pastures age (Myers and Robbins 1991; Graham *et al.* 1981). The mineral nitrogen in these rundown pastures becomes immobilised in the established grass plants and soil organic matter (Graham *et al.* 1985; Myers and Robbins 1991; Robertson *et al*. 1997).

Rundown affects all grass and grass-legume pastures but is most severe in the grass-only pastures that represent up to 70% of the total area planted in Queensland (Walker *et al*. 1997; Walker and Weston 1990). The economic impact of this rundown is estimated at over \$17 billion at the farm gate over the next 30 years (Peck *et al.* 2013a).

The effects of rundown can be mitigated by increasing the nitrogen supply to the soil with either fertilisers or legumes. Recent consultation with industry, review of scientific literature and economic analysis have confirmed the consensus that adapted legumes provide the best option to improve productivity of rundown sown grass pastures (Peck *et al.* 2013a). Legumes will provide significant productivity benefits across much of northern Australia, and generally good returns on capital investment across Queensland, as long as adapted legumes can be successfully established (Ash *et al.* 2013). Attempts to establish these legumes have routinely used low-cost, but high-risk methods, with little or no ground preparation. The subsequent failures have resulted in the widely-held perception that legumes are difficult to establish.

The MLA project (B.NBP.0639) '*Improving productivity of rundown sown grass pastures'* is currently assessing adapted legumes and demonstrating better agronomic practices to improve the reliability of establishment in Queensland. Annual medics have established in large areas of south Queensland, but with the exception of leucaena, there are very limited areas of perennial summer legumes that are established at adequate populations to mitigate rundown. Better agronomy to store soil moisture prior to planting and to reduce competition from existing grasses and weeds is showing potential to improve the reliability of establishing pasture legumes adapted to southern and central Queensland (Peck *et al.* 2013b).

Further improvements in pasture agronomy are now being investigated. An MLA project (B.NBP.0769) has reviewed the use of fertiliser phosphorus for increased productivity of legume-based sown pastures in the Brigalow Belt. While fertilisers are rarely used on rainfed pastures in southern and central Queensland, this review has concluded that applying phosphorus to increase legume growth for better animal production and increased grass pasture production can deliver significant internal rates of return (Peck *et al.* 2014) for each dollar invested:

- 9-15% when establishing and fertilising legumes into grass pasture on low Phosphorus soils;
- 12-24% when applying phosphorus fertiliser to already established grass legume pastures; and
- 15-22% when establishing legumes into high phosphorus soils that do not require additional phosphorus from fertiliser.

These are encouraging returns and highlight the opportunity for further intensification of the beef production systems across southern and central Queensland where sown pastures are predominately used.

The economic feasibility of using nitrogen fertilisers on grass-based pastures within the low-cost production systems of northern Australia has traditionally been dismissed in favour of legume augmentation as the long-term solution for pasture rundown (Jones *et al.* 1995; Peake *et al.* 1990). However, dramatic increases in both dry matter and feed quality have been measured by the ‘pasture rundown’ project across 50+ on-farm demonstrations of Green Urea® (Lawrence *et al.* 2013). These demonstrations were designed to help graziers to assess the extent of rundown in their pastures and show that a lack of available nitrogen is the underlying cause. Yet, these dramatic responses have raised interest from graziers and researchers in using nitrogen fertilisers in three situations:

1. To boost production on targeted areas of pasture (for example, providing quality feed to ‘finish’ stock, or to support stock while other paddocks across the property are progressively augmented with legumes)
2. On low-phosphorus soils where the potential of legumes is limited, and
3. In ley pasture rotations where soil nitrogen levels may be low but high dry matter production is required to maximise returns and soil health benefits.

These dry matter responses and anecdotal evidence from graziers that nitrogen fertiliser ‘does pay’ prompted this scoping study to investigate the feasibility of fertilising grass pastures and forages to boost animal production. Another argument underpinning the scoping study is that Queensland beef producers may have entered a development phase where it is ‘more economic’ to intensify their production system and improve the productivity of their existing property than to purchase additional land.

This report is focused on southern and central Queensland regions which cover the majority of the sown pastures, typically buffel grass. These regions are commonly called the ‘Mixed farming zone’ because they also contain most of the grain and cotton cropping in Queensland. This cropping activity reduces soil nutrient reserves and exacerbates rundown in pastures that are re-established after cropping. The mixed farming zone also includes large areas of forage crops, mainly sorghum and oats. While nitrogen responses of sown grasses were the catalyst for the study, the responses of forage crops were included due to anecdotal evidence from agronomists that many of these forage crops of oats and sorghum are also deficient in nitrogen and/or phosphorus.

2 Project objectives

There is renewed interest from graziers and scientists in the feasibility of using nitrogen fertilisers on sown grass pastures. This interest was sparked when dramatic dry matter and quality responses were observed in a large number of on-farm demonstrations designed to show that ‘pasture rundown’ was caused by a lack of available nitrogen. The size of these responses led to renewed questions about the feasibility of using nitrogen fertilisers for greater beef production, and to also sequester soil carbon for higher soil organic matter levels and healthier soils. If economically viable, the use of nitrogen fertilisers would provide another method of mitigating rundown to complement the long-term solution of establishing legumes.

Soil carbon data from forage sorghum and forage oats showed that long-term forage cropping paddocks were only ‘on-a-par’ with those used to grow grains. These data suggest that many forage crops were not reaching their full yield potential, as the higher dry matter levels possible in forages should ensure higher soil carbon levels than grain cropping systems, in which up to 50% of the above ground dry matter is removed. Anecdotal evidence suggests many forage crops are visibly nitrogen deficient and may also be grown in soils with declining soil phosphorus levels.

A considerable amount of research on nitrogen in ageing sown pastures was conducted in the 1970-90s, and the project team was aware of ‘unpublished data’ that was also discussed within the local scientific community. This short scoping study was commissioned to revisit the nitrogen fertiliser use on sown grasses, and investigate the use of both nitrogen and phosphorus on forage oats and forage sorghum. The project was not intended to be an exhaustive review of literature, but rather to collect the best readily-accessible input data for an economic assessment of fertiliser use. The specific objectives were to:

1. Quantify the dry matter (kg DM/kg N) and feed quality (protein) impacts of applying nitrogen fertiliser to existing sown grass pastures across central and southern Queensland;
2. Determine the loss of production and likely responses of forage crops (oats, sorghum) to better nitrogen and phosphorus management on mixed farms across central and southern Queensland;
3. Assess the likely economic returns and the conditions that determine the profitability of fertiliser use for beef producers in central and southern Queensland; and
4. Identify significant information gaps and priorities for any further research, development and/or extension investment.

3 Pasture development and soil fertility

The expansion of sown pastures across southern and central Queensland has been underpinned by the accidental introduction of buffel grass to Australia in the 1870s and the widespread sowings that occurred from the 1960s through the Brigalow Area Development Schemes (Cavaye 1991). Land was commonly developed by clearing and burning of timber and directly sowing pastures; or after a short cropping phase to control regrowth. Higher returns from this cropping phase helped recoup initial development costs, and encouraged prolonged or permanent cropping on the deeper and more fertile brigalow/belah soils.

Consequently, southern and central Queensland have become a ‘mixed farming zone’ that contains large areas of:

1. sown and naturalised pastures that are dominated by buffel grass and have never been cropped;
2. long-term cropping with both grains and forages; and

3. long-term cropping that has since been sown to pastures, or abandoned and left for invasion by the dominant pastures species in the local area.

Each of these land areas has its own specific challenges to maintain feed quantity and quality. For example, old cropping land, with very low levels of organic matter and mineralisation of nitrogen, may be expected to develop rundown much faster than recently developed country that still has higher levels of organic matter and nitrogen to support pasture growth. These older cropping soils may be more suited to nitrogen fertilisers if phosphorus is also depleted to levels that preclude productive legume growth. The viability of using phosphorus fertilisers on these soils to support legume production and subsequent mineralisation of nitrogen for increased grass growth is being assessed by the MLA project (B.NBP.0769). Finally, it is worth noting that while grasses and legumes may require similar levels of phosphorus (McIvor 1984), the potential phosphorus deficiencies in grasses are typically masked by a greater deficiency in available nitrogen.

3.1 Pasture rundown

Following initial development, pastures were very productive with abundant nitrogen available for grass growth as the naturally high levels of soil organic carbon and organic nitrogen under the original timber were mineralised. However, major declines in dry matter production were recognised within the first 10 years following development (e.g. Radford *et al*. 2007, Figure 1).

This decline in pasture productivity is commonly known as 'pasture rundown' and is caused by a decline in the levels of mineral nitrogen under ageing sown pastures. The levels of plant available nitrogen become insufficient to maintain the initial levels of pasture growth (Graham *et al.* 1981; Jones *et al.* 1995; Robbins *et al.* 1986; Robbins *et al.* 1987). Key conclusions on the process of rundown include:

- Pasture production is initially very high due to an initial 'flush' of nutrients when the original vegetation is removed, perhaps burnt, and a large pool of organic matter begins to mineralise nitrogen at rates as high as 100-300 kg/ha per annum (Dalal and Mayer 1984; Cox *et al.* 2002).

- On pastures that have never been cropped, the overall plant/soil nitrogen levels in rundown paddocks remain high. However, available nitrogen declines to very low levels in grass pastures as nitrogen becomes immobilised and unavailable for plant growth. This nitrogen is 'locked up' in the growing plants, litter, microbial biomass, but primarily, in the soil organic matter (Table 1. Graham *et al.* 1985; Robertson *et al.* 1997).

- Initial grass pasture mixtures of Rhodes, Green Panic and Buffel grass, which were commonly used across the brigalow belt, have become buffel dominant as the other species declined due to drought and low available nitrogen levels (Jones *et al*. 1995; Peck *et al*. 2012).

- Animal production per hectare typically declines by ~50% in line with the reduced dry matter production and nitrogen/protein content of rundown pastures (Jones *et al*. 1995, Radford *et al*. 2007; Robbins *et al*. 1987)

- The annual dry matter production from sown grass pastures can decline by ~50% within five to ten years of establishment across a range of soil and seasons (Figure 1, Radford *et al.* 2007; Graham *et al.* 1981; Myers and Robbins 1991; Robbins 1984; Robbins *et al.* 1986; Robbins *et al*. 1987). This rundown occurs most rapidly on the less fertile soils that have lower soil organic matter levels because they are unable to mineralise as much nitrogen each season compared to soils with higher soil organic matter levels (Jones *et al*. 1995; Mannetje and Jones 1990).

Table 1. Nitrogen content of soil (0-30cm) and plant pools in a 14 year old buffel grass pasture in central Queensland (Graham *et al*. 1985).

Component	**kg N/ha**	**Percent of total.**
Grass tops	21	0.63
Grass litter	4	0.12
Grass root	207	6.17
Microbial biomass	152	4.53
Soil Mineral N	10	0.30
Soil Organic N	2960	88.25
Total	3354	

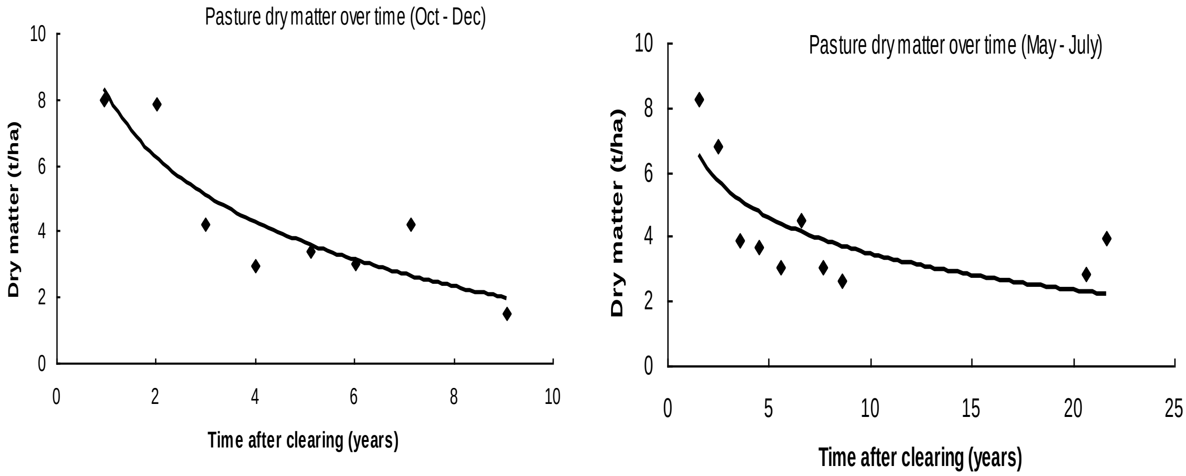

Figure 1: Pasture dry matter on offer during 22 years since clearing during the early growing season (October–December) and the end of the growing season (May–July) (Radford *et al*. 2007)

These impacts on pasture and animal production provide a strong imperative for the grazing industries and individual graziers to manage rundown and mitigate its impacts on their own properties. There are three basic strategies for mitigating these impacts on pasture productivity (Peck *et al.* 2013a):

1. Accept reduced pasture productivity: adjust management practices (e.g. reduce stocking rates) in line with productivity to maintain animal, environmental and economic performance.

2. Increase Nitrogen cycling and availability: practices (e.g. mechanical renovation) that provide soil disturbance, plant death and increase nitrogen cycling from decomposition of organic matter will increase the supply of available nitrogen, at least in the short-term.

3. Add Nitrogen: key practices to increase total and available soil nitrogen levels are direct addition by fertilisers, or biological fixation using pasture legumes.

The ongoing MLA project (B.NBP.0639) *'Improving productivity of rundown sown grass pastures'* is focusing on legumes as the most widely applicable and cost effective long-term solution. Using fertiliser to directly increase soil nitrogen, along with mechanical renovation practices, were initially assessed to have marginal returns for most graziers. This conclusion reinforced the colloquial dismissal of fertilisers as 'not economic', especially in southern and central Queensland where fertiliser for cropping is not yet universal. However, more recent dry matter responses that are well in excess of previously accepted levels, have prompted the current investigation of the feasibility of nitrogen fertilisers on sown grass pastures.

3.2 Soil fertility

Recent projects assessing soil organic matter and carbon levels on mixed farming systems across southern and central Queensland have highlighted major impacts on soil organic carbon levels from different land uses, farming practices and reduced soil nitrogen and phosphorus levels (Lawrence *et al.* 2012).

Soil organic carbon levels are a direct reflection of total dry matter production in the paddock and its subsequent decomposition in the soil (Hoyle *et al.* 2011). Results from southern and central Queensland suggest that dry matter production in both pastures and forage crops is being significantly reduced by nitrogen and phosphorus deficiencies across the region (Lawrence *et al.* 2013; Lawrence and Johnson 2013).

Specific soil test data (Lawrence, unpublished) from paired comparisons of ~600 paddocks with long-term (5-10+ years) management differences highlight that:

- Colwell bicarbonate phosphorus levels (0-10cm) on 100 mixed farming paddocks across south Queensland were as low as 1 mg/kg, with 23% of soils below 10 mg/kg and 45% of sites at 15 mg/kg or lower (a critical level below which most pasture legumes and forage crops are likely to respond to applied phosphorus fertiliser). The results for Brigalow/belah soils were very similar to the overall results from all soils. The Open downs/Coolibah soils were more fertile with a lower proportion of soils likely to be phosphorus deficient. The Poplar box/sandalwood woodland soils were less fertile with 30% of soils tested below 10 mg/kg and 57% at or below 15 mg/kg Colwell bicarbonate phosphorus.

- Total soil organic carbon (TOC) and total organic nitrogen (TON) levels (0-10 cm) under long-term cropping have typically declined to 50-60% of levels that existed under native vegetation. These declines were most extreme on the fertile brigalow/belah scrub soils that commonly declined from 3-3.5% TOC to 1-1.5% TOC after 30+ years of cropping. These data are consistent with past studies (Dalal & Mayer 1986) and with the associated decline in the amount of nitrogen that is mineralised annually on these clay soils (Figure 2, Cox *et al.* 2002).

- Reducing total soil nitrogen reserves to 30-40% of their original levels will impact on nitrogen cycling. Less nitrogen will be mineralised and become available for pasture growth, which could subsequently be expected to result in more rapid and severe rundown of grass-based pastures following prolonged periods of cropping. Declines of ~2% TOC (0-30 cm) in brigalow/belah soils under long-term cropping represent losses of soil nutrients worth ~$6000-$8000 per hectare (Lawrence *et al*. 2013). The benefit of legumes for mitigating pasture rundown will also be diminished if this decline means soil phosphorus levels become deficient and unable to support good legume growth.

- Total soil organic carbon (TOC) and total organic nitrogen (TON) levels have also decreased when native vegetation (remnant) is cleared and developed for either sown or native pastures. The sown pastures were typically ~10% higher than native pastures, but were themselves ~30% lower than the remnant soils. This is not surprising as the nitrogen deficiency that causes ‘sown pasture rundown’ will constrain total dry matter production to lower levels than timber stands can sustain, especially leguminous species such as Brigalow. These results are ‘in-line’ with the 20% mean decline in Total Nitrogen observed by Graham *et al*. (1981) between virgin and sown pasture paddocks, but at odds with the improvements they observed in some soils. These results also suggest that sown grass pastures that are fertilised with nitrogen to maintain high dry matter production will have significantly higher soil organic matter and soil organic carbon levels than those that are allowed to 'rundown' over time.

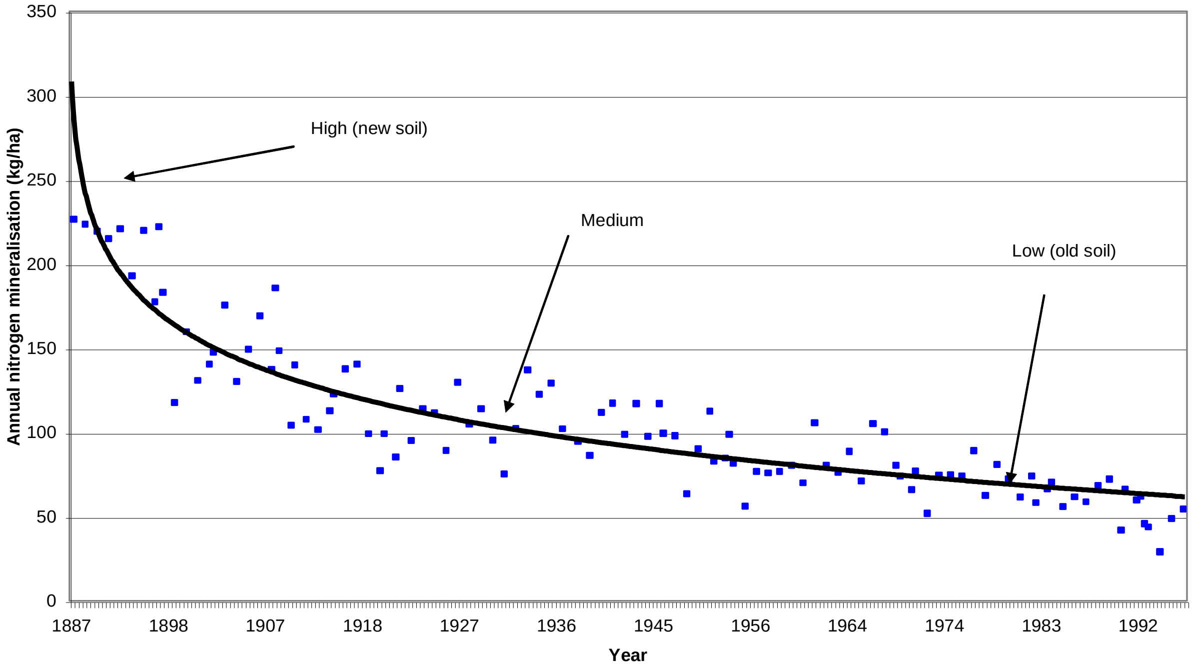

Figure 2. Simulation of reduced nitrogen mineralisation with age of cultivation on vertosols in central Queensland (Cox *et al*. 2002)

The opportunities and feasibility to fertilise for increased yield and quality in grass pastures and forages will depend on the underlying soil nitrogen and phosphorus fertility, and changes created by land uses and management. These results may reflect the increasing age of many sown pastures and cultivations across southern and central Queensland. The results also suggest that responses to nitrogen in sown pastures, and responses to nitrogen and phosphorus in forage crops, are likely to be more common and/or greater than measured in research ~30 years ago.

4 Sown pastures

This study of the feasibility of fertilisers on sown pasture grasses is focused on nitrogen because the supply of nitrogen to plants almost universally limits grassland productivity (Reuss and Innis 1977). Consequently, it is the soil's nitrogen status and ability to supply available nitrogen that interacts with rainfall to drive dry matter yields in most grass-based pastures.

Sown grasses and legumes have similar soil phosphorus requirements (McIvor 1984). However, the potential for phosphorus deficiency in grasses is usually masked by a more chronic nitrogen deficiency. Grass pastures rapidly deplete the available soil nitrogen and become acutely nitrogen deficient regardless of the soil phosphorus levels (McIvor *et al*. 2011). Legumes are commonly considered to require more phosphorus because their nitrogen requirements are typically met by biological nitrogen fixation. So, while sown grass pastures on highly deficient soils, such as the solodics of southern Queensland, may respond to high rates of phosphorus at establishment, direct responses to phosphorus are overwhelmed by responses to nitrogen as the pastures mature (Russell 1985a).

The study of fertilisers on forage crops includes phosphorus, as will the concurrent MLA project (B.NBP.0769): *Use of fertiliser Phosphorus for increased productivity of legume-based sown pastures in the Brigalow Belt region – a review*.

4.1 Dry matter responses to nitrogen applications

The growth of sown pastures, and hence the responses to added nitrogen, will depend on the underlying fertility of the soil, the age of the pasture and the subsequent degree of rundown, the extent of gaseous nitrogen losses when fertiliser is applied, the climate and the quantity of ensuing rainfall. However, the commercial use of nitrogen fertilisers to promote pasture yields in the region is limited, and advisers have used a generalised ‘response efficiency’ of 30 kg Dry matter (DM) for every kilogram of nitrogen (N) applied when discussing fertilisers with their clients (Lloyd *et al.* 2007). This figure (30 kg DM/kg N) arose from a study of three ‘moderately’ rundown buffel pastures in central Queensland with varying levels of Total Nitrogen that showed maximum yields at 240 kg N/ha, with near linear responses up to 120 kg N/ha and response efficiencies of 27-34 kg DM/kg N (Graham *et al*. 1981).

However, a series of 30 replicated and 40 non-replicated test strips across the region have suggested higher ‘response rates’ across a range of species and locations (Lawrence, Buck and Johnson, unpublished data). These strips were established with graziers to demonstrate that nitrogen was the cause of rundown and to help them assess the extent of rundown in their pastures. Green Urea® applied at ~100 kg N/ha in these trials increased dry matter yields by up to 200%. Sites that have been slashed or grazed, replicated and had nitrogen applied with support from scientists are confirming response rates up to 60 kg DM/kg N over several months. These higher response rates are consistent with results from northern New South Wales where tropical grass pastures have produced extra dry matter at response rates of up to 100 kg DM/kg N across the growing season (Boschma 2010).

Reinvestigation of reported data in a series of trials conducted in the 1960, 1970 and 1980s confirms that higher responses rates are possible. Mean response rates for nitrogen applications across several years, species and/or stocking rates varied from 19 to 46 kg DM/kg N, while individual nitrogen rates, species and/or years varied between 0 and 68 kg DM/kg N (Table 2).

Many of these trials were conducted within larger grazing experiments, with nitrogen responses reported as averages across different stocking rates and seasons. For example, Mannetje and Jones (1990) observed mean annual dry matter increases from 2000-2200 kg DM/ha up to 5500-7500 kg DM/ha with annual additions of 168 kg N/ha over the 13 years of their experiment. Results at Kogan in southern Queensland are summarised in the conclusion that 168 kg N/ha applied to Rhodes grass pastures will increase dry matter from 5.65 t/ha up to 12-13 t/ha with average rainfall (Peake *et al.* 1990); which represent response rates of 38-44 kg DM/kg N.

Nitrogen responses of 12-40 kg DM/ha N were recorded in a review of pasture cutting trials based on 220 observations at 13 Queensland sites with over 700 mm rainfall (Buchanan and Cowan 1990). Over half these observations were based on an average annual rainfall of 700 to 800 mm, yet there was no correlation between the response to nitrogen and rainfall or the soils’ moisture holding capacity. In contrast, water and nitrogen together had a dominating effect on grass yields on a duplex soil at Narayen, with no growth and so no response to nitrogen unless rainfall exceeded 30 mm, after which the response to nitrogen increased with rainfall to a yield limit at ~ 600mm rainfall (Henzell *et al.* 1975). A detailed analysis across soils, seasons and species is beyond the scope of this study, but a range of response rates is clearly needed for the project to assess the feasibility of using nitrogen fertilisers.

The standard nitrogen response rate of 30 kg DM/kg N was used to conclude that nitrogen fertiliser was not economically effective, at least when there was no carry-over effect into subsequent years (Peck *et al.* 2011). However, the higher response rates that have been observed and/or significant carryover responses may make fertiliser a viable option that requires less management than legumes.

Table 2. Summary of selected nitrogen fertiliser experiments

Author	Trial years	Location	Species	Nitrogen (kg N/ha)	Response (kg DM/kg N) Range (mean)
Buchanan & Cowan 1990	1990	>700 mm Qld	various	various	12-40
Cook & Mulder 1984	1976/77	Gympie, SQ	Green Panic Rhodes	<160 <160	5-35 (19) 7-48 (23)
Graham *et al.* 1981		Moura, SQ	Buffel	<320	27-34 (31)
Henzell *et al.* 1975	1968/71	Narayen, SQ	Buffel (3 trials)	168 84 168	6-50 (40) 4-68 (46) 0-59 (34)
Jones *et al.* 1995	1973/79	Narayen, SQ	Green panic & Rhodes	100	5-38* (23) * Means over 2 years and 4 stocking rates
Peake *et al*. 1990	1971/79	Narayen, SQ	Buffel Green panic	<168 <168	19-49 (37) 12-60 (31)
Russell 1985a	1974/79	Kogan, SQ	Rhodes	112	(22)

4.2 Plant nitrogen and protein responses to fertiliser

Declines in animal production of ~50% from rundown pastures are attributable to both reduced dry matter production and lower nitrogen levels in plant tops as nitrogen becomes less available in the soil (Robbins *et al.* 1987). Consequently, nitrogen fertiliser increases the nitrogen concentration (protein level) in affected plants, and can also increase digestibility and voluntary intake (Cook and Mulder 1984; Donaldson and Rootman 1977; Johnson *et al.* 2001).

Nitrogen fertiliser has increased the percentage of nitrogen in plant tops by up to 150% on ‘moderately’ rundown buffel pastures growing on brigalow-dawson gum woodland soils with low (~0.1%) to medium (~0.15%) total soil nitrogen levels (Graham *et al.* 1981). Annual additions of 80 kg N/ha increased plant nitrogen concentrations by up to 19% in the first year, and up to 60% after three years. The plant nitrogen levels without fertiliser ranged from 0.81-1.18% for the soils in the study. With these low levels of plant protein (~4-8%) any increase will significantly affect animal production (Donaldson and Rootman 1977).

A 60% increase in nitrogen concentration (protein) was also observed in ‘plucked’ green buffel leaves under annual applications of 168 kg N/ha at Narayen. Monthly averages of nitrogen in these leaves over the four year period of the trial rose from 1.6% N (10.0 % protein) to 2.6% N (16.0 % protein) (Mannetje and Jones 1990).

Over 20 years later, applications of ~100 kg N/ha to rundown sown pastures in Queensland are typically producing increases of over 50% with absolute increases of 2-4% protein (Lawrence *et al.* 2103). Fertiliser applications during the summers of 2012/13 resulted in the mean protein level measured in late autumn increasing from 5.0% to 8.6% in 49 associated plots to which 100 kg N/ha was applied as urea (Lawrence unpublished data). These increases are likely to have a significant impact on liveweight production per animal, and per hectare with the associated increases in dry matter production.

4.3 Liveweight gains after applying nitrogen

Stocking rate based on the quantity and quality of feed is a major determinant of overall liveweight gains. The final stocking rates used depend on many factors including the location of the pasture, the underlying soil fertility, rainfall, the type of stock, and individual grazier's approach to risk. General stocking rate guidelines for an adult equivalent (450 kg lightweight cow or bullock) in different scenarios across southern Queensland include (Thompson 1988):

Basaltic uplands	~1.5 ha/head
Darling Downs	~2.5 - 3.5 ha/head (depending on the soil & its fertility)
Western Downs	~2.5 - 5.0 ha/head (depending on the soil & its fertility)
Maranoa	~4.0 – 8.0 ha/head (depending on the soil & its fertility)

Lower stocking rates would be expected on rundown pastures while the addition of nitrogen fertiliser will enable higher stocking rates to utilise a proportion of the extra feed. However, while increased stocking rates to utilise extra dry matter from fertilised pastures may drive liveweight gain/ha, a range of experiments demonstrated that improving the nitrogen levels (and protein) in available feed will also contribute to higher individual animal production. For example, buffel grass fertilised at 0, 50 and 100 kg N/ha, then cut and fed to sheep as hay confirmed that both *in vivo* digestibility and voluntary intake increased as the resulting feed rose from 0.6 to 0.9% nitrogen (i.e. 3.8% to 5.9% protein), while mean daily liveweight gains improved from -4.5 to 57.3 g/day (Donaldson and Rootman 1977).

More stable pasture composition and increased levels of nitrogen in the plants typically complemented the increased dry matter production of fertilised pastures at Narayen and Kogan in southern Queensland (Jones *et al*. 1995; Mannetje and Jones 1990; Russell 1985b). The increase in feed quality subsequently improved liveweight gains and halved the liveweight declines in animals over winter from 60 kg/head to between 20-30 kg/head (Jones *et al.* 1995), presumably from later growth and/or better maintenance of feed quality late in the season. The impacts on liveweight gain per head were more pronounced at higher stocking rates that utilised the extra feed generated by nitrogen fertiliser (Mannetje and Jones 1990), a result in line with international experiences (Garay *et al.* 2004). Mean annual liveweight gains across all stocking rates on the unfertilised pastures varied from 95-144 kg/head depending on the season; and increased by 32-62% across all stocking rates during the 10 years of the trial reported (Mannetje and Jones 1990). Gains per head increased from 100 to 150 g/day/head in the 100 kg N/ha treatment when stocking rates were increased to 1.5 head/ha and 2.0 head/ha respectively (Jones *et al.* 1990). The only reported liveweight gain per hectare comparison was that the fertilised buffel grass produced seven times the total liveweight gain per hectare and had better carcass quality than unfertilised native pastures.

In summary, the overall response to applied nitrogen fertiliser on the buffel grass at Narayen ranged from 1.6-2.0 kg liveweight gain per kilogram of nitrogen applied over the life of the trials (Mannetje and Jones 1990), which is in line with results at Kogan (Russell 1985b) and overseas (Garay *et al.* 2004). These figures may be conservative, with unquantified long-term impacts still being observed at Narayen 20 years after the trials were abandoned, and carryover impacts of nitrogen fertiliser being observed in recent unpublished farm trials.

4.4 Carryover effects of nitrogen applications

Carryover responses to applied nitrogen are becoming more widely recognised. Responses should not be a surprise given that nearly all mature grasslands are constrained by available soil nitrogen (Reuss and Innis 1977). Unlike grain crops, nitrogen added to pastures is not removed and will ultimately increase the total organic nitrogen available for mineralisation (Roberston *et al.* 1997). This phenomenon may be strongest in sown species, but carryover impacts of nitrogen applications on biomass and nitrogen concentration also occur in native grasslands (Bennett and Adams 2001).

While these carryover effects have not been widely discussed, they were clearly identified in the early rundown trials at Narayen that had annual applications of 100 kg N/ha for up to 13 years. The carryover effects on pasture species composition lasted for at least 8 years after nitrogen applications stopped, while effects on cattle LWG lasted for 6-7 years (Jones *et al*. 1995; Mannetje and Jones 1990). The mean additional annual liveweight gains per head after fertiliser applications ceased were: 70 kg/hd (years 1-3); 30 kg/hd (years 4-6); and 15 kg/hd (years 7-8).

It is important to note that these results came from 13 repeated applications of 100 kg N/ha, a total addition of 1300 kg N. However, composition changes (green panic maintained on the nitrogen fertilised plots; buffel grass invading unfertilised sites), and dry matter increases of over 200% still remain 25 years after the last fertiliser was applied (Cook 2011). These long-lasting responses are being observed on a brigalow soil that is at the highest end of native fertility across southern Queensland. The initial levels of total soil nitrogen of between 0.26 and 0.38% in the topsoil (Jones *et al.* 1995), equate to between 6-10 tonnes of total soil nitrogen in 0-30 cm (assuming a typical bulk density of 1.3 and a 50:50 ratio for 0-10 and 10-30 cm stocks of soil organic carbon and soil organic nitrogen). Responses on such a high fertility soil may have been expected to be less pronounced. Furthermore, the longevity of the carryover responses suggests that additions of nitrogen are helping to sustain higher equilibrium soil organic matter levels and subsequent annual mineralisation of nitrogen.

Recent trials in southern Queensland have confirmed the potential for carryover nitrogen responses. For example, an application of 120 kg N/ha to rundown buffel grass at Glenmorgan in southern Queensland increased dry matter production from ~3500 kg/ha to ~7400 kg/ha over the subsequent six week period in late summer; a response rate of 32 kg N/kg N (Cook 2011). Without any additional nitrogen, the buffel grass continued to respond with a dry matter increase of ~1200 kg/ha during the following spring and another ~1200 kg/ha the following summer, that is a total of 2400 kg DM/ha (20 kg DM/kg N) in carryover responses from the original application (Cook unpublished).

Carryover nitrogen may help explain the larger dry matter responses to nitrogen that have been observed when applications are repeated annually (Peake *et al.* 1990). Alternatively, these carryover impacts should make it feasible to maintain pasture and animal responses with reduced rates of nitrogen applied over time (Mannetje and Jones 1990).

5 Forage sorghum and oats

Forage sorghum and oats are used by beef operations in southern and central Queensland to finish stock. Winter grown oats produce high quality feed at a time of the year when the quality of perennial sub-tropical pastures is low. This typically enables graziers to grow and/or finish stock for most of the year. However, forage sorghum grows during the summer period, the same time that sub-tropical perennial pastures are actively growing and providing high weight gains. Forage sorghum is grown to provide large amounts of forage which can be stocked at high rates to enable high liveweight gain on an area basis, while being able to rest perennial grass pastures. Other reasons for growing annual forages include:

- continuous supply of quality feed (i.e. filling feed gaps)
- flexibility to match feed supply to seasonal conditions
- opportunity to conserve excess fodder through hay or silage

- consistent growth of stock throughout their lives to target premium markets (e.g. MSA).

To obtain high animal performance (liveweight gain and stocking rate), forage crops need adequate nutrition to maintain forage production. In high fertility soils or recently cleared country, mineralisation from soil organic matter can supply enough of the main nutrients (nitrogen, phosphorus, sulphur, potassium) to sustain high forage yields and high feed quality. As cropping continues, soil organic matter declines and so does the supply of these nutrients. Fertilisers are then often needed to overcome nutrient deficiencies (see earlier section on Soil Fertility). The economics of fertilising forage sorghum and oats will depend on the price of fertiliser and application cost compared to the extra dry matter yield, the liveweight gain obtained and the sale price of stock. Hence, the economics of fertilising and grazing forage crops is likely to be highly variable.

Photo 2. Urine and manure patches commonly highlight nutrient deficiencies and loss of productivity in forage crops across southern and central Queensland

Conversations with beef and dairy extension officers within the Queensland Department of Agriculture, Fisheries and Forestry (DAFF) indicate that most forage sorghum and oats crops grown in coastal and south-east Queensland districts are fertilised, while the same forages grown in the Brigalow region of southern and central Queensland generally are not fertilised. This may reflect the higher inherent soil fertility of these brigalow soils, a lower intensity of farming, their more recent development, and/or lower stocking rates.

Most brigalow soils were developed in the last 20–50 years while many coastal and south-eastern districts were developed up to 100 years ago. Annual rainfall, rainfall reliability and stocking rates are also significantly lower in the Brigalow region, which further increases the riskiness of fertiliser application and reduces the incentive to apply fertilisers. However, forage yields and subsequent animal performance in the Brigalow region are declining as the native soil fertility is reduced under continued cultivation. Graziers and industry personnel alike are now seriously considering the feasibility of fertilising annual forages, and are assessing how the economics of fertilising compare to alternative feedbase options.

Research has investigated the effect of nitrogen fertiliser on forage yields of both forage sorghum and oats in southern and central Queensland. Some studies were conducted on soils with high levels of mineral nitrogen and did not respond to added nitrogen fertiliser, while other experiments have used irrigation to ensure adequate soil moisture levels so the plant can fully express responses to the next most limiting resource, typically soil nitrogen. Very little research has been undertaken into the impact of phosphorus fertiliser on forage yields.

Specific fertiliser recommendations are generally not included in text books and extension fact sheets as every situation, soil type, end-use etc. is different. Most publications provide generalised statements, such as 'at least 50 units of nitrogen before sowing', and, 'after each grazing, apply a further 50 units of nitrogen' (Stuart 2002). Others simply suggest applying rates of fertiliser similar to those applied to grain crops, or make vague statements that it is important to have a well-balanced soil to obtain optimum growth and quality. So it is clear that less R&D has been undertaken with annual forages than comparable grain cropping systems in the region, and so reliable crop and animal performance data are much harder to obtain.

There is a general understanding of the level of nutrient required for each tonne of dry matter produced. For instance, each tonne of forage sorghum requires between 20 and 28 kg N, 2-3 kg P, 15-20 kg K and 1-2 kg S (Stuart 2002; Bowen *et al*. 2010). Therefore, about 250 kg N/ha is required to grow a 10 t/ha forage sorghum crop. As described earlier (see section on Soil Fertility), soils used for forages in southern and central Queensland will supply around 75 kg N/ha (range 50-100 kg N/ha), so an extra 175 kg N/ha may be required from fertiliser to achieve maximum yields. Oats, a C3 plant, has higher N requirement per tonne of dry matter produced due to the higher protein levels generated. To produce 1 t/ha of dry matter at 22% protein, around 35 kg N/ha is needed (Bowen *et al*. 2010). So for a 4 t/ha oats crop, 140 kg N/ha is needed, with around 65 kg N/ha of that required from fertiliser.

Extension officers indicate that beef producers in southern and central Queensland apply only small amounts of fertiliser to their forage crops, typically nitrogen at less than <50 kg N/ha, or none at all. Many state that financial returns are unreliable because soil moisture is a greater constraint than soil nutrition. Further, most graziers do not appear to assess the quality of forage produced. Some graziers have only basic records of total stock numbers on their forage and most, if not all, rarely weigh cattle to determine weight gain benefits. Additionally, while many graziers might understand the concept of grazing forages like sorghum early to provide higher quality feed, in practice most leave grazing until there is a large body of feed with declining forage quality and greatly reduced individual animal performance.

The reliability of forage crop responses to N and P fertiliser depends on soil and management factors that are quite different to those for perennial grass pasture. Plants in a perennial pasture system are continually 'taking-up' nitrogen so available nitrogen levels are generally very low. Consequently, dry matter responses to fertiliser nitrogen are almost guaranteed with follow-up rainfall. Forage cropping systems use fallows to store moisture between crops. The fallows also mineralise organic nitrogen and some phosphorus which is then used to grow the forage crop. The amount of mineralisation for these nutrients depends on soil type and soil organic matter levels, age of cultivation, crop type, length of the fallow, rainfall and weed management, and past fertiliser use. Ultimately, higher levels of available nitrogen and phosphorus at sowing enables better yielding crops and reduces the reliability of obtaining a dry matter response compared to a perennial grass pasture.

5.1 Dry matter yield and protein responses to nitrogen – forage sorghum

Recent studies on the western Downs demonstrate dry matter yields of forage sorghum range from 7.6 to 22.2 t/ha and average around 14 t/ha (Bell *et al*. 2012). The general recommendation for managing this range in commercial yields is to match soil fertility (and hence any fertiliser application) to soil moisture levels at sowing and seasonal condition predictions. The resulting nitrogen fertiliser rates typically aim to ensure there is >100 kg N/ha available to the newly planted crop.

There have been some cases where adding N fertiliser to forage sorghum has resulted in no, or negative, yield response. This has been due to trials either being conducted on soils with high N levels that did not require fertiliser, or where there were establishment and environmental limitations to growth (Harms and Tucker 1973; Gorashi *et al*. 1980). For example when modest rates of N fertiliser (50 kg N/ha) as urea is placed close to the planted seed, plant establishment and dry matter yields can be negatively affected but forage nitrogen concentrations are improved (Wheeler *et al*. 1980). Where studies found a positive yield impact of N fertiliser, the responses can range between <6 to 50 kg DM/kg N (Table 3). The reason for this range of responses is sometimes difficult to ascertain. Obviously, climatic parameters at the geographic location (e.g. temperature and rainfall), or the use of irrigation in some studies, have played large roles in the plant response attained. But the soil nutrient status, particularly available soil nitrogen level, significantly affects dry matter responses to N fertiliser. Unfortunately, these levels are only occasionally reported in the publications.

High yield response rates of 30 to over 50 kg DM/kg N have been achieved across a range of locations where high rainfall or the use of irrigation has meant that soil moisture was not limiting. But the N rates needed to obtain a particular yield response can vary, and while generally not reported, it is assumed the response was determined by level of available soil N. For instance in south-east Queensland with irrigation, 14 t DM/ha was attained without N fertiliser, whereas fertilising increased yield to 19 t/ha (Rahman *et al*. 2001). In this study there was no significant yield benefit from applying 120 kg N/ha rather than 60 kg N/ha. However, plant N content generally increased with N fertiliser rate. The application of 120 kg N/ha, either all prior to planting or as two in-crop applications of 60 kg N/ha, provided significantly higher N contents in the forages than the unfertilised plants, or those fertilised with only 60 kg N/ha. Further, yields can be improved with low-moderate N rates under single cut conditions, and that higher N rates only increased N content (i.e. feed quality) (Rahman *et al.* 2001). In multi-cut situations, higher N rates are required to increase both dry matter and N content. This has applicability for forage sorghum crops that might be only grazed once, versus those which are grazed multiple times with the anticipation of obtaining higher utilisation.

Forage sorghum has also produced high yields (17 t DM/ha) under irrigation in New South Wales, but this required nitrogen rates as high as 350 kg N/ha (Muldoon 1985). Unfertilised forage sorghum in this study yielded only 1.8 t/ha, presumably due to very low inherent available soil N levels. Fertilising with 120 kg N/ha increased dry matter yield to around 8.2 t/ha, producing about 53 kg DM for every kg N applied. However, the ‘leaf percentage’ (in relation to stem) declined in a linear pattern with increasing N fertiliser up to 120 kg N/ha, and likewise plant N content and digestibility gradually decreased at the same fertiliser rates. More than 150 kg N/ha was needed to reverse the decline in ‘leaf percentage’, N% and digestibility, indicating that the fertiliser rates typically used in beef systems (below 100 kg N/ha) could have a negative impact on the quality of the forage produced.

In Victoria, nitrogen fertiliser applied to irrigated forage sorghum increased yield, albeit with high rates (Prichard 1985). In this study, 6 t/ha of dry matter was grown without fertiliser. However, yields of 10 t/ha required 100 kg N/ha to be applied and yields of 13 t/ha needed an additional 200 kg N/ha. Crude protein also increased with N fertiliser, from 8.1% without fertiliser, to 8.8% with 100 kg N/ha, 10.6% with 200 kg N/ha, and 11.6% with 300 kg N/ha applied.

Similar yield responses with N fertiliser have been attained in Brazil under high rainfall (>1000mm). In a higher rainfall year with an optimum sowing date, 7 t/ha of dry matter was produced without N fertiliser, whereas 300 kg N/ha produced dry matter yields of 13 t/ha (Restelatto *et al*. 2013). When 75 kg of N/ha was applied in the same study, 47 kg/ha of dry matter for every kg N was produced. In the second year, with lower rainfall and a delayed sowing, total dry matter yields with N fertiliser were between 5 and 6 t/ha, with 11 kg of dry matter produced per kg of N applied. Crude protein levels increased with N fertiliser as well as in vitro dry matter digestibility (IVDMD), whereas neutral detergent fibre (NDF) and acid detergent fibre (ADF) were not affected.

Table 3. Summary of dry matter responses of forage sorghum to nitrogen fertiliser

Reference	Dry matter response (kg DM/kg N)	Dryland or irrigated	Location
Rahman *et al.* 2001	40 – 50	Irrigated	SE QLD
Prichard 1985	35 – 40	Irrigated	Victoria
Muldoon 1985	53	Irrigated	NSW
Chataway *et al.* 2011	33	Dryland	D. Downs SQLD
Jacobs and Ward 2011	<6	Dryland	Victoria
Restelatto *et al.* 2013	47 (first year); 11 (second year)	Dryland	Brazil

Under drier, rain-fed conditions the dry matter responses to N fertiliser are generally lower than high rainfall or irrigated situations. Over a 5-year period on the Darling Downs, total yields on a vertosol with N fertiliser ranged between 5.6 and 14.4 t DM/ha, whereas yields on a sodosol with N fertiliser ranged from 3.0 to 8.4 t/ha (Chataway *et al*. 2011b). In the same experiment, yield increased by 33 kg for every kg N applied and there was a large increase in forage protein concentration from 9.2 to 13%. In dry summer environments, such as Victoria, dry matter yields to applied N can be low and variable without irrigation (Jacobs and Ward 2001). This is due to available water typically limiting growth; however crude protein levels can increase with N fertiliser indicating the extra N supply is not entirely wasted.

When forage sorghum is sown into a situation with adequate soil moisture and/or in-crop rainfall, it's apparent the addition of N fertiliser can significantly increase dry matter yields as few soils can mineralise enough nitrogen to supply the demands of such a productive crop. The nitrogen response rate will be higher on soil with low soil nitrogen levels, and lower on soils where a larger pre-planting supply of available nitrogen has been mineralised, especially after a long fallow period. Forage crop quality (protein and DMD) also increases with the addition of N fertiliser, however, in situations with very low N soil levels, it seems that large amounts of N (>150 kg N/ha) are required to improve both dry matter yield and forage protein levels.

These forage systems contrast with the almost ubiquitous lack of available nitrogen in perennial sown grass pastures, which do not have a fallow period in which to build available soil nitrogen for the subsequent forage growth.

5.2 Dry matter yield responses to phosphorus – forage sorghum

Research investigating the dry matter yield responses of forage sorghum to phosphorus (P) fertiliser has been very limited. A series of six experiments in northern NSW found the application of 20 kg P/ha more than doubled dry matter (Wheeler *et al.* 1980). Soil P levels (0-10 cm) at the experimental sites ranged from 9-30 mg/kg Colwell bicarbonate phosphorus (average 17 mg/kg), which are typical of soils used for forages in southern and central Queensland today. However, the dry matter yields in the study were very low (1.35-3.03 t/ha) compared to the yields of 9-14 t/ha expected in Queensland (Chataway *et al*. 2011b; Bell *et al*. 2012). The yield response of P fertiliser at each site varied, presumably due to rainfall and soil P level; ranging between 51 and 134 kg DM/kg P, with an average of 81 kg DM/kg P. These experiments also reported that Hydrocyanic acid (HCN), more commonly known as prussic acid, increased with applied nitrogen but decreased when phosphorus was applied.

5.3 Dry matter yield and protein responses to nitrogen – oats

Forage yields of oats crops in Queensland are highly variable and reflect the amount of soil moisture stored at planting along with in-crop rainfall received. However, available soil nitrogen supply is also a major determinant of the quality and quantity of the forage produced. Unfortunately, many of the studies with oats, like the research on forage sorghum, did not report the available soil N levels at planting. This makes it difficult to interpret the range of responses attained.

The variability of oats yield in south Queensland was highlighted by a recent study in which four sites on the western Darling Downs were planted to oats over a two year period. Forage yields ranged from 1.1 to 7.7 t DM/ha with an average of 3.2 t/ha including one site that failed due to dry conditions in one year (Bell *et al*. 2012). Soil moisture and pre-sowing N levels were assessed and N fertiliser was then applied to ensure >50 kg N/ha was available. These measurements demonstrate the range of dry matter yields obtained in commercial situations, and the importance of matching N supply to soil moisture and seasonal conditions.

Past research indicates a range of positive yield responses to N fertiliser (Table 4). Some research shows responses only at low rates of nitrogen whereas others responded positively at both low and high N rates, notably where irrigation was used. For example research undertaken in the southern wheat belt of NSW found that, while a low N rate (22 kg N/ha) significantly increased dry matter yields, the results from higher rates (44 and 90 kg N/ha) were less consistent (Southwood *et al*. 1974). In the lower yielding years (<2.2 t/ha), forage response with 22 kg N/ha averaged 16 kg DM/kg N applied. In higher yielding years (>3.1 t/ha) this response rate rose to average 23 kg DM/kg N applied. The application of N fertiliser significantly increased forage N concentration in a linear relationship up to 90 kg N/ha. This response continued even at the highest N fertiliser rate.

Similarly, research at Gatton over 30 years ago reported only limited yield responses to very high nitrogen fertiliser rates of 205-411 kg N/ha (Bowdler and Lowe 1980). The response rates to these fertiliser inputs were merely 5 kg DM/kg N in the first year and 8 kg DM/kg N in the second year. Nitrogen concentration in the forage did not significantly increase with added N fertiliser in the first year. However it did in the second, presumably due to the lower yield attained and the removal of available nitrogen by the first crop (yields without fertiliser were 6.2 t/ha and 4.2 t/ha in each year, respectively). The N status of the soil was not reported. As a 5 t/ha forage oats crop requires ~175 kg N/ha (Bowen 2010), it is clear that many trials have been conducted on soils with adequate nitrogen supply.

Other research, presumably on soils with a low fertility, shows a linear relationship of forage yield to increasing N fertiliser rate. For example, a Victorian study showed a linear relationship with increasing N rates up to 120 kg N/ha (Handson and Layne 1996). However, the authors assessed that the optimum rate was 60 kg N/ha, which increased yield by about 2 t/ha. Again, no available soil N levels or forage quality measures were reported.

In high yielding conditions at Gatton, linear responses to nitrogen were obtained up to 336 kg N/ha under irrigation, and up to 134 kg N/ha in rain-fed conditions (Lowe *et al*. 1980). These response rates were affected by seasonal rainfall; from 10 kg DM/kg N in low rainfall years with yield <4 t/ha, up to 39 kg DM/kg N in high rainfall years with yields >6 t/ha.

Overall, the literature suggests higher yield responses (per kg of N applied) at lower fertiliser rates (<60 kg N/ha) across a range of locations; suggesting that these soils remained nitrogen deficient even after previous fertiliser applications at traditional (low) rates. Although, without soil test results it is difficult to be certain. Similar results have been reported from recent dairy research in rain-fed systems on the Darling Downs. The application of N fertiliser at significantly higher rates than the industry standard (140 kg N/ha vs 55 kg N/ha) resulted in only a modest yield increase of 10 kg DM/kg N (Chataway *et al*. 2011a). This higher rate did, however, provide higher residual soil nitrate-N levels. The authors summarised that N fertiliser application more consistently increases N concentration than forage yield, and forage yield increased only when high in-crop rainfall was received.

While the Australian literature indicates higher production efficiencies at lower N rates, recent research undertaken in Brazil measured 19 kg DM/kg N from nitrogen fertiliser applications up to 80 kg/ha (Restelatto *et al.* 2013). This response rate continued up to 160 kg N/ha. Again, available soil nitrogen levels were not reported, however low levels may be assumed as the oats was double cropped after forage sorghum. Crude protein levels increased with N fertiliser up to 200 kg N/ha. However, there was no impact of N fertiliser on in vitro dry matter digestibility (IVDMD), neutral detergent fibre (NDF) or acid detergent fibre (ADF).

Table 4. Oats dry matter responses to N fertiliser at various locations

Reference	Oats response (kg DM/kg N)	Dryland/Irrigated	Location
Southwood *et al*. 1974	16 (low yielding year)	Dryland	Southern NSW
	23 (high yielding year)	Dryland	
Chataway *et al*. 20011a	10	Dryland	Darling Downs SQ
Lowe *et al*. 1980	10 (high yielding year)	Dryland & irrigated	Gatton SQ
	39 (low yielding year)	Dryland	
	31 (low yielding year)	Irrigated	
Bowdler and Lowe 1980	5 (first year)	Irrigated	Gatton SQ
	8 (second year)	Irrigated	
Handson and Layne 1996	40-45	Trial 1	Victoria
	21-40	Trial 2	
Restelatto *et al*. 2013	19	Dryland (1000 mm)	Brazil

The literature indicates that with adequate soil moisture and in-crop rainfall, the addition of N fertiliser can increase oat yields, but at lower response rates than those observed in forage sorghum. Also, higher production efficiencies seem to occur at N rates around 60 kg N/ha. Forage quality is also improved with the addition of N fertiliser, and there is evidence to suggest N fertiliser increases protein levels more reliability than dry matter yield, especially in Queensland due to the unreliability of in-crop rainfall.

5.4 Dry matter yield and protein responses to phosphorus – oats

No specific research on the dry matter and quality responses of oats to phosphorus was found.

5.5 Animal production impacts from fertiliser use

An extensive literature review of animal liveweight gain from both forage sorghum and oats was summarised in the first phase of the High-output forage project (Bowen *et al.* 2010). This review outlined the grazing outcomes from a large range of forage studies primarily in the Fitzroy basin area of central and southern Queensland. Stocking rates on forage sorghum were generally more than four times that of unfertilised grass-only pastures. Consequently, the main benefit of using forage sorghum is to improve kilograms of beef produced per hectare, not individual liveweight gain (Table 5). Oats can provide high quality forage at a time when the quality of grass-pastures are at their lowest, enabling both higher LWG per head and per hectare through higher stocking rates.

Table 5. Beef production from three in the Fitzroy catchment, Central Queensland

Forage	Initial SR (AE/ha)	LWG (kg/h/d)	Grazing days	Total beef (kg/ha)
Forage sorghum	1.9	0.68	84	109
Oats	1.5	0.84	77	97
Buffel grass (unfertilised)	0.3	0.48	365	53

5.5.1 Forage Sorghum

A range of studies have measured the beef cattle performance from fertilised forage sorghum. Unfortunately, most of these studies did not compare the animal performance to non-fertilised crops. Some authors reported investigations of N fertiliser impacts on both forage yield and liveweight gain, but from separate experiments that did not record concurrent data for both outcomes. For example, Blunt and Fisher (1973) investigated the optimum water and nitrogen regime for growing forage sorghum in the Ord River valley, Western Australia. Then in a second experiment, beef cattle liveweight gain was investigated. They concluded that 'good' forage yield (around 13.5 t/ha) was produced at 180 kg N/ha and there was no advantage to split N applications. No animal performance comparison of non-fertilised and fertilised forage sorghum was made, only liveweight gain at different stocking rates in the second experiment.

Only one study that investigated the effect of N fertiliser on liveweight gain was found. This research was conducted in Brazil and did not include a treatment in which the forage sorghum was not fertilised (Neumann *et al*. 2005). The effects of a complete fertiliser blend (NPK) at 2 N rates were compared, and as the N rates applied were low and similar (24 and 30 kg N/ha), there was no significant impact on dry matter, crude protein, digestibility or liveweight gain.

In contrast, studies with dairy cattle and sheep have demonstrated animal performance gains when fertilising forage crops with nitrogen. Research on the Darling Downs applied N fertiliser to forage crops including sorghum, millet and oats and measured the impact on milk production. Forage yield increased by 28 kg DM/kg N and milk yield improved by 4.7 L/kg N, confirming that nitrogen fertiliser can impact both forage yield and animal performance (Chataway *et al*. 1992). Other dairy research has reported mean milk responses over six years of up to 8 L/kg N for nitrogen rates of 0-150 kg N/ha on Rhodes grass at Mutdapilly in south Queensland (Cowan *et al.* 1995).

The performance of wethers on forage sorghum in New South Wales also improved with nitrogen rates of up to 84 kg N/ha. Total liveweight gain increased from 81 kg/ha without fertiliser to 242 kg/ha with 84 or 164 kg N/ha, indicating no extra liveweight response beyond 84 kg N/ha (Wheeler and Hedges 1971).

Based on the limited literature found and citied here, there appears to be positive animal impacts of fertilising forage sorghum with N fertiliser. However, there are no data supporting diet quality or the specific liveweight improvements (per head or per hectare) likely for beef cattle.

5.5.2 Oats

As with forage sorghum, a range of studies have investigated the animal liveweight performance from fertilised oats but most of this research did not compare animal performance to non-fertilised oats. This is highlighted by research on the production of oats in the Ord River Valley of Western Australia by Blunt and Fisher (1976). They concluded that oats produced an extra 14 kg DM/kg N when fertilised with 90 kg N/ha. However, the response declined with increasing N rates. While the authors did undertake liveweight gain measurements, these were again in a separate experiment.

Only one study (conducted in Brazil) was found which investigated beef cattle performance from a range of N fertiliser rates that also included an unfertilised control. Cattle production was compared from a black oats and Italian ryegrass pasture fertilised at three N rates (0, 150 and 300 kg N/ha). Average animal weight gain (kg/hd/d) was similar for each N rate. However, stocking rate, and therefore liveweight gain/ha, showed a linear response to N rate, providing an animal production efficiency of 2 kg beef/kg N for the 150 N/ha rate and 1.8 kg beef/kg N for the 300 kg N/ha rate (Lupatini *et al*. 2013). Research in Australia (Armidale) with sheep found that N fertiliser increased oats production by 30 kg DM/kg N in a high rainfall year, but only 15 kg DM/kg N in a drier year (Spurway *et al*. 1974). Forage protein content increased with N fertiliser from 14% to 19%. Sheep liveweight gain increased from 0.15 kg/h/d to 0.22 kg/h/d, but only in one of three grazing periods in one year.

The limited range of experiments that were possible to cite indicate a positive impact of N fertiliser on animal performance in a forage oats system. However, it is unclear in southern and central Queensland conditions as to what magnitude N fertiliser has on beef cattle diet quality and/or liveweight gain per head and per hectare.

6 Methods

This study of the potential to use fertilisers on sown grass pastures and forages is based on an agronomic ‘proof of concept’ assessment and an economic analysis of the associated profitability and riskiness of selected fertiliser options in southern and central Queensland.

The analysis is based on the collection and collation of ‘readily available’ scientific information and data from fertiliser trials across the region. Key aspects of the methodology and the methods used in each stage of the study are described below.

6.1 Scientific information and data collection

The introduction and background sections of this report are based on peer reviewed scientific literature but are supplemented with recent unpublished trial data and ‘grey literature’ where necessary. Much of the scientific information was published in the 1970-90s. There have been fewer studies published in the last 20 years, most likely reflecting a decline in resourcing and the conduct of sown pasture research. Personal contact with a range of regional experts was used to explore the available scientific information and to collect unpublished regional trial data.

Regional experts also provided insights and opinions to develop the scenarios, described below, that were ultimately tested in the project. This iterative process began prior to a two-day meeting of experts to develop scenarios for testing and continued throughout subsequent economic analysis.

6.2 Proof of concept

The agronomic potential for using fertilisers on sown grasses and forages was tested by a range of scenarios developed with information and insights from the ‘experts’ meeting’. This meeting considered the scale of nutrient deficiencies, the extent of responses to fertilisers, and the practicalities of applying fertilisers for a range of specific scenarios (Table 6).

The matrix of potential conditions was summarised into a smaller number of more general scenarios to test the feasibility of the concept and to facilitate a manageable number of outcomes for economic analysis.

Table 6. Structure for data collection to analyses fertiliser use on sown grasses and forages

Locations	Moura (Baralaba) in Central Queensland; Gatton, Chinchilla and St George (Nindigully) in south Queensland to cover a range of both average rainfall and seasonality
Soil moisture storage	100 & 180 mm Plant Available Water Holding Capacity
Soil N & P fertility	High; Medium; Low
Fertiliser scenarios (Grass pasture)	50 & 100 kg N/ha; no carryover & with carryover responses
Forage crops	Forage oats; Forage sorghum
Fertiliser scenarios (Forage)	No fertiliser; +N ; +P; +N/P

The resulting combinations of existing pasture production and response rates are intended to enable insights for scenarios with different underlying soil fertility, rainfall and extent of rundown. For example, a higher rainfall area with a fertile soil would be expected to have a higher level of production, more reliable responses to applied nitrogen, and a higher response rate as the extent of rundown increased. The combination of responses can then be selected for the location of interest.

The details of the final fertiliser scenarios that were assessed in the project are outlined in Sections 6.4 and 6.5. The biophysical data for each scenario was then used to conduct the economic analyses.

6.3 Economic assessment

The following description is an extract from the full economics report (see Appendices) that provides more details of the economic analysis.

The impact of applied fertiliser on beef production was assessed using paddock level enterprise budgets and discounted cash flow techniques. This method was applied as it is the most appropriate way to filter the production responses and identify the level of response needed to improve the relative profitability of pasture and forage systems.

Very little can be inferred from the results of applying this method about whether the application of fertiliser to pasture or forages is the most economic strategy to employ at the level of the farm business. Comment on the overall economic merit of the treatments analysed here is therefore largely limited to how they compare to the base treatment, and further extrapolation of the results to how the various predicted responses may, or may not, impact on the economic performance of any farm business would be misleading. Such analysis was not possible given the ‘dose rate/response rate’ nature of data that was readily available for the scoping study, and was therefore seen as being outside the scope of this review.

The paddock level enterprise modelled in this analysis was a trading enterprise that purchased store steers and sells finished Ox direct to the meatworks. The boundaries of the enterprise were the physical paddock boundaries. The only expenses incurred by the paddock enterprise were those that vary with the number of cattle run in the paddock, such as husbandry and selling costs. An allowance was made for the amount of additional effort and cost required to apply the fertiliser. The enterprise budgets were compiled in the form of paddock gross margins and were used to identify the profitability of differing levels of fertiliser response within paddocks.

Measuring relative profit at the paddock level using a gross margin format allowed the costs and incomes associated with the remainder of the business, that do not change with a change in fertiliser use, to be ignored, thereby simplifying the analysis.

A discounting process was also used to consider the relative value of strategies that are implemented over time and, therefore, have impact on the timing of income and costs. Discounting adjusts expected future costs and benefits to values at a common point in time (typically the present) to account for the time preference of money. With discounting, a stream of funds occurring at different time periods in the future is reduced to a single figure by summing their present value equivalents to arrive at a Net Present Value.

The application of the discounting process allowed the comparison of fertiliser strategies that have impacts on productivity at differing periods of time.

6.3.1 Gross margin (enterprise budget) notes in general

Some short-term decisions involve the use of resources that have an effective life of more than one production period. For example, farming plant normally lasts for a number of years and can contribute to the production of many activities.

In a gross margin analysis, the costs of farming equipment to an enterprise or activity are usually apportioned on an hourly and rate of use basis. This allows inclusion in the gross margin of the proportional amount of operating costs of the farming plant used by each enterprise or activity, improving the validity of the comparison where different forages require different amounts of machinery inputs.

Farming plant is normally costed in gross margins on the basis of the Fuel, Oil, Repairs and Maintenance (FORM) used on a per hour basis in the production of the output. Note that the ownership costs of the plant are not included.

For each tractor and implement combination used in the enterprise or activity modelled, the following rule of thumb calculations for the share of FORM costs are made:

- Fuel = fuel consumption (litres per hour) multiplied by the fuel cost (cents per litre net of rebates)

- Oil cost is assessed as 10% of fuel cost

- Repairs and Maintenance. To calculate a share of repairs and maintenance, the expected replacement cost of the machine is firstly identified. This can be the current new value of the machine or the second hand value if it is going to be replaced with a used machine. The total costs of all repairs likely to be incurred over the life of the machine are then identified and calculated as a percentage of the replacement value. The longer the machine is kept, the higher the percentage, up to 70% or more, for a tractor that is kept a long time (> 5000 hours) and used to undertake heavy work. To calculate the hourly cost of repairs and maintenance, the replacement cost of the machine is multiplied by the percentage of the replacement cost of the machine spent on repairs over the life of the machine and divided by the hours of life of the machine. For example, if a machine costs $10,000, and about $3,000 is expected to be spent on repairs and maintenance over its five year life, then about 30% of the cost of the machine will be spent on repairs. If the machine is used for 100 hours per annum, the hourly cost of repairs and maintenance is about $6 per hour of use.

These rules of thumb are sufficiently accurate to allow the inclusion of the proportional costs of FORM associated with machinery use in a gross margin analysis.

Gross margins are calculated in this analysis with an allowance for the labour costs associated with machinery operation included. This allows identification of the value of the additional labour required to spread fertiliser on the paddock, whether it is paid or unpaid.

6.3.2 The paddock

The hypothetical paddock chosen to explore the impact of fertiliser application was located about 180 kilometres from the Gracemere stock selling centre and about 580 kilometres from the Dinmore abattoirs. This theoretically placed the paddock somewhere in southern central Queensland in the Brigalow belt. The two selling centres were chosen due to the availability of price data and for no other reason.

The paddock had a total area of 100 hectares. Stocking rates on the base buffel pastures were 4.87 hectares per AE on the 3000 kg DM/ha pasture, and 2.7 hectares per AE on the 4500 kg DM/ha pasture, which reflect the rates recommended in Section 4.3 (Thompson 1988).

6.3.3 Paddock operations

The enterprise used a steer fattening activity that relies on the purchase of store steers from Gracemere sale yards at weights that allow the steers to be finished after 12 months of grazing on the buffel pasture, or 90 and 100 days grazing for forage oats and sorghum respectively.

For the purposes of this analysis, the paddock was treated as a separate enterprise that purchases replacement steers and sells finished Ox. The transfer of livestock into and out of the paddock generally occurs at about mid-year for the buffel enterprise. Steer prices in the enterprise budgets were set at the average market values of the last four years at the respective purchase or selling centre for the relevant class of livestock. The only other expenses incurred by the paddock enterprise were those that vary with the number of cattle run in the paddock, such as steer purchase, husbandry and selling costs, plus the cost of purchasing and spreading the fertiliser.

In the scenarios where forages are produced in the paddock, no other activities were undertaken except those associated with fallow weed control, planting and grazing the forages. A minimum tillage farming system, incorporating both mechanical and chemical weed control, was used to reflect the practices of most beef producers in the region who grow forage crops.

6.3.4 Steers prices

Price quotes provided by Elders Pty Ltd for Gracemere store sales and by Australian Meat Holdings for Dinmore abattoir have been compared for correlation and trend. Figure 3 shows the relationship over recent years between the prices of medium sized store steers at Gracemere and grass fed Jap Ox at Dinmore.

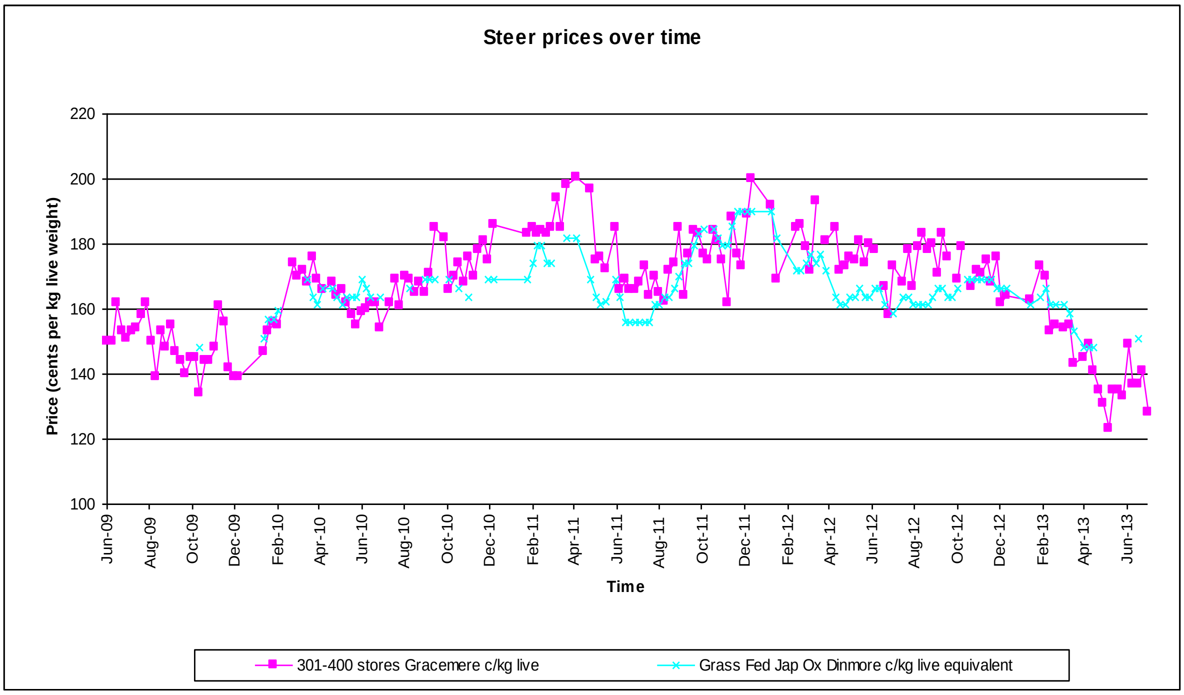

Figure 3. Steer selling prices over time

The price risk expected for the buffel enterprise was estimated by comparing purchase and selling prices twelve months apart for each class of animal (Figure 4). The correlation between steer purchase and selling prices over this period was identified as being 0.12 – or hardly any correlation at all. There also appears to be no set basis (or margin) over time between the purchase price of the store steers and the sale price of the finished Jap Ox.

The price basis can be up to 40 cents per kilogram positive or negative when measured on an equivalent liveweight basis with a twelve month lag between the purchase date and sale price. There is little or no correlation between the purchase and sale price of the classes of steers used in the buffel analysis and no easily recognisable or predictable pattern over time to establish a basis between the price of medium stores and Jap Ox.

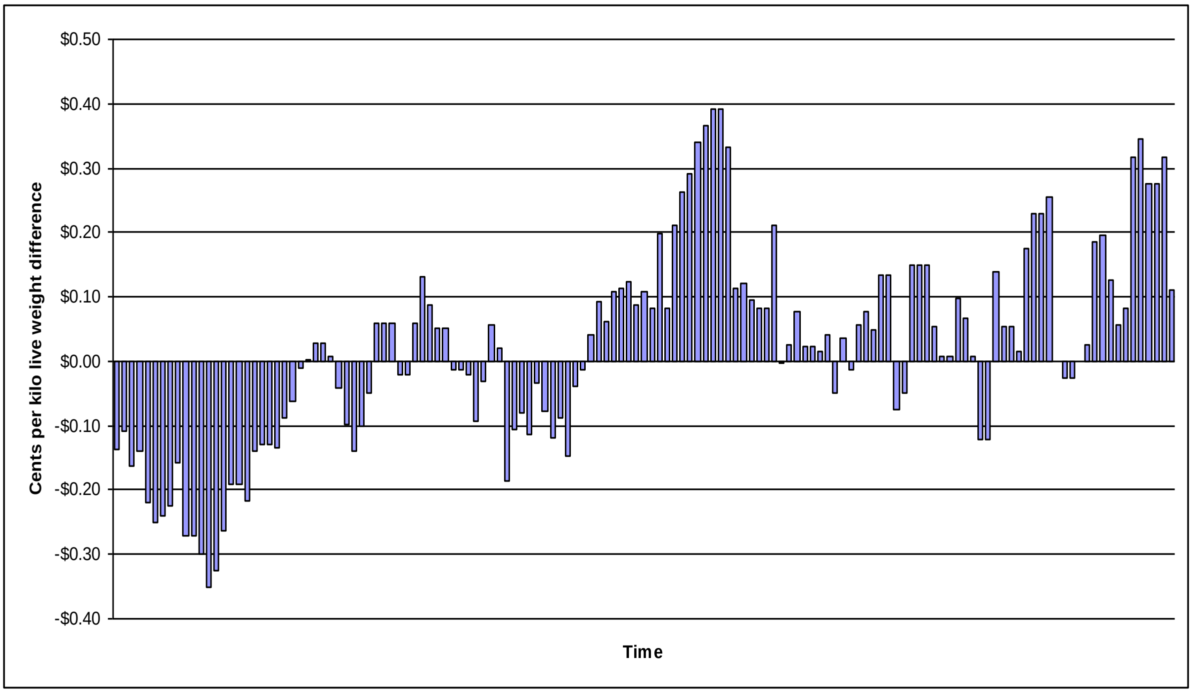

Figure 4. Difference between medium stores at Gracemere and Dinmore Ox prices with a twelve month lag starting in 2009

The price risk expected for the forage enterprises was estimated by comparing purchase and selling prices three months apart for each class of animal used in the forage enterprises (Figure 5). In this case the sale steers retained the same weight class, while the prices for the purchase steers came from the 401-500 kilogram liveweight sale class. The correlation between steer purchase and selling prices over the shorter ownership period was identified as being -0.15, or hardly any correlation at all.

There also appears to be no set basis (or margin) over time between the purchase price of the store steers and the sale price of the finished Jap Ox. The price basis can be up to 40 cents per kilogram positive or negative when measured on an equivalent liveweight basis and a three month lag between the purchase date and sale price is maintained.

The average (and median) price for Ox since 2009 at Dinmore is approximately $3.20 per kg dressed or $1.66 when expressed on an equivalent liveweight basis with a 52% dressing percentage. The maximum and minimum prices paid over the same period were $3.55 and $2.75 ($1.85 and $1.43 live). On this basis variation about the median over the period was approximately 15%.

The average price for medium stores at Gracemere over the same period was approximately $1.64 per kilogram live with a maximum and minimum of $2.00 and $1.23. The variation in store steer prices around the median was approximately 25% over the same period.

Finally, decisions to increase the production intensity in the beef industry are likely to increase the riskiness of the venture. The differentials in saleyard prices for heavy stores and Jap Ox in Figure 3 were used to assess the riskiness of fertilising sown grass pastures with nitrogen. These prices were applied to a stochastic model to assess the impact of historical price variability on average returns.

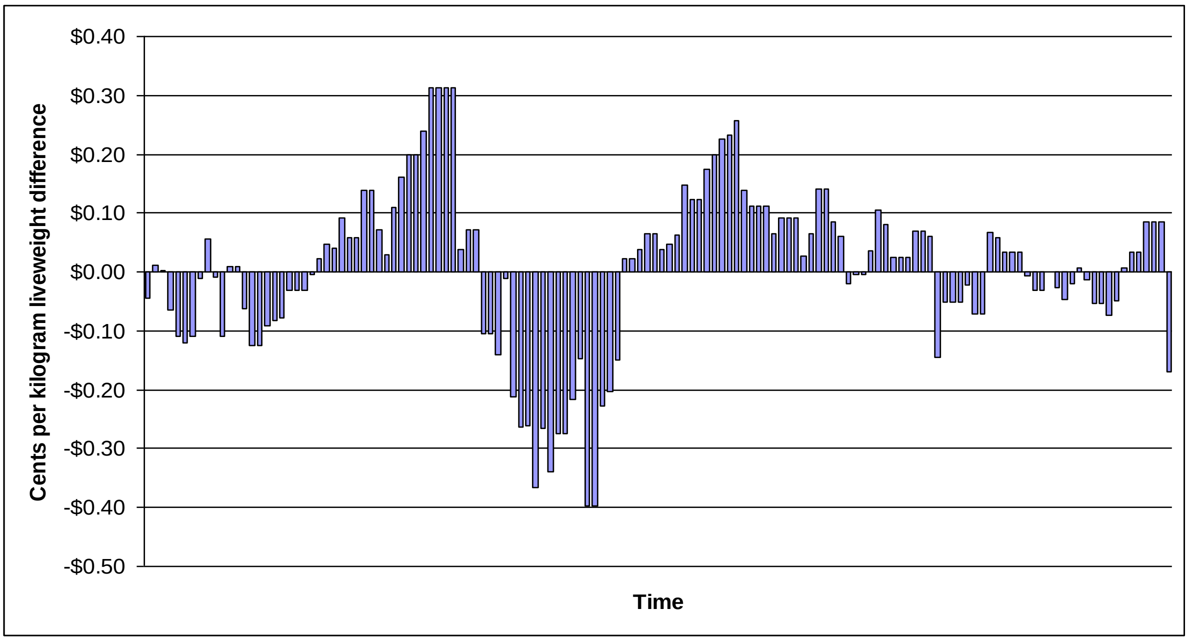

Figure 5. Difference between heavy stores at Gracemere and Dinmore Ox prices with a three month lag starting in 2009

6.4 Sown pasture scenarios

The pasture scenarios assessed in the study were based on brigalow soils that are now dominated by buffel grass. Annual pasture yields of 3000 kg dry matter/ha and 4500 kg dry matter/ha were selected for analysis to reflect the range of production levels from sown grass pastures across a range climates and underlying soil fertility (Figure 6).

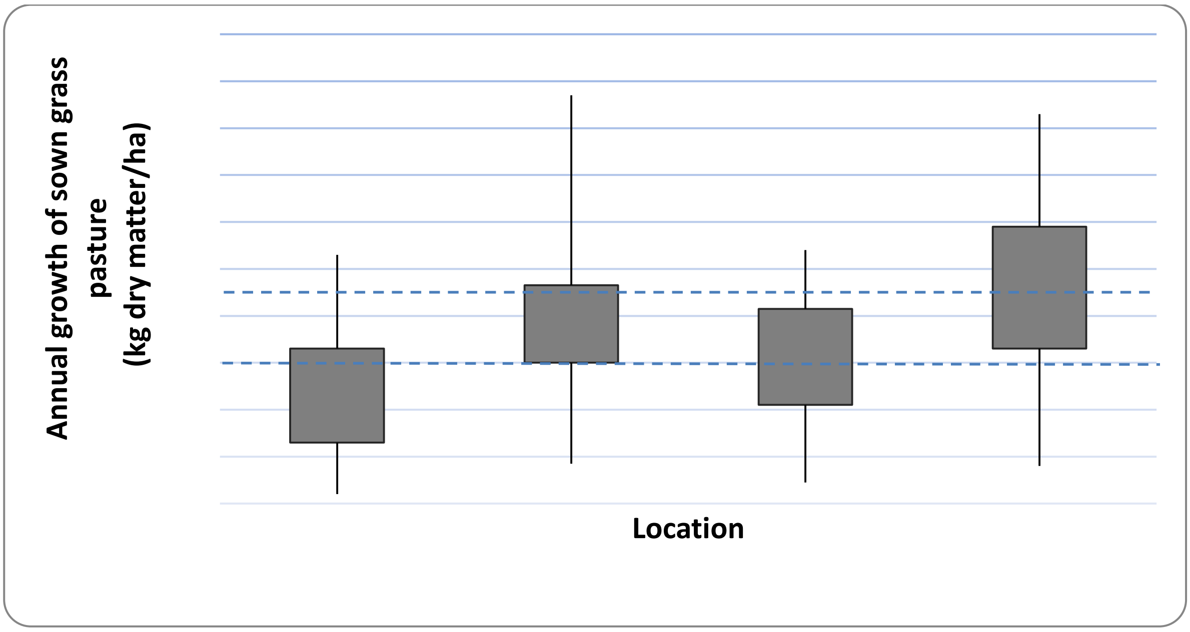

Figure 6. Simulation of annual dry matter production of sown grass on clay soils (PAWC 180mm; NO3 60 kg/ha/year) at Nindigully, Baralaba, Chinchilla and Gatton (J Owens, unpublished)

These selected levels, shown as a blue ‘dashed’ line on Figure 6, were considered to represent the likely average production levels of ‘rundown’ buffel that remained in reasonable condition on soils with a reasonable plant available water holding capacity.

6.4.1 Fertiliser - rates and responses

The project assessed the impact of single 'one-off' fertiliser applications only. While on-going trials suggest that larger responses may be possible from repeated applications, the lack of available data precluded further analyses.

The nitrogen fertiliser was applied at 100 kg N/ha as urea, the most commonly available formulation and the easiest for graziers to manage. This rate of 100 kg N/ha was considered by the project to be the most 'agronomically practical' and to reflect the rates being applied by the small number of graziers currently using nitrogen fertilisers. However, a 'half-rate' of 50 kg N/ha was also included to help assess the likely impact of using a lower rate over a larger area on the property. Urea contains 46% nitrogen and was costed at $700 per ton landed on property. Both rates were applied by a fertiliser spreader with the same application costs.

The project team expects that an average pasture response rate of 40 kg DM/kg N is achievable for urea fertiliser applied to rundown sown grass pastures. A response rate of 30 kg DM/kg N applied has been traditionally used by advisers and past fertiliser assessments (Peck *et al*. 2012). However, this current study was proposed because higher response rates have been common in recent years. Responses in replicated trials have been up to 60 kg DM/kg N in the first cut alone, with responses of up to 20 kg DM/kg N measured in 'second-cuts' after grazing. Re-analysis of past research confirms that higher mean response rates were also achieved in trials in the 1970/80s (Table 2). Consequently, the project team expects that response rates centred around 40 kg DM/kg applied N to be more realistic now that sown pastures are older and have, at least anecdotally, become further 'rundown' (Peck *et al*. 2012). Response rates of 30-50 kg DM/kg N were included to allow for higher and lower responses that may be expected due to different combinations of location, soils and climate, along with the seasonal conditions and the underlying level of rundown in each pasture.

Finally, a low response rate (20 kg DM/kg N) was included to assess the sensitivity of the possible pasture, animal and economic impacts. It is most relevant to very dry seasons or pastures that are not severely rundown. However, the extreme nitrogen deficiency in rundown pastures means that, even in dry seasons, applied nitrogen will likely lead to further higher delayed responses in the following season. Additional scenarios with carryover fertiliser responses into subsequent years were included in several selected analyses because recent trials show carryover responses of up to 20 kg DM/kg N. Production measures from old experimental sites confirm that production may be higher for at least 20 years (Section 4.2); albeit when 100+ kg N/ha was applied annually for many years.

Details of all scenarios analysed: those with no carryover nitrogen responses; and those with declining carryover responses in dry matter for up to 10 years and a small pasture quality carryover for one year at the 100 kg N/ha rate, are provided in the Results and Discussion (Section 7). With no published data on the carryover responses to single applications of nitrogen fertiliser, these initial estimates of possible 'carryover' impacts will require further research to explain the contribution of these applications to the long-term impacts that have been observed where repeated applications have been used.

6.4.2 Seasonality and rainfall

The analysis is based on average responses and does not account for seasonal variation at specific locations. However, the range of scenarios was designed to allow selection of the most appropriate average scenario for a given location. For example, low production pastures on less fertile soils are likely to provide big responses to fertilisers in favourable conditions, but they are unlikely to produce the highest response rates every year if they are in dry locations. Consequently, a lower response rate may need to be used to assess the likely long-term 'average' effects in dry locations and higher response rates in the wetter locations. Furthermore, the responses and outcomes developed in the project may help consider the viability of one-off use of fertilisers in favourable seasons and/or periods with increasing prices for beef, where more stock means higher returns. These assumptions may need testing with further research as some studies found that because nitrogen was such a dominating constraint on sown grass pastures, the amount of rainfall was not the most limiting factor to seasonal pasture growth (Buchannan and Cowan 1990).

6.4.3 Estimating animal production and carrying capacity

Animal production figures on the initial 'baseline' pastures were estimated with the following assumptions (Peck *et al.* 2012) which were modified as described below to account for the addition of 50 and 100 kg N/ha:

- Initial stocking rates were calculated as hectares per Adult Equivalent (AE), considered to be a 450 kg dry animal. The subsequent economic analysis used the average weight of stock over the grazing period to account for their growth while on the pasture.

- The average utilisation rate was either 25% (3000 kg DM /ha production) or 30% (4500 kg DM /ha production) for the base pasture in an unfertilised state.

- Residual pasture levels were set at 1800 kg DM/ha for the 3000 kg DM/ha/yr pasture and 2250 kg DM/ha of the 4500 kg DM/ha/yr pasture.

- Average dry matter intake per AE was estimated to be 2.2% of body weight (450 kg live) over the year. On this basis each AE ate approximately 10 kg per day or 3,650 kg of dry matter per year, and the stocking rate (in AE's) was derived by dividing 3650 by the amount of pasture available to be consumed per hectare.

- The level of spoilage was varied for production levels that increased in line with fertiliser applications (15% <4500 kg DM/ha; 20% 4501-7500 kg DM/ha; 25% >7500 kg DM/ha).

- The expected weight gain per AE per annum was initially set at 150 kg. This was increased in two scenarios for each fertiliser rate, that is 0.05 or 0.1 kg/AE/day with 50 kg N/ha, and 0.1 or 0.2 kg/AE/day with 100 kg N/ha when no carryover was included. The carryover analysis at 50 kg N/ha had no pasture quality effect in the second year, but the 100 kg/N/ha rate included a small liveweight gain in the second year. These analyses of carryover fertiliser responses included liveweight gains per AE that were roughly the midpoint of the ranges used for the 'static' analyses with no carryover.

- The "paddock size" was nominated as 100 hectares.

Table 7 shows the parameters used to calculate the average annual beef production of the base case buffel grass scenarios.

Table 7. Parameters for buffel pasture production without fertiliser

Annual pasture production [a] (kg DM/ha/yr)	**3000**	**4500**
Utilisation rate [b] (%)	25	30
Forage consumed (kg dry matter /annum)	750	1350
Spoilage %	15%	20%
Spoilage amount (kg /ha)	450	900
Residual amount (kg /ha)	1800	2250
stocking rate (ha/AE)	4.87	2.7
stocking rate (AE/ha)	0.21	0.37
Weight gain (kg per AE per annum)	150	150
kg of beef per ha per annum without fertiliser	30.82	55.48

a: Adapted from GRASP modelling and back calculation from other sources

b: Adapted from Whish (2011).

6.4.4 Budget parameters

The input parameters for the base enterprise budgets for the 3000 kg /ha DM and 4500 kg /ha DM scenario are identified in Tables 8 and 9. The number of steers purchased was derived from the stocking rate in hectares per AE, the weight gain per AE predicted and the chosen starting weight of the steers. The budget purchases “fractions” of steers to match the stocking rate calculated in the economic analysis and the production estimates.

Please note that the calculation of AE weighting in the enterprise budgets, both with and without fertiliser, is based on the formula (POWER [((opening weight + closing weight)/2], 0.75)/97.7) to account for growth while grazing the pastures. This formula gives a slightly different answer and reduces the over-estimation of carrying capacity that occurs when the more simple process of dividing by 3650 was used in the initial calculation of stocking rates.

Table 8. Input parameters and stocking rates for 3000 kg DM per ha base

Livestock purchase parameters	
Average age of purchased steers (months)	30
Number of steers purchased	18.30
Purchase price steers ($/kg live)	$1.64
Purchase weight steers (kg live)	450
Cost of purchased steers	$13,505
Gross cost of purchased steers (per head)	$738
Stocking rate (head per hectare)	0.18
Stocking rate (hectare per head)	5.46
Stocking rate (AE per hectare)	0.21
Stocking rate (hectare per AE)	4.87
Weight gain per day	0.41
Total days held	365

Table 9. Input parameters and stocking rates for 4500 kg DM per ha base

Livestock purchase parameters	
Average age of purchased steers (months)	30
Number of steers purchased	32.99
Purchase price steers ($/kg live)	$1.64
Purchase weight steers (kg live)	450
Cost of purchased steers	$24,348
Gross cost of purchased steers (per head)	$738
Stocking rate (head per hectare)	0.33
Stocking rate (hectare per head)	3.03
Stocking rate (AE per hectare)	0.37
Stocking rate (hectare per AE)	2.70
Weight gain per day	0.41
Total days held	365

6.4.5 Paddock enterprise budget

The enterprise budget for each initial carrying capacity of the paddock is shown in Table 10 and Table 11. These budgets represent the expected average performance of the paddock over time. No account is taken of any potential decline in pasture productivity that may or may not occur over the planning period.

The costs of transporting the steers to and from the property, minor health costs and selling costs are the other main variable costs included in the enterprise budgets. The opportunity cost of the capital tied up when steers are purchased is deducted from the gross margin to calculate the value of the gross margin after interest. (Only the opportunity cost of steer capital has been allowed for as no other capital costs differ significantly between the various treatments.) The opportunity cost of livestock capital was uniformly charged at an interest rate 5% per annum but only applied for the period that the livestock were held by the enterprise.

Table 10. Paddock budget for an annual turnover steer enterprise (3000 kg DM production)

Gross margin calculation	Total	per ha per annum
Livestock Sales (@$1.66/kg as per Section 6.3.4)	$18,385	$184
Livestock Purchases (@$1.64/kg as per Section 6.3.4)	$13,505	$135
Freight In	$241	$2
Freight Out	$1,003	$10
Treatment Expenses	$7	$0
Selling Expenses	$92	$1
Total Expenses	$14,848	$148
Gross Margin	$3,537	$35
Gross Margin per annum (after Interest)	$2,862	$29
Kilograms of liveweight gain per hectare per annum	27.45	

Table 11. Paddock budget for an annual turnover steer enterprise (4500 kg DM production)

Gross margin calculation	Total	per ha per annum
Livestock Sales (@$1.66/kg as per Section 6.3.4)	$33,145	$331
Livestock Purchases (@$1.64/kg as per Section 6.3.4)	$24,348	$243
Freight In	$434	$4
Freight Out	$1,808	$18
Treatment Expenses	$13	$0
Selling Expenses	$165	$2
Forage growing costs	$0	$0
Total Expenses	$26,768	$268
Gross Margin	$6,377	$64
Gross Margin per annum (after Interest)	$5,160	$52
Kilograms of liveweight gain per hectare per annum	49.5	

The expected average gross margin after interest for the 3000 kg DM/ha scenario is about half that for the 4500 kg DM/ha scenario. This is due to the difference in the starting productivity for the two pastures.

The impact of nitrogen fertiliser on animal production, as already noted, was estimated via the estimated pasture responses in dry matter production and feed quality:

- <u>For the scenarios in which no carryover benefits were included</u>, the new amount of pasture available for consumption was identified by deducting an allowance for spoilage (which was increased with total dry matter) and the desired residual from the total dry matter produced as a result of the fertiliser application. The average amount of dry matter available for consumption was then converted to a stocking rate in AE's per hectare by dividing 3650 by the available kilograms of forage per hectare. This approach led to an increase in the overall utilisation rate as a percentage of the total forage available when compared to the base scenario. Improved quality of the fertilised pastures, as an additional benefit to increased stocking rates, were included by increasing the annual weight gain per adult equivalent by a set average amount of 50, 100 or 200 grams per AE per day, depending upon the fertiliser scenario and the productivity of the base pasture.
- <u>For the scenario where there was an expected carryover of benefit</u>, the potential average increase in pasture and livestock production was identified at response levels of 30 and 40 kg extra dry matter per hectare per kilogram of applied N. This range was chosen to identify the likely level of response required to either breakeven or improve profitability. A minor amount of benefit in pasture dry matter production is predicted to last until ten years after fertiliser application due to some carryover effects of increased nitrogen levels in the pasture (Tables 26 -33). These effects are mostly lost by year five when the extra nitrogen supply from cycling is estimated to be only 5 kg N/ha/yr and 2 kg N/ha/yr for the 100 kg N/ha and 50 kg N/ha fertiliser treatments respectively. These estimates were based on very limited data from a single application of nitrogen at Glenmorgan (southern Queensland) and the responses being measured 25 years after nitrogen was applied for 10 years at Narayen (Cook 2011). An increase in forage quality was also built into the 100 kg N/ha treatment for

the year after the initial application of fertiliser, but not for the 50 kg N/ha treatment. The initial extra liveweight gains used in this analysis 'with carryover benefits' was more conservatively based on the mid-point the two liveweight scenarios used for the above scenario where there was no carryover benefit at all.

The analysis of 'carryover' benefits used the pasture yields, stocking rate and liveweight gain assumptions to calculate the net cash flows for the base pastures and the scenarios in which nitrogen was applied. The final net cash flow for each scenario was compared to calculate the partial Net present value (NPV) for each fertiliser application and response scenario. This figure represents the return to the extra dollars invested in livestock and fertiliser. The Internal Rate of Return (IRR) was calculated for each of these scenarios with a 'carryover' benefit.

6.5 Forage crop scenarios

6.5.1 Estimating animal production and carrying capacities

The impact of fertiliser applications on carrying capacity and production was modelled for a typical forage paddock in southern central Queensland. The paddock was formerly Brigalow country.

Two separate forages (oats and forage sorghum) were modelled with three base levels of starting production and with a range of levels of response to two different fertilisers.

Forage sorghum had starting base production levels of either 5000, 10000 or 15000 kg DM per hectare per annum. These starting levels are taken to represent average production from three levels of inherent soil fertility (i.e. low, medium and high) not different starting levels of PAWC. Similarly, oats had starting base production levels of either 2000, 4000 or 6000 kg DM per ha per annum. Paddocks with such nutrient levels are considered the most likely by the staff undertaking the scoping study to show an economic response to the application nitrogen and phosphorus fertiliser.

The response to nitrogen fertiliser was tested by treating each starting level of each forage crop with 50 kg N or 100 kg N and predicting an average response for combinations of 0.05, 0.1 or 0.2 kg extra liveweight gain per head and 10, 30, 40 or 50 kg DM extra per hectare for each kg of N fertiliser applied.

To test the response to phosphorus, the middle level of production (10000 kg DM/ha forage sorghum and 4000 kg DM/ha oats) was treated with either 5 kg P or 10 kg P per hectare with a range of responses estimated.

The assumptions to calculate the potential carrying capacity for the unfertilised forage were similar to those used for the sown pastures. However, an average utilisation rate was either 30% (forage sorghum) or 40% (oats) for the base forage in an unfertilised state (Bell *et al.* 2012). Annual forage production research in central Queensland by the High-output Forage project has confirmed similar utilisation rates (Buck *et al.* 2014 unpublished data)

Tables 12 and 13 show the parameters used to calculate the average annual beef production of the base case forage sorghum and oats scenarios.

Table 12. Parameters for forage sorghum production without fertiliser

Forage Sorghum	low	medium	high
baseline forage production kg/ha	5000	10000	15000
forage consumption / AE / day kg	9.9	9.9	9.9
forage duration days	100	100	100
total forage consumption kg/AE	990	990	990
spoilage kg/ha	2500	5500	8500
residual kg/ha	1000	1500	2000
forage for consumption kg (30% utilisation)	1500	3000	4500
stocking rate AE/ha	1.51	3.0	4.5
weight gain kg/AE (0.6kg/h/d)	60	60	60
liveweight kg/ha no fertiliser	91	182	273

Table 13. Parameters for oats production without fertiliser

Oats	low	medium	high
baseline forage production kg/ha	2000	4000	6000
forage consumption / AE / day kg	9.9	9.9	9.9
forage duration days	90	90	90
total forage consumption kg/AE	891	891	891
spoilage kg/ha	700	1400	2100
residual kg/ha	500	1000	1500
forage for consumption kg (40% utilisation)	800	1600	2400
stocking rate AE/ha	0.89	1.79	2.69
weight gain kg/AE (0.9kg/h/d)	81	81	81
liveweight kg/ha no fertiliser	73	145	218

6.5.2 Budget parameters

For each forage crop, the number of steers purchased was derived from the stocking rate in hectares per AE, the weight gain per AE predicted, and the chosen starting weight of the steers (Table 14 and Table 15). The analysis of forage crops used the same parameters already described for sown pastures to purchase "fractions" of steers, calculate stocking rates, estimate transport costs, and to assess the opportunity costs of capital invested in extra steers. Paddock budgets which include livestock sales and variable costs for unfertilised forage sorghum and oats are shown in tables 16 and 17.

Table 14. Input parameters and stocking rates for forage sorghum base

Livestock purchase parameters	low	medium	high
Average age of purchased steers (months)	30	30	30
Number of steers purchased	151.52	300	450
Purchase price steers ($/kg live)	$1.65	$1.65	$1.65
Purchase weight steers (kg live)	520	520	520
Cost of purchased steers	$130,004	$257,400	$386,100
Gross cost of purchased steers (per head)	$858	$858	$858
Stocking rate (head per hectare)	1.52	3.00	4.50
Stocking rate (hectare per head)	0.66	0.33	0.22
Weight gain per day	0.60	0.60	0.60
Total days held	100	100	100

Table 15. Input parameters and stocking rates for oats base

Livestock purchase parameters	low	medium	high
Average age of purchased steers (months)	30	30	30
Number of steers purchased	89.79	179.57	269.36
Purchase price steers ($/kg live)	$1.65	$1.65	$1.65
Purchase weight steers (kg live)	520	520	520
Cost of purchased steers	$77,040	$154,074	$231,111
Gross cost of purchased steers (per head)	$858	$858	$858
Stocking rate (head per hectare)	.90	1.8	2.69
Stocking rate (hectare per head)	1.11	0.56	0.37
Weight gain per day	0.90	0.90	0.90
Total days held	90	90	90

Table 16. Paddock budget for an annual turnover steer enterprise with unfertilised forage sorghum

Gross margin for	5000 kg DM yr Forage sorghum	10000 kg DM yr Forage sorghum	15000 kg DM yr Forage sorghum
	per ha per annum	per ha per annum	per ha per annum
Livestock Sales	$1,471	$2,913	$4,370
Variable costs			
Livestock Purchases	$1,300	$2,574	$3,861
Freight In	$23	$45	$67
Freight Out	$83	$164	$247
Treatment Expenses	$1	$1	$2
Selling Expenses	$8	$15	$23
Forage growing costs	$114	$114	$114
Total Expenses	$1,527	$2,913	$4,312
Gross Margin	-$56	$1	$58
Gross Margin / hectare /annum (after interest)	**-$74**	**-$35**	**$5**
Kilograms of liveweight gain per hectare per annum	91	180	270

Table 17. Paddock budget for an annual turnover steer enterprise with unfertilised oats

Gross margin for	2000 kg DM yr Oats	4000 kg DM yr Oats	6000 kg DM yr Oats
	per ha per annum	per ha per annum	per ha per annum
Livestock Sales	$904	$1,807	$2,711
Variable costs			
Livestock Purchases	$770	$1,541	$2,311
Freight In	$13	$27	$40
Freight Out	$49	$98	$148
Treatment Expenses	$0	$1	$1
Selling Expenses	$4	$9	$13
Forage growing costs	$153	$153	$153
Total Expenses	$990	$1,828	$2,666
Gross Margin	-$87	-$21	$45
Gross Margin per hectare per annum (after interest)	**-$96**	**-$40**	**$16**
Kilograms of liveweight gain per hectare per annum	73	145	218

6.5.3 Estimating the benefit of fertiliser application on forages

The scarcity of recent data identifying the impact on beef production of applying fertiliser to forage crops required all available sources of knowledge to be condensed into a range of “best bet” responses.

Nitrogen (N) fertiliser was applied at either 50 kg N/ha/yr or 100 kg N/ha/yr in the form of urea. Phosphorus (P) fertiliser was applied at either 5 kg P/ha/yr or 10 kg P/ha/yr in the form of Incitec triple super. The urea has 46% N and a cost of $700 per ton landed on property. The triple super has 20.1% P and a cost of $890 per ton.

6.5.4 Forage sorghum scenario

For each starting production level for forage sorghum, the expected average increase in pasture and livestock production was identified at response levels of 30, 40 or 50 kg extra dry matter per hectare per kilogram of applied N for both treatment levels; 50 kg and 100 kg N per hectare.

The effect of nitrogen fertiliser on forage quality and LGW per head was also included. The extra weight gain due to improved forage quality was assumed to be either 50 grams per head per day for 50 kg N applied or 100 grams per head per day for 100 kg N applied.

Phosphorus fertiliser was only applied to the 10000 kg DM production scenario at rates of 5 kg and 10 kg of P per hectare with response rates of 2, 5, 10, 20, 40, 80, 120 and 160 kg of DM per kg of P applied. Extra weight gain was also applied at 50 or 100 grams per head per day to identify where breakeven and profitable levels of phosphorus application may be found.

In each fertiliser scenario, the amount of pasture available for consumption was identified by deducting an allowance for spoilage and the desired residual from the total dry matter produced. This amount of dry matter available for consumption was converted to a stocking rate in AE's per hectare by dividing 3650 by the available kilograms of forage per hectare.

6.5.5 Forage oats scenario

For each starting production level for oats, the potential average increase in forage crop and livestock production was identified at response levels of 10, 30 or 50 kg extra dry matter per hectare per kg of applied nitrogen at treatment levels of 50 kg and 100 kg N per hectare.

The P fertiliser was only applied to the 4000 kg DM production scenario at rates of 5 kg and 10 kg of P per hectare with response rates of 2, 5, 10, 20, 40, 80, 120 and 160 kg of DM per kg of P applied.

Again, the new amount of pasture available for consumption was identified by deducting an allowance for spoilage and the desired residual from the total dry matter produced on the fertilised pasture. The dry matter available for consumption was converted to a stocking rate in AE's per hectare by dividing 3650 by the available kilograms of forage per hectare.

It was also proposed that adding N or P fertiliser to oats could improve the quality of the pasture providing additional benefits above and beyond those captured in the stocking rate increase generated by the additional dry matter production.

The potential increase in oats quality due to the application of fertiliser was included in this analysis by increasing the annual weight gain per adult equivalent by a set amount of 100 or 200 grams per AE per day depending upon the fertiliser scenario and the productivity of the base pasture.

6.6 Future research, development and extension priorities

The collation of data, discussion of assumptions for analyses, the levels of production predicted from these assumptions, and the ultimate economic assessments all contributed to the proposed investment priorities for fertiliser use on sown grasses and forages. The proposed priorities are those of the project team. They have been developed in discussions with 'regional experts', and circulated back to the participants of the project's 'expert meeting' for comment and input. However, the project team produced the final version included in this report.

7 Results and discussion

7.1 Sown pastures

The assumptions for the base pasture scenarios in Table 7 provided stocking rates that matched expectations and commercial experience. For example, the stocking rate for the 'base pasture' with an annual production of 3000 kg DM/ha was 4.9 ha/head (with 31 kg beef/ha), which is in line with expectations for less favoured paddocks on the western Downs and about average for the Maranoa; while the 4500 kg DM/ha 'base pasture' with 2.7 ha/head (and 55 kg beef/ha) matched the more productive pastures of the western Downs and Darling Downs it was designed to represent (Thompson 1988).

7.1.1 Production benefits from applied nitrogen (with no residual fertiliser response)

Where response rates to N were assumed to occur only in the year of application, the modelled average increase in beef production per hectare from 100 kg N/ha ranged from 170% up to 721% (Table 18, Table 19). As expected (based on the model assumptions), the relative increases were greater when higher response rates in forage yield and/or LWG per steer were used.

The project team expects rundown sown pastures that remain in good condition, with a good density of plants, to respond at around 40 kg DM/kg N applied. Using this response rate 100 kg N/ha was calculated to increase beef production by 190-230 kg/ha on the less productive base pasture, and 210-250 kg/ha on the more productive one. With 50kg N/ha and using the 40kg DM/kg N response rate, beef production was calculated to increase by 190-230 kg/ha on the less productive base pasture, and 210-250 kg/ha on the more productive one (Table 20, Table 21).

The calculated stocking rate figures, liveweight gains and resulting beef production estimates were inputs to the gross margin analysis of each fertiliser scenario.

Table 18. Average beef production increase due to 100 kg N/ ha fertiliser with a liveweight gain of an extra 0.1 kilograms per AE per day and a range of 20 to 50 kg dry matter per kg of N applied

Base pasture	**3000 kg DM/year**				**4500 kg DM/year**			
Pasture response kg DM /kg N	**20**	**30**	**40**	**50**	**20**	**30**	**40**	**50**
Extra pasture	2000	3000	4000	5000	2000	3000	4000	5000
% increase in pasture	67%	100%	133%	167%	44%	67%	89%	111%
New annual production	5000	6000	7000	8000	6500	7500	8500	9500
Spoilage %	20%	20%	20%	25%	20%	20%	25%	25%
spoilage	1000	1200	1400	2000	1300	1500	2125	2375
residual	1800	1800	1800	1800	2250	2250	2250	2250
Available for consumption	2200	3000	3800	4200	2950	3750	4125	4875
% increase in available pasture	193%	300%	407%	460%	119%	178%	206%	261%
stocking rate (ha/ae)	1.66	1.22	0.96	0.87	1.24	0.97	0.88	0.75
stocking rate (ae/ha)	0.60	0.82	1.04	1.15	0.81	1.03	1.13	1.34
New weight gain	185	185	185	185	185	185	185	185
Extra kg/ha/yr with fertiliser	111.51	152.05	192.60	212.88	149.52	190.07	209.08	247.09
% increase in LWG/ha	262%	393%	525%	591%	170%	243%	277%	345%

Table 19. Average beef production increase due to 100 kg N/ ha fertiliser with a liveweight gain of an extra 0.2 kilograms per AE per day and a range of 20 to 50 kg dry matter per kg of N applied

Base pasture	**3000 kg DM/year**				**4500 kg DM/year**			
Pasture response kg DM /kg N	**20**	**30**	**40**	**50**	**20**	**30**	**40**	**50**
Extra pasture	2000	3000	4000	5000	2000	3000	4000	5000
% increase in pasture	67%	100%	133%	167%	44%	67%	89%	111%
New annual production	5000	6000	7000	8000	6500	7500	8500	9500
Spoilage %	20%	20%	20%	25%	20%	20%	25%	25%
spoilage	1000	1200	1400	2000	1300	1500	2125	2375
residual	1800	1800	1800	1800	2250	2250	2250	2250
Available for consumption	2200	3000	3800	4200	2950	3750	4125	4875
% increase in available pasture	193%	300%	407%	460%	119%	178%	206%	261%
stocking rate (ha/ae)	1.66	1.22	0.96	0.87	1.24	0.97	0.88	0.75
stocking rate (ae/ha)	0.60	0.82	1.04	1.15	0.81	1.03	1.13	1.34
New weight gain	220	220	220	220	220	220	220	220
Extra kg/ha/yr with fertiliser	132.60	180.82	229.04	253.15	177.81	226.03	248.63	293.84
% increase in LWG/ha	330%	487%	643%	721%	220%	307%	348%	430%

Table 20. Average beef production increase due to 50 kg N/ha with a liveweight gain of an extra 0.05 kilograms per AE per day and a range of 20 to 50 kg dry matter per kg of N applied

Base pasture	**3000 kg DM/year**				**4500 kg DM/year**			
Pasture response kg DM /kg N	**20**	**30**	**40**	**50**	**20**	**30**	**40**	**50**
Extra pasture	1000	1500	2000	2500	1000	1500	2000	2500
% increase in pasture	33%	50%	67%	83%	22%	33%	44%	56%
New annual production	4000	4500	5000	5500	5500	6000	6500	7000
Spoilage %	20%	20%	20%	20%	20%	20%	20%	20%
spoilage	800	900	1000	1100	1100	1200	1300	1400
residual	1800	1800	1800	1800	2250	2250	2250	2250
Available for consumption	1400	1800	2200	2600	2150	2550	2950	3350
% increase in available pasture	87%	140%	193%	247%	59%	89%	119%	148%
stocking rate (ha/ae)	2.61	2.03	1.66	1.40	1.70	1.43	1.24	1.09
stocking rate (ae/ha)	0.38	0.49	0.60	0.71	0.59	0.70	0.81	0.92
New weight gain	170	170	170	170	170	170	170	170
Extra kg/ha/yr with fertiliser	65.21	83.84	102.47	121.10	100.14	118.77	137.40	156.03
% increase in LWG/ha	112%	172%	232%	293%	80%	114%	148%	181%

Table 21. Average beef production increase due to 50 kg N/ha with a liveweight gain of an extra 0.1 kilograms per AE per day and a range of 20 to 50 kg dry matter per kg of N applied

Base pasture	**3000 kg DM/year**				**4500 kg DM/year**			
Pasture response kg DM /kg N	**20**	**30**	**40**	**50**	**20**	**30**	**40**	**50**
Extra pasture	1000	1500	2000	2500	1000	1500	2000	2500
% increase in pasture	33%	50%	67%	83%	22%	33%	44%	56%
New annual production	4000	4500	5000	5500	5500	6000	6500	7000
Spoilage %	20%	20%	20%	20%	20%	20%	20%	20%
spoilage	800	900	1000	1100	1100	1200	1300	1400
residual	1800	1800	1800	1800	2250	2250	2250	2250
Available for consumption	1400	1800	2200	2600	2150	2550	2950	3350
% increase in available pasture	87%	140%	193%	247%	59%	89%	119%	148%
stocking rate (ha/ae)	2.61	2.03	1.66	1.40	1.70	1.43	1.24	1.09
stocking rate (ae/ha)	0.38	0.49	0.60	0.71	0.59	0.70	0.81	0.92
New weight gain	190	190	190	190	190	190	190	190
Extra kg/ha/yr with fertiliser	72.88	93.70	114.52	135.34	111.92	132.74	153.56	174.38
% increase in LWG/ha	136%	204%	272%	339%	102%	139%	177%	214%

7.1.2 Gross margin impacts of applying nitrogen fertiliser

The gross margins for the base pastures and the 100 kg N/ha fertiliser scenarios discussed above are provided in Tables 22-25. For convenience, the base pasture has been included once for each treatment at the left hand side of each of these tables.

Significant improvements in gross margin after interest (3-4 times that of the base scenario) occurred on low productivity pasture (base of 3000 kg DM /ha) only when the yield response rate was at least 40 kg DM/kg N and the cattle growth rate response was 200 g/hd/day. On higher productivity pasture (4500 kg DM/ha base), gross margin was significantly boosted (2-3 times that of the base scenario) when the yield response rate was at least 30 kg/ha and the cattle growth rate response was 200 g/hd/day. There were modest increases in gross margin (30-35% above the base scenario) for lower levels of pasture productivity and with the lower cattle growth rate response, but only when the yield response rate was at least 50 kg DM/kg N. The latter response rate is less likely in reality based on expert opinion.

For the expected dry matter response rate of 40 kg DM/kg N the gross margin declined from $29/ha and $52/ha for the 3000 kg DM and 4500 kg DM based to only $20/ha and $36/ha respectively with the lower estimates of liveweight gain (Table 22, Table 23). With a 100 gram per AE per day improvement in liveweight gain, it was only at the 50 kg DM/ha fertiliser response rate that the gross margins improved to $38/ha and $71/ha respectively. Lower fertiliser response rates of 20, 30 and 40 kg DM/kg N were calculated to all lose money.

The current enthusiasm of graziers with fertiliser trials is understandable if the recently measured on-farm response rates of 40+ kg DM/kg N occur in combination with LWG responses of at least 200 g/hd/d.

The traditionally quoted response rate of 30 kg DM/kg N only increased gross margins by 31% and 71% for the 3000 kg DM and 4500 kg DM pastures. This more modest return for the investment in fertiliser, the cost of purchasing stock, and the risk of seasonal and market variations is consistent with the lack of use of nitrogen fertiliser in the region.

However, gross margins for the 50 kg DM/kg N response rate increased by 307% and 218% for these pastures and demonstrates the potential gains possible from the 40-60 kg DM/kg response that have been observed in replicated trials over the recent good seasons.

It should also be noted that the low response rate of 20 kg DM/kg N which may occur in very dry seasons had lower gross margins than the base pasture in all scenarios.

The opportunity cost associated with extra investment in stock appears to be the major reason why very large improvements in pasture and animal production from N fertiliser, result in relatively modest increases in average gross margin.

In summary, where any carryover pasture response is ignored, nitrogen fertiliser appears to be worth considering only when response rates of 40 kg DM/kg N and extra liveweight gains of 200 grams per AE per day are achieved (Figure 7 and Figure 8). The results also suggest that any use of nitrogen fertiliser is best made on soils and pastures with the highest potential as the 4500 kg DM pasture showed consistently higher beef production and returns from applied nitrogen than the 3000 kg DM. These data also confirm that the economics of using a ‘half rate’ of 50 kg N/ha are much less attractive (Figure 7 and Figure 8).

Table 22. Average gross margins; 100 kg N applied to 3000 kg DM pasture (100g per AE/day)

Gross margin for 3000 kg DM pasture +.1 kg/day LWG	**Base pasture**	**20kg DM/kgN**	**30kg DM/kgN**	**40kg DM/kgN**	**50kg DM/kgN**
	$/ha/year	$/ha/year	$/ha/year	$/ha/year	$/ha/year
Livestock Sales	$184	$549	$747	$949	$1,047
Variable costs					
Livestock Purchases	$135	$384	$523	$664	$733
Freight In	$2	$8	$10	$13	$15
Freight Out	$10	$29	$40	$50	$56
Treatment Expenses	$0	$0	$0	$0	$0
Selling Expenses	$1	$3	$4	$5	$6
Forage growing costs	$0	$163	$163	$163	$163
Total Expenses	$148	$587	$740	$896	$972
Gross Margin	$35	-$38	$7	$53	$75
Gross Margin (after interest)	**$29**	**-$57**	**-$19**	**$20**	**$38**
Kilograms of liveweight gain /ha /annum	27	108	147	187	207

Table 23. Average gross margins; 100 kg N applied to 4500 kg DM pasture (100g per AE/day)

Gross margin for 4500 kg DM pasture +.1 kg/day LWG	**Base pasture**	**20kg DM/kgN**	**30kg DM/kgN**	**40kg DM/kgN**	**50kg DM/kgN**
	$/ha/year	$/ha/year	$/ha/year	$/ha/year	$/ha/year
Livestock Sales	$331	$735	$939	$1,035	$1,215
Variable costs					
Livestock Purchases	$243	$514	$657	$725	$850
Freight In	$4	$10	$13	$15	$17
Freight Out	$18	$39	$50	$55	$65
Treatment Expenses	$0	$0	$0	$0	$0
Selling Expenses	$2	$4	$5	$6	$6
Forage growing costs	$0	$163	$163	$163	$163
Total Expenses	$268	$731	$889	$963	$1,102
Gross Margin	$64	$4	$51	$72	$113
Gross Margin (after interest)	**$52**	**-$22**	**$18**	**$36**	**$71**
Kilograms of liveweight gain /ha /annum	49	145	185	204	240

Table 24. Average gross margin; 100 kg N applied to 3000 kg DM pasture (200g per AE/day)

Gross margin for 3000 kg DM pasture +.2 kg/day LWG	**Base pasture**	**20kg DM/kgN**	**30kg DM/kgN**	**40kg DM/kgN**	**50kg DM/kgN**
	$/ha/year	$/ha/year	$/ha/year	$/ha/year	$/ha/year
Livestock Sales	$184	$565	$769	$977	$1,078
Variable costs					
Livestock Purchases	$135	$358	$488	$620	$684
Freight In	$2	$7	$11	$14	$15
Freight Out	$10	$30	$41	$52	$57
Treatment Expenses	$0	$0	$0	$0	$0
Selling Expenses	$1	$3	$4	$5	$6
Forage growing costs	$0	$163	$163	$163	$163
Total Expenses	$148	$561	$707	$854	$925
Gross Margin	$35	$3	$62	$123	$152
Gross Margin (after interest)	**$29**	**-$14**	**$38**	**$92**	**$118**
Kilograms of liveweight gain /ha /annum	27	133	180	229	253

Table 25. Average gross margins; 100 kg N applied to 4500 kg DM pasture (200g per AE/day)

Gross margin for 4500 kg DM pasture +.2 kg/day LWG	**Base pasture**	**20kg DM/kgN**	**30kg DM/kgN**	**40kg DM/kgN**	**50kg DM/kgN**
	$/ha/year	$/ha/year	$/ha/year	$/ha/year	$/ha/year
Livestock Sales	$331	$756	$967	$1,065	$1,250
Variable costs					
Livestock Purchases	$243	$480	$613	$676	$793
Freight In	$4	$11	$14	$15	$18
Freight Out	$18	$40	$51	$57	$66
Treatment Expenses	$0	$0	$0	$0	$1
Selling Expenses	$2	$4	$5	$6	$7
Forage growing costs	$0	$163	$163	$163	$163
Total Expenses	$268	$698	$847	$917	$1,047
Gross Margin	$64	$58	$120	$149	$203
Gross Margin (after interest)	**$52**	**$34**	**$89**	**$115**	**$163**
Kilograms of liveweight gain /ha /annum	49	177	227	250	293

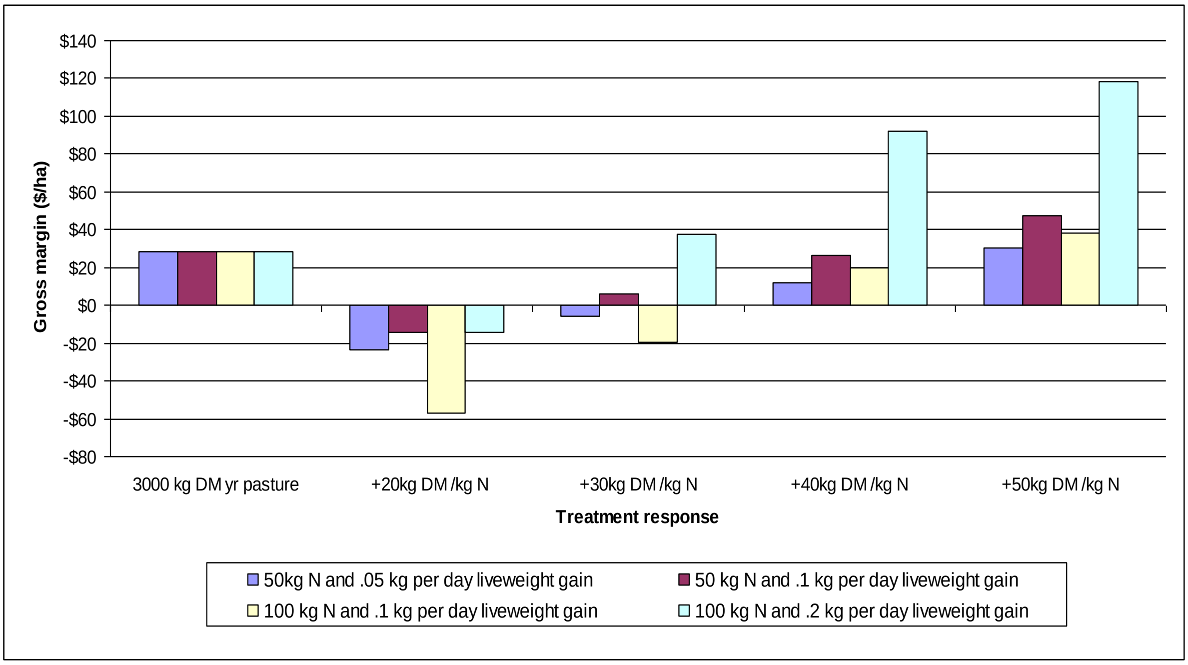

Figure 7. Estimated gross margins for a 3000 kg DM pasture with differing dry matter responses and animal production responses to fertiliser

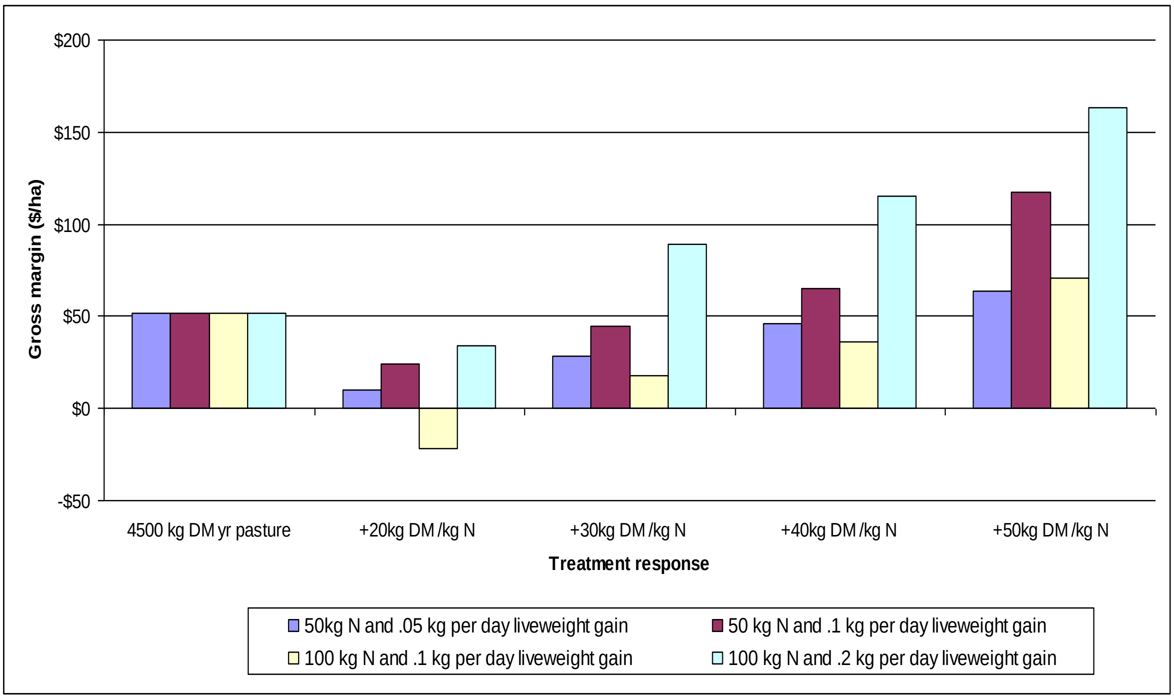

Figure 8. Estimated gross margins for a 4500 kg DM pasture with differing dry matter responses and animal production responses to fertiliser

All the above analyses have been based on average responses of pastures and animals, and the average long-term sale prices at Dinmore and Gracemere. However, the cost of nitrogen (~$1.50/kg) and the investment in extra stock means that graziers using fertiliser would be exposed to significant risks each year.

7.1.3 The riskiness of applying nitrogen fertiliser to sown grass pastures

Any decision to increase production intensity in the beef industry will increase the riskiness of the venture. The seasonal production risks can be minimised by only applying fertiliser in years with good existing conditions or good prospects for follow-up rainfall, and avoiding fertiliser when dry conditions are predicted as more likely.

It appears that the investment in extra stock to utilise the additional feed available is the greatest risk for the scenarios investigated in this analysis. The opportunity cost of investing in extra stock and the exposure to changing margins between buying and selling prices will likely be highest in a finishing enterprise that, like the one used in this analysis, purchases all required stock. For example, the investment in cattle per hectare before any freight or selling expenses rose from $135 to as high as $620 for the 3000 kg DM pasture (Table 24); and from $243 up to $676 for the 4500 kg DM pasture (Table 25) when 100 kg N/ha was applied with the expected response rate of 40 kg DM/kg N. These risks may be reduced where farm sourced stock are used. For example, the required investment in stock may effectively be reduced by up to 12c/kg when property sourced stock are used instead of buying all new stock at saleyards (Bowen *et al.* 2013). Despite this, graziers with more stock will still be more exposed to saleyard price difference in the buying and selling of these animals.

To test the riskiness of these ‘one-off’ fertiliser applications, the historical prices of cattle (Figures 3-5) were applied to a stochastic model to estimate the impact of price variability of average returns. This analysis is of the price risk only and includes no risk associated with seasonal variation.

The stochastic model was applied to an unfertilised buffel pasture producing 4500 kg dry matter with an average gross margin of $52/ha, and to the ‘half-rate’ of fertiliser that was estimated to comparable average gross margins (Figure 8):

- the same pasture fertilised with 50 kg N/ha providing a pasture response rate of 40 kg DM/kg N and a growth rate increase of 50 grams per AE per day. The average gross margin was 9% lower at $46/ha.

- the same pasture fertilised with 50 kg N/ha providing a pasture response rate of 40 kg DM/kg N and a growth rate increase of 100 grams per AE per day. The average gross margin was 25% higher at $65/ha.

The results of the stochastic model (Figure 9) show that the fertilised pasture is likely to increase returns in about 40-60% of years depending upon the additional weight gain assumptions for pasture quality. However, the producer could also be worse off in about 30-40% of years, due to the riskiness inherent in the prices paid and received for steers. This analysis is based on the ‘half-rate’ of fertiliser rather than the preferred rate of 100 kg N/ha. However, it clearly illustrates the positive and negative risk that unpredictable price difference will likely make for any intensification activity such as fertilising sown pastures.

With the pasture scenarios assessed in the project typically producing 100-250 kg/ha of extra beef per hectare, an entry/exit price differential of $0.01/kg will change the gross margins presented here by ~$1.00-$2.50. Many graziers will be able to reduce their transport costs by buying or selling more locally than Gracemere and Dinmore, which may significantly improve their gross margins, especially for the fertilised paddocks that will carry many more stock.

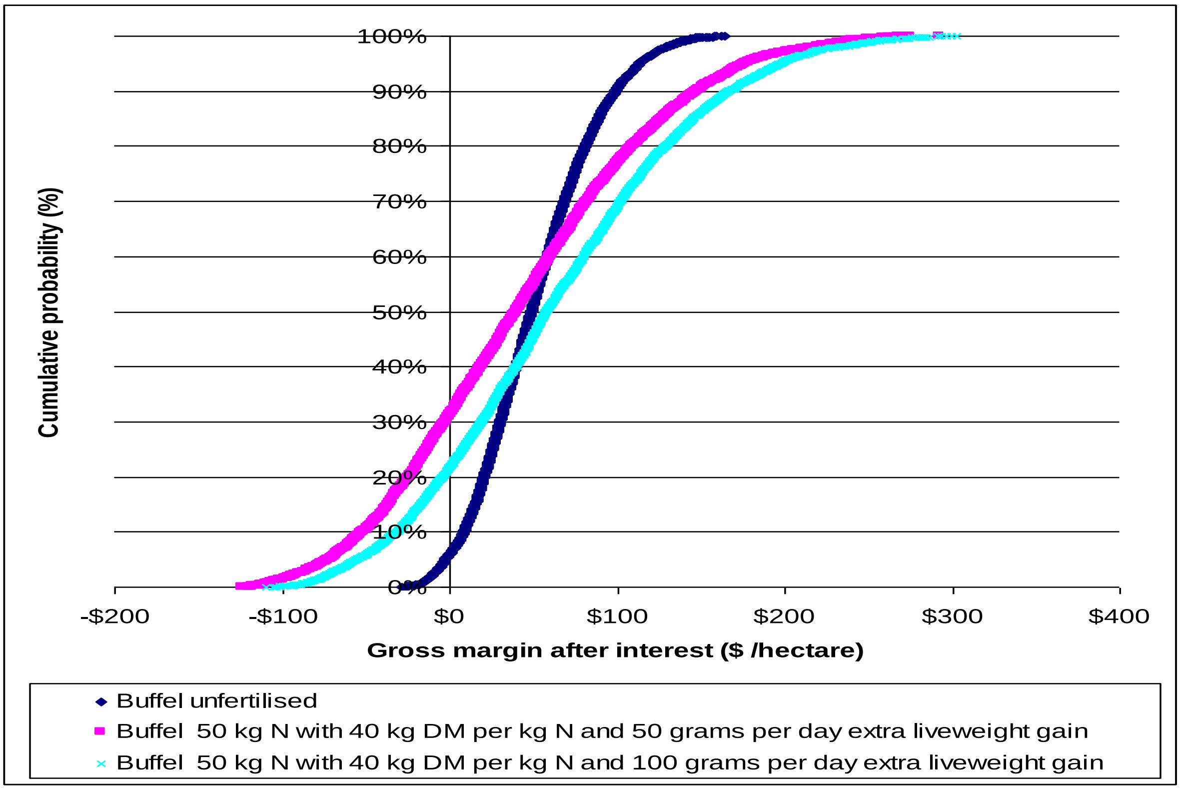

Figure 9. Distribution of expected gross margins for a buffel pasture producing 4500 kg DM/year before applying 50 kg N/ha (based on historical sale prices at Dinmore and Gracemere)

The increases in beef production from one-off applications of nitrogen fertiliser assuming no carryover response have provided a wide range of outcomes. Average gross margins for the fertiliser scenarios based on the traditional pasture response rate of 30 kg DM/kg N or lower were lower than the base pasture in all but two instances (i.e. where 200 grams/AE/day extra liveweight gain was assumed). However, the expected 40 kg DM/kg N pasture responses rate were calculated to provide increases of between 121% and 217% when the liveweight gain boost of 200 grams/hd/day was used.

Recent on-farm research confirms that carryover responses do occur for one-off applications. A discounting process was therefore used to consider the relative value of several fertiliser scenarios that included a small carryover response to a single application of nitrogen. Given the scarcity of research data on these carryover responses, these scenarios and their inherent assumptions, are only ‘best-bets’ by the project team for the purpose of this ‘scoping study’.

7.1.4 Assessing production from fertiliser applications with residual nitrogen responses

It is assumed that a single fertiliser application will have a small and declining residual effect on pasture growth and animal production in subsequent years. Any treatment that doubles or triples forage production will increase soil organic matter and nutrient cycling. The tested scenarios are based on the relativities of responses from experimental research with repeated applications, and recent observations of one-off applications on commercial properties.

The scenarios are the representations of results expected by the project team for the ‘full rate’ of 100 kg N/ha and the ‘half-rate’ of 50 kg N/ha applied to both the 3000 kg DM/ha (less productive) and the 4500 kg DM/ha (more productive) base pastures. The scenarios used the expected dry matter response rate of 40 kg DM/kg N and the response rate traditionally quoted by advisers (30 kg DM/kg N).

The base pastures were maintained with the same levels of productivity, spoilage and residual as in the previous section of the analysis. Details of the carryover responses for the 100 kg N/ha scenarios (Tables 26-29) and the half-rate applications of 50 kg N/ha (Tables 30-33) were based on 'best-bets' that require further research for clarification:

- Additional forage production was based on there being increased nitrogen availability in the years after the fertiliser applications. A minor yield benefit is predicted to last up to ten years but is mostly lost by year five. For example, the extra nitrogen available after year four was predicted to be only 5 kg N/ha/year for the full 100 kg N applications and 2 kg N/ha/year for the 50 kg N/ha half-rate

- Liveweight gains were more conservative than those used in the earlier analyses with no carryover. In the first year, these gains were the midpoint of the two rates used earlier. A small weight gain improvement was included in the second year, but only in the 100 kg N/ha scenarios. For example, the weight gain in the 100 kg N/ha scenarios on the 4500 kg DM pasture was 200 kg/AE in the first year, 170 kg/AE in the second year, before returning to the same 150 kg/AE per year as the base pasture. There was no residual pasture quality impact on liveweight gain included for the 50 kg N/ha scenarios.

Each scenario resulted in an estimated 'kilograms of beef' produced; with and without the applied fertiliser. For example, Figure 10 illustrates the kilograms of beef per hectare per annum with and without 50 kg N per ha on a buffel pasture producing 3000 kg dry matter per annum. The fertiliser is added once (year one) with identifiable benefits until year five. Steers gain weight at 180 kg per head in the first year only instead of the 150 kg per head gained on the base pasture. Weight gains per head are the same in both treatments after the first year but additional beef per hectare is produced in subsequent years due to the predicted carry over effect of N fertiliser on pasture production. The major benefits are still in the first year and the residual benefits will also be 'discounted' when graziers assess the economics of using fertiliser.

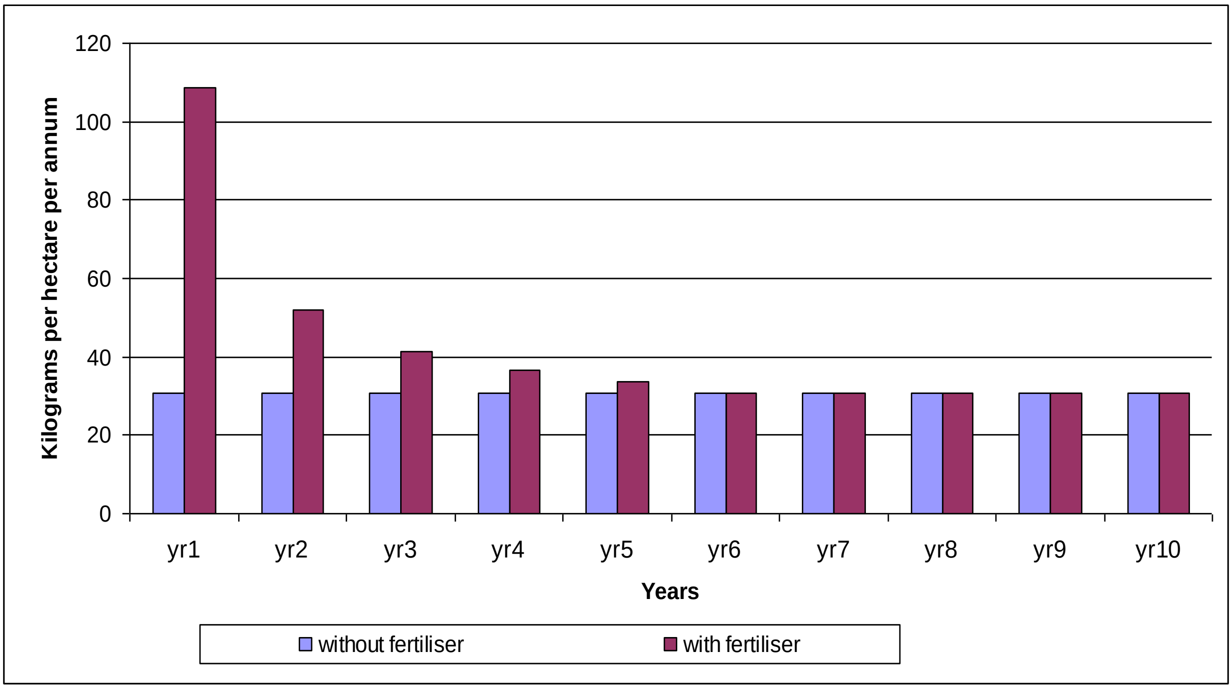

Figure 10. Kilograms of beef produced with and without fertiliser - 3000 kg DM/yr pasture, fertiliser at 50 kg N/ha and 40 kg DM /kg N

Table 26. Response for a 3000 kg DM/yr pasture fertilised at 100 kg N/ha & with a pasture response of 30 kg DM/kg N

Pasture response 30 kg DM /kg N	yr1	yr2	yr3	yr4	yr5	yr6	yr7	yr8	yr9	yr10
Extra nitrogen	**100**	**30**	**15**	**10**	**5**	**5**	**5**	**5**	**5**	**5**
Extra pasture	3000	900	450	300	150	150	150	150	150	150
increase	100%	30%	15%	10%	5%	5%	5%	5%	5%	5%
New annual production	6000	3900	3450	3300	3150	3150	3150	3150	3150	3150
Spoilage %	20%	15%	15%	15%	15%	15%	15%	15%	15%	15%
spoilage	1200	585	518	495	472.5	472.5	472.5	472.5	472.5	472.5
residual	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
Available for consumption	3000	1515	1133	1005	877.5	877.5	877.5	877.5	877.5	877.5
increase	300%	102%	51%	34%	17%	17%	17%	17%	17%	17%
stocking rate (ha/ae)	1.22	2.41	3.22	3.63	4.16	4.16	4.16	4.16	4.16	4.16
stocking rate (ae/ha)	0.82	0.42	0.31	0.28	0.24	0.24	0.24	0.24	0.24	0.24
New weight gain (kg/hd/year)	200	170	150	150	150	150	150	150	150	150
Extra kg per ha per annum with fertiliser	164.38	70.56	46.54	41.30	36.06	36.06	36.06	36.06	36.06	36.06
Increase above unfertilised pasture	433%	129%	51%	34%	17%	17%	17%	17%	17%	17%

Table 27. Response for a 3000 kg DM/yr pasture fertilised at 100 kg N/ha & with a pasture response of 40 kg DM/kgN

Pasture response 40 kg DM /kg N	yr1	yr2	yr3	yr4	yr5	yr6	yr7	yr8	yr9	yr10
Extra nitrogen	**100**	**30**	**15**	**10**	**5**	**5**	**5**	**5**	**5**	**5**
Extra pasture	4000	1200	600	400	200	200	200	200	200	200
increase	133%	40%	20%	13%	7%	7%	7%	7%	7%	7%
New annual production	7000	4200	3600	3400	3200	3200	3200	3200	3200	3200
Spoilage %	20%	15%	15%	15%	15%	15%	15%	15%	15%	15%
spoilage	1400	630	540	510	480	480	480	480	480	480
residual	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
Available for consumption	3800	1770	1260	1090	920	920	920	920	920	920
increase	407%	136%	68%	45%	23%	23%	23%	23%	23%	23%
stocking rate (ha/ae)	0.96	2.06	2.90	3.35	3.97	3.97	3.97	3.97	3.97	3.97
stocking rate (ae/ha)	1.04	0.48	0.35	0.30	0.25	0.25	0.25	0.25	0.25	0.25
New weight gain (kg/hd/year)	200	170	150	150	150	150	150	150	150	150
Extra kg per ha per annum with fertiliser	208.22	82.44	51.78	44.79	37.81	37.81	37.81	37.81	37.81	37.81
Increase above unfertilised pasture	576%	167%	68%	45%	23%	23%	23%	23%	23%	23%

Table 28. Response for a 4500 kg DM/yr pasture fertilised at 100 kg N/ha & with a pasture response of 30 kg DM/kgN

Pasture response 30 kg DM /kg N	yr1	yr2	yr3	yr4	yr5	yr6	yr7	yr8	yr9	yr10
Extra nitrogen	**100**	**30**	**15**	**10**	**5**	**5**	**5**	**5**	**5**	**5**
Extra pasture	3000	900	450	300	150	150	150	150	150	150
increase	67%	20%	10%	7%	3%	3%	3%	3%	3%	3%
New annual production	7500	5400	4950	4800	4650	4650	4650	4650	4650	4650
Spoilage %	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
spoilage	1500	1080	990	960	930	930	930	930	930	930
residual	2250	2250	2250	2250	2250	2250	2250	2250	2250	2250
Available for consumption	3750	2070	1710	1590	1470	1470	1470	1470	1470	1470
increase	178%	53%	27%	18%	9%	9%	9%	9%	9%	9%
stocking rate (ha/ae)	0.97	1.76	2.13	2.30	2.48	2.48	2.48	2.48	2.48	2.48
stocking rate (ae/ha)	1.03	0.57	0.47	0.44	0.40	0.40	0.40	0.40	0.40	0.40
New weight gain (kg/hd/year)	200	170	150	150	150	150	150	150	150	150
Extra kg per ha per annum with fertiliser	205.48	96.41	70.27	65.34	60.41	60.41	60.41	60.41	60.41	60.41
Increase above unfertilised pasture	270%	74%	27%	18%	9%	9%	9%	9%	9%	9%

Table 29. Response for a 4500 kg DM/yr pasture fertilised at 100 kg N/ha & with a pasture response of 40 kg DM/kgN

Pasture response 40 kg DM /kg N	yr1	yr2	yr3	yr4	yr5	yr6	yr7	yr8	yr9	yr10
Extra nitrogen	**100**	**30**	**15**	**10**	**5**	**5**	**5**	**5**	**5**	**5**
Extra pasture	4000	1200	600	400	200	200	200	200	200	200
increase	89%	27%	13%	9%	4%	4%	4%	4%	4%	4%
New annual production	8500	5700	5100	4900	4700	4700	4700	4700	4700	4700
Spoilage %	25%	20%	20%	20%	20%	20%	20%	20%	20%	20%
spoilage	2125	1140	1020	980	940	940	940	940	940	940
residual	2250	2250	2250	2250	2250	2250	2250	2250	2250	2250
Available for consumption	4125	2310	1830	1670	1510	1510	1510	1510	1510	1510
increase	206%	71%	36%	24%	12%	12%	12%	12%	12%	12%
stocking rate (ha/ae)	0.88	1.58	1.99	2.19	2.42	2.42	2.42	2.42	2.42	2.42
stocking rate (ae/ha)	1.13	0.63	0.50	0.46	0.41	0.41	0.41	0.41	0.41	0.41
New weight gain (kg/hd/year)	200	170	150	150	150	150	150	150	150	150
Extra kg per ha per annum with fertiliser	226.03	107.59	75.21	68.63	62.05	62.05	62.05	62.05	62.05	62.05
Increase above unfertilised pasture	307%	94%	36%	24%	12%	12%	12%	12%	12%	12%

Table 30. Response for a 3000 kg DM/yr pasture fertilised at 50 kg N/ha & with a pasture response of 30 kg DM/kgN

Pasture response 30 kg DM /kg N	yr1	yr2	yr3	yr4	yr5	yr6	yr7	yr8	yr9	yr10
Extra nitrogen	**50**	**15**	**7.5**	**4**	**2**	**2**	**2**	**2**	**2**	**2**
Extra pasture	1500	450	225	120	60	60	60	60	60	60
increase	50%	15%	8%	4%	2%	2%	2%	2%	2%	2%
New annual production	4500	3450	3225	3120	3060	3060	3060	3060	3060	3060
Spoilage %	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%
spoilage	675	518	484	468	459	459	459	459	459	459
residual	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
Available for consumption	2025	1133	941	852	801	801	801	801	801	801
increase	170%	51%	26%	14%	7%	7%	7%	7%	7%	7%
stocking rate (ha/ae)	1.80	3.22	3.88	4.28	4.56	4.56	4.56	4.56	4.56	4.56
stocking rate (ae/ha)	0.55	0.31	0.26	0.23	0.22	0.22	0.22	0.22	0.22	0.22
New weight gain (kg/hd/year)	180	150	150	150	150	150	150	150	150	150
Extra kg per ha per annum with fertiliser	99.86	46.54	38.68	35.01	32.92	32.92	32.92	32.92	32.92	32.92
Increase above unfertilised pasture	224%	51%	26%	14%	7%	7%	7%	7%	7%	7%

Table 31. Response for a 3000 kg DM/yr pasture fertilised at 50 kg N/ha & with a pasture response of 40 kg DM/kgN

Pasture response 40 kg DM /kg N	yr1	yr2	yr3	yr4	yr5	yr6	yr7	yr8	yr9	yr10
Extra nitrogen	**50**	**15**	**7.5**	**4**	**2**	**2**	**2**	**2**	**2**	**2**
Extra pasture	2000	600	300	160	80	80	80	80	80	80
increase	67%	20%	10%	5%	3%	3%	3%	3%	3%	3%
New annual production	5000	3600	3300	3160	3080	3080	3080	3080	3080	3080
Spoilage %	20%	15%	15%	15%	15%	15%	15%	15%	15%	15%
spoilage	1000	540	495	474	462	462	462	462	462	462
residual	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
Available for consumption	2200	1260	1005	886	818	818	818	818	818	818
increase	193%	68%	34%	18%	9%	9%	9%	9%	9%	9%
stocking rate (ha/ae)	1.66	2.90	3.63	4.12	4.46	4.46	4.46	4.46	4.46	4.46
stocking rate (ae/ha)	0.60	0.35	0.28	0.24	0.22	0.22	0.22	0.22	0.22	0.22
New weight gain (kg/hd/year)	180	150	150	150	150	150	150	150	150	150
Extra kg per ha per annum with fertiliser	108.49	51.78	41.30	36.41	33.62	33.62	33.62	33.62	33.62	33.62
Increase above unfertilised pasture	252%	68%	34%	18%	9%	9%	9%	9%	9%	9%

Table 32. Response for a 4500 kg DM/yr pasture fertilised at 50 kg N/ha & with a pasture response of 30 kg DM/kgN

Pasture response 30 kg DM /kg N	yr1	yr2	yr3	yr4	yr5	yr6	yr7	yr8	yr9	yr10
Extra nitrogen	**50**	**15**	**7.5**	**4**	**2**	**2**	**2**	**2**	**2**	**2**
Extra pasture	1500	450	225	120	60	60	60	60	60	60
increase	33%	10%	5%	3%	1%	1%	1%	1%	1%	1%
New annual production	6000	4950	4725	4620	4560	4560	4560	4560	4560	4560
Spoilage %	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
spoilage	1200	990	945	924	912	912	912	912	912	912
residual	2250	2250	2250	2250	2250	2250	2250	2250	2250	2250
Available for consumption	2550	1710	1530	1446	1398	1398	1398	1398	1398	1398
increase	89%	27%	13%	7%	4%	4%	4%	4%	4%	4%
stocking rate (ha/ae)	1.43	2.13	2.39	2.52	2.61	2.61	2.61	2.61	2.61	2.61
stocking rate (ae/ha)	0.70	0.47	0.42	0.40	0.38	0.38	0.38	0.38	0.38	0.38
New weight gain (kg/hd/year)	180	150	150	150	150	150	150	150	150	150
Extra kg per ha per annum with fertiliser	125.75	70.27	62.88	59.42	57.45	57.45	57.45	57.45	57.45	57.45
Increase above unfertilised pasture	127%	27%	13%	7%	4%	4%	4%	4%	4%	4%

Table 33. Response for a 4500 kg DM/yr pasture fertilised at 50 kg N/ha & with a pasture response of 40 kg DM/kgN

Pasture response 40 kg DM /kg N	yr1	yr2	yr3	yr4	yr5	yr6	yr7	yr8	yr9	yr10
Extra nitrogen	**50**	**15**	**7.5**	**4**	**2**	**2**	**2**	**2**	**2**	**2**
Extra pasture	2000	600	300	160	80	80	80	80	80	80
increase	44%	13%	7%	4%	2%	2%	2%	2%	2%	2%
New annual production	6500	5100	4800	4660	4580	4580	4580	4580	4580	4580
Spoilage %	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
spoilage	1300	1020	960	932	916	916	916	916	916	916
residual	2250	2250	2250	2250	2250	2250	2250	2250	2250	2250
Available for consumption	2950	1830	1590	1478	1414	1414	1414	1414	1414	1414
increase	119%	36%	18%	9%	5%	5%	5%	5%	5%	5%
stocking rate (ha/ae)	1.24	1.99	2.30	2.47	2.58	2.58	2.58	2.58	2.58	2.58
stocking rate (ae/ha)	0.81	0.50	0.44	0.40	0.39	0.39	0.39	0.39	0.39	0.39
New weight gain (kg/hd/year)	180	150	150	150	150	150	150	150	150	150
Extra kg per ha per annum with fertiliser	145.48	75.21	65.34	60.74	58.11	58.11	58.11	58.11	58.11	58.11
Increase above unfertilised pasture	162%	36%	18%	9%	5%	5%	5%	5%	5%	5%

The increases in beef production again varied considerably but with the same trends as the analyses with no carryover effects; that is, absolute increases in beef produced were largest with the higher nitrogen rate, the 40 kg DM/kg N response rate and the better base pasture production. However, higher relative increases were achieved on the less productive base pasture (3000 kg DM/ha).

These biophysical results, a proof-of-concept, are encouraging and confirm the potential for fertilisers to dramatically increase productivity on rundown pastures. However, it is also clear that the more conservative liveweight gains in the first year of grazing in these ‘carryover’ scenarios has resulted in lower production than the earlier scenarios with no carryover. The sensitivity of these variables reinforces the need for further research to confirm the magnitude of both forage responses and feed quality improvements that can be now achieved as sown grass pastures across the region become increasingly rundown. The key question is whether the responses and underlying relationships for the following have changed from the experimental research conducted 25-40 years ago:

- The response rate of the pasture (kg DM/kg N) to applied fertiliser. Liveweight gains per head from the increased feed quality.
- The longevity of carryover responses in both dry matter and feed quality.

The longevity of responses is particularly important to the economics of fertilising if, as the team expects, graziers using nitrogen fertiliser will focus on particular paddocks with repeated applications over a number of years. Any carryover, and the subsequent ability to reduce rates on these pastures, will enhance the profitability as well as the long-term productivity of the pasture resource. Of course, the use of nitrogen fertiliser will also depend on the economic viability of the responses that graziers see on their own paddocks.

7.1.5 The economic returns from fertiliser applications with residual nitrogen responses

Economic indicators for each fertiliser scenario were calculated using cash flow budgets. For example, the impact of applying 50 kg N/ha to the 4500 kg DM pasture was assessed by first calculating the net cash flow for the "without change" scenario of 4500 kg DM/ha base pasture (Table 34). The net cash flow for the "with fertiliser" scenario was then calculated using all the previous assumptions of benefits and an allowance made for the possible taxation benefits or costs of the proposal (Table 35).

Table 34. Net cash flow calculation for 100 hectare buffel paddock at 4500 kg DM per ha per annum

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Sales	$0	$33,145	$33,145	$33,145	$33,145	$33,145	$33,145	$33,145	$33,145	$33,145
Purchases	$24,348	$24,348	$24,348	$24,348	$24,348	$24,348	$24,348	$24,348	$24,348	$0
Selling costs	$0	$1,974	$1,974	$1,974	$1,974	$1,974	$1,974	$1,974	$1,974	$1,974
Variable costs	$446	$446	$446	$446	$446	$446	$446	$446	$446	$0
Net cash flow	($24,794)	$6,377	$6,377	$6,377	$6,377	$6,377	$6,377	$6,377	$6,377	$31,172

Table 35. Net cash flow calculation for 100 hectare buffel paddock at 4500 kg DM per ha per annum with 50 kg N and 40 kg DM /ha response

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Sales	$0	$74,194	$44,971	$38,910	$36,232	$34,687	$34,687	$34,687	$34,687	$34,687
Fertiliser	$8,675	$0	$0	$0	$0	$0	$0	$0	$0	$0
Purchases	$51,907	$33,035	$28,583	$26,616	$25,481	$25,481	$25,481	$25,481	$25,481	$0
Selling costs	$0	$4,410	$2,807	$2,428	$2,261	$2,165	$2,165	$2,165	$2,165	$2,165
Variable costs	$952	$606	$524	$488	$467	$467	$467	$467	$467	$0
Extra tax payable	-$8,419	$6,327	$2,004	$900	$494	$59	$59	$59	$59	$405
Net cash flow after tax	($53,115)	$29,816	$11,053	$8,477	$7,529	$6,515	$6,515	$6,515	$6,515	$32,117

The final net cash flow for each scenario was compared to calculate the partial Net Present Value (NPV) for each fertiliser application and response scenario. This figure represents the return to the extra dollars invested in livestock and fertiliser.

The results show that the investment of an additional $28,320 in Year 1 in fertiliser and steers will generate a total increase in wealth of about $1,923 over the life of the investment or $2.49 per ha per annum on average at a discount rate of 5% (Table 36). The values are negative at a 10% discount rate indicating that wealth would be decreased at this discount rate. Consequently, discount rates higher than 10% make investment in this 'half-rate' fertiliser scenario unviable.

Table 36. Calculation of economic indicators for the benefits of change (at 5% discount rate)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
With fertiliser	-$53,115	$29,816	$11,053	$8,477	$7,529	$6,515	$6,515	$6,515	$6,515	$32,117
Without fertiliser	-$24,794	$6,377	$6,377	$6,377	$6,377	$6,377	$6,377	$6,377	$6,377	$31,172
Extra Benefits or Costs	-$28,320	$23,439	$4,676	$2,100	$1,152	$138	$138	$138	$138	$946
Nominal IRR after tax		9.79%								
Discount rate	5.00%	7.50%	10.00%	12.50%						
NPV of Investment	$1,923	$859	-$75	-$897						
Annual value per ha	$2.49	$1.25	-$0.12	-$1.62						

The annual benefit of each fertiliser scenario at a 5% discount rate is summarised in Table 37. This is the 'dollar return' per hectare each year with a 5% discount rate. Table 37 also includes the Internal Rate of Return (IRR) achieved by the treatments in each scenario. For example, the discounted $2.49 annual benefit calculated for the half-rate of 50 kg N/ha fertiliser and a 40 kg DM/kg N response rate on the 4500 kg DM/ha pasture returns a total of $24.90 over 10 years.

The Internal Rates of Return of the scenarios tested all fall between 5% and 11%. The analysis of the full 100 kg N/ha fertiliser rate and the expected grass response rate of 40 kg DM/ha had a return of 11%. This suggests that graziers considering using nitrogen fertiliser will need to achieve an average response rate of 40 kg DM/kg N, or gain better liveweight gains than the more conservative rates used in this analysis of carryover responses. The analysis reinforces the suggestion from the earlier scenarios (with no carryover) that returns will be better from investments into the more productive pastures on each property.

Table 37. Amortised value per hectare and IRR's where N fertiliser has a carryover effect

Base pasture	**Nitrogen fertiliser scenarios**			
	50 kg N 30 kg DM	**50 kg N 40 kg DM**	**100 kg N 30 kg DM**	**100 kg N 40 kg DM**
3000 kg DM /ha	$0.66 (6%)	$2.19 (9%)	$1.96 (7%)	$7.58 (11%)
4500 kg DM /ha	$0.15 (5%)	$2.49 (10%)	$3.34 (9%)	$6.87 (11%)

Ultimately, the decision for each grazier on whether to use nitrogen fertiliser or not will depend on their other options for investment and how the Internal Rate of Return for those investments compare. For example;

- The earlier analyses with no carryover benefits calculated that the full 100 kg N/ha fertiliser rate and the expected 40 kg DM/kg N response rate increased the average gross margin by up to 122% and 271% for the 4500 kg DM and the 3000 kg DM base pastures respectively.
- The analysis of this same 100 kg N/ha treatment, but with carryover responses included and a more conservative liveweight gain estimate, was calculated to provide an 11% Internal Rate of Return with an average annual value of $6.87 and $7.58 per hectare per year for ten years with a 5% discount rate. At the 5% discount rate this equates to an overall benefit of $68.70 and $75.80 respectively over 10 years.
- Lower fertiliser rates, dry matter response rates and liveweight gains were estimated to lose money or provide only minor financial benefits

This analysis suggests that fertiliser decisions will largely be assessed on returns in the year of application, and that carryover responses and any subsequent improvements in pasture health and condition be considered an ancillary benefit.

As noted in the introduction (page 8), the Internal Rate of Return for establishing legumes and applying phosphorus fertiliser to those legumes has recently been estimated using the same economic approach. The resulting Internal Rate of Return estimates for each dollar invested were (Peck *et al.* 2014):

- 9-15% to establish and fertilise legumes into grass pasture on low Phosphorus soils
- 12-24% to apply phosphorus to already established grass legume pastures; and
- 15-22% to establish legumes into high phosphorus soils that do not required additional phosphorus from fertiliser.

It should also be noted that these estimates for both nitrogen and phosphorus fertiliser are all based on the average 'results'. They do not include seasonal variability or sale price differentials. As illustrated earlier, this price differential substantially increases the riskiness of any investment in stock, with clear prospects for larger profits and losses. The inference of this finding is that any investment that impacts primarily on carrying capacity and stock numbers will become increasingly “risky” with potential for greater profits…or losses. Conversely, investments that improve individual animal performance will involve less ‘risk’; either positive or negative.

The results of the production and economic analyses suggest that legumes will remain the preferred long-term option to mitigate the effects of sown pasture rundown across southern and central Queensland if they are planted on soils with adequate phosphorus or phosphorus fertiliser is applied. However, nitrogen fertiliser has the potential to support higher production on rundown pastures across the region; and, in some particular circumstances, may also be profitable. As such, it may complement graziers’ efforts to mitigate pasture rundown with legumes as nitrogen fertiliser has far less agronomic risk than the establishment of legumes.

There may also be potential to use nitrogen fertilisers where pasture legumes are not being established, on strategic paddocks where high quality feed is needed, to allow periodic spelling of other pastures, and even to reduce the area of forage sorghum that also carries large numbers of stock, but is more expensive due to fallowing, establishment and other costs.

Finally, the economic viability of using 100 kg N/ha of nitrogen fertiliser on grass pastures clearly depends on the fertiliser response rates and the feed quality contribution to liveweight gains. As such, there is value in further research to build confidence and confirm, or not, the quantitative relationships used in this scoping study.

7.2 Forage crops

7.2.1 Forage sorghum

7.2.1.1 Forage and animal impacts from nitrogen fertiliser application

A range of scenarios investigated the forage and animal impacts of nitrogen fertiliser on forage sorghum. The scenarios investigated included:

- Three (3) baseline forage production levels: low (5000 kg/ha); medium (10,000 kg/ha); high (15,000 kg/ha) (See Table 14 for baseline production data).
- Two (2) application rates of nitrogen: 50 kg N/ha; 100 kg N/ha
- Three (3) dry matter forage responses: 30 kg DM/kg N applied; 40 kg DM/kg N applied; 50 kg DM/kg N applied.
- Two (2) liveweight response levels (0.05 kg/hd/d; 0.1 kg/hd/d) depending on the rate of nitrogen fertiliser applied.

The calculated responses of forage yield, stocking rate, individual LWG, and LWG per ha are presented in Tables 38 and 39.

Applying 50 kg N/ha to a medium productivity site increased animal production per ha from 182 kg/ha to 227, 236 and 246 kg/ha for forage response rates of 30, 40 and 50 kg DM/kg N respectively. For application of 100 kg N/ha to the same site, animal production per ha increased from 182 kg/ha to 276, 297 and 318 kg/ha for forage response rates of 30, 40 and 50 kg DM/kg N respectively. Across all the scenarios, animal performance gains were primarily due to higher stocking rates from the extra dry matter produced, as opposed to the increase obtained in individual animal performance.

Table 38. Forage sorghum + 50kg N

	low DM yield			medium DM yield			high DM yield		
Yield response to N (kg DM/kg N)	**30**	**40**	**50**	**30**	**40**	**50**	**30**	**40**	**50**
N applied kg/ha	50	50	50	50	50	50	50	50	50
extra forage kg	1500	2000	2500	1500	2000	2500	1500	2000	2500
new forage production kg	6500	7000	7500	11500	12000	12500	16500	17000	17500
spoilage kg/ha	3550	3900	4250	6550	6900	7250	9550	9900	10250
residual kg/ha	1000	1000	1000	1500	1500	1500	2000	2000	2000
forage for consumption kg*	1950	2100	2250	3450	3600	3750	4950	5100	5250
increase %	30	40	50	15	20	25	10	13.3	16.7
Animal response to N	**+0.05kg/h/d**			**+0.05kg/h/d**			**+0.05kg/h/d**		
stocking rate AE/ha	2	2.12	2.27	3.48	3.63	3.78	5	5.15	5.3
new weight gain kg/AE	65	65	65	65	65	65	65	65	65
liveweight kg/ha with fertiliser	128	138	148	227	236	246	325	335	345
increase %	40.8	51.7	62.5	24.6	30	35.4	19.2	22.8	26.4

* 30% utilisation

Table 39. Forage sorghum + 100kg N

	low DM yield			medium DM yield			high DM yield		
Yield response to N (kg DM/kg N)	**30**	**40**	**50**	**30**	**40**	**50**	**30**	**40**	**50**
N applied kg/ha	100	100	100	100	100	100	100	100	100
extra forage kg	3000	4000	5000	3000	4000	5000	3000	4000	5000
new forage production kg	8000	9000	10000	13000	14000	15000	18000	19000	20000
spoilage kg/ha	4600	5300	6000	7600	8300	9000	10600	11300	12000
residual kg/ha	1000	1000	1000	1500	1500	1500	2000	2000	2000
forage for consumption kg*	2400	2700	3000	3900	4200	4500	5400	5700	6000
increase %	60.0	80.0	100.0	30.0	40.0	50.0	20.0	26.7	33.3
Animal response to added N	**+0.1kg/h/d**			**+0.1kg/h/d**			**+0.1kg/h/d**		
stocking rate AE/ha	2.42	2.73	3.03	3.94	4.24	4.55	5.45	5.76	6.06
new weight gain kg/AE	70.00	70	70	70	70	70	70	70	70
liveweight kg/ha with fertiliser	170	191	212	276	297	318	382	403	424
increase %	86.7	110.0	133.3	51.7	63.3	75.0	40.0	47.8	55.6

* 30% utilisation

7.2.1.2 Forage and animal impacts from phosphorus fertiliser application

Due to the very limited past research into the plant response impacts of P fertiliser, one production scenario (10,000 kg/ha) was used with a wide range of assumed phosphorus response rates. A boost in animal performance of 0.05 or 0.1 kg/h/d was included for applications of either 5 kg or 10 kg P/ha respectively.

Even at high rates of yield response, the overall impacts of phosphorus fertiliser on animal performance were modest (Tables 40 and 41). For example, the application of 5 kg P/ha with a response of 160 kg dry matter/kg P, produced only 17% extra beef (Table 40). At the high P rate of 10 kg P/ha, beef production increased by 35% (Table 41). It is difficult to put these findings in context due to the lack of published experimental data. However, P fertiliser applications on commercial farms across the target region have been observed to produce dry matter responses similar to those assumed in this study and subsequently enabled increased stocking rates and, presumably, increased beef per ha.

Table 40. Forage sorghum + 5kg P

	medium DM yield								
DM response to P(kg DM/kgP)	**1**	**2**	**5**	**10**	**20**	**40**	**80**	**120**	**160**
P applied kg/ha	5	5	5	5	5	5	5	5	5
extra forage kg	5	10	25	50	100	200	400	600	800
new forage production kg	100005	10010	10025	10050	10100	10200	10400	10600	10800
spoilage kg/ha	5504	5507	5518	5535	5570	5640	5780	5920	6060
residual kg/ha	1500	1500	1500	1500	1500	1500	1500	1500	1500
forage for consumption kg*	3002	3003	3008	3015	3030	3060	3120	3180	3240
increase %	0.1	0.1	0.3	0.5	1.0	2.0	4.0	6.0	8.0
Animal response to added P	**+0.05kg/h/d**			**+0.05kg/h/d**			**+0.05kg/h/d**		
stocking rate AE/ha	3.03	3.03	3.03	3.04	3.06	3.09	3.15	3.21	3.27
new weight gain kg/AE	65	65	65	65	65	65	65	65	65
liveweight kg/ha with fertiliser	197	197	197	198	199	201	205	209	213
increase %	8.4	8.4	8.6	8.9	9.4	10.5	12.7	14.8	17.0

* 30% utilisation

Table 41. Forage sorghum + 10kg p

	medium DM yield								
DM response to P (kg DM/kg P)	**1**	**2**	**5**	**10**	**20**	**40**	**80**	**120**	**160**
P applied kg/ha	10	10	10	10	10	10	10	10	10
extra forage kg	10	20	50	100	200	400	800	1200	1600
new forage production kg	10010	10020	10050	10100	10200	10400	10800	11200	11600
spoilage kg/ha	5507	5514	5535	5570	5640	5780	6060	6340	6620
residual kg/ha	1500	1500	1500	1500	1500	1500	1500	1500	1500
forage for consumption kg*	3003	3006	3015	3030	3060	3120	3240	3360	3480
increase %	0.1	0.2	0.5	1.0	2.0	4.0	8.0	12.0	16.0
Animal response to added P	**+0.1kg/h/d**			**+0.1kg/h/d**			**+0.1kg/h/d**		
stocking rate AE/ha	3.03	3.04	3.05	3.06	3.09	3.15	3.27	3.39	3.52
new weight gain kg/AE	70	70	70	70	70	70	70	70	70
liveweight kg/ha with fertiliser	212	213	213	214	216	221	229	238	246
increase %	16.8	16.9	17.3	17.8	19.0	21.3	26.0	30.7	35.3

* 30% utilisation

7.2.1.3 Economic impacts from nitrogen fertiliser application

The application of nitrogen fertiliser on forage sorghum makes the financial result worse in all cases. Except for the base scenario of 15000kg DM/ha without fertiliser, gross margins were negative (Figure 11). Increasing the production of beef through the addition of fertiliser simply increased the losses made.

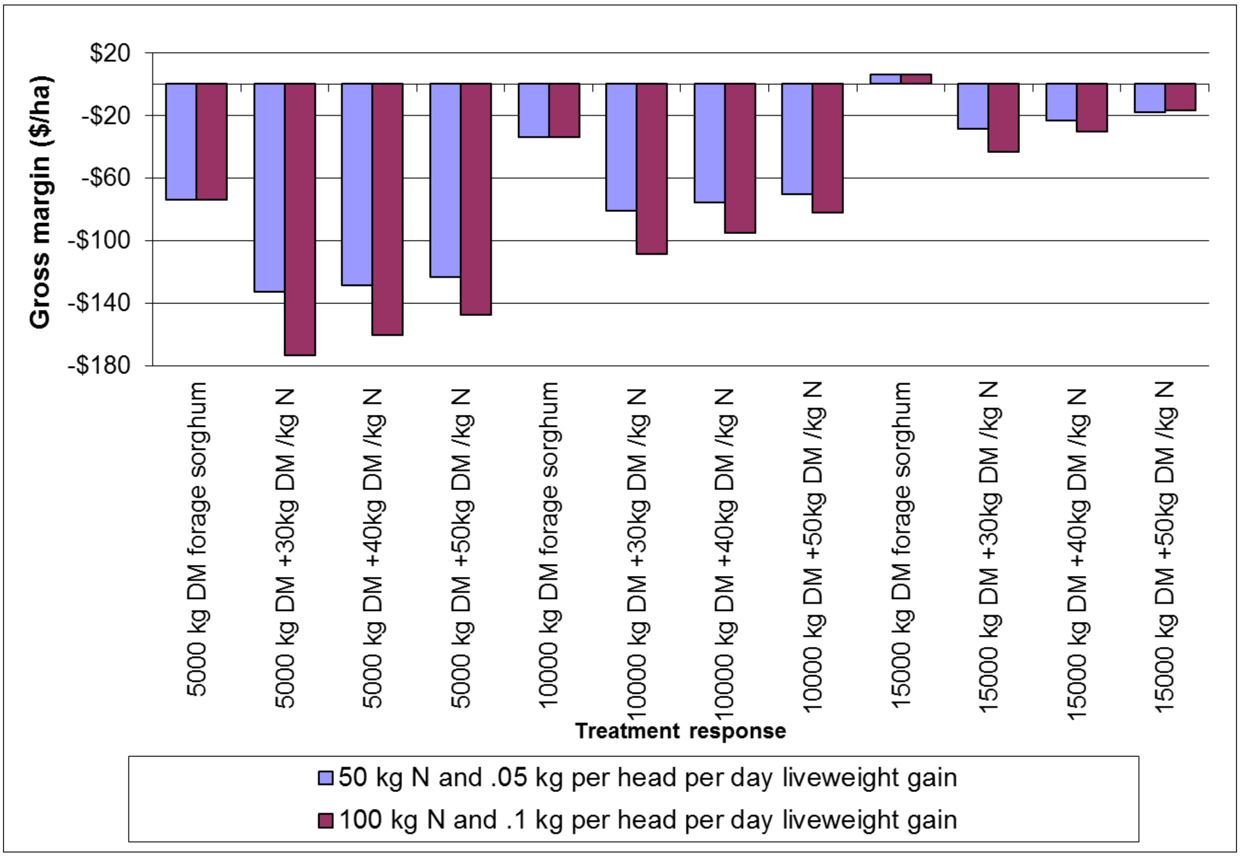

Figure 11. Gross margin for N fertiliser treatments and responses for forage sorghum

The relatively poor economic performance of the forage sorghum in the gross margins ‘with’ and ‘without’ fertiliser is largely a result of the high costs of producing the forage and the small difference (on average) between the buying and selling price of the steers. For more detail of these costs, refer to appendix 10.1.

7.2.1.4 Economic impacts from phosphorus fertiliser application

Similar to nitrogen fertiliser, the application of phosphorus fertiliser on forage sorghum makes the financial result worse in all cases (Figure 12). At the levels of response, prices and costs chosen, there appears to be no realistic scenario for the application of phosphorus fertiliser to forage sorghum that appears capable of significantly improving the returns of the producer. For more detail of these costs, refer to appendix 10.1.

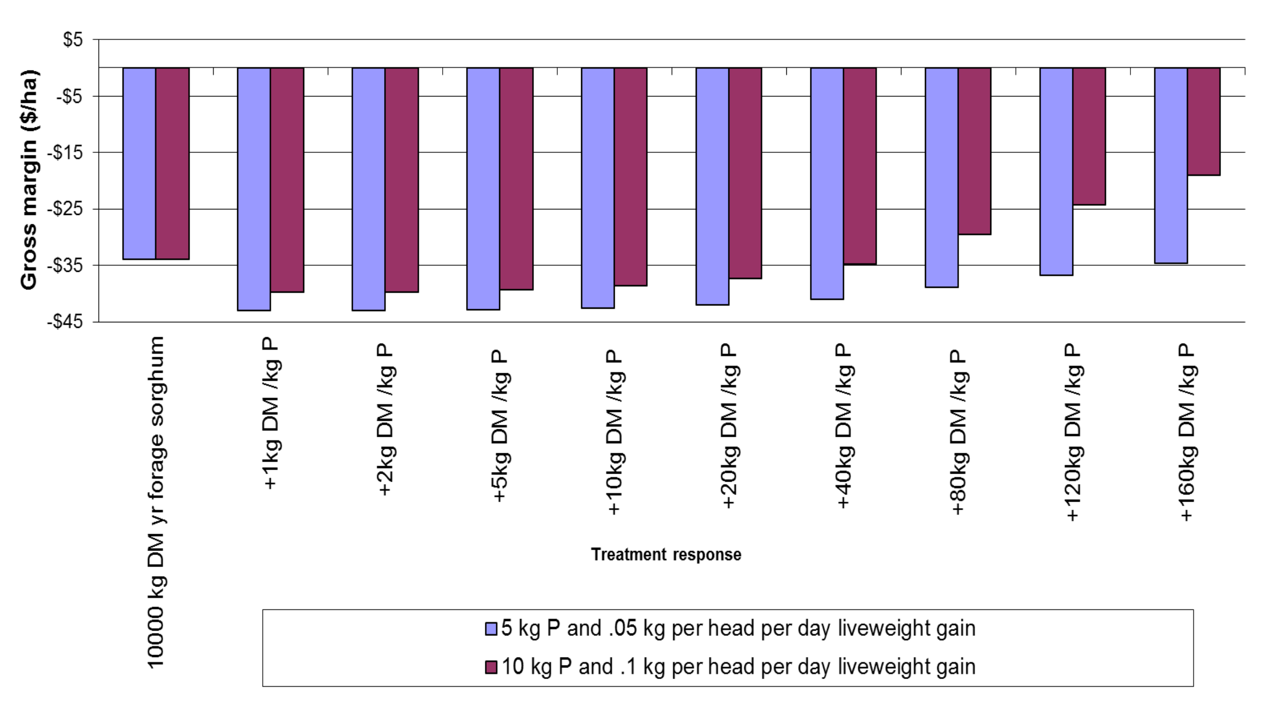

Figure 12. Gross margin for P fertiliser treatments and responses for forage sorghum

7.2.1.5 Implications of forage sorghum with nitrogen or phosphorus fertiliser

This study investigated the profitability of fertilising forage sorghum; not whether growing forage sorghum is profitable *per se*, or the impact of forage sorghum on the overall business. Under these parameters, the only situation that provides a positive gross margin, albeit very small, is when 15000 kg/ha dry matter is grown without N fertiliser. Even the highest plant response rate of 50 kg DM/kg N applied with an extra 0.1 kg/h/d of liveweight gain was not profitable. This indicates that growing forage sorghum is generally un-profitable under the animal response scenarios assumed in this study, and that higher responses are required to achieve a profitable outcome with the cost and price structure used here.

It is unlikely higher forage yield responses are biologically feasible. However, the magnitude of animal LWG responses to fertiliser is relatively unknown due to the paucity of past research into the impacts of fertiliser on diet quality. This analysis presumed applying fertiliser provides modest animal liveweight gain responses (0.05 kg/hd/d or 0.1 kg/hd/d) depending on the amount of fertiliser applied, whereas the main impact was to improve dry matter production and therefore stocking rates.

One implication of this economic analysis is that the use of fertiliser is unable to generate profitable outcomes from a crop with marginal economics. While some beef producers do fertilise forage sorghum, many have ceased growing annual forages and replaced these with a high production perennial legume-grass system (e.g. Leucaena). This gross margin analysis supports these actions and suggests that many producers may be losing money with forage sorghum. However, more complex, whole farm analysis is required to determine how forage sorghum contributes to the whole business as benefits, such as the opportunity to spell perennial grass paddocks, could occur. Recent analysis and case studies undertaken by the High-output Forage project investigated the impact of annual forages on whole farm profitability (Bowen 2014). Preliminary conclusions include:

- The effect of annual forages on farm profitability can be marginal and the increase in business risk can be significant, which requires a careful assessment of the role of annual forages in improving overall profitability.

- Where high-output annual forages are successfully grown and grain crops are a realistic option, it is most likely that grain crops will significantly outperform the alternative annual forage crop.

- Where grain crops are not an alternative and grass pasture is the alternative option under consideration, annual forages are a high-cost option with high timeliness requirements that may only add value to the beef enterprise if the opportunity cost of plant and unpaid labour are excluded. Comparatively, perennial forages may add value to the enterprise.

7.2.2 Forage Oats

7.2.2.1 Forage and animal impacts from nitrogen fertiliser application

A range of outcomes were generated investigating the forage and animal impact of nitrogen fertiliser on oats. The scenarios investigated included:

- Three (3) baseline forage production levels: low (2000 kg/ha); medium (4000 kg/ha); high (6000 kg/ha) (See Table 13 for baseline production data).

- Two (2) application rates of nitrogen: 50 kg N/ha; 100 kg N/ha

- Three (3) dry matter forage responses: 10 kg DM/kg N applied; 30 kg DM/kg N applied; 50 kg DM/kg N applied.

- Two (2) liveweight response levels (0.1 kg/hd/d; 0.2 kg/hd/d) depending on the rate of nitrogen fertiliser applied.

The predicted plant and animal production effect of fertilising was highest at low baseline forage productivity (2000 kg/ha) where the percentage increase was more than double that achieved for the forage crop with a higher initial production (6000 kg/ha). Where baseline dry matter yield was low (2000 kg/ha) and forage response to applied nitrogen high (50kg DM/kg N applied), 125-250% more dry matter was predicted depending on the fertiliser rate. However, animal performance gains were even greater. Where baseline dry matter yield was high and forage response to applied nitrogen low, predicted animal performance gains (kg/ha) were modest (~20-40%) (Tables 42 and 43).

As for forage sorghum, predicted animal performance gains were primarily due to higher stocking rates resulting from the extra dry matter produced, as opposed to the increase obtained in individual animal performance.

Table 42. Oats + 50kg N

	low DM yield			medium DM yield			high DM yield		
DM response to N (kg DM/kg N)	**10**	**30**	**50**	**10**	**30**	**50**	**10**	**30**	**50**
N applied kg/ha	50	50	50	50	50	50	50	50	50
extra forage kg	500	1500	2500	500	1500	2500	500	1500	2500
increase %	25	75	125	13	38	63	8	25	42
new forage production kg	2500	3500	4500	4500	5500	6500	6500	7500	8500
spoilage kg/ha	1000	1600	2200	1700	2300	2900	2400	3000	3600
residual kg/ha	500	500	500	1000	1000	1000	1500	1500	1500
forage for consumption kg*	1000	1400	1800	1800	2200	2600	2600	3000	3400
increase %	25.0	75.0	125.0	12.5	37.5	62.5	8.3	25.0	41.7
Animal response to added N	**+0.1kg/h/d**			**+0.1kg/h/d**			**+0.1kg/h/d**		
stocking rate AE/ha	1.12	1.57	2.02	2.02	2.46	2.91	2.91	3.36	3.81
new weight gain kg/AE	90	90	90	90	90	90	90	90	90
liveweight kg/ha with fertiliser	101	141	182	182	222	263	263	303	343
increase %	38.9	94.4	150.0	25.0	52.8	80.6	20.4	38.9	57.4

* 40% utilisation

Table 43. Oats + 100kg N

	low DM yield			medium DM yield			high DM yield		
DM response to N (kg DM/kg N)	**10**	**30**	**50**	**10**	**30**	**50**	**10**	**30**	**50**
N applied kg/ha	100	100	100	100	100	100	100	100	100
extra forage kg	1000	3000	5000	1000	3000	5000	1000	3000	5000
increase %	50	150	250	25	75	125	17	50	83
new forage production kg	3000	5000	7000	5000	7000	9000	7000	9000	11000
spoilage kg/ha	1300	2500	3700	2000	3200	4400	2700	3900	5100
residual kg/ha	500	500	500	1000	1000	1000	1500	1500	1500
forage for consumption kg*	1200	2000	2800	2000	2800	3600	2800	3600	4400
increase %	50.0	150.0	250.0	25.0	75.0	125.0	16.7	50.0	83.3
Animal response to added N	**+0.2kg/h/d**			**+0.2kg/h/d**			**+0.2kg/h/d**		
stocking rate AE/ha	1.34	2.24	3.14	2.24	3.14	4.04	3.14	4.04	4.93
new weight gain kg/AE	99	99	99	99	99	99	99	99	99
liveweight kg/ha with fertiliser	133	222	311	222	311	400	311	400	489
increase %	83.3	205.6	327.8	52.8	113.9	175.0	42.6	83.3	124.1

* 40% utilisation

7.2.2.2 Forage and animal impacts from phosphorus fertiliser application

As no past research into the plant response impacts of P fertiliser was found, one production scenario (4000 kg/ha) was chosen with a wide range of yield responses to cover a spectrum of potential plant responses. The effects of an assumed boost in animal performance response of 0.1 or 0.2 kg/h/d were also were also explored, for applications of either 5 kg or 10 kg P/ha respectively.

High forage yield and LWG/day response rates to P appear to be required to obtain even moderate improvements in total beef production (Tables 44 and 45). To lift total beef production by more than 20% when 5 kg P/ha is applied, a phosphorus response of at least 80 kg DM/kg P is needed. In contrast, a phosphorus response rate as low as 1 kg DM/kg P will lift total beef production by 20% when 10 kg P/ha is applied. This is primarily due to the assumed extra liveweight gain (+0.2 kg/h/d) with added phosphorus. Due to the lack of published data and recorded outcomes from commercial situations to compare, these results are difficult to put in context. The importance of adequate phosphorus in the diet of cattle consuming high quality forage is well known (Jackson *et al.* 2012). However the magnitude of weight gain benefits once oats is fertilised with phosphorus is relatively unknown.

Table 44. Oats + 5kg P

	medium DM yield								
DM response to P (kg DM/kg P)	**1**	**2**	**5**	**10**	**20**	**40**	**80**	**120**	**160**
P applied kg/ha	5	5	5	5	5	5	5	5	5
extra forage kg	5	10	25	50	100	200	400	600	800
increase %	0	0	1	1	3	5	10	15	20
new forage production kg	4005	4010	4025	4050	4100	4200	4400	4600	4800
spoilage kg/ha	1403	1406	1415	1430	1460	1520	1640	1760	1880
residual kg/ha	1000	1000	1000	1000	1000	1000	1000	1000	1000
forage for consumption kg*	1602	1604	1610	1620	1640	1680	1760	1840	1920
increase %	0.1	0.3	0.6	1.3	2.5	5.0	10.0	15.0	20.0
Animal response to added P		**+0.1kg/h/d**			**+0.1kg/h/d**			**+0.1kg/h/d**	
stocking rate AE/ha	1.79	1.80	1.80	1.81	1.84	1.88	1.97	2.06	2.15
new weight gain kg/AE	90	90	90	90	90	90	90	90	90
liveweight kg/ha with fertiliser	162	162	163	164	166	170	178	186	194
increase %	11.3	11.4	11.8	12.5	13.9	16.7	22.2	27.8	33.3

* 40% utilisation

Table 45. Oats + 10kg P

	medium DM yield								
DM response to P (kg DM/kg P)	**1**	**2**	**5**	**10**	**20**	**40**	**80**	**120**	**160**
P applied kg/ha	10	10	10	10	10	10	10	10	10
extra forage kg	10	20	50	100	200	400	800	1200	1600
increase %	0	1	1	3	5	10	20	30	40
new forage production kg	4010	4020	4050	4100	4200	4400	4800	5200	5600
spoilage kg/ha	1406	1412	1430	1460	1520	1640	1880	2120	2360
residual kg/ha	1000	1000	1000	1000	1000	1000	1000	1000	1000
forage for consumption kg*	1604	1608	1620	1640	1680	1760	1920	2080	2240
increase %	0.3	0.5	1.3	2.5	5.0	10.0	20.0	30.0	40.0
Animal response to added P		**+0.2kg/h/d**			**+0.2kg/h/d**			**+0.2kg/h/d**	
stocking rate AE/ha	1.80	1.80	1.81	1.84	1.88	1.97	2.15	2.33	2.51
new weight gain kg/AE	99	99	99	99	99	99	99	99	99
liveweight kg/ha with fertiliser	178	179	180	182	187	196	213	231	249
increase %	22.5	22.8	23.8	25.3	28.3	34.4	46.7	58.9	71.1

* 40% utilisation

7.2.2.3 Economic impacts from nitrogen fertiliser application

Unfertilised oats was calculated to produce negative gross margins, except for a slightly positive GM for the high producing site (Figure 13). The economics of unfertilised oats, at all levels of baseline productivity, were only made worse by the application of N fertiliser, unless the scenario included response rates of 50 kg DM/kg N and 0.2 kg/hd/d LWG at the higher producing sites. For more detail of these analyses, refer to appendix 10.2.

7.2.2.4 Economic impacts from phosphorus fertiliser application

Most production scenarios produced negative gross margins. A plant response of 40 kg DM/kg P applied with an extra liveweight gain of 0.2 kg/hd/d is needed before a barely positive gross margin is achieved (Figure 14). The highest gross margin of around $50/ha was achieved when a plant response of 160 kg DM/kg P applied and 0.2 kg/hd/d extra liveweight gain. It appears that oats crops which have a moderate level of production may show a profitable response to applications of phosphorus if a very high stocking rate response per kilogram of fertiliser applied plus a high weight gain per head response can be achieved. However low soil P levels together with high soil moisture or irrigation are needed before this occurs. For more detail of these costs, refer to appendix 10.2.

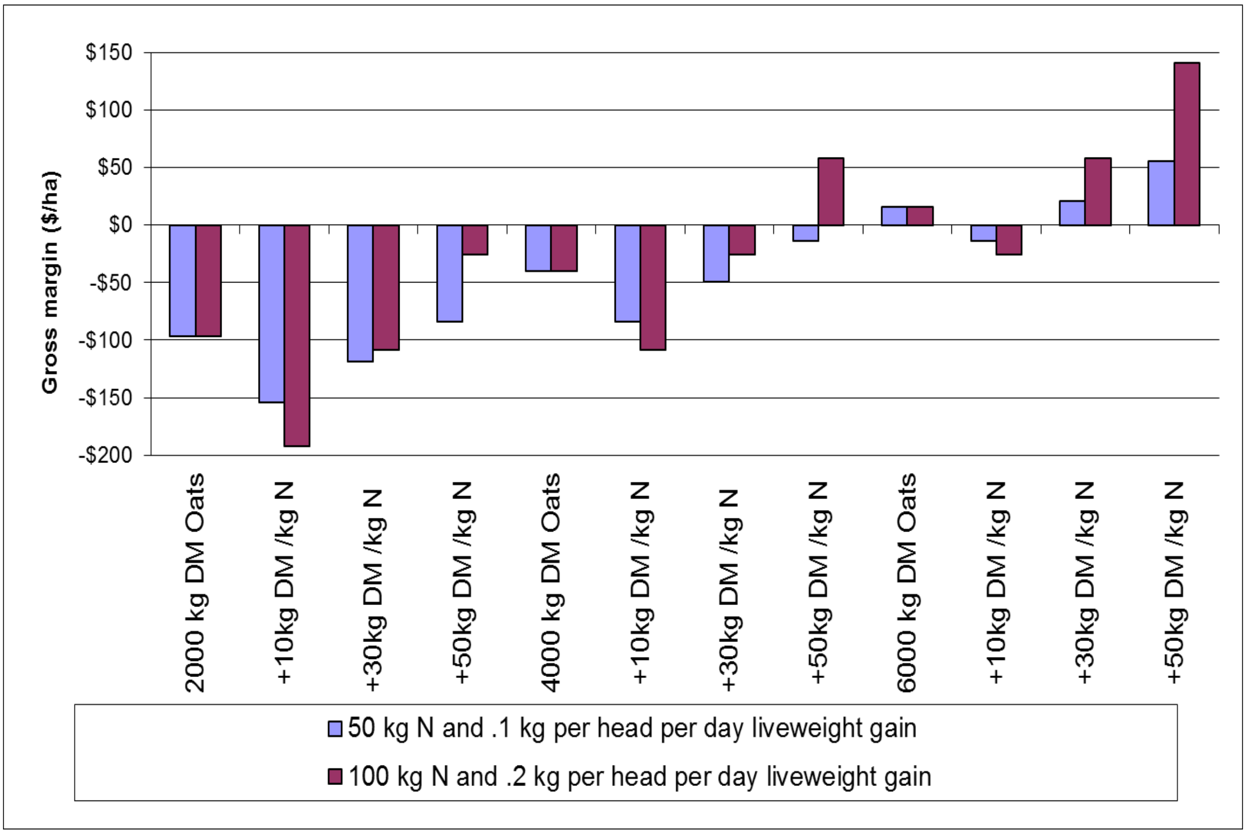

Figure 13. Gross margin for N fertiliser treatments and responses for oats

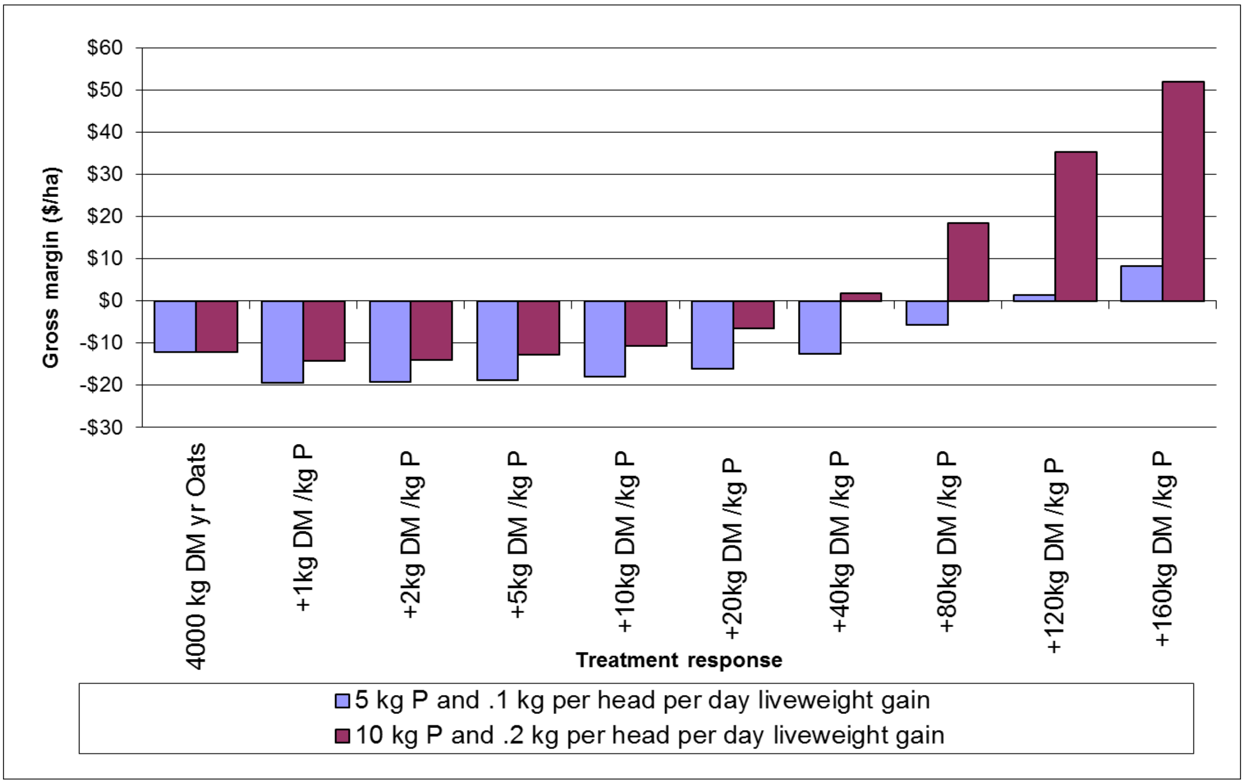

Figure 14. Gross margin for P fertiliser treatments and responses for oats

7.2.2.5 Implications of oats with nitrogen or phosphorus fertiliser

Compared to the forage sorghum scenarios, the assumed higher LWG response per head from fertilising oats improved relative profitability but instances of positive GMs were still rare. It is difficult to verify whether the assumed animal responses are conservative or optimistic due to the lack of available research data. We consider the responses used here to be conservative, but consistent with published data.

As with forage sorghum, an unprofitable, low yielding oats crops without fertiliser are unlikely to be improved by adding N fertiliser. A moderate yielding crop (4000 kg/ha) fertilised with nitrogen and responding at 50 kg/ha of extra dry matter per kilogram N applied, and with 0.2 kg/h/d of extra liveweight gain, was calculated to produce a profitable outcome. In general, it seems that large dry matter and liveweight responses are needed before a profitable outcome occurs. This may explain why the majority of oats crops in southern and central Queensland are not fertilised.

Oats is a popular winter forage crop in southern and central Queensland however irregularities of in-crop rainfall mean that obtaining high forage yields is difficult, and even harder to predict. Many producers who grow oats are also investigating other perennial forage options to improve profitability. This review indicates there are a limited range of scenarios which provide positive economic outcomes under current price and cost structures, and these positive outcomes only occur at the upper end of the response scenarios.

As with forage sorghum, a more detailed whole farm analysis is required to determine how oats can contribute to the whole business. This is especially relevant as oats provides high quality forage and weight gain at a time of year when the quality of perennial grass pasture is low. This could enable stock to be finished and marketed earlier whereas an extra 6 months (i.e. another summer season) might be required if the same animals were finished on grass. These outcomes are possible. However, case study scenarios described earlier (Bowen 2014) indicate that oats is risky and other production systems (e.g. perennial pastures) are likely to provide better economic outcomes. This could be due, in part at least, to some years being too dry to plant oats while, in other years, unreliable in-crop rainfall makes a high-yielding oats crop (>4000kg/ha dry matter) difficult to achieve.

8 Conclusions and recommendations

8.1 Applying nitrogen fertiliser to sown grass pastures

The consequences of ‘rundown’ in the sown pastures of Queensland are too serious to ignore. Production losses of ~50% are a major challenge for the profitability and sustainability of beef enterprises and the Queensland economy.

Sown grass pastures run down so quickly that even relatively young pastures (e.g. 10-15 years old) on the more fertile brigalow/belah soils will respond dramatically to nitrogen fertiliser. It is also clear that the levels of nitrogen cycling and mineralisation that occur once the pasture/soil system has stabilised are firmly within the range that provides linear nitrogen responses to applied nitrogen (Graham *et al.* 1981).

Legumes remain the preferred long-term option to address sown pasture rundown in most situations. They provide a lasting solution if satisfactory populations of the legumes can be achieved in the pastures. However, low phosphorus levels, poor establishment methods and subsequent management have resulted in relatively few pastures having adequate legume production. Leucaena is the exception and clearly demonstrates what can be achieved when better agronomy is used to establish legumes.

While better establishment methods and management of existing grass-legume pastures are subsequently re-emerging as priorities for the beef industry, it will take many years before pasture legumes are fully utilised across southern and central Queensland. Legume establishment programs on individual properties are likely to take at least ten years while species are assessed, paddocks selected for establishment each year, land prepared, and failures encountered. Consequently, there has been interest in using nitrogen fertilisers to complement these programs because fertilisers are far more reliable, easier to manage and provide rapid results.

8.1.1 Key findings

The desk-top scenario analyses in this study suggest that applying nitrogen fertilisers to rundown sown grass pastures will produce dramatic increases in dry matter and animal productivity. However, a relatively high and consistent response rate in both pasture yield and quality was required for any reasonable likelihood of the application of nitrogen fertiliser being profitable. Further, the analyses support expectations that 100 kg N/ha is the more effective and efficient rate of fertiliser to employ, relative to 50 kg N/ha. For the suggested 100 kg N/ha fertiliser rate:

- average gross margins in the year of application were calculated to increase by 121%-217% when dry matter responses of 40 kg DM/kg N and an additional LWG per head of 0.2 kg/Day (i.e. an extra 70 kg per animal per year) can be achieved; and

- an Internal Rate of Return of 11% was possible for the same dry matter response rate if potential carryover nitrogen responses were included in subsequent years and the additional liveweight gain was more conservatively spread across two years (50 kg/AE in the first year and 20 kg/AE in the second year).

Recent trials and reviews of past research suggests that 40 kg DM/kg N response rate is achievable. However, the economic analyses also suggest that lower dry matter response rates and liveweight gains will fail to provide major benefits, or lose money. For example:

- The average gross margins were similar to unfertilised paddocks if the additional liveweight boost per head was reduced to 35 kg (~0.1 kg/hd/day);

- The 100 kg N/ha fertiliser rate, at a response rate of 30 kg DM/kg N (as per older research trials) was estimated to provide an Internal Rate of Return of 7%-9%;

- The half-rate of 50 kg N/ha at the same 40 kg DM/kg N response rate was estimated to provide an Internal Rate or Return of 9%-10%; while

- The low response rate of 20 kg DM/kg N was consistently predicted to lose money.

The analyses in the project were largely based on average results and did not include any variability in seasonal conditions. Seasonal variability will increase risk in these fertiliser scenarios, or indeed, any effort to intensify production in the beef industry. For fertiliser, these risks can be minimised and managed to some extent by restricting applications to seasons in which conditions are already good and avoiding applications in dry seasons, or seasons with the prospect for continuing low rainfall.

However, with increased risk, comes the need for the likely boosts to profit to be relatively high, to help compensate for instances of reduced profit. Hence, only those few scenarios which were predicted to give very large increases in GM per ha are likely to be attractive to producers. As discussed below, current levels of confidence in the higher rates of biological response (to underpin such higher profits) are low and require further investigation.

8.1.2 Recommendations for Research, Development and Extension

The scenarios in this scoping study demonstrate the sensitivity of the economic outcomes on the underlying forage yield response rate of the pasture and any boost to LWG per head from better feed quality.

Recent response data from replicated and non-replicated on-farm trials suggests the required dry matter response rate of 40 kg DM/kg N is achievable. However, there is insufficient data to assess the reliability of these responses over a range of seasonal conditions. Mean responses from detailed experiments conducted 20-40 years ago ranged from 19-46 kg DM/kg N. As the region's sown pastures become older, graziers will need data from these anecdotally 'more rundown' pastures to make informed decisions on whether they should now consider using nitrogen fertilisers. Similarly, more reliable data on the feed quality impacts and additional liveweight gains that are achievable in current grazing systems will be required to make good decisions. Consequently, further research is needed to clarify the underlying relationships and confirm (or not) the assumed responses in this analysis, principally:

- The dry matter response rate of pastures to applied nitrogen fertiliser. Research is needed to clarify whether the expected rate of 40 kg DM/ha can be achieved consistently as sown pastures across Queensland become more rundown over time;

- Liveweight gains per head from increased feed quality. Relationships between applied nitrogen fertiliser, subsequent feed quality, and especially the impact of this improved feed on liveweight gain are not well documented or clear. This impact on liveweight gain is critical to the profitability of using fertilisers and needs clarification. There will be trade-offs between responses in carrying capacity and individual animal LWG, as increasing stocking rate may reduce the expression of any potential benefit to LWG per head. This means that teasing out the animal production responses curves to fertiliser may not be straight forward; and

- The longevity of carryover responses in both dry matter and feed quality. These carryover responses have been widely observed but have rarely been included when producers and advisers consider using nitrogen fertiliser use on their pastures.

8.2 Applying nitrogen and phosphorus fertiliser to forage sorghum and oats

Forage sorghum and oats are regularly used by beef producers in southern and central Queensland. However, there are significant knowledge gaps regarding forage and animal responses, and hence the profitability of fertilising with nitrogen or phosphorus in these regions. The desktop-generated beef and economic outcomes generated in this review were therefore difficult to verify.

8.2.1 Key findings

With current costs and prices, very high responses in animal production to either N or P fertiliser are required to make the practices financially attractive. More specifically;

- Forages have to be productive and express a high response on average in both stocking rate per hectare and growth rate per head before any potential economic return to fertiliser applications can be estimated. Adding fertiliser to a low production system does not appear viable.

- The high costs associated with the production of annual forages and the low average margins for steers makes the profitability of forages appear quite low both with or without fertiliser. Hence, high rates of response to fertiliser, in both dry matter production and liveweight gain, are required to improve the economics of forage crops. Further, the only scenarios that generated GMs that were positive were with oats and not forage sorghum.

- The increase in price risk arising from the application of fertiliser to forages is likely to inhibit many producers adopting the use of nitrogen or phosphorus fertilisers even if they recognise that the expected gross margin response is positive, and

- No account has been taken of the likely impact of seasonal variability on the production risk of fertiliser application to forages. Hence, the predicted economic outcomes in this report are likely to be at the higher end of actual expectations.

8.2.2 Recommendations for Research, Development and Extension

The review of past research and scenario-testing confirm that forage production can be improved with fertiliser, especially N. However, based on the assumptions used in these scenarios it appears that there are few situations where such practice will be profitable. It is unlikely that higher plant dry matter responses, above those assumed, are possible. In addition, there are few data to support assumptions on liveweight gain responses. Therefore research is recommended where collection of data includes both diet quality and animal responses from the same experiments that measure forage dry matter yield and plant quality. This research may be best suited to research stations due to the complexity of the operations involved, including paddock design, cattle movements and measurements over the various grazing periods of these forages.

8.3 Conclusion

This study highlights some of the challenges for intensifying the northern beef production systems and improving their average return on assets above the estimated ~2%. Producers should seek an Internal Rate of Return of at least 5%, and preferable 10%, for practices that involve significant seasonal and market risks. The analyses in this study suggest that it will be difficult to achieve these rates of return from practices that only increase carrying capacity. The opportunity cost of the extra investment in stock means that high rates of return will likely also require substantial increases in the performance of individual animals.

The scenarios suggested that fertilisers are likely to produce dramatic increases in dry matter production, feed quality and animal performance. However, the economic performance of these fertiliser options was much more modest.

Applying nitrogen fertiliser to grass pastures may be economic, with the doubling and tripling of average gross margins at responses rates that the review suggests are achievable. Internal rates of return of up to 11% may also be achieved with more conservative responses in liveweight gain if potential residual fertiliser responses are included. The economic analyses again highlighted that the performance gains of individual animals is critical because the increased investment in stock from higher carrying capacities reduced the likely returns from all the scenarios analysed. The economic outcomes may be more favourable for enterprises that source stock from the property, which will improve the entry/exit price differential by reducing buying and transport costs. The value proposition for N on grass pasture may be more attractive if there is a significant cost to the whole enterprise of not employing N fertiliser to a particular paddock, such as being forced to sell unfinished stock (assuming there is a price/kg penalty) or being unable to reduce grazing pressure during establishment of pastures elsewhere on the farm.

The analyses suggest that the use of fertiliser on forage crops is rarely, if ever, a profitable option. The investment in extra stock to utilise the additional feed from fertilised forages, which may use stocking rates of up to ten times higher than perennial grass pastures, again limited the profitability of most scenarios. Moreover, the analysis suggests that even unfertilised forage crops may not be profitable, at least where the only source of additional potential revenue is the direct capture by growing stock on the crop. The consequence of not growing a forage crop, especially something like oats, on the whole enterprise was not considered. For example, having to hold unfinished stock for another 6-12 months before sale could have a negative impact on an enterprise. It may also be more profitable to sell unfinished stock and invest the costs of growing forage into other activities, especially for forage sorghum where at least some of the same objectives may be achieved by fertilising sown grass pastures. Such considerations require a more detailed whole farm economic analysis.

The study focused on the agronomic and economic viability of fertilising sown grass pastures and forages. It has not addressed the other opportunities and benefits that are likely if total dry matter production was doubled. For example: soil organic matter would undoubtedly increase and lead to healthier soils with more nutrient cycling; fertilised pastures will be stronger and more resilient to invasion by Indian couch and other undesirable species; and there will be greater opportunity to spell paddocks, and so maintain pasture condition across the property.

Ultimately, this study provides a contemporary analysis for comparing fertiliser options. The biophysical assumptions and relationships, along with the average gross margins and Internal Rates of Return calculated in the study, will help industry assess the likely impacts for particular situations. Together with assessments of the risks and reliability of proposed practices, the analyses will also support RDE agencies to make more informed decisions on their investment options, including the most effective ways to intensify northern beef production.

9 Bibliography

Ash A, Hunt L, McDonald C, Scanlan J, Bell L, Cowley R, Watson I, McIvor J, MacLeod N (2013) Innovation and investment to boost productivity and profitability for the northern beef industry – what are the opportunities? In 'Proceedings of the Northern Beef Research Update Conference', Cairns. Northern Beef Research Council, Gympie, Australia. pp. 83-90.

Bell L, Lawrence J, Johnson B, Whitbread A (2012) Exploring short-term ley legumes in subtropical grain systems: production, water-use, water-use efficiency and economics of tropical and temperate options. *Crop and Pasture Science* **63,** 819-832.

Bennett LT, Adams MA (2001) Response of perennial grassland to nitrogen and phosphorus additions in sub-tropical, semi-arid Australia. *Journal of Arid Environments* **48**, 289-308.

Blunt C (1971) Irrigated forage crops and pastures. In 'Annual Report 1969-1970'. Division of Land Research and Regional Survey, CSIRO.

Blunt C, Fisher M (1973) Production and utilisation of fodder and grain sorghum as forage for cattle in the Ord River valley, Western Australia. *Australian Journal of Experimental Agriculture and Animal Husbandry* **13**, 234-237.

Blunt C, Fisher M (1976) Production and utilisation of oats as forage for cattle in the Ord River Valley, Western Australia. *Australian Journal of Experimental Agriculture and Animal Husbandry* **16**, 88-93.

Boschma SP (2010) 'Tropical perennial grasses – the role of fertilisers and nitrogen'. Primefact Number 1050. Industry and Investment NSW, Sydney, Australia.

Bowdler T, Lowe K (1980) Forage production from irrigated oats or ryegrass grown with annual legumes or nitrogen in south-eastern Queensland. *Queensland Journal of Agriculture and Animal Sciences* **37**(2), 133-140.

Bowen M, Buck S, Gowen R (2010) 'High-output forages for meeting beef markets – phase 1'. Final report B.NBP.0496. Meat and Livestock Australia. Sydney, Australia.

Buchanan IK, Cowan RT (1990) Nitrogen level and environmental effects on the annual dry matter yield of tropical grasses. *Tropical Grasslands* **24**, 299-304.

Cavaye JM (1991) 'The Buffel Book: A guide to buffel grass development in Queensland.' Department of Primary Industries, Brisbane, Australia.

Chataway R, Cooper J, Orr W, Cowan R (2011b) The role of tillage, fertiliser and forage species in sustaining dairying based on crops in southern Queensland 2. Double-crop and summer sole-crop systems. *Animal Production Science* **51**, 904-919.

Chataway R, Cowan R, Orr W, Buchanan I, Frantz A, Long P (1992) Effects of additional nitrogen fertiliser applied to dryland forage crops on milk production from Darling Downs farms. In 'Proceedings of Australian Society of Animal Production' **19**,119.

Chataway R, Orr W, Cooper J, Cowan R (2011a) The role of tillage, fertiliser and forage species in sustaining dairying based on crops in southern Queensland 1. Winter–dominant forage systems. *Animal Production Science* **51**, 890-903.

Chudleigh F (2013) 'The Economics of Fertilising pastures and Forages for Beef Production in Queensland'. Internal report: Department of Agriculture, Fisheries and Forestry, Toowoomba, Australia.

Chudleigh P, Bramwell T (1996) Assessing the impact of introduced tropical pasture plants in northern Australia. *Manuscript prepared for CSIRO Task Force Interested in Introduced Pasture Plants* **11**.

Cook BG, Mulder JC (1984) Responses of nine grasses to nitrogen fertilizer under rain-grown conditions in south-eastern Queensland: 1 Seasonal dry matter productivity. *Australian Journal of Experimental Agriculture and Animal Husbandry* **24**, 410-414.

Cook S (2011) 'The proof is in the pasture – addressing fertility rundown'. Queensland Murray-Darling Committee, Toowoomba, Australia.

Cowan RT, Lowe KF, Ehrlich W, Upton PC, Bowdler TM (1995) Nitrogen-fertilised grass in a subtropical dairy system: 2. Effect of level of nitrogen fertiliser on animal production. *Australian Journal of Experimental Agriculture* **35**, 137-143.

Cox H, Chudleigh F, Chapman V (2002) Central Queensland Sustainable Farming Systems Project – Modelling and Economics Phase 1 Report. Department of Primary Industries and Fisheries, Rockhampton.

Dalal RC, Mayer RJ (1986) Long-term trends in fertility of soils under continuous cultivation and cereal cropping in southern Queensland. II Total organic carbon and its rate of loss from the soil profile. *Australin Journal of Soil Research* **24**, 281-192.

Donaldson CH, Rootman GT (1977) Evaluation of Cenchrus ciliaris: 1. Effects of nitrogen level and cutting frequency on digestibility and voluntary intake. *Proceedings of the Grassland Society of South Africa* **12**, 91-93.

Garay AH, Sollenberger LE, McDonald DC, Ruegsegger GJ, Kalmbacher RS, Mislevy P (2004) Nitrogen fertilization and stocking rate affect stargrass pasture and cattle performance. *Crop Science* **44**, 1348-1354.

Gorashi A, Drolsom P, Scholl J (1980) Effect of stage of growth, temperature and N and P levels on the hydrocyanic acid potential of sorghums in the field and growth room. *Crop Science* **20**, 45-47.

Graham T, Myers R, Doran J, Catchpool V, Robbins G (1985) Pasture renovation: The effect of cultivation on the productivity and nitrogen cycling of a buffel grass (*Cenchrus ciliaris*) pasture. In 'XV International Grasslands Congress'. Kyoto, Japan pp. 24-31.

Graham T, Webb A, Waring S (1981) Soil nitrogen status and pasture productivity after clearing of brigalow (Acacia harpophylla). *Australian Journal of Experimental Agriculture* **21**, 109-118.

Handson P, Layne N (1996) Economic evaluation of nitrogen fertiliser on oats. In 'Agronomy – Science with its sleeves rolled up.' Proceedings of the 8th Australian Agronomy Conference, (Eds. DL Michalk, JE Pratley). 30 January – 2 February 1996. The University of Southern Queensland, Toowoomba, Queensland.

Harms D, Tucker B (1973) Influence of nitrogen fertiliser and other factors on yield, prussic acid, nitrate and total nitrogen concentrations of sudangrass cultivars. *Agronomy Journal* **65**, 21-26.

Henzell EF, Peake DCI, Mannetje L't, Stirk GB (1975) Nitrogen response of pasture grasses on duplex soils formed from granite in southern Queensland. *Australian Journal of Experimental Agriculture and Animal Husbandry* **15**, 498-507.

Hoyle FC, Baldock JA, Murphy DV (2011) Soil organic carbon – Role in rainfed farming systems. In 'Rainfed Farming Systems' (Eds. P Tow, I Cooper, I Partridge, C Birch). pp. 339-361.

Jackson D, Rolfe J, English B, Holmes W, Matthews R, Dixon R, Smith P & MacDonald N (2012) *Phosphorus management of beef cattle in northern Australia.* Meat and Livestock Australia Limited.

Jacobs J, Ward G (2011) Effect of nitrogen application on dry matter yields, nutritive characteristics and mineral content of summer-active forage crops in southern Australia. *Animal Production Science* **51**, 77-86.

Johnson CR, Reiling BA, Mislevy P, Hall MB (2001) Effects of nitrogen fertilization and harvest date on yield, digestibility, fiber, and protein fractions of tropical grasses. *Journal of Animal Science* **79**(9), 2439-2448.

Jones RM, McDonald CK, Silvey MW (1995) Permanent pastures on a brigalow soil: the effect of nitrogen fertiliser and stocking rate on pastures and liveweight gain. *Tropical Grasslands* **29**, 193-209.

Lawrence D, Bell M, Moody P, Johnson B, O'Connor R, Toms-Morgan R (2012) Paired-sites to engage farmers and understand soil organic matter and carbon. In 'Capturing opportunities and overcoming obstacles in Australian agronomy'. (Ed. I Yunusa) Proceedings of 16th Australian Agronomy Conference 2012, 14-18 October 2012, Armidale, NSW. <http://www.regional.org.au/au/asa/climate-change/8059 lawrencedn.htm>

Lawrence D, Johnson B (2013) Agronomy the key to productive pastures that can sustain profitable grain production in Queensland. GRDC Grain Research Update (Inglestone). July 2013, Grains Research and Development Corporation/ICAN, Sydney.

Lawrence DN, Johnson B, Buck S, O'Connor R, Argent S, Mace, G, Kedzlie G, (2013) pasture rundown – Are your sown pastures nitrogen deficient? In 'Proceedings of the Northern Beef Research Update Conference', Cairns. Northern Beef Research Council, Gympie, Australia. pp. 141.

Lloyd D, Johnson B, O'Brien S, Roesner L, Boschma S, Williams R (2007) 'LeyGrain - Pastures in farming systems: sustaining profit and the environment in the Northern Grainbelt of Australia. Department of Primary Industries and Grains Research and Development Corporation.

Lowe K, Bowdler T, Batianoff G (1980) Effect of seeding rate and nitrogen on the herbage production of rain-grown and irrigated oats in sub-coastal south-eastern Queensland. *Queensland Journal of Agricultural and Animal Sciences* **37**(2), 145-154.

Lupatini G, Restle J, Vaz R, Valente A, Roso C, Vaz F (2013) Beef cattle production on black oats and Italian ryegrass pasture under nitrogen fertilisation. *Ciencia Animal Brasileira* **14**(2), 164-171.

Mannetje L't, Jones RM (1990) Pasture and animal productivity of buffel grass with Siratro, lucerne or nitrogen fertilizer. *Tropical Grasslands* **24**, 269-281.

McCosker T, McLean D, Holmes P (2010). Northern beef situation analysis 2009. Project report B.NBP.0518. Meat and Livestock Australia, Sydney.

McIvor JG (1984) Phosphorus requirements and responses of tropical pasture species: native and introduced grasses, and introduced legumes. *Australian Journal of Experimental Agriculture and Animal Husbandry* **24**, 370-378.

McIvor JG, Guppy C, Probert ME (2011) Phosphorus requirements of tropical grazing systems: the northern Australian experience. *Plant and Soil* **349**, 55-67.

Muldoon D (1985) Summer forages under irrigation. 3. The effect of nitrogen fertiliser on the growth, mineral composition and digestibility of a sorghum x sudangrass hybrid and Japanese barnyard millet. *Australian Journal of Experimental Agriculture* **25**, 411-416.

Myers R, Robbins G (1991) Sustaining productive pastures in the tropics. 5. Maintaining productive sown grass pastures. *Tropical Grasslands* **25**, 104-110.

Neumann M, Restle J, Filho D, Maccari M, Pellegrini L, Souza A, Peixoto L (2005) Forage quality and beef cattle production of sorghum pasture (Sorghum bicolour, L.), fertilised with two fertiliser types, under continuous grazing. *Revista Brasileira de Agrociencia* **11**(2), 221-226.

Peake DCI, Myers RJK, Henzell EF (1990) Sown pasture production in relation to nitrogen fertilizer and rainfall in southern Queensland. *Tropical Grasslands* **24**, 291-298.

Peck G, Lawrence D, Buck S, Johnson B (2012) Graziers, pasture seed industry and researchers are concerned about pasture productivity decline. In 'Capturing opportunities and overcoming obstacles in Australian agronomy'. (Ed. I Yunusa) Proceedings of 16th Australian Agronomy Conference 2012, 14-18 October 2012, Armidale, NSW. <http://www.regional.org.au/au/asa/pastures/8223 peckg.htm>

Peck GA, Chudleigh F, Guppy C, Johnson B, Lawrence DN (2014) 'Use of fertiliser phosphorus for increased productivity of legume-based sown pastures in the Brigalow Belt region–a review'. Meat and Livestock Australia, Sydney.

Peck GA, Buck SR, Hoffman A, Holloway C, Johnson B, Lawrence DN, Paton CJ (2011) 'Review of productivity decline in sown grass pastures'. Meat and Livestock Australia, Sydney.

Peck GA, Johnson B, Lawrence D, Buck S, Kedzlie G, O'Connor R, Taylor D (2013a) Managing 'rundown' in grass pastures. In 'Proceedings of the Northern Beef Research Update Conference', Cairns. Northern Beef Research Council, Gympie, Australia. pp. 11-14.

Peck GA, Johnson B, Kedzlie G, O'Connor R, Watson J (2013b) Improving reliability of legume establishment in sown grass pastures. In 'Proceedings of the Northern Beef Research Update Conference', Cairns. Northern Beef Research Council, Gympie, Australia. pp. 150.

Prichard G (1985) Irrigated summer fodder crops – nitrogen responses. In 'Crop and pasture production – science and practice'. Proceedings of the 3rd Australian Agronomy Conference, (Ed. JJ Yates) January-February 1985. The University of Tasmania, Hobart, Tasmania.

Quirk M, McIvor JG (2005) 'Grazing Land Management Technical Manual.' (Meat and Livestock Australia Limited).

Radford BJ, Thornton CM, Cowie BA, Stephens ML (2007) The Brigalow Catchment Study: III. Productivity changes on brigalow land cleared for long-term cropping and for grazing. *Australian Journal of Soil Research* **45**, 512-523.

Rahman M, Fukai S, Blamey P (2001) Forage production and nitrogen uptake of forage sorghum, grain sorghum and maize as affected by cutting under different nitrogen levels. In 'Science and Technology: Delivering results for Agriculture'. Proceedings of the 10th Australian Agronomy Conference, (Ed. B Rowe, D Donaghy, N Mendham) January 2001. Hobart, Tasmania.

Restelatto R, Pavinato P, Sartor L, Paixao S (2013) Production and nutritional value of sorghum and black oat forages under nitrogen fertilisation. *Grass and Forage Science*. Early view on-line version (before issue inclusion). John Wiley and Sons Ltd.

Reuss JO, Innis GS (1977) A grassland nitrogen flow simulation model. *Ecology* **58**, 379-388.

Robbins G (1984) Relationships between productivity and age since establishment of pastures of Panicum maximum var. trichoglume. University of Queensland.

Robbins G, Bushell J, Butler K (1987) Decline in plant and animal production from ageing pastures of green panic (Panicum maximum var. trichoglume). *The Journal of Agricultural Science* **108**, 407-417.

Robbins G, Rickert K, Humphreys L (1986) Productivity decline in sown tropical grass pastures with age: the problem and possible solutions. *Proceedings of Australian Society of Animal Production* **16**, 319-322.

Robertson FA, Myers RJK, Saffigna PG (1997) Nitrogen cycling in brigalow clay soils under pasture and cropping. *Australian Journal of Soil Research* **35**, 1323-1339.

Russell JS (1985a) Soil treatment, plant species and management effects on improved pastures on a solodic soil in the semi-arid subtropics: 1. Dry matter and botanical composition. *Australian Journal of Experimental Agriculture* **25**, 367-379.

Russell JS (1985b) Soil treatment, plant species and management effects on improved pastures on a solodic soil in the semi-arid subtropics: 2. Cattle liveweight gains. *Australian Journal of Experimental Agriculture* **25**, 380-391.

Southwood O, Mengersen F, Milham P (1974) Response of oats to seeding rate and nitrogen in the southern wheat belt of New South Wales. *Australian Journal of Experimental Agriculture and Animal Husbandry* **14**, 231-236.

Spurway R, Wheeler F and Hedges D (1974) Forage and sheep production from oats, rape and vetch sown in autumn with or without nitrogen fertiliser. *Australian Journal of Experimental Agriculture and Animal Husbandry* **14**, 619-628.

Stuart P (2002) 'The Forage Book: A comprehensive guide to forage management'. 2nd Edition. Pacific Seeds, Toowoomba, Australia.

Thompson (1988) 'Improving Livestock Profitability with Pastures and Forage Crops' Bowdler, English and Wehl, Toowoomba, Australia.

Walker B, Baker J, Becker M, Brunckhorst R, Heatley D, Simms J, Skerman D, Walsh S (1997) Sown pasture priorities for the subtropical and tropical beef industry. *Tropical Grasslands* **31**, 266-272.

Walker B, Weston E (1990) Pasture development in Queensland—a success story. *Tropical Grasslands* **24**, 257–268.

Wheeler J, Hedges D (1971) Summer forage crops. In 'Reports on Research 1969-1970.' Pastoral Research Laboratory, Division of Animal Physiology, CSIRO.

Wheeler J, Hedges D, Archer K, Hamilton B (1980) Effect of nitrogen, sulphur and phosphorus fertiliser on the production, mineral content and cyanide potential of forage sorghum. *Australian Journal of Experimental Agriculture and Animal Husbandry* **20**, 330-338.

Whish G (ed.) (2011). Land types of Queensland. Version 2.0. Prepared by the Grazing Land Management Workshop Team, Department of Employment, Economic Development and Innovation, Brisbane. PR07-3212.

10 Appendices

10.1 Forage sorghum gross margins

Table 1. 50 N fertiliser 5000 kg DM

Gross margin for	**5000 kg DM yr Forage sorghum** per ha per annum	**+30kg DM /kg N +.05 kg day** per ha per annum	**+40kg DM /kg N +.05 kg day** per ha per annum	**+50kg DM /kg N +.05 kg day** per ha per annum
Livestock Sales	$1,471	$1,959	$2,078	$2,226
Variable costs				
Livestock Purchases	$1,300	$1,716	$1,820	$1,950
Freight In	$23	$30	$32	$34
Freight Out	$83	$110	$116	$125
Treatment Expenses	$1	$1	$1	$1
Selling Expenses	$8	$10	$11	$11
Forage growing costs	$114	$202	$202	$202
Total Expenses	$1,527	$2,068	$2,181	$2,323
Gross Margin	-$56	-$109	-$104	-$96
Gross Margin / hectare /annum (after interest)	**-$74**	**-$133**	**-$128**	**-$123**
Kilograms of liveweight gain per hectare per annum	91	130	138	148

Table 2. 50 N fertiliser 10000 kg DM

Gross margin for	**10000 kg DM yr Forage sorghum** per ha per annum	**+30kg DM /kg N +.05 kg day** per ha per annum	**+40kg DM /kg N +.05 kg day** per ha per annum	**+50kg DM /kg N +.05 kg day** per ha per annum
Livestock Sales	$2,913	$3,413	$3,562	$3,710
Variable costs				
Livestock Purchases	$2,574	$2,990	$3,120	$3,250
Freight In	$45	$52	$54	$56
Freight Out	$164	$191	$199	$208
Treatment Expenses	$1	$1	$1	$1
Selling Expenses	$15	$17	$18	$19
Forage growing costs	$114	$202	$202	$202
Total Expenses	$2,913	$3,454	$3,595	$3,736
Gross Margin	$1	-$40	-$33	-$26
Gross Margin / hectare /annum (after interest)	**-$35**	**-$81**	**-$76**	**-$71**
Kilograms of liveweight gain /hectare per annum	180	227	236	246

Table 3. 50 N fertiliser 15000 kg DM

Gross margin for	**15000 kg DM yr Forage sorghum** per ha per annum	**+30kg DM /kg N +.05 kg day** per ha per annum	**+40kg DM /kg N +.05 kg day** per ha per annum	**+50kg DM /kg N +.05 kg day** per ha per annum
Livestock Sales	$4,370	$4,898	$5,046	$5,194
Variable costs				
Livestock Purchases	$3,861	$4,290	$4,420	$4,550
Freight In	$67	$74	$77	$79
Freight Out	$247	$274	$282	$291
Treatment Expenses	$2	$2	$2	$2
Selling Expenses	$23	$25	$26	$27
Forage growing costs	$114	$202	$202	$202
Total Expenses	$4,312	$4,867	$5,009	$5,150
Gross Margin	$58	$30	$37	$44
Gross Margin per hectare per annum (after interest)	**$5**	**-$29**	**-$23**	**-$18**
Kilograms of liveweight gain per hectare per annum	270	325	335	345

Table 4. 100 N fertiliser 5000 kg DM

Gross margin for	**5000 kg DM yr Forage sorghum** per ha per annum	**+30kg DM /kg N +.1 kg day** per ha per annum	**+40kg DM /kg N +.1 kg day** per ha per annum	**+50kg DM /kg N +.1 kg day** per ha per annum
Livestock Sales	$1,471	$2,395	$2,694	$2,994
Variable costs				
Livestock Purchases	$1,300	$2,080	$2,340	$2,600
Freight In	$23	$36	$41	$45
Freight Out	$83	$133	$149	$166
Treatment Expenses	$1	$1	$1	$1
Selling Expenses	$8	$12	$14	$15
Forage growing costs	$114	$278	$278	$278
Total Expenses	$1,527	$2,540	$2,823	$3,106
Gross Margin	-$56	-$145	-$129	-$112
Gross Margin per hectare per annum (after interest)	**-$74**	**-$174**	**-$161**	**-$148**
Kilograms of liveweight gain per hectare per annum	91	170	191	212

Table 5. 100 N fertiliser 10000 kg DM

Gross margin for	**10000 kg DM yr Forage sorghum** per ha per annum	**+30kg DM /kg N +.1 kg day** per ha per annum	**+40kg DM /kg N +.1 kg day** per ha per annum	**+50kg DM /kg N +.1 kg day** per ha per annum
Livestock Sales	$2,943	$3,892	$4,191	$4,490
Variable costs				
Livestock Purchases	$2,600	$3,380	$3,640	$3,900
Freight In	$45	$59	$63	$68
Freight Out	$166	$216	$233	$249
Treatment Expenses	$1	$1	$2	$2
Selling Expenses	$15	$20	$21	$23
Forage growing costs	$114	$278	$278	$278
Total Expenses	$2,941	$3,954	$4,237	$4,519
Gross Margin	$2	-$62	-$46	-$29
Gross Margin per hectare per annum (after interest)	**-$34**	**-$108**	**-$95**	**-$82**
Kilograms of liveweight gain per hectare per annum	182	276	297	318

Table 6. 100 N fertiliser 15000 kg DM

Gross margin for	**15000 kg DM yr Forage sorghum** per ha per annum	**+30kg DM /kg N +.1 kg day** per ha per annum	**+40kg DM /kg N +.1 kg day** per ha per annum	**+50kg DM /kg N +.1 kg day** per ha per annum
Livestock Sales	$4,414	$5,388	$5,688	$5,987
Variable costs				
Livestock Purchases	$3,900	$4,680	$4,940	$5,200
Freight In	$68	$81	$86	$90
Freight Out	$249	$299	$316	$332
Treatment Expenses	$2	$2	$2	$2
Selling Expenses	$23	$27	$29	$30
Forage growing costs	$114	$278	$278	$278
Total Expenses	$4,355	$5,368	$5,650	$5,933
Gross Margin	$59	$21	$38	$54
Gross Margin per hectare per annum (after interest)	**$6**	**-$43**	**-$30**	**-$17**
Kilograms of liveweight gain per hectare per annum	273	382	403	424

Table 7. 5 kg P 10000 kg DM

Gross margin for	**10000 kg DM yr Forage sorghum** / ha / annum	**+1kg DM /kg P +.05 kg day** / ha / annum	**+2kg DM /kg P +.05 kg day** / ha / annum	**+5kg DM /kg P +.05 kg day** / ha / annum	**+10kg DM /kg P +.05 kg day** / ha / annum	**+20kg DM /kg P +.05 kg day** / ha / annum	**+40kg DM /kg P +.05 kg day** / ha / annum	**+80kg DM /kg P +.05 kg day** / ha / annum	**+120kg DM /kg P +.05 kg day** / ha / annum	**+160kg DM /kg P +.05 kg day** / ha / annum
Livestock Sales	$2,943	$2,970	$2,971	$2,976	$2,983	$2,998	$3,028	$3,087	$3,146	$3,206
Variable costs										
Livestock Purchases	$2,600	$2,601	$2,603	$2,607	$2,613	$2,626	$2,652	$2,704	$2,756	$2,808
Freight In	$45	$45	$45	$45	$45	$46	$46	$47	$48	$49
Freight Out	$166	$166	$166	$167	$167	$168	$169	$173	$176	$179
Treatment Expenses	$1	$1	$1	$1	$1	$1	$1	$1	$1	$1
Selling Expenses	$15	$15	$15	$15	$15	$15	$15	$16	$16	$16
Forage growing costs	$114	$148	$148	$148	$148	$148	$148	$148	$148	$148
Total Expenses	$2,941	$2,977	$2,979	$2,983	$2,990	$3,004	$3,032	$3,089	$3,145	$3,202
Gross Margin	$2	-$7	-$7	-$7	-$7	-$6	-$5	-$2	$1	$4
Gross Margin /ha /annum (after interest)	**-$34**	**-$43**	**-$43**	**-$43**	**-$43**	**-$42**	**-$41**	**-$39**	**-$37**	**-$35**
Kg of liveweight gain / ha per annum	182	197	197	197	198	199	201	205	209	213

Table 8. 10 kg P 10000 kg DM

Gross margin for	**10000 kg DM yr Forage sorghum** / ha /annum	**+1kg DM /kg P +.1kg day** / ha /annum	**+2kg DM /kg P +.1kg day** / ha /annum	**+5kg DM /kg P +.1 kg day** / ha /annum	**+10kg DM /kg P +.1kg day** / ha /annum	**+20kg DM /kg P +.1 kg day** / ha /annum	**+40kg DM /kg P +.1kg day** / ha /annum	**+80kg DM /kg P +.1 kg day** / ha /annum	**+120kg DM /kg P +.1 kg day** / ha /annum	**+160kg DM /kg P +.1 kg day** / ha / annum
Livestock Sales	$2,943	$2,997	$3,000	$3,009	$3,024	$3,053	$3,113	$3,233	$3,353	$3,473
Variable costs										
Livestock Purchases	$2,600	$2,603	$2,605	$2,613	$2,626	$2,652	$2,704	$2,808	$2,912	$3,016
Freight In	$45	$45	$45	$45	$46	$46	$47	$49	$50	$52
Freight Out	$166	$166	$166	$167	$168	$169	$173	$179	$186	$193
Treatment Expenses	$1	$1	$1	$1	$1	$1	$1	$1	$1	$1
Selling Expenses	$15	$15	$15	$15	$15	$15	$16	$16	$17	$18
Forage growing costs	$114	$170	$170	$170	$170	$170	$170	$170	$170	$170
Total Expenses	$2,941	$3,001	$3,004	$3,012	$3,026	$3,054	$3,111	$3,224	$3,337	$3,450
Gross Margin	$2	-$4	-$4	-$3	-$3	-$1	$2	$9	$16	$22
Gross Margin /ha /annum (after interest)	**-$34**	**-$40**	**-$40**	**-$39**	**-$39**	**-$37**	**-$35**	**-$29**	**-$24**	**-$19**
Kg of liveweight gain / ha per annum	182	212	213	213	214	216	221	229	238	246

10.2 Oats gross margins

Table 1. Oats 50 kg N 2000 kg DM

Gross margin for	**2000 kg DM yr Oats** per ha per annum	**+10kg DM /kg N +.1 kg day** per ha per annum	**+30kg DM /kg N +.1 kg day** per ha per annum	**+50kg DM /kg N +.1 kg day** per ha per annum
Livestock Sales	$904	$1,146	$1,605	$2,063
Variable costs				
Livestock Purchases	$770	$963	$1,348	$1,733
Freight In	$13	$17	$23	$30
Freight Out	$49	$62	$86	$111
Treatment Expenses	$0	$0	$1	$1
Selling Expenses	$4	$6	$8	$10
Forage growing costs	$153	$241	$241	$241
Total Expenses	$990	$1,288	$1,707	$2,126
Gross Margin	-$87	-$142	-$102	-$63
Gross Margin per hectare per annum (after interest)	**-$96**	**-$154**	**-$119**	**-$84**
Kilograms of liveweight gain per hectare per annum	73	101	141	182

Table 2. Oats 50 kg N 4000 kg DM

Gross margin for	**4000 kg DM yr Oats** per ha per annum	**+10kg DM /kg N +.1 kg day** per ha per annum	**+30kg DM /kg N +.1 kg day** per ha per annum	**+50kg DM /kg N +.1 kg day** per ha per annum
Livestock Sales	$1,807	$2,063	$2,522	$2,980
Variable costs				
Livestock Purchases	$1,541	$1,733	$2,119	$2,504
Freight In	$27	$30	$37	$43
Freight Out	$98	$111	$135	$160
Treatment Expenses	$1	$1	$1	$1
Selling Expenses	$9	$10	$12	$15
Forage growing costs	$153	$241	$241	$241
Total Expenses	$1,828	$2,126	$2,545	$2,964
Gross Margin	-$21	-$63	-$23	$17
Gross Margin per hectare per annum (after interest)	**-$40**	**-$84**	**-$49**	**-$14**
Kilograms of liveweight gain per hectare per annum	145	182	222	263

Table 3. Oats 50 kg N 6000 kg DM

Gross margin for	**6000 kg DM yr Oats** per ha per annum	**+10kg DM /kg N +.1 kg day** per ha per annum	**+30kg DM /kg N +.1 kg day** per ha per annum	**+50kg DM /kg N +.1 kg day** per ha per annum
Livestock Sales	$2,711	$2,980	$3,439	$3,898
Variable costs				
Livestock Purchases	$2,311	$2,504	$2,889	$3,274
Freight In	$40	$43	$50	$57
Freight Out	$148	$160	$185	$209
Treatment Expenses	$1	$1	$1	$1
Selling Expenses	$13	$15	$17	$19
Forage growing costs	$153	$241	$241	$241
Total Expenses	$2,666	$2,964	$3,383	$3,802
Gross Margin	$45	$17	$56	$96
Gross Margin per hectare per annum (after interest)	**$16**	**-$14**	**$21**	**$56**
Kilograms of liveweight gain per hectare per annum	218	263	303	343

Table 4. Oats 100 kg N 2000 kg DM

Gross margin for	**2000 kg DM yr Oats** per ha per annum	**+10kg DM /kg N +.2 kg day** per ha per annum	**+30kg DM /kg N +.2 kg day** per ha per annum	**+50kg DM /kg N +.2 kg day** per ha per annum
Livestock Sales	$904	$1,396	$2,326	$3,257
Variable costs				
Livestock Purchases	$770	$1,156	$1,926	$2,696
Freight In	$13	$20	$33	$47
Freight Out	$49	$74	$123	$172
Treatment Expenses	$0	$1	$1	$1
Selling Expenses	$4	$7	$11	$16
Forage growing costs	$153	$317	$317	$317
Total Expenses	$990	$1,574	$2,412	$3,249
Gross Margin	-$87	-$178	-$85	$8
Gross Margin per hectare per annum (after interest)	**-$96**	**-$192**	**-$109**	**-$25**
Kilograms of liveweight gain per hectare per annum	73	133	222	311

Table 5. Oats 100 kg N 4000 kg DM

Gross margin for	**4000 kg DM yr Oats** per ha per annum	**+10kg DM /kg N +.2 kg day** per ha per annum	**+30kg DM /kg N +.2 kg day** per ha per annum	**+50kg DM /kg N +.2 kg day** per ha per annum
Livestock Sales	$1,807	$2,326	$3,257	$4,188
Variable costs				
Livestock Purchases	$1,541	$1,926	$2,696	$3,467
Freight In	$27	$33	$47	$60
Freight Out	$98	$123	$172	$221
Treatment Expenses	$1	$1	$1	$2
Selling Expenses	$9	$11	$16	$20
Forage growing costs	$153	$317	$317	$317
Total Expenses	$1,828	$2,412	$3,249	$4,087
Gross Margin	-$21	-$85	$8	$101
Gross Margin per hectare per annum (after interest)	**-$40**	**-$109**	**-$25**	**$58**
Kilograms of liveweight gain per hectare per annum	145	222	311	400

Table 6. Oats 100 kg N 6000 kg DM

Gross margin for	**6000 kg DM yr Oats** per ha per annum	**+10kg DM /kg N +.2 kg day** per ha per annum	**+30kg DM /kg N +.2 kg day** per ha per annum	**+50kg DM /kg N +.2 kg day** per ha per annum
Livestock Sales	$2,711	$3,257	$4,188	$5,113
Variable costs				
Livestock Purchases	$2,311	$2,696	$3,467	$4,232
Freight In	$40	$47	$60	$73
Freight Out	$148	$172	$221	$270
Treatment Expenses	$1	$1	$2	$2
Selling Expenses	$13	$16	$20	$25
Forage growing costs	$153	$317	$317	$317
Total Expenses	$2,666	$3,249	$4,087	$4,920
Gross Margin	$45	$8	$101	$193
Gross Margin per hectare per annum (after interest)	**$16**	**-$25**	**$58**	**$141**
Kilograms of liveweight gain per hectare per annum	218	311	400	488

Table 7. Oats 5 kg P 4000 kg DM

Gross margin for	**4000 kg DM yr Oats** / ha / annum	**+1kg DM /kg P +.1 kg day** / ha / annum	**+2kg DM /kg P +.1 kg day** / ha / annum	**+5kg DM /kg P +.1 kg day** / ha / annum	**+10kg DM /kg P +.1 kg day** / ha / annum	**+20kg DM /kg P +.1 kg day** / ha / annum	**+40kg DM /kg P +.1 kg day** / ha / annum	**+80kg DM /kg P +.1 kg day** / ha / annum	**+120kg DM /kg P +.1 kg day** / ha / annum	**+160kg DM /kg P +.1 kg day** / ha / annum
Livestock Sales	$1,807	$1,836	$1,839	$1,846	$1,857	$1,880	$1,926	$2,018	$2,109	$2,201
Variable costs										
Livestock Purchases	$1,541	$1,543	$1,545	$1,550	$1,560	$1,579	$1,618	$1,695	$1,772	$1,849
Freight In	$27	$27	$27	$27	$27	$27	$28	$29	$31	$32
Freight Out	$98	$99	$99	$99	$100	$101	$103	$108	$113	$118
Treatment Expenses	$1	$1	$1	$1	$1	$1	$1	$1	$1	$1
Selling Expenses	$9	$9	$9	$9	$9	$9	$9	$10	$10	$11
Forage growing costs	$125	$159	$159	$159	$159	$159	$159	$159	$159	$159
Total Expenses	$1,800	$1,837	$1,839	$1,845	$1,856	$1,877	$1,919	$2,002	$2,086	$2,170
Gross Margin	$7	$0	$0	$0	$1	$3	$7	$15	$23	$31
Gross Margin per hectare per annum (after interest)	**-$12**	**-$19**	**-$19**	**-$19**	**-$18**	**-$16**	**-$13**	**-$6**	**$1**	**$8**
Kilograms of liveweight gain per hectare per annum	145	162	162	163	164	166	170	178	186	194

Table 8. Oats 10 kg P 4000 kg DM

Gross margin for	**4000 kg DM yr Oats** / ha / annum	**+1kg DM /kg P +.2 kg day** / ha / annum	**+2kg DM /kg P +.2 kg day** / ha / annum	**+5kg DM /kg P +.2 kg day** / ha / annum	**+10kg DM /kg P +.2 kg day** / ha / annum	**+20kg DM /kg P +.2 kg day** / ha / annum	**+40kg DM /kg P +.2 kg day** / ha / annum	**+80kg DM /kg P +.2 kg day** / ha / annum	**+120kg DM /kg P +.2 kg day** / ha / annum	**+160kg DM /kg P +.2 kg day** / ha / annum
Livestock Sales	$1,807	$1,868	$1,870	$1,884	$1,908	$1,954	$2,047	$2,233	$2,420	$2,606
Variable costs										
Livestock Purchases	$1,541	$1,546	$1,548	$1,560	$1,579	$1,618	$1,695	$1,849	$2,003	$2,157
Freight In	$27	$27	$27	$27	$27	$28	$29	$32	$35	$37
Freight Out	$98	$99	$99	$100	$101	$103	$108	$118	$128	$138
Treatment Expenses	$1	$1	$1	$1	$1	$1	$1	$1	$1	$1
Selling Expenses	$9	$9	$9	$9	$9	$9	$10	$11	$12	$13
Forage growing costs	$125	$181	$181	$181	$181	$181	$181	$181	$181	$181
Total Expenses	$1,800	$1,863	$1,865	$1,878	$1,899	$1,941	$2,025	$2,192	$2,360	$2,527
Gross Margin	$7	$5	$5	$7	$9	$13	$23	$41	$60	$78
Gross Margin per hectare per annum (after interest)	**-$12**	**-$14**	**-$14**	**-$13**	**-$11**	**-$6**	**$2**	**$19**	**$35**	**$52**
Kilograms of liveweight gain per hectare per annum	145	178	179	180	182	187	196	213	231	249

10.3 "*The economics of fertilising pastures and forages for beef production in Queensland"* (Fred Chudleigh, September 2013)

A report prepared for "Fertilising for yield and quality in grass pastures and forages (Scoping study)

Summary

This report estimates the potential economic benefits of strategically fertilising grass pastures and forages for beef production in southern and central Queensland. It includes an assessment of the riskiness of applying fertilisers.

It is a component of a scoping study undertaken to assess the potential for fertilisers to increase the dry matter production and nutritive value of sown pasture grasses, forage sorghum and forage oats.

The impact of applied fertiliser on beef production is assessed using paddock level enterprise budgets and discounted cash flow techniques. The gross margins calculated in this analysis include an allowance for the labour costs associated with machinery operation thereby allowing identification of the cost of the additional labour required to spread fertiliser on the paddock – whether it is paid or unpaid. Labour costs associated with livestock handling are not included in the analysis as they are not expected to vary significantly between the treatments.

The impact on profitability of strategically fertilising buffel pasture

The impact of strategic applications of nitrogen (N) fertiliser on carrying capacity and production was modelled for a typical buffel pasture in southern central Queensland. Separate scenarios were chosen to represent two discrete starting levels of productivity prior to the application of fertiliser, namely an annual pasture production of 3000 kilograms (kg) of dry matter (DM) per hectare (ha) per annum or an annual production of 4500 kg of DM per ha per annum.

These levels of starting pasture production are taken to represent the likely average production of rundown grass paddocks that are still in reasonable pasture condition and growing in soils of high and low soil fertility/rainfall.

The scarcity of recent data identifying the impact of fertilising buffel grass on beef production required all available sources of knowledge to be condensed into a range of "best bet" responses likely from the strategic application of either 50 kg N per ha per annum or 100 kg of N per ha per annum in the form of urea.

The range of responses was modelled:

- firstly, on the basis that there was no carryover of benefit from the year of application to the next, and
- secondly, on the basis that there was a carryover of benefit that reduced over time.

▪ Scenario where there is no carry-over of benefit

For the scenario where there was no expected carryover of benefit, the potential average increase in pasture and livestock production was calculated at average response levels of 20, 30, 40 or 50 kg extra dry matter per hectare per kg of applied N combined with additional average liveweight gains of 50, 100 or 200 grams per AE per day depending upon the fertiliser scenario and the productivity of the base pasture.

The liveweight gains from improved pasture quality are in addition to the increase in stocking rate provided by the extra dry matter. Both are due to the fertiliser application.

The combination of stocking rate and weight gain benefits provided an average increase in beef production per hectare ranging from 80% up to 339% depending upon the base level of pasture production before fertiliser application, the proposed improvement in weight gain per head due to improved pasture quality, together with the rate of response in dry matter production for each kilogram of N applied to the pasture.

Figure 1 shows the variation in gross margin produced by the combinations of fertiliser amount, dry matter and quality response on a base pasture that typically produced 3000 kg dry matter per hectare per annum. It can be seen that doubling the liveweight gain response per day due to improved pasture quality has as much (or more) impact on the gross margin as doubling the rate of response in dry matter production.

The combination of these two benefits provided a significant potential improvement in the gross margin.

Note: For convenience, the base pasture has been included once for each treatment at the left hand side of Figure 1. This is why there are four gross margins of the same amount against the 3000 kg DM yr pasture at the left of the graph.

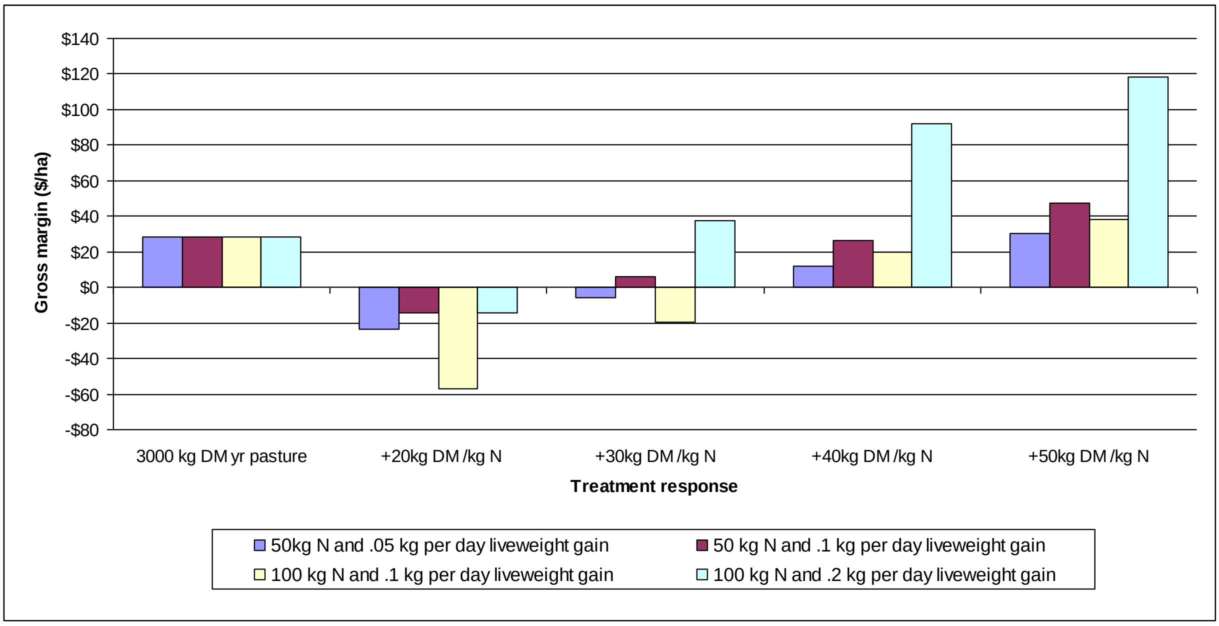

Figure 1: Possible gross margin response for a 3000 kg DM buffel pasture at differing levels of pasture dry matter and quality response

For the 3000 kg /ha DM scenario, the most profitable response identified from applying 50 kg N to buffel grass was the average response of 50 kg DM per kg of N applied combined with a quality benefit of 100 grams per head per day. The 100 hectare paddock would need to be stocked with almost three times as many steers (94 instead of 33) on average with those steers gaining 190 kg per head per annum on average instead of 150 kg per head per annum to gain this benefit.

An application rate of 100 kg N with an average response rate of 50 kg DM per kg N, and an extra 200 grams per head per day of weight gain produced a highly performing paddock. In this case, the 100 ha paddock was predicted to carry on average 133 steers with an average starting weight of 425 kg and gaining 220 kg per head per annum.

When there is no carry-over, most other levels of response to the application of 100 kg N per hectare were either worse off or were not significantly more profitable than the unfertilised pasture.

The benefits of strategically applying N fertiliser to a buffel pasture in moderate to good condition are shown in Figure 2. It can be seen that a significant weight gain bonus for pasture quality must be gained, as well as a carrying capacity improvement before the strategic use of N fertiliser is likely to prove beneficial.

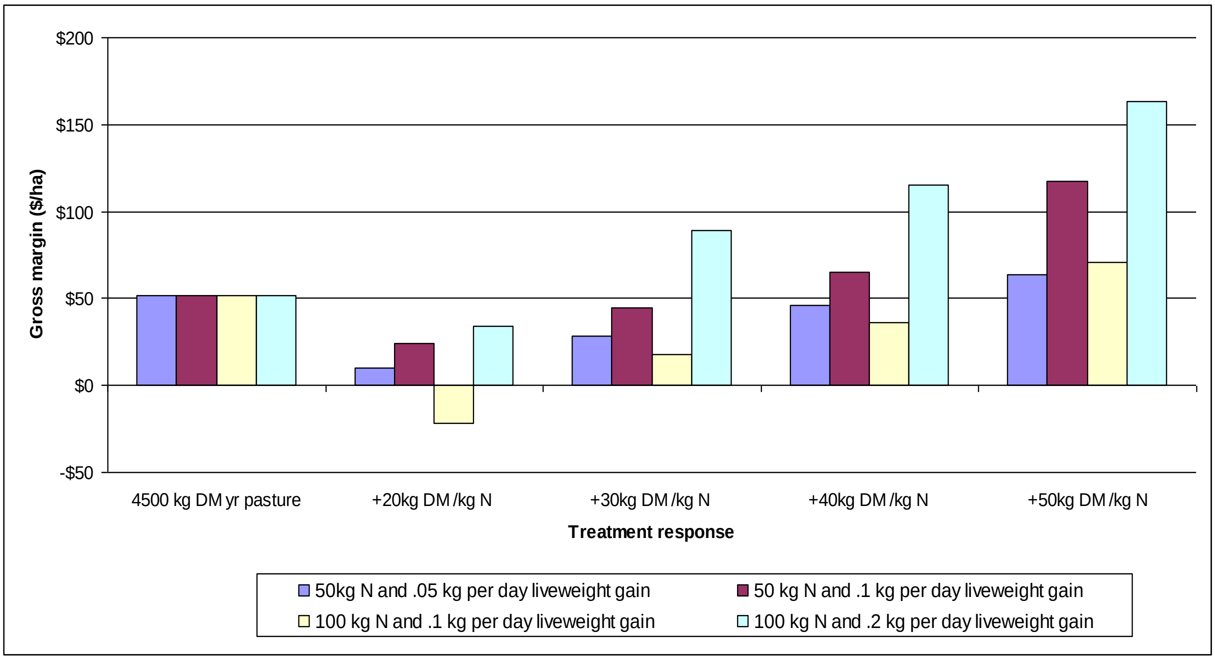

Figure 2: Possible gross margin response for a 4500 kg DM buffel pasture at differing levels of pasture dry matter and quality response

- The riskiness of the application of N fertiliser to buffel pasture

Please note that no risk associated with seasonal variation has been included in this component of the analysis.

The results of applying a stochastic model that incorporated the average production data, but applied variable and slightly correlated prices, showed that a fertilised buffel pasture that achieves a profitable gross margin is likely to provide higher returns in about 40% to 60% of years, but could make the producer significantly worse off in 30% of years. This variability is due to the riskiness inherent in the prices paid and received for steers as the potential variation in pasture response and extra weight gain were minimised in the model.

The price and other risks inherent in strategically fertilising pastures for beef production in central Queensland indicates that many beef producers are likely to reject fertilising pastures even though they may believe doing so could produce a substantially better gross margin on average. They will choose not to adopt because of the additional risk generated by the use of fertiliser.

- Scenario where there is a carry-over of benefit

For the scenario where there was an expected carry-over of benefit, the potential average increase in pasture and livestock production was only identified at response levels of 30 and 40 kg extra dry matter per hectare per kilogram of applied N. These two values were chosen to identify the likely level of response required to either breakeven or improve profitability.

Pasture response to fertiliser application was varied for both additional dry matter and quality in the years after the initial application. An increase in forage quality was built into the 100 kg N/ha treatment for the year of application and the year after. The 50 kg N/ha treatment improved pasture quality only in the year of application. A minor amount of benefit in pasture production was predicted to last until ten years after the fertiliser application, although most was lost by the end of the fifth year in all fertiliser treatments.

Figure 3 indicates the kilograms of beef per hectare per annum with and without 50 kg N per ha on a buffel pasture producing an average of 3000 kg dry matter per annum. The fertiliser is added to year one only and identifiable benefits are maintained until year five. Steers gain weight at 180 kg per head in the first year instead of the 150 kg per head gained on the base pasture. Weight gains per head are the same in both treatments after the first year, but additional beef is produced in subsequent years due to the predicted carryover effect of N fertiliser on pasture production.

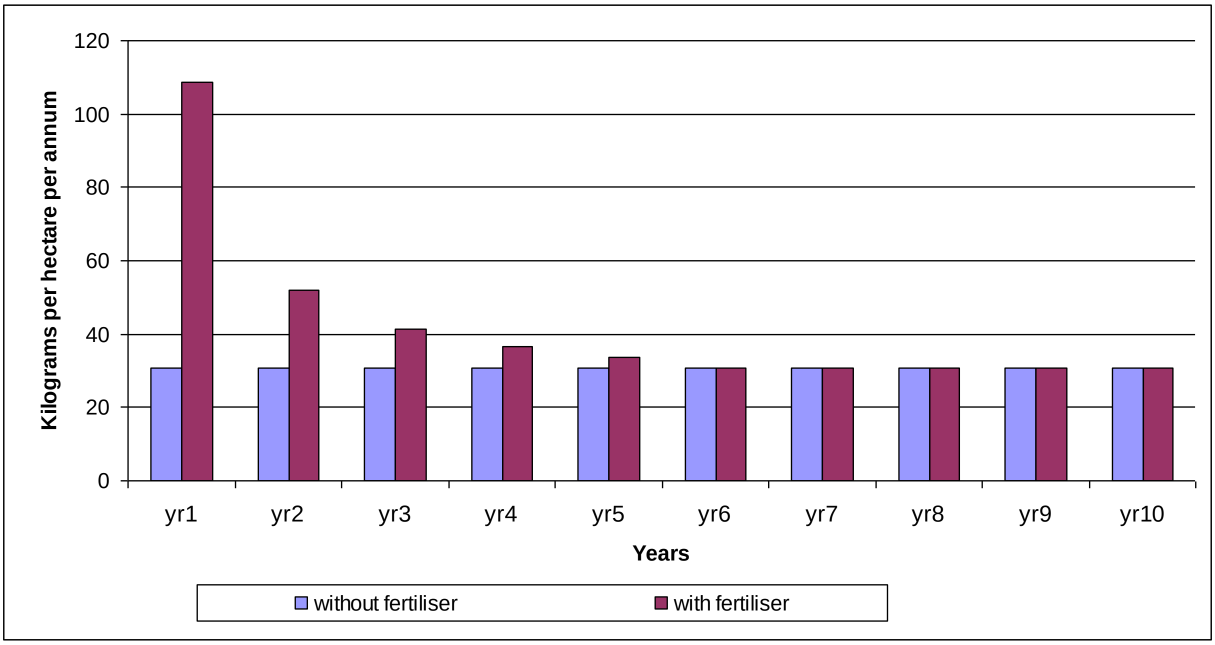

Figure 3: Kilograms of beef produced with and without fertiliser - 3000 kg DM/yr pasture, fertiliser at 50 kg N/ha and 40 kg DM/kg N

The liveweight gain benefits were combined with transfers of steers into and out of the paddock to develop a cash flow for the paddock over time – with and without fertiliser. The difference between the fertilised and unfertilised strategies was discounted to calculate the present value of the benefit of the strategy at discount rates of 5% and 10%.

Table 1 shows the amortised value of each predicted rate of response. These values were calculated using a discount rate of 5% and represent the extra annual value added per hectare by the fertiliser strategy at the predicted rate of response.

Table 1: Results of analysis – annual value added per hectare at a 5% discount rate of applying N fertiliser

Base pasture	Treatment			
	50 kg N 30 kg DM	50 kg N 40 kg DM	100 kg N 30 kg DM	100 kg N 40 kg DM
3000 kg DM /ha	$0.66	$2.19	$1.96	$7.58
4500 kg DM /ha	$0.15	$2.49	$3.34	$6.87

Table 2 shows the amortised value of each predicted rate of response calculated at a 10% discount rate.

Table 2: Results of analysis – annual value added per hectare at a 10% discount rate of applying N fertiliser

Base pasture	Treatment			
	50 kg N 30 kg DM	50 kg N 40 kg DM	100 kg N 30 kg DM	100 kg N 40 kg DM
3000 kg DM /ha	-$1.84	-$0.55	-$2.83	$2.24
4500 kg DM /ha	-$2.18	-$0.12	-$1.21	$1.89

Discount rates higher than 5% make this form of fertiliser application unviable. Given that there is some risk inherent in the application of fertiliser, it is probable that a beef producer would want to see a significantly positive return at a 10% discount rate.

It appears that applying N fertiliser to buffel pasture once every decade and achieving the levels of production response predicted is unlikely to produce acceptable returns. Even at the lower discount rate and without accounting for the impact of risk on perceived returns, the value added per hectare is only marginally better that not applying fertiliser.

The impact on profitability of strategically fertilising forages

Two separate forages (oats and forage sorghum) were modelled. The treatments were set at three base levels of starting production, three levels of response and two different fertilisers for each forage crop.

Forage sorghum had starting base production levels of either 5000, 10000 or 15000 kg DM per ha per annum. Oats had starting base production levels of 2000, 4000 or 6000 kg DM per ha per annum. These starting levels are taken to represent different starting levels of inherent soil fertility, not different starting levels of plant available water content (PAWC).

The response to strategic applications of N fertiliser was tested by treating each starting level of each forage crop with applications of 50 kg N or 100 kg of N and calculating the predicted response for combinations of 0.05, 0.1 or 0.2 kilograms per head of extra liveweight gain per day and 30, 40 or 50 kg /ha DM extra for each kg of N fertiliser applied.

To test the response to P, the middle level of production (10000 kg DM /ha forage sorghum and 4000 kg DM /ha oats) was treated with either 5 kg P /ha or 10 kg P /ha and a range of response levels estimated for both DM production and extra weight gain.

Fertiliser was applied in the form of urea (N) or Incitec triple super (P). The urea had 46% N and a cost of $700 per ton landed on property. The triple super had 20.1% P and a cost of $890 per ton.

- Results of strategically applying N and P fertiliser to forage sorghum

Figure 4 shows that most gross margins are likely to be negative for forage sorghum production with or without fertiliser.

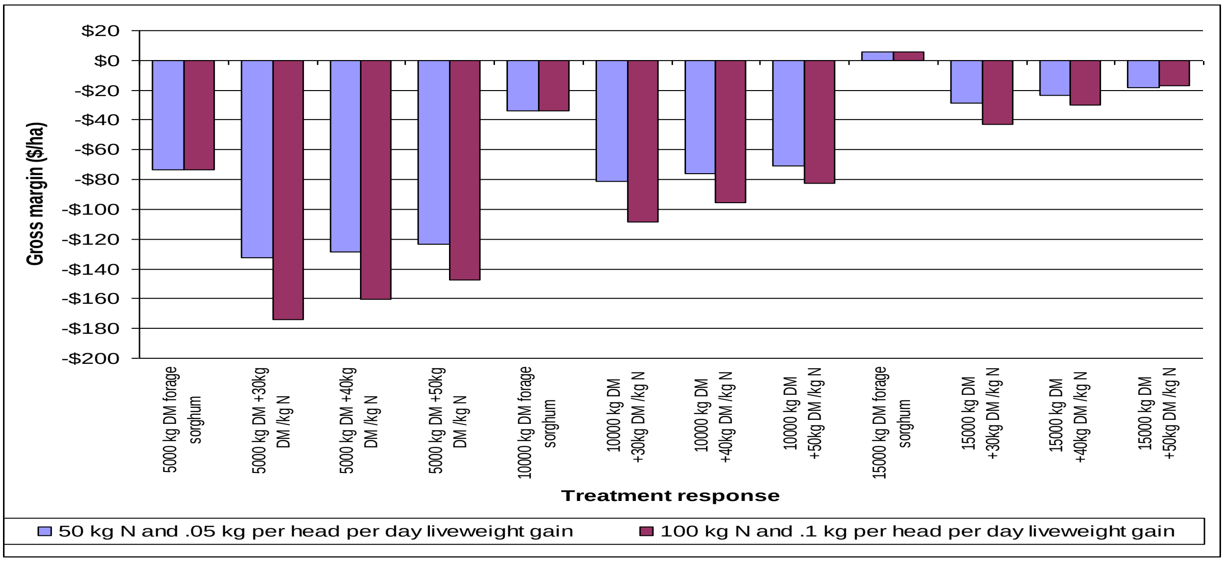

Figure 4: Gross margin for N fertiliser treatments and responses for forage sorghum

The application of fertiliser makes the financial result worse in all cases. Increasing the production of beef through the addition of fertiliser simply increases the losses made except for the forage sorghum with a starting productivity of 15,000 kg DM per ha. In this case a slight profit is converted to a loss through the addition of fertiliser.

The relatively poor economic performance of the forage sorghum gross margins, with and without fertiliser, is largely a result of the high costs of producing the forage and the small difference (on average) between the buying and selling price of the steers.

Figure 5 shows the potential gross margin response to P fertiliser for forage sorghum at differing levels of predicted response.

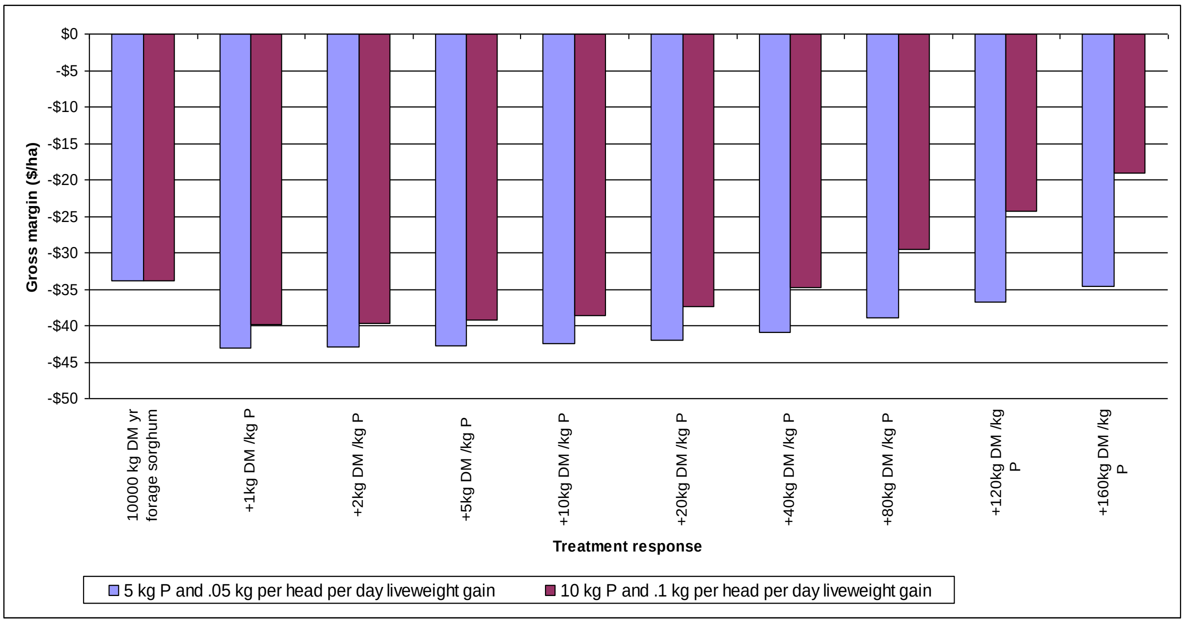

Figure 5: Gross margin for P fertiliser treatments and responses for forage sorghum

At the levels of response, prices and costs chosen, there appears to be no realistic scenario for the application of N or P fertiliser to forage sorghum that appears capable of significantly improving the returns of the producer.

- Results of strategically applying N and P fertiliser to oats

Figure 6 shows the gross margin for oats at the range of predicted responses for strategic N application.

The level of weight gain response due to improved forage quality in oats was predicted to be double that achieved for forage sorghum. Even so, the best performing oats crops were only improved when high responses in DM per kg of applied N were also achieved.

The economics of poorly performing oats crops were only made worse by the application of N fertiliser.

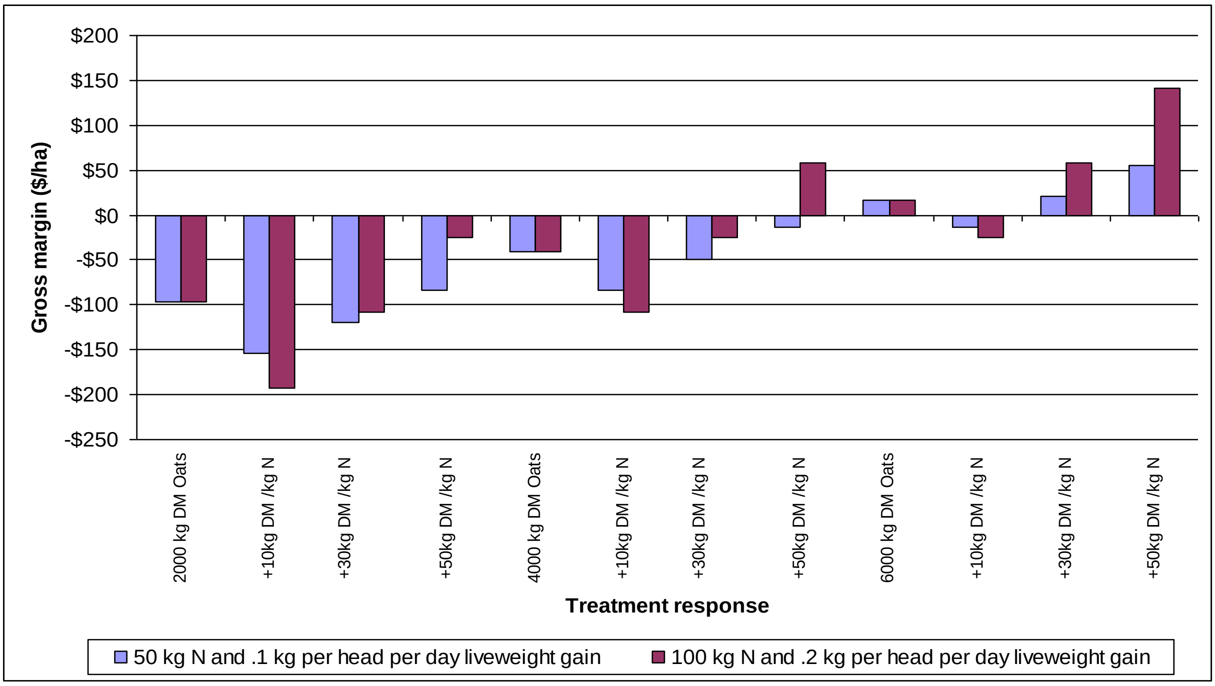

Figure 6: Gross margin for N fertiliser treatments and responses for oats

Figure 7 shows the gross margin for oats at the range of predicted responses for strategic P application.

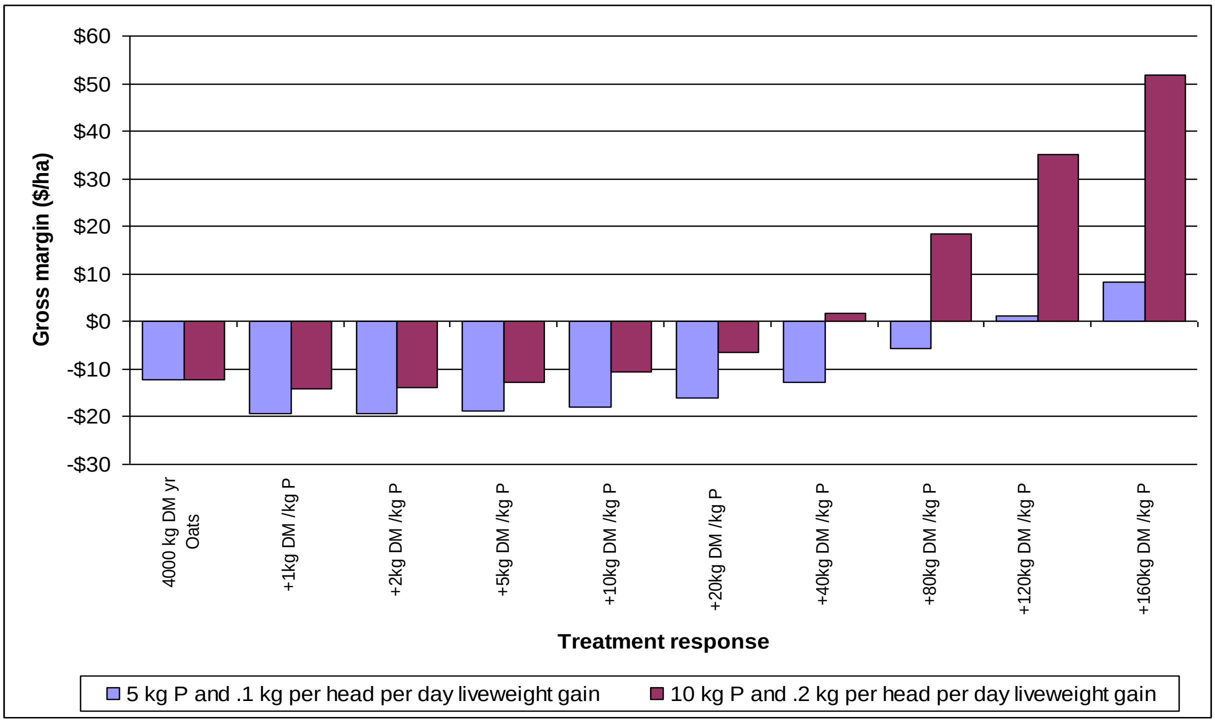

Figure 7: Gross margin for P fertiliser treatments and responses for oats

It appears that oats crops that have an inherently high level of production may show a profitable response to applications of N or P, if they can achieve both a high stocking rate response per kg of fertiliser applied, plus a high weight gain per head response.

Conclusions

1. Pastures and forages have to be in good condition, quite productive and show a significant response on average in both stocking rate per hectare and growth rate per head, before any potential economic return to strategic fertiliser applications can be estimated. Adding fertiliser to a low output system does not appear viable.

2. The high costs associated with the production of annual forages and the low average margins retained for steers makes the profitability of forages quite low with or without fertiliser. Very high rates of response in both DM production and live weigh gain are required to make strategic fertiliser application profitable on forages.

3. The increase in price risk arising from the application of fertiliser to pastures and forages is likely to prevent many producers adopting the use of N or P fertilisers, even though they see the predicted gross margin response is positive.

4. No account has been taken of the likely impact of seasonal variability on the production risk of strategic fertiliser application to pastures or forages, as estimates of response under differing seasonal scenarios were unable to be provided. It appears likely that the incorporation of seasonal climate risk would reduce expected returns below those predicted.

5. Tactical applications of N fertiliser made to take advantage of perceived market and seasonal opportunities may also be rejected by many producers, due to the inherent riskiness of the decision. There are no futures contracts available to mitigate price risk and seasonal forecasts are generally unreliable. On this basis it appears likely that the impact of risk aversion on the adoption of tactical applications of N fertiliser is likely to be similar to that shown for strategic applications.

The recent price matrix for beef cattle together with the high costs of inputs makes it very difficult to predict a profitable response to N or P fertiliser application on either pastures or annual forages.

Introduction

A scoping study is being undertaken to assess the potential for fertilisers to increase the dry matter production and nutritive value of sown pasture grasses, forage sorghum and forage oats across southern and central Queensland.

This analysis is a component of that scoping study and undertakes an economic assessment of the profitability of strategic fertiliser application to sown pasture grasses, forage sorghum and forage oats. It includes an assessment of the riskiness of applying fertilisers.

The scoping study has three other components:

- The collection and assessment of the extent of information about fertiliser use on pastures and forages for central and southern Queensland. The focus will be on scientific data, however, anecdotal evidence and expert opinion will be included where necessary.
- The review of available information and trial data to confirm (or not) the agronomic potential for using fertilisers and their impact of dry matter, feed quality and beef production.
- The incorporation of the results of this analysis with other data to identify key information gaps and support needed to enable appropriate practices to be tested and used to boost the productivity of beef enterprises.

The findings of the first two components will be reported on elsewhere but will be used as the basis of this analysis.

Background

Considerable research was conducted in the 1970-80s on the nitrogen responses of sown pasture species (see Peck *et al* 2011 for a review). Large nitrogen responses were documented but the use of fertilisers on large scale pastures was considered impractical and too costly, especially as areas of relatively fertile land were often available for development. However, the continued “rundown” of grass pastures and a reduction in the area of land suitable for clearing for pasture development has led to beef producers seeking additional ways to boost their productivity.

The MLA/DAFF Queensland project B.NBP.0639: *Improving productivity of rundown sown grass pastures* applied nitrogen fertiliser to 40 or more paddocks to demonstrate the capacity of additional nitrogen to boost pasture production. The original aim was to demonstrate the need to incorporate legumes into grass only pastures, however, the responses in many of these on-farm tests and extension demonstrations were so dramatic that some graziers are seriously reassessing strategic nitrogen fertiliser use.

B.NBP.0639 and associated projects identified two key opportunities to increase the productivity of existing grass pastures and forages with fertilisers: strategic applications of nitrogen fertiliser to increase dry matter and the nutritive value of sown grass pastures; and the potential for fertiliser to dramatically boost productivity of forage crops.

The key roles of such fertiliser use are seen as improving feed quality and quantity to increase production per unit area, ensuring forage that can finish cattle for key markets and to rejuvenate pastures by lifting background soil nitrogen levels.

Objective

The objective of this analysis is to:

- determine the profitability and the riskiness of strategically applying fertilisers to sown pasture grasses, forage sorghum and forage oats under southern and central Queensland conditions

Method

The impact of applied fertiliser on beef production is assessed using paddock level enterprise budgets and discounted cash flow techniques. This method is applied as it is the most appropriate way to filter the production responses and identify the level of response needed to improve the relative profitability of pasture and forage systems.

Very little can be inferred from the results of applying this method about whether the application of fertiliser to pasture or forages is the most economic strategy to employ at the level of the farm business. Comment on the overall economic merit of the treatments analysed here is therefore largely limited to how they compare in a relative sense to the base treatment, and further extrapolation of the results to how the various predicted responses may or may not impact the economic performance of any farm business would be misleading. Such analysis is not possible given the dose rate/response rate nature of data provided and is therefore seen as being outside the scope of this review.

The paddock level enterprise modelled in this analysis is a steer turnover/bullock production enterprise that purchases store steers and sells finished Ox to the abattoir. The boundaries of the enterprise are the physical paddock boundaries. The only expenses incurred by the paddock enterprise are those that vary with the number of cattle run in the paddock, such as husbandry and selling costs. An allowance is made for the amount of additional effort and cost required to apply the fertiliser. The enterprise budgets will be compiled in the form of paddock gross margins and will be used to identify the profitability of differing levels of fertiliser response within paddocks.

Measuring relative profit at the paddock level using a gross margin format, allows the costs and incomes associated with the remainder of the business that do not change with a change in fertiliser use to be ignored, thereby simplifying the analysis.

A discounting process is also used to consider relative value where strategies are implemented over time and therefore have impact on the timing of income and costs. Discounting adjusts expected future costs and benefits to values at a common point in time (typically the present) to account for the time preference[1] of money. With discounting, a stream of funds occurring at different time periods in the future, is reduced to a single figure by summing their present value equivalents to arrive at a Net Present Value.

The application of the discounting process allows the comparison of fertiliser strategies that have impacts on productivity at differing periods of time.

Gross margin (enterprise budget) notes in general

Some short term decisions involve the use of resources that have an effective life of more than one production period. For example, farming plant normally lasts for a number of years and can contribute to the production of many activities.

In a gross margin analysis, the costs of farming plant to an enterprise or activity are usually apportioned on an hourly and rate of use basis. This allows inclusion in the gross margin of the proportional amount of operating costs of the farming plant used by each enterprise or

[1] See glossary in the appendix for a definition of the economic terms used.

activity, improving the validity of the comparison where different forages require different amounts of machinery inputs.

Farming plant is normally costed in gross margins on the basis of the Fuel, Oil, Repairs and Maintenance (FORM) used on a per hour basis in the production of the output. Note that the ownership costs of the plant are not included.

For each tractor and implement combination used in the enterprise or activity modelled, the following rule of thumb calculations for the share of FORM costs are made:

- Fuel = fuel consumption (litres per hour) multiplied by the fuel cost (cents per litre net of rebates)
- Oil cost is assessed as 10% of fuel cost
- Repairs and Maintenance. To calculate a share of repairs and maintenance, the expected replacement cost of the machine is firstly identified. This can be the current new value of the machine or the second hand value if it is going to be replaced with a used machine. The total costs of all repairs likely to be incurred over the life of the machine are then identified and calculated as a percentage of the replacement value. The longer the machine is kept the higher the percentage – up to 70% or more for a tractor that is kept a long time (> 5000 hours) and used to undertake heavy work. To calculate the hourly cost of repairs and maintenance, the replacement cost of the machine is multiplied by the percentage of the replacement cost of the machine spent on repairs over the life of the machine and divided by the hours of life of the machine. For example, if a machine costs $10,000 and about $3,000 is expected to be spent on repairs and maintenance over its five year life, then about 30% of the cost of the machine will be spent on repairs. If the machine is used for 100 hours per annum, the hourly cost of repairs and maintenance is about $6 per hour of use.

These rules of thumb are sufficiently accurate to allow the inclusion of the proportional costs of FORM associated with machinery use in a gross margin analysis.

Gross margins are calculated in this analysis with an allowance for the labour costs associated with machinery operation included. This allows identification of the value of the additional labour required to spread fertiliser on the paddock – whether it is paid or unpaid.

The paddock

The hypothetical paddock chosen to explore the impact of fertiliser application is located about 180 kilometres from the Gracemere stock selling centre and about 580 kilometres from the Dinmore abattoirs. This would theoretically place the paddock somewhere in southern central Queensland in the Brigalow belt. The two selling centres were chosen due to the availability of price data and for no other reason.

The paddock has a total area of 100 hectares and, for the fertiliser application on buffel scenario, is assessed as having a stocking rate of either 4.87 hectares per AE or 2.7 hectares per AE depending on whether the 3000 kg or 4500 kg dry matter per hectare starting point is being considered.

- Paddock operations

The current activity is a steer fattening activity that relies on the purchase of store steers from Gracemere sale yards at weights that allow the steers to be finished after twelve months of grazing on the buffel pasture or 90 and 100 days grazing for forage oats and sorghum respectively.

For the purposes of this analysis, the paddock is treated as a separate enterprise that purchases replacement steers and sells finished Ox. The transfer of livestock into and out of the paddock generally occurs at about mid-year for the buffel enterprise. Steer prices in the enterprise budgets are set at the average market values of the last four years at the respective purchase or selling centre for the relevant class of livestock. The only other expenses incurred by the paddock enterprise are those that vary with the number of cattle run in the paddock, such as steer purchase, husbandry and selling costs, plus the cost of purchasing and spreading the fertiliser.

In the scenarios where forages are produced by the paddock, no other activities are undertaken except the activities associated with fallow weed control, planting and grazing the forages. The farming system applied is a minimum tillage system that incorporates both tillage implements and chemical weed control similar to that currently practiced by beef producers in the region who grow forage crops.

Steers prices

Price quotes provided by Elders Pty Ltd for Gracemere store sales and by Australian Meat Holdings for Dinmore abattoir have been compared for correlation and trend. Figure 8 shows the relationship over recent years between the prices of medium sized store steers at Gracemere and grass fed Jap Ox at Dinmore.

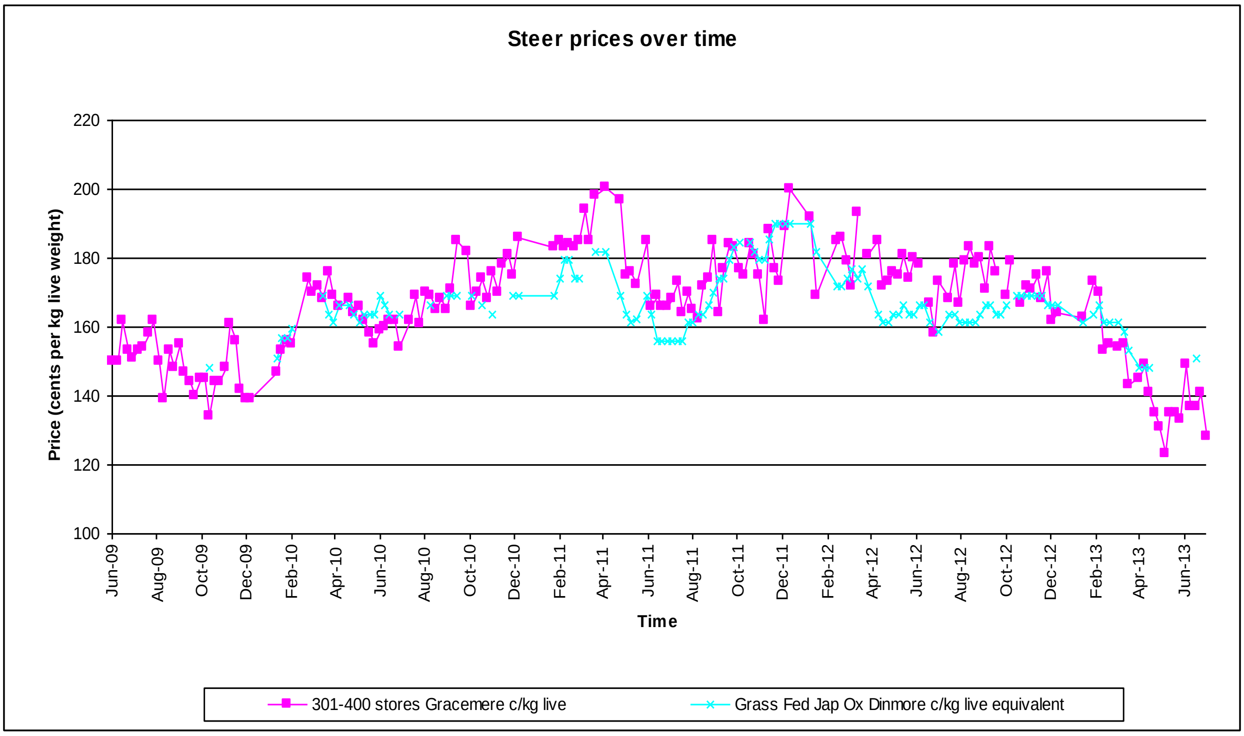

Figure 8: Steer selling prices over time

The price risk expected for the buffel enterprise was estimated by comparing purchase and selling prices twelve months apart for each class of animal. The correlation between steer purchase and selling prices over this period was identified as being 0.12 – or hardly any correlation at all. There also appears to be no set basis (or margin) over time between the purchase price of the store steers and the sale price of the finished Jap Ox.

The price basis can be up to 40 cents per kilogram positive or negative when measured on an equivalent live weight basis with a twelve month lag between the purchase date and sale price.

There is little or no correlation between the purchase and sale price of the classes of steers used in the buffel analysis and no easily recognisable or predictable pattern over time to establish a basis between the price of medium stores and Jap Ox.

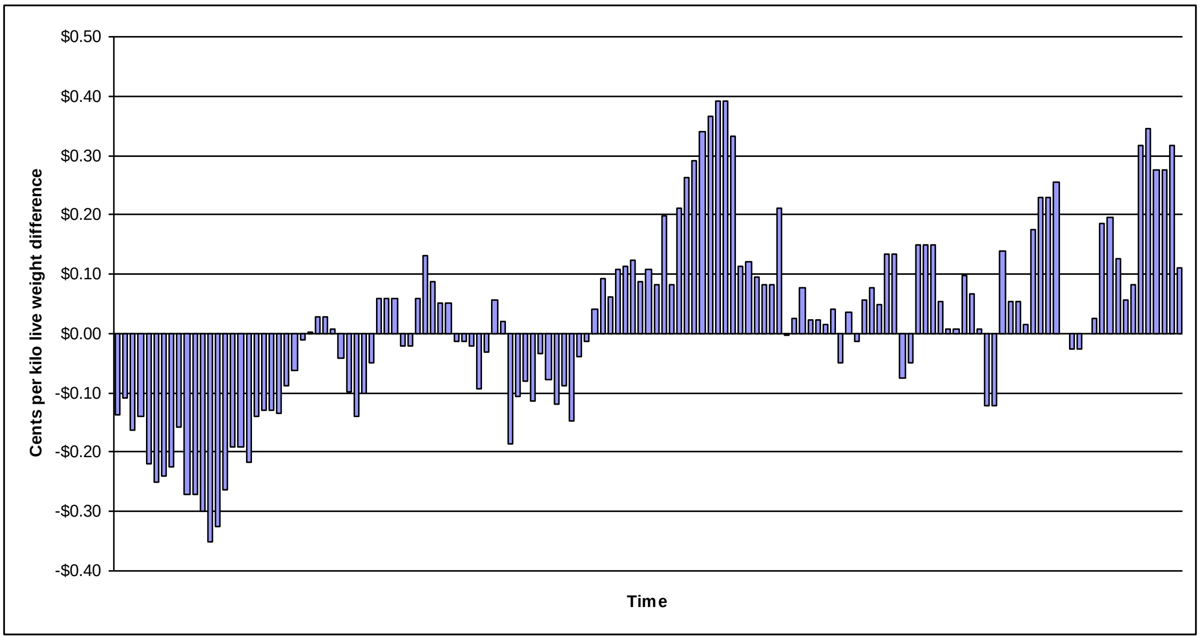

Figure 9: Difference between medium stores at Gracemere and Dinmore Ox prices with a twelve month lag starting in 2009

The price risk expected for the forage enterprises was estimated by comparing purchase and selling prices three months apart for each class of animal used in the forage enterprises. In this case the sale steers retained the same weight class, while the prices for the purchase steers came from the 401-500 kilogram liveweight sale class. The correlation between steer purchase and selling prices over the shorter ownership period was identified as being -0.15 – or hardly any correlation at all.

There also appears to be no set basis (or margin) over time between the purchase price of the store steers and the sale price of the finished Jap Ox. The price basis can be up to 40 cents per kilogram positive or negative when measured on an equivalent live weight basis and a three month lag between the purchase date and sale price is maintained.

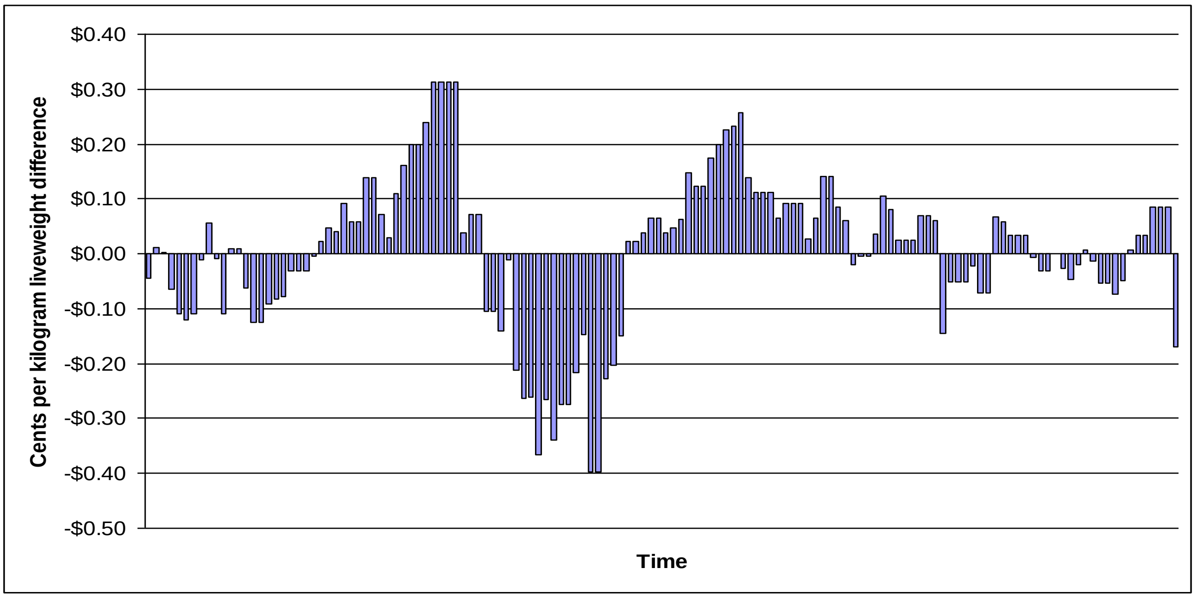

Figure 10: Difference between heavy stores at Gracemere and Dinmore Ox prices with a three month lag starting in 2009

The average (and median) price for Ox since 2009 at Dinmore over recent years is about $3.20 per kg dressed or $1.66 when expressed on an equivalent liveweight basis at a 52% dressing percentage. The maximum and minimum prices paid over the same period are $3.55 and $2.75 ($1.85 and $1.43 live). On this basis variation about the median over the period is about 15%.

The average price for medium stores at Gracemere over the same period is about $1.64 per kilogram live with a maximum and minimum of $2.00 and $1.23. The variation in store steer prices around the median is about 25% over the same period.

The expected impact of fertiliser on buffel pasture

Estimating animal production and carrying capacities

The impact of strategic nitrogen fertiliser application on carrying capacity and production was modelled for a typical buffel pasture in southern central Queensland. The pasture was formerly Brigalow country now dominated by buffel grass. Two separate scenarios were chosen to represent discrete levels of productivity prior to the application of fertiliser, namely an annual pasture production of 3000 kilograms (kg) of dry matter (DM) per hectare (ha) per annum or an annual production of 4500 kg of DM /ha /annum.

These two levels of starting pasture production are taken to represent the likely average production of either a slightly rundown paddock with reasonable underlying soil water holding capacity, or a paddock that is in reasonable condition also with a reasonable underlying soil water holding capacity. Paddocks in such condition are considered the most likely by the staff undertaking the scoping study to show an economic response to the strategic application nitrogen (N) fertiliser.

To calculate the potential carrying capacity for the unfertilised Brigalow land type the following assumptions we made:

- the average utilisation rate was either 25% (3000 kg DM /ha production) or 30% (4500 kg DM /ha production) for the base pasture in an unfertilised state
- Stocking rates were calculated as hectares per Adult Equivalent (AE)[2].
- Average dry matter intake per AE was estimated to be 2.2% of body weight (450 kg live) over the year. On this basis each AE ate approximately ten kilograms per day or 3,650 kg of dry matter per year and the stocking rate (in AE's) was derived by dividing 3650 by the amount of pasture available to be consumed per hectare.
- a level of spoilage, residual pasture and expected weight gain per AE per annum was nominated for each base case scenario. For example, spoilage rates used were 15% <4500; 20% 4500-7500; 25% >7500 kg/ha.
- The "paddock size" was nominated as 100 hectares and watering points and infrastructure were such that the whole paddock could be grazed evenly

Table 3 shows the parameters used to calculate the average annual beef production of the base case buffel grass scenarios.

[2] See the glossary of terms in the appendix for the definition of Adult Equivalent

Table 3: Parameters for buffel pasture production without fertiliser

Annual pasture production [a] (kg DM/ha/yr)		3000	4500
Utilisation rate [b] (%)		25	30
Forage consumed (kg dry matter /annum)		750	1350
Spoilage %		15%	20%
Spoilage amount (kg /ha)		450	900
Residual amount (kg /ha)		1800	2250
	stocking rate (ha/AE)	4.87	2.7
	stocking rate (AE/ha)	0.21	0.37
Weight gain (kg per AE per annum)		150	150
kg of beef per ha per annum without fertiliser		30.82	55.48

a: Adapted from GRASP modelling and back calculation from other sources
b: Adapted from Whish (2011).

Budget parameters

The input parameters for the base enterprise budgets for the 3000 kg /ha DM and 4500 kg /ha DM scenario are identified in Tables 4 and 5. The number of steers purchased was derived from the stocking rate in hectares per AE, the weight gain per AE predicted and the chosen starting weight of the steers. The budget purchases “fractions” of steers to match the stocking rate calculated in the economic analysis and the production estimates.

Table 4: Input parameters and stocking rates for 3000 kg DM per ha base

Livestock purchase parameters	
Average age of purchased steers (months)	30
Number of steers purchased	18.30
Purchase price steers ($/kg live)	$1.64
Purchase weight steers (kg live)	450
Cost of purchased steers	$13,505
Gross cost of purchased steers (per head)	$738
Stocking rate (head per hectare)	0.18
Stocking rate (hectare per head)	5.46
Stocking rate (AE per hectare)	0.21
Stocking rate (hectare per AE)	4.87
Weight gain per day	0.41
Total days held	365

Table 5: Input parameters and stocking rates for 4500 kg DM per ha base

Livestock purchase parameters	
Average age of purchased steers (months)	30
Number of steers purchased	32.99
Purchase price steers ($/kg live)	$1.64
Purchase weight steers (kg live)	450
Cost of purchased steers	$24,348
Gross cost of purchased steers (per head)	$738
Stocking rate (head per hectare)	0.33
Stocking rate (hectare per head)	3.03
Stocking rate (AE per hectare)	0.37
Stocking rate (hectare per AE)	2.70
Weight gain per day	0.41
Total days held	365

Please note that the calculation of AE weighting in the enterprise budget is based on the formula [POWER (((opening weight + closing weight)/2), 0.75)/97.7]. This formula gives a slightly different answer to that gained through applying the more simple process of dividing by 3650 as used in the initial calculation of stocking rate.

Paddock enterprise budget

The enterprise budget for each initial carrying capacity of the paddock is shown in Table 6 and Table 7. These budgets represent the expected performance of the paddock, on average, over time. No account is taken of any potential decline in pasture productivity that may or may not occur over the planning period.

The costs of transporting the steers to and from the property, minor health costs and selling costs are the other main variable costs included in the enterprise budgets. The opportunity cost of the capital tied up when steers are purchased is deducted from the gross margin to calculate the value of the gross margin after interest. (Only the opportunity cost of steer capital has been allowed for as no other capital costs differ significantly between the various treatments.) The opportunity cost of livestock capital was uniformly charged at an interest rate 5% per annum but only applied for the period that the livestock were held by the enterprise.

Table 6: Paddock enterprise budget for an annual turnover steer enterprise based on 3000 kg DM production

Gross margin calculation	Total	per ha per annum
Livestock Sales	$18,385	$184
Livestock Purchases	$13,505	$135
Freight In	$241	$2
Freight Out	$1,003	$10
Treatment Expenses	$7	$0
Selling Expenses	$92	$1
Total Expenses	$14,848	$148
Gross Margin	$3,537	$35
Gross Margin per annum (after Interest)	$2,862	$29
Kilograms of liveweight gain per hectare per annum	27.45	

Table 7: Paddock enterprise budget for an annual turnover steer enterprise based on 4500 kg dry matter production

Gross margin calculation	Total	per ha per annum
Livestock Sales	$33,145	$331
Livestock Purchases	$24,348	$243
Freight In	$434	$4
Freight Out	$1,808	$18
Treatment Expenses	$13	$0
Selling Expenses	$165	$2
Forage growing costs	$0	$0
Total Expenses	$26,768	$268
Gross Margin	$6,377	$64
Gross Margin per annum (after Interest)	$5,160	$52
Kilograms of liveweight gain per hectare per annum	49.5	

The expected average gross margin after interest for the 3000 kg DM/ha scenario is about half that for the 4500 kg DM/ha scenario. This is due to the difference in the starting productivity for the two pastures.

Estimating the benefit of strategic fertiliser application on buffel grass

The scarcity of recent data identifying the impact of regularly applying fertiliser to a pasture of buffel grass on beef production, required all available sources of knowledge to be condensed into a range of "best bet" responses for the application of 50 kg nitrogen (N) per ha per annum, or 100 kg of N per ha per annum in the form of urea.

These responses were modelled:

- firstly on the basis that there was no carryover of benefit from the year of application to the next, and
- secondly on the basis that there was a carryover of benefit that reduced over time

N is applied as urea fertiliser where the urea has 46% N. A cost of $700 per ton landed on property was used.

- Scenario where there is no carryover of benefit

For the scenario where there was no expected carryover of benefit, the potential average increase in pasture and livestock production was identified at response levels of 20, 30, 40 or 50 kg extra dry matter per hectare per kg of applied N. This range was chosen to identify the likely average level of response required to either breakeven or improve profitability.

The new amount of pasture available for consumption was identified by deducting an allowance for spoilage and the desired residual from the total dry matter produced as a result of the fertiliser application. The average amount of dry matter available for consumption was then converted to a stocking rate in AE's per hectare by dividing 3650 by the available kilograms of forage per hectare.

This method of calculating the response in liveweight production assumes that the additional forage net of residual dry matter and spoilage will all be consumed. This assumption leads to a relative increase in the overall utilisation rate when compared to the base scenario and expressed as a percentage of the total forage available.

It was also proposed that adding N fertiliser to buffel pasture will improve the quality of the pasture, and provide additional benefits above and beyond those captured in the stocking rate increase generated by the additional dry matter production.

The potential increase in forage quality, due to the application of fertiliser, is included in this analysis by increasing the annual weight gain per adult equivalent by a set average amount of 50, 100 or 200 grams per AE per day, depending upon the fertiliser scenario and the productivity of the base pasture.

Tables 8 and 9 indicate the average stocking rate and animal production calculated for each response rate when 50 kg of N was applied to each base pasture scenario. The impact of quality improvement on steer performance was tested at average growth rate responses of 0.05 kg per day extra (Table 8) or 0.1 kg per day extra (Table 9).

Table 8: 50 kg N per ha –Average beef production increase due to a liveweight gain of an extra 0.05 kilograms per AE per day and a range of 20 to 50 kg dry matter per kg of N applied

Base pasture		**3000**	**kg dm**			**4500**	**kg dm**	
Pasture response kg DM /kg N	**20**	**30**	**40**	**50**	**20**	**30**	**40**	**50**
Extra pasture	1000	1500	2000	2500	1000	1500	2000	2500
Increase %	33%	50%	67%	83%	22%	33%	44%	56%
New annual production	4000	4500	5000	5500	5500	6000	6500	7000
Spoilage %	20%	20%	20%	20%	20%	20%	20%	20%
Spoilage	800	900	1000	1100	1100	1200	1300	1400
Residual	1800	1800	1800	1800	2250	2250	2250	2250
Available for consumption	1400	1800	2200	2600	2150	2550	2950	3350
increase	87%	140%	193%	247%	59%	89%	119%	148%
stocking rate (ha/ae)	2.61	2.03	1.66	1.40	1.70	1.43	1.24	1.09
stocking rate (ae/ha)	0.38	0.49	0.60	0.71	0.59	0.70	0.81	0.92
New weight gain	170	170	170	170	170	170	170	170
kg beef /ha /annum with fertiliser	65.21	83.84	102.47	121.10	100.14	118.77	137.40	156.03
increase	112%	172%	232%	293%	80%	114%	148%	181%

Table 9: 50 kg N per ha –Average beef production increase due to a liveweight gain of an extra 0.1 kilograms per AE per day and a range of 20 to 50 kg dry matter per kg of N applied

Base pasture		**3000**	**kg dm**			**4500**	**kg dm**	
Pasture response kg DM /kg N	**20**	**30**	**40**	**50**	**20**	**30**	**40**	**50**
Extra pasture	1000	1500	2000	2500	1000	1500	2000	2500
increase	33%	50%	67%	83%	22%	33%	44%	56%
New annual production	4000	4500	5000	5500	5500	6000	6500	7000
Spoilage %	20%	20%	20%	20%	20%	20%	20%	20%
spoilage	800	900	1000	1100	1100	1200	1300	1400
residual	1800	1800	1800	1800	2250	2250	2250	2250
Available for consumption	1400	1800	2200	2600	2150	2550	2950	3350
increase	87%	140%	193%	247%	59%	89%	119%	148%
stocking rate (ha/ae)	2.61	2.03	1.66	1.40	1.70	1.43	1.24	1.09
stocking rate (ae/ha)	0.38	0.49	0.60	0.71	0.59	0.70	0.81	0.92
New weight gain	190	190	190	190	190	190	190	190
kg beef /ha /annum with fertiliser	72.88	93.70	114.52	135.34	111.92	132.74	153.56	174.38
increase	136%	204%	272%	339%	102%	139%	177%	214%

The calculated average increase in beef production per hectare ranged from 80% up to 339% depending upon the base level of production before fertiliser application, the improvement in weight gain due to pasture quality and the rate of response in dry matter production for each kilogram of N allied to the pasture.

Tables 10 and 11 indicate the average stocking rate and animal production calculated for each response rate when 100 kg of N was applied to each base pasture scenario. The impact of quality improvement on steer performance was tested at average growth rate responses of 0.1 kg per day extra (Table 10) or 0.2 kg per day extra (Table 11).

Table 10: 100 kg N per ha –Average beef production increase due to a liveweight gain of an extra 0.1 kilograms per AE per day and a range of 20 to 50 kg dry matter per kg of N applied

Base pasture		**3000**	**kg dm**			**4500**	**kg dm**	
Pasture response kg DM /kg N	**20**	**30**	**40**	**50**	**20**	**30**	**40**	**50**
Extra pasture	2000	3000	4000	5000	2000	3000	4000	5000
increase	67%	100%	133%	167%	44%	67%	89%	111%
New annual production	5000	6000	7000	8000	6500	7500	8500	9500
Spoilage %	20%	20%	20%	25%	20%	20%	25%	25%
spoilage	1000	1200	1400	2000	1300	1500	2125	2375
residual	1800	1800	1800	1800	2250	2250	2250	2250
Available for consumption	2200	3000	3800	4200	2950	3750	4125	4875
increase	193%	300%	407%	460%	119%	178%	206%	261%
stocking rate (ha/ae)	1.66	1.22	0.96	0.87	1.24	0.97	0.88	0.75
stocking rate (ae/ha)	0.60	0.82	1.04	1.15	0.81	1.03	1.13	1.34
New weight gain	185	185	185	185	185	185	185	185
Extra kg/ha/annum with fertiliser	111.51	152.05	192.60	212.88	149.52	190.07	209.08	247.09
increase	262%	393%	525%	591%	170%	243%	277%	345%

Table 11: 100 kg N per ha – Average beef production increase due to a liveweight gain of an extra 0.2 kilograms per AE per day and a range of 20 to 50 kg dry matter per kg of N applied

Base pasture		**3000**	**kg dm**			**4500**	**kg dm**	
Pasture response kg DM /kg N	**20**	**30**	**40**	**50**	**20**	**30**	**40**	**50**
Extra pasture	2000	3000	4000	5000	2000	3000	4000	5000
increase	67%	100%	133%	167%	44%	67%	89%	111%
New annual production	5000	6000	7000	8000	6500	7500	8500	9500
Spoilage %	20%	20%	20%	25%	20%	20%	25%	25%
spoilage	1000	1200	1400	2000	1300	1500	2125	2375
residual	1800	1800	1800	1800	2250	2250	2250	2250
Available for consumption	2200	3000	3800	4200	2950	3750	4125	4875
increase	193%	300%	407%	460%	119%	178%	206%	261%
stocking rate (ha/ae)	1.66	1.22	0.96	0.87	1.24	0.97	0.88	0.75
stocking rate (ae/ha)	0.60	0.82	1.04	1.15	0.81	1.03	1.13	1.34
New weight gain	220	220	220	220	220	220	220	220
Extra kg/ha/annum with fertiliser	132.60	180.82	229.04	253.15	177.81	226.03	248.63	293.84
increase	330%	487%	643%	721%	220%	307%	348%	430%

- Results of strategically applying N fertiliser to buffel pasture where there is no carryover

The results of the analysis where there is no carryover of benefit are presented in the following eight tables.

The format is as follows:

- column 2 presents the average gross margin for the paddock without added N
- columns 3 to 6 present the average gross margins for response rates increasing from 20 kg of extra dry matter per hectare per kg of N applied up to 50 kg N of extra dry matter per hectare per kg of N applied.

Tables of results are presented for each base pasture (3000 and 4500 kg DM), for each improvement in weight gain per head due to quality (0.05 and 0.1 at 50 kg N and 0.1 and 0.2 at 100 kg N) and for each level of fertiliser input (50 kg N /ha and 100 kg N /ha).

- Applying 50 kg N

It can be seen in Table 12, for example, that strategically fertilising a paddock that usually produces 3000 kg DM per ha with 50 kg N per ha and achieving a 293% increase in beef production with a response rate of 50 kg DM per kg of applied N only improves the expected gross margin by $1 per ha on average. For this pasture, all other levels of response appear likely, on average, to make the producer worse off.

If the producer regularly applies the 50 kg N and only achieves an average response rate of 20 kg DM per kg of DM and a lift in weight gain of 50 grams per day due to improved pasture quality, the expected gross margin becomes -$24 per hectare.

Table 12: Average gross margin response; 50 kg N applied to 3000 kg DM buffel, quality impact of 50 grams per head per day

Gross margin for	3000 kg DM yr pasture	+20kg DM /kg N +.05 kg day	+30kg DM /kg N +.05 kg day	+40kg DM /kg N +.05 kg day	+50kg DM /kg N +.05 kg day
	/ha/annum	/ha/ annum	/ha/ annum	/ha/annum	/ha/ annum
Livestock Sales	$184	$349	$449	$549	$651
Variable costs					
Livestock Purchases	$135	$248	$319	$390	$463
Freight In	$2	$4	$6	$7	$8
Freight Out	$10	$19	$25	$31	$36
Treatment Expenses	$0	$0	$0	$0	$0
Selling Expenses	$1	$2	$2	$3	$3
Forage growing costs	$0	$87	$87	$87	$87
Total Expenses	$148	$361	$439	$518	$597
Gross Margin	$35	-$11	$10	$32	$54
Gross Margin (after interest)	**$29**	**-$24**	**-$6**	**$12**	**$30**
kg of liveweight gain /ha/annum	27	57	74	90	107

Table 13 shows the expected response to 50 kg N per ha applied to a pasture with a base rate of production of 4500 kg DM per annum. The response has to average more than 40 kg DM per kg of applied N and achieve an improvement of at least 0.05 kg per day in weight gain due to improved quality to breakeven.

Table 13: Average gross margin response; 50 kg N applied to 4500 kg DM buffel, quality impact of 50 grams per head per day

Gross margin for	4500 kg DM yr pasture	+20kg DM /kg N +.05 kg day	+30kg DM /kg N +.05 kg day	+40kg DM /kg N +.05 kg day	+50kg DM /kg N +.05 kg day
	/ha/annum	/ha/annum	/ha/annum	/ha/annum	/ha/annum
Livestock Sales	$331	$536	$638	$735	$835
Variable costs					
Livestock Purchases	$243	$381	$453	$523	$594
Freight In	$4	$7	$8	$9	$11
Freight Out	$18	$30	$35	$41	$46
Treatment Expenses	$0	$0	$0	$0	$0
Selling Expenses	$2	$3	$3	$4	$4
Forage growing costs	$0	$87	$87	$87	$87
Total Expenses	$268	$507	$587	$663	$742
Gross Margin	$64	$29	$51	$72	$93
Gross Margin (after interest)	**$52**	**$10**	**$28**	**$46**	**$64**
kg of liveweight gain /ha/annum	49	88	104	120	137

Tables 14 and 15 show the expected gross margin if the benefit of improved pasture quality averages 100 grams per AE per day extra weight gain instead of 50 grams per AE per day. Once again, response levels have to be at or above 40 kg DM per kg of applied N to breakeven.

Table 14: Average gross margin response; 50 kg N applied to 3000 kg DM buffel, quality impact of 100 grams per head per day

Gross margin for	3000 kg DM yr pasture	+20kg DM /kg N +.1 kg day	+30kg DM /kg N +.1 kg day	+40kg DM /kg N +.1 kg day	+50kg DM /kg N +.1 kg day
	/ha/annum	/ha/annum	/ha/annum	/ha/annum	/ha/annum
Livestock Sales	$184	$357	$457	$559	$663
Variable costs					
Livestock Purchases	$135	$246	$315	$385	$457
Freight In	$2	$5	$6	$7	$8
Freight Out	$10	$20	$26	$32	$38
Treatment Expenses	$0	$0	$0	$0	$0
Selling Expenses	$1	$2	$2	$3	$3
Forage growing costs	$0	$87	$87	$87	$87
Total Expenses	$148	$359	$436	$513	$592
Gross Margin	$35	-$2	$22	$46	$71
Gross Margin (after interest)	**$29**	**-$15**	**$6**	**$27**	**$48**
Kilograms of liveweight gain /ha /annum	27	63	81	99	118

Table 15: Average gross margin response; 50 kg N applied to 4500 kg DM buffel, quality impact of 100 grams per head per day

Gross margin for	4500 kg DM yr pasture	+20kg DM /kg N +.1 kg day	+30kg DM /kg N +.1 kg day	+40kg DM /kg N +.1 kg day	+50kg DM /kg N +.1 kg day
	/ha/annum	/ha/annum	/ha/annum	/ha/annum	/ha/annum
Livestock Sales	$331	$546	$649	$749	$1,007
Variable costs					
Livestock Purchases	$243	$376	$447	$515	$694
Freight In	$4	$7	$8	$9	$12
Freight Out	$18	$31	$37	$43	$57
Treatment Expenses	$0	$0	$0	$0	$0
Selling Expenses	$2	$3	$3	$3	$5
Forage growing costs	$0	$87	$87	$87	$87
Total Expenses	$268	$503	$582	$658	$855
Gross Margin	$64	$43	$67	$91	$152
Gross Margin (after interest)	**$52**	**$24**	**$45**	**$65**	**$117**
Kilograms of liveweight gain /ha /annum	49	97	115	133	179

The most profitable response in Table 15 is when the average response of 50 kg DM per kg of N and 100 grams per day additional liveweight gain is achieved. The average gross margin after interest is more than doubled when compared to the base scenario but it must be remembered that the 100 hectare paddock is now stocked with three times as many steers (94 instead of 33) on average. This indicates the riskiness of the paddock enterprise will be increased.

- Applying 100 kg N

Tables 16 to 19 record the expected average gross margins for the application of 100 kg N per hectare. The premium on growth rate for pasture quality now increases to either 100 grams per AE per day (Tables 16 and 17) or 200 grams per AE per day on average (Tables 18 and 19).

Regularly applying 100 kg N to buffel pasture does not appear to breakeven unless an extra 200 grams per AE per day weight gain can be achieved. Even then, the average response in dry matter production has to be at least 30 kg DM per kg of N applied.

Table 16: Average gross margin response; 100 kg N applied to 3000 kg DM buffel, quality impact of 100 grams per head per day

Gross margin for	3000 kg DM yr pasture	+20kg DM /kg N +.1 kg day	+30kg DM /kg N +.1 kg day	+40kg DM /kg N +.1 kg day	+50kg DM /kg N +.1 kg day
	/ha/annum	/ha/annum	/ha/annum	/ha/annum	/ha/annum
Livestock Sales	$184	$549	$747	$949	$1,047
Variable costs					
Livestock Purchases	$135	$384	$523	$664	$733
Freight In	$2	$8	$10	$13	$15
Freight Out	$10	$29	$40	$50	$56
Treatment Expenses	$0	$0	$0	$0	$0
Selling Expenses	$1	$3	$4	$5	$6
Forage growing costs	$0	$163	$163	$163	$163
Total Expenses	$148	$587	$740	$896	$972
Gross Margin	$35	-$38	$7	$53	$75
Gross Margin (after interest)	**$29**	**-$57**	**-$19**	**$20**	**$38**
Kilograms of liveweight gain /ha /annum	27	108	147	187	207

Table 17: Average gross margin response; 100 kg N applied to 4500 kg DM buffel, quality impact of 100 grams per head per day

Gross margin for	4500 kg DM yr pasture	+20kg DM /kg N +.1 kg day	+30kg DM /kg N +.1 kg day	+40kg DM /kg N +.1 kg day	+50kg DM /kg N +.1 kg day
	/ha/annum	/ha/annum	/ha/annum	/ha/annum	/ha/annum
Livestock Sales	$331	$735	$939	$1,035	$1,215
Variable costs					
Livestock Purchases	$243	$514	$657	$725	$850
Freight In	$4	$10	$13	$15	$17
Freight Out	$18	$39	$50	$55	$65
Treatment Expenses	$0	$0	$0	$0	$0
Selling Expenses	$2	$4	$5	$6	$6
Forage growing costs	$0	$163	$163	$163	$163
Total Expenses	$268	$731	$889	$963	$1,102
Gross Margin	$64	$4	$51	$72	$113
Gross Margin (after interest)	**$52**	**-$22**	**$18**	**$36**	**$71**
Kilograms of liveweight gain /ha /annum	49	145	185	204	240

Table 18: Average gross margin response; 100 kg N applied to 3000 kg DM buffel, quality impact of 200 grams per head per day

Gross margin for	3000 kg DM yr pasture	+20kg DM /kg N +.2 kg day	+30kg DM /kg N +.2 kg day	+40kg DM /kg N +.2 kg day	+50kg DM /kg N +.2 kg day
	/ha/annum	/ha/annum	/ha/annum	/ha/annum	/ha/annum
Livestock Sales	$184	$565	$769	$977	$1,078
Variable costs					
Livestock Purchases	$135	$358	$488	$620	$684
Freight In	$2	$7	$11	$14	$15
Freight Out	$10	$30	$41	$52	$57
Treatment Expenses	$0	$0	$0	$0	$0
Selling Expenses	$1	$3	$4	$5	$6
Forage growing costs	$0	$163	$163	$163	$163
Total Expenses	$148	$561	$707	$854	$925
Gross Margin	$35	$3	$62	$123	$152
Gross Margin (after interest)	**$29**	**-$14**	**$38**	**$92**	**$118**
Kilograms of liveweight gain /ha /annum	27	133	180	229	253

Table 19: Average gross margin response; 100 kg N applied to 4500 kg DM buffel, quality impact of 200 grams per head per day

Gross margin for	4500 kg DM yr pasture	+20kg DM /kg N +.2 kg day	+30kg DM /kg N +.2 kg day	+40kg DM /kg N +.2 kg day	+50kg DM /kg N +.2 kg day
	/ha/annum	/ha/annum	/ha/annum	/ha/annum	/ha/annum
Livestock Sales	$331	$756	$967	$1,065	$1,250
Variable costs					
Livestock Purchases	$243	$480	$613	$676	$793
Freight In	$4	$11	$14	$15	$18
Freight Out	$18	$40	$51	$57	$66
Treatment Expenses	$0	$0	$0	$0	$1
Selling Expenses	$2	$4	$5	$6	$7
Forage growing costs	$0	$163	$163	$163	$163
Total Expenses	$268	$698	$847	$917	$1,047
Gross Margin	$64	$58	$120	$149	$203
Gross Margin (after interest)	**$52**	**$34**	**$89**	**$115**	**$163**
Kilograms of liveweight gain /ha /annum	49	177	227	250	293

The buffel paddock that responds at a rate of 50 kg DM per kg N and achieves an improvement in growth of 200 grams per head per day is a very high performing paddock. This 100 ha paddock will run an average of 133 steers that gain 220 kg per head per annum.

- The riskiness of strategic application of N fertiliser to buffel pasture when there is no carryover of benefit

Any decision to increase production intensity in the beef industry will increase the riskiness of the venture.

To test how the riskiness of a grass finishing enterprise could be impacted by strategic applications of N fertiliser, the prices previously identified were applied to a stochastic model to estimate the impact of price variability of average returns. Please note that no risk associated with seasonal variation has been included in this component of the analysis.

Figure 11 shows the potential range in gross margins for:

- an unfertilised buffel pasture producing 4500 kg dry matter;
- the same pasture fertilised with 50 kg N and achieving an improvement in growth rate due to pasture quality of 50 grams per AE per day extra plus a pasture response rate of 40 kg DM per kg of N.
- the same pasture fertilised with 50 kg N and achieving an improvement in growth rate due to pasture quality of 100 grams per AE per day extra plus a pasture response rate of 40 kg DM per kg of N.

These treatments showed a reasonable response in gross margin per hectare. The average gross margins for these scenarios are shown in columns 1 and 4 of Table 13 and column 4 of table 15.

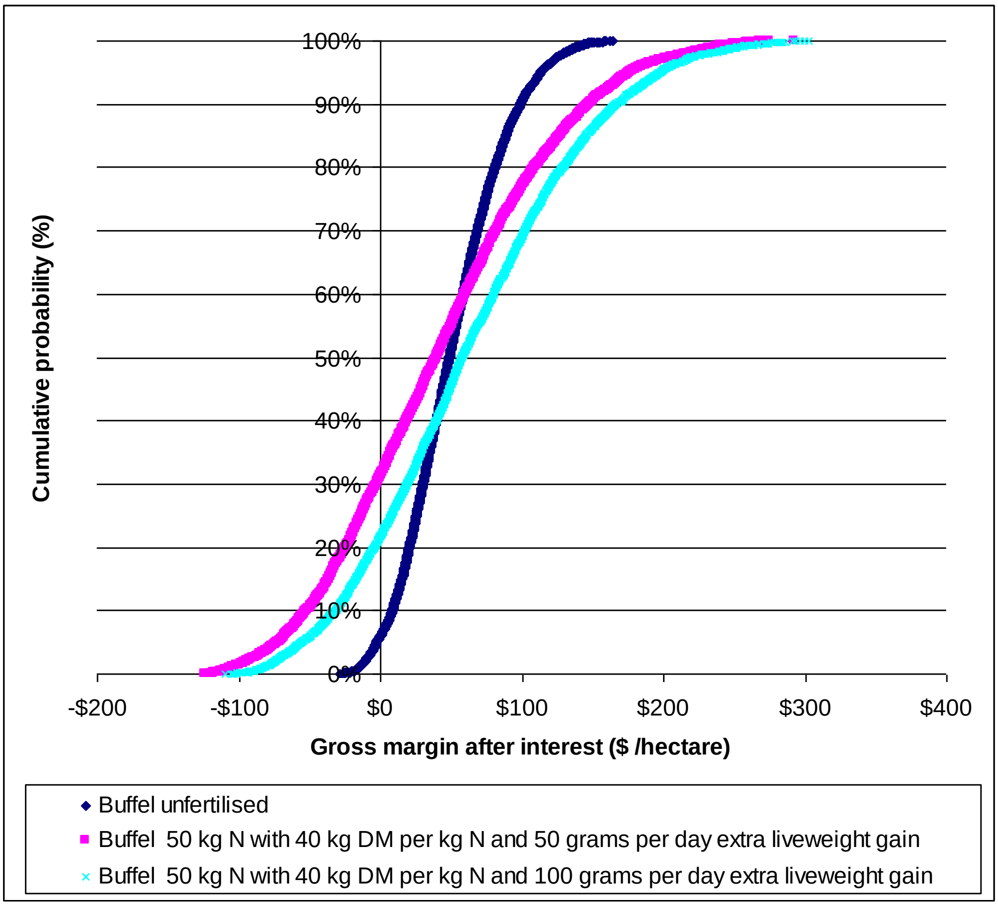

Figure 11: Distribution of gross margins for unfertilised buffel and buffel fertilised at 50 kg N per ha and achieving 50 or 100 grams per AE per day extra gain due to quality and 40 kg DM /kg of applied N. Base pasture is 4500 kg DM

The results of the stochastic model show that strategically fertilised pasture is likely to provide higher returns in about 40% or 60% of years depending upon the assumption concerning additional weight gained through pasture quality. The producer could also be worse off in about 30% or 40% of years.

This variability is due to the riskiness inherent in the prices paid and received for steers as the potential variation in pasture response and extra weight gain were minimised in the model.

The impact of this chance of making a larger loss in any year can be tested by calculating the risk premium required by producers with differing levels of risk aversion. The method used to calculate the risk premium is the SERF or Stochastic Efficiency with Respect to a Function method (see Hardaker *et al* 2004)

Figure 12 indicates all producers who expect a response of 40 kg DM per ha per kg applied N and 50 grams per head per day additional weight gain will reject the application of 50 kg N per ha of fertiliser as they see it as too risky.

About 40% of producers who believe that 50 kg N applied strategically will achieve a response of 40 kg DM per ha per kg N applied as well as a 100 gram per day boost in weight gain will also reject the application of fertiliser as they will also see it as too risky. This is even though they believe that they will be better off in most years.

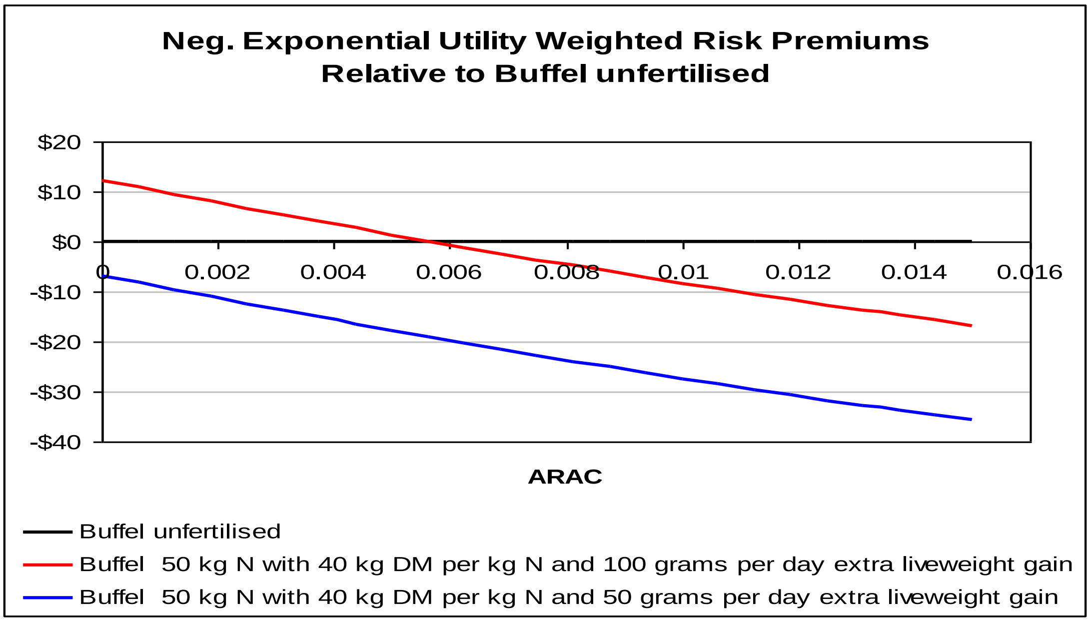

Figure 12: Negative exponential utility weighted risk premiums relative to buffel

The risk associated with seasonal variability has not been modelled due to a lack of data. Incorporation of seasonal variability, as well as price risk, is likely to increase the risk premium further making it more unlikely for many producers to regularly apply N fertiliser to pastures. This is simply because of the perceived increase in the level of risk.

Tactical applications of N fertiliser made to take advantage of perceived market and seasonal opportunities may also be rejected by many producers, due to the inherent riskiness of the decision. There are no futures contracts available to mitigate price risk and seasonal forecasts are generally unreliable. On this basis it appears likely that the impact of risk aversion on the adoption of tactical applications of N fertiliser is likely to be similar to that shown for strategic applications.

Scenario where there is a carryover of benefit

For the scenario, where there was an expected carryover of benefit, the potential average increase in pasture and livestock production was identified at response levels of 30 and 40 kg extra dry matter per hectare per kilogram of applied N. This range was chosen to identify the likely level of response required to either breakeven or improve profitability.

An increase in forage quality was built into the 100 kg N/ha treatment for the year after the initial application of fertiliser, but not for the 50 kg N/ha treatment. A minor amount of benefit in pasture production is predicted to last until ten years after fertiliser application at both rates, but is mostly lost by the end of year five. Figure 13 shows the relationship between beef produced with and without fertiliser for one scenario.

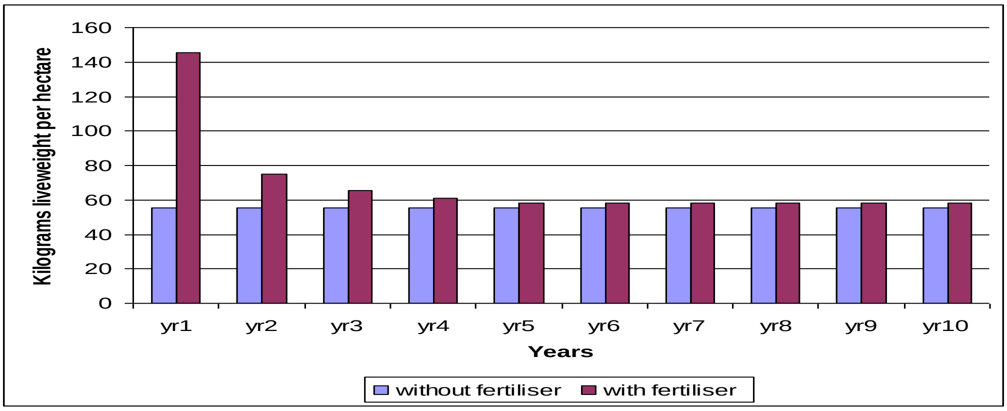

Figure 13: Kilograms of beef produced with and without fertiliser - 4500 kg DM/yr pasture, fertiliser at 50 kg N/ha and 40 kg DM /kg N

Base pastures were maintained at 3000 and 4500 kg DM per annum with the same levels of productivity, spoilage and residual as in the previous section of the analysis. Each base pasture scenario had initial response rates of 30 and 40 kg DM per kg applied N calculated for "one off" applications of 50 and 100 kg of N.

Additional weight gain due to improved pasture quality was included in the year of application for the 50 kg N fertiliser application at 30 kg per AE. Additional weight gain due to improved pasture quality was also included in the year of application, and the first year after that for the 100 kg N fertiliser application at 50 kg and 20kg per AE respectively.

The expected decline in available nitrogen and the impact of this on pasture production and quality is shown for each scenario in Tables 20 to 27.

Table 20: Response for 3000 kg DM/yr pasture fertilised at 50 kg N/ha and 30 kg DM/kg N

Pasture response kg DM /kg N	yr1	yr2	yr3	yr4	yr5	yr6	yr7	yr8	yr9	yr10
Extra nitrogen	**50**	**15**	**7.5**	**4**	**2**	**2**	**2**	**2**	**2**	**2**
Extra pasture	1500	450	225	120	60	60	60	60	60	60
increase	50%	15%	8%	4%	2%	2%	2%	2%	2%	2%
New annual production	4500	3450	3225	3120	3060	3060	3060	3060	3060	3060
Spoilage %	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%
spoilage	675	518	484	468	459	459	459	459	459	459
residual	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
Available for consumption	2025	1133	941	852	801	801	801	801	801	801
increase	170%	51%	26%	14%	7%	7%	7%	7%	7%	7%
stocking rate (ha/ae)	1.80	3.22	3.88	4.28	4.56	4.56	4.56	4.56	4.56	4.56
stocking rate (ae/ha)	0.55	0.31	0.26	0.23	0.22	0.22	0.22	0.22	0.22	0.22
New weight gain	180	150	150	150	150	150	150	150	150	150
kg per ha per annum with fertiliser	99.86	46.54	38.68	35.01	32.92	32.92	32.92	32.92	32.92	32.92
increase	224%	51%	26%	14%	7%	7%	7%	7%	7%	7%

Table 21: Response for 3000 kg DM/yr pasture fertilised at 50 kg N/ha and 40 kg DM/kg N

Pasture response kg DM /kg N	yr1	yr2	yr3	yr4	yr5	yr6	yr7	yr8	yr9	yr10
Extra nitrogen	**50**	**15**	**7.5**	**4**	**2**	**2**	**2**	**2**	**2**	**2**
Extra pasture	2000	600	300	160	80	80	80	80	80	80
increase	67%	20%	10%	5%	3%	3%	3%	3%	3%	3%
New annual production	5000	3600	3300	3160	3080	3080	3080	3080	3080	3080
Spoilage %	20%	15%	15%	15%	15%	15%	15%	15%	15%	15%
spoilage	1000	540	495	474	462	462	462	462	462	462
residual	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
Available for consumption	2200	1260	1005	886	818	818	818	818	818	818
increase	193%	68%	34%	18%	9%	9%	9%	9%	9%	9%
stocking rate (ha/ae)	1.66	2.90	3.63	4.12	4.46	4.46	4.46	4.46	4.46	4.46
stocking rate (ae/ha)	0.60	0.35	0.28	0.24	0.22	0.22	0.22	0.22	0.22	0.22
New weight gain	180	150	150	150	150	150	150	150	150	150
kg per ha per annum with fertiliser	108.49	51.78	41.30	36.41	33.62	33.62	33.62	33.62	33.62	33.62
increase	252%	68%	34%	18%	9%	9%	9%	9%	9%	9%

Table 22: Response for 3000 kg DM/yr pasture fertilised at 100 kg N/ha and 30 kg DM/kg N

Pasture response kg DM /kg N	yr1	yr2	yr3	yr4	yr5	yr6	yr7	yr8	yr9	yr10
Extra nitrogen	**100**	**30**	**15**	**10**	**5**	**5**	**5**	**5**	**5**	**5**
Extra pasture	3000	900	450	300	150	150	150	150	150	150
increase	100%	30%	15%	10%	5%	5%	5%	5%	5%	5%
New annual production	6000	3900	3450	3300	3150	3150	3150	3150	3150	3150
Spoilage %	20%	15%	15%	15%	15%	15%	15%	15%	15%	15%
spoilage	1200	585	518	495	472.5	472.5	472.5	472.5	472.5	472.5
residual	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
Available for consumption	3000	1515	1133	1005	877.5	877.5	877.5	877.5	877.5	877.5
increase	300%	102%	51%	34%	17%	17%	17%	17%	17%	17%
stocking rate (ha/ae)	1.22	2.41	3.22	3.63	4.16	4.16	4.16	4.16	4.16	4.16
stocking rate (ae/ha)	0.82	0.42	0.31	0.28	0.24	0.24	0.24	0.24	0.24	0.24
New weight gain	200	170	150	150	150	150	150	150	150	150
Extra kg per ha per annum with fertiliser	164.38	70.56	46.54	41.30	36.06	36.06	36.06	36.06	36.06	36.06
increase	433%	129%	51%	34%	17%	17%	17%	17%	17%	17%

Table 23: Response for 3000 kg DM/yr pasture fertilised at 100 kg N/ha and 40 kg DM/kg N

Pasture response kg DM /kg N	**yr1**	**yr2**	**yr3**	**yr4**	**yr5**	**yr6**	**yr7**	**yr8**	**yr9**	**yr10**
Extra nitrogen	**100**	**30**	**15**	**10**	**5**	**5**	**5**	**5**	**5**	**5**
Extra pasture	4000	1200	600	400	200	200	200	200	200	200
increase	133%	40%	20%	13%	7%	7%	7%	7%	7%	7%
New annual production	7000	4200	3600	3400	3200	3200	3200	3200	3200	3200
Spoilage %	20%	15%	15%	15%	15%	15%	15%	15%	15%	15%
spoilage	1400	630	540	510	480	480	480	480	480	480
residual	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
Available for consumption	3800	1770	1260	1090	920	920	920	920	920	920
increase	407%	136%	68%	45%	23%	23%	23%	23%	23%	23%
stocking rate (ha/ae)	0.96	2.06	2.90	3.35	3.97	3.97	3.97	3.97	3.97	3.97
stocking rate (ae/ha)	1.04	0.48	0.35	0.30	0.25	0.25	0.25	0.25	0.25	0.25
New weight gain	200	170	150	150	150	150	150	150	150	150
Extra kg per ha per annum with fertiliser	208.22	82.44	51.78	44.79	37.81	37.81	37.81	37.81	37.81	37.81
increase	576%	167%	68%	45%	23%	23%	23%	23%	23%	23%

Table 24: Response for 4500 kg DM/yr pasture fertilised at 50 kg N/ha and 30 kg DM/kg N

Pasture response kg DM /kg N	yr1	yr2	yr3	yr4	yr5	yr6	yr7	yr8	yr9	yr10
Extra nitrogen	50	15	7.5	4	2	2	2	2	2	2
Extra pasture	1500	450	225	120	60	60	60	60	60	60
increase	33%	10%	5%	3%	1%	1%	1%	1%	1%	1%
New annual production	6000	4950	4725	4620	4560	4560	4560	4560	4560	4560
Spoilage %	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
spoilage	1200	990	945	924	912	912	912	912	912	912
residual	2250	2250	2250	2250	2250	2250	2250	2250	2250	2250
Available for consumption	2550	1710	1530	1446	1398	1398	1398	1398	1398	1398
increase	89%	27%	13%	7%	4%	4%	4%	4%	4%	4%
stocking rate (ha/ae)	1.43	2.13	2.39	2.52	2.61	2.61	2.61	2.61	2.61	2.61
stocking rate (ae/ha)	0.70	0.47	0.42	0.40	0.38	0.38	0.38	0.38	0.38	0.38
New weight gain	180	150	150	150	150	150	150	150	150	150
Extra kg per ha per annum with fertiliser	125.75	70.27	62.88	59.42	57.45	57.45	57.45	57.45	57.45	57.45
increase	127%	27%	13%	7%	4%	4%	4%	4%	4%	4%

Table 25: Pasture response for 4500 kg DM/yr pasture fertilised at 50 kg N/ha and 40 kg DM/kg N

Pasture response kg DM /kg N	yr1	yr2	yr3	yr4	yr5	yr6	yr7	yr8	yr9	yr10
Extra nitrogen	50	15	7.5	4	2	2	2	2	2	2
Extra pasture	2000	600	300	160	80	80	80	80	80	80
increase	44%	13%	7%	4%	2%	2%	2%	2%	2%	2%
New annual production	6500	5100	4800	4660	4580	4580	4580	4580	4580	4580
Spoilage %	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
spoilage	1300	1020	960	932	916	916	916	916	916	916
residual	2250	2250	2250	2250	2250	2250	2250	2250	2250	2250
Available for consumption	2950	1830	1590	1478	1414	1414	1414	1414	1414	1414
increase	119%	36%	18%	9%	5%	5%	5%	5%	5%	5%
stocking rate (ha/ae)	1.24	1.99	2.30	2.47	2.58	2.58	2.58	2.58	2.58	2.58
stocking rate (ae/ha)	0.81	0.50	0.44	0.40	0.39	0.39	0.39	0.39	0.39	0.39
New weight gain	180	150	150	150	150	150	150	150	150	150
Extra kg per ha per annum with fertiliser	145.48	75.21	65.34	60.74	58.11	58.11	58.11	58.11	58.11	58.11
increase	162%	36%	18%	9%	5%	5%	5%	5%	5%	5%

Table 26: Pasture response for 4500 kg DM/yr pasture fertilised at 100 kg N/ha and 30 kg DM/kg N

Pasture response kg DM /kg N	yr1	yr2	yr3	yr4	yr5	yr6	yr7	yr8	yr9	yr10
Extra nitrogen	100	30	15	10	5	5	5	5	5	5
Extra pasture	3000	900	450	300	150	150	150	150	150	150
increase	67%	20%	10%	7%	3%	3%	3%	3%	3%	3%
New annual production	7500	5400	4950	4800	4650	4650	4650	4650	4650	4650
Spoilage %	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
spoilage	1500	1080	990	960	930	930	930	930	930	930
residual	2250	2250	2250	2250	2250	2250	2250	2250	2250	2250
Available for consumption	3750	2070	1710	1590	1470	1470	1470	1470	1470	1470
increase	178%	53%	27%	18%	9%	9%	9%	9%	9%	9%
stocking rate (ha/ae)	0.97	1.76	2.13	2.30	2.48	2.48	2.48	2.48	2.48	2.48
stocking rate (ae/ha)	1.03	0.57	0.47	0.44	0.40	0.40	0.40	0.40	0.40	0.40
New weight gain	200	170	150	150	150	150	150	150	150	150
Extra kg per ha per annum with fertiliser	205.48	96.41	70.27	65.34	60.41	60.41	60.41	60.41	60.41	60.41
increase	270%	74%	27%	18%	9%	9%	9%	9%	9%	9%

Table 27: Pasture response for 4500 kg DM/yr pasture fertilised at 100 kg N/ha and 40 kg DM/kg N

Pasture response kg DM /kg N	yr1	yr2	yr3	yr4	yr5	yr6	yr7	yr8	yr9	yr10
Extra nitrogen	100	30	15	10	5	5	5	5	5	5
Extra pasture	4000	1200	600	400	200	200	200	200	200	200
increase	89%	27%	13%	9%	4%	4%	4%	4%	4%	4%
New annual production	8500	5700	5100	4900	4700	4700	4700	4700	4700	4700
Spoilage %	25%	20%	20%	20%	20%	20%	20%	20%	20%	20%
spoilage	2125	1140	1020	980	940	940	940	940	940	940
residual	2250	2250	2250	2250	2250	2250	2250	2250	2250	2250
Available for consumption	4125	2310	1830	1670	1510	1510	1510	1510	1510	1510
increase	206%	71%	36%	24%	12%	12%	12%	12%	12%	12%
stocking rate (ha/ae)	0.88	1.58	1.99	2.19	2.42	2.42	2.42	2.42	2.42	2.42
stocking rate (ae/ha)	1.13	0.63	0.50	0.46	0.41	0.41	0.41	0.41	0.41	0.41
New weight gain	200	170	150	150	150	150	150	150	150	150
Extra kg per ha per annum with fertiliser	226.03	107.59	75.21	68.63	62.05	62.05	62.05	62.05	62.05	62.05
increase	307%	94%	36%	24%	12%	12%	12%	12%	12%	12%

- Results of applying N fertiliser to buffel pasture where there is a carryover effect

Tables 28 and 29 show examples of the cash flows used to calculate the economic indicators for the scenario where 50 kg of N was applied to a base pasture of 4500 kg DM per ha and achieves a 40 kg improvement in DM per ha per kg N applied. Table 20 previously showed the assumptions for the benefits produced by this scenario.

The net cash flow over time was initially calculated for the “without change” scenario. The net cash flow for the “with fertiliser” scenario was then calculated and an allowance made for the possible taxation benefits or costs of the proposal.

Table 28: Net cash flow calculation for 100 hectare buffel paddock at 4500 kg DM per ha per annum

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Sales	$0	$33,145	$33,145	$33,145	$33,145	$33,145	$33,145	$33,145	$33,145	$33,145
Purchases	$24,348	$24,348	$24,348	$24,348	$24,348	$24,348	$24,348	$24,348	$24,348	$0
Selling costs	$0	$1,974	$1,974	$1,974	$1,974	$1,974	$1,974	$1,974	$1,974	$1,974
Variable costs	$446	$446	$446	$446	$446	$446	$446	$446	$446	$0
Net cash flow	($24,794)	$6,377	$6,377	$6,377	$6,377	$6,377	$6,377	$6,377	$6,377	$31,172

Table 29: Net cash flow calculation for 100 hectare buffel paddock at 4500 kg DM per ha per annum with 50 kg N and 40 kg DM /ha response

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Sales	$0	$74,194	$44,971	$38,910	$36,232	$34,687	$34,687	$34,687	$34,687	$34,687
Fertiliser	$8,675	$0	$0	$0	$0	$0	$0	$0	$0	$0
Purchases	$51,907	$33,035	$28,583	$26,616	$25,481	$25,481	$25,481	$25,481	$25,481	$0
Selling costs	$0	$4,410	$2,807	$2,428	$2,261	$2,165	$2,165	$2,165	$2,165	$2,165
Variable costs	$952	$606	$524	$488	$467	$467	$467	$467	$467	$0
Extra tax payable	-$8,419	$6,327	$2,004	$900	$494	$59	$59	$59	$59	$405
Net cash flow after tax	($53,115)	$29,816	$11,053	$8,477	$7,529	$6,515	$6,515	$6,515	$6,515	$32,117

The final net cash flow for each scenario was compared to calculate the partial Net Present Value (NPV) for each fertiliser application and response scenario. This figure represents the return to the extra dollars invested in livestock and fertiliser.

The results shown in Table 30 indicate that the investment of an additional $28,320 in Year 1 in fertiliser and steers will generate a total increase in wealth of about $1,923 over the life of the investment or $2.49 per ha per annum on average at a discount rate of 5%. The values are negative at a 10% discount rate indicating that wealth would be decreased at this discount rate.

Table 30: Calculation of economic indicators for the benefits of change

	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
With fertiliser	-$53,115	$29,816	$11,053	$8,477	$7,529	$6,515	$6,515	$6,515	$6,515	$32,117
Without fertiliser	-$24,794	$6,377	$6,377	$6,377	$6,377	$6,377	$6,377	$6,377	$6,377	$31,172
Extra Benefits or Costs	-$28,320	$23,439	$4,676	$2,100	$1,152	$138	$138	$138	$138	$946
Nominal IRR after tax		9.79%								
Discount rate	5.00%	7.50%	10.00%	12.50%						
NPV of Investment	$1,923	$859	-$75	-$897						
Annual value per ha	$2.49	$1.25	-$0.12	-$1.62						

Discount rates higher than 10% make the investment unviable. Given that there is some risk inherent in the application of fertiliser, it is probable that the cautious investor would want to see a positive return at a 10% discount rate.

Table 31 records the annual average benefit of each treatment at a 5% discount rate and the Internal Rate of Return (IRR) achieved by each treatment.

Table 31: Amortised value and per hectare and IRR's where N fertiliser has a carryover effect

Base pasture	Treatment			
	50 kg N 30 kg DM	50 kg N 40 kg DM	100 kg N 30 kg DM	100 kg N 40 kg DM
3000 kg DM /ha	$0.66 (6%)	$2.19 (9%)	$1.96 (7%)	$7.58 (11%)
4500 kg DM /ha	$0.15 (5%)	$2.49 (10%)	$3.34 (9%)	$6.87 (11%)

Table 31 indicates that applying N fertiliser to buffel pasture once every decade is unlikely to produce spectacular returns. Even at a low discount rate, the value added per hectare is only marginally better than not applying fertiliser. As no allowance for seasonal variability has been included in the economic analysis, it is likely that the amortised values per hectare and Internal Rate of Return figures are both above those likely to be achievable on average in the paddock.

The expected impact of fertiliser on forages

Estimating animal production and carrying capacities

The impact of strategic fertiliser applications on carrying capacity and production was modelled for a typical forage paddock in southern central Queensland. As in the buffel analysis, the paddock was formerly Brigalow country but is now used for forage production.

Two separate forages (oats and forage sorghum) were modelled with three base levels of starting production with a range of levels of response to two different fertilisers.

Forage sorghum had starting base production levels of either 5000, 10000 or 15000 kg DM per ha per annum. These starting levels are taken to represent starting levels of inherent soil fertility not different starting levels of PAWC.

Oats had starting base production levels of either 2000, 4000 or 6000 kg DM per ha per annum.

The response to N fertiliser was tested by treating each starting level of each forage crop with 50 kg N or 100 kg N and predicting an average response for combinations of 0.05, 0.1 or 0.2 kilograms extra liveweight gain per head and 30, 40 or 50 kg DM extra per hectare for each kg of N fertiliser applied.

To test the response to P, the middle level of production (10000 kg DM /ha forage sorghum and 4000 kg DM /ha oats) was treated with either 5kg P or 10 kg P per hectare with a range of responses estimated.

The starting levels of forage production were taken to represent the likely average production of a slightly rundown paddock, a paddock that is in reasonable condition or a paddock that is in excellent condition. All are taken to have the same underlying level of soil water holding capacity. Paddocks in such condition are considered the most likely by the staff undertaking the scoping study to show an economic response to the application nitrogen (N) and phosphorus (P) fertiliser.

To calculate the potential carrying capacity for the unfertilised forage the following assumptions we made:

- the average utilisation rate was either 30% (forage sorghum) or 40% (oats) for the base forage in an unfertilised state
- stocking rates were calculated as hectares per Adult Equivalent (AE)[3]
- average dry matter intake per AE was estimated to be 2.2% of body weight (450 kg live) over the year. On this basis each AE ate approximately ten kg per day or 3,650 kg of dry matter per year and the stocking rate (in AE's) was derived by dividing 3650 by the amount of pasture available to be consumed per hectare
- a level of spoilage, residual pasture and expected weight gain per AE per annum was nominated for each base case scenario
- the "paddock size" was nominated as 100 hectares and watering points and infrastructure are such that the whole paddock can be grazed evenly.

[3] See definition in the appendix

Tables 32 and 33 show the parameters used to calculate the average annual beef production of the base case forage sorghum and oats scenarios.

Table 32: Parameters for forage sorghum production without fertiliser

Forage Sorghum	low	medium	high
baseline forage production kg/ha	5000	10000	15000
forage consumption / AE / day kg	9.9	9.9	9.9
forage duration days	100	100	100
total forage consumption kg/AE	990	990	990
spoilage kg/ha	2500	5500	8500
residual kg/ha	1000	1500	2000
forage for consumption kg (30% utilisation)	1500	3000	4500
stocking rate AE/ha	1.51	3.0	4.5
weight gain kg/AE (0.6kg/h/d)	60	60	60
liveweight kg/ha no fertiliser	91	182	273

Table 33: Parameters for oats production without fertiliser

Oats	low	medium	high
baseline forage production kg/ha	2000	4000	6000
forage consumption / AE / day kg	9.9	9.9	9.9
forage duration days	90	90	90
total forage consumption kg/AE	891	891	891
spoilage kg/ha	200	900	1600
residual kg/ha	1000	1500	2000
forage for consumption kg (40% utilisation)	800	1600	2400
stocking rate AE/ha	0.89	1.79	2.69
weight gain kg/AE (0.9kg/h/d)	81	81	81
liveweight kg/ha no fertiliser	73	145	218

Budget parameters

For each forage crop, the number of steers purchased was derived from the stocking rate in ha per AE, the weight gain per AE predicted and the chosen starting weight of the steers.

Table 34: Input parameters and stocking rates for forage sorghum base

Livestock purchase parameters	low	medium	high
Average age of purchased steers (months)	30	30	30
Number of steers purchased	151.52	300	450
Purchase price steers ($/kg live)	$1.65	$1.65	$1.65
Purchase weight steers (kg live)	520	520	520
Cost of purchased steers	$130,004	$257,400	$386,100
Gross cost of purchased steers (per head)	$858	$858	$858
Stocking rate (head per hectare)	1.52	3.00	4.50
Stocking rate (hectare per head)	0.66	0.33	0.22
Weight gain per day	0.60	0.60	0.60
Total days held	100	100	100

Table 35: Input parameters and stocking rates for oats base

Livestock purchase parameters	low	medium	high
Average age of purchased steers (months)	30	30	30
Number of steers purchased	89.79	179.57	269.36
Purchase price steers ($/kg live)	$1.65	$1.65	$1.65
Purchase weight steers (kg live)	520	520	520
Cost of purchased steers	$77,040	$154,074	$231,111
Gross cost of purchased steers (per head)	$858	$858	$858
Stocking rate (head per hectare)	.90	1.8	2.69
Stocking rate (hectare per head)	1.11	0.56	0.37
Weight gain per day	0.90	0.90	0.90
Total days held	90	90	90

As previously, the budget purchases “fractions” of steers to match the stocking rate calculated in both the economic analysis and the production estimates.

Please note that the calculation of AE weighting in the enterprise budget is based on the formula (POWER (((opening weight + closing weight)/2), 0.75)/97.7). This formula gives a slightly different answer to that gained through applying the more simple process of dividing by 3650 as used in the initial calculation of stocking rate.

The costs of transporting the steers to and from the property, minor health costs and selling costs are the other main livestock variable costs included in the enterprise budgets. The opportunity cost of the capital tied up when steers are purchased is deducted from the gross margin to calculate the value of the gross margin after interest. (Only the opportunity cost of steer capital has been allowed for as no other capital costs differ significantly between the various treatments.)

Estimating the benefit of strategic fertiliser application on forages

The scarcity of recent data identifying the impact on beef production of applying fertiliser to forage crops required all available sources of knowledge to be condensed into a range of “best bet” responses.

Nitrogen (N) fertiliser was applied at either 50 kg per ha per annum or 100 kg of N per ha per annum in the form of urea. Phosphorus (P) fertiliser was applied at either 5 kg per ha per annum or 10 kg P per hectare per annum in the form of Incitec triple super.

The urea has 46% N and a cost of $700 per ton landed on property. The triple super has 20.1% P and a cost of $890 per ton.

- Forage sorghum scenario

For each starting production level for forage sorghum, the expected average increase in pasture and livestock production was identified at response levels of 30, 40 or 50 kg extra dry matter per hectare per kg of applied N at treatment levels of 50 kg and 100 kg N per hectare.

N fertiliser was also modelled as providing a boost to the quality of the forage. This better quality forage led to an improved weight gain per head per day for the steers grazing the fertilised forage. The extra weight gain due to improved forage quality was taken as either 50 grams per head per day for 50 kg N applied or 100 grams per head per day for 100 kg N applied.

The P fertiliser was only applied to the 10000 kg DM production scenario at rates of 5 kg and 10 kg of P per hectare with response rates of 2, 5, 10, 20, 40, 80, 120 and 160 kg of DM per kg of P applied. A premium for weight gain was also applied at either 50 or 100 grams per head per day to identify where breakeven and profitable levels of application may be found.

In each case, the new amount of pasture available for consumption was identified by deducting an allowance for spoilage and the desired residual from the total dry matter produced as a result of the fertiliser application. This amount of dry matter available for consumption was converted to a stocking rate in AE's per hectare by dividing 3650 by the available kilograms of forage per hectare.

Tables 36 to 39 indicate the stocking rate and animal production calculated for each response rate for each forage crop.

Table 36: Forage sorghum + 50 kg N

	low DM yield			medium DM yield			high DM yield		
DM response to added N (kg DM/kg N)	30	40	50	30	40	50	30	40	50
N applied kg/ha	50	50	50	50	50	50	50	50	50
extra forage kg	1500	2000	2500	1500	2000	2500	1500	2000	2500
increase %	30	40	50	15	20	25	10	13	17
new forage production kg	6500	7000	7500	11500	12000	12500	16500	17000	17500
spoilage kg/ha	2550	2900	3250	5550	5900	6250	8550	8900	9250
residual kg/ha	2000	2000	2000	2500	2500	2500	3000	3000	3000
forage for consumption kg (30% utilisation)	1950	2100	2250	3450	3600	3750	4950	5100	5250
increase %	30.0	40.0	50.0	15.0	20.0	25.0	10.0	13.3	16.7
Animal response to added N	+0.05kg/h/d			+0.05kg/h/d			+0.05kg/h/d		
stocking rate AE/ha	2.0	2.12	2.27	3.48	3.63	3.78	5.0	5.15	5.30
new weight gain kg/AE	65	65	65	65	65	65	65	65	65
liveweight kg/ha with fertiliser	128	138	148	227	236	246	325	335	345
increase %	40.8	51.7	62.5	24.6	30.0	35.4	19.2	22.8	26.4

Table 37: Forage sorghum + 100 kg N

	low DM yield			medium DM yield			high DM yield		
DM response to added N (kg DM/kg N)	30	40	50	30	40	50	30	40	50
N applied kg/ha	100	100	100	100	100	100	100	100	100
extra forage kg	3000	4000	5000	3000	4000	5000	3000	4000	5000
increase %	60	80	100	30	40	50	20	27	33
new forage production kg	8000	9000	10000	13000	14000	15000	18000	19000	20000
spoilage kg/ha	3600	4300	5000	6600	7300	8000	9600	10300	11000
residual kg/ha	2000	2000	2000	2500	2500	2500	3000	3000	3000
forage for consumption kg (30% utilisation)	2400	2700	3000	3900	4200	4500	5400	5700	6000
increase %	60.0	80.0	100.0	30.0	40.0	50.0	20.0	26.7	33.3
Animal response to added N	+0.1kg/h/d			+0.1kg/h/d			+0.1kg/h/d		
stocking rate AE/ha	2.42	2.73	3.03	3.94	4.24	4.55	5.45	5.76	6.06
new weight gain kg/AE	70.00	70	70	70	70	70	70	70	70
liveweight kg/ha with fertiliser	170	191	212	276	297	318	382	403	424
increase %	86.7	110.0	133.3	51.7	63.3	75.0	40.0	47.8	55.6

Table 38: Forage sorghum + 5kg P

	medium DM yield								
DM response to added P (kg DM/kg P)	1	2	5	10	20	40	80	120	160
P applied kg/ha	5	5	5	5	5	5	5	5	5
extra forage kg	5	10	25	50	100	200	400	600	800
increase %	0	0	0	1	1	2	4	6	8
new forage production kg	10005	10010	10025	10050	10100	10200	10400	10600	10800
spoilage kg/ha	5003.5	5007	5017.5	4535	4570	4640	4280	4420	4560
residual kg/ha	2000	2000	2000	2500	2500	2500	3000	3000	3000
forage for consumption kg (30% utilisation)	3001.5	3003	3007.5	3015	3030	3060	3120	3180	3240
increase %	0.1	0.1	0.3	0.5	1.0	2.0	4.0	6.0	8.0
Animal response to added P		+0.05kg/h/d			+0.05kg/h/d			+0.05kg/h/d	
stocking rate AE/ha	3.03	3.03	3.03	3.04	3.06	3.09	3.15	3.21	3.27
new weight gain kg/AE	65	65	65	65	65	65	65	65	65
liveweight kg/ha with fertiliser	197	197	197	198	199	201	205	209	213
increase %	8.4	8.4	8.6	8.9	9.4	10.5	12.7	14.8	17.0

Table 39: Forage sorghum + 10 kg p

	medium DM yield								
DM response to added P (kg DM/kg P)	1	2	5	10	20	40	80	120	160
P applied kg/ha	10	10	10	10	10	10	10	10	10
extra forage kg	10	20	50	100	200	400	800	1200	1600
increase %	0	0	1	1	2	4	8	12	16
new forage production kg	10010	10020	10050	10100	10200	10400	10800	11200	11600
spoilage kg/ha	5007	5014	5035	4570	4640	4780	4560	4840	5120
residual kg/ha	2000	2000	2000	2500	2500	2500	3000	3000	3000
forage for consumption kg (30% utilisation)	3003	3006	3015	3030	3060	3120	3240	3360	3480
increase %	0.1	0.2	0.5	1.0	2.0	4.0	8.0	12.0	16.0
Animal response to added P		+0.1kg/h/d			+0.1kg/h/d			+0.1kg/h/d	
stocking rate AE/ha	3.03	3.04	3.05	3.06	3.09	3.15	3.27	3.39	3.52
new weight gain kg/AE	70	70	70	70	70	70	70	70	70
liveweight kg/ha with fertiliser	212	213	213	214	216	221	229	238	246
increase %	16.8	16.9	17.3	17.8	19.0	21.3	26.0	30.7	35.3

- Forage oats scenario

For each starting production level for oats, the potential average increase in forage crop and livestock production was identified at response levels of 30, 40 or 50 kg extra dry matter per hectare per kg of applied N at treatment levels of 50 kg and 100 kg N per hectare.

The P fertiliser was only applied to the 4000 kg DM production scenario at rates of 5 kg and 10 kg of P per hectare with response rates of 2, 5, 10, 20, 40, 80, 120 and 160 kg of DM per kg of P applied.

In each case, the new amount of pasture available for consumption was identified by deducting an allowance for spoilage and the desired residual from the total dry matter produced as a result of the fertiliser application. This amount of dry matter available for consumption was converted to a stocking rate in AE's per hectare by dividing 3650 by the available kilograms of forage per hectare.

It was also proposed that adding N or P fertiliser to oats could improve the quality of the pasture providing additional benefits above and beyond those captured in the stocking rate increase generated by the additional dry matter production.

The potential increase in oats quality due to the application of fertiliser is included in this analysis by increasing the annual weight gain per adult equivalent by a set amount of 100 or

200 grams per AE per day depending upon the fertiliser scenario and the productivity of the base pasture.

Tables 40 to 43 indicate the stocking rate and animal production calculated for each response rate for each forage crop.

Table 40: Oats + 50 kg N

	low DM yield			medium DM yield			high DM yield		
DM response to added N (kg DM/kg N)	10	30	50	10	30	50	10	30	50
N applied kg/ha	50	50	50	50	50	50	50	50	50
extra forage kg	500	1500	2500	500	1500	2500	500	1500	2500
increase %	25	75	125	13	38	63	8	25	42
new forage production kg	2500	3500	4500	4500	5500	6500	6500	7500	8500
spoilage kg/ha	0	100	700	200	800	1400	900	1500	2100
residual kg/ha	1500	2000	2000	2500	2500	2500	3000	3000	3000
forage for consumption kg (40% utilisation)	1000	1400	1800	1800	2200	2600	2600	3000	3400
increase %	25.0	75.0	125.0	12.5	37.5	62.5	8.3	25.0	41.7
Animal response to added N		+0.1kg/h/d			+0.1kg/h/d			+0.1kg/h/d	
stocking rate AE/ha	1.12	1.57	2.02	2.02	2.46	2.91	2.91	3.36	3.81
new weight gain kg/AE	90	90	90	90	90	90	90	90	90
liveweight kg/ha with fertiliser	101	141	182	182	222	263	263	303	343
increase %	38.9	94.4	150.0	25.0	52.8	80.6	20.4	38.9	57.4

Table 41: Oats + 100 kg N

	low DM yield			medium DM yield			high DM yield		
DM response to added N (kg DM/kg N)	10	30	50	10	30	50	10	30	50
N applied kg/ha	100	100	100	100	100	100	100	100	100
extra forage kg	1000	3000	5000	1000	3000	5000	1000	3000	5000
increase %	50	150	250	25	75	125	17	50	83
new forage production kg	3000	5000	7000	5000	7000	9000	7000	9000	11000
spoilage kg/ha	-200	1000	2200	500	1700	2900	1200	2400	3600
residual kg/ha	2000	2000	2000	2500	2500	2500	3000	3000	3000
forage for consumption kg (40% utilisation)	1200	2000	2800	2000	2800	3600	2800	3600	4400
increase %	50.0	150.0	250.0	25.0	75.0	125.0	16.7	50.0	83.3
Animal response to added N		+0.2kg/h/d			+0.2kg/h/d			+0.2kg/h/d	
stocking rate AE/ha	1.34	2.24	3.14	2.24	3.14	4.04	3.14	4.04	4.93
new weight gain kg/AE	99	99	99	99	99	99	99	99	99
liveweight kg/ha with fertiliser	133	222	311	222	311	400	311	400	489
increase %	83.3	205.6	327.8	52.8	113.9	175.0	42.6	83.3	124.1

Table 42: Oats + 5 kg P

	medium DM yield								
DM response to added P (kg DM/kg P)	1	2	5	10	20	40	80	120	160
P applied kg/ha	5	5	5	5	5	5	5	5	5
extra forage kg	5	10	25	50	100	200	400	600	800
increase %	0	0	1	1	3	5	10	15	20
new forage production kg	4005	4010	4025	4050	4100	4200	4400	4600	4800
spoilage kg/ha	403	406	415	-70	-40	20	-360	-240	-120
residual kg/ha	2000	2000	2000	2500	2500	2500	3000	3000	3000
forage for consumption kg (40% utilisation)	1602	1604	1610	1620	1640	1680	1760	1840	1920
increase %	0.1	0.3	0.6	1.3	2.5	5.0	10.0	15.0	20.0
Animal response to added P		+0.1kg/h/d			+0.1kg/h/d			+0.1kg/h/d	
stocking rate AE/ha	1.79	1.80	1.80	1.81	1.84	1.88	1.97	2.06	2.15
new weight gain kg/AE	90	90	90	90	90	90	90	90	90
liveweight kg/ha with fertiliser	162	162	163	164	166	170	178	186	194
increase %	11.3	11.4	11.8	12.5	13.9	16.7	22.2	27.8	33.3

Table 43: Oats + 10 kg P

					medium DM yield				
DM response to added P (kg DM/kg P)	1	2	5	10	20	40	80	120	160
P applied kg/ha	10	10	10	10	10	10	10	10	10
extra forage kg	10	20	50	100	200	400	800	1200	1600
increase %	0	1	1	3	5	10	20	30	40
new forage production kg	4010	4020	4050	4100	4200	4400	4800	5200	5600
spoilage kg/ha	406	412	430	-40	20	140	-120	120	360
residual kg/ha	2000	2000	2000	2500	2500	2500	3000	3000	3000
forage for consumption kg (40% utilisation)	1604	1608	1620	1640	1680	1760	1920	2080	2240
increase %	0.3	0.5	1.3	2.5	5.0	10.0	20.0	30.0	40.0
Animal response to added P		+0.2kg/h/d			+0.2kg/h/d			+0.2kg/h/d	
stocking rate AE/ha	1.80	1.80	1.81	1.84	1.88	1.97	2.15	2.33	2.51
new weight gain kg/AE	99	99	99	99	99	99	99	99	99
liveweight kg/ha with fertiliser	178	179	180	182	187	196	213	231	249
increase %	22.5	22.8	23.8	25.3	28.3	34.4	46.7	58.9	71.1

▪ Results of applying N and P fertiliser to forage sorghum

The results of the analysis are presented in the following eight tables.

The format is as follows:

- Where N is applied, Colum 2 presents the gross margin for the paddock without added N, columns 3 to 6 present the gross margins for response rates increasing from 30 kg of extra dry matter per hectare per kg of N applied up to 50 kg N of extra dry matter per hectare per kg of N applied.
- Where P is applied, Colum 2 presents the gross margin for the paddock without added P, columns 3 to 11 present the gross margins for response rates increasing from 1 kg of extra dry matter per hectare per kg of N applied up to 160 kg N of extra dry matter per hectare per kg of P applied.

Tables of results are presented for each base production level, for each improvement in weight gain per head due to quality and for each level of fertiliser input.

It can be seen in Table 44, for example, that fertilising a paddock that usually produces 5000 kg DM per ha with 50 kg N per ha with a response rate of 50 kg DM per kg of applied N reduces the expected gross margin by $50 per hectare. For this scenario, all levels of response actually make the producer worse off.

There appears to be no scenario for the application of N or P fertiliser to forage sorghum that appears likely to improve the returns of the producer.

Table 44: 50 N fertiliser 5000 kg DM

Gross margin for	5000 kg DM yr Forage sorghum	+30kg DM /kg N +.05 kg day	+40kg DM /kg N +.05 kg day	+50kg DM /kg N +.05 kg day
	per ha/annum	per ha/annum	per ha/annum	per ha/annum
Livestock Sales	$1,471	$1,959	$2,078	$2,226
Variable costs				
Livestock Purchases	$1,300	$1,716	$1,820	$1,950
Freight In	$23	$30	$32	$34
Freight Out	$83	$110	$116	$125
Treatment Expenses	$1	$1	$1	$1
Selling Expenses	$8	$10	$11	$11
Forage growing costs	$114	$202	$202	$202
Total Expenses	$1,527	$2,068	$2,181	$2,323
Gross Margin	-$56	-$109	-$104	-$96
Gross Margin / hectare /annum (after interest)	**-$74**	**-$133**	**-$128**	**-$123**
Kilograms of liveweight gain per hectare per annum	91	130	138	148

Table 45: 50 N fertiliser 10000 kg DM

Gross margin for	10000 kg DM yr Forage sorghum	+30kg DM /kg N +.05 kg day	+40kg DM /kg N +.05 kg day	+50kg DM /kg N +.05 kg day
	per ha/annum	per ha/annum	per ha/annum	per ha/annum
Livestock Sales	$2,913	$3,413	$3,562	$3,710
Variable costs				
Livestock Purchases	$2,574	$2,990	$3,120	$3,250
Freight In	$45	$52	$54	$56
Freight Out	$164	$191	$199	$208
Treatment Expenses	$1	$1	$1	$1
Selling Expenses	$15	$17	$18	$19
Forage growing costs	$114	$202	$202	$202
Total Expenses	$2,913	$3,454	$3,595	$3,736
Gross Margin	$1	-$40	-$33	-$26
Gross Margin / hectare /annum (after interest)	**-$35**	**-$81**	**-$76**	**-$71**
Kilograms of liveweight gain /hectare per annum	180	227	236	246

Table 46: 50 N fertiliser 15000 kg DM

Gross margin for	15000 kg DM yr Forage sorghum	+30kg DM /kg N +.05 kg day	+40kg DM /kg N +.05 kg day	+50kg DM /kg N +.05 kg day
	per ha/annum	per ha/annum	per ha/annum	per ha/annum
Livestock Sales	$4,370	$4,898	$5,046	$5,194
Variable costs				
Livestock Purchases	$3,861	$4,290	$4,420	$4,550
Freight In	$67	$74	$77	$79
Freight Out	$247	$274	$282	$291
Treatment Expenses	$2	$2	$2	$2
Selling Expenses	$23	$25	$26	$27
Forage growing costs	$114	$202	$202	$202
Total Expenses	$4,312	$4,867	$5,009	$5,150
Gross Margin	$58	$30	$37	$44
Gross Margin per hectare per annum (after interest)	**$5**	**-$29**	**-$23**	**-$18**
Kilograms of liveweight gain per hectare per annum	270	325	335	345

Table 47: 100 N fertiliser 5000 kg DM

Gross margin for	5000 kg DM yr Forage sorghum	+30kg DM /kg N +.1 kg day	+40kg DM /kg N +.1 kg day	+50kg DM /kg N +.1 kg day
	per ha/annum	per ha/annum	per ha/annum	per ha/annum
Livestock Sales	$1,471	$2,395	$2,694	$2,994
Variable costs				
Livestock Purchases	$1,300	$2,080	$2,340	$2,600
Freight In	$23	$36	$41	$45
Freight Out	$83	$133	$149	$166
Treatment Expenses	$1	$1	$1	$1
Selling Expenses	$8	$12	$14	$15
Forage growing costs	$114	$278	$278	$278
Total Expenses	$1,527	$2,540	$2,823	$3,106
Gross Margin	-$56	-$145	-$129	-$112
Gross Margin per hectare per annum (after interest)	**-$74**	**-$174**	**-$161**	**-$148**
Kilograms of liveweight gain per hectare per annum	91	170	191	212

Table 48: 100 N fertiliser 10000 kg DM

Gross margin for	10000 kg DM yr Forage sorghum	+30kg DM /kg N +.1 kg day	+40kg DM /kg N +.1 kg day	+50kg DM /kg N +.1 kg day
	per ha/annum	per ha/annum	per ha/annum	per ha/annum
Livestock Sales	$2,943	$3,892	$4,191	$4,490
Variable costs				
Livestock Purchases	$2,600	$3,380	$3,640	$3,900
Freight In	$45	$59	$63	$68
Freight Out	$166	$216	$233	$249
Treatment Expenses	$1	$1	$2	$2
Selling Expenses	$15	$20	$21	$23
Forage growing costs	$114	$278	$278	$278
Total Expenses	$2,941	$3,954	$4,237	$4,519
Gross Margin	$2	-$62	-$46	-$29
Gross Margin per hectare per annum (after interest)	**-$34**	**-$108**	**-$95**	**-$82**
Kilograms of liveweight gain per hectare per annum	182	276	297	318

Table 49: 100 N fertiliser 15000 kg DM

Gross margin for	15000 kg DM yr Forage sorghum	+30kg DM /kg N +.1 kg day	+40kg DM /kg N +.1 kg day	+50kg DM /kg N +.1 kg day
	per ha/annum	per ha/annum	per ha/annum	per ha/annum
Livestock Sales	$4,414	$5,388	$5,688	$5,987
Variable costs				
Livestock Purchases	$3,900	$4,680	$4,940	$5,200
Freight In	$68	$81	$86	$90
Freight Out	$249	$299	$316	$332
Treatment Expenses	$2	$2	$2	$2
Selling Expenses	$23	$27	$29	$30
Forage growing costs	$114	$278	$278	$278
Total Expenses	$4,355	$5,368	$5,650	$5,933
Gross Margin	$59	$21	$38	$54
Gross Margin per hectare per annum (after interest)	**$6**	**-$43**	**-$30**	**-$17**
Kilograms of liveweight gain per hectare per annum	273	382	403	424

Table 50: 5 kg P 10000 kg DM

Gross margin for	10000 kg DM yr Forage sorghum	+1kg DM /kg P +.05 kg day	+2kg DM /kg P +.05 kg day	+5kg DM /kg P +.05 kg day	+10kg DM /kg P +.05 kg day	+20kg DM /kg P +.05 kg day	+40kg DM /kg P +.05 kg day	+80kg DM /kg P +.05 kg day	+120kg DM /kg P +.05 kg day	+160kg DM /kg P +.05 kg day
	per ha/annum	per ha/annum	per ha/annum	per ha/annum	per ha/annum	per ha/annum	per ha/annum	per ha/annum	per ha/annum	per ha/annum
Livestock Sales	$2,943	$2,970	$2,971	$2,976	$2,983	$2,998	$3,028	$3,087	$3,146	$3,206
Variable costs										
Livestock Purchases	$2,600	$2,601	$2,603	$2,607	$2,613	$2,626	$2,652	$2,704	$2,756	$2,808
Freight In	$45	$45	$45	$45	$45	$46	$46	$47	$48	$49
Freight Out	$166	$166	$166	$167	$167	$168	$169	$173	$176	$179
Treatment Expenses	$1	$1	$1	$1	$1	$1	$1	$1	$1	$1
Selling Expenses	$15	$15	$15	$15	$15	$15	$15	$16	$16	$16
Forage growing costs	$114	$148	$148	$148	$148	$148	$148	$148	$148	$148
Total Expenses	$2,941	$2,977	$2,979	$2,983	$2,990	$3,004	$3,032	$3,089	$3,145	$3,202
Gross Margin	$2	-$7	-$7	-$7	-$7	-$6	-$5	-$2	$1	$4
Gross Margin /ha /annum (after interest)	**-$34**	**-$43**	**-$43**	**-$43**	**-$43**	**-$42**	**-$41**	**-$39**	**-$37**	**-$35**
kg of liveweight gain / ha per annum	182	197	197	197	198	199	201	205	209	213

Table 51: 10 kg P 10000 kg DM

Gross margin for	10000 kg DM yr Forage sorghum	+1kg DM /kg P +.1kg day	+2kg DM /kg P +.1kg day	+5kg DM /kg P +.1 kg day	+10kg DM /kg P +.1kg day	+20kg DM /kg P +.1 kg day	+40kg DM /kg P +.1kg day	+80kg DM /kg P +.1 kg day	+120kg DM /kg P +.1 kg day	+160kg DM /kg P +.1 kg day
	per ha/annum	per ha/annum	per ha/annum	per ha/annum	per ha/annum	per ha/annum	per ha/annum	per ha/annum	per ha/annum	per ha/annum
Livestock Sales	$2,943	$2,997	$3,000	$3,009	$3,024	$3,053	$3,113	$3,233	$3,353	$3,473
Variable costs										
Livestock Purchases	$2,600	$2,603	$2,605	$2,613	$2,626	$2,652	$2,704	$2,808	$2,912	$3,016
Freight In	$45	$45	$45	$45	$46	$46	$47	$49	$50	$52
Freight Out	$166	$166	$166	$167	$168	$169	$173	$179	$186	$193
Treatment Expenses	$1	$1	$1	$1	$1	$1	$1	$1	$1	$1
Selling Expenses	$15	$15	$15	$15	$15	$15	$16	$16	$17	$18
Forage growing costs	$114	$170	$170	$170	$170	$170	$170	$170	$170	$170
Total Expenses	$2,941	$3,001	$3,004	$3,012	$3,026	$3,054	$3,111	$3,224	$3,337	$3,450
Gross Margin	$2	-$4	-$4	-$3	-$3	-$1	$2	$9	$16	$22
Gross Margin /ha /annum (after interest)	**-$34**	**-$40**	**-$40**	**-$39**	**-$39**	**-$37**	**-$35**	**-$29**	**-$24**	**-$19**
kg of liveweight gain / ha per annum	182	212	213	213	214	216	221	229	238	246

- Results of applying N and P fertiliser to oats

The results of the analysis are presented in the following eight tables.

The format is as follows:

- Where N is applied, Colum 2 presents the gross margin for the paddock without added N, columns 3 to 6 present the gross margins for response rates increasing from 30 kg of extra dry matter per hectare per kg of N applied up to 50 kg N of extra dry matter per hectare per kg of N applied.
- Where P is applied, Colum 2 presents the gross margin for the paddock without added P, columns 3 to 11 present the gross margins for response rates increasing from 1 kg of extra dry matter per hectare per kg of N applied up to 160 kg N of extra dry matter per hectare per kg of P applied.

Tables of results are presented for each base production level, for each improvement in weight gain per head due to quality and for each level of fertiliser input.

It appears that oats crops that have an inherently high level of production may show a profitable response to applications of N or P if they can achieve both a high DM response per kg of fertiliser applied plus a weight gain response.

Table 52: Oats 50 kg N 2000 kg DM

Gross margin for	**2000 kg DM yr Oats**	**+10kg DM /kg N +.1 kg day**	**+30kg DM /kg N +.1 kg day**	**+50kg DM /kg N +.1 kg day**
	per ha per annum	per ha per annum	per ha per annum	per ha per annum
Livestock Sales	$904	$1,146	$1,605	$2,063
Variable costs				
Livestock Purchases	$770	$963	$1,348	$1,733
Freight In	$13	$17	$23	$30
Freight Out	$49	$62	$86	$111
Treatment Expenses	$0	$0	$1	$1
Selling Expenses	$4	$6	$8	$10
Forage growing costs	$153	$241	$241	$241
Total Expenses	$990	$1,288	$1,707	$2,126
Gross Margin	-$87	-$142	-$102	-$63
Gross Margin per hectare per annum (after interest)	**-$96**	**-$154**	**-$119**	**-$84**
Kilograms of liveweight gain per hectare per annum	73	101	141	182

Table 53: Oats 50 kg N 4000 kg DM

Gross margin for	**4000 kg DM yr Oats**	**+10kg DM /kg N +.1 kg day**	**+30kg DM /kg N +.1 kg day**	**+50kg DM /kg N +.1 kg day**
	per ha per annum	per ha per annum	per ha per annum	per ha per annum
Livestock Sales	$1,807	$2,063	$2,522	$2,980
Variable costs				
Livestock Purchases	$1,541	$1,733	$2,119	$2,504
Freight In	$27	$30	$37	$43
Freight Out	$98	$111	$135	$160
Treatment Expenses	$1	$1	$1	$1
Selling Expenses	$9	$10	$12	$15
Forage growing costs	$153	$241	$241	$241
Total Expenses	$1,828	$2,126	$2,545	$2,964
Gross Margin	-$21	-$63	-$23	$17
Gross Margin per hectare per annum (after interest)	**-$40**	**-$84**	**-$49**	**-$14**
Kilograms of liveweight gain per hectare per annum	145	182	222	263

Table 54: Oats 50 kg N 4000 kg DM

Gross margin for	6000 kg DM yr Oats	+10kg DM /kg N +.1 kg day	+30kg DM /kg N +.1 kg day	+50kg DM /kg N +.1 kg day
	per ha per annum	per ha per annum	per ha per annum	per ha per annum
Livestock Sales	$2,711	$2,980	$3,439	$3,898
Variable costs				
Livestock Purchases	$2,311	$2,504	$2,889	$3,274
Freight In	$40	$43	$50	$57
Freight Out	$148	$160	$185	$209
Treatment Expenses	$1	$1	$1	$1
Selling Expenses	$13	$15	$17	$19
Forage growing costs	$153	$241	$241	$241
Total Expenses	$2,666	$2,964	$3,383	$3,802
Gross Margin	$45	$17	$56	$96
Gross Margin per hectare per annum (after interest)	**$16**	**-$14**	**$21**	**$56**
Kilograms of liveweight gain per hectare per annum	218	263	303	343

Table 55: Oats 100 kg N 2000 kg DM

Gross margin for	2000 kg DM yr Oats	+10kg DM /kg N +.2 kg day	+30kg DM /kg N +.2 kg day	+50kg DM /kg N +.2 kg day
	per ha per annum	per ha per annum	per ha per annum	per ha per annum
Livestock Sales	$904	$1,396	$2,326	$3,257
Variable costs				
Livestock Purchases	$770	$1,156	$1,926	$2,696
Freight In	$13	$20	$33	$47
Freight Out	$49	$74	$123	$172
Treatment Expenses	$0	$1	$1	$1
Selling Expenses	$4	$7	$11	$16
Forage growing costs	$153	$317	$317	$317
Total Expenses	$990	$1,574	$2,412	$3,249
Gross Margin	-$87	-$178	-$85	$8
Gross Margin per hectare per annum (after interest)	**-$96**	**-$192**	**-$109**	**-$25**
Kilograms of liveweight gain per hectare per annum	73	133	222	311

Table 56: Oats 100 kg N 4000 kg DM

Gross margin for	4000 kg DM yr Oats	+10kg DM /kg N +.2 kg day	+30kg DM /kg N +.2 kg day	+50kg DM /kg N +.2 kg day
	per ha per annum	per ha per annum	per ha per annum	per ha per annum
Livestock Sales	$1,807	$2,326	$3,257	$4,188
Variable costs				
Livestock Purchases	$1,541	$1,926	$2,696	$3,467
Freight In	$27	$33	$47	$60
Freight Out	$98	$123	$172	$221
Treatment Expenses	$1	$1	$1	$2
Selling Expenses	$9	$11	$16	$20
Forage growing costs	$153	$317	$317	$317
Total Expenses	$1,828	$2,412	$3,249	$4,087
Gross Margin	-$21	-$85	$8	$101
Gross Margin per hectare per annum (after interest)	**-$40**	**-$109**	**-$25**	**$58**
Kilograms of liveweight gain per hectare per annum	145	222	311	400

Table 57: Oats 100 kg N 6000 kg DM

Gross margin for	**6000 kg DM yr Oats**	**+10kg DM /kg N +.2 kg day**	**+30kg DM /kg N +.2 kg day**	**+50kg DM /kg N +.2 kg day**
	per ha per annum	per ha per annum	per ha per annum	per ha per annum
Livestock Sales	$2,711	$3,257	$4,188	$5,113
Variable costs				
Livestock Purchases	$2,311	$2,696	$3,467	$4,232
Freight In	$40	$47	$60	$73
Freight Out	$148	$172	$221	$270
Treatment Expenses	$1	$1	$2	$2
Selling Expenses	$13	$16	$20	$25
Forage growing costs	$153	$317	$317	$317
Total Expenses	$2,666	$3,249	$4,087	$4,920
Gross Margin	$45	$8	$101	$193
Gross Margin per hectare per annum (after interest)	**$16**	**-$25**	**$58**	**$141**
Kilograms of liveweight gain per hectare per annum	218	311	400	488

Table 58: 5 kg P 4000 kg DM

Gross margin for	4000 kg DM yr Oats	+1kg DM /kg P +.1 kg day	+2kg DM /kg P +.1 kg day	+5kg DM /kg P +.1 kg day	+10kg DM /kg P +.1 kg day	+20kg DM /kg P +.1 kg day	+40kg DM /kg P +.1 kg day	+80kg DM /kg P +.1 kg day	+120kg DM /kg P +.1 kg day	+160kg DM /kg P +.1 kg day
	per ha per annum	per ha per annum	per ha per annum	per ha per annum	per ha per annum	per ha per annum	per ha per annum	per ha per annum	per ha per annum	per ha per annum
Livestock Sales	$1,807	$1,836	$1,839	$1,846	$1,857	$1,880	$1,926	$2,018	$2,109	$2,201
Variable costs										
Livestock Purchases	$1,541	$1,543	$1,545	$1,550	$1,560	$1,579	$1,618	$1,695	$1,772	$1,849
Freight In	$27	$27	$27	$27	$27	$27	$28	$29	$31	$32
Freight Out	$98	$99	$99	$99	$100	$101	$103	$108	$113	$118
Treatment Expenses	$1	$1	$1	$1	$1	$1	$1	$1	$1	$1
Selling Expenses	$9	$9	$9	$9	$9	$9	$9	$10	$10	$11
Forage growing costs	$125	$159	$159	$159	$159	$159	$159	$159	$159	$159
Total Expenses	$1,800	$1,837	$1,839	$1,845	$1,856	$1,877	$1,919	$2,002	$2,086	$2,170
Gross Margin	$7	$0	$0	$0	$1	$3	$7	$15	$23	$31
Gross Margin per hectare per annum (after interest)	**-$12**	**-$19**	**-$19**	**-$19**	**-$18**	**-$16**	**-$13**	**-$6**	**$1**	**$8**
Kilograms of liveweight gain per hectare per annum	145	162	162	163	164	166	170	178	186	194

Table 59: 10 kg P 4000 kg DM

Gross margin for	4000 kg DM yr Oats	+1kg DM /kg P +.2 kg day	+2kg DM /kg P +.2 kg day	+5kg DM /kg P +.2 kg day	+10kg DM /kg P +.2 kg day	+20kg DM /kg P +.2 kg day	+40kg DM /kg P +.2 kg day	+80kg DM /kg P +.2 kg day	+120kg DM /kg P +.2 kg day	+160kg DM /kg P +.2 kg day
	per ha per annum	per ha per annum	per ha per annum	per ha per annum	per ha per annum	per ha per annum	per ha per annum	per ha per annum	per ha per annum	per ha per annum
Livestock Sales	$1,807	$1,868	$1,870	$1,884	$1,908	$1,954	$2,047	$2,233	$2,420	$2,606
Variable costs										
Livestock Purchases	$1,541	$1,546	$1,548	$1,560	$1,579	$1,618	$1,695	$1,849	$2,003	$2,157
Freight In	$27	$27	$27	$27	$27	$28	$29	$32	$35	$37
Freight Out	$98	$99	$99	$100	$101	$103	$108	$118	$128	$138
Treatment Expenses	$1	$1	$1	$1	$1	$1	$1	$1	$1	$1
Selling Expenses	$9	$9	$9	$9	$9	$9	$10	$11	$12	$13
Forage growing costs	$125	$181	$181	$181	$181	$181	$181	$181	$181	$181
Total Expenses	$1,800	$1,863	$1,865	$1,878	$1,899	$1,941	$2,025	$2,192	$2,360	$2,527
Gross Margin	$7	$5	$5	$7	$9	$13	$23	$41	$60	$78
Gross Margin per hectare per annum (after interest)	**-$12**	**-$14**	**-$14**	**-$13**	**-$11**	**-$6**	**$2**	**$19**	**$35**	**$52**
Kilograms of liveweight gain per hectare per annum	145	178	179	180	182	187	196	213	231	249

References

Whish G (ed.) (2011). Land types of Queensland. Version 2.0. Prepared by the Grazing Land Management Workshop Team, Department of Employment, Economic Development and Innovation, Brisbane. PR07-3212.

Peck, G. A., S. R. Buck, A. Hoffman, C. Holloway, B. Johnson, D. N. Lawrence and C. J. Paton (2011). Review of productivity decline in sown grass pastures. Sydney, Meat and Livestock Australia.

Hardaker, B.J., Richardson J.W., Lein, G. and Schumann K.D. (2004), Stochastic efficiency analysis with risk aversion bounds: a simplified approach, The Australia Journal of Agricultural and Resource Economics, Volume 48, Issue 2, June 2004

Appendix

Glossary of key terms used in evaluation and economic analysis

Adult equivalent (AE): Cattle of different ages and body weight have different requirements for feed. In determining the composition and grazing pressure of a herd, it is necessary to work on a common animal unit. In this analysis an AE is defined as a 450 kg dry animal.

Note: Adult Equivalents for dry cattle are based on relativity to a standard weight of beast carried for 12 months. AEs for breeders are based on weight, plus a loading for breeders that wean a calf. This loading represents the extra nutritional requirement of a cow that rears a calf, relative to a dry cow. The suggested loading for rearing a calf is 0.35 AE. This covers the extra load of pregnancy, lactation, and pasture consumed by the calf itself up to age 5 months, at which point the weaner can be rated in its own right.

Adult Equivalents are calculated for a PERIOD of time, not for a point in time. Except for weaners and sale cattle, this will be 12 months, e.g. from age 12 months to 24 months. The weaner group will usually be rated for 7 months (ages 5 to 12 months) for keepers, and less for those sold.

One adult equivalent (AE) can be thought of as the amount of feed consumed in 12 months by a non-lactating animal of average weight 450 kg. Therefore, if average feed consumption is 2.2% of bodyweight, this would be equivalent to approximately 3,650 kg dry matter per year for one AE. Cattle supplemented with phosphorus or urea will eat more than unsupplemented cattle of the same bodyweight. For full-year supplementation, feed intake could be 20% higher than for unsupplemented cattle. When comparing herds with and without supplementation, reduce the total AE of the supplemented herd to ensure a fair comparison (17% reduction will equate to 20% extra feed consumption), applying pro-rate reduction for part-year supplementation.

Assumptions: Hypotheses about factors or risks which could affect the progress or success of an intervention. Note: Assumptions can also be understood as hypothesised conditions that bear on the validity of the evaluation itself, e.g. about the characteristics of the population when designing a sampling procedure for a survey.

Attribution: The ascription of a causal link between observed (or expected to be observed) changes and a specific intervention. Note: Attribution refers to that which is to be credited for the observed changes or results achieved. It represents the extent to which observed effects can be attributed to a specific intervention, or to the performance of one or more partner taking account of other interventions, (anticipated or unanticipated) confounding factors, or external shocks.

Base-line study: An analysis describing the situation prior to an intervention, against which progress can be assessed or comparisons made.

Benefit-cost analysis (BCA): A conceptual framework that can be applied to the economic evaluation of projects and programs in the public sector. It differs from a private financial appraisal in that it considers all gains (benefits) and all losses (costs), regardless of to whom they accrue.

Benefit-cost ratio (B/C Ratio): The ratio of the present value of investment benefits to the present value of investment costs. A value greater than 1.0 suggests a profitable investment.

Counterfactual: The situation or condition which hypothetically may prevail for individuals, organisations, or groups where there is no intervention.

Cost effectiveness: Comparison of the relative costs of achieving a given result or output by different means

Data collection tools: Methodologies used to identify information sources and collect information during an evaluation. Note: Examples are informal and formal surveys, direct and participatory observation, community interviews, focus groups, expert opinion, case studies and literature search.

Demand elasticity: The proportional change in the quantity demanded for a given change in the relevant price. Usually negative, e.g. "an own-price beef demand elasticity" of -1.0 means that a 1% increase in the price of beef induces a 1% decrease in the demand for beef over the relevant period of adjustment. Values greater than –1 in absolute value are called “elastic” and imply high responsiveness to price; values less than –1 in absolute value are called “inelastic” and imply low responsiveness to price.

Discounting: The process of adjusting expected future costs and benefits to values at a common point in time (typically the present), to account for the time preference of money. With discounting, a stream of funds occurring at different time periods in the future is reduced to a single figure by summing their present value equivalents to arrive at a Net Present Value. Note that discounting is not carried out to account for inflation. Discounting would still be applicable in periods of nil inflation.

Dry sheep equivalent (DSE): Defined as a 2 year old merino sheep (weaner or non-lactating non-pregnant ewe). There are roughly 8 DSEs to one AE.

Effect: Intended or unintended change due directly or indirectly to an intervention. Related terms: results, outcome.

Effectiveness: The extent to which the intervention’s objectives were achieved, or are expected to be achieved, taking into account their relative importance. Note: Also used as an aggregate measure of, or judgment about, the merit or worth of an activity, i.e. the extent to which an intervention has attained, or is expected to attain, its major relevant objectives efficiently in a sustainable fashion and with a positive institutional impact.

Environmental benefit: Can be measured by changes in biodiversity, hydrology, water quality, soil health, salinity, vegetation and sediment load.

Note: During past evaluations, considerable emphasis has been placed on the social and environmental benefits provided for the industries impacted by the investment outcomes. For such benefits to be used in an analysis, not only does the outcome need to be measureable in some form, a causal link needs to be established between the investment and the outcome claimed. It is the responsibility of the person seeking to claim benefits arising from such an investment to provide sufficient evidence to satisfactorily establish the link, for or example, if the social benefits of an investment are identified as:

- promoting a safer and more efficient working environment
- increasing water security for businesses relying on dam water
- providing extra employment.

The transformation of the identified benefits into measurable outcomes might involve assessing, over time, the safety records of staff involved in the enterprise to identify improvement due to the investment, surveying industry participants to determine the value of improved water security, and conducting an industry-wide survey to determine the outcome that the activity will have on the labour market.

A similar process needs to be applied to claimed environmental benefits. To convert indicators such as reduced pressure on water resources and a reduction in nutrient and pesticide leaching into measurable impacts, project staff would need to quantify the volume of water likely to be saved, the level of improvement in water quality likely to be made and the region in which that saving or improvement will be made. Some estimate for the environmental value of water quantity and quality in that region would then need to be determined.

Evaluation: The systematic and objective assessment of an on-going or completed project, program or policy, its design, implementation and results. The aim is to determine the relevance and fulfilment of objectives, development efficiency, effectiveness, impact and sustainability. An evaluation should provide information that is credible and useful, enabling the incorporation of lessons learned into the decision-making process of both recipients and donors. Evaluation also refers to the process of determining the worth or significance of an activity, policy or program, an assessment, as systematic and objective as possible, of a planned, on-going, or completed development intervention.

Note: Evaluation in some instances involves the definition of appropriate standards, the examination of performance against those standards, an assessment of actual and expected results and the identification of relevant lessons. Related term: review.

Ex-ante evaluation: An evaluation that is performed before implementation of an intervention. Related terms: appraisal, quality at entry. Evaluates a potential investment based on a number of assumptions of the likely level of inputs, outputs, impacts and outcomes (and their values) that will occur as the investment proceeds.

Ex-post evaluation: Evaluation of an intervention after it has been completed.

Note: It may be undertaken directly after or long after completion. The intention is to identify the factors of success or failure, to assess the sustainability of results and impacts, and to draw conclusions that may inform other interventions.

Ex-post or historical analysis: Occurs after the research investment has been completed. It analyses the investment after completion with respect to benefit and cost outcomes attributable to the investment.

Gross margin budget: A gross margin is the gross income from an enterprise less the variable costs incurred in achieving it. It excludes fixed or overhead costs.

Impacts: Positive (and negative), primary, direct effects produced by the adoption of an intervention. Impacts can sometimes be indirect, intended or unintended but are usually characterised by a direct relationship between the adoption of an output and a resulting firm or individual level impact. Outcomes are seen as the broader result of impacts.

Indicator: Quantitative or qualitative factor or variable that provides a simple and reliable means to measure achievement, to reflect the changes connected to an intervention, or to help assess the performance of a development actor.

Industry development: general term used to describe activities progressing industry growth.

Inputs: The financial, human, and material resources used for the intervention. Inputs are resources used to implement activities that are directed towards achieving the desired goals/outcomes.

Internal Rate of Return (IRR): The discount rate at which the present value of income from a project equals the present value of total expenditure (capital and annual costs) on the project; the breakeven discount rate.

Investment appraisal: An evaluation of the profitability of an investment.

Investment criteria: Are measures of the economic worth of an investment such as Net Present Value, Benefit-Cost Ratio and Internal Rate of Return.

Key Performance Indicators (KPIs): KPIs are tracking indicators used during a project or program to measure the achievement of outputs against targets.

Logical framework (Logframe): A management tool used to improve the design of interventions, most often at the project level. It involves identifying strategic elements (objectives, inputs, outputs, impacts, outcomes) and their causal relationships, indicators, and the assumptions or risks that may influence success and failure. It thus facilitates planning, execution and evaluation of a development intervention. Related term: results-based management.

Market failure: A situation in which, through imperfections in the market mechanism, economic efficiency has not been achieved. Market failure may manifest itself either in the inability of the system to produce goods which are wanted, or by misdistribution of resources which would be improved in such a way that some consumers would be better off and none worse off. That is, resource allocation is not Pareto-optimum.

Monitoring: The ongoing process of collecting performance data concerning an activity, project, program or activity to determine whether set standards or requirements are being met. Related term: performance monitoring, indicator.

Net Present Value (NPV): The discounted value of the benefits of an investment less the discounted value of the costs, i.e. present value of benefits - present value of costs.

Objectives: At the agency level, objectives are the generalised long-term statements that the organisation is aiming to achieve to realise its vision. At the project or activity level, objectives identify the intent or purpose of the project or activity.

Opportunity cost: The benefit foregone by using a scarce resource for one purpose instead of its next best alternative use.

Outcome: The likely or achieved effects of an intervention's outputs and impacts. In this definition, impacts are seen as the direct result of adoption of outputs by adoptees and outcomes are seen as the more general, broader implications of the adoption of impacts. For example, the introduction of the biological control for banana skipper in Papua New Guinea had the direct impact of reducing the damage caused by the pest on production, resulting in improved food security. The resulting outcomes were a release of labour for production of cash and other crops and a reduction in the incidence of malnutrition. The release of a biological control in Australia is unlikely to have similar outcomes for food security. Related terms: result, outputs, impacts, effect.

Outputs: The products, capital goods and services that result from an intervention; may also include changes resulting from the intervention which are relevant to the achievement of outcomes.

Present Value of Benefits (PVB): The discounted value of a stream of future benefits.

Present Value of Costs (PVC): The discounted value of a stream of future costs.

Private benefit: The benefit to the user of a good or service.

Private goods have two specific properties:

- Rivalry. Consumption of the good (or service) decreases the amount available to others. The good (or service) can therefore be measured and sold in units.
- Excludability. A price system can be used and this will exclude people from using the good (or service) if they are not prepared to pay.

Examples of private goods are fertiliser, fuel and gold.

Public goods have two specific properties:

- Non-rivalry. Consumption of the good (or service) does not decrease the amount available to others. The good (or service) cannot be measured and sold in units.
- Non-excludability. A price system cannot operate because people who are not prepared to pay (free riders) cannot be excluded from using the good (or service).

Examples of public goods are the provision of defense services for the country, the results of much agricultural and environmental research. Public goods do not necessarily mean something is good for the public. Incorrect usage of the term “public good” includes – “the public good aspects of what we do”; “protection of the public good is a fundamental role of government”; “extension services clearly lead to public goods”; “in the public good”; and “public versus private good”.

Public benefit: this term is <u>not</u> synonymous with Public Good. It is probably best described as the total of private benefits.

Product: A product is a physical entity that is created as a result of a project or activity.

Project: An intervention that consists of a set of planned, interrelated tasks designed to achieve defined objectives within a given budget and a specified period of time. Therefore, projects have identifiable start and end dates whereas activities do not.

Project evaluation: Evaluation of an individual intervention designed to achieve specific objectives within specified resources and implementation schedules, often within the framework of a broader program.

Note: Cost benefit analysis is a major instrument of project evaluation for projects with measurable benefits. When benefits cannot be quantified, cost-effectiveness may be a suitable approach.

Project or program objective: The intended physical, financial, institutional, social, environmental, or other results to which a project or program is expected to contribute.

Purpose: The publicly stated objectives of the program or project.

Salary on costs: Staff on-costs cover payroll tax, superannuation, work cover premiums, leave loadings, long service leave accrual and performance-based annual salary increment.

Social benefit: May be measured by changes in such things as education, health, cultural heritage and diversity, safety and security and leisure.

Supply elasticity: The proportional change in the quantity supplied for a given change in the relevant price. Usually positive, e.g. an “own-price cattle supply elasticity” of +1.0 means that a 1% increase in the price of beef induces a 1% increase in the supply of cattle over the relevant period of adjustment. Values greater than +1 are called “elastic” and imply high responsiveness to price, or a flexible production system; values less than +1 are called “inelastic” and imply low responsiveness to price, or an inflexible production system.

Stochastic: A process with an indeterminate or random element as opposed to a deterministic process that has no random element.

Review: An assessment of the performance of an intervention, periodically or on an *ad hoc* basis.

Note: Frequently “evaluation” is used for a more comprehensive and/or more in-depth assessment than “review.” Reviews tend to emphasize operational aspects. Often the terms “review” and “evaluation” are used as synonyms with the Terms of Reference identifying the scope of the activity. Related term: evaluation.

Research: An activity that meets the Australian Standard Research Classification definition – “creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of [humankind], culture and society, and the use of this stock of knowledge to devise new applications”. A methodical investigation into a subject in order to discover facts, establish or revise a theory or to develop a plan of action based on the facts discovered.

Risk analysis: An analysis or an assessment of factors (called assumptions in the logframe) that affect or are likely to affect the successful achievement of an intervention’s objectives. A detailed examination of the potential unwanted and negative consequences to human life, health, property, or the environment posed by interventions; a systematic process to provide information regarding such undesirable consequences; the process of quantification of the probabilities and expected impacts for identified risks.

Sensitivity analysis: An analytical technique to test systematically what happens to the earning capacity of a project if events differ from the estimates made about them in planning.

Stakeholders: Agencies, organizations, groups or individuals who have a direct or indirect interest in the intervention or its evaluation.

Sustainability: The continuations of benefits from an intervention after major activities are completed. The probability of continued long-term benefits and the resilience to risk of the net benefit flows over time.

Terms of reference: Written document presenting the purpose and scope of the evaluation, the methods to be used, the standard against which performance is to be assessed or analyses are to be conducted, the resources and time allocated, and reporting requirements. Two other expressions sometimes used with the same meaning are “scope of work” and “evaluation mandate.”

Time preference (or value) of money: An expression referring to the concept that values (or money) received earlier are worth more than values received later. It is the concept underlying discounting.

Triangulation: The use of three or more theories, sources or types of information, or types of analysis to verify and substantiate an assessment.

Note: by combining multiple data sources, methods, analyses or theories, evaluators seek to overcome the bias that comes from single informants, single methods, single observer or single theory studies.

Whole farm budget: Accounts for the gross margins of each of the enterprises considered as well as the fixed or overhead costs of the farm (also called a profit and loss statement). Usually includes a statement of farm assets and liabilities (or a balance sheet).

Validity: The extent to which the data collection strategies and instruments measure what they purport to measure.

Variable costs: Costs which change according to the size of an activity. The essential characteristic of a variable cost is that it changes proportionately to changes in enterprise size (or to change in components of the enterprise)