Burdekin Rangelands beef production systems

Profitable management strategies to build resilience

Queensland Department of Agriculture and Fisheries - Animal Science & Rural Economic Development. February 2024.





GrazingFutures Livestock Business Resilience (GFLBR) project is part of the Farm Business Resilience Program which is jointly funded through the Australian Government's Future Drought Fund and the Queensland Government's Drought and Climate Adaptation Program.

Australian Government

Future Drought Fund

Drought and Climate Adaptation Program

Queensland Government

This publication has been compiled by:
Queensland's Department of Agriculture and Fisheries
Note: all of the herd models, financial and economic analyses have been compiled in the Breedcow and Dynama suite of programs.

Acknowledgements
We thank all Queensland's Department of Agriculture and Fisheries staff, industry partners and producers that provided input into this report.

Summary

This report details the economic implications of management decisions to improve profitability and increase property resilience in the Burdekin Rangelands region of Queensland. Accompanying reports in this series present strategies and results for other regions across Queensland's grazing lands. It is intended that these analyses will support decision-making and the implementation of profitable and resilient grazing, livestock management and business practices. The property-level, regionally specific livestock and business models that we have developed can be used by consultants, advisors and producers to assess both strategic and tactical management decisions for specific properties.

We applied scenario analysis to examine a range of management strategies and technologies that may contribute to building more profitable and drought resilient beef properties in the Burdekin Rangelands region. The production parameters applied in this analysis were intended to represent the long-term average expectation for this region. However, there is an obvious challenge in adequately accounting for the high annual rainfall variability that occurs in this region. Regardless, the analysis provides a broad understanding of the opportunities available for improvement, the potential response functions, and an appropriate framework to support decision making.

The initial constructed base property was 25,000 ha dominated by *Eucalypt* woodlands supporting native pastures and with naturalised legumes from the *Stylosanthes* genus present across the property. The property was marginally deficient in phosphorus (P) for cattle on average (6-8 mg/kg bicarbonate-extracted P in the top 100 mm of soil). Around 50% of the property was considered to be currently in C land condition (scale A-D) due, primarily, to a high incidence of the invasive Indian couch (*Bothriochloa pertusa*) pasture grass. The property was stocked at the estimated long-term safe carrying capacity, and a systematic wet season pasture spelling regime was in place, so as to maintain the existing land condition ratings. The property carried 2,903 head of cattle consisting of 1,216 breeders mated, 759 calves weaned, and with a steer turnoff age of 42 months (546 kg average liveweight in the paddock). Using linear weight adult equivalent (AE) methodology, as applied in the Breedcow and Dynama (BCD) herd budgeting software, this was rated as 2,500 AE (1 AE: 10 ha). Discussion of alternative AE methodologies, and the corresponding total property AE rating and optimal age of steer turnoff calculations, are given in the report. The management features of the self-replacing Brahman beef breeding herd included continuous mating and dry season nitrogen (N) and P supplementation as a loose mineral mix. Initial herd performance parameters were: 62% weaning rate, 3.0% mortality rate of breeders, 2.0% mortality rate across the whole herd, and an average annual post-weaning weight gain for steers of 122 kg/head. It is important to recognise that these performance parameters are long-term (30-year) average expectations over the full range of seasonal conditions expected in the Burdekin Rangelands. The stocking rate was expected to fluctuate above and below 2,500 AE, according to seasonal conditions. However, representative herd numbers were modelled as an average expectation over 30 years with the understanding that in some years greater numbers would be carried and in other years, less. Drought feeding was not incorporated in the modelling of the representative base herd.

To increase viability, and to build resilience to droughts, floods and market shocks, beef producers need to increase profit and equity. Furthermore, to make timely and optimal management decisions producers need to assess the impact of alternative strategies on profitability, risk, and the period of time before benefits can be expected. Management strategies or technologies that can be applied to

improve the profitability and resilience of a beef property to drought are generally of a strategic nature. A change in management strategy is best initially assessed using a long-term budgeting framework that applies herd models integrated with partial discounted cash flow budgets. The economic and financial effect of implementing each strategy was assessed by comparison to a base production system for the constructed property. Property-level productivity and profitability was assessed over a 30-year investment period and incorporated (1) change in profit and risk generated by alternative operating systems, (2) changes in unpaid labour, herd structure and capital, and (3) the implementation phase.

Management decisions considered in response to, or recovery from, drought need consideration of both short-term and long-term implications. These were examined in our previous analyses for the Fitzroy, Northern Gulf and Central West Mitchell Grasslands regions of Queensland, and those reports contain detailed examples of drought response and recovery analysis (Bowen and Chudleigh 2018b, Bowen *et al.* 2019a,b). We have not repeated this exercise for the Burdekin Rangelands region but instead refer readers to the previous reports which are available from the project internet page: https://futurebeef.com.au/resources/improving-profitability-and-resilience-of-beef-and-sheep-businesses-in-queensland-preparing-for-responding-to-and-recovering-from-drought/. Additionally, spreadsheet tools that can be used to assess drought response and recovery options, and recorded presentations giving detailed explanation of how to use them, are provided on the project internet page.

Preparing for drought by improving the profit and resilience of the beef enterprise

The first step in any analysis of strategies to improve property profit and resilience should be to determine the optimal herd structure, i.e. the most profitable sale age for steers and cull females. The most profitable herd structure for the Burdekin Rangelands beef cattle property based on adjusted last 7.5-year cattle prices (October 2014-April 2022) was found to be either a 30 or 42-month steer sale target and 12-year female cull age. The most profitable age to sell excess heifers was found to be at about 30 months of age. Reducing the maximum cull cow age to 10 years of age reduced the herd gross margin by about 2%. Therefore, beef producers concerned about the risk of managing the older cohorts of cows in the herd can reduce the cull age and not suffer a large penalty. The 42-month steer sale age (546 kg paddock liveweight) was applied as the base herd structure throughout the report. The effect of moving from a weaner sale target (the least profitable age of turnoff) to a 42-month steer sale age was assessed and found to provide an extra $127,100 profit/annum on average over the 30 years of the analysis (Table 1). However, the delay in steer sales caused by moving from a weaner to older age of steer turnoff can provide a significant obstacle to implementing this strategy for some producers. Short term changes in the relative prices of cattle classes may result in a different optimal age of steer sale to that identified based on longer-term historical prices and may identify opportunities to increase profitability in the short term by deviating from the long-term sale target. However, having an understanding of the optimal herd structure based on cattle price data over a more extended period (e.g. 7-10 years) will allow profit to be maximised over the long term by moving back to the long-term optimal herd structure following deviations.

In addition to optimising the age of turnoff for steers over the longer term, the strategies that added most to the profit of the Burdekin Rangelands representative property included supplementing with P during the wet season to address the marginal-P deficiency of the cattle herd, planting stylo-only or stylo-grass pastures for steers and using home-bred bulls.

The analysis indicated that changing from a strategy of annual supplementation with loose lick supplements supplying N+P during the dry season to a strategy of annual supplementation with P during the wet season is likely to improve the profit of the property by ca. $37,700/annum (Table 2). Properties with land types resulting in more severe P deficiency of cattle than the representative property (i.e. deficient to acutely deficient) would benefit from even greater improvements in profitability due to provision of effective wet season P supplements. This analysis indicates that supplementing with N+P on an annual basis in the dry season is not profitable for herds either adequate or marginally deficient in P. We assumed in our analysis that other herd best-practice management was followed including (1) stocking to the long-term safe carrying capacity including timely adjustment of stock numbers to match forage supply, and (2) timely weaning to maintain breeder body condition.

Establishing stylo-only or stylo-grass pastures for all steers in cultivated strips on moderate fertility land types (e.g. red earths) added substantially to the profitability of the representative property but only when herd numbers were increased rapidly so that the extra pasture biomass produced could be fully utilised as soon as possible. Targeting the most profitable steer sale age was also important. The most profitable scenario when cultivated strips of sown pasture were established on moderate fertility land types was that of sowing stylo and grass with a quick herd build-up and turn-off of steers at 35 months of age in November ($77,800 extra profit/annum). Additionally, if a 25 c/kg liveweight price premium were received at this November sale time, the profitability of the strategy increased by 1.7-fold (to $129,700/annum). However, the long period of time before these sown pasture investments were paid back (12-18 years), and the substantial peak deficits, would provide an obstacle to adoption of this strategy for many producers.

Compared to large-scale sown pasture development on the moderate fertility land types, targeting a smaller area (500 ha in this example) of highly suited land types for stylo or stylo-grass establishment in cultivated strips was a relatively lower risk investment and provided more reliable returns which were in the range of $35,000 to $45,000 extra profit/annum. For instance, targeting the more fertile land types reduced payback periods by at least 50% and resulted in substantially smaller peak deficits, in the range of -$102,000 to -$166,000 cf. $1 million or greater peak deficit for the large-scale, moderate fertility, pasture development.

The substantial improvement in property profit due to utilising home-bred bulls (i.e. $35,800/annum) arises from the high average prices some beef property managers pay for herd bulls and the difference between that cost and costs associated with breeding, and objectively selecting, bulls from male weaners produced by the herd. This strategy is also associated with a relatively small peak deficit (-$17,300) and short payback period (2 years).

This analysis could not show substantial business benefits when genetic change, supplementation of young cows and reducing calf loss was assessed. However, this contrasts with BREEDPLAN's BreedObjective (Barwick, 1997) which is a calculated impact on animal profitability in a beef system and Fordyce (2019) who demonstrated that strategic targeted true protein supplementation of beef females may improve business margins. The analysis found that where calf losses were reduced by 50% (from a median loss rate of 12.9%) by either low levels of expenditure per cow ($10) or capital expenditure of $200,000 a small positive NPV was achieved. This however could change if calf loss rates were higher. At the time of this report, large scale research work is currently underway to assess management options to reduce calf loss. The analysis does, however, reinforce the critical importance of implementing low-cost strategies to achieve optimal breeder body condition and herd structure such as good pasture management and weaning management to achieve drought resilience and business resilience more broadly.

As demonstrated in this study, the application of an economically sound framework is critical to evidence-based decision making. The scenarios modelled here are aimed at providing a broad understanding of the range of opportunities available for improvement, the potential response functions in the production system, as well as an appropriate framework to support decision making. The property-level, regionally specific, herd and business models that we have developed can be used to assess both strategic and tactical decisions for individual businesses. Whilst every effort was made to ensure the assumptions used in each scenario were accurate and validated with industry participants, relevant experts or published scientific studies, the results presented should be viewed as indicative only.

Table 1 - Profitability and financial risk of implementing alternative strategies to improve profitability and resilience of a beef property in the Burdekin Rangelands region

The analysis was conducted for a 30-year investment period using current input costs (2022) and average cattle prices over the 7.5-year period, October 2014-April 2022, with adjustment downwards to account for seasonally driven demand from early 2021

Scenario	Annualised NPV[A]	Peak deficit (with interest)[B]	Years to peak deficit	Payback period (years)[C]	IRR (%)[D]
Increasing the age of steer turnoff from weaners to 42 months[E] (p. 50)	$127,100	-$371,600	3	3	n/c
Genetic improvement of weaning rate (p. 57)					
Immediate changeover of bulls	$1,500	-$173,700	6	24	6.1
Gradual changeover of bulls	$10,700	n/c	n/c	n/c	n/c
Home-bred bulls (p. 62)	$35,800	-$17,300	2	2	142
Reducing foetal/calf loss by 50% by spending (p. 64)					
$10/breeder	$11,000	-$13,600	1	1	96
$20/breeder	-$2,400	-$162,200	29	n/c	-2.2
$30/breeder	-$15,700	-$1,042,700	n/c	n/c	n/c
$200,000 capital	$11,900	-$200,000	1	11	12
$400,000 capital	-$400	-$403,900	5	n/c	4.9
$600,000 capital	-$12,800	-$852,800	n/c	n/c	1.8
Supplementing weaner heifers to improve conception rates as 2-year-olds at first mating (p. 68)	-$88,300	-$5,867,200	n/c	n/c	n/c
Supplementing the lightest third of the weaner heifer cohort to improve conception rates as 2-year-olds at first mating (p. 71)	-$28,600	-$1,902,200	n/c	n/c	n/c
Supplementing first-calf heifers to improve re-conception rates (p. 74)	-$22,500	-$1,494,800	n/c	n/c	n/c
Cultivated strips of sown pastures for all steers (p. 77)					
(1) Stylo-grass pastures					
18-month sale age, June					
Slow herd build up	-$75,500	-$5,292,500	29	n/c	n/c
Quick herd build up	$67,400	-$970,200	3	12	13%
35-month sale age, November					
Slow herd build up					
Average cattle prices	-$25,100	-$3,202,800	18	n/c	3%

Scenario	Annualised NPV[A]	Peak deficit (with interest)[B]	Years to peak deficit	Payback period (years)[C]	IRR (%)[D]
+25 c/kg liveweight	$20,400	-$2,230,800	13	n/c	6%
Quick herd build up					
Average cattle prices	$77,800	-$1,925,800	5	16	10%
+25 c/kg liveweight	$129,700	-$1,879,600	4	13	13%
38-month sale age, February					
Slow herd build up	-$28,400	-$3,766,000	23	n/c	4%
Quick herd build up	$54,800	-$2,450,500	7	n/c	8%
(2) Stylo-only pastures					
18-month sale age, June					
Slow herd build up	-$96,900	-$6,549,600	29	n/c	n/c
Quick herd build up	$25,100	-$1,045,400	3	18	8%
35-month sale age, November					
Slow herd build up					
Average cattle prices	-$73,800	-$5,257,500	29	n/c	n/c
+25 c/kg liveweight	-$29,600	-$2,942,600	18	n/c	3%
Quick herd build up					
Average cattle prices	-$20,600	-$2,058,400	13	n/c	3%
+25 c/kg liveweight	$27,200	-$1,902,000	5	n/c	7%
38-month sale age, February					
Slow herd build up	-$78,300	-$6,213,700	29	n/c	0.5%
Quick herd build up	-$44,400	-$4,114,600	28	n/c	2%
Cultivated strips of stylo-grass pastures for steers, 500 ha of more fertile land types (p. 88)					
(1) Stylo-grass pastures					
18-month sale age, June	$44,600	-$164,300	4	6	30
30-month sale age, June	$42,900	-$165,800	4	6	28
35-month sale age, November (+25c/kg liveweight)	$44,700	-$137,800	4	6	32
(2) Stylo-only pastures					
18-month sale age, June	$36,800	-$123,300	4	6	35
30-month sale age, June	$35,300	-$125,000	4	6	32
35-month sale age, November (+25c/kg liveweight)	$34,600	-$102,200	4	6	36

AE, adult equivalent expressed as linear weight AE; n/c, not able to be calculated.

[A]**Annualised (or amortised) NPV** (net present value) is the sum of the discounted values of the future income and costs associated with a farm project or plan amortised to represent the average annual value of the NPV. A positive annualised NPV at the required discount rate means that the project has earned more than the 5% rate of return used as the discount rate. In this case it is calculated as the difference between the base property and the same property after the management strategy is implemented. **The annualised NPV provides an indication of the potential average annual change in profit over 30 years, resulting from the management strategy.**

[B]**Peak deficit is the maximum difference in cumulative net cash flow between the implemented strategy and the base scenario over the 30-year period of the analysis.** It is compounded at the discount rate and is a measure of riskiness.

[C]**Payback period is the number of years it takes for the cumulative net cash flow to become positive.** The cumulative net cash flow is compounded at the discount rate and, other things being equal, the shorter the payback period, the more appealing the investment.

[D]**IRR (internal rate of return) is the rate of return on the additional capital invested**. It is the discount rate at which the present value of income from the project equals the present value of total expenditure (capital and annual costs) on the project, i.e., the break-even discount rate. It is a discounted measure of project worth. n/c indicates that the IRR model was unable to identify a value.

[E]The base herd for this comparison was turning off weaner steers. All subsequent strategies were assessed with comparison to a base herd turning off 42 month-old steers (the optimum).

Table 2 - Profitability and financial risk of feeding inorganic supplements to cattle herds grazing land types in the Burdekin Rangelands region which are either Adequate, Marginal, Deficient or Acutely Deficient in phosphorus for cattle[A] (p. 94)

The analysis was conducted for a 30-year investment period using current input costs (May 2022) and average cattle prices over the 7.5-year period, October 2014-April 2022, with adjustment downwards to account for seasonally driven demand from early 2021

Note that the Marginal P, 2,500 AE herd with dry season N+P supplements was the representative base property against which strategies were assessed in Table 1, whereas a herd fed no supplements was the base for each scenario in Table 2

Scenario	Annualised NPV	Peak deficit (with interest)	Years to peak deficit	Payback period (years)	IRR (%)
Adequate P herd					
No P or N	Base	Base	Base	Base	Base
Wet season P	-$25,700	-$1,709,400	n/c	n/c	n/c
Dry season N+P	-$39,400	-$2,620,900	n/c	n/c	n/c
Dry season N+P, wet season P	-$64,900	-$4,311,100	n/c	n/c	n/c
Marginal P herd					
No P or N	Base	Base	Base	Base	Base
Wet season P	$32,700	-$85,800	2	2	56
Dry season N+P	-$5,000	-$356,600	29	n/c	-0.31
Dry season N+P, wet season P	$27,100	-$215,700	2	4	31
Deficient P herd					
No P or N	Base	Base	Base	Base	Base
Wet season P	$98,400	-$119,800	2	2	113
Dry season N+P	$8,900	-$241,800	2	7	14
Dry season N+P, wet season P	$96,000	-$312,300	2	2	53
Acute P herd					
No P or N	Base	Base	Base	Base	Base
Wet season P	$168,900	-$158,400	2	2	115
Dry season N+P	$79,500	-$266,200	2	3	40
Dry season N+P, wet season P	$166,700	-$367,800	2	2	64

n/c, not able to be calculated; N, nitrogen; P, phosphorus.

[A]Definitions of the economic metrics and abbreviations are given in the footnotes of Table 1.

Key recommendations for future economic analysis

1. Integrated development, extension and economist activities should continue with the objective of facilitating the adoption of:
   - an appropriate decision-making framework for producers
   - strategies that will improve profitability and business resilience.

   The appropriate decision-making framework, as demonstrated in this analysis and report, combines farm-management economics framework with the knowledge and skills of scientists, industry development extension officers, and property managers, to assess a range of management alternatives for a grazing business.

The first step in conducting a valid analysis of the value of making a change in management requires a marginal economic analysis at the property level, incorporating the impact of the implementation phase, to be conducted. This approach appropriately considers the decisions facing producers and determines the effect of implementing the strategy on property profitability and financial risk. A complete analysis must incorporate:

- the additional capital and labour required
- the effect on herd structure
- the implementation phase
- the timing of costs and benefits
- the economic life of the investment
- an assessment of the financial impacts and risks associated with each change in management.

The benefits and costs of implementing an alternative management strategy must be assessed by altering, over time, the herd performance and inputs of the base scenario to construct new scenarios.

Two key components often missing from the producer decision-making framework are firstly, the collection of relevant data by producers, and secondly the collation of that data into information that can be applied in the analysis of management change. Knowing what data to collect and how to use that data in decision making is key to making better decisions.

2. Regionally relevant economic analysis should be revisited regularly as more, or better, data becomes available. A representative property, developed using local knowledge and data, is a powerful platform for exploring the potential impacts of a change in management strategy with groups of local land managers. The regionally specific herd models developed for the Burdekin Rangelands, and other, regions can be adapted and extended as required to conduct additional analyses and allow individual landholders to incorporate the generic learnings into their decision-making framework.

3. New or developing technologies or management recommendations for industry should be assessed using sound planning methods (as described above and demonstrated in this report) to indicate under what circumstances the technology or strategy would be economically and financially viable.

   For example, sensitivity analysis can indicate the required change in biological performance, or the cost of implementation, at which the technology or strategy would become viable.

Knowledge gaps and research questions identified by the Burdekin Rangelands analysis and report

High-priority research gaps, identified through the analysis and literature review conducted for the Burdekin Rangelands region, should be addressed in future work programs to support profitable and environmentally sustainable grazing businesses. The knowledge gaps identified for the Burdekin Rangelands region are consistent with those identified for five other Queensland regions, and one in the Northern Territory, as part of this same body of work. These include:

1. The most appropriate sown legume and/or grass options for a range of land types across northern Australia as well as an understanding of the required establishment process, grazing and other management required for persistence in grazed paddocks over time.
2. Better data is required to document pasture biomass growth, selection preferences and diet quality for cattle, and resulting animal performance, across seasonal and annual cycles for a range of improved and native pasture options, land types and regions in northern Australia for cattle run under extensive grazing conditions. Historically, data has been collected for either pasture or livestock, rarely for both in an appropriately integrated and complete manner. Data should be collected for different classes of cattle, including steers, heifers, and young breeders.
3. Further research to better quantify and test the link between steer production (annual liveweight gain of either yearling steers or heifers) and breeder production (kg weaned per cow retained) as reported by McGowan (2011) in the Cashcow project and Fordyce (2022) at Spyglass Research Facility. A positive link could vastly increase the amount of research data from grazing trials using steers that could be used to analyse breeding enterprises.
4. Economic analysis undertaken at the herd/property level to determine the best (most profitable) allocation of improved nutrition from perennial legume-grass pastures in the northern forest region amongst classes of cattle, i.e., between heifers, young breeders, and steers.
5. Economic modelling to provide a more sophisticated understanding of the efficiency of non-protein nitrogen supplements for cattle across the Burdekin Rangelands and other regions of Northern Australia to identify the classes of cattle, and under what seasonal conditions, supplementation is profitable.
6. Measured data for changes in breeder cattle performance under commercially relevant extensive grazing situations for strategies of interest, including changes in grazing management. This data should be used to extend/improve the functions of Mayer *et al.* (2012) which enable prediction of conception and mortality rates of breeders under northern Australian conditions. These functions should be more widely applied in future bio-economic modelling studies.
7. Economic modelling (i.e., a marginal analysis at the property and herd level) should be conducted to indicate the biological (pasture, land condition and cattle performance) and economic consequences of implementing:
    - alternative pasture utilisation rates (stocking rates) over time
    - grazing management strategies designed to achieve producer management goals/outcomes, such as:
        - maintaining current land condition over a 30-year period
        - improving current land condition over a 30-year timeframe
        - maximising profit
    - wet season spelling strategies in the Burdekin Rangelands and elsewhere across Northern Australia based on sound production and management assumptions at the property level.

These analyses should be conducted for a range of land types, regions and starting land condition status, using breeder herd models with both appropriate starting performance and impacts for changes in herd performance. Importantly they should be conducted as a marginal analysis of change that fully accounts for the economic, financial and risk aspects of the implementation phase and include industry-relevant management, costs, and prices. Analyses should be conducted and interpreted in light of regulatory obligations and developing market incentives and costs related to environmental outcomes.

1. Bio-economic modelling, applying a marginal analysis at the property level, to examine the consequences of alternative grazing (and other) management strategies over a number of historical climate cycles with different starting points (wet vs dry sequences of years, and initial land condition).
2. Research to develop more effective solutions to avoid and address degradation of grazing lands, for example, assessment of the economic incentives required to encourage voluntary reduction in grazing pressure for property managers.
3. Measured data for improvements over time in reproductive efficiency of breeders (i.e., changes in conception rate, foetal/calf loss prior to weaning and weaning rate), mortality, female and steer growth rates, mature cow weight and steer carcass quality, due to the introduction of bulls with superior EBVs for reproductive efficiency, growth, or selection indices. This should be conducted for breeder herds across a range of regions in northern Australia. This data, along with data for changes in 'breed average' EBVs over time would allow improved economic analysis of the effect of genetic improvement of beef cattle in northern Australia.

This report has proposed conclusions and identified knowledge gaps through strong economic modelling built on a set of specific, well-tested assumptions. It is proposed that these outputs inform industry, RD&E providers and governments in planning future research, development and extension programs for effectively balancing economic and environmental outcomes in northern Australia.

Table of contents

Table of figures

Table of tables

1 General introduction

More than 80% of Queensland's total area of 173 million ha is used for grazing livestock on lands extending from humid tropical areas to arid western rangelands (QLUMP 2022). Most extensive grazing enterprises occur on native pastures. Introduced (sown) pastures constitute less than 10% of the total grazing area and occur on the more fertile land types (McIvor 2005; QLUMP 2022). Grazing industries make an important contribution to the Queensland economy. In 2019-20 the beef cattle industry accounted for 48% ($6.5 billion) of the total gross value of Queensland agricultural production while sheep meat and wool accounted for 0.69% ($0.09 billion), (ABS 2020b).

Queensland's variable rainfall, especially long periods of drought, is one of the biggest challenges for grazing land managers. As well as the potential for causing degradation of the grazing resource and impacting animal welfare, drought has a severe impact on business viability, is a regular occurrence, and provides the context for many of the production and investment decisions made by managers of grazing enterprises. Climate change is expected to result in increased severity and impact of droughts in Queensland in addition to an overall decrease in annual precipitation (2-3% lower by 2050) and warmer temperatures (1.4-1.9^{0}C greater by 2050), (Queensland Government 2022). The Queensland beef and sheep industries are also challenged by variable commodity prices and by pressures on long-term financial performance and viability due to an ongoing disconnect between asset values and returns, high debt levels and a declining trend in terms of trade (ABARES 2019). Although record cattle prices have allowed the gross value of beef production to increase to record prices in 2021-22, commodity prices are expected to ease over the medium term while input cost pressure is likely to sharpen (ABARES 2022). These factors will necessitate a continued focus on farm productivity and profitability.

To remain in production, and to build resilience, beef and sheep properties need to be profitable and to build equity (Figure 1 - The link between profit and growth in equityFigure 1). Building resilience usually means investments must be made and alternative management strategies considered well before encountering extended dry spells or drought. To make profitable management decisions, graziers need to be able to appropriately assess the impact of different strategies on profitability, the associated risks, and the period of time before benefits can be expected. The effects of such alternative management strategies are best assessed using property-level, regionally relevant models that determine whole-of-property productivity and profitability (Malcolm 2000, Malcolm *et al.* 2005).

Decision making during drought often has a more tactical, short-term focus but also relies upon applying a framework to assess the relative value of the alternatives over both the short and medium term. Recovery from drought is also a challenging period when decision making should include both the strategic response – returning to the most profitable herd structure, and the tactical response – how to survive while the production system is being rebuilt. Simple spreadsheets applying a farm management economics framework can be used to quickly gather relevant information and highlight possible outcomes of decision making during and after drought. These tools can complement traditional decision-making processes. Spreadsheets that can be used for this purpose have been made available at the internet page for this project: https://futurebeef.com.au/resources/improving-profitability-and-resilience-of-beef-and-sheep-businesses-in-queensland-preparing-for-responding-to-and-recovering-from-drought/#spreadsheet%20tools.

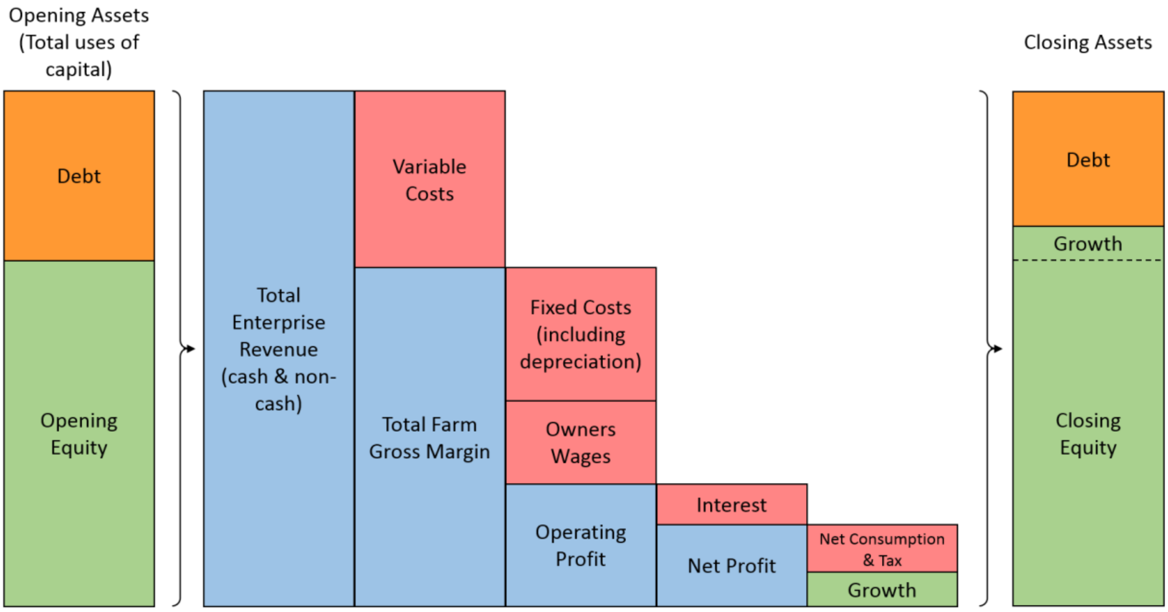

Figure 1 - The link between profit and growth in equity

Although regularly achieving a profit is a key ingredient of a resilient livestock production system, profit does not necessarily drive the goals of the vast majority of livestock producers (McCartney 2017; Paxton 2019). The factors that motivate producers are much more complex and diverse. However, to be a livestock producer in northern Australia you need to be efficient, i.e., you need to regularly produce a profit. Therefore, profit is necessarily the focus of this report, while acknowledging the importance to many of achieving social and environmental sustainability goals.

This report was produced as part of the project titled, '*GrazingFutures Livestock Business Resilience*'. The objective of our work within this project was to improve the knowledge and skills of advisors and graziers in assessing the economic implications of management decisions which can be applied to (1) prepare for, (2) respond to, or (3) recover from drought. We have applied scenario analysis to examine a range of management strategies and technologies that may contribute to building both more profitable and more drought resilient grazing properties for a number of disparate regions across Queensland (Bowen and Chudleigh 2018b, 2021a, 2021b; Bowen *et al.* 2019a, 2019b, 2020a). In doing this we have developed property-level, regionally specific herd, flock and business models, incorporating spreadsheets and a decision support framework that can be used by consultants and advisors to assist producers to assess both strategic and tactical scenarios. This report details the analysis of the economic implications of management decisions for a beef cattle enterprise in the Burdekin Rangelands region of Queensland.

1.1 The Burdekin Rangelands region of Queensland

1.1.1 The land resource

The Burdekin Rangelands region for this report encompasses 5.5 million ha of grazing land (DNRM 2022a; DNRM 2022b) used primarily for cattle production on native pastures (Figure 2). The region comprises the Upper Burdekin and Cape Campaspe sub-catchments of the Burdekin catchment (NQ Dry Tropics 2022). The Burdekin catchment constitutes what is currently designated as the North Queensland (NQ) Dry Tropics Natural Resource Management (NRM) region, used for statistical reporting. The northern part of the Burdekin Rangelands region is dominated by *Eucalypt* woodlands growing on low to moderate fertility soils with important areas of more fertile basaltic soils supporting both woodlands and open grasslands (Rogers *et al*. 1999). In the southern part of the region there are areas of brigalow-gidyea scrubs that have been extensively cleared and developed with sown pastures. Native pastures include black speargrass (*Heteropogon contortus*), *Aristida-Bothriochloa* spp., and *Spinifex* spp. Sown pastures on the more fertile clay soils are primarily buffel grass (*Cenchrus ciliaris*).

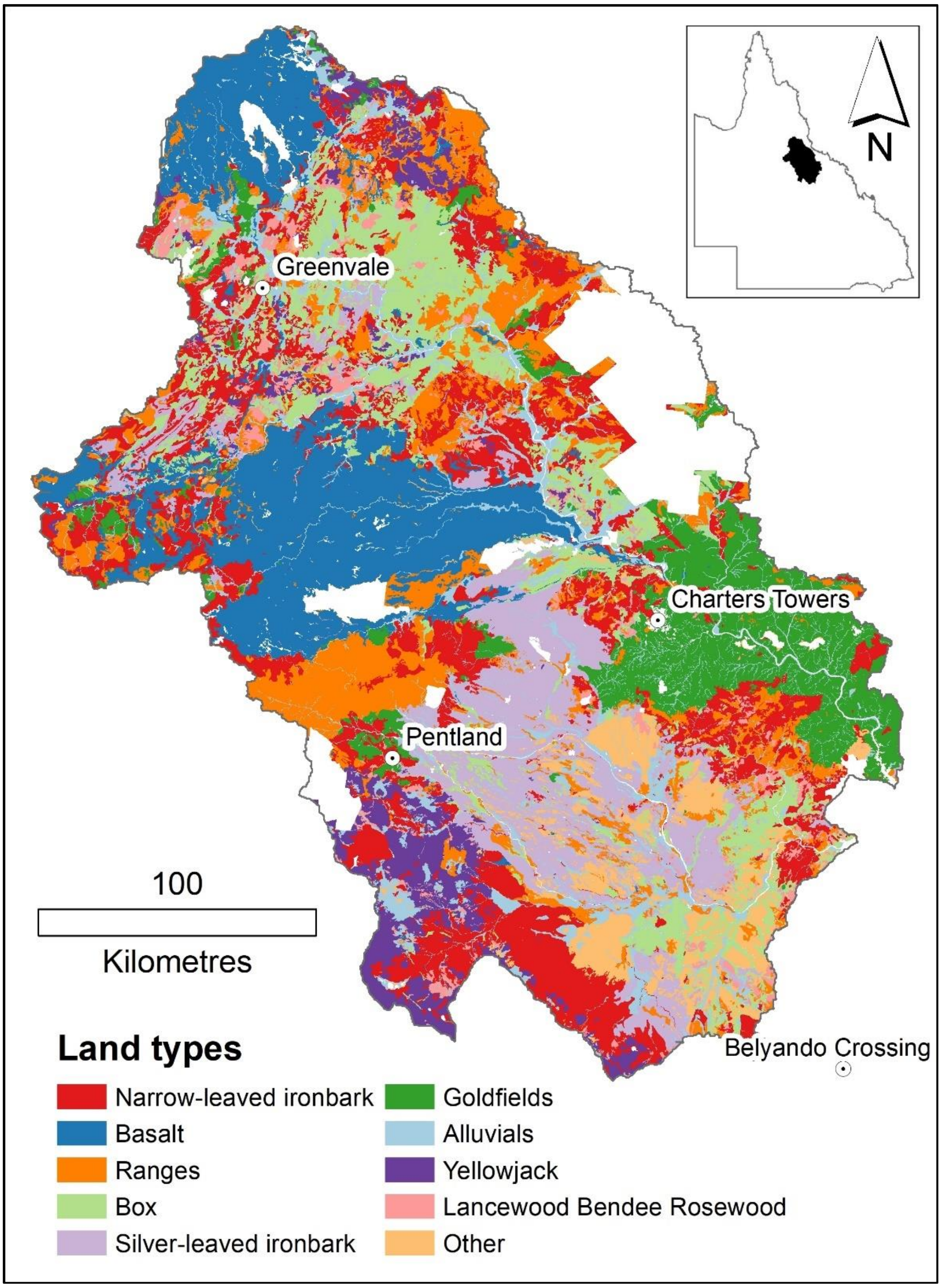

Figure 2 – Map of the Burdekin Rangelands region of Queensland

The Burdekin Rangelands region comprises the Upper Burdekin and Cape Campaspe sub-catchments of the Burdekin catchment. Land used for purposes other than grazing is marked white on the map

1.1.2 Rainfall and drought

The Burdekin Rangelands region is located in the dry tropics and is characterised by a warm, sub-humid climate with a strongly dominant summer rainfall (75-85% falling between October and March). Winters are generally warm and dry. Rainfall is highly variable from year to year. Examples of seasonal distribution of rainfall are shown for five locations across, or just outside, the region (BOM 2022a; Table 3). Annual rainfall in the region ranges from 671 mm at Charters Towers to 578 mm at Beylando Crossing. The variability of annual rainfall in the Burdekin Rangelands region ranges from ‘moderate’ to ‘moderate to high’ (scale low to extreme) based on an index of variability determined by percentile analysis (BOM 2022b; Figure 3). Examples of rainfall variability, expressed as the coefficient of variation of the mean annual rainfall figures, are presented for five locations across, or just outside, the region (BOM 2022a; Table 4). Another example of the variability in annual rainfall in the region is provided in Figure 4 for Charters Towers. Over the 140-year period, 1882-2021, with one missed year of data (2005), the annual rainfall ranged from 109 mm (1902) to 1,632 mm (1974). The average and median rainfall over this 140-year period were 656 and 626 mm, respectively.

Table 3 - Median seasonal distribution of rainfall (mm) at Greenvale, Charters Towers, Ravenswood, Pentland and Belyando Crossing for the 30-year climate normal period 1961-1990 (BOM 2022a)[A]

Town	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Greenvale	96.6	125.4	101.2	36.9	15.1	4.2	0.0	0.0	0.2	8.2	57.0	83.6	622.3
Charters Towers	120.7	99.4	101.2	37.5	14.5	13.9	6.6	3.8	3.0	19.1	37.3	91.8	670.6
Ravenswood	85.2	122.4	69.8	29.2	14.1	9.8	5.1	0.0	0.0	14.9	52.1	78.5	636.2
Pentland	92.0	112.8	69.3	21.2	16.4	5.6	2.0	5.9	0.5	18.0	31.6	85.4	613.2
Belyando Crossing[B]	101.2	64.8	67.0	11.9	26.8	12.4	5.3	4.9	1.3	15.6	49.0	94.4	578.0

[A]Statistics calculated over standard periods of 30 years are called ‘climate normals’ and are used as reference values for comparative purposes. A 30-year period is considered long enough to include the majority of typical year-to-year variation in the climate but not so long that it is significantly influenced by longer-term climate changes. In Australia, the current reference climate normal is generated over the 30-year period 1 January 1961 to 31 December 1990 (BOM 2022a).

[B]Mt Douglas, 1.8 km northeast of Belyando Crossing.

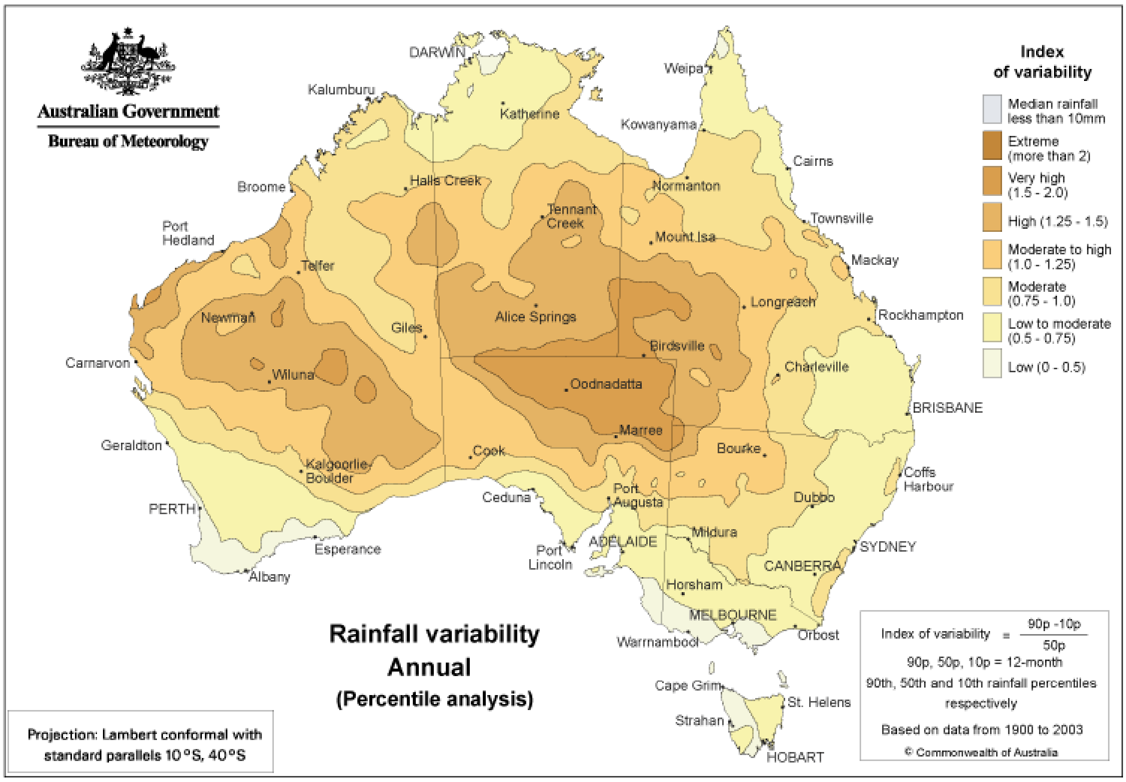

Figure 3 - Map of the annual rainfall variability across Australia determined using the percentile analysis (BOM 2022b)

Table 4 - Mean annual rainfall (mm) and rainfall variability (coefficient of variation) at Greenvale, Charters Towers, Ravenswood, Pentland and Belyando Crossing for the 30-year climate normal period 1961-1990 (BOM 2022a)

Town	**Mean annual rainfall (mm)**	**Rainfall variability expressed as the Coefficient of variation (%)**
Greenvale	673	39
Charters Towers	700	38
Ravenswood	669	36
Pentland	660	37
Belyando Crossing	614	31

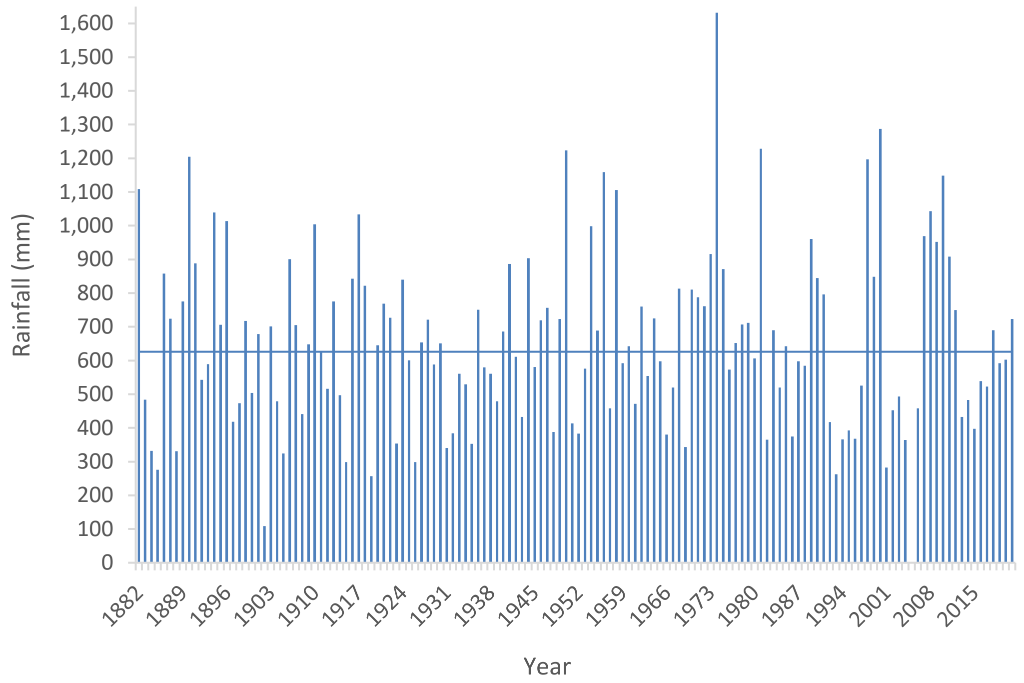

Figure 4 - Annual rainfall at Charters Towers over the 140-year period 1882-2021 (BOM 2022a) with median rainfall (626 mm) over the period shown as a horizontal line

Queensland's variable climate, especially long periods of drought, is one of the biggest challenges for managers of grazing enterprises. Drought regularly has a severe impact on profitability and provides the context for many production and investment decisions made by managers of grazing properties. While there is no universal definition of drought, one that is common in agriculture is the 'drought percentile method' (BOM 2022a). For instance, rainfall for the previous 12-month period is expressed as a percentile, which is a measure of where the rainfall received fits into the long-term distribution. A rainfall value <10% is considered 'drought' (Commonwealth of Australia 2022). This means that a 12-month rainfall total in the bottom 10% of all historical values indicates a drought. An example of historical drought data obtained from the Australian CliMate website using this definition is presented for Charters Towers (Table 5). Using this definition, there have been 27 droughts at Charters Towers since 1900, the longest lasting 12 months. Figure 5 shows the percentage of time, over the period 1964-2022, that Queensland shires have been drought declared (The State of Queensland 2022b). The region designated in the current report as Burdekin Rangelands has been drought declared 20-50% of the time with the southwestern section of the region having the longest time in drought (40-50%), the northern section having the least amount of time in drought (20-30%), and the south-eastern section having an intermediate period of time in drought (30-40% of the time).

Table 5 - Historical droughts (1900–2022) at Charters Towers ranked by depth and duration and with subsequent recovery rainfall[A]

Rank	Drought period	Drought length (months)	Drought depth (percentile)	Subsequent recovery rainfall (mm)
1	Apr 1902 - Mar 1903	12	0	349
2	Feb 1926 - Dec 1926	11	0	232
3	Apr 1993 - Feb 1994	11	0.8	309
4	Mar 1931 - Dec 1931	10	0	247
5	Mar 1961 - Nov 1961	9	1.7	168
6	Oct 1994 - Sep 1995	12	1.7	331
7	Jun 1915 - Jan 1916	8	3.3	206
8	Jan 1952 - Sep 1952	9	0.8	309
9	Feb 1935 - Jan 1936	12	4.2	337
10	Apr 2015 - Nov 2015	8	3.3	37
11	Mar 1905 - Dec 1905	10	3.3	160
12	Jan 1983 - Mar 1983	3	0.8	128
13	Feb 1912 - May 1912	4	2.5	183
14	Jul 1969 - Dec 1969	6	5.8	94
15	Nov 1919 - Dec 1919	2	1.7	7
16	Jan 2003 - Mar 2003	3	2.5	303
17	Feb 1992 - Apr 1992	3	5.8	183
18	Nov 1996 - Jan 1997	3	3.3	131
19	Jan 1967 - Feb 1967	2	1.7	144
20	Feb 1919 - Mar 1919	2	4.2	102
21	Jan 1924	1	0.8	8
22	Dec 2001	1	2.5	34
23	Jan 2016 - Feb 2016	2	4.1	182
24	Jan 1933	1	7.4	45
25	Oct 1932	1	7.5	15
26	May 1966 - Aug 1966	4	9.2	40
27	Dec 2004	1	9.1	50

[A] Drought defined using the 'drought percentile method' and using a 1-year residence period so that rainfall for the previous 12-month period was expressed as a percentile. Rainfall values <10% are considered as 'drought'. (Commonwealth of Australia 2022).

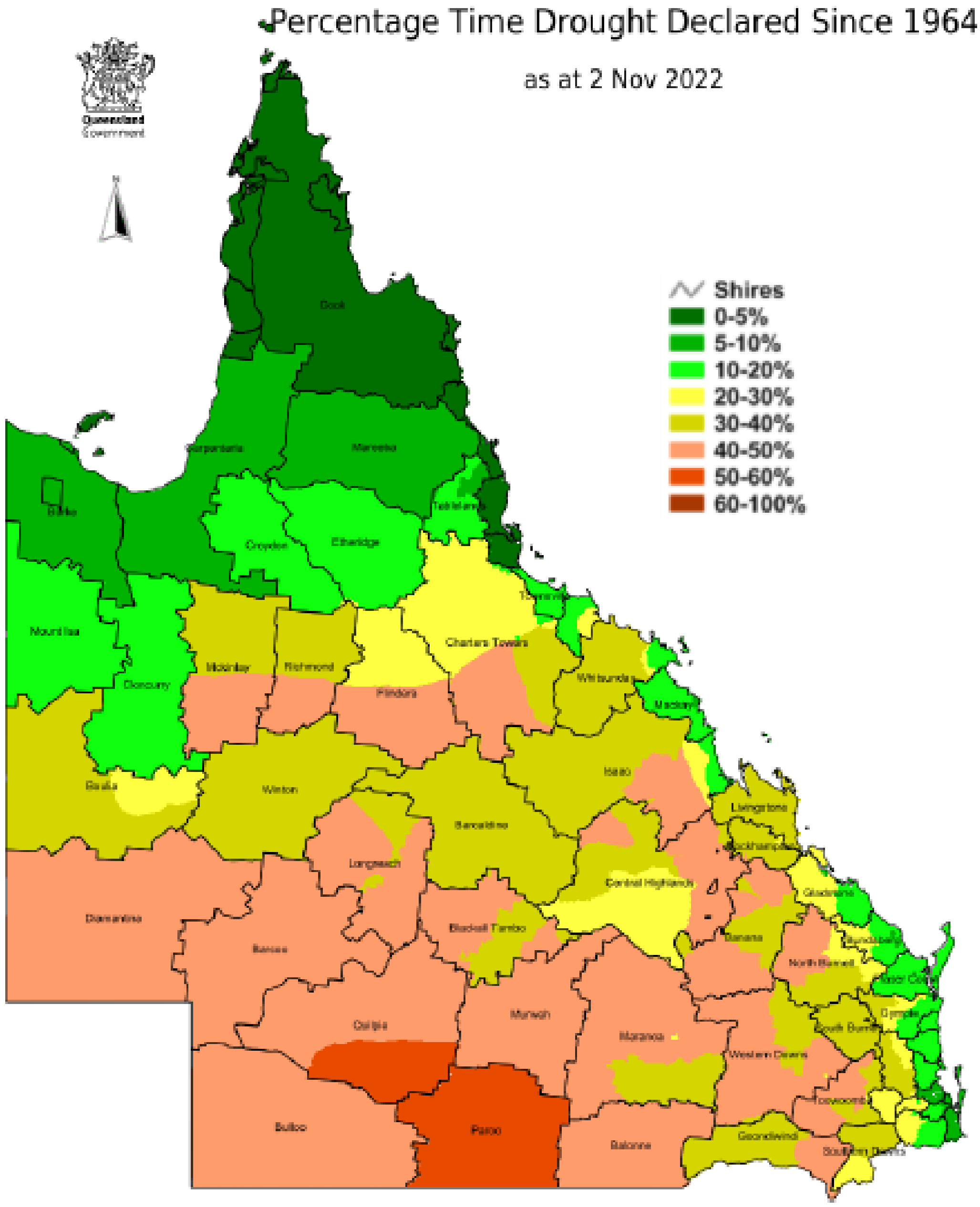

Figure 5 - Map showing the percentage of time Queensland shires have been drought declared over the period 1964-2022 (The State of Queensland 2022b)

1.1.3 Burdekin Rangelands beef production systems

Extensive beef cattle production, primarily on native pastures, is the principal land use across the Burdekin Rangelands region. The region falls within the NQ Dry Tropics NRM region for statistical reporting which is a total 11.6 million ha. A total of 90% of the area is used for grazing, supporting 655 beef cattle businesses (ABS 2020a). The NQ Dry Tropics region has a total meat cattle herd size of 1.2 million, representing 6% of Australia's and 12% of Queensland's meat cattle numbers and producing $756 million or 5% of Australia's and 12% of Queensland's gross value of cattle in 2019-20 (ABS 2020a,b).

The characteristics of an average beef property in the Burdekin Rangelands were described in McCullough and Musso (2004) as 26,500 ha (18,500 ha useable area, i.e. 70%) running 1,200 breeders (3,000 total head of cattle), with a weaning rate of 65 calves per 100 cows mated, and annual steer growth rates ranging from 110-160 kg/head. Additionally, phosphorus (P) supplements were fed on 43% of properties and continuous mating occurred for 79% of cattle.

As for other tropical rangeland regions of northern Australia, the single most important constraint to cattle production in the Burdekin Rangelands is the quantity and quality of available pastures. Generally low soil fertility limits the digestibility and mineral content of pasture with specific mineral deficiencies, most notably P, occurring on some land types (McCosker and Winks 1994; The State of Queensland 2021). Additionally, the summer dominant pattern of rainfall means there is a rapid decline in pasture quality as the pasture matures during the growing season (November to April) so that cattle diets may become deficient in protein and energy as early as March, compromising growth, fertility and survival during the subsequent dry season (McCullough and Musso 2004). The large year-to-year variability in rainfall amount and distribution in the region complicates these challenges for beef producers. Introduction of the tropically adapted legume, stylo (*Stylosanthes* spp.) and supplementation with inorganic supplements, especially P, to address deficiencies in the pasture are the primary strategies applied to address nutritional constraints of cattle.

The economics of beef production in the Burdekin Rangelands region was last studied in the 1980s and 1990s (Hinton 1993; 1995) which was a low-profit and challenging period for the Burdekin beef industry. These studies showed an overall poor performance for beef cattle properties in the Dalrymple Shire with an estimated average rate of return to total capital of -0.2% for the period 1986-87 to 1988-89. A key finding from these studies was that unsuccessful management decisions made during drought periods had affected property business performance for several years. Those property managers who did not sell cattle early in the drought suffered financially with cattle losses, and high fodder and agistment payments. However, it is important to note that the collapse in beef cattle prices preceding the drought period provided an impediment to timely destocking.

Hinton (1995) also concluded that properties with lower economic performance had higher levels of land degradation and greater variability in soils and vegetation types (Hinton 1995). Furthermore, a weak positive relationship existed between stocking pressure and property debt. These findings were hypothesised to indicate that property owners, with low cash incomes and high debt, are more likely to increase stocking pressure with subsequent negative effects on long-term land condition. This rationale is supported by evidence from other rangeland regions of Queensland which suggests that financial pressures are likely contributors to high stocking rates (Rolfe *et al.* 2016; Bowen and Chudleigh 2018a).

Hinton (1995) demonstrated economies of property and herd size in the Dalrymple Shire with an estimate of 1,400-2,100 adult equivalents (AE) required to achieve a zero return on capital at that time (Hinton 1995). The point at which a 5% return on capital would be achieved was 5,200-8,000 AE while the actual, average herd size in the Dalrymple Shire at the time of the survey was 2,120 AE. In contrast, under current cost and price structures, the 2,500 AE herd modelled in this report was considered to be a viable entity.

1.1.4 Land management in the Burdekin Rangelands

1.1.4.1 Land degradation in the Burdekin Rangelands

Land degradation is defined as the reduction in the character and quality of soil, vegetation and landscapes (McKeon *et al.* 2004). The Burdekin Rangelands region has a long history of well-documented degradation of grazing lands. Soil erosion, undesirable pasture composition changes, and weed invasion in the region have been reported from the mid-1980s. Serious degradation events in the 1980s were related to severe drought periods that coincided with a collapse in the market price of beef cattle (McKeon *et al.* 2004; McIvor 2012). During this period, limited profitable marketing options impeded timely destocking during periods of low forage availability.

An assessment of pasture communities in northern Australia in 1991, indicated that 55% of the black speargrass (*Heteropogon contortus*) pastures in northern Queensland bore evidence of land degradation with 15% of pastures deemed beyond recovery (Tothill and Gillies 1992). A 1990 assessment of land degradation specific to the Dalrymple Shire (a similar area to the Burdekin Rangelands region in this report) also found substantial degradation issues (De Corte *et al.* 1994; Rogers *et al.* 1999). The 1990 survey found that pastures were in a degraded state at 43% of the sites surveyed and in marginal condition at 26% of the sites. Serious levels of soil erosion were apparent on at least one third of the Shire and woody or exotic weeds were found to be both widespread and increasing. More recently, estimates from satellite imagery for the 1996-2010 time period indicated that the Burdekin Rangelands region (average of data for Upper Burdekin and Camp Campaspe sub-catchments) had ca. 26%, 36%, 30%, and 8% of the area in A, B, C and D land condition, respectively (Beutel *et al.* 2014), (scale A-D; Quirk and McIvor 2003). That same study indicated that the land condition rating in the overall Burdekin catchment was substantially lower than for the adjoining Fitzroy catchment, e.g., 24% vs. 47% of the region in A land condition, respectively.

In addition to reducing productive capacity of grazing lands, land condition decline also contributes to sediment runoff to the Great Barrier Reef lagoon. The Burdekin catchment has been identified as the largest contributor of anthropogenic fine sediment loads of the 35 catchments that drain to the Great Barrier Reef lagoon, delivering more than double the loads of any other region and with most coming from gully erosion in grazing areas (The State of Queensland 2011-2022a). Consequently, much effort is currently applied in the river catchments flowing to the Great Barrier Reef lagoon, including the Burdekin Rangelands region, to encourage graziers to implement management practices that will allow 2025 water quality targets to be met (The State of Queensland 2011-2022b).

1.1.4.2 Safe carrying capacity to maintain land condition

Grazing research and pasture modelling from northern Australia has indicated that stocking around the ‘safe’, long-term carrying capacity, with timely adjustment of stock numbers to match forage supply, will maintain land condition (Hunt *et al.* 2014; O’Reagain *et al.* 2014). A safe carrying capacity for a property is defined as a strategic, i.e., long-term (e.g., 20-30 years), estimate of livestock numbers that can be carried without any decrease in land condition and without accelerated soil erosion (Johnston *et al.* 1996). The commonly accepted approach to determining the safe, long-term carrying capacity for a particular land type is the use of the safe pasture utilisation rate concept (Hunt 2008). For the majority of pasture types in Australia, the safe stocking rates are those that result in the utilisation of ca. 20-30% of annual pasture biomass growth although for less productive and ecologically fragile land types, the recommended safe utilisation rates are lower (The State of Queensland 2022a). Short-term, tactical (seasonal or annual) safe stocking rates may be higher or lower than the long-term safe carrying capacity but must be based on seasonal forage budgeting principles and safe utilisation rates of pasture (Johnston *et al.* 1996).

Where properties are overstocked, reducing livestock numbers to match safe stocking rates (seasonal or annual) and safe carrying capacities (over 30-40 years) for the property in its current land condition, is therefore expected to arrest declining land condition. By maintaining land condition over time, pasture yields will be maintained (e.g., Ash 2001; Ash et al. 2002; McIvor et al. 1995). An additional benefit of reduced stocking rates, even in the absence of land condition change, is an anticipated improvement in individual livestock performance due to the ability to select a higher quality diet (Jones and Sandland 1974; Stobbs 1975; O'Reagain *et al.* 2009; Burrows *et al.* 2010).

Long term grazing trials on native pasture communities in Queensland indicate that it may take decades to seriously impact land condition at high levels of pasture utilisation (Silcock et al. 2005; Orr et al. 2010; Orr and Phelps 2013; O'Reagain et al. 2009, 2022; Hall et al. 2017). However, O'Reagain 2009, 2018, 2022 also reported a rapid decline (within 5 years) in land condition in two grazing trial treatments (VAR and SOI) in 2002/03 due to a period of heavy stocking coinciding with an emerging drought. The impact of this event is still evident some 20 years later despite stocking rates being cut sharply for several years after the 2002 event. Ash et al. (2011) also a reported dramatic decline in land condition with overstocking within 3-4 years of starting their Ecograze project with these effects persisting, despite increased rainfall.

Given these complexities, there may be little immediate feedback to beef enterprise managers to indicate that land condition is changing. Furthermore, year-to-year variability in climatic conditions in the rangelands may make changes in land condition difficult to discern.

To support land managers profitably match livestock numbers to safe pasture utilisation rates, maintain land condition and avoid land degradation over decadal time scales, when feedback on grazing management decisions can be slow or unclear, requires further economic and environmental analyses to be conducted for a range of land types, regions, climatic conditions and starting land conditions.

1.1.4.3 Economics of land restoration

The recovery of degraded land in response to grazing management strategies can be slow and uncertain. The uncertainty of land condition recovery is compounded by the financial and economic impacts of transitioning from one state to another. The feature of changing from an existing grazing strategy is that cash and profit becomes more volatile and uncertain during the transition. Furthermore, changes, sometimes unintended, to herd structure, cash flow and costs occur. Therefore, once a land manager has an existing grazing strategy in place, they are likely to find it very difficult to change due to the uncertainty of the transition phase (F. Chudleigh, pers. comm.). It has been demonstrated that a property manager who understands their current management system and is 'comfortable' with it, finds it very difficult to change without a clear and strong value proposition and technical support (e.g., Bowen and Hopkins 2016; Chudleigh *et al.* 2017; Jackson and Malcolm 2018).

While mechanical interventions to improve degraded land, such as pasture seeding following deep ripping or ploughing, result in more timely and certain production benefits than changes in grazing management alone, there appear to be clear economic constraints. An economic analysis for the Burdekin Catchment concluded that all three mechanical intervention strategies decreased profitability of a beef enterprise (Moravek and Hall 2014). The conclusions from this more recent work are consistent with an evaluation of restoration projects relevant to the semi-arid and arid rangelands where the finding was that there was limited economic attraction to private land users to undertake rangeland restoration projects which included four types of mechanical intervention (MacLeod and Johnston 1990).

Again, avoidance of land degradation (or its cessation) is to be preferred, particularly when there is uncertainty under which conditions a reversal of decline can be practically and cost-effectively achieved. Significant demonstration and extension activity is underway within Queensland by the Department of Agriculture and Fisheries to support graziers in making grazing land management decisions, with some financial incentives available.

1.1.4.4 Conclusions for the Burdekin Rangelands

The Queensland government invests in RD&E, incentives and regulatory mechanisms towards promoting sustainable grazing land management and maintained or improved land condition outcomes in Queensland. Like many grazing land managers, it does not support or condone land degradation and seeks for these natural resources to continue to be used by future generations.

Despite the empirical evidence supporting sustainable grazing practices, and a concerted extension effort over more than three decades, there is evidence of continuing land condition decline in the Burdekin catchment and elsewhere across Queensland's grazing lands (e.g., Shaw *et al.* 2007; Beutel *et al.* 2014; Hassett 2022).

It is evident that the tension between achieving profitable grazing businesses and maintaining land condition over time will continue to present challenges for managers of grazing businesses across Queensland, including in the Burdekin Rangelands region. Those challenges have not been analysed in this report. All management strategies in the present analysis were assessed at equivalent grazing pressure that was designed to maintain the land condition of the base property. The strategies assessed in this report were selected by the local industry participants.

Integrated development, extension and economist activities should continue with the objective of facilitating the adoption of appropriate decision-making frameworks for producers and strategies that will improve profitability and business resilience, including sustainable natural resource management. This should draw on the knowledge and skills of scientists, industry development extension officers, and property managers when considering options. Some high priority research areas are outlined in the Summary.

2 General methods – approach to economic evaluation

2.1 Summary of approach

The implications of alternative management strategies on the capacity of a beef enterprise to prepare for, respond to, and recover from drought were investigated for a constructed, example beef cattle property in the Burdekin Rangelands region of Queensland using scenario analysis. The levels of production associated with this constructed base property, and the production responses to alternative management strategies, were determined with reference to interrogation of existing data sets and published literature where available, and the expert opinion of experienced Department of Agriculture and Fisheries, Queensland (DAF) staff and local beef cattle producers. An approach of conducting workshops, training events and discussions with skilled and experienced scientific and extension colleagues, has been applied to develop the assumptions and parameters applied in the modelling. This has involved an iterative process of obtaining feedback and then applying adjustments to the models to ensure that the models have been adequately structured and calibrated for the base property and for each scenario.

The analysis applied an expected values approach that relied on estimating the expected, average level of production and performance over the investment period. This approach was considered equally as capable of predicting the relative differences between the alternative strategies as the stochastic and dynamic modelling approach, which is more complex to apply and communicate. The approach applied here allowed a focus on 1) the key parameters that underscore the difference between the strategies and 2) identifying the strategies most capable of building resilience over time.

The standard methods of farm management economics (Malcolm *et al.* 2005) were applied to test the relative and absolute value of alternative management strategies for the same property using the Breedcow and Dynama herd budgeting software (BCD; Version 6.02; Holmes *et al.* 2017). In all cases, a change to the existing herd management strategy was considered. That is, there was an investment and a herd already in place and the analysis considered options/alternatives that may improve the efficiency of that system. Hence, the scenario analysis was undertaken as a marginal analysis using partial budgeting, over a uniform investment period of 30 years. The term marginal has the meaning of ‘extra’ or ‘added’. The principal of marginality emphasises the importance of evaluating change for extra effects, not the average level of performance.

The scenarios/strategies were assessed for their potential impact on:

- the current net worth of the beef property (impact measured as NPV of change)
- the maximum cumulative cash deficit/difference between the two strategies (peak deficit)
- the number of years before the peak deficit is achieved (years to peak deficit)
- the number years before the investment is paid back (payback period).

Although the BCD programs can be used to evaluate changes in equity and risk levels as well as avenues to finance the beef property, these critical aspects of managing a beef property were not included in this analysis. Therefore, the relative profitability and financial risk of strategies analysed for the Burdekin Rangelands region should be interpreted in the context of debt and risk exposure of individual beef businesses. It is also important to note that many properties in the region with similar characteristics to our constructed property can be part of larger beef businesses that may involve a number of properties in the same region or across multiple regions. The same processes and strategies applied in this analysis can be applied to identifying the optimal management strategy for individual properties within a portfolio, prior to optimising the overall portfolio. It is necessary to look at the individual property and its optimum management prior to looking at how it is best managed within a portfolio of properties.

Components of the BCD suite of programs were applied in an integrated manner during the model building process. Initially Breedcowplus was used to identify the optimal (most profitable) age of female culling (sale) and the optimal steer sale age for the base herd and for strategies resulting in a change in herd performance. This is important as a change in herd performance may change the optimum cull age for the heifers and the breeding herd which sometimes contributes to a change in economic performance. Breedcowplus is a 'steady-state' herd model that applies a constantly recurring pattern of calving, losses and sales for a stable herd with a pre-determined grazing pressure constraint that effectively sets the property or herd size (total number of AE). Breedcowplus is not suitable for considering scenarios that take time to implement, increase the financial risk of the property, require a change in capital investment or additional labour, or result in an incremental change in herd structure, performance or production. As most change scenarios require consideration of such factors over time, it is necessary to undertake the scenario analysis in the Dynamaplus model. Dynamaplus considers herd structures and performance with annual time steps and can import modelled herd structures, costs, AE ratings and prices from Breedcowplus thereby facilitating the analysis of any change in the herd costs, incomes or management strategy over time.

In this study, Breedcowplus was applied to identify (1) optimal or current herd structures for the start of each scenario, and (2) each annual change in herd structure or herd performance expected to occur for as long as it took to implement change and reach the expected herd structure. The incremental Breedcowplus models were transferred to the Dynamaplus model, thereby accurately modelling the impact of the change over time on an annual basis and allowing optimal herd structures and sales targets to be maintained.

Once the herd structure for both a) a herd that did not change, and b) a herd that did change were fully implemented in separate Dynamaplus models over a period of 30 years, the difference between the two Dynamaplus models was identified with the Investan program (also within the BCD suite). To take full account of the economic life and impact of the investments modelled, the capability of the Dynamaplus and Investan models were extended to 30 years.

Discounted cash flow techniques were applied using an extended version of the Investan program (Holmes *et al.* 2017) to look at the net returns associated with any additional capital or resources invested. The DCF analysis was compiled in real (constant value) terms, with all variables expressed in terms of the price level of the current year (2022), except for livestock prices. Cattle prices were based on the historic 7.5-year average obtained through North Queensland saleyards but adjusted downwards to account for the seasonally driven demand experienced since early 2021 (Section 2.4.2). The resulting cattle prices were then applied to represent the expected value of real livestock prices going forward. It was assumed that future inflation would equally affect all costs and benefits.

The DCF analysis was calculated at the level of operating profit where: *operating profit = (total receipts – variable costs = total gross margin) – overheads*. Operating profit was defined as the return to total capital invested after the variable and overhead (fixed) costs involved in earning the revenue were deducted. Operating profit represents the benefit resulting from all of the capital managed by the property. The calculation of operating profit included an allowance for the labour and management supplied by the owner as a fixed cost, even though it is often unpaid or underpaid. For a true estimate of farm profit, this allowance needs to be valued appropriately and included as an operating cost. Our definition of an operator’s allowance was that it is the value of the owners’ labour and management and is estimated by reference to what professional farm managers/overseers are paid to manage a similar property. Another fixed cost deducted in the calculation of annual operating profit was depreciation. This is not a cash cost. It is a form of overhead or fixed cost that allows for the use or fall in value of assets that have a life of more than one production period. It is an allowance deducted from gross revenue each year so that all of the costs of producing an output in that year are set against all of the revenues produced in that year.

The annual figures applied in the calculation of operating profit were modified to calculate the NPV for the property or each strategy. For example, depreciation was not part of the calculation of NPV and was replaced by the relevant capital expenditure or salvage value of a piece of plant when it occurred. Opening and salvage values for land, plant and livestock were applied at the beginning and end of the discounted cash flow analysis to capture the opening and residual value of assets. Residual land values were not modified where strategies may lead to improved stocking rates occurring at the end of the 30-year investment period. Our view was that, for the strategies assessed that are likely to improve carrying capacity, it may be too generous in this risky production environment to extend their impact past 30 years in the form of an increase in closing land value.

It is important to recognise that while gross margins can be a first step in determining the value of an alternative strategy, they do not indicate whether the strategy will be more or less profitable compared to the base operating system or to other alternatives. To make this assessment it is necessary to conduct a property-level economic analysis that applies a marginal perspective, analyses the investment over its expected life and applies partial discounted net cash flow budgets to define NPV at the required rate of return and the internal rate of return (IRR). Such an analysis accounts for changes in unpaid labour, herd structure and capital and includes the implementation phase. Such an analysis also provides an estimate of the extra return on additional capital invested in developing an existing operation. This is the approach we have taken in the present analysis.

In summary, for each scenario, the regionally relevant herd was applied in the BCD suite of programs to determine and compare expected and alternative productivity and profitability over a 30-year investment period. The uniform 30-year investment period was chosen to match the expected economic life of some of the more long-lived investments and to provide sufficient time for the benefits of investments in improved nutrition or herd productivity to be fully realised. Having a consistent time horizon is one of the essential requirements for comparing or ranking investments by NPV and IRR, the others being that the options are not mutually exclusive and have the same initial investment outlay. This latter requirement is met by starting each analysis with the same land, herd, plant and equipment investment. Change was implemented by altering the herd performance and inputs of the base scenario in annual increments to construct the new scenario. The comparison of the two scenarios, one of which reflected the implementation and results of the proposed change from a common starting point, was the focus of the analysis.

The BCD herd models are available from the authors of the report at no cost. A summary of the role of each component of the BCD suite of programs is provided in Appendix 1. Breedcow and Dynama software. Additionally, a more detailed explanation of the methods and terminology used in investment analysis is provided in Appendix 2. Discounting and investment analysis.

2.2 Criteria used to compare the strategies

The economic criteria were NPV at the required rate of return (5%; taken as the real opportunity cost of funds to the producer) and the IRR. A present value model is a mathematical relationship that depicts the value of discounted future cash flows in the current period. It provides a measure of the net impact of the investment in current value terms and accounts for the timing of benefits and costs over the life of the investment. NPV is the sum of the discounted values of the future income and costs associated with the change in the herd or pasture management strategy and was calculated as the incremental net returns (operating profit as adjusted) over the life of the investment, expressed in present day terms. In an IRR model, NPV is equal to zero and the discount rate is unknown and must be determined. The IRR was calculated as 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 (i.e., the break-even discount rate). An amortised (annualised) NPV was calculated at the discount rate (5%) over the investment period to assist in communicating the difference between the constructed, base property and the property after the management strategy was implemented. This measure is different to the average annual difference in operating profit between any two strategies but is automatically calculated in the Investan program and presented to users of the program as a measure of the average annual difference between strategies. The average annual change in operating profit is likely to be greater than the value of the amortised NPV for any given investment as the amortised NPV is discounted back to a present value whereas the average annual change in operating profit is undiscounted. The amortised NPV can be considered as an approximation of potential average annual change in profit over 30 years, resulting from the management strategy.

The financial criteria were peak deficit, the number of years to the peak deficit, and the payback period in years. The beef property started with no debt but over the 30-year analysis period accumulated debt and paid interest as required by the implementation of each strategy. Peak deficit in cash flow was calculated assuming interest was paid on the deficit and compounded in each additional year that the deficit continued into the investment period. The payback period was calculated as the number of years taken for the cumulative net cash flow to become positive. The net cash flow was compounded at the discount rate.

2.3 Estimating grazing pressure equivalence for cattle in the rangelands of northern Australia

As the profit generated by a grazing business is very sensitive to pasture utilisation rate and therefore stocking rate (e.g. Bowen and Chudleigh 2018a) it is critically important to maintain an equivalent or appropriate level of grazing pressure across scenarios that are being compared within the one economic analysis. Not doing so, will strongly bias the scenario or strategy assigned the greater level of grazing pressure. Maintaining equivalent grazing pressure across different management scenarios and various classes of livestock requires conversion to a standard animal unit to describe and quantify the grazing pressure applied to the feed base by foraging ruminants. In Australia, the most commonly applied standard animal units are AE and dry sheep equivalent (DSE) ratings. However, there are many different definitions of AE and DSE in use and a wide variation in the literature in the relationship between the two (McLennan *et al.* 2020). In this section, we have briefly summarised the relevant literature to provide background and justification for the definitions and approach that we have adopted in our economic analysis to estimate grazing pressure equivalence between management scenarios for the Burdekin Rangelands beef cattle property.

The most commonly applied AE systems in Northern Australia for grazing cattle include:

1. **Linear weight AE** where the liveweight of cattle classes are expressed relative to a standard animal, often a 450 kg or a 455 kg (1,000 lbs) liveweight steer at maintenance.
2. **Metabolic weight AE** where the metabolic liveweight (liveweight to the power 0.75) of cattle classes are expressed relative to the metabolic weight of a standard animal, often a 450 kg liveweight steer at maintenance.
3. **Metabolisable energy (ME) requirement AE** where the ME requirement of cattle classes are expressed relative to the ME requirement of a standard animal. Recently, McLennan *et al.* (2020) re-defined the standard bovine animal as a 2.25 year-old, 450 kg liveweight *Bos taurus* steer at maintenance, walking 7 km/day and consuming a diet of 55% dry matter digestibility (DMD; 7.75 MJ/kg dry matter (DM)) and therefore requiring 64.3 MJ/day and consuming 7.9 kg DM/day for cattle on tropical diets (72.6 MJ/day and 9.4 kg DM/day for temperate pastures). The ME requirements for cattle consuming tropical diets were calculated using the Australian ruminant feeding standards equations (NRDR 2007) with modifications to address previously identified issues of over-estimation of ME requirements and associated dry matter intakes (DMI) for cattle consuming tropical forages in northern Australia (McLennan and Poppi 2005; Dove *et al.* 2010; McLennan 2014; Bowen *et al.* 2015).

2.3.1 General scenario analysis in Breedcow and Dynama herd-budgeting software (BCD)

In the BCD herd-budgeting software (Holmes *et al.* 2017), which was applied to conduct economic and financial scenario analyses in this project, an AE was taken as a non-pregnant, non-lactating beast of average weight 455 kg (1,000 lbs) carried for 12 months (i.e. a weight linear AE, not adjusted for metabolic weight or estimated ME requirements). An additional allowance of 0.35 AE was made for each breeder (cow) that rears a calf. This rating was placed on the calves themselves, effectively from conception to age five months, while their mothers were rated entirely on weight. In the development of the BCD software (F. Chudleigh, pers. comm.), the 0.35 AE rating for calves was derived with input from S. McLennan (pers. comm.) with use of an early version of the QuikIntake spreadsheet based on equations in the Australian ruminant feeding standards at that time (SCA 1990; McLennan and Poppi 2005).

The simplified linear weight AE approach to assigning stocking rates and maintaining constant grazing pressure, between alternative scenarios and classes of cattle, has proven robust over many years in conducting scenario analysis for cattle herds using BCD (W. Holmes and F. Chudleigh, pers. comm.). However, modified versions of BCD have been developed to test the effect of applying the alternative AE approaches, i.e. (1) metabolic weight AE and (2) ME requirement AE. Previous analyses (unpublished) to test the effect of applying these alternative methods on the ranking of management strategies for profitability, have demonstrated that the ranking is the same regardless of which of the three AE systems above are applied within BCD. This is also the case for determination of the optimal age of steer turnoff, which is the strategy for which rankings are most likely to be affected by the AE system applied. Additionally, we have tested the robustness of the 0.35 AE allowance for calves up to five months, using the revised equations for calculating ME requirement AE (McLennan *et al.* 2020) applied in the most recent version of QuikIntake (Version 6, McLennan and Poppi 2019) and concluded that this weighting was still appropriate for use in the BCD software for cattle. Therefore, for simplicity of operation, the linear weight AE was retained in the BCD model for our Burdekin Rangelands analysis.

However, to give confidence in the ranking of management strategies determined in this Burdekin Rangelands analysis we again tested the effect of applying the three alternative AE approaches identified above, to determine the optimal age of steer turnoff for an example Burdekin Rangelands cattle herd. Note that this herd is not the same as the base herd applied in the remainder of the report. The example here uses a higher stocking rate (3,000 vs 2,500 linear AE) and corresponding lower levels of herd performance than for the herd adopted as the representative Burdekin Rangelands herd for the broader analysis.

Modified versions of BCD, incorporating either the metabolic weight AE calculations, or the ME requirement AE (using the modified equations of McLennan *et al.* (2020) for tropical pastures) were used to test the ranking of economic outcomes for comparison with the traditional linear weight AE approach applied in BCD. The starting point for these analyses was a 3,492 cattle herd with 1,981 breeders mated, 1,216 calves weaned and an 18-month steer age of turnoff at 296 kg paddock liveweight. Table 6 summarises the herd AE rating and steer age of turnoff optimisation for each of the three AE methods.

Compared to the using the linear weight AE method, the total herd AE rating (for the same herd of cattle) was 6% higher for the metabolic weight AE method (3,198 AE) and 21.7% higher for the ME requirement AE method (3,651 AE). However, the ranking of optimal age of steer turnoff for herd gross margin was the same for all three methods with a 42-month steer sale age being the optimum and a weaner sale age being the least profitable option. As the ranking of age of turnoff for herd gross margin did not differ with the AE methods applied, the application of the simplified, linear weight AE approach in the economic scenario analyses was continued in this study to be comparable with earlier regional analyses within this project. A key point is that so long as one of the three methods of calculating AEs (as described above) are used consistently when modelling alternative management strategies, the results provide an acceptable guide to the relative profitability of the options assessed. However, to conduct tactical pasture budgeting, it would be advisable to apply the ME requirement AE approach which more accurately estimates pasture DMI for specific combinations of cattle breed, class, forage type, quality and expected growth rates.

Table 6 – Herd adult equivalent (AE) rating and steer age of turnoff herd gross margin comparison using either (1) linear weight AE, (2) metabolic weight AE, or (3) ME requirement AE to maintain constant grazing pressure

Note that the starting herd structure prior to each optimisation was that for a herd running 3,492 head of cattle (1,981 breeders) with an 18 month old steer sale age. The starting herd structure is identified in the table as the column with dark shading. The herd AE rating obtained using each AE method is identified with light shading

Parameter	**Age of steer turnoff**			
	Weaner steers 176 kg in paddock (6 months)	**Yearling steers 296 kg in paddock (18 months) Base herd**	**Feed on steers 392 kg in paddock (28 months)**	**Slaughter steers 535 kg in paddock (42 months)**
Linear weight AE				
Total cattle carried	3,169	3,492	3,694	3,551
Weaner heifers retained	668	608	550	463
Total breeders mated	2,176	1,981	1,791	1,509
Total breeders mated and kept	1,763	1,604	1,451	1,222
Total calves weaned	1,336	1,216	1,099	926
Total AE	*3,000*	*3,000*	*3,000*	*3,000*
Herd gross margin less interest on livestock capital	*$563,097*	*$683,818*	*$694,420*	*$729,689*
Ranking	*4*	*3*	*2*	*1*
Metabolic weight AE				
Total cattle carried	3,217	3,492	3,676	3,558
Weaner heifers retained	678	608	547	464
Total breeders mated	2,209	1,981	1,782	1,511
Total breeders mated and kept	1,790	1,604	1,444	1,224
Total calves weaned	1,356	1,216	1,094	928
Total AE	*3,198*	*3,198*	*3,198*	*3,198*
Herd gross margin less interest on livestock capital	*$571,606*	*$683,767*	*$690,947*	*$731,017*
Ranking	*4*	*3*	*2*	*1*
ME requirement AE				
Total cattle carried	3,250	3,492	3,645	3,491
Weaner heifers retained	685	608	542	455
Total breeders mated	2,232	1,980	1,767	1,483
Total breeders mated and kept	1,808	1,604	1,432	1,202
Total calves weaned	1,370	1,216	1,085	910
Total AE	*3,651*	*3,651*	*3,651*	*3,651*
Herd gross margin less interest on livestock capital	*$577,528*	*$683,743*	*$685,171*	*$717,376*
Ranking	*4*	*3*	*2*	*1*

2.3.2 Estimating stocking rates and ensuring equivalent grazing pressure on sown forage paddocks

When calculating the equivalent grazing pressure and applied stocking rates on areas of sown pastures/forages (i.e. stylo or stylo-grass pastures in the Burdekin Rangelands analysis), the ME requirement AE approach was applied using the modified equations of McLennan *et al.* (2020) which provide more accurate estimates of forage intakes for tropical cattle and diets (cf. the NRDR (2007) equations). The spreadsheet calculator QuikIntake Version 6 (McLennan and Poppi 2019) was used to calculate daily cattle DMI (and AE rating) for (1) the specified average DMD of each forage type over the grazing period and the (2) breed and (3) class of cattle grazing the pastures along with (4) their expected liveweight gain. The resultant estimates of pasture DMI are used in conjunction with assumed pasture biomass production of legume and grass components, and associated utilisation rates, to determine stocking rates of alternative classes of steers over defined grazing periods. The steer stocking rates and areas of sown pastures were combined with herd models in an iterative process to calculate total cattle numbers on the property once the area of improved pasture was developed. This process is described in more detail in the sown stylo and stylo-grass section of this report.

2.4 Initial, constructed, base beef cattle property

The base property, herd and business characteristics were informed by industry surveys and research relevant to the region (Round 1978; Hinton 1993,1995; Bortolussi *et al.* 1999, 2005; McCullough and Musso 2004; McGowan *et al.* 2014; O'Reagain *et al.* 2018, 2022) as well as consultation with regional producer groups and experienced DAF staff in 2022. The production parameters assumed for the base property were intended to represent the long-term average expectation for this region. The parameters and strategies adopted for the example property are considered adequate to provide (1) a broad understanding of the range of opportunities available for improvement, (2) the potential response functions and (3) an appropriate framework to support decision making.

The constructed, example property was located centrally in the Burdekin Rangelands region, near Charters Towers (**Error! Reference source not found.**). The property was modelled as a total area o f 25,000 ha of black speargrass (*Heteropogon contortus*) and associated native pastures growing on primarily narrow and silver-leaved ironbark *Eucalyptus crebra* and *E. melanophloia*, respectively) land types. Additionally, the property was assumed to have some areas of more fertile land types that would be most commonly alluvial frontage and/or perhaps some areas of brigalow/gidyea or basalt land types in some parts of the region (The State of Queensland 2022a). Naturalised legumes from the *Stylosanthes* genus were present across the property as well as a high incidence of the invasive, and less productive, Indian couch pasture grass. The proportions of the property comprising land types with high, medium and low fertility were 15%, 45% and 40%, respectively.

The proportions of the base property considered to be in A, B, C and D land condition (scale A-D; Quirk and McIvor 2003) were 15%, 30%, 50%, and 5%, respectively, reflecting a high incidence of Indian couch pasture grass. These land condition ratings are in line with the trend expected following estimates reported by Beutel *et al.* (2014) for the 1996-2010 period, and with more recent Land Condition Assessment Tool data up to March 2022 (R. Hassett, pers. comm.). The property was stocked at the estimated long-term safe carrying capacity and a systematic wet season pasture spelling regime was in place, so as to maintain the existing land condition ratings. It was not considered possible to improve land condition ratings by reducing stocking rate below the long-term safe carrying capacity, due to the high incidence of Indian couch on the representative property, as is typical in this region.

These collective assumptions defining appropriate land types, grazing management, long-term carrying capacity, land condition ratings and the potential change over time were based on the input of local, experienced industry personnel and consideration of the following key references: 'Annual Carrying Capacity Ready Reckoner – Upper Burdekin Catchment (Charters Towers Region)' (R. Shepherd pers. comm.); Beutel *et al.* (2014), Land Condition Assessment Tool data up to March 2022 (R. Hassett, pers. comm.); Ash (2001), Bartley *et al.* (2014), Ash *et al.* (2002), and Bartley *et al.* (2023).

The average stocking rate for the representative property, of 2,500 AE (linear weight AE; 1 AE : 10 ha), was selected to align with the original moderate stocking rate treatment applied in the local, long-term grazing research project at 'Wambiana' over 1997-98 to 2000-01 (O'Reagain and Bushell 2011; O'Reagain *et al.* 2018). The 'Wambiana' moderate stocking rate treatment was increased by 20%, to 1 AE : 8 ha, from 2000-01 to present due to concerns that the initial, long term safe-carrying capacity had been underestimated (O'Reagain and Bushell 2011). However, there are now indications that land condition is declining over time (O'Reagain *et al.* 2022; R. Shepherd pers. comm.). For this reason, the original, more conservative estimate of long-term carrying capacity, of 1 AE : 10 ha, was applied in our analysis.

Cattle numbers on the representative property were expected to be managed according to seasonal conditions so that stocking rate fluctuated above and below 2,500 AE. However, representative herd numbers were modelled as an average expectation over 30 years with the understanding that in some years greater numbers would be carried, and in other years, less. According to best-practice recommendations, cattle numbers were expected to be reduced during extended and severe dry periods to prevent serious damage to pastures and so that expensive drought feeding to maintain livestock on the property would not be required. On this basis, drought feeding was not incorporated in the modelling of the representative base herd which was modelled as a mean expectation over 30 years. Furthermore, substantial peaks in breeder mortality would not be expected during drought periods.

The property carried 2,903 head of cattle consisting of 1,216 breeders mated, 759 calves weaned, and with a steer turnoff age of 42 months (546 kg average liveweight in the paddock). Using linear weight AE methodology, as used in the BCD herd budgeting software, this was rated as 2,500 AE (1 AE: 10 ha). Discussion of alternative AE methodologies is given in Section 2.3 of the report. The management features of the self-replacing, Brahman beef breeding herd included continuous mating and dry season nitrogen (N) and P supplementation as a loose mineral mix.

2.4.1 Starting base herd performance and structure

A self-replacing Brahman (> 75% *B. indicus*) breeding herd grazed a mix of land types considered to result in a marginal P status for cattle, on average. Marginal P status was defined as 6-8 mg/kg bicarbonate-extracted P (Colwell 1963) in the top 100 mm of soil as per the categorisation of Bowen *et al.* (2020b). This average P status for the property was determined according to recently up-dated mapping of soil P status conducted by The State of Queensland (2021) and the earlier publication of McCosker and Winks (1994). The overall P status reflected the periodic access of the cattle herd to more fertile (and higher P) land types. All classes of cattle were fed a dry season, urea-based, loose mix supplement containing N and P for 150 days to meet target crude protein (CP) and P requirements for each class of cattle. All cattle were vaccinated against Botulism.

The herd was continuously mated with two main musters to wean calves and identity cull breeding cows. The herd was segregated, and pregnancy testing was utilised as a routine management tool. Replacement heifers were separated from the breeding herd until first mated at about 2 years of age. Steers mostly grazed the better land types on the property until they were sold as slaughter steers at an average of 42 months and 546 kg paddock liveweight. The maximum breeder culling age was 12 years of age. Data used to describe the reproduction efficiency of the breeder herd reflected the expected conception rates of breeders and the typical loss of calves between conception and weaning experienced by breeders grazing in this region and receiving the dry season supplementation program (Table 7). The assumed foetal/calf loss parameters reflected the CashCow, Northern Forest data (McGowan *et al.* 2014) but adjusted downwards by ca. 2 percentage points due to the slightly better land types for the representative Burdekin Rangelands property. An average mortality rate between 2.3-4.1% was applied to the various classes of livestock to reflect industry expectations. The resulting average mortality rate across all breeders was 3.0% and across the entire base herd was 2.0%. An overall proportion of bulls to cows was set at 4% and bull mortality was expected to average 5%/annum.

Table 7 – Reproduction parameters and mortality rates for the Burdekin Rangelands base herd

Initial cattle age **Final cattle age**	**6 months** **1**	**1** **2**	**2** **3**	**3** **4**	**4** **8**	**8** **10**	**10** **11**	**11** **12**
Expected conception rate for age group (%)	n/a	0	76	46	76	76	71	66
Expected calf loss from conception to weaning (%)	n/a	0	14	7.5	10	12	12	12
Female death rate (%)	2.3	2.3	4.1	2.7	2.7	2.7	2.7	2.7
Male death rate (%)	2.3	2.3	2.3	2.3	n/a	n/a	n/a	n/a

AE, adult equivalent; n/a, not applicable.

The application of the data for reproduction efficiency and mortality rates to the herd model produced an expected average weaning rate of 62.36% (weaners from all cows mated). The base property produced 759 weaners from 1,216 females mated and sold 686 head/annum (female culls and steers). Cull female sales made up 48.4% of total sales. The combination of growth, mortality and reproduction rates, and total AE in the herd model, resulted in the herd structure shown in Table 8.

Table 8 – Average herd structure for the Burdekin Rangelands base property

Age at start of period	**Number kept for the whole year**	**Number sold**	**AE/head kept**	**AE/head sold**	**Total AE**
Extra for cows weaning a calf	n/a	n/a	0.35	n/a	266
Weaners 5 months	759	0	0.22	0.03	164
Heifers 1 year but less than 2	371	0	0.52	0.25	193
Heifers 2 years but less than 3	216	146	0.77	0.38	221
Cows 3 years plus	776	186	1.01	0.49	877
Steers 1 year but less than 2	371	0	0.56	0.27	208
Steers 2 years but less than 3	362	0	0.83	0.27	300
Bullocks 3 years but less than 4	0	354	1.10	0.54	191
Bulls all ages	79	7	1.54	0.77	80
Total number	*2,903*	*693*	-	-	*2,500*

AE, adult equivalent; n/a, not applicable.

The average weaning weight at 6 months of age was estimated to be ca. 179 kg for steers and 167 kg for heifers. Average, annual post-weaning weight gain was assumed to be ca. 122 kg/head for steers and 112 kg/head for heifers. These growth rates were selected to be slightly better than the long-term growth rates of steers under the moderate stocking rate treatment at the 'Wambiana' grazing research trial (115 kg/annum over 1997-1998 to 2016-2017; O'Reagain *et al.* 2018) to align with the slightly better land condition and land types used for steers on the representative property as well as the lower stocking rate (cf. the current moderate stocking rate treatment on 'Wambiana') and the feeding of a dry season N and P loose lick supplement to steers. Figure 6 shows the estimated average growth path for steers and heifers. It was assumed that 100% of steer cohort were sold at an average of 42 months old and ca. 546 kg liveweight in the paddock.

Average steer age (months) and liveweight in the paddock (kg) at sale shown

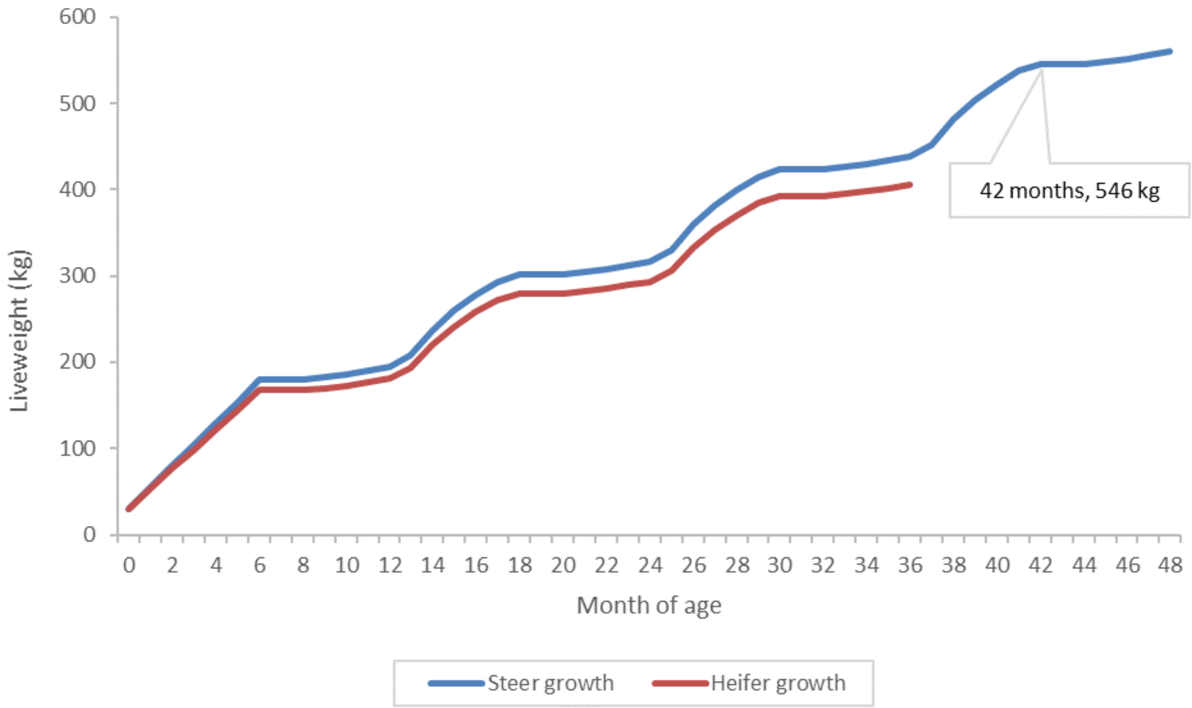

Figure 6 - Estimated average steer and heifer growth paths for the base Burdekin Rangelands property

Table 9 shows the treatments applied to the various classes of cattle held for 12 months in the herd model. Sale stock may or may not have received the treatment depending upon the timing of sale.

Table 9 - Husbandry treatments applied and cost ($/head.annum) for the Burdekin Rangelands base herd

Treatments	Weaners	Females			Steers			
		1-2 years	2-3 years	3+ years	1-2 years	2-3 years	3-4 years	Bulls
Management tag	$1.94	-	-	-	-	-	-	-
NLIS tag for sale cattle	$2.77	$2.77	$2.77	$2.77	$2.77	$2.77	$2.77	$2.77
Botulism vaccine	$1.22	$1.00	$1.00	$1.00	$1.00	$1.00	$1.00	$1.00
Ultravac 7-in-1 vaccine (heifers, 2 doses)	$4.10	-	-	-	-	-	-	-
Ultravac 5-in-1 vaccine (steers, 2 doses)	$0.96	-	-	-	-	-	-	-
Vibriosis vaccine	-	-	-	-	-	-	-	$8.84
Dry season loose lick	$14.75	$19.67	$30.53	$30.53	$19.67	$23.60	$27.53	$30.53
Weaner hay (3 kg/head x 10 days; $288/t)	$8.64	-	-	-	-	-	-	-
Pregnancy diagnosis	-	-	$5.00	$5.00	-	-	-	-

2.4.2 Cattle price data

The hypothetical, base property was located near Charters Towers with saleyards in Charters Towers, and abattoirs and live export markets in Townsville available for sale stock. Price data by sale class over the past 7.5 years (October 2014–April 2022) was analysed for north Queensland saleyards markets, over-the-hooks markets, and live export markets (see Meat and Livestock Australia (MLA) market statistics database at http://statistics.mla.com.au/Report/List). Figure 7 indicates prices over this 7.5-year period for (1) live export light steers exported from Darwin and (2) grassfed bullocks sold through the North Queensland saleyards. Note that long-term price data is not available for live export steers from Townsville. However, as indicated in Bowen *et al.* (2020a), the on-farm prices (net of freight costs) for live export steers are similar whether sold through Darwin or Townsville. Therefore, price trends for Darwin, for the same class of steers, can be applied to indicate long-term values, on-farm, for the Burdekin Rangelands property. Table 10 indicates the average prices for relevant classes of cattle sold through North Queensland sale yards and the Darwin live export prices for the last 1, 2, 5 and 7.5 years, respectively.

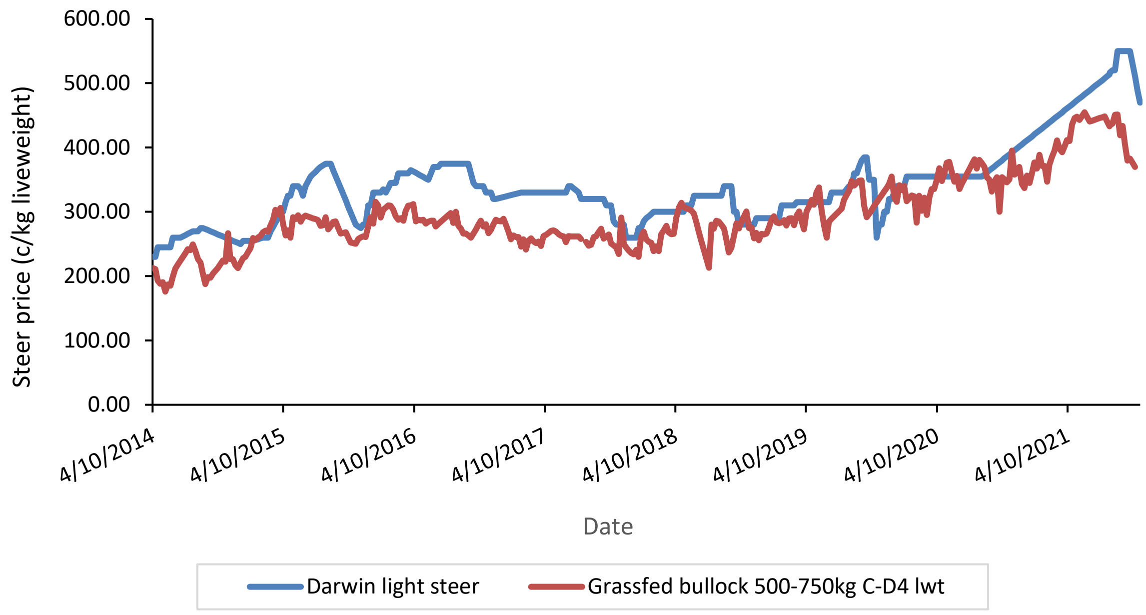

Figure 7 – Cattle prices over time from 2014 to 2022 for live export steers at Darwin and grassfed bullocks sold through North Queensland saleyards

Table 10 – Cattle price data (c/kg liveweight) for October 2014-April 2022 for the North Queensland saleyards and Darwin live export market

Average price over last	North Queensland saleyards						Darwin live export	
	Restocker steer 200-330 kg D2	Restocker heifer 200-330 kg D2	Light steer 330-400 kg D2	Medium steer 400-500 kg D2	Grassfed bullock 500-750 kg C-D4	Medium cow 400-520 kg D3	Light heifer	Light steer
1 year	568.88	508.98	473.62	431.11	403.27	333.83	441.19	471.31
2 years	491.56	439.82	418.80	393.26	372.90	300.35	381.00	412.43
5 years	362.82	312.19	326.73	308.48	314.60	240.21	325.25	353.72
7.5 years	338.86	293.19	310.45	292.73	297.10	229.69	314.26	340.26

As is evident from the example price data presented in **Error! Reference source not found.** and Table 10, livestock price volatility along with seasonally driven restocker demand, made it difficult to identify appropriate prices for budgeting purposes. The prices used in this analysis were based on the historic 7.5-year average obtained through north Queensland saleyards but adjusted downwards to account for the seasonally driven demand experienced since early 2021. In setting the price assumptions, consideration was given to the likelihood that the factors that have driven increased demand and prices over the previous 18 months (to April 2022) will ease into the future. No adjustment was made for the possible impact of inflation on the value of prices received in early years of the data. The saleyards prices were considered indicative of all relevant markets for cattle sold from the Burdekin Rangelands representative property as previous analysis by Bowen *et al.* (2020a) indicated that the north Queensland saleyards price data is closely related to prices obtained in all the available markets in north Queensland. The price data applied in the herd model to calculate the net price per head of stock sold are given in Table 11 and Table 12. An allowance for 5% weight loss was made between the paddock weights and the sale weights. Transport and other selling costs were estimated for each class of cattle to the Dalrymple saleyards at Charters Towers.

Table 11 - Sale prices, selling costs, gross and net prices applied in the analysis for female cattle grazing the Burdekin Rangelands representative base property

Parameter	Class of cattle			
	Heifer weaners 5-11 months	**Heifers 1 year**	**Heifers 2 years**	**Cows 3+ years**
Sale weight (kg)	159	266	372	418
Price ($/kg)	$2.95	$2.85	$2.90	$2.40
Commission (% of value)	4%	4%	4%	0%
Other selling costs ($/head)	$17.00	$17.00	$17.00	$5.00
Freight ($/head)	$8.50	$9.44	$11.72	$22.22
Gross price ($/head)	$468.02	$758.10	$1,079.96	$1,003.20
Total selling and freight costs ($/head)	$44.22	$56.76	$71.92	$27.22
Net price ($/head)	*$423.80*	*$701.34*	*$1,008.04*	*$975.98*

Table 12 - Sale prices, selling costs, gross and net prices applied in the analysis for male cattle grazing the Burdekin Rangelands representative base property

Parameter	Class of cattle					
	Steer weaners 5-11 months	**Steers 1 year**	**Steers 2 years**	**Steers 3 years**	**Steers 4 years**	**Cull bulls**
Sale weight (kg)	170	286	402	519	635	665
Price ($/kg)	$3.40	$3.30	$3.15	$3.10	$3.05	$2.50
Commission (% of value)	4%	4%	4%	0%	0%	0%
Other selling costs ($/head)	$17.00	$17.00	$17.00	$5.00	$5.00	$5.00
Freight ($/head)	$8.50	$10.00	$12.14	$26.09	$33.33	$37.50
Gross price ($/head)	$578.17	$943.64	$1,265.83	$1,607.97	$1,935.53	$1,662.50
Total selling and freight costs ($/head)	$48.63	$64.75	$79.77	$31.09	$38.33	$42.50
Net price ($/head)	*$529.54*	*$878.89*	*$1,186.05*	*$1,576.88*	*$1,897.20*	*$1,620.00*

2.4.3 Herd outputs and gross margin

The sale prices, sale weights, selling costs, treatment costs and bull replacement strategy identified previously for the base cattle herd and property were applied to the herd structure shown in Table 8 to produce the herd gross margin shown in Table 13.

Table 13 - Herd parameters and gross margin for the Burdekin Rangelands base herd with steer sale age of 42 months (546 kg average paddock liveweight)

Parameter	**Base herd**
Total AE	2,500
Total cattle carried	2,903
Weaner heifers retained	379
Total breeders mated	1,216
Total breeders mated and kept	993
Total calves weaned	759
Weaners/total cows mated	62.36%
Overall breeder deaths	3.00%
Female sales/total sales	48.43%
Total cows and heifers sold	332
Maximum cow culling age	12
Heifer joining age	2
One year-old heifer sales	0.00%
Two-year-old heifer sales	45.42%
Total steers and bullocks sold	354
Maximum bullock turnoff age	3
Average female price	$990.05
Average steer and/or bullock price	$1,576.88
Capital value of herd	$2,553,045
Imputed interest on herd value	$127,652
Net cattle sales	$886,740
Direct costs excluding bulls	$88,097
Bull replacement	$46,566
Herd gross margin	$752,078
Herd gross margin after imputed interest	$624,425
Gross margin/AE	*$301*
Gross margin/AE less interest on livestock capital	*$250*

AE, adult equivalent.

Note: bull sales are included in net bull replacement, not net cattle sales.

2.4.4 Expected property returns

The additional information required to complete an investment or profit analysis includes fixed, capital and finance expenses incurred, together with the opening and closing value of the land, plant and improvements. Fixed costs are those costs which are not affected by the scale of the activities but must be met in the operation of the beef property. Table 14 gives the assumed fixed cash costs for the property. Non-cash fixed costs include part or all of the operator’s allowance plus an allowance for plant replacement and will be identified later.

Table 14 – Annual fixed cash costs for the Burdekin Rangelands base property

Item	Cost
Accounting	$8,500
Administration, computer, postage	$3,500
Electricity, power	$6,000
Fuel and oil	$40,000
Contract mustering	$40,000
Insurance	$18,000
Motor Vehicle	$35,000
Rates Rents	$33,500
Repairs and Maintenance	$45,000
Telephone	$3,000
Wages and associated costs	$120,000
Total	*$352,500*

AE, adult equivalent.

Table 15 shows the plant inventory for the base property. The replacement cost is an estimate of how much it would cost to replace the item if it were to be replaced now. The salvage value is estimated on the basis of the item being valued now but with the item in a condition equivalent to what it will be in when it is replaced. The items were either salvaged or replaced in the DCF analysis at the intervals and capital values indicated in Table 15. The estimate of depreciation is not applied in the DCF analysis as that would double count the cost of the plant to the property.

The replacement allowance was applied as part of the calculation of the expected return on total capital shown in Table 16. It should be noted that this depreciation allowance is not the one found in the tax returns of the enterprise. The depreciation allowance calculated here is used as a cost in the calculation of the annual operating profit (not reported in this analysis) and it is therefore related to the economic life rather than the depreciation life of the item for taxation purposes. The allowance calculated in Table 15 essentially allows for the annual use and fall in value of assets that have a life of more than one production period. It is not a cash cost but is an allowance that is deducted from gross revenue each year so that all of the costs of producing an output in that year are set against all of the revenues produced in that year to estimate the operating profit of the enterprise.

Table 15 - Plant inventory, replacement cost and salvage value for the Burdekin Rangelands base property

Item	Market value	Years to replacement	Replacement cost	Subsequent replacement	Salvage value	Replacement allowance
4WD ute	$30,000	5	$70,000	5	$30,000	$8,000
Tractor	$45,000	30	$65,000	30	$20,000	$1,500
Farm truck	$75,000	15	$92,000	15	$30,000	$4,133
Motorbikes	$10,000	10	$20,000	10	$0	$2,000
Quad bike	$3,000	10	$12,000	10	$3,000	$900
Slasher	$1,500	20	$7,000	20	$1,500	$275
Fuel trailer	$1,750	25	$3,500	25	$1,000	$100
Welder trailer	$5,000	10	$10,000	10	$2,000	$800
Molasses tank mixer	$7,000	25	$12,000	25	$5,000	$280
Workshop and saddlery	$25,000	16	$40,000	16	$0	$2,500
Total	*$203,250*	-	*$331,500*	-	-	*$20,488*

AE, adult equivalent.

The allowance for operator's labour and management was set at $100,000. This value was based on an assessment of the opportunity cost of labour necessary to operate the property at its current standard of management. The value of the land and fixed improvements for the example property was taken to be $8,650,000. This resulted in an opening value of the total of land, plant and improvements for the property of $8,853,250. The profit analysis identified that the beef property returned about 2.32% on total capital invested over 30 years (Table 16). No allowance for any potential change in the real value of the land asset over time (i.e., capital gain net of inflation) was included. Additionally, in this steady-state herd model the property was assumed to start with no existing debt. However, to implement strategies (in subsequent sections of the report) the property accumulated debt and paid interest as required.

Table 16 - Expected value of annual outcomes for the Burdekin Rangelands base beef property

Parameter	Value
AE	2,500
Operating profit	$280,657
Rate of return on total capital	2.32%

AE, adult equivalent.

3 Strategies to build profit and drought resilience

The strategies examined in this section of the report have been identified by producers and industry as having the potential to improve productivity and profitability of a beef property in the Burdekin Rangelands. Each strategy was assessed for its capacity to improve the profit and therefore the drought and business resilience of the base beef property over time. The results of this section relate to the base property running 2,500 AE and the associated assumptions made for the expected production responses to changing the management strategy. Different results may be obtained for different properties or production systems and hence it is recommended that beef producers or their advisors use the tools and models developed in this study to conduct their own analyses specific to their circumstances.

The information provided here should be used, firstly, as a guide to an appropriate method to assess alternative strategies aimed at improving profitability and drought resilience of a beef property. Secondly, this report indicates the data required to conduct such an analysis and the potential level of response to change revealed by relevant research and the expert opinion of scientists and beef extension officers with extensive knowledge of the region and of the northern Australian cattle industry. Whilst every effort was made to ensure that the assumptions used in each scenario were accurate and validated with industry participants, relevant experts or published scientific studies, the results presented should be viewed as indicative only.

3.1 Optimising steer sale age and female culling

3.1.1 Introduction

The first step in any analysis of strategies to improve property profit and resilience should be to determine the optimal herd structure, i.e. the most profitable sale age for steers and cull females. The optimal age of male turnoff and of female culling (i.e. the optimal herd structure) on beef properties in northern Australia is driven by the:

- available markets and relative prices of steers, heifers and cows
- proportions of steer beef produced by the herd
- opportunity cost of herd capital
- cattle growth rates and breeder reproductive performance.

The optimal herd structure can only be identified by calculating the marginal change in herd profit for each age of steer or cull heifer turnoff at the property level. Modelling exercises using the BCD software (Holmes *et al.* 2017) have consistently indicated that sale of older steers was more profitable than sale of weaners in northern Australia, with the optimal age varying with region and the parameters identified above (FutureBeef 2011a). Regardless, a number of producers continue to target sale of weaner steers as a regular strategy.

3.1.2 Methods

The effect of steer and female sale ages on the profitability of the Burdekin Rangelands property was initially modelled by comparing the alternative ages of sale in steady-state herd models, whilst maintaining equivalent grazing pressure. This exercise identified the optimum age of sale for male and female cattle. Secondly, the effect on profitability of transitioning from a weaner steer sale target to the optimum was examined in a farm-level, partial discounted cash-flow analysis.

3.1.3 Results and discussion

3.1.3.1 Determining the optimal herd structure

The effect on herd steady-state gross margin of selling steers at five alternative ages: 6, 18, 30, 42 and 54 months old, is presented in Table 17. It was recognised that annual variability in seasonal conditions will lead to corresponding variability in the time taken to attain liveweight targets. However, these weight for age values were adopted as being representative of the expected long term average performance of the constructed property and herd. In accord with data for other regions of northern Australia, the weaner sale age was the least profitable sale age despite weaner steers receiving the highest price per kilogram over time (Chudleigh *et al.* 2019b; Bowen and Chudleigh 2021c,d). Herd gross margin was similar for a steer sale target of feed-on steers (423 kg average liveweight at 30 months) and the scenario of selling slaughter steers (546 kg average liveweight at 42 months). This indicates that the property manager could select either of these targets for steer turnoff without compromising profitability of the property. The attitude of the manger to risk would influence the decision to target feed-on vs. slaughter steers as 228 less breeders are mated (at equivalent grazing pressure) when turning off slaughter steers cf. feed-on steers, potentially improving drought resilience and reducing risk. For this reason, the 42-month-old steer sale age was adopted in the base herd for this analysis and used to test additional strategies. Following steer sale optimisation at 42-months, the optimal final cull age for mature cows was assessed and found to be 12 years with surplus heifers sold at 2 years.

Table 17 – Steer age of turnoff herd gross margin comparison for the Burdekin Rangelands representative herd

Note that there will be year-to-year variability in the steer age at which average liveweight targets are achieved

Parameter	**Age of steer turnoff**				
	Weaner steers **179 kg in paddock** **(6 months)**	**Yearling steers** **301 kg in paddock** **(18 months)**	**Feed on steers** **423 kg in paddock** **(30 months)**	**Slaughter steers** **546 kg in paddock** **(42 months)** **Base herd**	**Slaughter steers** **668 kg in paddock** **(54 months)**
Total AE	2,500	2,500	2,500	2,500	2,500
Total cattle carried	2,588	2,853	3,015	2,903	2,779
Weaner heifers retained	548	499	450	379	324
Total breeders mated	1,758	1,599	1,444	1,216	1,038
Total breeders mated and kept	1,434	1,305	1,178	993	847
Total calves weaned	1,096	997	900	759	647
Weaners/total cows mated	62.36%	62.36%	62.36%	62.36%	62.36%
Weaners/cows mated and kept	76.42%	76.42%	76.42%	76.42%	76.42%
Overall breeder deaths	3.00%	3.00%	3.00%	3.00%	3.00%
Female sales/total sales %	46.69%	47.27%	47.85%	48.43%	49.01%
Total cows and heifers sold	480	437	394	332	283
Maximum cow culling age	12	12	12	12	12
Heifer joining age	2	2	2	2	2
One-year-old heifer sales	0.00%	0.00%	0.00%	0.00%	0.00%
Two-year-old heifer sales	45.42%	45.42%	45.42%	45.42%	45.42%

Parameter	Age of steer turnoff				
	Weaner steers **179 kg in paddock** **(6 months)**	**Yearling steers** **301 kg in paddock** **(18 months)**	**Feed on steers** **423 kg in paddock** **(30 months)**	**Slaughter steers** **546 kg in paddock** **(42 months)** **Base herd**	**Slaughter steers** **668 kg in paddock** **(54 months)**
Total steers and bullocks sold	548	487	430	354	295
Maximum bullock turnoff age	0	1	2	3	4
Average female price	$990.05	$990.05	$990.05	$990.05	$990.05
Average steer/bullock price	$529.54	$878.89	$1,186.05	$1,576.88	$1,897.20
Capital value of herd	$2,307,465	$2,363,366	$2,520,000	$2,553,045	$2,654,415
Imputed interest on herd value	$115,373	$118,168	$126,000	$127,652	$132,721
Net cattle sales	$765,473	$860,536	$899,921	$886,740	$840,148
Direct costs excluding bulls	$95,367	$94,088	$93,998	$88,097	$83,763
Bull replacement	$67,280	$61,211	$55,257	$46,566	$39,733
Herd gross margin	$602,825	$705,237	$750,665	$752,078	$716,652
Herd gross margin less interest on livestock capital	$487,452	$587,069	$624,665	$624,425	$583,931

AE, adult equivalent.

3.1.3.1.1 Impact of last 3 years of cattle prices on the optimal age of steer turnoff

As indicated in Section 2.4.2, cattle prices underwent a substantial increase from early 2021. The average prices of the last 3 years to 04/11/2022 (Table 18) were applied to investigate the effect on optimal age of steer turnoff of the higher prices of recent years, and changes in the relative price of cattle classes.

Table 18 – Cattle price data (c/kg liveweight) for comparison over alternative time periods for the North Queensland saleyards

Time period	North Queensland saleyards					
	Restocker steer **200-330 kg D2**	**Restocker heifer** **200-330 kg D2**	**Light steer** **330-400 kg D2**	**Medium steer** **400-500 kg D2**	**Grassfed bullock** **500-750 kg C-D4**	**Medium cow** **400-520 kg D3**
3 years (04/10/2019-04/11/2022)	458.54	402.44	397.38	375.02	364.68	291.69
7.5 years (10/10/2014-22/04/2022 with adjustment downwards to account for seasonally-driven demand from early 2021)	340.00	285.00	330.00	315.00	305.00	240.00
Difference	*118.54*	*117.44*	*67.38*	*60.02*	*59.68*	*51.69*

The prices of the last 3 years were applied to the Breedcow model for the representative Burdekin Rangelands base herd to investigate the effect of applying the more recent price period, on the optimal age of steer turnoff. As indicated in Table 19, despite a proportionally greater increase in prices paid for younger cattle, the weaner sale target was still the least profitable and the 30-month sale target the most profitable. A greater relative increase in price for the 30-month steers cf. the 42-month steers marginally increased the benefit to the 30-month sale age compared to the adjusted 7.5-year prices applied for the remainder of the analyses in this report.

This exercise indicates that despite the sharp increases in prices and the changes in the relativity between cattle classes over the last 3 years, the optimum age of steer turnoff is quite robust for Burdekin Rangelands producers. Beef producers would have suffered no significant penalty if they had maintained an older age of turnoff for steers over the last 3 years. Furthermore, they would have been significantly better off, on average, over the last decade maintaining a balanced herd structure targeting the sale of mature steers. The extreme price premiums for young steers and heifers over the last 12 months have been sufficient to justify the sale of all young cattle in the herd during that period. This is the only time in the last 40 years that this has occurred, and it appears these extreme premiums have dissipated over recent months.

The long-term herd management strategy of targeting the sale of older steers also challenges the notion that steers should be sold down first in a drought. It is usually better to evaluate alternative methods of reducing the herd size as the drought and market impacts unfold. The general rule is to sell the class of cattle first that does the least damage to medium term income prospects, and this may not be steers. A series of presentations available on the project internet page explain how these short-term decisions are best assessed: https://futurebeef.com.au/resources/improving-profitability-and-resilience-of-beef-and-sheep-businesses-in-queensland-preparing-for-responding-to-and-recovering-from-drought/.

Table 19 – Steer age of turnoff herd gross margin comparison for the Burdekin Rangelands representative herd when last 3-year (to November 2022) cattle prices are applied

Note that there will be year-to-year variability in the steer age at which average liveweight targets are achieved

Parameter	**Age of steer turnoff**			
	Weaner steers 179 kg in paddock (6 months)	**Yearling steers 301 kg in paddock (18 months)**	**Feed on steers 423 kg in paddock (30 months)**	**Slaughter steers 546 kg in paddock (42 months) <u>Base herd</u>**
Total AE	2,500	2,500	2,500	2,500
Total cattle carried	2,588	2,853	3,015	2,903
Weaner heifers retained	548	499	450	379
Total breeders mated	1,758	1,599	1,444	1,216
Total breeders mated and kept	1,434	1,305	1,178	993
Total calves weaned	1,096	997	900	759
Weaners/total cows mated	62.36%	62.36%	62.36%	62.36%
Weaners/cows mated and kept	76.42%	76.42%	76.42%	76.42%
Overall breeder deaths	3.00%	3.00%	3.00%	3.00%
Female sales/total sales %	46.69%	47.27%	47.85%	48.43%
Total cows and heifers sold	480	437	394	332

Parameter	Age of steer turnoff			
	Weaner steers **179 kg in paddock** **(6 months)**	**Yearling steers** **301 kg in paddock** **(18 months)**	**Feed on steers** **423 kg in paddock** **(30 months)**	**Slaughter steers** **546 kg in paddock** **(42 months)** **Base herd**
Maximum cow culling age	12	12	12	12
Heifer joining age	2	2	2	2
One-year-old heifer sales	0.00%	0.00%	0.00%	0.00%
Two-year-old heifer sales	45.42%	45.42%	45.42%	45.42%
Total steers and bullocks sold	548	487	430	354
Maximum bullock turnoff age	0	1	2	3
Average female price	$1,272.09	$1,272.09	$1,272.09	$1,272.09
Average steer/bullock price	$725.44	$1,071.05	$1,417.52	$1,862.17
Capital value of herd	$2,900,432	$3,000,524	$3,179,691	$3,192,774
Imputed interest on herd value	$145,022	$150,026	$158,985	$159,639
Net cattle sales	$1,008,222	$1,077,321	$1,110,565	$1,081,361
Direct costs excluding bulls	$95,367	$94,088	$93,998	$88,097
Bull replacement	$63,773	$58,021	$52,378	$44,139
Herd gross margin	$849,081	$925,212	$964,189	$949,125
Herd gross margin less interest on livestock capital	$704,059	$775,185	$805,204	$789,487
Gross margin increase compared to adjusted last 7.5 year prices applied in Table 17	**$216,607**	**$188,117**	**$180,539**	**$165,061**
% increase in gross margin	**44.44%**	**32.04%**	**28.90%**	**26.43%**

AE, adult equivalent.

3.1.3.1.2 Potential impact of drought on the mortality risk of breeders

While the optimal final cull age for mature cows was 12 years in this analysis, an important additional consideration is the increased risk of mortality presented by cows older than 10 years of age during drought periods. This important aspect was assessed in detail in accompanying reports for the Fitzroy and Northern Gulf regions of Queensland (Bowen and Chudleigh 2018b; Bowen *et al.* 2019a) and in recorded presentations available from the project internet page: https://futurebeef.com.au/resources/improving-profitability-and-resilience-of-beef-and-sheep-businesses-in-queensland-preparing-for-responding-to-and-recovering-from-drought/. A summary of key aspects of the mortality risk of breeders is also presented here.

The weight loss associated with drought will affect different age classes as well as the lactating (hereafter ‘wet’) and non-lactating (hereafter ‘dry’) breeders differently and hence the proportion of these groups in the herd is an important factor to consider. The proportion of the breeding herd likely to be lactating as the drought progresses is important, particularly if breeding bulls are not removed during the year. The overall herd structure will also likely have effects on the capacity of the property to respond to drought which will be related to the proportion of breeders in the herd. Assessing these aspects well prior to drought can enable adjustments to herd structure to be made that increase drought resilience.

The potential effect of the drought on the mortality and conception rates of components of the herd can be assessed by applying the prediction equations developed by Mayer *et al.* (2012), for breeding cattle in northern Australia, to the herd output data from the Breedcow model (Holmes *et al.* 2017). Mayer *et al.* (2012) concluded that breeder liveweight, body condition score (BCS; range 0-9)) and age were key factors affecting mortality and conception rates. However, it was concluded that variation in the parameter 'body condition ratio' (BCR) could be used to model the effect of a change in BCS on mortality and conception rates in mature female cattle. BCR is defined as the ratio of current liveweight to expected body weight for age of animals in average condition ('N'). 'N', in turn, is calculated using an exponential equation describing weight from birth to maturity, given adequate nutrition and relies on use of a 'standard reference weight' (SRW) which is defined as the weight of a mature animal of average body condition. The relationship between breeder BCS and BCR derived by Mayer *et al.* (2012) can be used to determine the expected liveweight at each BCS and BCR increment, for a herd with an assumed SRW of 450 kg which was considered as broadly representative for contemporary Brahman cattle (>75% *B. indicus*) in the Burdekin Rangelands region (Table 20).

Table 20 – Equivalence of breeder body condition score (BCS) to body condition ratio (BCR) and calculated liveweight based on a breeder standard reference weight (SRW) of 450 kg liveweight; calculated using equations from Mayer et al. (2012)

All terms defined in the text and in the Glossary of terms and abbreviations

Description of animal	BCS value (scale 0-9)	Nominal BCR range	Calculated BCR	Calculated liveweight (kg)
Emaciated	0	0.5–0.6	0.50	225
Very poor	1	0.6–0.7	0.60	270
Poor	2	0.7–0.8	0.70	315
Backward store	3	0.8–0.9	0.80	360
Store	4	0.9–1.0	0.90	405
Forward store	5	1.0–1.1	1.00	450
Prime	6	1.1–1.2	1.10	495
Fat Prime	7	1.2–1.3	1.20	540
Fat	8	1.3–1.4	1.30	585
Over-fat	9	1.4–1.5	1.40	630
Over-fat	9	1.4-1.5	1.50	675

Figure 8 demonstrates the relationship of mortality rate to BCR and weight change in either 1 year-old or 12 year-old breeders, calculated by applying the equation of Mayer *et al.* (2012). It can be seen that 12 year-old cows that have a low starting BCR and then lose weight will have a substantially greater rate of mortality than yearling heifers that have a similar BCR and lose a similar amount of weight. Table 21 and Table 22 show the expected rate of mortality in breeders as predicted by the Mayer *et al.* (2012) mortality equation. The values were calculated for female stock that start the calendar with a BCR of either 1 or 0.9 and then lose liveweight over varying rates over during the next 12 months. Combined, the data indicates a serious risk of high rates of mortality if a breeding herd has a high proportion of aged cows and they begin a drought in less than forward store body condition. Having breeder BCS in less than a forward store condition (lower than score 5 on a 9 point scale) going into a drought could substantially increase the mortality risk of mature and aged cows who are considered likely to lose more than 10% of their starting liveweight.

All terms defined in the text and in the Glossary of terms and abbreviations

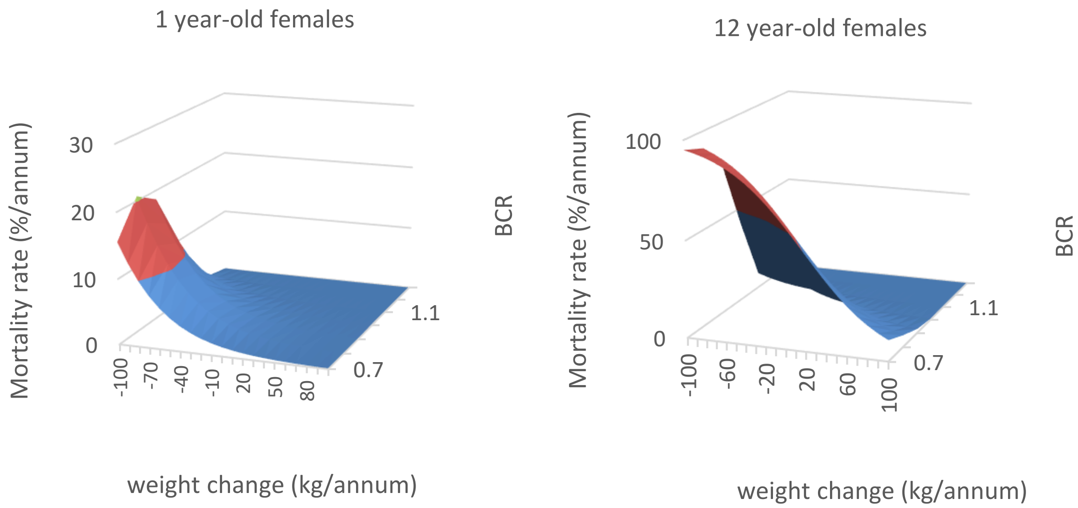

Figure 8 – Fitted mortality surface (%/annum) for the interaction between weight change (kg/annum) and body condition ratio (BCR) for 1 year-old and 12 year-old females

Table 21 - Rate of mortality by class of female stock starting with a body condition ratio (BCR) of 1 at the start of the calendar year and then losing various amounts of liveweight over the next 12 months

All terms described in the text and in the Glossary of terms and abbreviations

Female age class	Liveweight loss over 12 months (kg)				
	-20	-40	-50	-60	-80
Heifer weaners	1.58%	2.60%	3.33%	4.26%	6.89%
Heifers 1 year	1.84%	3.03%	3.88%	4.95%	7.97%
Heifers 2 years	1.84%	3.03%	3.88%	4.95%	7.97%
Cows 3 years	2.15%	3.53%	4.50%	5.74%	9.20%
Cows 4 years	2.50%	4.10%	5.23%	6.65%	10.60%
Cows 5 years	2.92%	4.77%	6.07%	7.69%	12.19%
Cows 6 years	3.40%	5.53%	7.02%	8.88%	13.97%
Cows 7 years	3.95%	6.41%	8.12%	10.24%	15.96%
Cows 8 years	4.59%	7.42%	9.37%	11.77%	18.18%
Cows 9 years	5.33%	8.57%	10.79%	13.51%	20.64%
Cows 10 years	6.18%	9.89%	12.40%	15.45%	23.33%
Cows 11 years	7.16%	11.37%	14.21%	17.61%	26.25%
Cows 12 years	8.27%	13.06%	16.23%	20.00%	29.40%
Cows 13 years	9.54%	14.94%	18.48%	22.64%	32.76%

Table 22 - Rate of mortality by class of female stock starting with a body condition ratio (BCR) of 0.9 at the start of the calendar year and then losing various amounts of liveweight over the next 12 months

All terms described in the text and in the Glossary of terms and abbreviations

Female age class	**Liveweight loss over 12 months (kg)**				
	-20	**-40**	**-50**	**-60**	**-80**
Heifer weaners	2.89%	4.72%	6.00%	7.62%	12.07%
Heifers 1 year	3.66%	5.96%	7.56%	9.54%	14.94%
Heifers 2 years	3.66%	5.96%	7.56%	9.54%	14.94%
Cows 3 years	2.15%	3.53%	4.50%	5.74%	9.20%
Cows 4 years	5.86%	9.39%	11.80%	14.72%	22.33%
Cows 5 years	7.37%	11.71%	14.61%	18.09%	26.88%
Cows 6 years	9.24%	14.50%	17.96%	22.03%	31.99%
Cows 7 years	11.53%	17.83%	21.88%	26.54%	37.57%
Cows 8 years	14.29%	21.73%	26.37%	31.61%	43.50%
Cows 9 years	17.58%	26.21%	31.43%	37.16%	49.62%
Cows 10 years	21.43%	31.24%	36.96%	43.07%	55.75%
Cows 11 years	25.87%	36.76%	42.86%	49.18%	61.71%
Cows 12 years	30.87%	42.64%	48.97%	55.32%	67.34%
Cows 13 years	36.35%	48.75%	55.10%	61.30%	72.51%

This data indicates that the age structure of the females in a breeding herd may increase (or decrease) the risk of mortality rates increasing in a drought. Table 23 indicates the age structure of the Burdekin Rangelands base herd and identifies that approximately 14% of the retained cow herd could be 9-10 years old, or older, going into a drought.

Table 23 - Age structure of the Burdekin Rangelands base herd

Retained breeder numbers for age classes 9 years and above are shaded grey

Parameter	**Number of females in each age class (1-12)**											
Cow age start of calendar year	1	2	3	4	5	6	7	8	9	10	11	12
Cows/heifers available at start of year	371	362	207	147	126	108	92	79	68	58	48	31
Cows mated in each age group	0	284	207	147	126	108	92	79	68	58	48	0
Mated cows retained in each group	0	216	151	129	111	95	81	69	59	49	32	0
Calves weaned from each group	0	185	87	101	86	74	63	53	45	36	28	0

The results of the gross margin analysis for the Burdekin Rangelands base herd (Table 17) indicated that at equivalent grazing pressure, the number of breeders retained on the property fell as the age of steer turnoff increased. The base herd turning off weaner steers had ca. 45% more calving and lactating females than the herd turning off 42-month-old slaughter steers. During an extended dry season or drought, the larger number of breeders increases the mortality risk of the overall herd. Therefore, moving to an older age of steer turnoff can improve drought resilience, as well as improving profitability in this instance. Reducing the maximum cull cow age to 10 years of age reduced the herd gross margin by about 2% (data not presented). Therefore, beef producers concerned about the risk of managing the older cohorts of cows in the herd can reduce the cull age and not suffer a large penalty. This, combined with an older age of turnoff for steers improves the drought resilience of the total herd.

3.1.3.2 Effect on property profit of changing from weaner steer production to the optimal

Table 24 shows the results of the 30-year analysis of the value of converting from sale of 6 month-old steers (179 kg average liveweight) to sale of 42 month-old steers (546 kg average liveweight) which was selected as the target for the representative Burdekin Rangelands herd. Implementing the change added ca. $127,100 to the annual profit of the enterprise. However, a significant peak deficit occurred in Year 3 of the analysis (-$371,600) as the breeder herd was reduced and the steer herd retained to the older sale age. The property manager considering the changed age of sale for steers would need to consider the impact of this deficit on the cash flow of the property.

An important consideration is that short term changes in the relative prices of cattle classes may result in a different optimal age of steer sale to that identified based on longer-term historical prices and may identify opportunities to increase profitability in the short term by deviating from the long-term sale target. However, having an understanding of the optimal herd structure based on cattle price data over a more extended period (e.g. 7-10 years) will allow profit to be maximised over the long term by moving back to the long-term optimal herd structure following deviations.

Table 24 - Returns for converting from weaner steer production to 42 month-old steer production

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Discount rate for NPV	5.00%
NPV	$1,953,251
Annualised NPV	$127,062
Peak deficit (with interest)	-$371,648
Years to peak deficit	3
Payback period (years)	3
IRR	n/c

3.2 Genetic improvement of weaning rate

3.2.1 Introduction

Research has identified that improvement in herd weaning rates are possible by applying selection for reproduction efficiency. Examples of relevant research results include:

- Johnston *et al.* (2013) identified that opportunities exist, particularly in Brahman cattle, to improve weaning rates though genetic selection.
- Burns *et al.* (2014) estimated that an EBV for sperm motility in Brahman cattle may lift lifetime weaning percentage by 6 percentage points in 10 years.

3.2.2 Methods

The benefits expected to arise from converting the base female herd to a breeding herd with different genes for reproduction that provide a 6 percentage point improvement in breeder weaning rates, as per Burns *et al.* (2014), were tested. This strategy was tested using two methods of implementation. One approach (Scenario 1) changed over the bulls within the breeding herd in the first year and incurred a capital cost and the second approach (Scenario 2) replaced the bulls as they came due for replacement and incurred no additional capital costs. Both approaches to implementing the change paid no more per head for the bulls with the genes for improved fertility compared to the purchase of regular herd bulls.

In Scenario 1 it was assumed that the property manager converted all of the current breeding bull herd to one with different genes in the first year of the analysis with the first group of genetically different calves born towards the end of the second year. The calendar year was used in the analysis which resulted in calves being born around December of the first year from the mating prior to the changeover of the bulls. On this basis it was Year 4 before heifers with genes capable of providing a 6 percentage point improvement in conception rate were first mated and calved. Heifer culling and mating strategies were maintained as the genes for reproduction efficiency spread through the breeder herd. This meant that ca. 30% of replacement heifers were culled before mating and empty replacement heifers were all culled after their first mating. Mature cows were culled on the basis of pregnancy status and their age. The cow culling strategy of the base herd was maintained in the herd with genetic improvement of weaning rate to allow identification of the net benefits of the change in weaning rates.

The cost of replacement herd bulls was set at the same price used in the base herd, i.e. $6,000. The average price for replacement bulls was set relative to the long-term cattle prices used for the base herd. Existing herd bulls were sold at 50% of their current value with 50% of these sold to industry and the other 50% sold to the abattoirs. The net cost of the changeover of all of the herd bulls at the beginning of the investment period (Year 1 of the analysis) was $147,000 (49 x $6,000 for the new bulls less 49 x $3,000 for the old ones).

No other herd performance parameters were changed. The herd structure was rebalanced to maintain grazing pressure as the genes for improved reproduction efficiency flowed through the breeding herd. The age for final culling for mature breeders was maintained at the same age as the base herd (i.e. 12 years). Table 25 shows the change in weaning rate and other factors as the genes flowed through the breeding herd and performance increased. The herd modelling indicated that it was likely to take at least 13 years for the overall herd weaning rate to improve by 5.53 percentage points (to 67.89%) if the entire bull herd was replaced in the first year. The increase in weaning rate stabilised at 5.53 percentage points rather than 6 percentage points due to the numbers in the first calf cow class increasing as a proportion of the herd as herd structure changed with implementation of the scenario. This reduced overall herd efficiency as the improved conception rate of first calf cows (i.e. from their second mating) at 51.5% was still well below that of the mature breeders not yet benefiting from any genetic improvement (e.g. 76% for 4-10 year age class).

Table 25 - Modelled steps in genetic change of weaning rate with bull replacement in Year 1 (immediate changeover of bulls) at the same cost as regular bulls

The herd weaning rate is shaded grey

Parameter	Base herd (Year 1-3)	Year 4	Year 5	Year 6	Year 7	Year 8	Year 10	Year 13
Total AE	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500
Total cattle carried	2,903	2,904	2,905	2,905	2,906	2,906	2,907	2,903
Weaner heifers retained	379	380	381	382	383	383	384	380
Total breeders mated	1,216	1,196	1,181	1,172	1,163	1,156	1,146	1,138
Total breeders mated and kept	993	993	988	984	981	979	975	975
Total calves weaned	759	759	762	764	765	766	769	772
Weaners/total cows mated	62.36%	63.45%	64.48%	65.18%	65.77%	66.28%	67.08%	67.89%
Overall breeder deaths	3.00%	3.00%	3.00%	2.99%	2.98%	2.98%	2.98%	2.97%
Female sales/total sales %	48.43%	48.43%	48.46%	48.48%	48.49%	48.50%	48.52%	48.56%
Total cows and heifers sold	332	332	334	335	336	337	338	340
Maximum cow culling age	12	12	12	12	12	12	12	12
Heifer joining age	2	2	2	2	2	2	2	2
Two year-old heifer sales %	45.42%	45.17%	48.08%	49.97%	51.47%	52.66%	54.28%	54.28%
Total steers and bullocks sold	354	354	355	356	357	357	358	360
Maximum bullock turnoff age	3	3	3	3	3	3	3	3

Scenario 2 involved introduction of the different genes for fertility at a slower rate and without the additional capital costs as incurred in Scenario 1. In Scenario 2, replacement bulls with the different genes for fertility were purchased at the same cost as the previous replacement herd bulls (i.e. $6,000/head) as herd bulls became due for replacement. Another assumption applied in this scenario was that no additional costs would be incurred in herd management. The heifers produced by the bulls with different genes for fertility were grouped with the heifers without the genes for fertility of the same age and all were subject to the same selection criteria as they moved through the age cohorts of the breeding herd. The constraint that no additional costs should be incurred prevented the identification of the genetically different heifers. The result was that females with and without the different genes had the same chance of being culled. The bulls with the different genes were allocated to mature cow groups with the highest conception rates so that proportionally more heifers with the genes for fertility were likely to be mated in any age cohort as the different genes flowed through the herd. Whether this would be possible in an actual herd is difficult to determine but appears unlikely.

Table 26 shows the incremental change in conception rates over the first 14 matings as the genetically different bulls replaced the current bull herd. All heifers had the different genes from the fifth mating, and it was Year 14 before the entire breeder herd was converted with the impact from that mating to occur in Year 17.

Table 26 - Incremental steps in genetic change of conception rate with bulls replaced over time (Gradual changeover of bulls)

Herd parameter	Mating					
	1st	**2nd**	**3rd**	**4th**	**5th**	**14th**
Total herd bulls	45	45	45	45	45	
Bulls with different genes	9	18	27	36	45	
Mature cows mated to different bulls	226	453	679	906		
Number that conceive	186	371	557	745		
Number that wean a calf	167	335	502	672		
Heifer weaners produced	84	167	251	336		
Yearling heifers	82	164	245	328		
Two year heifers pre culling	80	160	240	321		
Heifers with different genes mated	59	119	178	238		
total heifers mated	273	273	273	273		
Percentage of heifers with different genes	21.7%	43.4%	65.2%	87.1%	100%	
Improvement in conception rate of mated heifers	1.3%	2.6%	3.9%	5.2%	6.0%	6.0%
Improvement in conception rate of 3-4 year heifers		1.3%	2.6%	3.9%	5.2%	6.0%
Improvement in conception rate of 4-5 year cows			1.3%	2.6%	3.9%	6.0%
Improvement in conception rate of 5-6 year cows				1.3%	2.6%	6.0%
Improvement in conception rate of 6-7 year cows					1.3%	6.0%
Improvement in conception rate of 7-8 year cows						6.0%
Improvement in conception rate of 8-9 year cows						6.0%
Year of impact	Year 4	Year 5	Year 6	Year 7	Year 8	Year 17

Table 27 shows the change in herd structure over the 17 years taken to fully implement the strategy.

Table 27 - Modelled steps in genetic change of weaning rate and herd structure with bulls replaced over time (Gradual bull changeover) at the same cost as regular bulls

The herd weaning rate is shaded grey

Herd component	Base herd (Year 1-3)	Years 4	Year 6	Year 8	Year 10	Year 14	Year 17
Total AE	2,500	2,500	2,500	2,500	2,500	2,500	2,500
Total cattle carried	2,903	2,903	2,904	2,905	2,906	2,908	2,908
Weaner heifers retained	379	379	380	382	383	385	385
Total breeders mated	1,216	1,212	1,194	1,172	1,156	1,138	1,134
Total breeders mated and kept	993	993	990	984	979	972	972
Total calves weaned	759	759	761	764	767	770	771
Weaners/total cows mated	62.36%	62.512%	63.69%	65.17%	66.29%	67.66%	67.94%
Overall breeder deaths	3.00%	3.00%	3.00%	2.99%	2.98%	2.97%	2.97%
Female sales/total sales %	48.43%	48.43%	48.45%	48.44%	48.50%	48.53%	48.54%
Total cows and heifers sold	332	332	333	335	337	339	339
Maximum cow culling age	12	12	12	12	12	12	12
Heifer joining age	2	2	2	2	2	2	2
Two year-old heifer sales %	45.42%	45.45%	47.12%	49.89%	52.61%	55.09%	55.41%
Total steers and bullocks sold	354	354	355	356	357	359	359
Maximum bullock turnoff age	3	3	3	3	3	3	3

3.2.3 Results and discussion

The beef property was slightly better off with the investment in better genetics for breeder fertility, when bulls were gradually replaced over time to improve the average herd weaning rate by 5.6 percentage points with an annualised NPV of $10,700/annum (Table 28). The alternative to replacing the bull herd gradually was to replace all bulls in Year 1 with those that had the potential to improve breeder fertility as predicted by Burns *et al*. (2014). This strategy resulted in a non-impactful effect on property profit (likely to be unmeasurable on a commercial property), i.e. < ±$5,000/annum (Table 28).

Table 28 - Returns for investing in genetically superior bulls to improve breeder fertility when superior bulls are the same cost as regular bulls

All terms defined in the Glossary of terms and abbreviations

Factor	Year 1 bull changeover	Gradual bull changeover
Period of analysis (years)	30	30
Discount rate for NPV	5.00%	5.00%
NPV	$23,638	$164,775
Annualised NPV	$1,538	$10,719
Peak deficit (with interest)	-$173,731	n/c
Years to peak deficit	6	n/c
Payback period (years)	24	n/c
IRR	6.10%	n/c

The results for investment in genetic improvement in weaning rate in the Burdekin Rangelands were similar to those in the Northern Gulf (Bowen *et al.* 2019a) where returns were also unchanged with immediate bull replacement (< ±$5,000/annum) and only slightly improved with gradual bull replacement ($6,800). Comparable analyses for the more productive regions of central Queensland and the Northern Downs produced even poorer results for the same strategies with returns either slightly reduced or unchanged compared to the base herd (Bowen and Chudleigh 2018b; Chudleigh *et al.* 2019a; Bowen *et al.* 2020a). An effect of diminishing returns for change in weaning rate occurred in more productive herds such as the Fitzroy NRM region and Northern Downs where the representative base herds had weaning rates of 77% and 65%, respectively from cows mated cf. 59% in the Northern Gulf and 62% in the Burdekin Rangelands. Previous analyses have indicated that benefits of increasing weaning rate quickly decrease once 65% weaning rate (from all cows mated) is exceeded (Bowen and Chudleigh 2018b; Chudleigh *et al.* 2019a; Bowen *et al.* 2019a, 2020a).

Importantly, beef producers should be aware that the time taken to change the reproduction efficiency of the herd through selecting only replacement bulls with the characteristics described by Burns *et al.* (2014) would be decades, and any reduction in other herd performance parameters due to the introduction of the genes for changed reproduction efficiency would quickly negate any potential for economic gains. Additionally, economic returns will be reduced if a premium is paid for genetically superior bulls.

3.3 Objectively selected home-bred bulls

3.3.1 Introduction

Replacement bulls are a substantial cost to the property. If home-bred bulls, produced from a group of breeders with sound performance, are objectively selected, tested for soundness, and used in the breeding herd, this could substantially reduce the cost of bull replacement. This strategy would rely on the selected bulls at least maintaining the performance parameters of the total herd over time.

3.3.2 Methods

In this strategy, the potential economic impact of selecting breeding bulls from the male weaners, rather than purchasing replacement bulls, was tested. The strategy involved the objective selection of home-bred bulls so as to maintain the starting performance parameters of the total herd over time. The opening complement of herd bulls required for the breeding herd, when stabilised at 2,500 AE, was about 49 bulls (bull to cow ratio of 4%). In the base herd, ca. ten replacement bulls entered the herd annually (ca. 20% of bull herd) as 2 year-olds, purchased for an average landed cost of $6,000. The average price for replacement bulls was set relative to the long-term cattle prices used for the base herd. Herd bulls were kept for 5 years with the annual mortality rate expected to average 5%. The percentage of bulls used in the breeding herd was expected to continue at 4% when the change to home-bred bulls was made. Table 29 shows the structure and replacement strategy for the breeding bull herd for the base property.

Table 29 – Bull replacement strategy and cost for the base herd using purchased bulls

Parameter	Value
Number of bulls required	49
Cost of bulls purchased annually (10 bulls costing $6,000 each)	$60,000
Value of bulls sold annually (7 bulls at $1,620 each)	$11,340
Average value per head of bulls on hand	$4,123
Net bull replacement cost (total)	$46,693
Net bull replacement cost per calf weaned	$61.52

The home-bred bull scenario involved identifying a group of male weaners at the first round weaning that had been produced by cows with sound reproductive performance. The weaner bulls were kept to yearling age when 50% were sold after being culled on objective measures such as weight gain, tick score and scrotal size. Cull yearling bulls were sold at the same average price for steers of the same age. The final group of selected bulls entered the breeding bull herd after testing for soundness. Culled herd bulls of a mature age were sold to the abattoirs for the same average value as for the base herd using purchased bulls. The first group of weaner bulls was retained in the first year of the analysis and entered the bull herd in the third year.

This scenario relied upon the maintenance of accurate records for the reproduction performance of heifers over their first two matings so that young cows with better reproduction performance could be identified, segregated and their progeny identified. These young females were used to maintain a group of cows to produce the calves from which the weaner bulls were selected. It was assumed that 100 cows would be kept as a separate breeder group for the purpose of producing home-bred bulls. Any non-pregnant females in the separate breed group were replaced with cows that had produced a viable weaner at their first mating and were then pregnancy tested as 'in calf' (PTIC) at first round weaning after their second mating.

The additional costs expected to be incurred by the bull selection process were $65 per weaner bull retained ($1,300/annum). These costs included costs of additional record keeping, bull testing and some additional labour. A total of $10,000 worth of additional fencing and water infrastructure was required to keep the weaner and yearling bulls separate until they entered the bull herd. Additional expenses incurred in maintaining the records for the heifers and the segregated breeders were expected to be about $20 per cow retained in the segregated herd ($2,000/annum).

3.3.3 Results and discussion

The investment in conversion to home-bred bulls rather than purchased bulls was paid back by the end of year two of the analysis, with an annualised NPV of $35,800/annum (Table 30). The return on the extra funds invested was 142% per annum. The key assumptions were that the bull to cow mating ratio could be maintained, and that no aspect of herd performance (reproduction or growth) would be impacted by the change. The relatively large positive returns for this scenario, comparative to others examined for the Burdekin Rangelands property, indicates that a strategy of investing in producing home-bred bulls is worthy of further consideration. Similar, positive returns for investing in production of home-bred bulls was determined for constructed properties in the Northern Gulf (Bowen *et al.* 2019a) and the Northern Downs (Bowen *et al.* 2020a) regions of Queensland.

Table 30 - Returns for investing in production of home-bred bulls compared to the base herd using purchased bulls

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Discount rate for NPV	5.00%
NPV	$551,093
Annualised NPV	$35,849
Peak deficit (with interest)	-$17,265
Year of peak deficit	2
Payback period (years)	2
IRR	142.10%

3.4 Investing to reduce foetal/calf loss

3.4.1 Introduction

Foetal/calf loss, or calf wastage, is reproductive loss between a confirmed pregnancy and weaning. Foetal/calf loss has been shown to be typically 5-15% in tropical and sub-tropical Australia and, in some instances, up to 40% (McCosker *et al.* 2022). Neonatal mortality (i.e. death during the first week following birth) accounts for two-thirds of foetal/calf loss in tropical herds with the majority of these mortalities unable to be explained (Bunter *et al.* 2014). Fordyce *et al.* (2022) concluded that poor pre-partum nutrition and high ambient heat load around calving are associated with increased calf wastage. These two risk factors are commonly associated with the peak calving period in northern Australia which is during the late dry season (November – January) so as to synchronise the maximum nutritional requirements of breeders with the best quality pasture during the wet, growing season.

The MLA-funded CashCow project (McGowan *et al.* 2014) identified median values of 16.4% foetal/calf loss in heifers, 9.5% in first lactation cows and an overall rate of 12.9% for the Northern Forest region, which is applicable to the Burdekin Rangelands region study area. (Table 31). These losses occurred sometime between conception (pregnancy testing) and weaning. Calf losses were identified in the CashCow project if a heifer or cow was diagnosed as pregnant in one year and was recorded as dry (non-lactating) at an observation at least one month after the expected calving month the following year. This measure of foetal/calf loss, as it was derived in the CashCow project, excludes cow mortality during the same period and subsequent calf loss due to that source.

Table 31 - Median reproduction performance for Northern Forest data (McGowan et al. 2014)

Reproduction performance indicator	Heifers	First lactation cows	2nd lactation cows	Mature	Aged	Overall
P4M*		11%	6%	16%	20%	15%
Annual pregnancy**	67%	43%		68%	63%	66%
Foetal/calf loss	16.4%	9.5%		11.8%	13.7%	12.9%
Contributed a weaner^	55%	23%		57%	52%	53%
Pregnant missing#		7.7%		11.3%	11.9%	10.6%

*P4M - Lactating cows that became pregnant within 4 months of calving

** Percentage of cows in a management group (mob) that became pregnant within a 1-year period. For continuously mated herds, this included cows that became pregnant between September 1 of the previous year and August 31 of the current year

^Females were recorded as having successfully weaned a calf if they were diagnosed as being pregnant in the previous year and were recorded as lactating (wet) at an observation after the expected calving date.

#Pregnant animals that fail to return for routine measures, but not including irregular absentees. It comprises mortalities, animals whose individual identity is lost, and those that permanently relocate either of their own accord or without being recorded by a manager.

Assumed reproduction parameters for the Burdekin Rangelands 2,500 AE herd were, on average, slightly better than those measured in the CashCow project, reflecting the slightly better land types compared to the average of the CashCow, Northern Forest data sets, and also conservative grazing management on the Burdekin Rangelands property to match the property safe carrying capacity of 2,500 AE (Table 32).

Table 32 - Reproduction parameters and mortality rates for the Burdekin Rangelands property stocked at 2,500 AE

Initial cattle age	**6 months**	**1**	**2**	**3**	**4**	**8**	**10**	**11**
Final cattle age	**1**	**2**	**3**	**4**	**8**	**10**	**11**	**12**
Expected conception rate for age group (%)	n/a	0	76	46	76	76	71	66
Expected calf loss from conception to weaning (%)	n/a	0	14	7.5	10	12	12	12
Female death rate (%)	2.3	2.3	4.1	2.7	2.7	2.7	2.7	2.7
Male death rate (%)	2.3	2.3	2.3	2.3	n/a	n/a	n/a	n/a

AE, adult equivalent; n/a, not applicable.

The CashCow project (McGowan *et al.* 2014) developed a possible causal pathway for calf loss (Figure 9). Each property manager would need to work their way through the factors likely to affect calf/foetal loss in their herd based on the modelling of the CashCow project and the causal pathways identified in Figure 9, if a relatively high value for loss in any age class of females was identified. From there an analysis based on the identified cause and effect pathway could proceed. In the absence of a demonstrated technology to effectively address the foetal/calf loss issue at present, an economic analysis of the value of addressing this issue can be conducted by assuming that a certain amount of money can be spent per head or per property to achieve a desired result. This approach can be considered a scoping study of the potential economic value of addressing this issue and identifies how much money can be invested to achieve the desired result, if a positive economic outcome is desired.

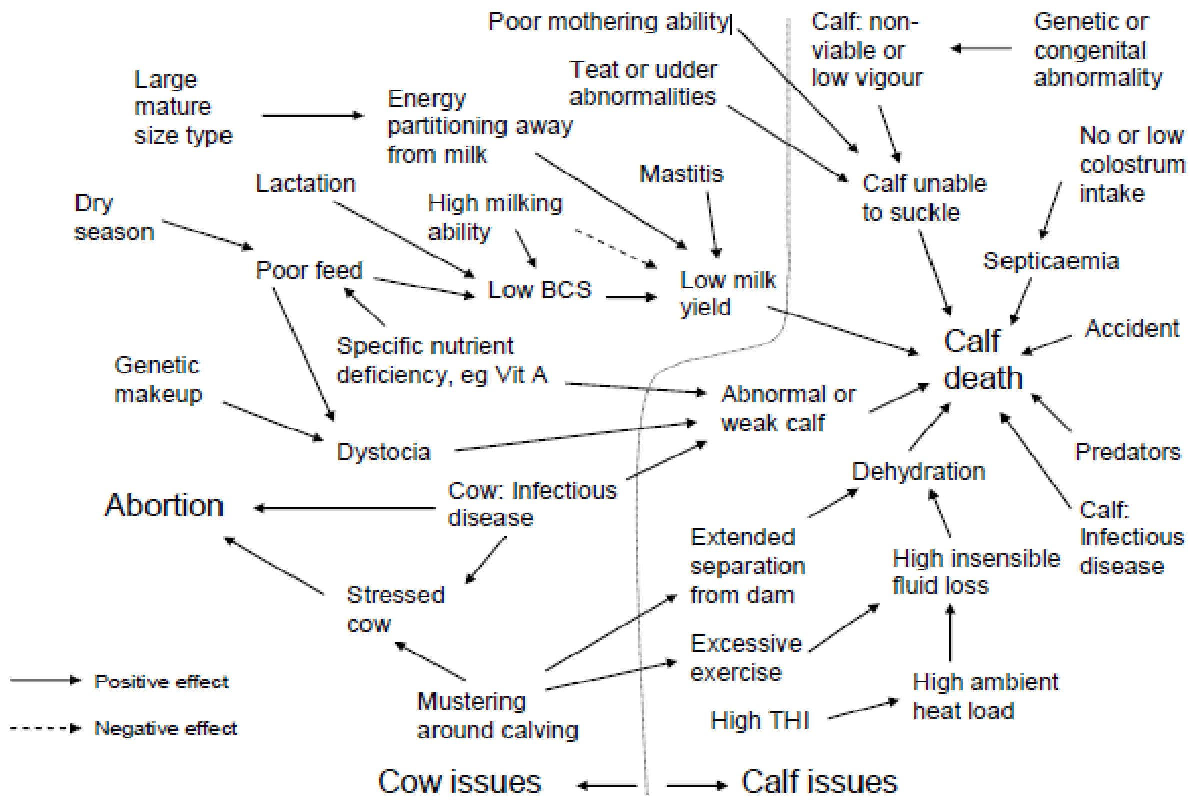

Figure 9 - Possible causal pathway for foetal and calf loss in northern Australia (McGowan et al. 2014)

3.4.2 Methods

In this strategy an investment to reduce foetal/calf loss in all breeders was investigated. The wide range of possible agents and combinations of agents identified by the CashCow project (McGowan *et al.* 2014), together with a lack of other research data indicating a 'typical' cause and effect relationship for our beef property limits the identification of appropriate examples for analysis and requires us to rephrase the question. Therefore, the question was rephrased to look at what level of expenditure could be incurred to resolve a foetal/calf loss problem. The first question was:

1. If $10, $20 or $30 was spent per head across the entire breeder herd (excluding weaner heifers and cull breeders in each year), and foetal/calf loss reduced by 50%, what would be the return on the funds spent?

   As the CashCow project (McGowan *et al.* 2014) also identified that additional capital costs (such as effective fencing, good paddock design, appropriate segregation, training of cattle, and selection for temperament) could be required to address the problem of foetal/calf loss, a second question was assessed.

2. What amount of capital could be spent (upfront) to reduce calf mortality by 50% across all breeders on this property? Returns for investment of $200,000, $400,000, or $600,000 were examined.

The data from the new steady-state herd model with 50% lower rates of calf loss across all breeders and weaner females were imported as the new herd culling target for the base investment herd model and the additional treatment costs were inserted from the first year. Where the examples considered additional capital expenditure, the capital costs were added to the capital purchases section of the first year of the investment model. A 1-year lag between expenditure and receipt of benefits was applied for all strategies aimed at improving foetal/calf loss. The treatment cost allocated included the cost of any treatment plus any additional labour required to undertake the treatment. The effective economic life of additional capital invested was taken to be 30 years with no residual value. The base herd model (without change) and the 'with change' herd models were compared to identify the additional returns achieved.

3.4.3 Results and discussion

Table 33 presents the results of the investment analysis to achieve a 50% reduction in calf loss across all breeding females at cost levels of $10, $20 and $30 per retained female per annum or upfront capital expenditure of $200,000, $400,000 and $600,000. The analysis indicates that no more than $10/head.annum across the entire breeding herd excluding weaner heifers should be spent on reducing foetal/calf loss by 50% if a return on the funds invested was being sought. For this size of herd and property (25,000 ha; 2,500 AE), expenditure of up to $200,000 as upfront capital expenditure with no additional ongoing expenses appears worth further consideration on the basis that foetal/calf loss is reduced by at least 50% across the entire breeding herd. The maximum amount of capital that can be invested upfront to resolve a calf loss issue is directly related to the size and current productivity of the herd together with the level of change in productivity achieved. On the other hand, the size of the herd would not impact the benefits arising from applying per head treatment costs as only the current level of herd productivity and the change in herd productivity would impact benefits.

Table 33 - Returns for investing to achieve a 50% reduction in calf loss across all breeding females

All terms defined in the Glossary of terms and abbreviations

Factor	Investment type					
	$10/head .annum	**$20/head. annum**	**$30/head. annum**	**$200,000 capital**	**$400,000 capital**	**$600,000 capital**
Period of analysis (years)	30	30	30	30	30	30
Discount rate for NPV	5%	5%	5%	5%	5%	5%
NPV	$168,986	-$36,142	-$241,269	$183,637	-$6,840	-$197,316
Annualised NPV	$10,993	-$2,351	-$15,695	$11,946	-$445	-$12,836
Peak deficit (with interest)	-$13,620	-$162,234	-$1,042,749	-$200,000	-$403,862	-$852,788
Year of peak deficit	1	29	n/c	1	5	n/c
Payback period (years)	1	n/c	n/c	11	n/c	n/c
IRR	95.73%	-2.16%	n/c	11.96%	4.85%	1.75%

It is very important to recognise that the likely benefit of any combination of upfront capital and expenditure on additional livestock treatments should not be inferred from this analysis. Additionally, it should be recognised that, at present, a clear understanding of biological responses to strategies that can achieve a 50% reduction in calf loss have not been identified and demonstrated, despite an understanding of possible causal pathways (Figure 9). However, as current research activities are being conducted in this area of reducing foetal/calf loss it was deemed pertinent to consider the amount of money that could be invested in reducing foetal/calf loss for an individual beef property if a return on funds invested was being sought.

These results for the Burdekin Rangelands region are in accord with those for both less productive (Northern Gulf; Bowen *et al.* (2019a)) and more productive (central Queensland; Bowen and Chudleigh (2018b) and Northern Downs; Bowen *et al.* (2020a)) regions of Queensland. It is evident that more can be spent to achieve the same 50% reduction in foetal/calf loss where median breeder reproductive performance is lower. This is because of the effect of diminishing returns in the more productive regions. Additionally, higher cattle prices will also result in an increase in the economic benefit from an investment to achieve a production benefit.

3.5 Supplementing weaner heifers to improve conception rates as 2-year-olds at first mating

3.5.1 Introduction

Nutritional limitations in northern Australia can result in weaning weights and post-weaning growth being less than optimal for maximising heifer liveweight premating and therefore for maximising the subsequent pregnancy and weaning rates of first-calf heifers. Many studies have demonstrated the positive relationship between premating liveweight of heifers and pregnancy rates. The pregnancy rate of 80% has been commonly adopted when selecting target premating weights (e.g. Rudder *et al.* 1985; Doogan *et al.* 1991; Fordyce *et al.* 1996; Schatz and Hearnden 2017). An average weight at puberty for Brahman heifers of 334 kg (range of 196-485 kg) is widely quoted from the study of Johnston *et al.* (2009). More recently, Schatz and Hearnden (2017) reported a similar figure of 338 kg average weight at first conception of 2 year-old Brahman heifers conceiving over a 3-month mating period. In this latter study, the relationship between pregnancy rate and pre-mating weight predicted a pregnancy rate of 80% in 2 year-old maiden Brahman heifers from a (curfewed) premating weight of 278 kg in late December. Poppi *et al.* (2018) concluded that 2 year-old heifers need to weigh 300 kg at the start of the wet season mating period to achieve 80% pregnancy rate. Improved nutrition can increase the proportion of heifers in a cohort attaining the target premating weight by the start of the joining period. Research in northern Australia with *B. indicus* heifers has examined relationships between varying levels of post-weaning supplementation and subsequent reproductive performance (Schatz 2010; Poppi *et al.* 2018; Silva *et al.* 2022).

There is ongoing interest from producers, including in the Burdekin Rangelands region, in the value of post-weaning supplements for heifers to improve pre-mating liveweight and subsequent reproductive performance. The combined research of Schatz (2010), Schatz and Hearnden (2017), Poppi *et al.* (2018), and Silva *et al.* (2022) can be used to assess the effect of supplementing weaner heifers, to improve premating weights and conception rates, on whole herd productivity and profitability.

3.5.2 Supplementing the entire weaner heifer cohort

3.5.2.1 Methods

In this strategy, a change in the conception rate of 2 year-old, maiden heifers was sought by improving their bodyweight prior to first mating with a molasses production mix supplement containing, on an as fed basis: molasses 877 g/kg, urea 17.5 g/kg, salt 8.77 g/kg, dicalcium phosphate 8.77 g/kg, wheat gluten pellets 87.7 g/kg, with a nutrient composition (dry matter basis) of 13.3% CP, 11.1 MJ ME/kg.

The parameters for the supplementation scenario were based on the weaner supplementation study reported by Poppi *et al.* (2018), and Silva *et al.* (2022) in conjunction with the response functions for pregnancy rates reported by Schatz (2010) and Schatz and Hearnden (2017). These studies were undertaken with high *B. indicus* content heifers in the Northern Territory of Australia with the average growth rates of heifers reported in those studies generally representative of much of northern Australia including the target region for the present study, the Burdekin Rangelands.

The growth model for the Burdekin Rangelands base herd indicates that weaner heifers will average ca. 167 kg liveweight in mid-June at 6 months of age (average age of cohort). Feeding the heifers with the molasses production mix ($483/t delivered on-property), at an average rate of 3 kg/head for 156 days during their first dry season after weaning, is expected to allow the heifers to gain an additional 52 kg of liveweight compared to non-supplemented heifers by mid-December. That is, supplemented heifers will average 233 kg in mid-December, cf. 181 kg for non-supplemented heifers in the base herd. It is assumed that the heifers will eat ca. 3 kg supplement per day (13.3% CP and 11.1 MJ ME/kg DM) in addition to 1.8 kg DM grass (ca. 6% CP and 6.5 MJ ME/kg DM) which would allow a liveweight gain of ca. 0.4 kg/day.

As per the studies of Poppi *et al.* (2018) and Silva *et al.* (2022) the weight advantage of supplemented heifers was expected to decrease over time due to compensatory gain over the subsequent wet seasons. As per Poppi *et al*. (2018), our assumptions were that the 53% of the liveweight advantage would have been lost during the first wet season after weaning (and supplementation), 66% lost by the start of the second wet season and 94% lost by the end of the second wet season after weaning. This erosion of liveweight benefit to supplementation over time resulted in the supplemented weaner heifers having a ca. 13 kg weight advantage by mid-January at 25 months of age (319 cf. 306 kg LW for unsupplemented heifers). The average weight of mature cows (460 kg) did not change as a result of weaner heifer supplementation, but cull heifers had slightly heavier sale weights than in the base herd.

In the base herd, the conception rate of maiden 2-3 year-old heifers was 76%. Expected calf loss from conception to weaning was 14.4%, giving a weaning rate per heifers mated of 65.14% for that cohort. The relationships of Schatz (2010) and Schatz and Hearnden (2017) suggest a 1.5-1.9% increase in pregnancy rate per 10 kg additional weight at ca. 300-310 kg pre-mating liveweight. However, we applied a 4% increase in conception rates in the supplemented heifer group following their first mating, i.e. from 76% to 80% to model a best case scenario in terms of response to supplementation. Expected calf loss from conception to weaning is expected to be unchanged in the supplemented heifer group at first mating (i.e. 14.4%) giving a weaning rate per heifers mated of 68.68% for the supplemented heifer cohort. As a consequence of annual supplementation of weaner heifers for 156 days with the molasses production mix, the overall weaning rate (weaners per total cows mated) for the herd changed from 62.36% to 63.10%, i.e. by 0.74 percentage points.

No conception rate advantage was applied to the first-calf heifers at their second mating following supplementation as weaners. The small expected differences in expected liveweight between heifers supplemented as weaners and those not supplemented, by their second mating, indicates that any benefits in conception rates by this time, are unlikely.

The calculation of the expected feeding cost of the molasses production mix supplement is shown in Table 34. One-off capital expenditure of $5,000 was required for troughs and infrastructure to feed the supplement. As the supplement was delivered to the property, directly into troughs, there were no additional feeding out costs.

Table 34 – Calculation of feeding costs for weaner heifers

Parameter	Value
Number of weaner heifers to be fed	372
Average body weight (kg)	200
Supplement consumed (1.5% liveweight; kg/head.day)	3.0
Number of days to be fed	156
Total supplement consumed daily (t/day)	1.1
Cost of supplement ($/t delivered on-property)	$483
Total supplement fed (t)	174.1
Total cost of supplement ($)	*$84,088*
Cost per head fed	*$226.04*

3.5.2.2 Results and discussion

Table 35 shows the predicted investment returns for feeding the molasses production supplement to weaner heifers to achieve a 4% increase in their conception rates at first mating as 2 year-olds. The investment produced a negative annualised NPV of ca. $88,300/annum. Therefore, implementing this strategy is likely to substantially reduce the ongoing profitability of the property.

Table 35 - Returns for investment in a molasses production supplement for weaner heifers to improve their reproductive performance at first mating as 2-year-olds

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Discount rate for NPV	5.00%
NPV	-$1,357,533
Annualised NPV	-$88,309
Peak deficit (with interest)	-$5,867,181
Year of peak deficit	n/c
Payback period (years)	n/c
IRR	n/c

The unprofitability of this strategy is in accord with gross margin analysis presented in Poppi *et al.* (2018) which found no gross margin advantage from supplementing either normally or early weaned heifers. Despite the lack of a significant difference in their experiment for pregnancy rates of supplemented weaner heifers mated at 2 years of age (cf. unsupplemented heifers), the gross margin analysis applied an assumed change in conception rates of ca. 5% in maiden heifers based on the weight and conception relationships developed by Schatz (2010). This approach is similar to that applied in our current analysis. However, our analysis was conducted at the herd level and indicates the effect on whole of property profitability from implementing the strategy.

An important consideration is that the average pre-mating liveweight of heifers in the Burdekin Rangelands base herd was already close to the pre-mating targets indicated by research, e.g. 300 kg liveweight for 2 year-old heifers at the start of the wet season mating period to achieve 80% pregnancy rate as suggested by Poppi *et al.* (2018). The heifers in the Burdekin Rangelands base herd were expected to be an average of 293 kg liveweight in mid-December and 306 kg liveweight in mid-January. At this pre-mating liveweight, the conception rate response is expected to be much less than at lower liveweights, e.g. 4% increase in conception rates per 10 kg liveweight increase for 260 kg heifers pre-mating vs. 1.9% increase in conception rates per 10 kg liveweight increase for 300 kg heifers pre-mating (Schatz 2010). However, even when an optimistic conception rate response of 4% was applied, this scenario was unprofitable. This result indicates that targeting a lighter liveweight group of the weaner heifer cohort, to improve their conception rates as 2 year-olds, may be a more appropriate strategy.

3.5.3 Supplementing the lightest one third of the heifer cohort

3.5.3.1 Methods

In this strategy, the lightest one third of the heifer cohort (126 head) were targeted with molasses production mix to improve their liveweight and hence their conception rates as 2 year-old, maiden heifers. The molasses production mix supplement contained, on an as fed basis: molasses 877 g/kg, urea 17.5 g/kg, salt 8.77 g/kg, dicalcium phosphate 8.77 g/kg, wheat gluten pellets 87.7 g/kg, with a nutrient composition (dry matter basis) of 13.3% CP, 11.1 MJ ME/kg.

The parameters for the supplementation scenario were based on the weaner supplementation study reported by Poppi *et al.* (2018), and Silva *et al.* (2022) in conjunction with the response functions for pregnancy rates reported by Schatz (2010) and Schatz and Hearnden (2017). These studies were undertaken with high *B. indicus* content heifers in the Northern Territory of Australia with the average growth rates of heifers reported in those studies generally representative of much of northern Australia including the target region for the present study, the Burdekin Rangelands.

The growth model for the Burdekin Rangelands base herd indicates that weaner heifers will average ca. 167 kg liveweight in mid-June at 6 months of age (average age of cohort). If a standard deviation of 20 kg is assumed for the heifer cohort, the average weight of the lightest one third of the heifer group (126 head) would be 145 kg liveweight. Feeding this group of light heifers with the molasses production mix ($483/t delivered on-property), at an average rate of 2.6 kg/head for 183 days (6 months) during their first dry season after weaning, is expected to allow the heifers to gain an additional 41 kg of liveweight compared to non-supplemented heifers by mid-December. That is, supplemented heifers will average 200 kg in mid-December, cf. 158 kg for non-supplemented heifers in that same light cohort. It is assumed that the heifers will eat ca. 2.6 kg supplement per day (13.3% CP and 11.1 MJ ME, as fed) in addition to 1.2 kg grass (ca. 6% CP and 6.5 MJ ME/kg DM) which would allow a liveweight gain of ca. 0.3 kg/day.

As per the studies of Poppi *et al.* (2018) and Silva *et al.* (2022) the weight advantage of supplemented heifers was expected to decrease over time due to compensatory gain over the subsequent wet seasons. As per Poppi *et al*. (2018), our assumptions were that the 53% of the liveweight advantage would have been lost during the first wet season after weaning (and supplementation), 66% lost by the start of the second wet season and 94% lost by the end of the second wet season after weaning. This erosion of liveweight benefit to supplementation over time resulted in the supplemented weaner heifers having a ca. 11 kg weight advantage by mid-January at 25 months of age (294 cf. 283 kg LW for unsupplemented heifers in the light cohort). The average weight of mature cows (460 kg) did not change as a result of weaner heifer supplementation, but cull heifers at 30 months of age had slightly heavier sale weights than in the base herd.

In the base herd, the conception rate of the entire maiden 2-3 year-old heifer cohort was 76%. Expected calf loss from conception to weaning was 14.4%, giving a weaning rate per heifers mated of 65.14% for that cohort. The relationships of Schatz (2010) and Schatz and Hearnden (2017) suggest a 2.8% increase in pregnancy rate per 10 kg additional weight at ca. 280 kg pre-mating liveweight. However, we applied a 4 percentage point increase in conception rates in the supplemented heifer group following their first mating, i.e. from 76% to 80% to model a best possible scenario in terms of response to supplementation, although this response appears unlikely at the premating liveweights in our base Burdekin Rangelands herd. The 4 percentage point increase in conception rate of the lightest one third of the maiden heifers resulted in an average increase for the entire cohort of 1 percentage point (i.e. from 76% to 77% average conception rate for 2-3 year-old maiden heifers). As a consequence of annual supplementation of the lightest one third of weaner heifers for 183 days with the molasses production mix, the overall weaning rate (weaners per total cows mated) for the breeder herd changed from 62.36% to 62.55%, i.e. by 0.2 percentage points.

No conception rate advantage was applied to the first calf heifers at their second mating following supplementation as weaners. The small, expected differences in expected liveweight between heifers supplemented as weaners and those not supplemented, by their second mating, indicates that any benefits in conception rates by this time, are unlikely.

The calculation of the expected feeding cost of the molasses production mix supplement is shown in Table 36. One-off capital expenditure of $1,667 was required for troughs and infrastructure to feed the supplement. As the supplement was delivered to the property, directly into troughs, there were no additional feeding out costs.

Table 36 – Calculation of costs for feeding the lightest one third of the weaner heifer cohort

Parameter	Value
Number of weaner heifers to be fed	126
Average body weight (kg)	173
Supplement consumed (1.5% liveweight; kg/head.day)	2.6
Number of days to be fed	183
Total supplement consumed daily (kg/day)	327.6
Cost of supplement ($/t delivered on-property)	$483
Total supplement fed (t)	60
Total cost of supplement ($)	*$28,956*
Cost per head fed	*$229.81*

3.5.3.2 Results and discussion

Table 37 shows the predicted investment returns for feeding the lightest one third of the weaner heifer cohort (126 head) with molasses production mix to improve their liveweight and hence their conception rates as 2 year-old, maiden heifers. The 4 percentage point improvement in conception rate assumed for lightest one third of heifers increased the average conception rate of the entire maiden heifer cohort by 1 percentage point. The investment produced a negative annualised NPV of about $28,600/annum. Therefore, as for the strategy of supplementing the entire weaner heifer cohort, this strategy is likely to substantially reduce the ongoing profitability of the property.

Table 37 - Returns for investment in a molasses production supplement for the lightest one third of the weaner heifer cohort to improve their reproductive performance at first mating as 2-year-olds

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Discount rate for NPV	5.00%
NPV	-$440,131
Annualised NPV	-$28,631
Peak deficit (with interest)	-$1,902,223
Year of peak deficit	n/c
Payback period (years)	n/c
IRR	n/c

This strategy of targeting supplements to the lightest one third of the weaner heifer cohort was considered due to the negative returns for targeting the entire heifer cohort. However, the average pre-mating liveweight across the entire heifer cohort in the Burdekin Rangelands base herd was already close the pre-mating targets indicated by research, e.g. 300 kg liveweight for 2 year-old heifers at the start of the wet season mating period to achieve 80% pregnancy rate as suggested by Poppi *et al.* (2018). Therefore, supplementing the lightest one third of the maiden heifers (average liveweight 145 kg at weaning cf. 167 kg) was considered a more relevant strategy. Research indicates that the lightest one third of the heifer cohort would benefit from a 2.8% increase in pregnancy rate per 10 kg additional weight at ca. 280 kg pre-mating liveweight (Schatz 2010; Schatz and Hearnden 2017). However, we applied a 4 percentage point increase in conception rates in the supplemented heifer group following their first mating, i.e. from 76% to 80% to model a best possible scenario in terms of response to supplementation. Across the entire maiden heifer cohort, this provided a 1 percentage point increase in conception rate. Even when an optimistic conception rate response of 4% was applied, and only the lightest one third of the heifer cohort were targeted, this scenario was unprofitable.

As for the previous scenario of supplementing the entire weaner heifer cohort, the unprofitability of this strategy is in accord with gross margin analysis presented in Poppi *et al.* (2018) which found no gross margin advantage from supplementing either normally or early weaned heifers. Despite the lack of a significant difference in their experiment for pregnancy rates of supplemented weaner heifers mated at 2 years of age (cf. unsupplemented heifers) in that study, the gross margin analysis applied an assumed change in conception rates of ca. 5% in maiden heifers based on the weight and conception relationships developed by Schatz (2010). This approach is similar to that applied in our current analysis. However, our analysis was conducted at the herd level and indicates the effect on whole of property profitability from implementing the strategy.

3.6 Supplementing first-calf heifers to improve re-conception rates

3.6.1 Introduction

Energy and protein supplements for first-calf heifers are often recommended as best management practice to increase re-conception rates which are lower for first-calf heifers than for other breeder age cohorts (Dixon 1998; FutureBeef 2011b; Schatz 2012). Research by Schatz (2010, 2014) investigated whether pre-partum supplementation during the dry season with a suitable supplement could reliably increase re-conception rates in first-lactation heifers in the low productivity Victoria River District of the Northern Territory. Schatz (2010) concluded that feeding pre-partum protein supplements for a period of at least 100 days until green grass is available at the start of the wet season is a reliable method of changing re-conception rates in first-lactation heifers in the Victoria River District. The trial groups achieved a 42% improvement in re-conception rates with the predicted pregnancy rate changing by between 4-4.6% (average 4.4%), for each 10 kg change in the pre-calving weight corrected for stage of pregnancy, for heifers with pre-calving body weights between about 380 and 460 kg.

3.6.2 Methods

In this strategy, a change in the re-conception rate of first-calf heifers was sought by improving their bodyweight prior to calving with an M8U supplement (molasses with 8% urea by weight). On an as-fed basis the supplement contained: molasses 912 g/kg, urea 79 g/kg, dicalcium phosphate 10 g/kg, with a nutrient composition (dry matter basis) of 34% CP, 10.3 MJ ME/kg.

The base herd had 45.5% of first lactation heifers likely to conceive in the 3-4 year age group. The parameters for this supplementation scenario were based on a study undertaken by Schatz (2010, 2014). That study investigated whether pre-partum supplementation during the dry season with a high-protein supplement could reliably increase re-conception rates in first-lactation heifers at the Kidman Springs Research Station of the Northern Territory. The available nutrition and climate of the Burdekin Rangelands and Kidman Springs are sufficiently similar for the Northern Territory trial results to be considered relevant.

The growth model for the Burdekin Rangelands base herd indicates that first-calf heifers are likely to average about 406 kg liveweight just prior to calving at ca. three years of age. Feeding the heifers with an M8U mix ($470/t, delivered on-property) for 136 days prior to calving is expected to allow the heifers to gain an additional 20 kg of bodyweight (0.25 kg/day), as long as the pasture being grazed has at least 6 MJ ME/kg DM available, so that heifers average 426 kg just prior to calving. It is assumed that the heifers will eat ca. 2 kg M8U supplement per day (34% CP and 10.3 MJ ME/kg DM) in addition to 5.7 kg DM grass (ca. 6% CP and 6.5 MJ ME/kg DM).

The additional 20 kg of bodyweight is expected to improve the re-conception rate by 8 percentage points in the supplemented heifer group, from 45.5% to 53.5% (Schatz 2010). The new conception rate was applied to the Burdekin Rangelands base herd model to identify the investment returns that may be gained by feeding first lactation heifers with a suitable protein supplement. Additional surplus weaner heifers created by the change in reproduction efficiency were sold as 2-3 year-olds to maintain the same grazing pressure and culling strategy as the base herd. The existing conception rates for heifers and age groups older than the 3-4 year age group were maintained at the same level. The one-off feeding of the M8U supplement to one group of heifers was considered unlikely to change the overall average sale weight of culls cows from the herd or the grazing pressure applied by the fed group, so the sale weights and paddock weights were maintained.

The overall weaning rate (weaners per total breeders mated) for the herd changed from 62.36% to 63.74%, i.e. a change of 1.38 percentage points. The breeder herd with the heifer feeding strategy produced about two more weaners per annum on average and total female sales increased by two per annum due to the improved efficiency of the breeding herd (Table 38).

Table 38 - Cows mated and weaners produced with heifer feeding

Parameter	Without heifer supplementation	With heifer supplementation
Total cows and heifers mated	1,216	1,194
Calves weaned	759	761
Total female sales	332	334

The calculation of the expected feeding cost of the M8U supplement is shown in Table 39. One-off capital expenditure of $5,000 was required for troughs and infrastructure to feed out the supplement.

Table 39 – Calculation of feeding costs for pregnancy tested in calf (PTIC), 2-3 year age group heifers

Parameter	Value
Number of PTIC heifers to be fed	205
Average body weight (kg)	409
Supplement consumed (0.49% liveweight; kg/head.day)	2.0
Number of days to be fed	136
Total supplement consumed (kg/day)	410
Cost of supplement ($/t delivered on-property)	$470
Total supplement fed (t)	55.8
Total cost of supplement ($)	*$26,607*
Cost per head fed	*$127.84*

3.6.3 Results and discussion

Table 40 shows the predicted investment returns for feeding M8U supplement to first-calf heifers to achieve an improved re-conception rate of 8 percentage points (45.5% to 53.5%). The investment produced a negative annualised NPV of ca. $22,500/annum. Implementing this strategy would be likely to substantially reduce the ongoing profitability of the property. This result is in accord with similar analyses for other regions in Australia, although cattle prices and supplement costs are both relatively greater in the present analysis (Bowen and Chudleigh 2018; Bowen et al. 2019a, 2020a; Bowen and Chudleigh 2021c).

Table 40 - Returns for investment in M8U supplement for first-calf heifers to improve re-conception rates

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Discount rate for NPV	5.00%
NPV	-$345,856
Annualised NPV	-$22,498
Peak deficit (with interest)	-$1,494,770
Year of peak deficit	n/c
Payback period (years)	n/c
IRR	n/c

3.7 Sown stylo pastures for steers

3.7.1 Introduction

Cooksley (2003) reported that legumes from the *Stylosanthes* genus (hereafter, stylo; mainly *Stylosanthes scabra* cv. Seca and Siran, and *S. hamata* cv. Verano and Amiga) had been successfully oversown into at least 600,000 ha of northern Australian pasture lands with ca. 60,000 ha sown annually. On the light-textured, largely P–deficient soils across north Queensland, stylos can add 1,000-2,000 kg DM/ha of biomass to the ca. 1,000-2,000 kg DM/ha of native pasture biomass typically produced and hence double carrying capacity (Cooksley 2003). Over-sowing native pastures with stylos results in greater annual beef cattle liveweight gains due to increased diet quality as well as higher carrying capacity due to the increased forage biomass (Gillard and Winter 1984; Miller and Stockwell 1991; Coates *et al.* 1997; Hasker 2000). Data summarised in Hasker (2000) for four sites across northern Australia indicated that the annual liveweight gain advantage to cattle grazing stylo-grass pastures compared to grass pastures was usually in the range of 30-60 kg/head with the oversown pastures capable of being grazed at 2-3 times the rate for native grass pastures in northern regions. Cattle grow faster on stylo-grass pastures for most of the year, but the main advantage occurs during the late wet and dry seasons when the growth advantage can average 0.25 and 0.15 kg/day, respectively. Pasture improvement with stylo pastures has previously been recommended for soils with >/= 4-5 ppm P (in the top 100 mm) to ensure that the legume can be maintained in the pasture without application of fertiliser (Partridge *et al.* 1996; Hasker 2000). However, to maximise yield potential, soil P concentrations of >8 ppm in the top 100 mm of soil are required (Peck *et al.* 2015).

A risk with stylo-grass pastures is that, under continuous heavy grazing conditions, the stylo component of the pasture tends to dominate which can result in increased variability in animal production as well as pasture and land degradation. Trial sites have indicated that the target 50/50 balance of stylo to native 3P grass species can be maintained by periodically easing grazing pressure over the wet season to allow grass seed set (Cooksley 2003). Furthermore, research indicated that pastures which have become dominated by oversown stylo can be successfully rehabilitated by a regime of annual burning and wet season spelling (9-12 weeks from start of the wet season) under moderate stocking rates (ca. 2.3-3.5 head/ha), (Cooksley 2003).

Although pasture seeds establish best in a fine, firm seed-bed, in monsoonal regions of northern Australia with reliable wet seasons, stylo seed is usually broadcast into undisturbed native pasture in timbered country (Partridge *et al.* 1996). In southern regions of Queensland where seasonal rainfall is less reliable, stylo seed is usually broadcast onto vegetation and soil which have been disturbed to check the growth of existing pasture plants and increase the likelihood of a successful establishment. Sowing in strips across the paddock, either cultivated or aerially, is one approach to reduce establishment costs but will have a lower rate of increase of stylo biomass throughout the grazing area than will seeding the entire paddock area. Managers need to be mindful that the lower the rate of sowing stylos into pastures, the slower the spread of the legume throughout the paddock.

Despite the proven benefits of sown pastures, and particularly legumes, for increasing productivity and profitability of beef businesses, many areas of northern Australia have few or no well-adapted pasture plants. Recent field experiments in northern Australia have identified the most productive lines of key legume and grass species suited to north and central Queensland (Cox *et al.* 2019; Cox 2021; Cox *et al.* 2022). Species that performed well under grazing in the Burdekin Rangelands region included lines within stylo species *Stylosanthes scabra* (known as Seca or Shrubby stylo) and *Stylosanthes seabrana* (Caatinga stylo), and the grass species *Bothriochloa insculpta* (creeping bluegrass) and *Digitaria milanjiana* (known as jarra or finger grass). Importantly, these grass and legumes species grew well together, in a mixed sward.

3.7.2 Cultivated strips of stylo-grass or stylo-only pastures for all steers

3.7.2.1 Methods

3.7.2.1.1 Overview of scenarios

This strategy assessed the value of establishing, in cultivated strips, the highest-performing lines of stylo and introduced grass pastures suited to the Burdekin Rangelands region, as identified in MLA-funded projects B.NBP.0766 and B.NBP.0812 (Cox *et al.* 2019; Cox 2021; Cox *et al.* 2022). The benefits of establishing sufficient sown stylo-grass or stylo-only pastures to carry all steers on the Burdekin Rangelands property from weaning to sale, were assessed. The pastures were sown into existing native pasture in strips so that 50% of the grazing area for steers was sown. This whole-farm economic analysis was undertaken as a collaboration with project B.NBP.0812 and comparable results will also be reported as part of deliverables for that project although with slightly different base property assumptions.

A total of 16 scenarios were assessed to examine the various combinations of sown pasture type, month of steer sale, slow or quick herd build up to utilise the additional pasture biomass, and the effect of receiving a price premium for cattle at the November sale date (Table 41).

Table 41 – Scenarios assessed to examine the value of sowing stylo-only or stylo-grass pastures to carry all steers from weaning, in cultivated strips in the Burdekin Rangelands

Scenario number	Sown pasture type	Steer sale month	Average steer sale age and paddock liveweight	Herd build up strategy	Cattle sale price
1	Stylo-grass	June	18 months, 352 kg	Slow	Average
2	Stylo-grass	June	18 months, 352 kg	Quick	Average
3	Stylo-grass	November	35 months, 565 kg	Slow	Average
4	Stylo-grass	November	35 months, 565 kg	Slow	+25 c/kg liveweight
5	Stylo-grass	November	35 months, 565 kg	Quick	Average
6	Stylo-grass	November	35 months, 565 kg	Quick	+25 c/kg liveweight
7	Stylo-grass	February	38 months, 618 kg	Slow	Average
8	Stylo-grass	February	38 months, 618 kg	Quick	Average
9	Stylo-only	June	18 months, 352 kg	Slow	Average
10	Stylo-only	June	18 months, 352 kg	Quick	Average
11	Stylo-only	November	35 months, 565 kg	Slow	Average
12	Stylo-only	November	35 months, 565 kg	Slow	+25 c/kg liveweight
13	Stylo-only	November	35 months, 565 kg	Quick	Average
14	Stylo-only	November	35 months, 565 kg	Quick	+25 c/kg liveweight
15	Stylo-only	February	38 months, 618 kg	Slow	Average
16	Stylo-only	February	38 months, 618 kg	Quick	Average

The sale months and ages of steers were selected to target either the feed-on market in June (18-month average steer sale age) or finished steers in either November (35-month average steer sale age) or February (38-month average steer sale age). The benefit of a possible price premium for slaughter cattle of 25 c/kg liveweight in November was also examined. This price premium was derived from examination of seasonal trends for cattle price data over the last 20 years to December 2021. Figure 10 indicates the seasonal variation in prices for heavy steers over the last 7, 10 or 20 years to 2021. Over the longer term, prices later in the year can be up to 30 c/kg dressed greater in November than in April to June. In particular, mid-November, the forty sixth week of the year, tends to be associated with a peak in prices. Although the variation in prices in any year may not match this pattern, the strategy of selling steers later in the year off stylo pastures may provide, on average, a relative price benefit to other sale months.

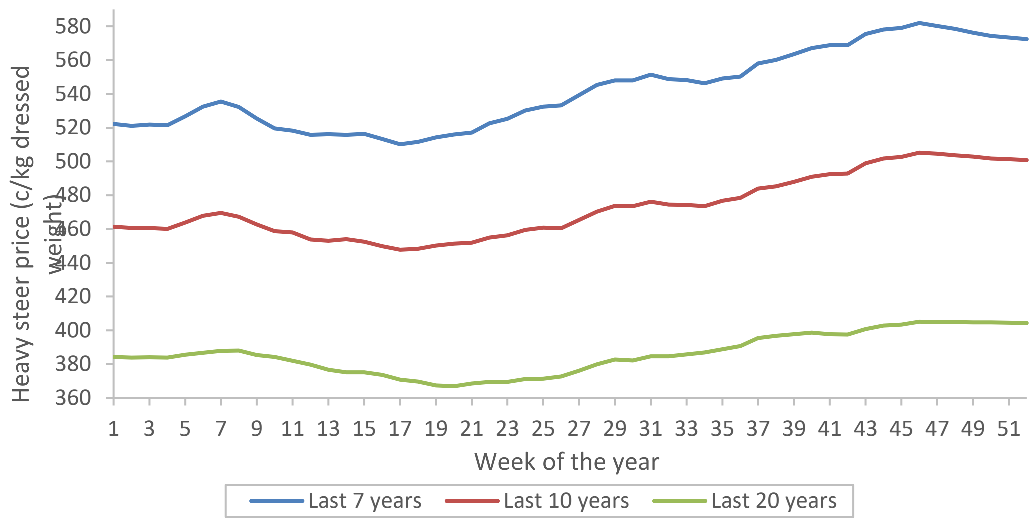

Figure 10 – Weekly average prices for heavy steers for the last 7, 10 or 20 years to 2021 (Source 'MLA – Australia North Queensland OTH cattle indicators weekly')

Table 42 indicates the price benefit of selling heavy steers in November. A price premium of 25 c/kg liveweight was selected for the November sale of steers in this analysis in line with the 7-year average prices which were used to inform the Burdekin Rangelands analyses. The difference over the past 7 years between a June sale and a November sale was 27 c/kg liveweight (52 c/kg dressed weight). This premium was moderated downwards, in line with the approach taken for the base herd cattle price data, to adjust for the seasonally driven demand experienced since early 2021. No substantial price difference was evident between June and the February sale month and therefore a price premium was not applied to steers sold in February in this analysis.

Table 42 – The difference to minimum weekly average heavy steer prices, in June and November, over the last 7 or 10 years to 2021

Time period	**Difference to minimum weekly average price - Heavy Steer June (c/kg carcass weight)**	**Difference to minimum weekly average price - Heavy Steer November (c/kg carcass weight)**	**Difference in price premium June to November (c/kg carcass weight)**
Last 7 years	20	72	52
Last 10 years	12	57	46
Average			*49*

3.7.2.1.2 Pasture establishment process

The pasture development process involved initial burning or heavy grazing of a suitable area of native pasture. This was followed by cultivation of 50% of the area (in strips) and sowing with stylo and grass or stylo only. Table 43 gives the forage development costs per hectare for the two sown pastures scenarios. Following pasture establishment, it was assumed that applications of fertiliser would need to be made at regular intervals to replace the P and sulphur (S) being extracted from the paddock by the increased levels of animal production. Table 44 shows the ongoing fertiliser application rate and cost per hectare. Single superphosphate fertiliser was reapplied to the entire paddock area sown to pasture every 5 years at 100 kg/ha, which was half the original rate of application.

Table 43 – Direct development costs for pastures sown in cultivated strips on moderately fertile land types in the Burdekin Rangelands

Sown pasture	Item or treatment	Rate of application	Cost/unit	Number of applications	% of area treated	Cost per hectare
Stylo + grass	Chisel plough	1	$38.77/ha	2	50	$38.77
	Pasture planter	1	$16.18/ha	2	50	$16.18
	Stylo seed	2 kg/ha	$20/kg	1	50	$20.00
	Grass seed	3 kg/ha	$25/kg	1	50	$37.50
	Fertiliser spreader	1	$7.84/ha	1	50	$3.92
	Fertiliser blend (single superphosphate)	200 kg/ha	$1/kg	1	50	$100.00
	Linkage spray rig	1	$4.35/ha	1	50	$2.18
	Roundup CT	1.5 L/ha	$11/L	1	50	$8.25
	Total cost	-	-	-	-	*$227*
Stylo	Chisel plough	1	$38.77/ha	2	50	$38.77
	Pasture planter	1	$16.18/ha	1	50	$8.09
	Stylo seed	2 kg/ha	$20/kg	1	50	$20.00
	Fertiliser spreader	1	$7.84/ha	1	50	$3.92
	Fertiliser blend (single superphosphate)	200 kg/ha	$1/kg	1	50	$100.00
	Total cost	-	-	-	-	*$171*

Table 44 - Ongoing fertiliser treatment applied every 5 years on sown pastures

Sown pasture	Item or treatment	Rate of application	Cost/unit	Number of applications	% of area treated	Cost per hectare
Stylo + grass and stylo-only	Fertiliser spreader	1	$7.84/ha	1	100	$7.85
	Fertiliser blend (single superphosphate)	100 kg/ha	$1/kg	1	100	$100.00
	Total cost	-	-	-	-	*$107.85*

For the 18-month steer sale target, to allow for establishment failure or poor strike rates, pastures were re-sown in Year three at a total cost of 20% of the original development costs, i.e., an allowance was made for 20% of the planted area to be replanted in Year three. Additional capital costs of $30,000 in Year 1 were incurred to appropriately fence and water the paddocks being developed to improved pastures.

For the older ages of turnoff at 35 and 38 months of age, the pasture development was spread over 3 years with one third of the area developed each year. For these scenarios, the fencing and water costs of $30,000 were also spread over the first 3 years ($10,000 per year). The allowance for 20% of the planted area to be re-seeded was applied in Year 3, 4 and 5 (for the 1/3 planted in Years 1-3). Fertiliser was applied every 5 years, stagged in-line with development.

For all three steer sale age scenarios, in Year 1 of the analysis, extra steers were sold to free up the grazing area and the first stylo-grass or stylo-only plantings occurred. In Year 3 of the analysis, 6-month-old weaner steers commenced grazing sown pasture paddocks and achieved the expected weight gains for stylo-grass and stylo-only pastures. Therefore, sale of the first cohort of steers that had grazed sown pastures since weaning occurred in Year 4 for the 18-month-old sale steers, Year 5 for the 35-month-old sale steers and Year 6 for the 38-month-old sale steers.

3.7.2.1.3 Cattle performance

All steers entered the paddocks sown to stylo and stylo-grass at the same average age (6 months) and weight (179 kg) and grazed the paddocks until reaching the target sale age. Annual steer growth rates on stylo-grass and stylo-only pastures were assumed to be equivalent, i.e. 172 kg/head. The steers were sold as they exited their paddocks at the end of their grazing period of 12, 29 or 32 months. Table 45 indicates the assumed forage and steer growth parameters for native grass-only pastures and for pastures sown to either stylo and grass or to stylo only. The assumptions for pasture yields, composition, utilisation rates, diet digestibility and animal performance were based on Projects B.NBP.0766 and B.NBP.0812 ((Cox *et al.* 2019; Cox 2021; Cox *et al.* 2022) as well previous published data applicable to the region (Miller *et al.* 1982; McLennan *et al.* 1988; Coates 1994, 1996; Coates *et al.* 1997; Hunt 2008; Ash *et al.* 2011; Peck *et al.* 2015; Bowen *et al.* 2019a) and unpublished DAF internal data (B. English, C. Lemin, C.P. Miller, and J. Rolfe, pers. comm.). The selected parameters for pasture and animal performance were conservative relative to experimental results to account for reduced performance expected under commercial grazing situations compared to carefully controlled and managed research trials. In particular, the pasture yields in sown pasture paddocks were reduced by 25% compared to measured yields in experiments of Cox *et al.* (2019); Cox (2021); Cox *et al.* (2022).

The carrying capacity of each pasture was calculated by multiplying the median annual pasture biomass production by the specified utilisation level and then dividing by the annual pasture consumption of a standard animal unit AE. An AE was defined here in terms of the forage DMI at the specified diet dry matter digestibility (DMD), of a standard animal which was defined as a 2.25 year-old, 450 kg *B. taurus* steer at maintenance, walking 7 km/day on a level one, gentle slope. The spreadsheet calculator, QuikIntake (McLennan and Poppi 2019), which is based on the Australian Feeding Standards (NRDR 2007) with some modifications for tropical feeding systems (McLennan 2014), was used to calculate daily cattle DMI for the specified pasture DMDs.

Table 45 – Assumed forage and steer growth parameters for native grass pastures and sown stylo-grass or stylo-only pastures on moderately fertile land types in the Burdekin Rangelands

Biological parameter	Native grass	Stylo + grass pasture		Stylo only	
		Stylo	Grass	Stylo	Grass
Median, annual pasture biomass production (kg DM/ha)	1,500	688	1,691	1,334	675
Utilisation of annual biomass growth (%)	23	40	40	31	31
Median, annual biomass available for consumption (kg DM/ha)	345	951		623	
Average, stylo content in the diet across the year (%)	0	29		66	
Average, annual diet DMD of grazing cattle (%)	49.5	52		51.1	

Biological parameter	Native grass	Stylo + grass pasture		Stylo only	
		Stylo	Grass	Stylo	Grass
Average, annual steer LWG (kg/head)	121	172		172	
Daily live weight gain (kg/day); annual average	0.33	0.47		0.47	
January	0.4	0.7		0.7	
February	1.0	0.8		0.8	
March	0.8	0.6		0.6	
April	0.6	0.85		0.85	
May	0.5	0.62		0.62	
June	0.3	0.6		0.6	
July	0.0	0.44		0.44	
August	0.0	0.26		0.26	
September	0.1	0.2		0.2	
October	0.1	0.2		0.2	
November	0.1	0.19		0.19	
December	0.2	0.23		0.23	
Carrying capacity (ha/AE)[A]	9.53	3.25		5.08	

DM, dry matter; DMD, dry matter digestibility; LWG, live weight gain.

[A]AE defined in terms of the forage intake of a 2.25 year-old, 450 kg *Bos taurus* steer at maintenance, consuming a diet of the specified DMD and walking 7 km/day on level 1, gentle slope.

3.7.2.1.4 Calculation of grazing area required for each forage type

The stocking rate (and hence the number of hectares required) for each grazing period on native grass pasture, and paddocks sown with strips of stylo-grass or stylo-only pasture was determined by calculating available pasture biomass for consumption per hectare (based on the specified forage utilisation rate for that scenario) and then dividing by the calculated steer intake of pasture dry matter over that period. For pastures that included stylo, the respective annual biomass production and utilisation levels of the grass and edible stylo components were summed to determine the total biomass available. The pasture biomass available for consumption during a defined growth path was adjusted proportionally for days greater or less than the full annual period.

The average DM intake by steers of each forage type within each growth path was estimated using the QuikIntake Excel spreadsheet calculator (McLennan and Poppi 2019) modified from the Australian ruminant feeding standards (NRDR 2007) to better predict intake for *B. indicus* content cattle and tropical diets (McLennan 2014). The average DMD, liveweight of the cattle (i.e., liveweight at the mid-way point) and the assumed average daily gain over the relevant period were used as key inputs. The cattle were assumed to be Brahman, to have a standard reference weight (SRW) of 660 kg, to walk 7 km/day on level one slope/terrain.

The base property (without sown pastures) had 11,293 ha allocated to the growing of steers from weaning to turnoff as 546 kg, 42-month slaughter steers on native pasture. The breeder herd was allocated to the remainder of each property and supplied weaner steers to the steer growing system. The area required to meet the needs for each steer growth path was initially based on the supply of weaners steers in the baseline scenario. In all sown pasture scenarios, implementing the alternative growth paths reduced the area of the property required to operate the steer component of the beef enterprise, allowing proportionally more breeders to be carried and hence more weaner steers to be produced. An iterative process of balancing the supply of weaner steers, with the area of the property required to meet the needs of the growth path and the needs of the breeder herd, identified the optimal size of the breeding component that was able to supply the weaner numbers to meet the needs of the area of stylo grass pasture. In all scenarios, the performance of the breeding herd was the same with no allowance for the potential impact on components of the breeder herd most likely having access to better pasture nutrition within the property as the area of the property allocated to carrying breeders, increased. The herd size and structure were optimised within the limits applied by the property size and the respective areas and the quality of forage type. The forage area allocated in each scenario was sufficient to meet the needs of the steers for the entire period they were on the stylo-grass or stylo-only pasture.

The paddock areas required to run all steers from weaning to sale for each of the sown pasture and age of turn-off scenarios were as follows:

1. Stylo-grass cultivated strips:

- 1,843 ha to run all steers for 365 days from weaning to sale at 18 months (352 kg paddock liveweight) in June.
- 4,953 ha to run all steers from weaning to sale at 35 months (596 kg paddock liveweight) in November.
- 5,533 ha to run all steers from weaning to sale at 38 months (618 kg paddock liveweight) in February.

2. Stylo-only cultivated strips.

- 2,784 ha to run all steers for 365 days from weaning to sale at 18 months (352 kg paddock liveweight) in June.
- 7,025 ha to run all steers from weaning to sale at 35 months (565 kg paddock liveweight) in November.
- 7,770 ha to run all steers from weaning to sale at 38 months (618 kg paddock liveweight) in February.

3.7.2.1.5 Herd build-up strategies

The impact on returns of the rate at which herd numbers increased to reach the new total property carrying capacity was assessed by either (1) selling the usual proportion of cull cows, maintaining cash flow and building up numbers slowly or (2) retaining additional cull cows, foregoing some cash flow and building up more quickly. No additional cattle were purchased beyond the increased bull requirements for the larger breeding herd. The herd build-up strategy was continued until the new herd size was attained or until the period for the investment analysis finished.

In the slow build-up strategy, steer cohorts were sold to transfer to a younger sale age (18 months vs. 42 months) and the female culling strategy was maintained until Year 4 when the full benefit of the sown pastures and the increased carrying capacity begins. In the quick build-up strategy, steers were sold down as for the slow build up strategy to transfer to the younger sale age of 18 months. However, to build the herd up more quickly so as to allow the sown pasture paddocks to be fully stocked as soon as possible, the female selling strategy was amended for the first 5 years until target weaner numbers were reached. When the property was fully stocked the normal selling strategy in terms of sales as a percentage of opening numbers averaged 22% of the combined 2-year-old heifers and 3- and 4-year-old cows. To build up weaner numbers, the sales of these three breeder classes was reduced so that in Year 1-2, Year 3, 4 and 5, ca. 5%, 3%, 7% and 8% of opening female numbers were sold. Figure 11 demonstrates, for the scenario with cultivated strips of stylo-grass pastures and an 18-month steer sale target, that the strategy of retaining cull heifers and cows, allows the operation to reach full herd capacity by about Year 6 compared to not reaching capacity over 30 years when additional females are not retained. Figure 12 and Figure 13 show the change in AE over time for the stylo-grass pastures with 35 and 38-month steer sale ages, respectively. Full herd capacity was reached with slow-build-up by 25 and 23 years for 35 and 38-months steer sale age targets, respectively.

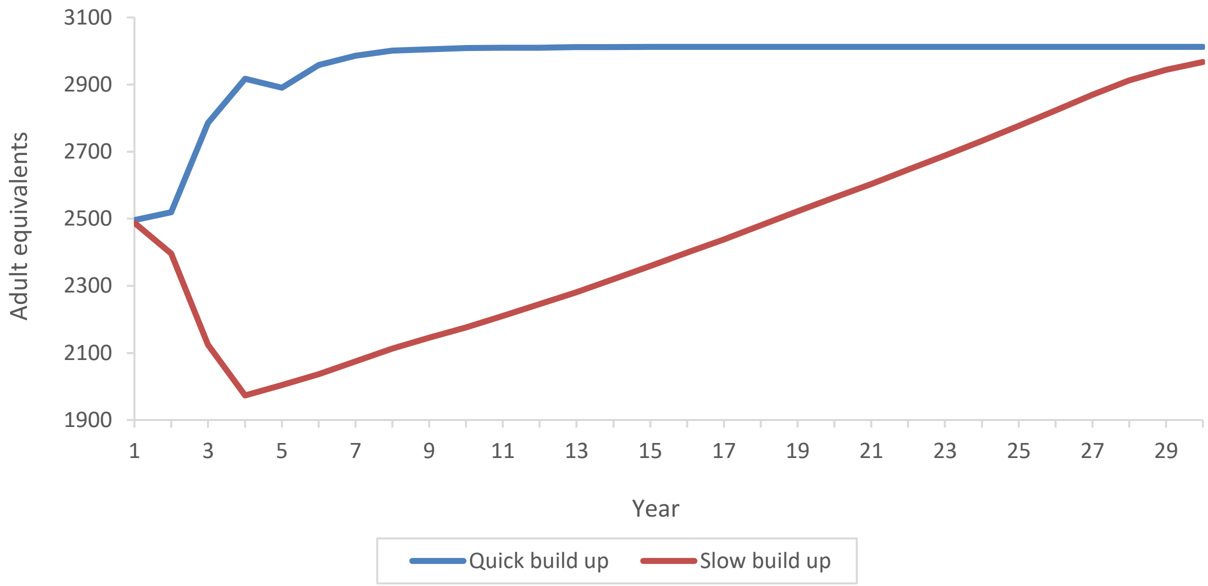

Figure 11 – Herd build-up strategies for the Burdekin Rangelands property with sown strips of stylo-grass pastures to run all steers from weaning until sale at 18 months (transitioning from 42-month steer sale age on native pastures)

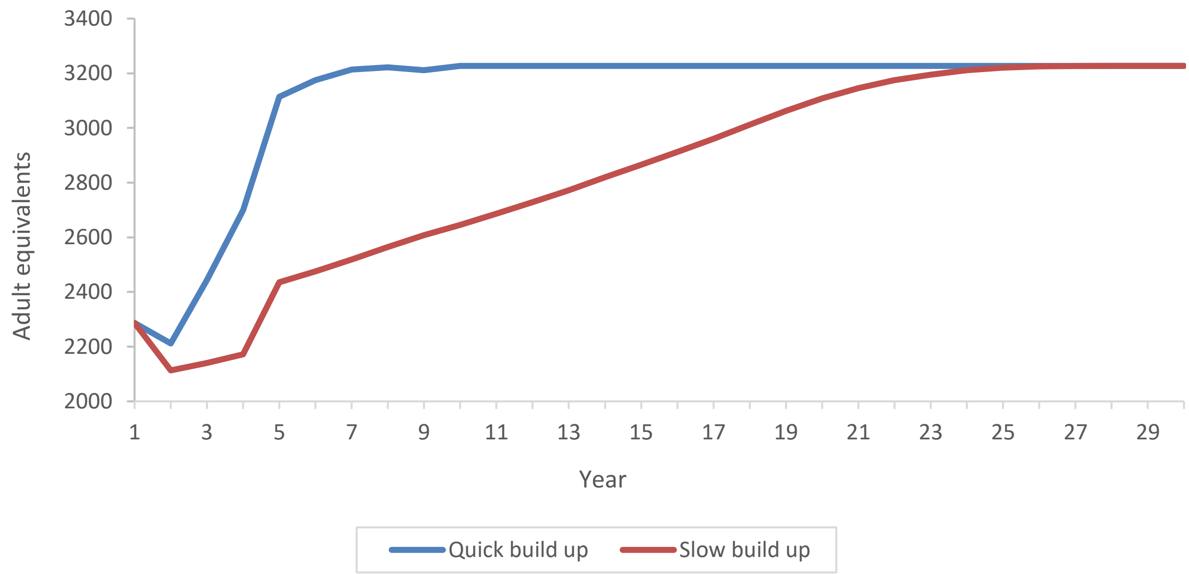

Figure 12 – Herd build-up strategies for the Burdekin Rangelands property with sown strips of stylo-grass pastures to run all steers from weaning until sale at 35 months (transitioning from 42-month steer sale age on native pastures)

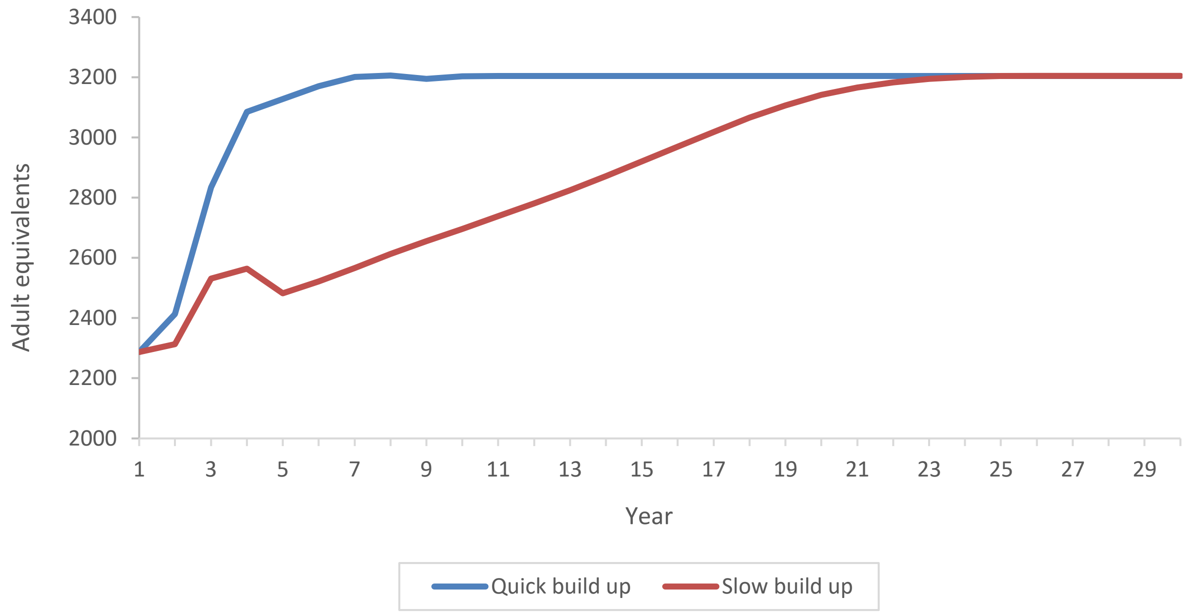

Figure 13 – Herd build-up strategies for the Burdekin Rangelands property with sown strips of stylo-grass pastures to run all steers from weaning until sale at 38 months (transitioning from 42-month steer sale age on native pastures)

Table 46 shows the change in herd structure enabled by the utilisation of stylo-grass or stylo-only pasture for the Burdekin Rangelands property with three alternative sale age targets for steers.

Table 46 – Breeder herd components without the sown pasture development and with the stylo-grass or stylo-only development, once fully established, for 18, 35 and 38 month steer sale age targets

	Breeder herd components		
	Total cows and heifers mated	**Calves weaned**	**Weaner steers**
Native grass pasture selling slaughter steers	1,220	759	380
Stylo-grass pasture (weaners to 18 months)	1,924	1,198	599
Stylo-only pasture (weaners to 18 months)	1,849	1,151	575
Stylo-grass pasture (weaners to 35 months)	1,691	1,052	526
Stylo-only pasture (weaners to 35 months)	1,534	955	477
Stylo-grass pasture (weaners to 38 months)	1,644	1,023	512
Stylo-only pasture (weaners to 38 months)	1,483	923	461

3.7.2.2 Results and discussion

The returns to the Burdekin Rangelands property over the longer term (30 years) from developing a sufficient area to stylo-grass or stylo-only pastures to run all steers from weaning to sale at either 18, 35 or 38 months are presented in Table 47 to Table 50.

Table 47 – Returns for investing in sufficient stylo-grass or stylo-only pasture, sown in strips, to run all steers from weaning to sale at 18 months (352 kg paddock liveweight), in June

All terms defined in the Glossary of terms and abbreviations

Factor	Stylo-grass		Stylo-only	
	Slow build-up	Quick build-up	Slow build-up	Quick build-up
Period of analysis (years)	30	30	30	30
Discount rate for NPV	5%	5%	5%	5%
NPV	-$1,160,038	$1,035,444	-$1,490,255	$385,918
Annualised NPV	-$75,462	$67,357	-$96,943	$25,105
Peak deficit (with interest)	-$5,292,523	-$970,232	-$6,549,559	-$1,045,391
Years to peak deficit	29	3	29	3
Payback period (years)	n/c	12	n/c	18
IRR	n/c	13%	n/c	8%

Table 48 – Returns for investing in sufficient stylo-grass pasture, sown in strips, to run all steers from weaning to sale at 35 months (565 kg paddock liveweight), in November

All terms defined in the Glossary of terms and abbreviations

Factor	Slow build-up		Quick build-up	
	Average prices	+25 cents/kg liveweight	Average prices	+25 cents/kg liveweight
Period of analysis (years)	30	30	30	30
Discount rate for NPV	5%	5%	5%	5%
NPV	-$385,327	$313,206	$1,195,780	$1,994,226
Annualised NPV	-$25,066	$20,375	$77,787	$129,727
Peak deficit (with interest)	-$3,202,799	-$2,230,770	-$1,925,847	-$1,879,648
Years to peak deficit	18	13	5	4
Payback period (years)	n/c	n/c	16	13
IRR	3%	6%	10%	13%

Table 49 – Returns for investing in sufficient stylo-only pasture, sown in strips, to run all steers from weaning to sale at 35 months (565 kg paddock liveweight), in November

All terms defined in the Glossary of terms and abbreviations

Factor	Slow build-up		Quick build-up	
	Average prices	+ 25 cents/kg live	Average prices	+ 25 cents/kg live
Period of analysis (years)	30	30	30	30
Discount rate for NPV	5%	5%	5%	5%
NPV	-$1,134,411	-$454,472	-$316,939	$418,853
Annualised NPV	-$73,795	-$29,564	-$20,617	$27,247
Peak deficit (with interest)	-$5,257,548	-$2,942,580	-$2,058,432	-$1,901,993
Years to peak deficit	29	18	13	5
Payback period (years)	n/c	n/c	n/c	n/c
IRR	n/c	3%	3%	7%

Table 50 – Returns for investing in sufficient stylo-grass or stylo-only pasture, sown in strips, to run all steers from weaning to sale at 38 months (618 kg paddock liveweight), in February
All terms defined in the Glossary of terms and abbreviations

Factor	**Stylo-grass**		**Stylo-only**	
	Slow build up	**Quick build up**	**Slow build up**	**Quick build up**
Period of analysis (years)	30	30	30	30
Discount rate for NPV	5%	5%	5%	5%
NPV	-$436,751	$842,060	-$1,203,990	-$682,067
Annualised NPV	-$28,411	$54,777	-$78,321	-$44,369
Peak deficit (with interest)	-$3,765,951	-$2,450,497	-$6,213,695	-$4,114,611
Years to peak deficit	23	7	29	28
Payback period (years)	n/c	n/c	n/c	n/c
IRR	4%	8%	0.5%	2%

Establishing stylo-only or stylo-grass pastures for all steers in cultivated strips added substantially to the profitability of the business but generally only if the extra carrying capacity was utilised immediately through a 'quick' herd build up strategy which in this instance was achieved through retention of a greater proportion of cull cows. The only slow build up scenario to result in positive returns was when a price a 25 c/kg price premium was applied to 35-month old sale steers in November after grazing stylo-grass pastures from weaning. Collectively, the results indicate that if managers are unable to fully stock and utilise the sown pastures immediately, the viability of the investment will be severely impacted under the assumptions, costs and prices applied in this study.

Targeting the most profitable steer sale age was also important to profitability. For stylo-grass pastures, all three sale targets were profitable, as long as a quick herd build strategy was applied. However, there was a $23,000 difference in extra profit/annum between the most profitable age of turnoff (35 months) and the least (38 month) when average cattle prices were applied. If a 25 c/kg liveweight price premium were received at the November sale time (35-month steer sale age), the profit added increased by 1.7-fold relative to when average cattle prices were applied. For stylo-only pasture scenarios with quick herd build-up, only the 18-month steer sale target in June was profitable unless a 25c/kg liveweight price premium was received in November for 35-month old steers.

Sowing strips to stylo-grass pastures rather than stylo-only provided greater returns in general, and positive returns across a wider range of age of turnoff scenarios. The better returns for stylo-grass pastures cf. stylo-only were the result of the greater available biomass and carrying capacity despite greater initial establishment costs. The most profitable scenario when cultivated strips of sown pasture were applied was that of sowing stylo and grass with a quick herd build-up and turn-off of steers at 35 months of age in November. However, the long period of time before these sown pasture investments were paid back (12-18 years), and the substantial peak deficits, would provide an obstacle to adoption of this strategy for many producers.

It should be noted that the predicted returns for sown pastures in cultivated strips on in the Burdekin Rangelands region are dependent on largely untested assumptions concerning the relative yields, utilisation rates, diet quality and animal performance from grazing of stylo-grass pastures under commercial paddock grazing in North Queensland over 30 years. We adopted the precautionary principle in adopting conservative figures for performance of legumes and cattle which were discounted relative to experimental results. Additionally, the application of re-planting costs, at 20% of the original development cost, was intended to account for establishment failures and other issues that may negatively affect performance under commercial grazing conditions. Regardless, a similar positive effect on property profit from investing in perennial legumes for steers has been reported for leucaena and shrubby legumes in the less productive Northern Gulf (Bowen *et al.* 2019a) and more productive central Queensland regions (Bowen and Chudleigh 2018b, 2018c). While a lower-cost establishment approach of aerially seeding was applied in the Northern Gulf study, a similar approach to that assessed in the present study was applied in central Queensland, i.e. establishment in cultivated strips over 50% of the paddock. In these previous studies for the Northern Gulf and central Queensland regions, only stylo seed was sown (not grass) whereas in the present study the expected benefits of sowing stylos with grass were also assessed and found to be the most profitable approach when the extra biomass produced could be immediately utilised.

The results of the present study again demonstrate the sensitivity of profitability to forage biomass availability, utilisation rates, and hence stocking rate. This concept has been demonstrated by Bowen and Chudleigh (2018a) for tropical grass pastures in central Queensland and the same principle applies regardless of forage type. The importance for property viability, of fully utilising pastures within safe utilisation constraints, has also been demonstrated for a beef cattle property in the semiarid grasslands of northern Australia (Bowen *et al.* 2021). In this latter study, stock numbers were rebuilt following drought through either natural herd increase or more quickly through purchases or taking cattle on agistment. Relying on natural increase to build up herd numbers resulted in negative property-level returns, similar to the slow herd build-up strategy (natural increase) examined for the Burdekin Rangelands property in the present analysis.

Importantly, large areas of land suited to cultivation in strips are unlikely to be available on most properties in the Burdekin Rangelands area, making this strategy unfeasible. For the 25,000 ha representative property, the areas required to run all steers produced by the property from weaning to sale ranged from 1,843–7,770 ha, dependant on sown pasture type and steer sale age. Additionally, the large peak deficits and long payback periods (e.g. -$1.9 million and 13-16 years, respectively for the stylo-grass pastures with a 35-month old steer sale age) would be a constraint to adoption of this strategy for all steers on the property.

3.7.3 Cultivated strips of stylo-grass or stylo-only pastures for steers on 500 ha of more fertile land types

3.7.3.1 Methods

Given that establishing sufficient areas of sown pastures, in cultivated strips, to run all steers from weaning to sale appeared to be unfeasible for the Burdekin Rangelands property, an alternative scenario was examined for utilising high quality sown legume and grass pastures established by cultivation. In this scenario a smaller area of 500 ha of better quality land types (e.g. alluvial frontage, basalt, or brigalow/gidyea) was targeted for development. The parameters for pasture and animal performance in this scenario were based on the trial results of Cox *et al.* (2019); Cox (2021); Cox *et al.* (2022) for the red basalt land type as an example of more fertile and higher-productivity land types in the Burdekin Rangelands region.

3.7.3.1.1 Overview of scenarios

Similar to the larger property development scenario described in Section 3.7.2, this strategy assessed the value of establishing, in cultivated strips, the highest-performing lines of stylo and introduced grass pastures suited to more fertile soils in Burdekin Rangelands region, as identified in MLA projects B.NBP.0766 and B.NBP.0812 (Cox *et al.* 2019; Cox 2021; Cox *et al.* 2022). The benefits of establishing a 500 ha area with sown stylo-grass or stylo-only pastures to carry a cohort of steers from weaning to sale, were assessed. The pastures were sown into existing native pasture in strips so that 50% of the grazing area for steers was sown. This economic analysis was undertaken as a collaboration with project B.NBP.0812 and comparable results will also be reported as part of deliverables for that project although with slightly different base property assumptions.

A total of 6 scenarios were assessed to examine the combinations of sown pasture type, steer sale age and weight, (Table 51). In all scenarios, steers entered the sown pasture paddock as weaners and were sold upon exit from the sown pasture after 12, 24 or 29 months of grazing. The sale months and ages of steers were selected to target either the feed-on market in June (18-month average steer sale age) or finished steers in either June (30-month average steer sale age) or November (35-month average steer sale age). The benefit of a possible price premium for slaughter cattle of 25 c/kg liveweight in November was the basis for the November sale date. This price premium was derived from examination of seasonal trends for cattle price data over the last 20 years to December 2021 as indicated in Figure 10 and Table 42 in Section 3.7.2.

Table 51 – Scenarios assessed to examine the value of establishing stylo-only or stylo-grass pastures in cultivated strips on 500 ha of more fertile land types in the Burdekin Rangelands to run weaner steers until sale

All terms defined in the Glossary of terms and abbreviations

Scenario number	Sown pasture type	Months grazing sown pastures	Steer sale month	Average steer sale age and paddock liveweight	Cattle sale price
1	Stylo-grass	12	June	18 months, 379 kg	Average
2	Stylo-grass	24	June	30 months, 579 kg	Average
3	Stylo-grass	29	November	35 months, 613 kg	+25 c/kg liveweight
4	Stylo-only	12	June	18 months, 352 kg	Average
5	Stylo-only	24	June	30 months, 579 kg	Average
6	Stylo-only	29	November	35 months, 613 kg	+25 c/kg liveweight

3.7.3.1.2 Pasture establishment process

The pasture development process involved initial burning of a suitable area of native pasture. This was followed by cultivation of 50% of the area (in strips) and sowing with stylo and grass or stylo only. Table 52 gives the forage development costs per hectare for the two sown pastures scenarios. As most land types in the Burdekin Rangelands are very low in S, including the higher fertility alluvial frontage and red basalt land types, S fertiliser was applied at establishment. Following pasture establishment, it was assumed that applications of fertiliser would need to be made at regular intervals to replace the S being extracted from the paddock by the increased levels of animal production. Table 53 shows the ongoing fertiliser application rate and cost per hectare. Granulated S fertiliser was reapplied to the entire paddock area sown to pasture on the Burdekin Rangelands property every 5 years at 30 kg/ha, which was the same rate as the original application.

Table 52 – Direct development costs for pastures sown in cultivated strips on more fertile land types in the Burdekin Rangelands

Sown pasture	Item or treatment	Rate of application	Cost/unit	Number of applications	% of area treated	Cost per hectare
Stylo + grass	Chisel plough	1	$38.77/ha	2	50	$38.77
	Pasture planter	1	$16.18/ha	1	50	$8.09
	Stylo seed	2 kg/ha	$20/kg	1	50	$20.00
	Grass seed	3 kg/ha	$25/kg	1	50	$37.50
	Fertiliser spreader	1	$7.84/ha	1	50	$3.92
	Granulated sulphur	30 kg/ha	$1.10/kg	1	50	$16.50
	Linkage spray rig	1	$4.35/ha	1	50	$2.18
	Roundup CT	1.5 L/ha	$11/L	1	50	$8.25
	Total cost	-	-	-	-	*$135*
Stylo	Chisel plough	1	$38.77/ha	2	50	$38.77
	Pasture planter	1	$16.18/ha	1	50	$8.09
	Stylo seed	2 kg/ha	$20/kg	1	50	$20.00
	Fertiliser spreader	1	$7.84/ha	1	50	$3.92
	Granulated sulphur	30 kg/ha	$1.10/kg	1	50	$16.50
	Total cost	-	-	-	-	*$87*

Table 53 - Ongoing fertiliser treatment applied every five years on pastures sown on more fertile land types in the Burdekin Rangelands

Sown pasture	Item or treatment	Rate of application	Cost/unit	Number of applications	% of area treated	Cost per hectare
Stylo + grass and stylo-only	Fertiliser spreader	1	$7.84/ha	1	100	$7.85
	Granulated sulphur	30 kg/ha	$1.10/kg	1	100	$33.00
	Total cost	-	-	-	-	*$40.85*

Additional capital costs of $10,000 in Year 1 were incurred to appropriately fence and water the area being developed to improved pastures. In Year 1 of the analysis, extra steers were sold to free up the grazing area and the area was burnt. In Year 2, the pasture was sown in February and the area was grazed at approximately 25% of the full stocking rate from the middle of June when the first cohort of weaner steers commenced grazing. In Year 3, the sown pasture paddock/s were grazed at 50% of the full stocking rate across the entire area. In Year 4, 100% of the full stocking rate was achieved. The sale of the full complement of steers available due to the pasture development was achieved in Year 5.

3.7.3.1.3 Cattle performance

Steers entered the paddock/s sown to stylo and stylo-grass at the same average age (6 months) and weight (179 kg) and grazed the paddocks until reaching the target sale age. Annual steer growth rates on stylo-grass and stylo-only pastures were assumed to be equivalent, i.e. 200 kg/head. The steers were sold as they exited their paddocks at the end of their grazing period of 12, 24 or 29 months. Table 54 indicates the assumed forage and steer growth parameters for native grass-only pastures and for pastures sown to either stylo and grass or to stylo only. The assumptions for pasture yields, composition, utilisation rates, diet digestibility and animal performance were based on Projects

B.NBP.0766 and B.NBP.0812 (Cox *et al.* 2019; Cox 2021) as well previous published data applicable to the region (Miller *et al.* 1982; McLennan *et al.* 1988; Coates 1994, 1996; Coates *et al.* 1997; Hunt 2008; Ash *et al.* 2011; Peck *et al.* 2015; Bowen *et al.* 2019a) and unpublished DAF internal data (B. English, C. Lemin, C.P. Miller, and J. Rolfe, pers. comm.). The selected parameters for pasture and animal performance were conservative relative to experimental results to account for reduced performance expected under commercial grazing situations compared to carefully controlled and managed research trials. In particular, the pasture yields in sown pasture paddocks were reduced by 25% compared to measured yields in experiments of Cox *et al.* (2019); Cox (2021); Cox *et al.* (2022).

The carrying capacity of each pasture was calculated by multiplying the median annual pasture biomass production by the specified utilisation level and then dividing by the annual pasture consumption of a standard animal unit AE. An AE was defined here in terms of the forage DMI at the specified diet dry matter digestibility (DMD), of a standard animal which was defined as a 2.25 year-old, 450 kg *B. taurus* steer at maintenance, walking 7 km/day on a level 1, gentle slope. The spreadsheet calculator, QuikIntake (McLennan and Poppi 2019), which is based on the Australian Feeding Standards (NRDR 2007) with some modifications for tropical feeding systems (McLennan 2014), was used to calculate daily cattle DMI for the specified pasture DMDs.

Table 54 – Assumed forage and steer growth parameters for native grass pastures and sown stylo-grass or stylo-only pastures grown on 500 ha of more fertile land types on the Burdekin Rangelands property

Biological parameter	Native grass	Stylo + grass pasture		Stylo only	
		Stylo	Grass	Stylo	Grass
Median, annual pasture biomass production (kg DM/ha)	2,900	1,534	2446	2,472	1450
Total annual pasture biomass production (kg DM/ha)	2,900	3,980		3,922	
Utilisation of annual biomass growth (%)	22	41		37	
Median, annual biomass available for consumption (kg DM/ha)	638	1,632		1,451	
Average, stylo content in the diet across the year (%)	0	39		63	
Average, annual diet DMD of grazing cattle (%)	49.5	52		51.1	
Average, annual steer LWG (kg/head)	119	200		200	
Daily live weight gain (kg/day); annual average	0.33	0.55		0.55	
January	0.9	0.9		0.9	
February	1.0	1.0		1.0	
March	1.0	1.0		1.0	
April	0.8	1.0		1.0	
May	0.2	0.8		0.8	
June	0.1	0.6		0.6	

Biological parameter	Native grass	Stylo + grass pasture		Stylo only	
		Stylo	Grass	Stylo	Grass
July	0.0	0.3		0.3	
August	0.0	0.2		0.2	
September	0.0	0.2		0.2	
October	-0.1	0.2		0.2	
November	-0.1	0.2		0.2	
December	0.1	0.2		0.2	
Carrying capacity (ha/AE)[A]	5.15	1.89		2.18	

DM, dry matter; DMD, dry matter digestibility; LWG, live weight gain.

[A]AE defined in terms of the forage intake of a 2.25 year-old, 450 kg *Bos taurus* steer at maintenance, consuming a diet of the specified DMD and walking 7 km/day on level 1, gentle slope.

3.7.3.1.4 Calculation of the number of steers grazed on each pasture type until sale

The number of steers that could be run on each pasture type for each age of sale for the 500 ha paddock was determined by calculating available pasture biomass for consumption per hectare (based on the specified forage utilisation rate for that scenario) and then dividing by the calculated steer intake of pasture dry matter over that period. For pastures that included stylo, the respective annual biomass production and utilisation levels of the grass and edible stylo components were summed to determine the total biomass available. The pasture biomass available for consumption during a defined growth path was adjusted proportionally for days greater or less than the full annual period.

The average DM intake by steers of each forage type within each growth path was estimated using the QuikIntake Excel spreadsheet calculator (McLennan and Poppi 2019) modified from the Australian ruminant feeding standards (NRDR 2007) to better predict intake for *B. indicus* content cattle and tropical diets (McLennan 2014). The average DMD, liveweight of the cattle (i.e., liveweight at the mid-way point) and the assumed average daily gain over the relevant period were used as key inputs. The cattle were assumed to be Brahman, to have a standard reference weight (SRW) of 660 kg, to walk 7 km/day on level 1 slope/terrain.

For a 500 ha paddock prior to the sowing of stylo-grass and with steers sold in June (i.e. the baseline, native pasture scenario for the more fertile land type paddock): 53 weaner steers enter the paddock in June, one death is expected to the end of the year. A total of 52 yearling steers from the previous weaning will be in the paddock at the same time and one of these will die during the year. A total of 50 steers that are 24 months old will also start the year with these sold as the weaners enter the paddock. This age structure and sale pattern matches the steer herd age structure and sale pattern for the property. For a 500 ha paddock that has been fully developed to stylo-grass strips with steers sold in June at 18 months of age: 253 weaner steers will enter the paddock in June with a total of 247, 18 month-old steers sold as the weaners enter. For a 500 ha paddock that has been fully developed to stylo-only strips and with steers sold in June at 18 months of age: 217 weaner steers will enter the paddock in June with a total of 213, 18 month-old steers sold as the weaners enter.

3.7.3.2 Results and discussion

The returns from investing in a strategy of establishing sown pastures in cultivated strips on 500 ha of better quality land types within the Burdekin Rangelands are shown in Table 55. For the red basalt parameters used in this example, all sub-scenarios substantially added to the profitability of the property, resulting in 28-36% return on the additional capital invested and added $34,600-$44,700 profit/annum over the longer term (30 years). Compared to cultivated strips containing stylo-only, strips sown to stylo-grass pastures resulted in ca. $8,500 additional profit/annum over 30 years for the 500 ha paddock but required slightly larger peak deficits. The sale age of steers (18, 30 or 35 months), and therefore the length of the grazing period on the improved pastures (12, 24 or 29 months), made little difference to the economic performance of the investment.

Table 55 – Returns for investing in 500 ha of sown pastures for steers from weaning to sale
The comparison was the 500 ha paddock with and without sown pasture development. All terms defined in the Glossary of terms and abbreviations

Factor	**Stylo-grass**			**Stylo-only**		
	18-month steer sale age	**30-month steer sale age**	**35-month steer sale age**	**18-month steer sale age**	**30-month steer sale age**	**35-month steer sale age**
Period of analysis (years)	30	30	30	30	30	30
Discount rate for NPV	5%	5%	5%	5%	5%	5%
NPV	$685,785	$659,901	$687,015	$565,261	$543,150	$532,390
Annualised NPV	$44,611	$42,927	$44,691	$36,771	$35,333	$34,633
Peak deficit (with interest)	-$164,305	-$165,837	-$137,806	-$123,279	-$125,015	-$102,248
Years to peak deficit	4	4	4	4	4	4
Payback period (years)	6	6	6	6	6	6
IRR	30.18%	28.28%	32.36%	35.13%	32.04%	36.49%

As for the previous scenario (Section 3.7.2), it should be noted that the predicted returns for sown pastures in cultivated strips on in the Burdekin Rangelands region are dependent on largely untested assumptions concerning the relative yields, utilisation rates, diet quality and animal performance from grazing of stylo-grass pastures under commercial paddock grazing in North Queensland over 30 years. Therefore, we adopted the precautionary principle in this analysis in adopting conservative figures for performance of legumes and cattle which were discounted relative to experimental results.

Compared to the scenario of developing larger areas of sown pastures in cultivated strips on lower fertility land types (Section 3.7.2), the smaller area of better quality land types assessed in the present analysis reduced payback periods by at least 50% and resulted in substantially smaller peak deficits, in the range of -$102,200 to -$165,800 rather than in $1M or greater. This approach of targeting more fertile land types on a property with sown pasture developments in cultivated strips appears to be lower risk and to provide more reliable returns than targeting larger areas of moderate fertility land types.

Similar, favourable returns to investing in legume pastures on a 500 ha area were determined for the Northern Gulf for stylos on low-fertility land types and leucaena on high-fertility frontage country (Bowen *et al.* 2019a). The present results are also in line with analyses more broadly indicating the benefits of legume-grass pastures for profitability of extensive beef enterprises across northern Australia (Bowen and Chudleigh 2021c).

3.8 Inorganic supplements fed to cattle herds either Adequate, Marginal, Deficient, or Acutely Deficient in phosphorus

3.8.1 Introduction

Low levels of inorganic, supplements such as P and non-protein N (urea) are one of the few low-cost options for beef producers in northern Australia to reduce the effects of nutritional deficiencies in pasture and increase breeder productivity (McCosker and Winks 1994; Dixon 1998). During dry periods in northern Australia the N content of pastures is generally limiting for optimal production of cattle, and the N deficiencies are likely to be more severe on less fertile country types which are also those most likely to be deficient in P. Urea-based (non-protein N) supplements fed during dry periods have been shown to substantially reduce breeder liveweight loss and increase fertility during severe dry seasons across northern Australia (Dixon 1998).

In the extensive areas of northern Australia with low-P soils, P deficiency is a major constraint to productivity of cattle (Winks 1990; McCosker and Winks 1994; Dixon *et al.* 2020). Phosphorus deficiency results in decreased pasture and energy intakes, poor growth, reduced fertility and milk production, high breeder mortality. In addition, bone weakness can affect animals' gait and in severe cases breakages occur when animals are handled. In addition to poor animal performance there is an increased risk of deaths from botulism associated with osteophagia when cattle chew bones in their craving for the mineral (Dixon *et al.* 2019). Feeding a P supplement to P-deficient cattle will increase feed consumption by 10–40%, growth rates by up to 100 kg liveweight/annum and weaning rates by 10-30% (Wadsworth *et al.* 1990; Winks 1990; McCosker and Winks 1994; Jackson *et al.* 2012). The biological response to P supplements is related to soil P status. Maps showing the soil P status in the Burdekin Rangelands of Queensland (McCosker and Winks 1994; The State of Queensland 2021) indicate that grazing properties in the region can range from adequate (e.g. Basalt country) to acutely deficient in P (e.g. Desert uplands ironbark country).

Research from the 1970s to the 1990s concluded that P supplementation is most effective when fed during the wet, or pasture growing season when the diet has adequate protein and energy (Winks 1990; McCosker and Winks 1994; Dixon 1998; Jackson *et al.* 2012). This is still the established recommendation for growing cattle. In the absence of evidence to the contrary in the 1990s, the P nutrition of breeder cows was assumed to parallel that of growing cattle. Thus, recommendations for P supplementation of breeders were, similarly, that P supplements should be fed in the pasture growing seasons and not during dry periods except for cows in late pregnancy or early lactation. However, more recent evidence has shown that there are substantial differences between growing cattle and breeders in late pregnancy and early lactation. In the breeder, the P in body reserves, especially in bone and also in soft tissues, can be used when there is a dietary deficiency, and this P can be replenished later in the annual cycle when animal P requirements reduce (Dixon *et al*. 2017; Anderson *et al*. 2017). Weaning is critical because it reduces P requirements and replenishment can occur. Thus, when P supplements are fed during the dry season P can be stored in bone and used later during the wet season.

Dry season supplementation programs are easier to implement and manage than feeding supplements during the wet pasture growing season when access to paddocks to distribute supplements is often difficult. Additionally, it can be difficult in the wet season to achieve the voluntary intake of supplements required to provide the supplementary P required. Most contemporary dry season supplementation programs across northern Australia include some P, as well as N (e.g., at a rate of ca. 2-4% P) as per current best-practice recommendation and there is extensive anecdotal information from the industry suggesting that this alleviates the severe symptoms of P deficiency and improves productivity (Jackson *et al.* 2012).

3.8.2 Methods

In this analysis, the profitability of various supplementation regimes to supply N and/or P were assessed. Four properties were assessed with the following categories of average P deficiency: 1) Adequate, 2) Marginal, 3) Deficient or 4) Acute defined as >8, 6-8, 4-5, and 2-3 mg/kg bicarbonate-extracted P (Colwell 1963) in the top 100 mm of soil respectively. Therefore, the base property and herd used as representative of the Burdekin Rangelands in the remainder of this report, considered Marginal in P, was modified to create the alternatives. In total, 16 scenarios were modelled, encompassing the four categories of herd P status each with the base (no supplement) compared to herds fed mineral loose mixes supplying P in the wet season and/or N+P in the dry season.

Supplements were designed to provide adequate P and/or N in the wet and/or dry seasons (Table 56). Supplement composition, supplement and nutrient intakes, costs of supplementation, and estimated responses to supplementation strategies were as described in Table 56 to Table 64 for breeders and growing cattle. All supplements were costed as pre-mixed products using current (May 2022) prices. An initial capital expense of $20,000 was applied in the first year of each feeding scenario to allow investment in infrastructure for feeding out loose lick, e.g. construction of lick feeding sheds and installation of troughs. Labour costs for feeding out loose lick in the paddock ranged from $1.25-$2.40/head.annum, dependent on number of times fed per annum and the number of cattle in each feeding group.

Biological responses to each of the supplement regimes were estimated by evaluating published and unpublished research including studies conducted close to the target region (e.g. Holroyd *et al*.,1977, 1979, 1983, 1988; Dixon 1998, 2007; Smith 2000; Dixon *et al.* 2011, 2020; Dixon and Mayer 2021) and those with N and/or P supplementation treatments within the one experiment (Ridley and Schatz 2006). Additionally, the expert opinion of scientists and beef extension officers with extensive knowledge of the northern beef industry was collated, in particular, R. Dixon (formerly QAAFI) and M. Sullivan (DAF). The parameters were derived with consideration of the seasonal variation in supplement responses likely to occur over 30 years to give an average value. An important assumption was that although P was the primary limiting factor for cattle performance when P intake from pasture was inadequate, the P supplementation program did not return the performance of Marginal- Deficient- or Acutely P-deficient herds to the level of the Adequate-P herd, due to other nutritional constraints associated with these lower fertility land-types (Kerridge *et al.* 1990; Coates *et al.* 1997). Mortality rates were assigned with the assumption that all cattle were vaccinated for botulism regardless of P supplementation.

In the herd models, the numbers of cattle in the supplemented scenario herds were reduced to account for the higher average liveweight of the supplemented cattle and to maintain equivalent grazing pressure. Each supplementation scenario was modelled to include the effects of implementing the change. Herd structures changed as reproductive efficiency and mortality rates changed. Therefore, cow, heifer and steer numbers were adjusted to maintain the same grazing pressure. Cull cows, cull bulls and heifers were sold at the same age regardless of supplementation strategy but at heavier liveweights. The same steer sale age and cow cull age was used in all scenarios. A cow culling age of 13 years was selected as this was the optimum for each base herd (i.e. 'No P or N') scenario. Sale prices ($/kg) were not changed with supplementation strategy. During the modelling calculations, although all classes of cattle were fed supplement from Year 1, it was assumed that the new levels of reproductive efficiency, liveweight and mortality rates were achieved during Year 3. Also, additional weaners produced by implementation of the supplementation program did not add to the returns of the property until they were sold.

Table 56 – Supplement loose mix (lick) composition (as-fed basis) and cost per tonne for a Burdekin Rangelands region property with different levels of phosphorus (P status)

The dry-matter contents of mineral and copra meal were assumed to be 970 and 900 g/kg, respectively. Adequate-P, adequate P-deficiency status; Marginal-P, marginal P-deficiency status; Deficient-P, deficient P-deficiency status; Acute-P, acute P-deficiency status. N, nitrogen.

Parameter	**Wet-season supplement**	**Dry-season supplement**					
	P: Adequate, Marginal, Deficient, Acute-P herds	**N+P: Adequate, Marginal-P breeders**	**N+P: Adequate. Marginal-P growing cattle**	**N+P: Deficient-P breeders**	**N+P: Deficient-P growing cattle**	**N+P: Acute-P breeders**	**N+P: Acute-P growing cattle**
Urea (g/kg)	0	300	300	300	300	300	300
Ammonium sulfate (GranAm), (g/kg)	0	80	60	80	60	80	60
Canola meal (g/kg)	0	50	100	50	100	50	100
Soyabean meal (g/kg)	0	50	100	50	100	50	100
Calcium phosphate (Kynofos) (g/kg)	800	100	50	200	70	250	100
Salt (g/kg)	200	420	390	320	370	270	340
Crude protein (g/kg)	0	1004	1020	1004	1020	1004	1020
P (g/kg)	168	22	13	43	17	54	23
Supplement cost ($/t)	*$2,067*	*$1,327*	*$1,281*	*$1,504*	*$1,321*	*$1,606*	*$1,391*
Freight to property ($/t)	*$30*	*$30*	*$30*	*$30*	*$30*	*$30*	*$30*
Total supplement cost ($/t)	***$2,097***	***$1,357***	***$1,311***	***$1,534***	***$1,351***	***$1,636***	***$1,421***

Table 57 – Supplement and nutrient intakes for breeder cattle in the Burdekin Rangelands region supplemented with mineral loose mix (lick) supplements in the wet and/or dry seasons, containing nitrogen (N) and/or phosphorus (P) for scenarios covering land types and cattle herds either Adequate, Marginal, Deficient or Acutely deficient in P

Scenario	Days fed supplement		Supplement (g/head.day)		Crude protein (g/head.day)		Phosphorus (g/head.day)		Supplement cost ($/head)		Total supplement cost ($/head.annum)[A]
	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	
1. Adequate-P herd											
a. No P or N (base scenario)	0	0	0	0	0	0	0	0	0	0	0
b. Wet season P	120	0	30	0	0	0	5.0	0	$7.55	0	$7.55
c. Dry season N+P	0	120	0	150	0	151	0	3.3	0	$24.43	$24.43
d. Dry season N+P, wet season P	120	120	30	150	0	151	5.0	3.3	$7.55	$24.43	$31.98
2. Marginal-P herd											
a. No P or N (base scenario)	0	0	0	0	0	0	0	0	0	0	0
b. Wet season P	150	0	30	0	0	0	5.0	0	$9.44	0	$9.44
c. Dry season N+P	0	150	0	150	0	151	0	3.3	0	$30.53	$30.53
d. Dry season N+P, wet season P	150	120	30	150	0	151	5.0	3.3	$9.44	$24.43	$33.86
3. Deficient-P herd											
a. No P or N (base scenario)	0	0	0	0	0	0	0	0	0	0	0
b. Wet season P	150	0	50	0	0	0	8.4	0	$15.73	0	$15.73
c. Dry season N+P	0	180	0	150	0	151	0	6.5	0	$41.42	$41.42
d. Dry season N+P, wet season P	150	150	50	150	0	151	8.4	6.5	$15.73	$34.52	$50.24
4. Acute-P herd											
a. No P or N (base scenario)	0	0	0	0	0	0	0	0	0	0	0
b. Wet season P	150	0	75	0	0	0	12.6	0	$23.59	0	$23.59
c. Dry season N+P	0	180	0	150	0	151	0	8.0	0	$44.17	$44.17
d. Dry season N+P, wet season P	150	150	75	150	0	151	12.6	8.0	$23.59	$36.81	$60.40

[A]Supplement costs including freight but not labour costs to feed out supplements. These latter costs are accounted for elsewhere in the analysis.

Table 58 – Supplement and nutrient intakes for <u>weaner cattle</u> in the Burdekin Rangelands region supplemented with mineral loose mix (lick) supplements in the wet and/or dry seasons, containing nitrogen (N) and/or phosphorus (P) for scenarios covering land types and cattle herds either Adequate, Marginal, Deficient or Acutely deficient in P

Scenario	Days fed supplement		Supplement (g/head.day)		Crude protein (g/head.day)		Phosphorus (g/head.day)		Supplement cost ($/head)		Total supplement cost ($/head.annum)[A]
	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	
1. Adequate-P herd											
a. No P or N (base scenario)	0	0	0	0	0	0	0	0	0	0	0
b. Wet season P	0	0	0	0	0	0	0	0	0	0	0
c. Dry season N+P	0	150	0	75	0	77	0	1.0	0	$14.75	$14.75
d. Dry season N+P, wet season P	0	150	0	75	0	77	0	1.0	0	$14.75	$14.75
2. Marginal-P herd											
a. No P or N (base scenario)	0	0	0	0	0	0	0	0	0	0	0
b. Wet season P	0	0	0	0	0	0	0	0	0	0	0
c. Dry season N+P	0	150	0	75	0	77	0	1.0	0	$14.75	$14.75
d. Dry season N+P, wet season P	0	150	0	75	0	77	0	1.0	0	$14.75	$14.75
3. Deficient-P herd											
a. No P or N (base scenario)	0	0	0	0	0	0	0	0	0	0	0
b. Wet season P	0	0	0	0	0	0	0	0	0	0	0
c. Dry season N+P	0	180	0	75	0	77	0	1.3	0	$18.24	$18.24
d. Dry season N+P, wet season P	0	180	0	75	0	77	0	1.3	0	$18.24	$18.24
4. Acute-P herd											
a. No P or N (base scenario)	0	0	0	0	0	0	0	0	0	0	0
b. Wet season P	0	0	0	0	0	0	0	0	0	0	0
c. Dry season N+P	0	180	0	75	0	77	0	1.7	0	$19.18	$19.18
d. Dry season N+P, wet season P	0	180	0	75	0	77	0	1.7	0	$19.18	$19.18

[A]Supplement costs including freight but not labour costs to feed out supplements. These latter costs are accounted for elsewhere in the analysis.

Table 59 – Supplement and nutrient intakes for heifers 1-2 years old in the Burdekin Rangelands region supplemented with mineral loose mix (lick) supplements in the wet and/or dry seasons, containing nitrogen (N) and/or phosphorus (P) for scenarios covering land types and cattle herds either Adequate, Marginal, Deficient or Acutely deficient in P

Scenario	**Days fed supplement**		**Supplement (g/head.day)**		**Crude protein (g/head.day)**		**Phosphorus (g/head.day)**		**Supplement cost ($/head)**		**Total supplement cost ($/head.annum)[A]**
	Wet season	**Dry season**	**Wet season**	**Dry season**	**Wet season**	**Dry season**	**Wet season**	**Dry season**	**Wet season**	**Dry season**	
1. Adequate-P herd											
a. No P or N (base scenario)	0	0	0	0	0	0	0	0	0	0	0
b. Wet season P	120	0	20	0	0	0	3.4	0	$5.03	0	$5.03
c. Dry season N+P	0	120	0	90	0	92	0	1.1	0	$14.16	$14.16
d. Dry season N+P, wet season P	120	120	20	90	0	92	3.4	1.1	$5.03	$14.16	$19.19
2. Marginal-P herd											
a. No P or N (base scenario)	0	0	0	0	0	0	0	0	0	0	0
b. Wet season P	150	0	20	0	0	0	3.4	0	$6.29	0	$6.29
c. Dry season N+P	0	150	0	90	0	92	0	1.1	0	$17.70	$17.70
d. Dry season N+P, wet season P	150	120	20	90	0	92	3.4	1.1	$6.29	$14.16	$20.45
3. Deficient-P herd											
a. No P or N (base scenario)	0	0	0	0	0	0	0	0	0	0	0
b. Wet season P	150	0	30	0	0	0	5.0	0	$9.44	0	$9.44
c. Dry season N+P	0	180	0	90	0	92	0	1.5	0	$21.89	$21.89
d. Dry season N+P, wet season P	150	150	30	90	0	92	5.0	1.5	$9.44	$18.24	$27.68
4. Acute-P herd											
a. No P or N (base scenario)	0	0	0	0	0	0	0	0	0	0	0
b. Wet season P	150	0	35	0	0	0	5.9	0	$11.01	0	$11.01
c. Dry season N+P	0	180	0	90	0	92	0	2.1	0	$23.02	$23.02
d. Dry season N+P, wet season P	150	150	35	90	0	92	5.9	2.1	$11.01	$19.18	$30.19

[A]Supplement costs including freight but not labour costs to feed out supplements. These latter costs are accounted for elsewhere in the analysis.

Table 60 – Supplement and nutrient intakes for <u>steers 1-2 years old</u> in the Burdekin Rangelands region supplemented with mineral loose mix (lick) supplements in the wet and/or dry seasons, containing nitrogen (N) and/or phosphorus (P) for scenarios covering land types and cattle herds either Adequate, Marginal, Deficient or Acutely deficient in P

Scenario	**Days fed supplement**		**Supplement (g/head.day)**		**Crude protein (g/head.day)**		**Phosphorus (g/head.day)**		**Supplement cost ($/head)**		**Total supplement cost ($/head.annum)[A]**
	Wet season	**Dry season**	**Wet season**	**Dry season**	**Wet season**	**Dry season**	**Wet season**	**Dry season**	**Wet season**	**Dry season**	
1. Adequate-P herd											
a. No P or N (base scenario)	0	0	0	0	0	0	0	0	0	0	0
b. Wet season P	120	0	20	0	0	0	3.4	0	$5.03	0	$5.03
c. Dry season N+P	0	120	0	90	0	92	0	1.1	0	$14.16	$14.16
d. Dry season N+P, wet season P	120	120	20	90	0	92	3.4	1.1	$5.03	$14.16	$19.19
2. Marginal-P herd											
a. No P or N (base scenario)	0	0	0	0	0	0	0	0	0	0	0
b. Wet season P	150	0	20	0	0	0	3.4	0	$6.29	0	$6.29
c. Dry season N+P	0	150	0	90	0	92	0	1.1	0	$17.70	$17.70
d. Dry season N+P, wet season P	150	120	20	90	0	92	3.4	1.1	$6.29	$14.16	$20.45
3. Deficient-P herd											
a. No P or N (base scenario)	0	0	0	0	0	0	0	0	0	0	0
b. Wet season P	150	0	30	0	0	0	5.0	0	$9.44	0	$9.44
c. Dry season N+P	0	180	0	90	0	92	0	1.5	0	$21.89	$21.89
d. Dry season N+P, wet season P	150	150	30	90	0	92	5.0	1.5	$9.44	$18.24	$27.68
4. Acute-P herd											
a. No P or N (base scenario)	0	0	0	0	0	0	0	0	0	0	0
b. Wet season P	150	0	40	0	0	0	6.7	0	$12.58	0	$12.58
c. Dry season N+P	0	180	0	90	0	92	0	2.1	0	$23.02	$23.02
d. Dry season N+P, wet season P	150	150	40	90	0	92	6.7	2.1	$12.58	$19.18	$31.77

[A]Supplement costs including freight but not labour costs to feed out supplements. These latter costs are accounted for elsewhere in the analysis.

Table 61 – Supplement and nutrient intakes for steers 2-3 years old in the Burdekin Rangelands region supplemented with mineral loose mix (lick) supplements in the wet and/or dry seasons, containing nitrogen (N) and/or phosphorus (P) for scenarios covering land types and cattle herds either Adequate, Marginal, Deficient or Acutely deficient in P

Scenario	**Days fed supplement**		**Supplement (g/head.day)**		**Crude protein (g/head.day)**		**Phosphorus (g/head.day)**		**Supplement cost ($/head)**		**Total supplement cost ($/head.annum)[A]**
	Wet season	**Dry season**	**Wet season**	**Dry season**	**Wet season**	**Dry season**	**Wet season**	**Dry season**	**Wet season**	**Dry season**	
1. Adequate-P herd											
a. No P or N (base scenario)	0	0	0	0	0	0	0	0	0	0	0
b. Wet season P	120	0	20	0	0	0	3.4	0	$5.03	0	$5.03
c. Dry season N+P	0	120	0	115	0	117	0	1.5	0	$18.09	$18.09
d. Dry season N+P, wet season P	120	120	20	115	0	117	3.4	1.5	$5.03	$18.09	$23.12
2. Marginal-P herd											
a. No P or N (base scenario)	0	0	0	0	0	0	0	0	0	0	0
b. Wet season P	150	0	20	0	0	0	3.4	0	$6.29	0	$6.29
c. Dry season N+P	0	150	0	115	0	117	0	1.5	0	$22.61	$22.61
d. Dry season N+P, wet season P	150	120	20	115	0	117	3.4	1.5	$6.29	$18.09	$24.38
3. Deficient-P herd											
a. No P or N (base scenario)	0	0	0	0	0	0	0	0	0	0	0
b. Wet season P	150	0	30	0	0	0	5.0	0	$9.44	0	$9.44
c. Dry season N+P	0	180	0	115	0	117	0	1.9	0	$27.97	$27.97
d. Dry season N+P, wet season P	150	150	30	115	0	117	5.0	1.9	$9.44	$23.30	$32.74
4. Acute-P herd											
a. No P or N (base scenario)	0	0	0	0	0	0	0	0	0	0	0
b. Wet season P	150	0	40	0	0	0	6.7	0	$12.58	0	$12.58
c. Dry season N+P	0	180	0	115	0	117	0	2.7	0	$29.41	$29.41
d. Dry season N+P, wet season P	150	150	40	115	0	117	6.7	2.7	$12.58	$24.51	$37.09

[A]Supplement costs including freight but not labour costs to feed out supplements. These latter costs are accounted for elsewhere in the analysis.

Table 62 – Supplement and nutrient intakes for steers 3-4 years old in the Burdekin Rangelands region supplemented with mineral loose mix (lick) supplements in the wet and/or dry seasons, containing nitrogen (N) and/or phosphorus (P) for scenarios covering land types and cattle herds either Adequate, Marginal, Deficient or Acutely deficient in P

Scenario	**Days fed supplement**		**Supplement (g/head.day)**		**Crude protein (g/head.day)**		**Phosphorus (g/head.day)**		**Supplement cost ($/head)**		**Total supplement cost ($/head.annum)[A]**
	Wet season	**Dry season**	**Wet season**	**Dry season**	**Wet season**	**Dry season**	**Wet season**	**Dry season**	**Wet season**	**Dry season**	
1. Adequate-P herd											
a. No P or N (base scenario)	0	0	0	0	0	0	0	0	0	0	0
b. Wet season P	120	0	20	0	0	0	3.4	0	$5.03	0	$5.03
c. Dry season N+P	0	120	0	135	0	138	0	1.7	0	$21.24	$21.24
d. Dry season N+P, wet season P	120	120	20	135	0	138	3.4	1.7	$5.03	$21.24	$26.27
2. Marginal-P herd											
a. No P or N (base scenario)	0	0	0	0	0	0	0	0	0	0	0
b. Wet season P	150	0	20	0	0	0	3.4	0	$6.29	0	$6.29
c. Dry season N+P	0	150	0	135	0	138	0	1.7	0	$26.55	$26.55
d. Dry season N+P, wet season P	150	120	20	135	0	138	3.4	1.7	$6.29	$21.24	$27.53
3. Deficient-P herd											
a. No P or N (base scenario)	0	0	0	0	0	0	0	0	0	0	0
b. Wet season P	150	0	30	0	0	0	5.0	0	$9.44	0	$9.44
c. Dry season N+P	0	180	0	135	0	138	0	2.3	0	$32.83	$32.83
d. Dry season N+P, wet season P	150	150	30	135	0	138	5.0	2.3	$9.44	$27.36	$36.79
4. Acute-P herd											
a. No P or N (base scenario)	0	0	0	0	0	0	0	0	0	0	0
b. Wet season P	150	0	40	0	0	0	6.7	0	$12.58	0	$12.58
c. Dry season N+P	0	180	0	135	0	138	0	3.1	0	$34.53	$34.53
d. Dry season N+P, wet season P	150	150	40	135	0	138	6.7	3.1	$12.58	$28.78	$41.36

[A]Supplement costs including freight but not labour costs to feed out supplements. These latter costs are accounted for elsewhere in the analysis.

Table 63 – Estimated liveweight (LW) and weaning rate responses to phosphorus (P) and nitrogen (N) supplementation strategies for cattle grazing Burdekin Rangelands properties either Adequate, Marginal, Deficient or Acutely deficient in P

Parameter	P status of cattle herd			
	Adequate	Marginal	Deficient	Acute
Average cow LW over 12 months (kg)				
a. No P or N (base scenario)	450	440	425	410
b. Wet season P	450	450	440	430
c. Dry season N+P	460	460	435	425
d. Dry season N+P, wet season P	460	460	455	445
Cull cow LW in June (kg)				
a. No P or N (base scenario)	450	440	425	410
b. Wet season P	450	450	445	440
c. Dry season N+P	450	440	435	420
d. Dry season N+P, wet season P	450	450	445	440
Weaner LW at 6 months (kg)				
a. No P or N (base scenario)	173	166	146	141
b. Wet season P	173	173	166	161
c. Dry season N+P	176	173	166	156
d. Dry season N+P, wet season P	176	176	171	166
Steer LW gain post weaning (kg/head.annum)				
a. No P or N (base scenario)	137	117	102	92
b. Wet season P	137	124	121	117
c. Dry season N+P	142	122	112	102
d. Dry season N+P, wet season P	142	134	130	125
Heifer LW gain post weaning (kg/head.annum)				
a. No P or N (base scenario)	126	108	94	85
b. Wet season P	126	114	111	108
c. Dry season N+P	131	112	103	94
d. Dry season N+P, wet season P	131	123	120	115
Weaning rate (%)				
a. No P or N (base scenario)	62	56	52	47
b. Wet season P	62	59	58	57
c. Dry season N+P	67	62	56	55
d. Dry season N+P, wet season P	67	63	61	58

Table 64 – Estimated mortality rate responses to phosphorus (P) and nitrogen (N) supplementation strategies for cattle grazing Burdekin Rangelands properties either Adequate, Marginal, Deficient or Acutely deficient in P

Parameter	**P status of cattle herd**			
	Adequate	**Marginal**	**Deficient**	**Acute**
Breeder 3+ years mortality rate (%)				
a. No P or N (base scenario)	3	4	7	9
b. Wet season P	3	3	4	5
c. Dry season N+P	2	3	4	5
d. Dry season N+P, wet season P	2	2	2	3
Heifer 2-3 years mortality rate (%)				
a. No P or N (base scenario)	4	6	9	12
b. Wet season P	4	5	7	9
c. Dry season N+P	3	4	5	7
d. Dry season N+P, wet season P	3	3	3	4
Heifer 1-2 years mortality rate (%)				
a. No P or N (base scenario)	2	3	3	4
b. Wet season P	2	2	2	2
c. Dry season N+P	1	2	2	2
d. Dry season N+P, wet season P	1	2	2	2
Steer 1+ years mortality rate (%)				
a. No P or N (base scenario)	2	3	3	4
b. Wet season P	2	2	2	2
c. Dry season N+P	1	2	2	2
d. Dry season N+P, wet season P	1	2	2	2
Weaner mortality rate (%)				
a. No P or N (base scenario)	3	4	5	8
b. Wet season P	3	3	4	7
c. Dry season N+P	2	2	4	5
d. Dry season N+P, wet season P	2	2	3	4

3.8.3 Results and discussion

The effects of feeding inorganic supplements on the modelled production outputs of herds either Adequate, Marginal, Deficient or Acutely deficient in P, are shown in Table 65 to Table 68. In Adequate-P herds, only the strategy of supplementing with N+P in the dry season increased weaners produced per cows mated, decreased breeder mortality, and consequently, increased female sales as a proportion of the total sales. All supplementation strategies positively affected these parameters for Marginal-P, Deficient-P and Acute-P herds with the benefits more pronounced as the P-deficiency category became more severe. These changes to herd performance resulted in substantial changes to the structure of the herd over time, particularly for Acutely P-deficient herds.

The herd gross margin after interest of the base property with no supplementation was $750,800, $626,800, $497,700, and $338,800 for Adequate-, Marginal-, Deficient-, and Acute-P status properties, respectively. Herd gross margin after interest was decreased for all supplementation strategies applied to Adequate-P herds. With Marginal-P herds, the herd gross margin after interest was increased with wet season P supplementation alone or when combined with dry season N+P supplementation but was similar to the unsupplemented herd when only N+P dry season supplementation was fed (Table 65 to Table 68). All supplementation strategies increased herd gross margin after interest for Deficient-P and Acute-P herds.

The marginal returns (NPV) for any type of supplementation strategy for Adequate-P herds was negative, decreasing profit compared to the base situation of no supplementation by up to $64,900/annum with year-round supplementation (Table 69). In contrast, all supplementation strategies increased profit for Deficient-P and Acute-P herds. The profit of Marginal-P herds was increased with wet season or year-round supplementation strategies but not with dry season supplementation alone.

While returns for dry season N+P supplementation were negative for Adequate- and Marginal-P herds they were positive for Deficient-P and Acute-P herds: $8,900 and $79,500 extra profit/annum, respectively. These results are in line with the expected association of P deficiency status with other soil fertility and nutritional constraints across land types. The representative Burdekin property against which all other strategies in this report were assessed was designated as being marginal in P and with the cattle herd fed N and P supplements in the dry season. The results of the present analysis indicate that the annual feeding of dry season supplements decreased potential profitability of the base property by ca. $5,000 per annum. Furthermore, the results indicate that the property could improve its profit by about $37,600 per annum by changing to a wet season P, only, supplementation strategy.

In summary, this analysis indicates that supplementing with N+P on an annual basis in the dry season is not profitable for Adequate- and Marginal-P herds. This result is in accord with results for a Marginal-P breeder herd in central Queensland (Bowen *et al*. 2020b) and a Deficient-P herd in the mulga lands (Bowen *et al.* 2022). However, an important consideration is that while our analysis reflects the average responses to supplementation over time, responses will vary from year to year, according to the timing and amount of rainfall and the length of the dry season. We have also assumed in our analysis that other herd best-practice management was followed including (1) stocking to the long-term safe carrying capacity and (2) timely weaning to maintain breeder body condition. In herds where grazing pressure is high and breeder body condition not well managed, dry season N+P supplementation can be critical in preventing liveweight loss and mortalities in extended dry seasons. Therefore, the current industry best practice recommendations to monitor seasonal conditions and breeder condition, and to destock and/or supplement with N+P as required, are still appropriate. In our analysis, we did not include the use of water medication options for non-protein N delivery to cattle. These systems would reduce the costs of non-protein N supplementation, relative to the provision of traditional loose mineral mx supplements and are likely to increase the profitability of dry season supplementation above values reported in our analysis.

Investing in P supplements in either the wet season alone or in combination with dry season N+P supplements, improved the profit of Marginal-, Deficient-, and Acute-P herds. Phosphorus supplementation of herds only in the wet season provided substantially greater returns than did supplementing with N+P during the dry season and slightly greater returns than supplementing with N+P during the dry season in combination with P supplementation during the wet season. The returns from wet season P supplementation increased with increasingly severe P deficiency status of the herd; annualised NPVs for wet season P supplementation (alone) were: $32,700, $98,400, and $168,900 for Marginal, Deficient and Acutely P-deficient herds, respectively. Therefore, our results indicate that for land types where a P deficiency exists, P supplementation in the wet season only, will provide the most profitable result, assuming that the property is managed to the long-term safe carrying capacity and that the breeder herd is otherwise managed according to best-practice principles. These results are in accord with previous analyses completed for the central Queensland region where Marginal-, Deficient-, and Acute-P cattle herds were assessed (Bowen *et al.* 2020b) and for a Deficient-P cattle herd in the Mulga Lands (Bowen *et al.* 2022).

In conclusion, the large economic benefits of P supplementation, where a deficiency for cattle exists, are in accord with previous studies (Bowen *et al.* 2020b, 2022; Holmes 1990: McCosker and Winks 1994; Jackson *et al.* 2012) and should support increased adoption of P supplementation. Also consistent with previous studies is the finding that wet season P (cf. dry season N+P) supplementation delivers better responses at a lower cost and with optimal economic benefits. Additionally, in accord with previous analysis of dry season N+P supplementation (Bowen *et al.* 2020b, 2022) our study suggests that for optimal economic outcomes, dry season supplements are best fed in a strategic, targeted manner, as seasonal conditions dictate, rather than as a routine, annual strategy.

Table 65 – Modelled production outputs and herd gross margins for phosphorus (P) and nitrogen (N) supplementation strategies for cattle grazing Burdekin Rangelands properties
<u>Adequate in P</u>

Parameter	**Adequate P herd**			
	No P or N	**Wet season P**	**Dry season N+P**	**Dry season N+P, wet season P**
Total AE	2,500	2,500	2,500	2,500
Total cattle carried	2,841	2841	2,920	2,920
Weaner heifers retained	381	381	399	399
Total breeders mated	1,227	1,227	1,189	1,189
Total breeders mated and kept	924	924	898	898
Total calves weaned	761	761	798	798
Weaners/total cows mated	62.02%	62.02%	67.11%	67.11%
Weaners/cows mated and kept	82.37%	82.37%	88.81%	88.81%
Overall breeder deaths	2.95%	2.95%	1.96%	1.96%
Female sales/total sales %	48.63%	48.63%	49.17%	49.17%
Total cows and heifers sold	336	336	371	371
Maximum cow culling age	13	13	13	13
Heifer joining age	2	2	2	2
One-year-old heifer sales %	0.00%	0.00%	0.00%	0.00%
Two-year-old heifer sales %	31.49%	31.49%	35.70%	35.70%
Total steers and bullocks sold	355	355	384	384
Maximum bullock turnoff age	3	3	3	3
Average female price	$1,024.11	$1,024.11	$1,001.37	$1,001.37
Average steer/bullock price	$1,703.98	$1,703.98	$1,576.88	$1,576.88
Capital value of herd	$2,586,406	$2,586,406	$2,558,818	$2,558,818
Imputed interest on herd value	$129,320	$129,320	$127,941	$127,941
Net cattle sales	$948,775	$948,775	$976,410	$976,410
Direct costs excluding bulls	$21,653	$44,947	$82,635	$108,337
Bull replacement	$46,973	$46,973	$45,513	$45,513
Herd gross margin	$880,148	$856,855	$848,262	$822,560
Herd gross margin less interest on livestock capital	***$750,828***	***$727,534***	***$720,321***	***$694,619***
Gross margin/AE	$352	$343	$339	$329
Gross margin/AE after interest	*$300*	*$291*	*$288*	*$278*

AE, adult equivalent.

Table 66 – Modelled production outputs and herd gross margins for phosphorus (P) and nitrogen (N) supplementation strategies for cattle grazing Burdekin Rangelands properties <u>Marginal in P</u>

Parameter	**Marginal P herd**			
	No P or N	**Wet season P**	**Dry season N+P**	**Dry season N+P, wet season P**
Total AE	2,500	2,500	2,500	2,500
Total cattle carried	3,014	2,918	2,920	2,799
Weaner heifers retained	384	382	388	375
Total breeders mated	1,372	1,296	1,252	1,192
Total breeders mated and kept	1,093	996	971	907
Total calves weaned	768	765	776	750
Weaners/total cows mated	55.99%	59.02%	61.99%	62.87%
Weaners/cows mated and kept	70.31%	76.81%	79.95%	82.67%
Overall breeder deaths	4.17%	3.18%	3.05%	2.16%
Female sales/total sales %	47.32%	48.30%	48.49%	49.06%
Total cows and heifers sold	314	331	339	341
Maximum cow culling age	13	13	13	13
Heifer joining age	2	2	2	2
One-year-old heifer sales %	0.00%	0.00%	0.00%	0.00%
Two-year-old heifer sales %	25.25%	32.63%	36.58%	35.95%
Total steers and bullocks sold	349	355	360	354
Maximum bullock turnoff age	3	3	3	3
Average female price	$973.09	$1,004.07	$987.68	$1,020.74
Average steer/bullock price	$1,510.24	$1,590.43	$1,573.94	$1,668.64
Capital value of herd	$2,608,159	$2,601,347	$2,564,174	$2,537,614
Imputed interest on herd value	$130,408	$130,067	$128,209	$126,881
Net cattle sales	$832,347	$897,013	$901,508	$939,130
Direct costs excluding bulls	$22,627	$52,976	$94,915	$108,883
Bull replacement	$52,518	$49,594	$47,931	$45,637
Herd gross margin	$757,203	$794,442	$757,937	$784,610
Herd gross margin less interest on livestock capital	***$626,795***	***$664,375***	***$629,948***	***$657,729***
Gross margin/AE	$303	$318	$303	$314
Gross margin/AE after interest	*$251*	*$266*	*$252*	*$263*

AE, adult equivalent.

Table 67 – Modelled production outputs and herd gross margins for phosphorus (P) and nitrogen (N) supplementation strategies for cattle grazing Burdekin Rangelands properties <u>Deficient in P</u>

Parameter	**Deficient P herd**			
	No P or N	**Wet season P**	**Dry season N+P**	**Dry season N+P, wet season P**
Total AE	2,500	2,500	2,500	2,500
Total cattle carried	3,250	2,982	3,041	2,876
Weaner heifers retained	395	386	386	384
Total breeders mated	1,520	1,330	1,378	1,257
Total breeders mated and kept	1,283	1,057	1,104	941
Total calves weaned	790	772	773	768
Weaners/total cows mated	51.97%	58.06%	56.09%	61.14%
Weaners/cows mated and kept	61.57%	73.10%	70.00%	81.67%
Overall breeder deaths	7.10%	4.41%	4.12%	2.45%
Female sales/total sales %	43.66%	47.13%	47.24%	48.84%
Total cows and heifers sold	273	314	318	344
Maximum cow culling age	13	13	13	13
Heifer joining age	2	2	2	2
One-year-old heifer sales %	0.00%	0.00%	0.00%	0.00%
Two-year-old heifer sales %	27.02%	29.88%	26.23%	30.43%
Total steers and bullocks sold	352	353	356	361
Maximum bullock turnoff age	3	3	3	3
Average female price	$907.85	$988.08	$957.55	$1,003.50
Average steer/bullock price	$1,317.79	$1,553.32	$1,466.06	$1,637.55
Capital value of herd	$2,601,026	$2,603,966	$2,607,776	$2,565,141
Imputed interest on herd value	$130,051	$130,198	$130,389	$128,257
Net cattle sales	$710,796	$858,703	$826,067	$936,581
Direct costs excluding bulls	$23,850	$66,900	$114,581	$145,037
Bull replacement	$59,238	$51,841	$53,684	$48,112
Herd gross margin	$627,708	$739,962	$657,802	$743,433
Herd gross margin less interest on livestock capital	***$497,657***	***$609,764***	***$527,413***	***$615,176***
Gross margin/AE	$251	$296	$263	$297
Gross margin/AE after interest	*$199*	*$244*	*$211*	*$246*

AE, adult equivalent.

Table 68 – Modelled production outputs and herd gross margins for phosphorus (P) and nitrogen (N) supplementation strategies for cattle grazing Burdekin Rangelands properties
<u>Acutely deficient in P</u>

Parameter	**Acute P herd**			
	No P or N	**Wet season P**	**Dry season N+P**	**Dry season N+P, wet season P**
Total AE	2,500	2,500	2,500	2,500
Total cattle carried	3,343	3,049	3,169	2,943
Weaner heifers retained	376	388	399	384
Total breeders mated	1,600	1,361	1,449	1,324
Total breeders mated and kept	1,502	1,142	1,185	1,019
Total calves weaned	751	776	797	769
Weaners/total cows mated	46.97%	57.03%	55.03%	58.06%
Weaners/cows mated and kept	50.04%	67.98%	67.30%	75.45%
Overall breeder deaths	9.17%	5.42%	5.05%	2.93%
Female sales/total sales %	37.89%	45.78%	46.19%	48.31%
Total cows and heifers sold	196	291	311	333
Maximum cow culling age	13	13	13	13
Heifer joining age	2	2	2	2
One-year-old heifer sales %	0.00%	0.00%	0.00%	0.00%
Two-year-old heifer sales %	29.69%	44.58%	43.89%	30.01%
Total steers and bullocks sold	321	345	362	357
Maximum bullock turnoff age	3	3	3	3
Average female price	$849.22	$964.73	$899.20	$984.37
Average steer/bullock price	$1,216.36	$1,492.57	$1,347.24	$1,579.83
Capital value of herd	$2,618,577	$2,605,505	$2,565,429	$2,574,166
Imputed interest on herd value	$130,929	$130,275	$128,271	$128,708
Net cattle sales	$555,963	$796,512	$767,608	$891,273
Direct costs excluding bulls	$23,866	$84,014	$132,515	$167,237
Bull replacement	$62,331	$53,039	$56,450	$50,677
Herd gross margin	$469,766	$659,459	$578,643	$673,359
Herd gross margin less interest on livestock capital	***$338,837***	***$529,184***	***$450,371***	***$544,651***
Gross margin/AE	$188	$264	$231	$269
Gross margin/AE after interest	*$136*	*$212*	*$180*	*$218*

AE, adult equivalent.

Table 69 – Profitability and financial risk of implementing phosphorus (P) and nitrogen (N) supplementation strategies for cattle grazing Burdekin Rangelands properties either Adequate, Marginal, Deficient or Acutely deficient in P

Scenario	NPV of change	Annualised NPV	Peak deficit (with interest)	Years to peak deficit	Payback period (years)	IRR (%)
1. Adequate-P herd						
a. No P or N	Base	Base	Base	Base	Base	Base
b. Wet season P	-$395,519	-$25,729	-$1,709,400	30	Never	n/c
c. Dry season N+P	-$606,421	-$39,449	-$2,620,900	30	Never	n/c
d. Dry season N+P, wet season P	-$997,489	-$64,888	-$4,311,100	30	Never	n/c
2. Marginal-P herd						
a. No P or N	Base	Base	Base	Base	Base	Base
b. Wet season P	$501,939	$32,652	-$85,799	2	2	56.0
c. Dry season N+P	-$76,735	-$4,992	-$356,600	29	n/c	-0.31
d. Dry season N+P, wet season P	$416,944	$27,123	-$215,672	2	4	30.6
3. Deficient-P herd						
a. No P or N	Base	Base	Base	Base	Base	Base
b. Wet season P	$1,512,112	$98,365	-$119,810	2	2	112.7
c. Dry season N+P	$137,268	$8,930	-$241,769	2	7	13.9
d. Dry season N+P, wet season P	$1,475,412	$95,978	-$312,289	2	2	53.4
4. Acute-P herd						
a. No P or N	Base	Base	Base	Base	Base	Base
b. Wet season P	$2,596,043	$168,876	-$158,415	2	2	115.3
c. Dry season N+P	$1,222,522	$79,527	-$266,163	2	3	39.7
d. Dry season N+P, wet season P	$2,562,228	$166,677	-$367,750	2	2	63.5

4 General discussion

In this study we have applied scenario analysis to examine a range of management strategies and technologies that may contribute to building both more profitable and more drought resilient properties in the Burdekin Rangelands region of Queensland. The results of this analysis can be used to support informed decision making by property managers. The information provided here should be used, firstly, as a guide to an appropriate method to assess alternative strategies aimed at improving profitability and drought resilience in the target region and, secondly, to indicate the potential level of response to change revealed by relevant research.

The production parameters assumed for the hypothetical, representative property were intended to represent the long-term average expectation for this region. However, there is an obvious challenge in adequately accounting for the high annual rainfall variability that occurs in this region. Regardless, the example property constructed in this study provides a broad understanding of the opportunities available for improvement, the potential response functions, and an appropriate framework to support decision making. Whilst every effort was made to ensure the assumptions used in each scenario were accurate and validated with industry participants, relevant experts or published scientific studies, the results presented should be viewed as indicative only.

The key to improving the performance of individual beef properties is the ability of management to recognise relevant opportunities and then being able to assess the trade-offs, responses, costs and benefits likely from the implementation of any opportunity on their property (Stafford Smith and Foran 1988; Foran *et al.* 1990; Bowen and Chudleigh 2021c). Considering the results of an analysis based on the circumstances of another property or an ‘example’ property, as used in this study, is a way of understanding the key factors in the decision but rarely an accurate indicator of the likely outcome for each separate property. Managers and their advisors can use the tools and models developed in this study to conduct their own analyses specific to their circumstances.

The value of changing the enterprise on the property or changing the enterprise mix can only be assessed by comparing the expected future performance of the production system that is already in place with the expected future performance of the alternative enterprise or enterprise mix (Malcolm *et al.* 2005). An analysis that looks at alternative futures for the constructed property needs to include the implementation phase and all identifiable impacts on capital expenditure, changes in the amount and timing of costs (including opportunity costs) and income over time. Allowance may also need to be made for the extra management time and effort required by the property owner or manager to operate the changed production system, even though this may not be paid. We have applied this accepted farm-management economics framework in the current analysis.

Similar to grazing properties elsewhere in northern Australia, in the Burdekin Rangelands beef businesses are challenged by substantial climate variability, including extended and extensive droughts (LongPaddock 2022), variable commodity prices, and a long-term declining trend in terms of trade (ABARES 2019). Therefore, to remain in business through these challenges and to build resilience to droughts, floods and market uncertainty, beef producers need to build capital and equity.

A number of alternative beef production strategies are available, and it is shown in this study that some are likely to both reduce profit and increase drought risk while others could both improve profit and reduce drought risk. Those strategies identified as likely to increase profitability in the Burdekin Rangelands region were consistent with findings for other regions across Queensland and the Northern Territory and included increasing age of steer turnoff to the optimal, P supplementation in the pasture growing season where deficiencies exist, establishing legume pastures for steers, and home-bred bulls (Bowen and Chudleigh 2018b, 2021a, 2021b, 2021c, 2021d; Bowen *et al.* 2019a, 2020a, 2020b; 2022; Chudleigh *et al.* 2019b).

As we have demonstrated previously (Bowen and Chudleigh 2021c, 2021d), the first step in any analysis of strategies to improve property profit and resilience should be to determine the optimal herd structure, i.e. the most profitable sale age for steers and cull females. The most profitable herd structure for the Burdekin Rangelands beef cattle property based on adjusted last 7.5-year cattle prices (October 2014-April 2022) was found to be either a 30 or 42-month steer sale target and 12-year female cull age. The effect of moving from a weaner sale target (the least profitable age of turnoff) to a 42-month steer sale age was assessed and found to provide an extra $127,100 profit/annum on average over the 30 years of the analysis. If the optimal age of steer turnoff is older than in the starting herd this strategy can provide an added benefit to drought resilience due to a reduction in the size of the breeder herd relative to growing cattle at the same grazing pressure. However, an important consideration is that the implementation of this strategy will cause a substantial peak deficit in cash flow as steer cohorts are initially held back from sale which would create a barrier to management change that would be difficult for some managers to overcome. Short term changes in the relative prices of cattle classes may result in a different optimal age of steer sale to that identified based on longer-term historical prices and may identify opportunities to increase profitability in the short term by deviating from the long-term sale target. However, having an understanding of the optimal herd structure based on cattle price data over a more extended period (e.g. 7-10 years) will allow profit to be maximised over the long term by moving back to the long-term optimal herd structure following deviations.

Low levels of inorganic, supplements such as P and non-protein N (urea) are one of the few low-cost options for beef producers in northern Australia to reduce the effects of nutritional deficiencies in pasture and increase breeder productivity and are widely applied (McCosker and Winks 1994; Dixon 1998). Our analysis for the Burdekin Rangelands region is in accord with previous studies in demonstrating the large economic benefits of P supplementation for cattle, where a deficiency exists (Bowen *et al.* 2020b, 2022; Holmes 1990: McCosker and Winks 1994; Jackson *et al.* 2012) and should support increased adoption of P supplementation. Also consistent with previous studies is the finding that wet season P (cf. dry season N+P) supplementation delivers better responses at a lower cost and with optimal economic benefits. Additionally, in accord with previous analysis of dry season N+P supplementation (Bowen *et al.* 2020b, 2022) our study suggests that for optimal economic outcomes, dry season supplements are best fed in a strategic, targeted manner, as seasonal conditions dictate, rather than as a routine, annual strategy.

Introducing adapted perennial legumes, such as stylos or leucaena, to established grass pastures so as to improve steer growth rates has been consistently shown to be a profitable strategy across relevant regions of northern Australia (Bowen and Chudleigh 2018c, 2021c). Similarly, in the current study, establishing stylo-only or stylo-grass pastures for steers in cultivated strips added substantially to the profitability of the Burdekin Rangelands property (up to $129,700 extra profit/annum). However, when a sufficient area of legume-grass pastures were established on moderate fertility land types to run all steers from weaning to sale, the relatively intensive and expensive method of pasture establishment in this example meant that in order for the strategy to be profitable, herd numbers needed to be increased rapidly to fully utilise the extra pasture biomass as soon as possible. The age of turnoff of steers was also important to profitability. Regardless, the large peak deficits and long periods of time before the investments were paid back (12-18 years) would provide an obstacle to adoption of this strategy for many producers.

Compared to large-scale sown pasture development on the moderate fertility land types, targeting a smaller area (500 ha in this example) of better quality land types for stylo or stylo-grass establishment in cultivated strips was a relatively lower risk investment and provided more reliable returns which were in the range of $35,000 to $45,000 extra profit/annum. For instance, targeting the more fertile land types reduced payback periods by at least 50% and resulted in substantially smaller peak deficits, in the range of -$102,000 to -$166,000, compared to >/=$1 million for large-scale pasture development on moderate fertility land types.

The strategy of utilising home-bred bulls resulted in relatively large positive returns compared to other strategies examined for the Burdekin Rangelands property. The investment in conversion to home-bred bulls rather than purchased bulls was paid back by the end of Year 2 of the analysis, with an extra profit of $35,800/annum and a return on extra funds invested (IRR) of 142%. The key assumptions were that the bull to cow mating ratio could be maintained, and that no aspect of herd performance (reproduction or growth) would be impacted by the change. Similar, positive returns for investing in production of home-bred bulls was determined for representative properties in the Northern Gulf (Bowen *et al.* 2019a) and the Northern Downs (Bowen *et al.* 2020a) regions of Queensland. The improvement in property profit due to utilising home-bred bulls arises from the high average value some beef property managers pay for herd bulls and the difference between that cost and costs associated with breeding, and objectively selecting, bulls from male weaners produced by the herd. The home-bred bull strategy is also associated with a relatively small peak deficit (-$17,300) and short payback period (2 years).

Conversely, strategies that improved breeder herd efficiency, such as genetic improvement of weaning rate or reducing foetal/calf loss (should an effective technology or management strategy be identified), had relatively minor effects on business profit. Furthermore, targeting supplements to improve the reproductive performance of specific breeder cohorts, such as maiden heifers or first-calf heifers, resulted in substantial negative effects on property profitability. The lack of capacity to identify investments that can profitably improve breeder reproductive efficiency is consistent with findings for other regions across Northern Australia (Chudleigh *et al.* 2016, 2017, 2019a, 2019b; Bowen and Chudleigh 2021c). This finding highlights the critical importance of implementing low-cost strategies to achieve optimal breeder body condition and herd structure as key factors in improving profitability and drought resilience.

While the analysis of Ash et al. (2015) indicated a substantial increase in enterprise profit from implementing strategies to improve the reproductive efficiency of breeders, this study did not incorporate the implementation phase required for each of the scenarios. The importance of incorporating the implementation phase in any analysis of change in the management of grazing properties in northern Australia have been conclusively demonstrated in the studies of Chudleigh *et al*. (2016, 2017, 2019a, 2019b), Bowen and Chudleigh (2018a, 2018c, 2021c, 2021d, 2022), and Bowen *et al.* (2020b, 2021, 2022). These analyses, as well as our current study, have highlighted the importance of appropriately modelling the steps in moving from an existing base property and enterprise to an alternative situation. Additionally, the studies have identified the critical importance of correctly incorporating any change in the timing and/or amount of benefits and costs when implementing alternative strategies. These analyses, like the present study, indicated that capital constraints and perceived risk are likely to play a large role in the level and rate at which a strategy is likely to be adopted and implemented. Applying a method that appropriately highlights the financial risks associated with the implementation of a strategy, as well as the potential economic benefits, is necessary to assist understanding of the nature of the alternative investments. This assertion was also made by Foran *et al.* (1990) who concluded that the ‘whole-of-property' approach is essential for both comparing management options and for setting priorities for research and development in the Australian rangelands.

A key insight from our analyses is that the value of any change in management to build profitability and resilience depends upon the circumstances of the manager and the property considering the change. It is necessary to apply the right planning framework and to reassess the strategy as change occurs. We suggest that beef production systems which exhibit resilience are predominately those where managers spend considerable time and resources assessing their business and frequently monitor their pastures, livestock, financial position, markets, options and wellbeing. Furthermore, we propose that having the right production system in place prior to drought is a key factor in surviving drought, as is maintaining a clear framework for the timely assessment of options when responding to, and recovering from, drought.

5 Conclusions

This study has provided insights into the opportunities to improve profitability and resilience of a hypothetical grazing enterprise in the Burdekin Rangelands region. As demonstrated in this study, the application of a logical, rational framework is critical to evidence-based decision making. We have applied the farm-management economics framework to examine a range of management strategies and technologies relevant to the region. The scenarios modelled here are aimed at providing a broad understanding of the range of opportunities available for improvement, the potential response functions in a production system, and an appropriate framework to support decision making. The property-level, regionally specific, herd and business models that we have developed can be used to assess both strategic and tactical decisions for individual businesses.

6 References

ABARES (Australian Bureau of Agricultural and Resource Economics and Sciences) (2019) 'Agricultural commodities: March quarter 2019'. (Australian Bureau of Agricultural and Resource Economics and Sciences: Canberra, Qld). Available at https://www.agriculture.gov.au/sites/default/files/sitecollectiondocuments/abares/agriculture-commodities/AgCommodities201903_v1.0.0.pdf [Verified 17 March 2022]

ABARES (Australian Bureau of Agricultural and Resource Economics and Sciences) (2022) 'Agricultural forecasts and outlook: March quarter 2022. Agricultural Commodities Report, Vol. 12.1'. (Australian Bureau of Agricultural and Resource Economics and Sciences: Canberra, Qld). Available at https://daff.ent.sirsidynix.net.au/client/en_AU/search/asset/1033304/0 [Verified 17 March 2022]

ABS (Australian Bureau of Statistics) (2020a) 71210DO002 Agricultural Commodities, Australia, 2019-20. Available at Agricultural Commodities, Australia, 2019-20 financial year | Australian Bureau of Statistics (abs.gov.au) [Verified 17 March 2022]

ABS (Australian Bureau of Statistics) (2020b) 75030DO001 Value of Agricultural Commodities Produced, Australia, 2019-20. Available at Value of Agricultural Commodities Produced, Australia, 2019-20 financial year | Australian Bureau of Statistics (abs.gov.au) [Verified 17 March 2022]

Anderson ST, Kidd LJ, Benvenutti MA, Fletcher MT, Dixon RM (2017) New candidate markers of phosphorus status in beef breeder cows. *Animal Production Science* **57**, 2291-2303.

Ash A, (2001) Managing woodlands: developing sustainable beef production systems for northern. Project NAP3.205 final report. Meat and Livestock Australia, Sydney.

Ash AJ, Bellamy JA, Stockwell TGH (1994) State and transition models for rangelands. 4. Application of state and transition models to rangelands in northern Australia. *Tropical Grasslands* **28**, 223-228.

Ash A, Corfield J, Ksiksi T (2002) The Ecograze Project – developing guidelines to better manage grazing country. (CSIRO Sustainable Ecosystems: Townsville)

Ash AJ, Corfield JP, McIvor JG, Ksiksi TS (2011) Grazing management in tropical savannahs: utilisation and rest strategies to manipulate rangeland condition. *Rangeland Ecology and Management* **64,** 223-239

Ash AJ, O'Reagain PJ, McKeon GM, Stafford Smith M (2000) Managing climate variability in grazing enterprises: a case study of the Dalrymple Shire. In: 'Applications of seasonal climate forecasting in Agricultural and natural ecosystems – The Australian experience.' (Eds GL Hammer, N Nicholls, C Mitchell) pp. 271-289. (Springer Dordrecht: The Netherlands)

Ash A, Hunt L, McDonald C, Scanlan J, Bell L, Cowley R, Watson I, McIvor J, MacLeod N (2015) Boosting the productivity and profitability of northern Australia beef enterprises: exploring innovation options using simulation modelling and systems analysis. *Agricultural Systems* **139**, 50-65.

Bartley R, Abbott BN, Ghahramani A, Ali A, Kerr R, Hoth, CH, Kinsey-Henderson AE (2023) Do regenerative grazing management practices improve vegetation and soil health in grazed rangelands? Preliminary insights from a space-for-time study in the Great Barrier Reef catchments, Australia. *The Rangeland Journal.* Online early.

Bartley R, Corfield JP, Hawdon AA, Kinsey-Henderson AE, Abbott BN, Wilkinson SN, Keen RJ (2014) Can changes to pasture management reduce runoff and sediment loss to the Great Barrier Reef? The results of a 10-year study in the Burdekin catchment, Australia. *The Rangeland Journal* **36**, 67-84.

Barwick S, (1997) Upgrading the analytical capabilities of the National Beef Recording Scheme Project UNE.035 final report prepared by the Animal Genetics and Breeding Unit (University of New England). Meat and Livestock Australia, Sydney, NSW, Australia.

Beutel TS, Tindall D, Denham R, Trevithick R, Scarth P, Abbott B, Holloway C (2014) Getting ground cover right: thresholds and baselines for a healthier reef. Report to the Reef Rescue Research and Development Program. Reef and Rainforest Research Centre Limited, Cairns, Qld.

BOM (Bureau of Meteorology) (2022a) Climate data online. Available at http://www.bom.gov.au/climate/data/index.shtml [Verified 17 March 2022]

BOM (Bureau of Meteorology) (2022b) Climate data online. Rainfall variability. Available at http://www.bom.gov.au/jsp/ncc/climate_averages/rainfall0variability/index.jsp?period=an [Verified 17 March 2022]

Bortolussi G, Hodgkinson JJ, Holmes CR, McIvor JG, Coffey SG (1999) 'Report on the Northern Australian Beef Industry Survey Activity. Extracted Qld Regional Report.' (CSIRO Division of Tropical Agriculture: Brisbane, Qld)

Bortolussi G, McIvor JG, Hodgkinson JJ, Coffey SG, Holmes CR (2005) The northern Australian beef industry, a snapshot. 2. Breeding herd performance and management. *Australian Journal of Experimental Agriculture* **45**, 1075-1091.

Bowen MK, Chudleigh F (2018a) Grazing pressure, land condition, productivity and profitability of beef cattle grazing buffel grass pastures in the subtropics of Australia: a modelling approach. *Animal Production Science* **58**, 145101458. doi: 10.1071/AN17780. Available at https://www.publish.csiro.au/AN/AN17780 [Verified 23 March 2022]

Bowen MK, Chudleigh F (2018b) 'Fitzroy beef production systems. Preparing for, responding to, and recovering from drought.' (The State of Queensland, Department of Agriculture and Fisheries, Queensland: Brisbane) Available at https://futurebeef.com.au/resources/improving-profitability-and-resilience-of-beef-and-sheep-businesses-in-queensland-preparing-for-responding-to-and-recovering-from-drought/ [Verified 17 March 2022]

Bowen MK, Chudleigh F (2018c) Productivity and profitability of alternative steer growth paths resulting from accessing high quality forage systems in the subtropics of northern Australia: a modelling approach. *Animal Production Science* **59**, 173901751. doi: 10.1071/AN18311.

Bowen MK, Chudleigh F (2021a) 'Rangelands of central-western Queensland. Building resilient and diverse livestock production systems.' (The State of Queensland, Department of Agriculture and Fisheries, Queensland: Brisbane) Available at https://futurebeef.com.au/resources/improving-profitability-and-resilience-of-beef-and-sheep-businesses-in-queensland-preparing-for-responding-to-and-recovering-from-drought/ [Verified 14 May 2021]

Bowen MK, Chudleigh F (2021b) 'Mulga Lands production systems. Preparing for, responding to, and recovering from drought.' (The State of Queensland, Department of Agriculture and Fisheries, Queensland: Brisbane) Available at https://futurebeef.com.au/resources/improving-profitability-and-resilience-of-beef-and-sheep-businesses-in-queensland-preparing-for-responding-to-and-recovering-from-drought/ [Verified 8 June 2022]

Bowen MK, Chudleigh F (2021c) An economic framework to evaluate alternative management strategies for beef enterprises in northern Australia. *Animal Production Science* **61**, 271-281. doi: 10.1071/AN20125. Available at https://www.publish.csiro.au/an/pdf/AN20125 [Verified 16 February 2021]

Bowen MK, Chudleigh F (2021d) Achieving drought resilience in the grazing lands of northern Australia: preparing, responding and recovering. *The Rangeland Journal* **43,** 67-76. doi: 10.1071/RJ20058. Available at https://www.publish.csiro.au/rj/pdf/RJ20058 [Verified 7 September 2022]

Bowen MK, Hopkins K (2016) Report on extension activities for the project High-output Forage Systems for Meeting Beef Markets – Phase 2. Project B.NBP.0636 final report. Meat and Livestock Australia, Sydney, NSW, Australia.

Bowen MK, Chudleigh F, Perry L (2020a) 'Northern Downs beef production systems. Preparing for, responding to, and recovering from drought.' (The State of Queensland, Department of Agriculture and Fisheries, Queensland: Brisbane) Available at https://futurebeef.com.au/resources/improving-profitability-and-resilience-of-beef-and-sheep-businesses-in-queensland-preparing-for-responding-to-and-recovering-from-drought/ [Verified 14 May 2021]

Bowen MK, Chudleigh F, Phelps D (2021) Bio-economic evaluation of grazing-management options for beef cattle enterprises during drought episodes in semiarid grasslands of northern Australia. *Animal Production Science* **61**, 72-83. doi: 10.1071/AN19691. Available at https://www.publish.csiro.au/AN/AN19691 [Verified 16 February 2021]

Bowen MK, Chudleigh F, Rolfe JW, English B (2019a) 'Northern Gulf beef production systems. Preparing for, responding to, and recovering from drought.' (The State of Queensland, Department of Agriculture and Fisheries, Queensland: Brisbane) Available at https://futurebeef.com.au/resources/improving-profitability-and-resilience-of-beef-and-sheep-businesses-in-queensland-preparing-for-responding-to-and-recovering-from-drought/ [Verified 17 March 2022]

Bowen MK, Chudleigh F, Sallur NM, Sommerfield J (2022) Opportunities to build resilience of cattle properties in the mulga Lands of southwest Queensland, Australia. *The Rangeland Journal* (**44**, 115-128. doi: 10.1071/RJ21057. Available at https://www.publish.csiro.au/rj/pdf/RJ21057 [Verified 7 September 2022]

Bowen MK, Chudleigh F, Whish G, Phelps D (2019b) 'Central West Mitchell Grasslands livestock production systems. Preparing for, responding to, and recovering from drought.' (The State of Queensland, Department of Agriculture and Fisheries, Queensland: Brisbane) https://futurebeef.com.au/resources/improving-profitability-and-resilience-of-beef-and-sheep-businesses-in-queensland-preparing-for-responding-to-and-recovering-from-drought/ [Verified 17 March 2022]

Bowen, MK, Chudleigh F, Buck S, Hopkins K, Brider J (2015) High-output forage systems for meeting beef markets: Phase 2. Project B.NBP.0636 final report. Meat and Livestock Australia, Sydney, NSW, Australia.

Bowen MK, Chudleigh F, Dixon RM, Sullivan MT, Schatz T, Oxley T (2020b) The economics of phosphorus supplementation of beef cattle grazing northern Australian rangelands. *Animal Production Science* **60**, 683-693. doi: 10.1071/AN19088. Available at http://www.publish.csiro.au/AN/AN19088 [Verified 16 February 2021]

Bowman PJ, McKeon GM, White DH (1995) The impact of long range climate forecasting on the performance of sheep flocks in Victoria. *Australian Journal of Agricultural Research* **46**, 687-702.

Bunter KL, Johnston DJ, Wolcott ML, Fordyce G (2014) Factors associated with calf mortality in tropically adapted beef breeds managed in extensive Australian production systems. *Animal Production Science* **54**, 25036.

Burns BM, Corbet NJ, McGowan MR, Holroyd RG (2014) Male indicator traits to improve female reproductive performance. Project B.NBP.0361 final report. Meat and Livestock Australia, Sydney.

Burrows WH, Orr DM, Hendricksen RE, Rutherford MT, Myles DJ, Back PV, Gowen R (2010) Impacts of grazing management options on pasture and animal productivity in a *Heteropogon contortus* (black speargrass) pasture in central Queensland. 4. Animal production. *Animal production science* **50**, 284-292.

Chudleigh F, Bowen M, Holmes B (2019a) Farm economic thinking and the genetic improvement of fertility in northern beef herds. In 'Proceedings of the 63rd Australasian Agricultural and Resource Economics Society (AARES) Annual Conference'. Melbourne, Victoria, Australia. Available at https://ageconsearch.umn.edu/record/285095?ln=en [Verified 24 August 2022]

Chudleigh F, Oxley T, Bowen M (2019b) 'Improving the performance of beef enterprises in northern Australia.' (The State of Queensland, Department of Agriculture and Fisheries: Brisbane, Qld) Available at https://www.daf.qld.gov.au/__data/assets/pdf_file/0008/1439720/Improving-the-performance-of-beef-production-systems-in-northern-Australia.pdf [Verified 11 March 2021]

Chudleigh F, Cowley T, Moravek T, McGrath T, Sullivan M (2017) Assessing the value of changing beef breeder herd management strategy in northern Australia. In 'Proceedings of the 61st Australasian Agricultural and Resource Economics Society (AARES) Annual Conference'. Brisbane, Queensland, Australia. Available at https://ageconsearch.umn.edu/record/258661?ln=en [Verified 31 March 2022]

Chudleigh F, Oxley T, Cowley T, McGrath T, Moravek T, Sullivan M (2016) The impact of changing breeder herd management and reproductive efficiency on beef enterprise performance. Project B.NBP.0763 final report. Meat and Livestock Australia, Sydney. Unpublished.

Coates DB (1994) The effect of phosphorus as fertiliser or supplement on pasture and cattle productivity in the semi-arid tropics of north Queensland. *Tropical Grasslands* **28**, 90-108.

Coates DB (1996) Diet selection by cattle grazing *Stylosanthes*-grass pastures in the seasonally dry tropics: effect of year, season, stylo species and botanical composition. *Australian Journal of Experimental Agriculture* **36**, 781-798.

Coates DB, Miller CP, Hendricksen RE, Jones RJ (1997) Stability and productivity of *Stylosanthes* pastures in Australia. II. Animal production from *Stylosanthes* pastures. *Tropical Grasslands* **31**, 494-502.

Colwell JD (1963) The estimation of phosphorus fertiliser requirements of wheat in southern New South Wales by soil analyses. *Australian Journal of Experimental Agriculture and Animal Husbandry* **3**, 190-197.

Commonwealth of Australia (2022) Australian CliMate. Available at https://climateapp.net.au/ [Verified 21 March 2022]

Cooksley DG (2003) Managing native pastures and stylos. Project NAP3.221 final report. Meat and Livestock Australia, Sydney.

Cox K (2021) Progressing superior tropical grasses and legumes in seasonally dry Queensland. Project B.NBP.0812 milestone report. Meat and Livestock Australia, Sydney.

Cox K, Lemin C, Dayes S, Gorman J, Bambling L, Buck S, Brazier N, Finlay V, English B, Rolfe J, Wright C (2022) Progressing superior tropical grasses and legumes in seasonally dry Queensland. Project B.NBP.0812 final report. Meat and Livestock Australia, Sydney.

Cox K, Black E, Broad K, Buck S, Dayes S, English B, Gorman J, Gunther R, Lemin C, Keating M, McGrath T, Rolfe J, Wright C (2019) Assessment of promising pasture legumes and grasses. Project B.NBP.0766 summary report. Meat and Livestock Australia, Sydney.

De Corte MWM, Barry EV, Bright MJ, Cannon MG, Scanlan JC (1994) ‘Land degradation in the Dalrymple Shire. A preliminary assessment methods and results.’ (Queensland Government: Brisbane)

Denny D, Moravek T (2019) 'Managing ground cover for economic and sustainability outcomes on grazing lands in the Great Barrier Reef Lagoon catchments. Literature review.' (The State of Queensland, Department of Agriculture and Fisheries, Queensland: Brisbane)

Dixon R (1998) Improving cost-effectiveness of supplementation systems for breeder herds in northern Australia. Project DAQ.098 final report. Meat and Livestock Australia, Sydney.

Dixon R (2007) Utilising faecal NIRS measurements to improve prediction of grower and breeder cattle performance and supplement management: NIRS Task 2 project. Project NBP.302 final report. Meat and Livestock Australia, Sydney, NSW, Australia.

Dixon RM, Mayer RJ (2021) Effects of a nitrogen-based supplement on intake, live weight and body energy reserves in breeding *Bos indicus* cross cows. *Tropical Grasslands-Forrajes Tropicales* **9**, 70-80.

Dixon RM, Playford C, Coates DB (2011) Nutrition of beef breeder cows in the dry tropics. 1. Effects of nitrogen supplementation and weaning on breeder performance. *Animal Production Science* **51**, 515-528.

Dixon RM, Anderson ST, Kidd LJ, Fletcher MT (2020) Management of phosphorus nutrition of beef cattle grazing seasonally dry rangelands: a review. *Animal Production Science* **60**, 863-879.

Dixon RM, Fletcher MT, Goodwin KL, Reid DJ, McNeill DM, Yong KWL, Petherick JC (2019) Learned behaviours lead to bone ingestion by phosphorus-deficient cattle. *Animal Production Science* **59**, 921-932.

Dixon RM, Kidd LJ, Coates DB, Anderson ST, Benvenutti MA, Fletcher MT, McNeill DM (2017) Utilising mobilisation of body reserves to improve the management of phosphorus nutrition of breeder cows. *Animal Production Science* **57**, 2280-2290.

DNRM (Queensland Government, Department of Natural Resources and Mines) (2022a) Queensland spatial catalogue – QSpatial. Grazing land management land types. Available at http://qldspatial.information.qld.gov.au/catalogue/custom/search.page?q=%22Grazing%20land%20management%20land%20types%200%20 [Verified 17 March 2022]

DNRM (Queensland Government, Department of Natural Resources and Mines) (2022b) Queensland spatial catalogue – QSpatial. Land use mapping – 1999 to Current – Queensland. Available at http://qldspatial.information.qld.gov.au/catalogue/custom/search.page?q=%22Land%20use%20mapping%200%201999%20to%20Current%200%20Queensland%22 [Verified 17 March 2022]

Donaghy P, Rolfe J, Gaffney J (2007) Unravelling the economic and environmental tradeoffs of reducing sediment movement from grazed pastures. In 'Proceedings of the 51st Australasian Agricultural and Resource Economics Society (AARES) Annual Conference'. Queenstown, New Zealand. Available at https://ageconsearch.umn.edu/record/10417?ln=en [Verified 25 November 2022]

Doogan VF, Fordyce G, Shepherd RK, James TA, Holroyd RG (1991) The relationships between weight, growth from weaning to mating and conception rate of *Bos indicus* cross heifers in the dry tropics of North Queensland. *Australian Journal of Experimental Agriculture* **31**, 139-144.

Dove H, McLennan SR, Poppi DP (2010) Application of nutrient requirement schemes to grazing animals. In 'Proceedings of the 4th grazing livestock nutrition conference'. (Eds BW Hess, T DelCurto, JGP Bowman, RC Waterman) pp. 133-149. (Western Section of American Society of Animal Science: Champaign, Illinois)

Ferris A, Malcolm B (1999) Sense and nonsense in dairy farm management economic analysis. In 'Proceedings of the 43rd annual conference of Australian Agricultural and Resource Economics Society (AARES)', 20-22 January 1999, Christchurch, New Zealand. pp. 1-66. Available at https://ageconsearch.umn.edu/record/123803?ln=en [Verified 23 February 2023]

Foran BD, Stafford Smith DM, Niethe G, Stockwell T, Michell V (1990) A comparison of development options on a Northern Australian Beef property. *Agricultural Systems* **34**, 77-102.

Fordyce G, Cooper NJ, Kendall IE, O'Leary BM (1996) Improving conception rates through nutrition in 2-year-old Brahman cross heifers in the dry tropics. In 'Proceedings of reproduction in tropical cattle, satellite meeting of the 13th international congress on animal reproduction 1996'. Free Communication 8. (Tropical Beef Centre: Rockhampton, Qld, Australia)

Fordyce G, Coates R, Debney M, Haselton S, Rebgetz R, Laing AR., Cooper NJ., Hall R, Holmes WE, Doogan VJ (2009) A systems evaluation of high-input management using fortified molasses for beef production in Australia's dry tropics.*Animal Production Science* **49**, 177-191.

Fordyce G, Fitzpatrick L A, Mullins T J, Cooper NJ, Reid D J, Entwistle K W (1997) Prepartum supplementation effects on growth and fertility in Bos indicus-cross cows.*Australian Journal of Experimental Agriculture* **37**, 141-149.

Fordyce G, McCosker KD, Barnes TS, Perkins NR, O'Rourke PK, McGowan MR (2022) Reproductive performance of northern Australia beef herds. 6. Risk factors associated with reproductive losses between confirmed pregnancy and weaning. *Animal Production Science* (Online early, AN19441)

Fordyce G, Smith DR, McGowan MR, McCosker KD (2022). "Live weight accounting for beef cow management." Livestock Science **262**: 104960.

FutureBeef (2011a) ‘Age of turnoff economics – a critical issue for profitability northern Australia’. (Queensland Government: Brisbane). Available at https://futurebeef.com.au/knowledge-centre/age-of-turnoff-economics/ [Verified 4 November 2022]

FutureBeef (2011b) 'Heifer management'. (FutureBeef: Brisbane). Available at https://futurebeef.com.au/resources/heifer-management/ [Verified 31 October 2022]

Gillard P, Winter WH (1984) Animal production from *Stylosanthes* based pastures in Australia. In ‘The Biology and Agronomy of Stylosanthes.’ (eds Stace HM, Edye LA) pp. 405-432. (Academic Press: Australia)

Hall TJ, Jones P, Silcock RG, Filet PG (2017) Grazing pressure impacts on two *Aristida/Bothriochloa* native pasture communities of central Queensland. *The Rangeland Journal* **39**, 227-243.

Hasker PJS (2000) ‘Beef cattle performance in northern Australia: a summary of recent research'. (The State of Queensland, Department of Primary Industries: Brisbane)

Hassett R (2022) 'Land condition assessment tool. Data analysis – March 2020 to March 2022'. (The State of Queensland, Department of Agriculture and Fisheries: Brisbane)

Hinton AW (1993) ’Economics of beef production in the Dalrymple Shire. Department of Primary Industries Project Report QO93005.’ (State of Queensland, Department of Primary Industries: Brisbane, Qld, Australia)

Hinton AW (1995) ‘Land condition and profit. A study of Dalrymple Shire properties.’ (State of Queensland, Department of Primary Industries: Brisbane, Qld, Australia)

Holmes WE (1990) Phosphorus and beef production in northern Australia. 11. A case study approach to the assessment of phosphorus supplementation. *Tropical Grasslands* **24**, 250-255.

Holmes WE, Chudleigh F and Simpson G (2017) ‘Breedcow and Dynama herd budgeting software package. A manual of budgeting procedures for extensive beef herds. Version 6.02.’ (Department of Agriculture and Fisheries, Queensland: Brisbane, Qld). Available at https://breedcowdynama.com.au/ [Verified 23 March 2022]

Holroyd RG, Allan PJ, O’Rourke PK (1977) Influence of pasture type and supplementary feeding on the reproductive performance of cattle in the dry tropics of north Queensland. *Australian Journal of Experimental Agriculture and Animal Husbandry* **17**, 197-206.

Holroyd RG, O’Rourke PK, Allan PJ (1979) Effect of pasture type and supplementary feeding on the milk yield of Shorthorn and Brahman cross cows and the growth rate of their progeny in the dry tropics of north Queensland. *Australian Journal of Experimental Agriculture and Animal Husbandry* **19**, 389-394.

Holroyd RG, O’Rourke PK, Clarke MR, Loxton ID (1983) Influence of pasture type and supplement on fertility and liveweight of cows, and progeny growth rate in the dry tropics of northern Queensland. *Australian Journal of Experimental Agriculture and Animal Husbandry* **23**, 4-13.

Holroyd RG, Mason GWJ, Loxton ID, Knights PT, O’Rourke PK (1988) Effects of weaning and supplementation on performance of Brahman cross cows and their progeny. *Australian Journal of Experimental Agriculture* **28**, 11-20.

Hunt LP (2008) Safe pasture utilisation rates as a grazing management tool in extensively grazed tropical savannahs of northern Australia. *The Rangeland Journal* **30**, 305-315.

Hunt LP, McIvor JG, Grice AC, Bray SG (2014) Principles and guidelines for managing cattle grazing in the grazing lands of northern Australia: stocking rates, pasture resting, prescribed fire, paddock size and water points – a review. *The Rangeland Journal* **36**, 105-119.

Hunt LP, Petty S, Cowley R, Fisher A, White A, MacDonald N, Pryor M, Ash A, McCosker K, McIvor J, MacLeod N (2013) Sustainable development of Victoria River District (VRD) grazing lands. Project B.NBP.0375 final report. Meat and Livestock Australia, Sydney.

Jackson D, Rolfe J, English B, Holmes B, Matthews R, Dixon, R, Smith P, MacDonald N (2012) 'Phosphorus management of beef cattle in northern Australia.' (Ed. I Partridge) (Meat and Livestock Australia Limited: North Sydney)

Jackson T, Malcolm B (2018) Using returns, risks and learning to understand innovation adoption. *Australasian Agribusiness Review* **26**, 32-47.

Johnston D, Grant T, Prayaga K, Walkley J (2013) Early predictors of lifetime female reproductive performance. Project B.NBP.0363 final report. Meat and Livestock Australia, Sydney.

Johnston DJ, Barwick SA, Corbet NJ, Fordyce G, Holroyd RG, Williams PM, Burrow HM (2009) Genetics of heifer puberty in two tropical beef genotypes in northern Australia and associations with heifer- and steer-production traits. *Animal Production Science* **49**, 399-412.

Johnston PW, McKeon GM, Day KA (1996) Objective 'safe' grazing capacities for southwest Queensland, Australia: development of a model for individual properties. *The Rangeland Journal* **18**, 244-258.

Jones P, Silcock R, Scanlan JH, Moravek T (2016) Spelling strategies for recovery of pasture condition. Project B.NBP.0555 final report. Meat and Livestock Australia, Sydney.

Jones RJ and Sandland RL (1974) The relation between animal gain and stocking rate: derivation of the relation from the result of grazing trials. *Journal of Agricultural Science* **83**, 335-342.

Kerridge PC, Gilbert MA, Coates DB (1990) Phosphorus and beef production in northern Australia 8. The status and management of soil phosphorus in relation to beef production. *Tropical Grasslands* **24**, 221-230.

LongPaddock (2022) 'Drought declarations archive.' (The State of Queensland 1995-2022, Queensland Government: Brisbane, Qld, Australia) Available at https://www.longpaddock.qld.gov.au/drought/archive/ [Verified 8 September 2022]

MacLeod ND, Johnston BG (1990) An economic framework for evaluation of rangeland restoration projects. *The Australian Rangeland Journal* **12**, 40-53.

MacLeod ND, McIntyre S (1997) Stocking rate impacts on the production and economic performance of steers grazing black speargrass pastures. *The Rangeland Journal* **19**, 174-189.

MacLeod ND, Ash AJ, McIvor JG (2004) An economic assessment of the impact of grazing land condition on livestock performance in tropical woodlands. *The Rangeland Journal* **26**, 49-71.

MacLeod ND, Brown JR, Noble JC (1993) Ecological and economic considerations for the management of shrub encroachment in Australian Rangelands. Proceedings of the 10th Australian and 14th Asian-Pacific Weed Science Society Conference Volume 2, Brisbane. pp. 118-121.

MacLeod ND, Nelson, BS, McIvor JG, Corfield JP (2009) Wet season resting – economic insights from scenario modelling. *The Rangeland Journal* **31**, 143-150.

Malcolm B (2000) Farm management economic analysis: a few disciplines, a few perspectives, a few figurings, a few futures. In ‘Proceedings of the Annual Conference of Australian Agricultural and Resource Economics Society’. (Australian Agricultural and Resource Economics Society: Sydney). Available at https://ageconsearch.umn.edu/bitstream/171920/2/malcolm.pdf [Verified 16 February 2021]

Malcolm B, Makeham J, Wright V (2005) ‘The Farming Game, Agricultural Management and Marketing’. (Cambridge University Press: Cambridge, Melbourne)

Mayer D (2013) Improved empirical models of cattle growth, reproduction and mortality from native pastures in northern Australia. Project B.NBP.0641 final report. Meat and Livestock Australia, Sydney.

Mayer DG, McKeon GM, Moore AD (2012) Prediction of mortality and conception rates of beef breeding cattle in northern Australia. *Animal Production Science* **52**, 329-337.

McCartney F (2017) ‘Factors limiting decision making for improved drought preparedness and management in Queensland grazing enterprises: rural specialists’ perspectives and suggestions.’ (The State of Queensland, Department of Science, Information Technology and Innovation: Brisbane) Available at https://www.longpaddock.qld.gov.au/dcap/grazing-industry/ [Verified 16 February 2021]

McCosker KD, Fordyce G, O'Rourke PK, McGowan MR (2022) Reproductive performance of northern Australia beef herds. 2. Descriptive analysis of monitored reproductive performance (Online early, AN17495)

McCosker T, Winks L (1994) ‘Phosphorus nutrition of beef cattle in northern Australia.’ (Department of Primary Industries: Brisbane, Qld, Australia)

McCullough M, Musso B (Eds) (2004) ‘Healthy Rangelands. Principles for sustainable systems. Focus on Australia’s Burdekin rangelands.’ (Tropical Savannas Cooperative Research Centre: Darwin)

McGowan M, McCosker K, Fordyce G, Smith D, O’Rourke P, Perkins N, Barnes T, Marquart L, Morton J, Newsome T, Menzies D, Burns B, Jephcott S (2014) Northern Australian beef fertility project: CashCow. Project B.NBP.0382 final report. Meat and Livestock Australia, Sydney.

McIvor JG (2005) Australian grasslands. In ‘Grasslands of the world.’ (Eds JM Suttie, SG Reynolds, C Batello) pp. 343-374. (Food and Agriculture Organization on the United Nations: Rome)

McIvor J (2012) ‘Sustainable management of the Burdekin grazing lands. A technical guide of options for stocking rate management, pasture spelling, infrastructure development and prescribed burning to optimise animal production, profitability, land condition and water quality outcomes.’ (State of Queensland, Department of Agriculture, Fisheries and Forestry: Brisbane)

McIvor JG, Scanlan JC (1994) State and transition models for rangelands. 8. A state and transition model for the northern speargrass zone. *Tropical Grasslands* **28**, 256-259.

McIvor JG, Ash AJ, Cook GD (1995) Land condition in the tropical tallgrass pasture lands. 1. Effects on herbage production. *The Rangeland Journal* **17**, 69-85.

McKeon GM, Ash AJ, Hall WB, Stafford Smith M (2000) Simulation of grazing strategies for beef production in north-east Queensland. In: ‘Applications of seasonal climate forecasting in

Agricultural and natural ecosystems – The Australian experience.' (Eds GL Hammer, N Nicholls, C Mitchell) pp. 227-252. (Springer Dordrecht: The Netherlands)

McKeon GM, Hall WB, Henry BK, Stone GS, Watson IW (2004) 'Pasture degradation and recovery in Australia's rangelands: Learning from history.' (The State of Queensland, Department of Natural Resources, Mines and Energy: Brisbane, Qld)

McLennan SR (2014) Optimising growth paths of beef cattle in northern Australia for increased profitability. Project B.NBP.0391 final report. Meat and Livestock Australia, Sydney.

McLennan SR, Poppi D (2005) Improved prediction of the performance of cattle in the tropics. Project NBP.331 final report. Meat and Livestock Australia, Sydney, NSW, Australia.

McLennan SR, Poppi DP (2019) 'QuikIntake version 6 spreadsheet calculator.' (Department of Agriculture and Fisheries, Queensland: Brisbane, Qld)

McLennan SR, McLean I, Paton C (2020) Re-defining the animal equivalence (AE) for grazing ruminants and its application for determining forage intake, with particular relevance to the northern Australian grazing industries. Project B.GBP.0036 final report. Meat and Livestock Australia, Sydney.

McLennan SR, Hendricksen RE, Beale IF, Winks L, Miller CP, Quirk MF (1988) Nutritive value of native pastures in Queensland. In 'Native pastures in Queensland: their resources and management pp. 125-160. (Department of Primary Industries in Queensland, Brisbane)

Miller CP, Stockwell TGH (1991) Sustaining productive pastures in the tropics. 4. Augmenting native pasture with legumes. *Tropical Grasslands* **25**, 98-103.

Miller CP, Webb CD, Rankine RJ (1982) Performance of perennial stylo pastures on a high phosphorus soil in the dry tropics. *Proceedings of the Australian Society of Animal Production* **14**, 373-376.

Moravek T, Hall TJ (2014) Impacts of rehabilitating degraded lands on soil health, pastures, runoff, erosion, nutrient and sediment movement. Part III: Economic analysis of rehabilitation techniques in the Burdekin River catchment to improve water quality flowing from grazing lands onto the Great Barrier Reef. RRRD.024 Final Report for the Australian Government's Caring for Our Country Reef Rescue Water Quality Research and Development Program. (State of Queensland, Department of Agriculture, Fisheries and Forestry: Brisbane)

Moravek T, Schrobback P, East M, Star M, Rust S (2017) 'Understanding the economics of grazing management practices and systems for improving water quality run-off from grazing lands in the Burdekin and Fitzroy Catchments. Reef Plan Action 4: gap analysis report.' (The State of Queensland, Department of Agriculture and Fisheries, Queensland: Brisbane)

NQ Dry Tropics (2022) 'Basins, catchments and sub-catchments of the BDT.' (NQ Dry Tropics: Townsville) Available at https://nrm.nqdrytropics.com.au/water/subcatchments/ [Verified 21 March 2022]

NRDR (2007) 'Nutrient requirements of domesticated ruminants.' (CSIRO Publishing: Melbourne)

O'Reagain PJ, Bushell JJ (2011) 'The Wambiana grazing trial. Key learnings for sustainable and profitable management in a variable environment.' (The State of Queensland, Department of Employment, Economic Development and Innovation: Brisbane, Qld)

O'Reagain PO, Bushell J, Holmes B (2011) Managing for rainfall variability: long-term profitability of different grazing strategies in a northern Australian tropical savanna. *Animal Production Science* **51**, 210-224.

O'Reagain P, Bushell JJ, Holloway CH, Reid A (2009) Managing for rainfall variability: effect of grazing strategy on cattle production in a dry tropical savanna. *Animal Production Science* **49**, 1-15.

O'Reagain P, Bushell J, Pahl L, Scanlan J (2018) Wambiana grazing trial phase 3: stocking strategies for improving carrying capacity, land condition and biodiversity outcomes. Project B.ERM.0107 final report. Meat and Livestock Australia, Sydney.

O'Reagain P, Scanlan J, Hunt L, Cowley R, Walsh D (2014) Sustainable grazing management for temporal and spatial variability in north Australian rangelands – a synthesis of the latest evidence and recommendations. *The Rangeland Journal* **36**, 233-232.

O'Reagain P, Bushell J, Jones P, Smith D, Pringle M, Owens J, Anderson A (2022) Wambiana: grazing strategies and tools to improve profitability and land condition. Project B.ERM.0108 DRAFT final report. Meat and Livestock Australia, Sydney.

Orr DM, Burrows WH, Hendricksen RE, Clem RL, Back PV, Rutherford MT, Myles DJ, Conway MJ (2010) Impacts of grazing management options on pasture and animal productivity in a *Heteropogon contortus* (black speargrass) pasture in central Queensland. 1. Pasture yield and composition. *Crop and Pasture Science* **61**, 170-181.

Orr DM, O'Reagain P (2011) Managing for rainfall variability: impacts of grazing strategies on perennial grass dynamics in a dry tropical savanna. *The Rangeland Journal* **33**, 209-220.

Orr DM, Phelps DG (2013) Impacts of utilisation by grazing on an *Astrebla* (Mitchel grass) grassland in north-western Queensland between 1984 and 2010. 1. Herbage mass and population dynamics of *Astrebla* spp. *The Rangeland Journal* **35**, 1-15.

Partridge I, Middleton C, Shaw K (1996) 'Stylos for better beef.' (The State of Queensland, Department of Primary Industries: Brisbane)

Passmore G, Brown C (1991) Analysis of rangeland degradation using stochastic dynamic programming. *The Australian Journal of Agricultural Economics* **35**, 131-157.

Paxton G (2019) 'Towards greater drought preparedness in Queensland grazing: Lessons from qualitative interviews and discourse analysis.' (The State of Queensland, Department of Environment and Science: Brisbane) Available at https://www.longpaddock.qld.gov.au/dcap/grazing-industry/ [Verified 16 February 2021]

Peck G, Chudleigh F, Guppy, C, Johnson B, Lawrence D (2015) Use of phosphorus fertiliser for increased productivity of legume-based sown pastures in the Brigalow Belt region – a review. Project B.NBP.0769 final report. Meat and Livestock Australia, Sydney.

Poppi D, Silva T, Quigley S, Kidd L, Anderson S, McCosker K, Mohr-Bell R, Schatz T (2018) Target dry season weight gains for weaner heifers. Project B.GBP.0005 final report. Meat and Livestock Australia, Sydney, NSW, Australia.

QLUMP (Queensland Land Use Mapping Program) (2022) Datasets – Land use mapping – 1999 to Current – Queensland. Available at https://www.qld.gov.au/environment/land/vegetation/mapping/qlump [Verified 17 March 2022]

Queensland Government (2022) Climate change in Queensland. Available at http://qgsp.maps.arcgis.com/apps/MapJournal/index.html?appid=1f3c05235c6a44dcb1a6faebad4683fc [Verified 17 March 2022]

Quirk M, McIvor J (2003) 'Grazing Land Management: Technical Manual.' (Meat and Livestock Australia: North Sydney)

Rickert KG, Stuth JW, McKeon GM (2000) Modelling pasture and animal production. In 'Field and laboratory methods for grassland and animal production research'. (Eds L 't Mannetje, RM Jones) pp. 29-66. (CABI Publishing: New York, NY USA)

Ridley PER, Schatz TR (2006) Meeting post weaning market specifications for the live cattle export trade to South East Asia. Project NAP 3.111 final report. Meat and Livestock Australia, Sydney.

Rogers LG, Cannon MG, Barry EV (1999) 'Land resources of the Dalrymple Shire. Volume 1.' (Department of Natural Resources, Queensland: Brisbane)

Rolfe JW, Larard AE, English BH, Hegarty ES, McGrath TB, Gobius NR, De Faveri J, Srhoj JR, Digby MJ, Musgrove RJ (2016) Rangeland profitability in the northern Gulf region of Queensland: understanding beef business complexity and the subsequent impact on land resource management and environmental outcomes. *The Rangeland Journal* **38**, 261-272.

Round PJ (1978) 'Beef cattle production in the Burdekin-Dalrymple region. Technical Bulletin No. 14, Beef Cattle Husbandry Branch.' (State of Queensland, Department of Primary Industries, Queensland: Brisbane, Qld, Australia)

Rudder TH, Seifert GW, Burrow HM (1985) Environmental and genotype effects on fertility in a commercial beef herd in central Queensland. *Australian Journal of Experimental Agriculture and Animal Husbandry* **25**,489-496.

SCA (Standing Committee on Agriculture) (1990) 'Feeding standards for Australian livestock. Ruminants.' (CSIRO Publications, Melbourne, VIC, Australia)

Scanlan JC, MacLeod ND, O'Reagain PJ (2013) Scaling results up form a plot and paddock scale to a property – a case study from a long-term grazing experiment in northern Australia. *The Rangeland Journal* **35**, 193-200.

Scanlan JC, Whish GL, Pahl LI, Cowley RA, MacLeod ND (2011) Assessing the impact of pasture resting on pasture condition in the extensive grazing lands of northern Australia. In: 'MODSIM2011, 19th International Congress on Modelling and Simulation'. (Eds F Chan, D Marinova, RS Anderssen) pp. 877-883. (Modelling and Simulation Society of Australia and New Zealand: Canberra, ACT)

Schatz T (2010) Understanding and improving heifer fertility in the Northern Territory. Project NBP.339 final report. Meat and Livestock Australia, Sydney.

Schatz T (2012) 'Heifer management in northern beef herds. 2nd Edition'. (Ed. I Partridge) (Meat and Livestock Australia Limited: North Sydney)

Schatz TJ (2014) Pre-partum supplementation increases first-lactation heifer re-conception rates in the Victoria River District, NT. *Animal Production Science* **55**, 180-184.

Schatz TJ, Hearnden MN (2017) The effect of weight and age on pregnancy rates in Brahman heifers in northern Australia. *Animal Production Science* **57**, 2091-1095.

Shaw KA, Rolfe JW, English BH, Kernot JC (2007) A contemporary assessment of land condition in the Northern Gulf region of Queensland. *Tropical Grasslands* **41**, 245-252.

Silcock RG, Jones P, Hall TJ, Waters DK (2005) 'Enhancing pasture stability and profitability for producers in Poplar Box and Silver-leaved Ironbark woodlands.' Project NAP3.208 Final Report. (Meat and Livestock Australia: North Sydney)

Silva TACC, Quigley SP, Kidd LJ, Anderson ST, McLennan SR, Schatz TJ, McCosker KD, Poppi DP (2022) Growth and reproductive performance responses to post-weaning supplementation of early and normally-weaned Brahman crossbred heifers raised in tropical rangelands. *PLoS One* **17**, e0263786.

Smith D (2000) Northern Stocking Rate Demonstration. Promis 1480. Project NHT 962011 final report for the Natural Heritage Trust. (State of Queensland, Department of Primary Industries, Queensland: Brisbane, Qld, Australia)

Stafford Smith DM, Foran BD (1988) Strategic decisions in pastoral management. *Australian Rangelands Journal* **10**, 82-95.

Stafford Smith DM, Buxton R, McKeon G, Ash A (2000). Seasonal climate forecasting and the management of rangelands: do production benefits translate into enterprise profits? In: 'Applications of seasonal climate forecasting in Agricultural and natural ecosystems – The Australian experience.' (Eds GL Hammer, N Nicholls, C Mitchell) pp. 271-289. (Springer Dordrecht: The Netherlands)

Stobbs TH (1975) Factors limiting the nutritional value of grazed tropical pasture for both beef and milk production. *Tropical Grasslands* **9**, 141-150.

Teague WR, Kreuter UP, Grant WE, Diaz-Solis H, Kothmann MM (2009) Economic implications of maintaining rangeland ecosystem health in semi-arid savannah. *Ecological Economics* **68**, 1417-1429.

The State of Queensland (2021) 'Burdekin, Herbert, Wet Tropics, Tablelands, Fitzroy, Burnett, Southeast, Darling Downs and Balonne-Maranoa. Bicarbonate-extractable phosphorus. (Soil and Land Resources, Queensland Department of Environment and Science: Brisbane Qld, Australia) Available at CM269_gda2020.ai (publications.qld.gov.au) [Verified 30 November 2020]

The State of Queensland (2022a) 'Land types of Queensland. Version 4.0. (Queensland Department of Agriculture and Fisheries: Brisbane, Qld, Australia). Available at https://futurebeef.com.au/knowledge-centre/land-types-of-queensland/ [Verified 4 November 2022]

The State of Queensland (2022b) 'Queensland drought duration report.' (Queensland Government: Brisbane).

The State of Queensland (Department of Environment and Science), (2011-2022a) 'Reef 2050 Water Quality Improvement Plan. Burdekin region – Burdekin catchment water quality targets.' (Queensland Government: Brisbane). Available at https://www.reefplan.qld.gov.au/__data/assets/pdf_file/0015/46032/catchment0targets0burdekin0burdekin.pdf [Verified 22 March 2022]

The State of Queensland (Department of Environment and Science), (2011-2022b) 'Reef 2050 Water Quality Improvement Plan.' (Queensland Government: Brisbane). Available at https://www.reefplan.qld.gov.au/land0use/grazing [Verified 22 March 2022]

Tothill JC, Gillies C (1992) 'The pasture lands of northern Australia. Their condition, productivity, and sustainability. Report prepared for the Meat Research Corporation. Tropical Grassland Society of Australia Occasional Publication No. 5.' (Tropical Grassland Society of Australia Inc: Brisbane)

Wadsworth JC, McLean RW, Coates DB, Winter WH (1990) Phosphorus and beef production in northern Australia. 5. Animal phosphorus status and diagnosis. *Tropical Grasslands* **24**, 185-196.

Winks L (1990) Phosphorus and beef production in northern Australia. 2. Responses to phosphorus by ruminants: a review. *Tropical Grasslands* **24**, 140-158.

7 Glossary of terms and abbreviations

<table>
<tr><th>Abbreviations</th><th>Glossary of terms</th></tr>
<tr><td>AE</td><td>
Adult equivalent. An AE is a standard animal unit used to describe and quantify grazing pressure imposed on pasture by foraging ruminants. An AE rating is applied to grazing ruminants which approximates their grazing pressure relative to a standard animal. A wide range of AE approaches, and definitions of a standard animal, are in use across Australia and internationally.
The most commonly applied AE systems in northern Australia for grazing cattle include:

Linear weight AE where the liveweight of cattle classes are expressed relative to a standard animal, animal, often a 450 kg or a 455 kg (1,000 lbs) liveweight steer at maintenance,
Metabolic weight AE where the metabolic liveweight (liveweight to the power 0.75) of cattle classes are expressed relative to the metabolic weight of a standard animal, being a 450 kg liveweight steer at maintenance.
Metabolisable energy (ME) requirement AE where the ME requirement of cattle classes are expressed relative to the ME requirement of a standard animal. The standard animal is defined as a 2.25 year-old, 450 kg liveweight Bos taurus steer at maintenance, walking 7 km/day and consuming a diet of 55% dry matter digestibility (DMD; 7.75 MJ/kg DM) and therefore requiring 64.3 MJ/day and consuming 7.9 kg DM/day for cattle on tropical diets (72.6 MJ/day and 9.4 kg DM/day for temperate pastures); McLennan et al. (2020).

<u>Burdekin Rangelands analysis</u>
In the <u>Breedcow and Dynama (BCD) software</u> an AE was taken as a non-pregnant, non-lactating beast of average weight 455 kg (1,000 lbs) carried for 12 months (i.e., a linear weight AE, not adjusted for metabolic weight or metabolisable energy intake estimates). An additional allowance of 0.35 AE was made for each breeder that reared a calf. This rating was placed on the calves themselves, effectively from conception to age 5 months, while their mothers were rated entirely on weight. Analyses (including in this report) have repeatedly demonstrated that the profitability ranking of alternative management strategies, including the optimal age of steer turnoff, is the same regardless of which of the three AE systems, above, are applied within BCD. We have again tested and confirmed that this is the case, in this analysis for the Burdekin Rangelands representative herd. Therefore, for simplicity of operation, the linear weight AE has been retained in the BCD model in the current analysis.
</td></tr>
</table>

Abbreviations	Glossary of terms
	When calculating the equivalent grazing pressure and applied stocking rates on sown forages (i.e. stylo or stylo-grass pastures in this analysis), the **ME requirement AE** was applied. The spreadsheet calculator QuikIntake Version 6 (McLennan and Poppi 2019) was used to calculate daily cattle dry matter intakes (and AE rating) for (1) the specified average dry matter digestibility of each forage type and the (2) breed and (3) class of cattle grazing the pastures along with (4) their expected liveweight gain.
Amortise	An amortised value is the annuity (series of equal payments) over the next *n* years equal to the present value at the chosen relevant compound interest rate.
Break-even	The break-even point is the point at which total cost (including opportunity cost) and total revenue are equal. At the break-even point there is neither profit nor loss.
BCD	Breedcow and Dynama software. A herd budgeting program designed to evaluate the profitability and financial risk of alternative management strategies for extensive beef businesses, at the property level (Holmes *et al.* 2017). This software can be downloaded free from https://breedcowdynama.com.au/. In the analyses documented in other regional reports in this series, herd models and analyses were compiled in a modified version of the Breedcow and Dynama suite of programs to allow comparison of beef, goat and sheep enterprises. Please contact the authors if you would like a copy of any of these files.
BCR	Body condition ratio. A BCR is the ratio of liveweight to the expected liveweight for age of animals at average condition ('N').
BCS	Body condition score. A visual assessment of cow BCS (scale 0-9) is used to rate her body fat reserves or 'condition'.
Cash asset	The cash asset for a livestock business is the cash surplus or deficit (liability) generated on an annual basis by the herd/flock.
Climate normal	Climate statistics calculated over standard periods of 30 years are called 'climate normals' and are used as reference values for comparative purposes. A 30-year period is considered long enough to include the majority of typical year-to-year variation in the climate but not so long that it is significantly influenced by longer-term climate changes. In Australia, the current reference climate normal is generated over the 30-year period 1 January 1961 to 31 December 1990.
Constant (real) dollar terms	All variables are expressed in terms of the price level of a single given year.
CP	Crude protein. Calculated as the total N content in a feed source x 6.25 as the agreed convention in the practical feeding of ruminants in Australia and overseas. The factor of 6.25 is based on the assumption of 16% N in

Abbreviations	Glossary of terms
	proteins which is a generalisation that ranks the N in amides, nucleic acids and other compounds equally with the N in amino acids. Non-protein N has nutritional value for ruminants because it is incorporated in the microbial protein synthesised during ruminal fermentation, which in turn forms an important part of their protein supply. Non-protein N sources account for about 0.2 of the N in fresh herbage (on average).
Cumulative cash flow	Cumulative cash flow is the predicted final bank balance of the property at the end of the investment period due to the implementation of the strategy.
Current (nominal) dollar terms	All variables are expressed in terms of the year in which the costs or income occur. The impact of expected inflation is explicitly reflected in the cash flow projections.
DAF	Department of Agriculture and Fisheries, Queensland Government
DCF	Discounted cash flow. This technique is a way of allowing that when money is invested in one use, the chance of spending that money in another use is gone. Discounting means deducting from a project's expected earnings the amount which the investment funds could earn in its most profitable alternative use. Discounting the value of money to be received or spent in the future is a way of adjusting the future net rewards from the investment back to what they would be worth in the hand today.
Depreciation (as applied in estimating operating profit)	A form of overhead cost that allows for the use (fall in value) of assets that have a life of more than one production period. It is an allowance that is deducted from gross revenue each year so that all of the costs of producing an output in that year are set against all of the revenues produced in that year. Depreciation of assets is estimated by valuing them at either current market value or expected replacement value, identifying their salvage value in constant dollar terms and then dividing by the number of years until replacement. The formula used in this analysis is: (replacement cost – salvage value)/number of years until replacement.
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 (NPV). Note that discounting is not carried out to account for inflation. Discounting would still be applicable in periods of nil inflation.
Discount rate	The interest rate used to determine the present value of a future value by discounting. This helps determine if the future cash flows from a project or investment will be worth more than the capital outlay needed to fund the project or investment in the present.

Abbreviations	Glossary of terms
DM	Dry matter. DM is determined by oven drying feed or faecal material in an oven until constant weight is reached (i.e., all moisture is removed).
DMD	Dry matter digestibility. The proportion of feed an animal digests in the stomachs. DMD is calculated as the intake of DM minus the amount of DM in the corresponding faeces, expressed as a proportion of the intake (or as a percentage).
DMI	Dry matter intake. The intake of feed by an animal, expressed on a dry weight basis.
DSE	Dry sheep equivalent. This standard ovine unit represents a 2 year-old, 45 kg Merino sheep (wether, or non-lactating, non-pregnant ewe) at maintenance. In the Breedewe and Sheepdyn programs a linear DSE is calculated, i.e., not adjusted for metabolic weight. In analyses for other regions, to estimate grazing pressure equivalence between cattle, sheep and goats, we adopted the approach of McLennan *et al.* (2020) where the energy requirements of a standard animal unit (defined AE or DSE) are assumed to represent equivalent grazing pressure. A ratio of DSE : AE of 8.4 : 1 was adopted.
Economic analysis	Economic analysis usually focusses on profit as the true measure of economic performance or how efficiently resources are applied. The calculation of profit includes non-cash items like opportunity costs, unpaid labour, depreciation and change in the value of livestock or crop inventory. NPV and amortised NPV are both measures of profit.
Equity capital	The value of the owner's capital. This is equal to total capital minus total liabilities.
Financial analysis	Financial analysis focusses on cash flow and the determination of whether all business and family cash costs can be met. Financial analysis can also include analysis of debt servicing capacity.
Fixed (or overhead) costs	Defined as costs which are not affected by the scale of the activities in the farm business. They must be met in the operation of the farm. Examples include: wages and employee on-costs, repairs, insurance, shire rates and land taxes, depreciation of plant and improvements, consultants fees and the operators allowance for labour and management. Some fixed costs (such as depreciation or operator's allowance) are not cash costs. It is usual to count the smaller amounts of interest on a typical overdraft or short-term working capital as an operating expense (fixed cost) and deducted in the calculation of operating profit. The returns to lenders of fixed capital (interest, rent, lease payments) are deducted in the calculation of net profit.
FORM	The annual fuel, oil, repairs and maintenance allowance for the property.

Abbreviations	Glossary of terms
Gross margin	The gross income received from an activity less the variable costs incurred. Gross margins are only the first step in determining the effect of a management decision on farm or business profitability. To determine the value of a potential strategy to the ‘whole farm’ or business, a more complete economic analysis is required in the form of a marginal analysis that considers the effect of alternative strategies at the property or business level.
IRR	Internal rate of return. This is 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, i.e., the break-even discount rate. This indicates the maximum interest that a project can pay for the resources used if the project is to recover its investment expenses and still just break even. *IRR can be expressed as either* ***the return on the total investment*** *or* ***the return on the extra capital****.*
M8U	Molasses mixture containing 8% urea by weight.
Marginal	Extra or added. Principle of marginality emphasises the importance of evaluating the changes for extra effects, not the average level of performance.
ME	Metabolisable energy. The energy from a feed source remaining for use by a ruminant after losses in faeces, urine and methane gas are subtracted.
MLA	Meat and Livestock Australia. MLA delivers research, development and marketing services to Australia’s cattle, sheep and goat producers. MLA is funded by industry levies.
N	Nitrogen
n/a	Not applicable
n/c	Not able to be calculated
Net profit	This is the reward to the farmers own capital. Net Profit equals Operating profit less the returns to outside capital. The returns to lenders of fixed capital (interest, rent, leases) are deducted from Operating Profit in the calculation of Net Profit. It is available to the owner of the business to pay taxes or to provide living expenses (consumption) or it can be used to reduce debt. Net profit minus income tax minus personal consumption (above operators allowance if it has already been deducted from operating profit) = change in equity.
NLIS	National livestock identification system. Australia’s tagging system for identification and traceability of cattle, sheep and goats.
Non-cash asset	The total of land, plant, equipment and livestock capital. In the Dynama spreadsheet (within the Breedcow and Dynama (BCD) software package) livestock capital is adjusted on an annual basis for inventory change and

Abbreviations	Glossary of terms
	land capital is the average of opening and closing value. The calculation of non-cash assets in Dynama does not include the accumulation of cash surplus or deficit over time.
NPV	Net present value. Refers to the net returns (income minus costs) over the life of an investment, expressed in present day terms. A discounted cash-flow allows future cash-flows (costs and income) to be discounted back to an NPV so that investments over varying time periods can be compared. The investment with the highest NPV is usually preferred. NPV was calculated at a 5% rate of return which was taken as the real opportunity cost of funds to the producer. Annualised NPV converts the Marginal NPV to an amortised, annual value. *The **annualised NPV** can be considered as an approximation of the **average annual change in profit over 30 years**, resulting from the management strategy.*
NQ	North Queensland
NRM region	Natural Resource Management region. NRM regions across Australia are based on catchments or bioregions. The boundaries of NRM regions are managed by the Australian Government and used for statistical reporting and allocation and reporting of environmental investment programs.
Operator's allowance	An allowance for the owners labour and management; it can be estimated by reference to what professional farm managers/overseers are paid. Although it is often not paid in the farm accounts, it is an input required to generate the operating profit and must be deducted if a true estimate of operating profit and the return to the total capital in the business/property is to be calculated. It is generally not equal to the irregular wages paid to or drawings made by the owners. If some wages have been paid to the owners in the farm accounts and they are already included in the calculation of fixed costs, then the only difference between the wages paid and the true opportunity cost of their labour and management will need to be allowed for when calculating operating profit.
Operating profit	The return to total capital (equivalent to total assets) invested after the variable and overhead (fixed) costs involved in earning the revenue have been deducted. Operating profit represents the reward to all of the owners of the capital tied up in the enterprise. Operating profit equals gross margin (total receipts minus variable costs) minus overheads. When operating profit is expressed as a percentage return to total capital it indicates the efficiency of the use of all of the capital invested in the farm enterprise. In the Dynama spreadsheet (within the Breedcow and Dynama (BCD) software package) the 'return on total non-cash assets' is equivalent to the operating profit. Both calculations are identical and are adjusted for the annual change in livestock inventory and the annual cash surplus or deficit.

Abbreviations	Glossary of terms
Opportunity cost	The benefit foregone by using a scarce resource for one purpose instead of its next best alternative use.
OTH	Over-the-hooks. Where cattle are sold direct to the processing plant (abattoir) and the producer is paid on a price grid. The weight of the processed carcass along with the carcass grade is used to determine price. Over-the-hook indicators reported by Meat and Livestock Australia (MLA) are calculated as a weighted average of northern processor grids. North Queensland is defined by MLA for these indicators as north of, and including Rockhampton.
P	Phosphorus
Payback period	The number of years it takes for the cumulative present value to become positive. Other things being equal, the shorter the payback period, the more appealing the investment.
Peak deficit	This is an estimate of the peak deficit in cash flow caused by the implementation of the management strategy. It assumes interest is paid on the deficit and is compounded for each additional year that the deficit continues into the investment period. It is a rough estimate of the impact of the investment on the overdraft if funds for the development are not borrowed but sourced from the cash flow of the business.
PTE	Pregnancy tested empty (not in calf)
PTIC	Pregnancy tested in calf
Rate of return on total capital	An estimate of how profitable a business is relative to its total capital (or total assets). It is the operating profit expressed as a percentage of the average of the total capital employed for the period under review (usually a year). In the Dynama spreadsheet (within the Breedcow and Dynama (BCD) software) the 'percentage return on total non-cash assets' can be taken as equivalent to the rate of return on total capital but only for steady-state base cattle herds before implementing a change in management.
S	Sulphur
Safe carrying capacity	A safe carrying capacity for a property is defined as a strategic, i.e., long-term (e.g., 20-30 years) estimate of livestock numbers that can be carried without any decrease in pasture condition and without accelerated soil erosion.
Safe stocking rate	A safe stocking rate is a short-term, tactical (seasonal or annual) stocking rate based on seasonal forage budgeting principles and safe utilisation rates of pasture. A safe stocking rate may be higher or lower than the long-term safe carrying capacity due to seasonal variability in rainfall.
SRW	Standard reference weight. The SRW is the liveweight that would be achieved by an animal of specified breed and sex when skeletal

Abbreviations	Glossary of terms
	development is complete and conditions score is in the middle of the range. This is an important parameter in the prediction of the energy, fat and protein content of empty body gain in immature animals.
Variable costs	These costs change according to the size of an activity. The essential characteristic of a variable cost is that it changes proportionately to changes in business size (or to change in components of the business).
Year of peak deficit	The year in which the peak deficit is expected to occur.

8 Acknowledgements

We would like to thank all Department of Agriculture and Fisheries staff, industry partners and producers that provided input into the development of this report.

9 Appendix 1. Breedcow and Dynama software

9.1 Brief description of the Breedcow and Dynama software

The Breedcow and Dynama (BCD) package of software programs is used to assess choices for the management of beef cattle herds run under extensive conditions Holmes *et al.* (2017). **It is not an accounting package or a paddock records package and does not record individual animals**. It presents budgeting processes, adapted to the special needs of extensive beef producers.

Breedcow and Dynama programs are based on four budgeting processes:

1. Comparing the likely profitability of the herd under different management or turnoff systems (Breedcowplus program).
2. Making forward projections of stock numbers, sales, cash flow, net income, debt and net worth (Dynamaplus program).
3. Deciding what to sell when the plan goes sour or what to buy when there is an opportunity. (Bullocks and Cowtrade programs).
4. Evaluating investments in herd or property improvement to determine the rate of return on extra capital, the number of years to breakeven and the peak debt (Investan program).

In short, Breedcowplus is a steady-state herd model that generates its own structure around a starting number of weaner heifers retained and Dynamaplus program is a 10-year herd budgeting program that usually starts with the current herd numbers and structure. The term 'herd budgeting' is used to emphasise the central role of herd dynamics in cattle enterprise budgeting. Figure 14 indicates the relationships between the individual components of the BCD software package. A menu system within Dynamaplus enables data from Breedcowplus to be imported. The flow of data is indicated by the arrows shown in Figure 14.

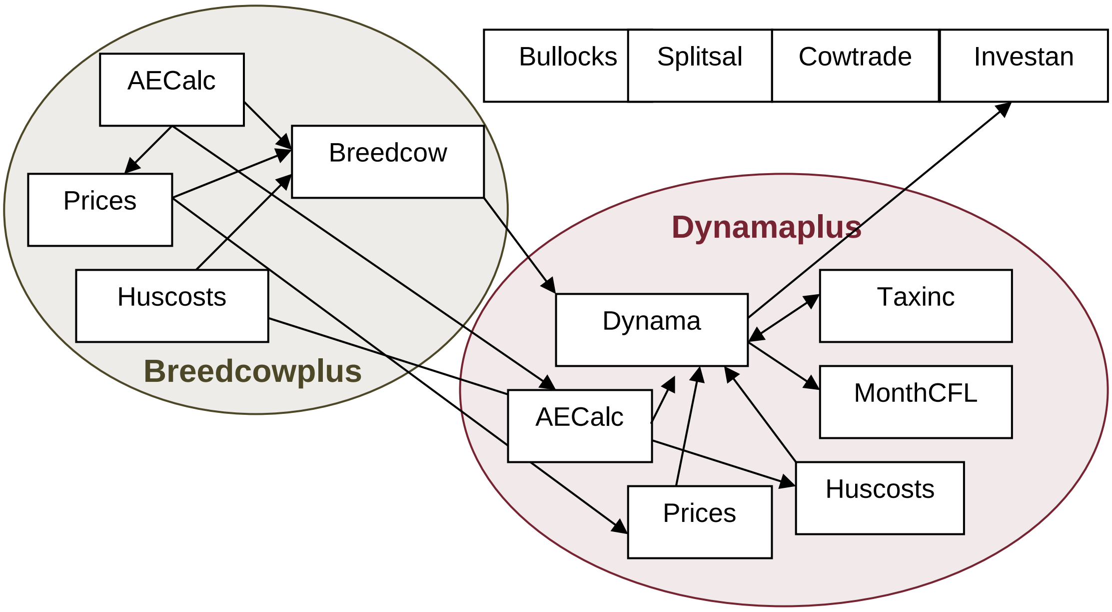

Figure 14 - Relationships within the Breedcow and Dynama software package

9.2 Summary of the components of the Breedcow and Dynama software

The package currently comprises eleven components that make up six separate programs: Breedcowplus, Dynamaplus, Investan, Cowtrade, Bullocks and Splitsal.

9.2.1 Breedcowplus

The Breedcowplus program can quickly determine the best strategies for a beef breeding herd run under extensive conditions. It is a steady-state herd model that generates its own structure around a starting number of weaner heifers retained. The overall herd size is adjusted by altering the starting number of weaner heifers and the final herd structure depends on the weaning and death rates chosen and the sales from each age group.

Breedcowplus is used to test the most profitable turnoff age for male cattle, the most profitable balance between heifer culling rate and the sale of mature cows and the comparative profitability of new cattle husbandry or pasture management practices. The outputs of the Breedcowplus program are herd structure, herd value, turnoff, and gross margins.

The Breedcowplus program contains Prices, AECalc, Huscosts and Breedcow as separate worksheets that can be used to record the detail of how sale prices, husbandry costs or adult equivalents have been calculated.

- The **AECalc** sheet records the weights and expected weight gain of each livestock class in the breeding herd and calculates AE from this data. Adult equivalent ratings are used when comparing herds of differing composition to ensure that ratios such as gross margins (per adult equivalents) are based on the use of the same amount of (forage) resource.
- The **Prices** sheet calculates net cattle selling prices from estimates of sale weight, price per kilogram, selling costs (as percentage of value or per head) and freight costs per head. The program also includes a transport cost calculator to help in the estimation of transport costs to alternative destinations.
- The **Huscosts** sheet has a similar role to the Prices sheet in that it can be used to store the detail of assumptions made concerning the treatment and other costs incurred by the various classes of livestock included in the model.
- The **Breedcow** sheet collects the various inputs from the AECalc, Prices and Huscosts sheets then allows users to complete the herd model by adding information about breeder performance, losses, total adult equivalents and the variable costs incurred by the management strategy under consideration. Once all of the variables have been entered a herd structure, turnoff and gross margin are produced.

9.2.2 Dynamaplus

The Dynamaplus program is a 10-year herd budgeting program that usually starts with the current herd numbers and structure. It has a structure similar to the Breedcowplus program with individual worksheets for the calculation of AE, prices and husbandry costs. It also has additional worksheets that provide a detailed analysis of the expected monthly cash flow for the herd (MonthCFL) and the approximate taxable income generated by the herd over time (Taxinc).

Dynamaplus is used exclusively once planning moves out of 'policy' and into the real world. The core use for Dynamaplus is cash flow budgeting starting with the existing herd structure. The composition of most herds usually is to some extent out of balance from the last drought or some other recent disturbance. The budgeting process may be a tug-of-war between trying to get the herd restabilised and meeting loan service commitments.

- The **AECalc and Prices** sheets are as previously described for the Breedcowplus program except that they can now have up to 10 years of data entered in each worksheet.
- The **Huscosts** sheet stores the annual average variable costs of the beef enterprise by classes of livestock.
- The **Dynama** sheet projects carryover cattle numbers for each year based on starting numbers, expected weaning rates, death rates and sales. It tracks herd structure and growth, cash flow, debt, net income and net worth for up to 10 years.
- The **MonthCFL** sheet produces monthly cash flow summaries and calculates closing overdraft balances for each month. This also enables a more accurate estimate of overdraft interest than that calculated in the Dynamaplus program.
- The **Taxinc** sheet uses herd data from the Dynama worksheet to calculate livestock trading accounts, plus other information to produce approximations of taxable income.

9.2.3 Investan

Investan is an investment analysis program that compares scenarios developed in the Dynamaplus program starting with the same herd and asset structure, but with one Dynamaplus scenario involving additional investment or income sacrifice to implement a program of change. Investan calculates the NPV and IRR for the 'change' option relative to 'without change' or 'business as usual'. Investan compares Dynamaplus scenarios showing year by year differences in cash flow and the end-of-budget difference in non-cash assets. Investan calculates NPV, IRR and the annualised return on these differences and calculates peak deficit and displays the year in which it occurs.

9.2.4 Cowtrade, Bullocks and Splitsal

Cowtrade, Bullocks and Splitsal are separate programs to Breedcowplus and Dynamaplus and have no direct linkages to other programs.

The Cowtrade program is used when seasons and prices are out of line with long term expectations. It can be used to set sales priorities when drought or financial crisis requires abnormal sales. Cowtrade can also be used to assess breeder purchase options. The Bullocks program focuses on selecting the most profitable turnover cattle, but it may be also used to evaluate forced sales options or whether to keep the slow steers until they finish or sell them early. Cowtrade and Bullocks are used independently of the other programs and cover a budgeting need not met by the other programs - namely comparing selling and buying options to minimise the financial damage from forced sales, maximise the profit from trading or make better decisions on restocking.

Splitsal is a program to provide estimates of numbers (and average weights) above and below a certain cut-off weight, when mob average weight and range of weights are known. This can be used for male turnoff over two seasons or for estimating numbers and weights from the tail or lead of a group of heifers or steers.

10 Appendix 2. Discounting and investment analysis

In undertaking investment analysis, it is necessary to make predictions of cash inflows and outflows for a future time period. A key feature of investment analysis is the process of discounting these future cash flows to present values. Discounting is used to evaluate the profitability of an investment whose life extends over a number of years. Discounting is also used when selecting among investments with differing lives and cash flow patterns.

10.1 The need to discount

Investors generally prefer to receive a given amount of money now rather than receiving the same amount in the future. This is because money has an opportunity cost. For example, if asked an amount of money they would just prefer to receive in 12 months' time in preference to $100 now, most people would nominate a figure around the $110 mark (certainly more than $100!). In other words, money has an opportunity cost of around 10% to the general population. At an opportunity cost of 10%, an amount of $100 now has a future value of $110 in 12 months' time ($100 x 1.1). It would have a future value of $121 in two years' time (i.e., $100 x 1.1 x 1.1). For similar reasons, society puts an opportunity cost on funds employed in public sector development projects making discounting equally important in the allocation of public funds.

Because of the time preference for money (opportunity cost), it is difficult to compare money values received at different points of time. To compare and aggregate money values over time, it is first necessary to discount them to their 'present value' equivalents. Thus, $121 in two years' time has a present value of $100 at an opportunity cost (discount rate) of 10%.

The general formula for discounting a future amount to its present value is:

present value = A / (1+i)n

and where A = future amount; i = discount rate; n = number of periods in the future

The stream of funds occurring at different time periods in the future is then reduced to a single figure by summing their present value equivalents.

It is important to recognise that discounting is not carried out to account for inflation. Discounting would still be applicable in periods of nil inflation. It is common, however, to remove the inflation component from discount rates when undertaking investment analyses. Nominal interest rates are those quoted on cash investments. Real discount rates have the inflation component removed from this nominal rate. It is necessary in investment analysis using real discount rates that future cash inflows and outflows are expressed in real (constant) terms i.e., they should not include an allowance for inflation. If, alternatively, cash inflows and outflows are expressed in current (nominal) dollar terms a nominal (inflation included) discount rate should be used.

10.2 Profitability measures

Three profitability criteria can be calculated. They are:

- Net present value (NPV) - the stream of future cash flows is reduced to a single figure. The NPV is the difference between the present value of the investment inflows and the present value of the investment outflows. An investment is acceptable if the NPV is positive.
- Benefit-cost ratio - the present value of the investment inflows divided by the present value of the investment outflows. An investment benefit-cost ratio greater than one is required.

- The internal rate of return (IRR) - the discount rate at which the present value of inflows equals the present value of outflows. It is internal because it is calculated independently of the cost of borrowed funds. It represents the maximum rate of interest that could be paid if all funds for the investment were borrowed and the investment was to break even.

The three decision criteria are interrelated. For example, Table 70 presents an example of the range of values expected for each profitability criteria at a discount rate of 8%.

Table 70 - Relationship between profitability measures at a discount rate of 8%

Factor	Relative value		
NPV	Negative	Zero	Positive
IRR	< 8%	8%	>8%
Benefit-cost ratio	Less than 1	1	Greater than 1

The criterion of choice in investment analysis is the NPV or IRR although NPV is usually the preferred measure. The NPV for individual investments can be converted to an annuity and presented as the net annual economic benefit generated during the next x years. The IRR is useful in comparing the likely returns of alternative investments. The benefit-cost ratio, i.e., benefits in relation to costs, is generally less used in investment analysis but is widely used in processes like benefit costs analysis. A calculated benefit-cost ratio of greater than one indicates a profitable investment.

Having a consistent time horizon is one of the essential requirements for comparing or ranking investments by NPV and IRR. The other requirements for consistent ranking are that the options are not mutually exclusive and have the same investment outlay.

Discounted cash flow (DCF) analyses do not include allowances for opportunity costs of capital. These opportunity or imputed costs are commonly applied to average results (e.g. average gross margin, average net profit) to give a rough indication of whether the average is able to cover those unpaid costs. However, the calculus of the discounting procedure that is used to calculate NPV and IRR is based on assessing whether the flow of net returns over the time horizon is adequate to cover the capital outlays that are involved. For example, if the calculated NPV is positive at a discount rate that reflects the cost of capital then it indicates that the capital has been recovered. Including allowances for opportunity interest on capital (e.g., livestock) in the annual cost calculations of a multi-year cash flow analysis represents a case of double-counting.

Net present value estimates, applied in the context of comparing alternative beef production systems on the same property, carry two separate opportunity cost components, one of which might not be appreciated. The first component is that adopting the structural changes under a given scenario necessarily foregoes the opportunity to capture the baseline productivity and profitability (hence the use of the ‘marginal’ terminology and approach). The second component is the assumption that the net outcome of the change above the baseline performance can out-yield the opportunity foregone of either not investing the capital outlays in some alternative investment or borrowing the funds at a particular rate – the discount rate. The procedure also assumes that the net annual returns are being reinvested each year from when they occur at this opportunity return (discount) rate. The IRR is a manipulation of the NPV formula which drives the NPV to zero implying that the present value of the cumulative gain from a scenario over the first opportunity cost (baseline performance) is of no additional value above the present value of the second opportunity cost (return on equivalent outlays that are invested at the discount rate). The calculated IRR also assumes that the annual cash flows are continuously reinvested at that rate (which is rarely the case).

So, when the impact of a particular scenario is described along the lines of ‘the profitability of the beef system was substantially improved compared to the baseline with additional returns of $X and Y%’ (i.e. large positive NPV value, IRR well in excess of the assumed discount rate) it is correct that the investment in the scenario option ticks the criteria check boxes (NPV > 0, IRR > discount rate); this is an economically sound investment. However, it may not be well understood that this economic construct is not the actual gain in profit above the baseline that would be obtained but represents the value of a lesser sum that is above the baseline but minus the opportunity cost of the discount rate earning alternative investment.

In the context of a multi-period investment analysis, it can be difficult for those not conversant with economic methodology to appreciate what a single absolute NPV value might mean in terms of the average annual performance of that investment. The ‘annualised NPV’ procedure that has been adopted in our report is intended to address that issue, by calculating a series of equal annual values for which the present value of their sum is equivalent to the single NPV estimate for the whole period. However, these amortised values do not really measure the average annual profit advantage of the investment; they are an indication.

10.3 ‘With’ and ‘without’ scenarios

There are two critical questions that must be considered in any investment analysis:

1. What is likely to happen with the change? (Or for ex post analyses - what happened with the change?)
2. What is likely to happen without the change? (Or for ex post analyses - what happened without the change?). This is also known as the ‘counterfactual’ or ‘baseline scenario’ and often is represented by an enterprise or investment structure that is currently in place.

Since the ‘with’ change scenario is hypothetical by definition, specifying it is necessarily subjective, and consequently more problematic than the ‘without’ change scenario. It should be inferred from the best available information, and the necessarily subjective underlying assumptions made explicit. The specification of a counterfactual or baseline scenario is a key part of any impact analysis. Use of the ‘with’ and ‘without’ principle forces formal consideration of the net impact of the investment.

10.4 Compounding and discounting

Future costs and benefits can be valued in real (constant) or nominal (current) prices. In the real terms approach, all variables are expressed in terms of the price level of a single given year. While any year may be used, the present year will usually carry most meaning as a base. Note that if an entire analysis is conducted in the prices of the year in which the analysis takes place, it is being carried out in real terms. The method assumes that the current relationship between costs and prices will be maintained for the period of the analysis. If there are good reasons for thinking that particular cost or benefit streams will not follow general price movements, those changes in relative prices should be built into the analysis. If land rents, for example, in the context of a property evaluation, are expected to exceed the rate of inflation by 2%/annum for the next three years, the analysis should include this parameter. Assumptions regarding expected relative price changes should be made explicit.

In the nominal price approach, the impact of expected inflation is explicitly reflected in the cash flow projections. As in the real price case, different inflation rates can be applied, if necessary, to different cost and benefit streams. Because of the demanding nature of the data requirements under this approach (inflation rates need to be estimated for the entire project period), the approach is not generally used.

As already noted, when using constant values, it is usual to accept the prices of the first year of the project. However, when the cost-benefit analysis is undertaken as part of an ex post evaluation, the convention is to use the prices of the final year of the project.

The Australian Bureau of Statistics publishes numerous implicit price deflators which may be used to convert nominal net benefits to real net benefits (see Australian National Accounts – National Income and Expenditure, annual, ABS Catalogue No. 5204.0). However, unless a specific implicit price deflator seems applicable, a general deflator such as the 'Gross Non-Farm Product' implicit price deflator may appropriately be used.

It is important that real prices and nominal prices are not confused in the analysis. In particular, when the analysis is presented in nominal prices, the discount rate should be adjusted for inflation. This captures the point that investors require compensation for anticipated inflation as part of the price of making funds available. With annual compounding, the formula for converting a real discount (r) into a nominal one (n) is:

$$n = (1 + r)\,(1 + \text{inflation rate}) - 1.$$

Thus, with a real discount rate of say 6%, and an expected annual rate of price inflation of 3%, the correct nominal discount rate is 9.2%. Note that the 'intuitive' alternative of summing the real discount rate and the inflation rate (to give 9%), slightly underestimates the correct value.

Conversely, to convert nominal discount rates into real discount rates, the equation is:

$$r = (1 + n)\,/\,(1 + \text{inflation rate}) - 1$$

Thus, if the nominal discount rate is 9% and the expected inflation rate is 3%, the corresponding real discount rate is 5.8%. Note here that an intuitive 'subtraction' approach overestimates the correct value.

For most investment analyses, all benefits and costs should be expressed in constant dollar terms and discounted or compounded by the discount rate to the current year.