Mulga Lands production systems

Preparing for, responding to, and recovering from drought

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Note: all of the herd models, financial and economic analyses have been compiled in the Breedcow and Dynama suite of programs. Please contact the authors if you would like a copy of any of the files.

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Summary

This report details the analysis of the economic implications of management decisions to prepare for drought in the Mulga Lands 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 the implementation of resilient grazing, livestock management and business practices necessary to manage seasonal variability. 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 Mulga Lands. In doing this, we developed property-level, regionally specific herd and business models for a constructed, example beef cattle property. Due to very limited available herd data for this region, the assumptions were largely informed by the knowledge and experience of Department of Agriculture and Fisheries (DAF) research and industry extension staff who have worked across northern Australia's grazing regions, as well as through consultation with regional producers. As there is an absence of contemporary beef cattle research data to validate the assumptions made for the Mulga Lands analysis, we strongly recommend that the results be considered as a guide only and that the assumptions be adjusted to suit the circumstances of individual properties and local managers.

The initial constructed, base property was 20,000 ha with representative mulga and other land types and initially carried ca. 600 adult equivalents (AE). The management features of the self-replacing beef breeding herd included continuous mating with two main musters each year to castrate male calves, sell steers and identify cull (i.e., saleable) breeding cows. Over the 30-year analysis period the average overall mortality rate of the base herd was 7.6% with a 12.5% breeder mortality rate. The average branding rate from all cows mated was 47.5%. Most steer calves were left on their mothers until they were 10-12 months old and then sold directly to the saleyards at an average weight of about 220 kg in the paddock. These average performance values need to be considered in the context of the very high annual variability in rainfall, liveweight gain and stocking rate for this region which may result in different average performance over a future sequence of years than the averages chosen in our analysis. Regardless, this initial base property returned -2.47% on the capital invested over a 30-year period and hence total farm income was insufficient to pay total costs of the property.

To increase viability, and to build resilience to droughts, floods and market shocks, beef producers will 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. The Breedcow and Dynama herd budgeting software (BCD) was used to develop herd models integrated with discounted cash flow budgets for each alternative management strategy. 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) the change in profit and risk generated by alternative operating systems, (2) the changes in unpaid labour, herd structure and capital, and (3) included 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 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 Mulga Lands but instead refer readers to the previous reports which are available from the project internet page: Improving profitability and resilience of grazing businesses in Queensland - Preparing for, responding to, and recovering from drought - FutureBeef. 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 major challenges facing beef producers in the Mulga Lands are associated with the inherently low productivity and profitability of the region exacerbated by widespread, and well-documented, pasture degradation. Four initial strategies to implement basic levels of herd management for the representative property were considered, sequentially and additively, for their ability to improve profitability and resilience, and hence prepare for drought. This involved (1) a reduction in the long-term, average stocking rate from 600 to 500 AE to match what was considered the safe carrying capacity of the representative property; (2) implementation of weaning, pregnancy testing and basic herd vaccinations against botulism, leptospirosis and vibriosis; (3) targeting the optimum age of steer turnoff, and (4) providing supplements to supply adequate sulphur (S), phosphorus (P) and nitrogen (N).

The results of the analysis of these basic management strategies are given in Table 1 and Table 2. Table 1 and Table 2 show the net difference in returns between the initial, base property with 600 AE and low-level management and the same property after sequential implementation of basic management strategies. It is important to note that a negative net present value (NPV) from these analyses does not necessarily indicate that a property implementing such a strategy is unprofitable, just that the strategy causes the property to be less profitable than the base scenario. After the initial strategy of implementing the safe carrying capacity of 500 AE, the long-term economic and financial outlook for the property was not substantially improved with only $520/annum additional profit over 30 years expected as a result of the change. The annual rate of return on total capital invested at the property-level was -2.60% and hence similar to that when running 600 AE. Implementing weaning, pregnancy testing and basic herd vaccinations also provided no measurable impact on the economic and financial performance of the property over 30 years when combined with stocking rate reduction, with <$200/annum added to the total property profit. However, increasing the age of steer turnoff, from yearlings to the optimal of 18 months, in combination with implementing the safe carrying capacity, weaning, pregnancy testing and basic herd vaccinations, did have a more substantial positive effect on profit, adding $12,400/annum benefit to the property over 30 years. Despite this improvement, the total property returns were still negative at –1.88%.

Table 1 - Profitability and financial risk of sequentially implementing basic management strategies of (1) reduction in the long-term, average stocking rate from 600 to 500 AE, (2) weaning, pregnancy testing and basic herd vaccinations and (3) targeting the optimal age of steer turnoff, on the Mulga Lands property compared to the 600 AE starting herd

The analysis was conducted for a 30-year investment period using current input costs and average cattle prices over the period January 2010 to December 2019

Scenario	**Annualised NPV[A]**	**Peak deficit (with interest)[B]**	**Year of peak deficit**	**Payback period (years)[C]**	**IRR (%)[D]**
Implementing safe carrying capacity (p. 43)	$520	-$16,988	30	n/c	4.3
Safe carrying capacity + weaning, pregnancy testing and basic vaccination program (p. 48)	$173	-$14,975	30	n/c	4.6
Safe carrying capacity + weaning, pregnancy testing and basic vaccinations + increasing age of steer turnoff from yearling steers to 18 months (p. 52)	$12,405	n/c	n/c	n/c	n/c

AE, adult equivalent; 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.

The value of appropriate supplementation to address S, P and N deficiencies in cattle using mineral loose mix (i.e., ‘inorganic’) supplements was then compared to a modified base herd where the initial basic management strategies (Table 1) were fully implemented. Table 2 shows the added value of applying the different inorganic supplement strategies to the property after the full implementation of a lower average stocking rate, the weaning, pregnancy testing and basic herd vaccination programs and the change in steer sale age to the optimal of 18 months. Feeding S and P supplements during the growing period only, improved property profit by $7,080/annum over 30 years. Despite this additional improvement, the total property returns were still negative at -1.53%. Implementing dry period supplements decreased property returns when fed alone and decreased the benefit to growing period supplements when fed in combination. The ongoing lack of viability of the Mulga Lands property, even after implementing basic herd management strategies, highlighted the importance of identifying additional strategies to improve the performance of the property.

Table 2 - Profitability and financial risk of implementing inorganic supplements to improve profitability and drought resilience of the Mulga Lands property which had already implemented the safe carrying capacity, weaning, pregnancy testing, basic herd vaccinations and optimal steer sale age[A]

The analysis was conducted for a 30-year investment period using current input costs and average cattle prices over the period January 2010 to December 2019

Scenario	**Annualised NPV**	**Peak deficit (with interest)**	**Year of peak deficit**	**Payback period (years)**	**IRR (%)**
Inorganic supplements (p. 57)					
S, P, N dry period	-$2,035	-$102,233	20	n/c	n/c
S, P growing period	$7,080	n/c	n/c	4	n/c
S, P, N dry period + S, P growing period	$4,074	-$33,527	6	11	17.5%

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

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

The effect of additional strategies to improve viability of the Mulga Lands property were investigated by comparison with the steady-state, base herd after implementation of the basic herd management strategies outlined in Table 1, and Table 2, i.e., after implementing the safe carrying capacity, weaning, pregnancy testing, basic herd vaccinations, optimal age of steer turnoff, and inorganic supplementation in the growing period. The modified base herd had an average overall mortality rate of 2.45% and an average female mortality rate of 4.0%. The average weaning rate from all cows mated was 63.06%. Weaned steer calves were sold to the saleyards at 18 months old and an average weight of about 295 kg in the paddock. The results of the analysis of additional strategies for the Mulga Lands property are shown in Table 3. These results are the net difference in returns between the revised base property with basic herd management strategies in place and the same property after investing in the specified management strategy. The benefits of Table 3 are additive to those identified in Table 1 and Table 2. That is, the original representative property can potentially add benefits from Table 3 to those in Table 1 and Table 2.

A key finding was that destocking in response to drought was likely to add to the profitability of the property if savings in fuel, oil, repairs and maintenance costs (FORM) associated with feeding mulga browse, could be reduced by at least 20% on average over time in combination with a reduction in operator's allowance of 10%. The most appropriate strategy to destock (sale or agistment) and to rebuild herd numbers in the recovery phase (natural increase, purchases, agistment income) will depend upon the costs and prices of livestock at the time and the availability and/or demand for agistment.

Table 3 - Profitability and financial risk of implementing additional strategies to improve profitability and drought resilience of a beef property in the Mulga Lands with basic herd management strategies already in place[A]

The analysis was conducted for a 30-year investment period using current input costs and average cattle prices over the period January 2010 to December 2019

Scenario	Annualised NPV	Peak deficit (with interest)	Year of peak deficit	Payback period (years)	IRR (%)
Converting from breeding to steer turnover (p. 65)	-$16,130	-$718,466	n/c	n/c	n/c
Controlled mating (p. 71)					
Remove bulls, only	-$2,970	-$99,731	n/c	n/c	n/c
Sell PTE females, first year only	-$1,948	-$34,554	n/c	n/c	n/c
Sell PTE females annually, replace with PTIC	$651	n/c	n/c	n/c	n/c
Feeding whole cottonseed to the breeder herd (p. 78)					
$700/t landed	-$50,588	-$1,971,476	n/c	n/c	n/c
$350/t landed	-$25,138	-$1,082,073	n/c	n/c	n/c
Buffel paddock development (p. 82)	$1,717	-$10,578	7	16	13.6
Destocking through livestock sales (p. 84)					
Recovery by natural increase in numbers					
20% mulga cost savings from Year 5	$5,100	n/c	n/c	n/c	n/c
10% mulga cost savings from Year 5	$880	n/c	n/c	n/c	n/c
Recovery through purchase of replacement PTIC breeders	$8,000	n/c	n/c	n/c	n/c
Recovery by taking cattle on agistment					
$3/AE per week	-$3,000	-$152,600	n/c	n/c	n/c
$5/AE per week	-$760	-$52,200	n/c	n/c	n/c
$7/AE per week	$1,500	n/c	n/c	n/c	n/c
Destocking by sending breeders on agistment (p. 90)					
$3 per AE per week	$7,500	-$25,000	5	6	n/c
$5 per AE per week	$6,100	-$38,838	5	7	n/c
$7 per AE per week	$4,700	-$52,700	5	8	n/c

AE, adult equivalent; n/c, not able to be calculated; PTE, pregnancy-tested, 'empty' cows (i.e., not pregnant); PTIC, pregnancy-tested, in-calf cows.

[A]The base herd for each comparison was the herd after implementation of the safe carrying capacity, weaning, pregnancy testing and basic vaccinations, the optimal age of steer turnoff, and inorganic supplements fed in the growing season (i.e., these responses are additive to those in Table 1 and Table 2 for the original, constructed property). Definitions of the economic metrics and abbreviations are given in the footnotes of Table 1.

Regardless, as is evident from Table 3, there was in general very limited opportunity to improve profitability, and hence viability, of the beef enterprise overall. This understanding led to examination of alternative investment options for the Mulga Lands property including production of rangeland goats and carbon farming. Although, historically, Merino wool sheep were the dominant livestock production system in the Mulga Lands, sheep production is now uncommon in the target region. For this reason, as well as the lack of interest by our local advisory group in examining sheep wool or meat enterprises for this mulga-dominant property, they were not included in this study. Merino wool and meat sheep enterprises were examined for the Longreach region with results presented in the

'Rangelands of central-western Queensland' report. This report can be accessed from the project internet page: Improving profitability and resilience of grazing businesses in Queensland - Preparing for, responding to, and recovering from drought - FutureBeef. Furthermore, the property-level, regionally specific herd and business models developed for that analysis are available for use by others and can be applied to assess sheep scenarios for the Mulga Lands, if required. There may be a case for the amalgamation of properties in low-productivity regions such as the Mulga Lands as a way of improving drought preparedness but the ongoing disconnect between land value and production potential in these regions will limit the capacity of local landholders to achieve such an outcome. Additional work and analysis would be required to appropriately examine the economic impacts of property, and herd or flock size, relevant to each Queensland region examined in this series of reports to enable identification of the size at which real efficiencies are achieved for each. Such analysis was beyond the scope of the current project.

The profitability and resilience of alternative investment options

When the Mulga Lands property was modelled to run rangeland goats only, instead of beef cattle, the steady-state analysis produced positive total property returns of 1.59%, cf. negative returns of -1.53 and -1.88% for a self-replacing beef herd (with basic management herd management in place) or a steer turnover operation, respectively (Table 4). However, an important assumption for the rangeland goat enterprise analyses was that wild dogs had minimal impact on the goat production system, i.e., that the property was already protected from wild dogs with suitable fencing. It was also assumed that internal fencing was already at a suitable standard to allow effective control of goats under rangeland conditions.

Table 4 – Modelled property-level returns expressed as the operating profit, rate of return on total capital, and the gross margin per dry sheep equivalent (DSE) after interest, for alternative enterprises on a representative property in the Mulga Lands of Queensland[A]

Calculation of property-level returns	Enterprise scenario		
	Beef cattle		Rangeland goats[C] (p. 92)
	Self- replacing herd[B] (p. 57)	Steer turnover (p. 65)	
Net livestock sales	$121,722	$493,098	$241,370
Husbandry costs	$8,488	$3,830	$17,458
Net bull, steer or buck replacement	$4,000	$393,136	$6,000
Gross margin (before interest)	*$109,234*	*$96,132*	*$217,912*
Gross margin/DSE after interest	*$21.01*	*$17.00*	*$47.44*
Operating overheads	$97,600	$96,600	$106,600
Plant replacement allowance	$14,089	$14,089	$14,089
Allowance for operator's labour and management	$45,000	$45,000	$45,000
Operating profit	*-$47,455*	*-$59,557*	*$52,223*
Rate of return on total capital	*-1.53%*	*-1.88%*	*1.59%*

[A]The DSE was used as a basis for comparisons between beef cattle and rangeland goat enterprises at equivalent grazing pressure.

[B]The self-replacing beef herd was the herd after implementation of the safe carrying capacity, weaning, pregnancy testing and basic vaccinations, the optimal age of steer turnoff, and phosphorus and sulphur supplements fed in the growing season.

[C]The assumption was made that suitable exclusion and internal fencing was already in place.

The steady-state analyses above, indicate the profitability of enterprises that are assumed to be already in place. However, for the Mulga Lands base property with an existing beef enterprise, to fully or partially integrate production of rangeland meat goats, investment of capital, and time to learn new skills, is required. An example scenario, for converting the property completely to rangeland goat production, was modelled (Table 5). It needs to be clearly stated that the results of this example analysis do not indicate whether change is warranted for any particular property. Each property considering change faces different circumstances and, therefore, the results shown may only indicate the value of change for properties that have similar characteristics to the constructed property and face similar prices, costs and outputs in the future.

Where the constructed property was (1) operated as a beef property, (2) had some existing infrastructure to manage sheep or goats, but (3) required the construction of an external boundary exclusion fence and some improvements to internal fencing to operate a goat enterprise, the relative profitability of the property was improved over the long term with an investment in an exclusion fence and a switch to a rangeland goat enterprise. The investment resulted in ca. $48,000 extra profit/annum for the property which was substantially greater than the outcome of any of the previous strategies examined to improve the performance of the existing beef enterprise. However, the performance of this investment is heavily dependent upon the assumption that the relative and absolute price of goat meat will be maintained over the longer term. The significant constraint on the investment was the level of additional debt required to make the change (indicated by the peak deficit), and the number of years before the property would be back to the same financial position that it would have maintained without the investment (i.e., the payback period). These aspects make the investment in an exclusion fence quite risky for the constructed property where it is initially operated solely as a beef production enterprise and has minimal goat infrastructure.

Table 5 - Profitability and financial risk of converting to from a self-replacing beef herd to production of rangeland meat goats with investment in exclusion fencing for a representative property in the Mulga Lands[A]

The analysis was conducted for a 30-year investment period

Scenario	Annualised NPV	Peak deficit (with interest)	Year of peak deficit	Payback period (years)	IRR (%)
Convert from self-replacing beef herd to rangeland meat goats with investment in exclusion fencing (p. 92)	$48,326	-$876,011	3	14	10.8%

[A]The self-replacing beef herd was the herd after implementation of the safe carrying capacity, weaning, pregnancy testing and basic vaccinations, the optimal age of steer turnoff, and phosphorus and sulphur supplements fed in the growing season. Definitions of the economic metrics and abbreviations are given in the footnotes Table 1.

Carbon farming is the process of changing agricultural practices or land use to increase the amount of carbon stored in the soil and vegetation (sequestration) and to reduce greenhouse gas emissions from livestock, soil or vegetation (avoidance). Table 6 indicates the potential returns to the investment in differing levels of carbon farming, through carbon sequestration, on the modelled Mulga Lands property. The 'without change' property scenario assumed that the property was fully stocked with either (1) beef cattle or (2) rangeland goats at the start of the conversion to carbon farming.

Partial conversion of a beef enterprise to carbon farming, substantially improved the profitability of the property, with 75% conversion adding more profit than 50% conversion. However, partial conversion of a rangeland meat goat enterprise to carbon farming decreased the profitability of the property.

Table 6 - Profitability and financial risk of implementing a carbon farming enterprise to improve profitability and drought resilience of a specialist beef or goat property in the Mulga Lands[A]

The analysis was conducted for a 30-year investment period

Scenario (p. 103)	Annualised NPV	Peak deficit (with interest)	Year of peak deficit	Payback period (years)	IRR (%)
Convert from self-replacing beef herd to carbon farming on 50% of the property	$26,605	n/c	n/c	n/c	n/c
Convert from self-replacing beef herd to carbon farming on 75% of the property	$36,834	n/c	n/c	n/c	n/c
Convert from rangeland meat goat herd to carbon farming on 50% of the property	-$17,405	-$1,542,488	30	n/c	n/c
Convert from rangeland meat goat herd to carbon farming on 75% of the property	-$36,840	-$2,834,930	30	n/c	n/c

n/c, not able to be calculated.

[A]The self-replacing beef herd was the herd after implementation of the safe carrying capacity, weaning, pregnancy testing and basic vaccinations, the optimal age of steer turnoff, and phosphorus and sulphur supplements fed in the growing season. Definitions of the economic metrics and abbreviations are given in the footnotes of Table 1.

The analysis of investment in carbon farming indicated that the opportunity cost, and other key factors determining whether carbon farming is attractive to a landholder, are dynamic and uncertain. Each part of a property eligible to be allocated to a carbon farming project will have different characteristics leading to different assumptions and different investment returns. It is critical that managers not only apply the correct methodology when assessing the potential for carbon sequestration, but also apply an appropriate framework to assess the economic and financial value of carbon farming. Furthermore, our analysis did not incorporate any potential impacts on the level of tax payable when carbon farming is added to the income mix of the hypothetical property. Income from carbon farming is not treated as income from primary production and specialist taxation advice should be sought by any landholder considering an investment in carbon farming. The potential implications of carbon agreements for future sale of the property also needs to be considered.

The adoption of carbon farming in the rangelands to date has been due predominately to the extended droughts and lower commodity prices of the last decade reducing the opportunity costs and/or increasing the discount rates of some landholders to the point that carbon farming became quite attractive. A return to better seasonal conditions and the continuation of higher commodity prices could slow the conversion of large parts of the Mulga Lands to carbon farming. Even so, the relative profitability of carbon farming, on suitable land types and paddocks in the Mulga Lands, indicates that carbon farming on portions of properties is likely to be considered closely by many landholders who have not yet adopted the enterprise. This is particularly likely if carbon prices show increases, in real terms, over time.

Conclusions

The central finding of these analyses was that the representative beef cattle property had low inherent productivity and profitability with very limited opportunity to improve upon this base situation. When combined with the apparent disconnect between land value and the possible returns from the investment, this suggests that low profitability and debt servicing pressures will make investment in alternative beef cattle management strategies unaffordable for many Mulga Land region beef cattle businesses. This understanding led to examination of alternative investment options for the Mulga Lands property including production of rangeland goats and carbon farming. The modelling approach applied in this study allowed the integration of alternative investments to beef cattle within the one investment model and enabled a whole-of-business analysis of the impact of change on productivity and profitability at the property level.

The steady-state analysis of alternative livestock enterprises indicated that the rangeland goat enterprise produced a positive operating profit and rate of return on total capital in comparison to the negative profitability of both the self-replacing beef herd and steer turnover operations. However, where full investment in an exclusion fence around the majority of the property was required to facilitate a shift from beef to rangeland goat production, the investment was likely to increase the riskiness of the overall enterprise. This was the case even though the long-term profitability and resilience of the property could be substantially improved by a change to the production of rangeland meat goats. The lack of reliable data for managed rangeland meat goat production in this region limits the confidence in conclusions about the role of rangeland goats, long-term. However, maintenance of the demand for goat meat, together with increased knowledge of effective goat management strategies, could see rangeland goats play a very important role in maintaining profitable and resilient production systems in the future.

The potential returns to the investment in differing levels of carbon farming, through carbon sequestration, on the modelled Mulga Lands property when initially fully stocked with either (1) beef cattle or (2) rangeland goats at the start of the conversion, produced different results depending on the starting enterprise in place. Partial conversion of a beef enterprise to carbon farming, substantially improved the profitability of the property, with 75% conversion adding more profit than 50% conversion. However, partial conversion of a rangeland meat goat enterprise to carbon farming decreased the profitability of the property. Importantly, each part of a property eligible to be allocated to a carbon farming project will have different characteristics, leading to different assumptions and different investment returns which may or may not be the same as those in our analysis. It is critical that managers not only apply the correct methodology when assessing the potential for carbon sequestration, but also apply an appropriate framework to assess the economic and financial value of carbon farming. The tax implications of this non-primary production income stream, and potential implications for property sale value, should also be considered.

Regardless, the application of a logical, rational 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.

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1 General introduction

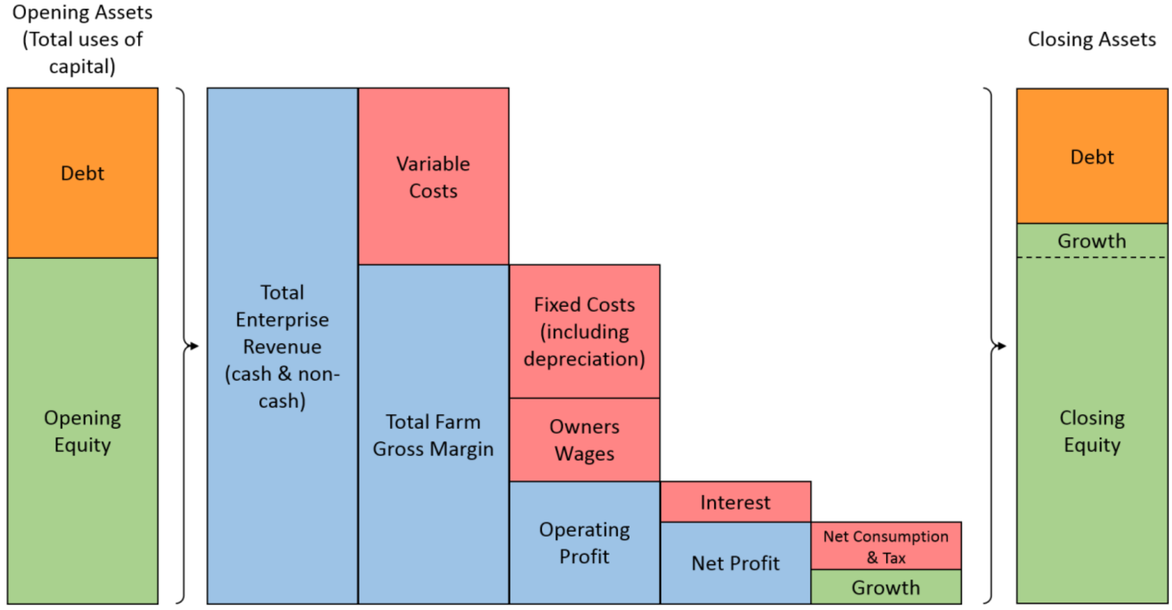
More than 80% of Queensland's total area of 173 million ha is used for grazing livestock on lands extending from humid tropical areas to arid western rangelands (QLUMP 2017). Most extensive grazing enterprises occur on native pastures. Introduced (sown) pastures constitute less than 10% of the total grazing area and occur on the more fertile land types (McIvor 2005; QLUMP 2017). Grazing industries make an important contribution to the Queensland economy. In 2018-19 the beef cattle industry accounted for 45% ($5.8 billion) of the total gross value of Queensland agricultural production while sheep meat and wool accounted for 0.98% ($0.1 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 2018). 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).

To remain in production, and to build resilience, beef and sheep properties need to be profitable and to build equity (Figure 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.

Figure 1 - The link between profit and growth in equity



Although regularly achieving a profit is a key ingredient of a drought 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.

This report was produced as part of the project titled, '*Delivering integrated production and economic knowledge and skills to improve drought management outcomes for grazing enterprises*'. The objective of 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. 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 Mulga Lands of Queensland.

1.1 The Mulga Lands region of Queensland

1.1.1 The land resource

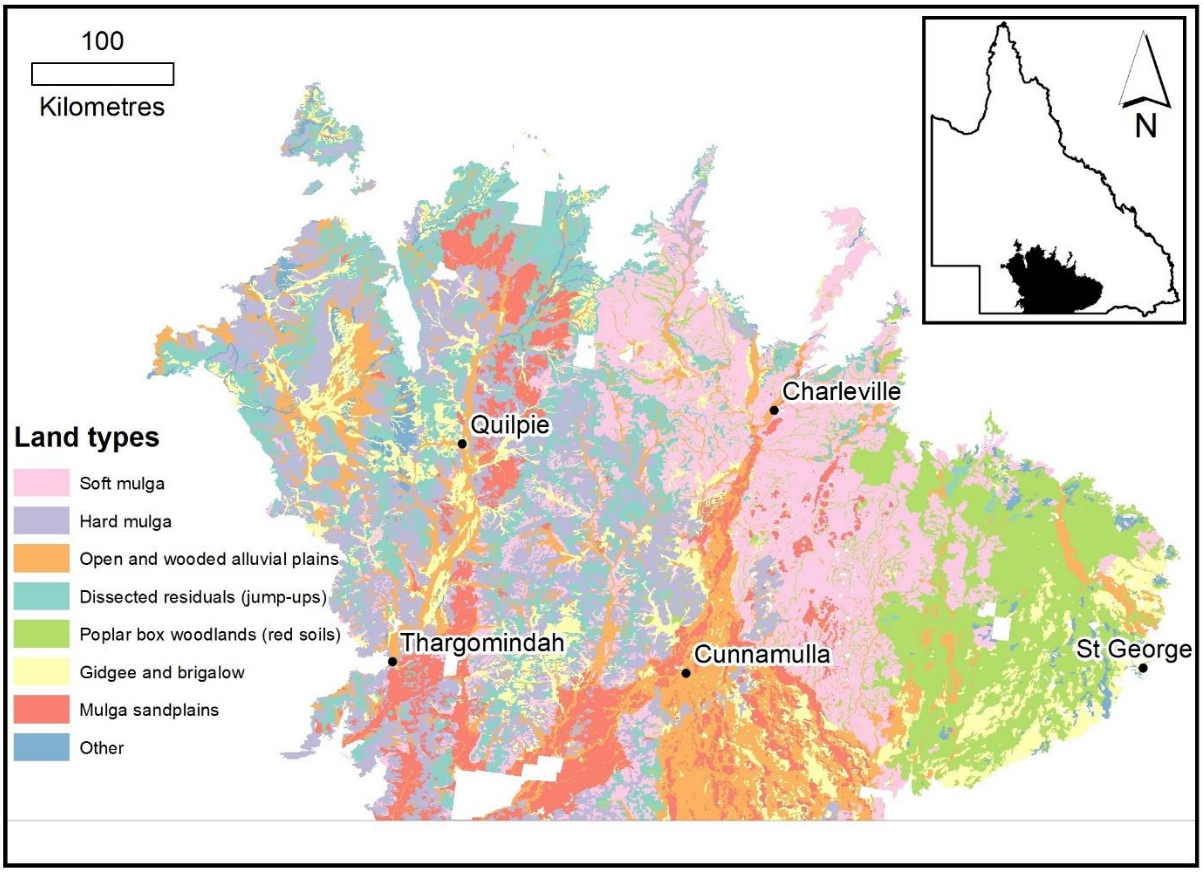
The Mulga Lands target region for this report encompasses 18.6 million ha of grazing land (DNRM 2010; DNRM 2017) used for cattle and sheep production (Figure 2). The region falls within the northern part of the Murray-Darling Basin in south west Queensland and is within the Southern Queensland Landscapes region (formerly South West Queensland Natural Resource Management (NRM) region). The Mulga Lands region of Queensland is part of the larger Mulga Lands bioregion which extends into northern New South Wales with a total area of 25.2 million ha (Commonwealth of

Australia 2008). The Mulga Lands consist of largely flat to undulating plains with strips of low hills (Beale 1994). The soils are largely shallow, infertile, acidic red earths with low water holding capacity (Dawson and Ahern 1973). Mulga soils are characterised as having a severe deficiency of available phosphorus (P) and nitrogen (N), high levels of iron, manganese and aluminium (Dawson and Ahern 1973; Beale 1994; McLennan *et al.* 1999; P. Zund, pers. comm.). Mulga (*Acacia aneura*) and eucalypt woodlands are the dominant vegetation types (Partridge 1996; Commonwealth of Australia 2008; The State of Queensland 2019a).

Pasture species vary according to grazing pressure, tree canopy cover and topography with common species including the native pasture species mulga Mitchell (*Thyridolepis mitchelliana*), mulga oats (*Monachather paradoxus*), *Eragrostis* spp. and wire grasses (*Aristida* spp.), (Clarke 1991; Partridge 1996). Some areas of cleared woodland have been sown to the introduced species, buffel grass *(Cenchrus ciliaris*), and it has continued to naturalise on some of the more fertile soil types such as heavier soils growing poplar box trees (*Eucalyptus populnea*) within the Soft mulga land type (Beale 1994; Partridge 1996; The State of Queensland 2019a). However, the spread and persistence of buffel grass is limited by soil P levels due its higher requirement for soil P compared to native pasture species (Beale 1994). Research conducted by the Queensland Government's Charleville Pastoral Laboratory in the 1960s and 1970s attempted to identify suitable introduced pasture species that would improve the nutrition of grazing animals in the Mulga Lands. The field trials indicated little opportunity to improve upon the existing pasture base as all species, including more than 500 accessions, either had establishment problems, were unable to compete with wire grass, or were highly palatable and therefore overgrazed, and therefore did not perform better than native mulga country grasses or the previously introduced buffel grass cultivars (Clarke 1991; Beale 1994). Mulga leaves (phyllodes) are palatable to livestock and can constitute a significant part of the diet, particularly in times of drought but even in favourable seasons (Clarke 1991; Doran and Turnbull 1997). As the quality and quantity of grass pasture declines, mulga leaf contributes an increasingly larger proportion of the diet (Beale 1975 (cited in Pressland 1984); McMeniman *et al.* 1986a,b).

Figure 2 - Map of the Mulga Lands region of Queensland showing the distribution of the major land types on land used for grazing

The Mulga Lands region is the Mulga Lands bioregion but with the southern boundary set as the Queensland border. Land used for purposes other than grazing is marked white on the map



1.1.2 Rainfall and drought

The climate of the Mulga Lands region in south west Queensland is described as semi-arid to arid with highly variable and unreliable rainfall across all seasons from year to year (BOM and CSIRO 2019). The proportion of annual rainfall falling over the summer pasture growing season (October to March) at Charleville averaged 66% over the 30-year, climate normal period of 1961-1990 (BOM 2020a). Although rainfall in autumn, winter and spring can produce high quality herbage (C_3 pasture species), rainfall during these seasons has been less reliable than summer rainfall over the past 30 years (BOM and CSIRO 2019). Additional climatic features of the Mulga Lands region include high summer temperatures and low relative humidity resulting in high evaporation rates, winter frost incidence which increases towards the south, and extended dry periods generally regarded as droughts (Beale 1994; BOM and CSIRO 2019). Examples of seasonal distribution of rainfall are shown for four locations across the region (BOM 2020a; Table 7). Annual rainfall in the region ranges from 293 mm near Thargomindah to 463 mm at Charleville. The variability of annual rainfall in the Mulga Lands region ranges from 'high' in the west to 'moderate' in the east (scale low to extreme) based on an index of variability determined by percentile analysis (BOM 2020b; Figure 3). Examples of rainfall variability, expressed as the coefficient of variation of the mean annual rainfall figures, are presented for four locations across the region (BOM 2020a; Table 8). Another example of the variability in annual rainfall in the region is provided in Figure 4 for Charleville. Over the 76-year period, 1943-2018, with one missed year of data (2009) the annual rainfall ranged from 203 mm (2017) to 1,134 mm (2010). The average and median rainfall over this 76-year period were 486 and 477 mm, respectively.

Table 7 - Median seasonal distribution of rainfall (mm) at Charleville, Quilpie, Cunnamulla and Thargomindah for the 30-year 'climate normal' period 1961-1990 (BOM 2020a)[A]

Town	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Charleville	51.9	43.9	45.8	19.2	22.5	11.4	15.2	13.3	10.0	24.0	19.7	45.7	463.4
Quilpie	38.2	15.4	39.0	6.1	12.3	9.2	11.8	10.7	7.2	15.9	11.4	21.3	368.5
Cunnamulla	42.5	24.2	31.8	6.4	19.5	9.1	15.9	19.0	12.0	19.5	24.2	22.1	382.1
Thargomindah[B]	21.4	10.5	31.0	1.9	12.5	6.6	7.8	11.1	5.4	8.6	7.1	20.5	292.7

[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 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 2020a).

[B]Norley Station 23.6 km north of Thargomindah.

Figure 3 - Map of the annual rainfall variability across Australia determined using the percentile analysis (BOM 2020b)

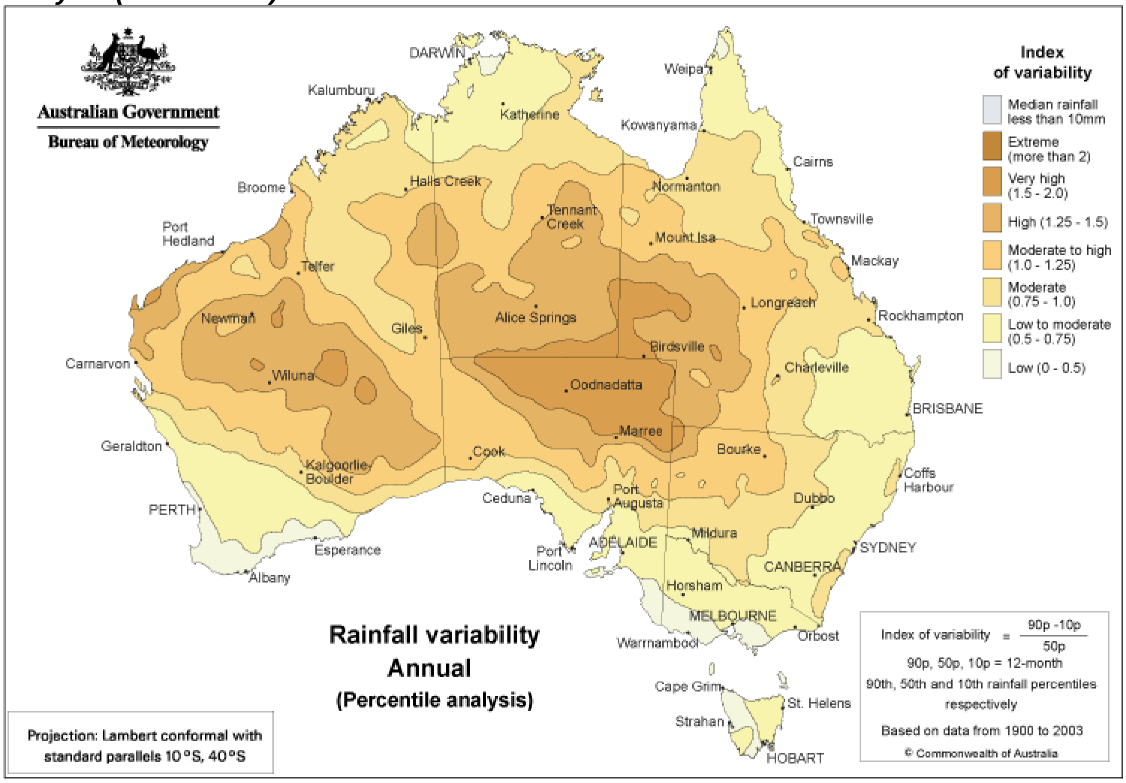
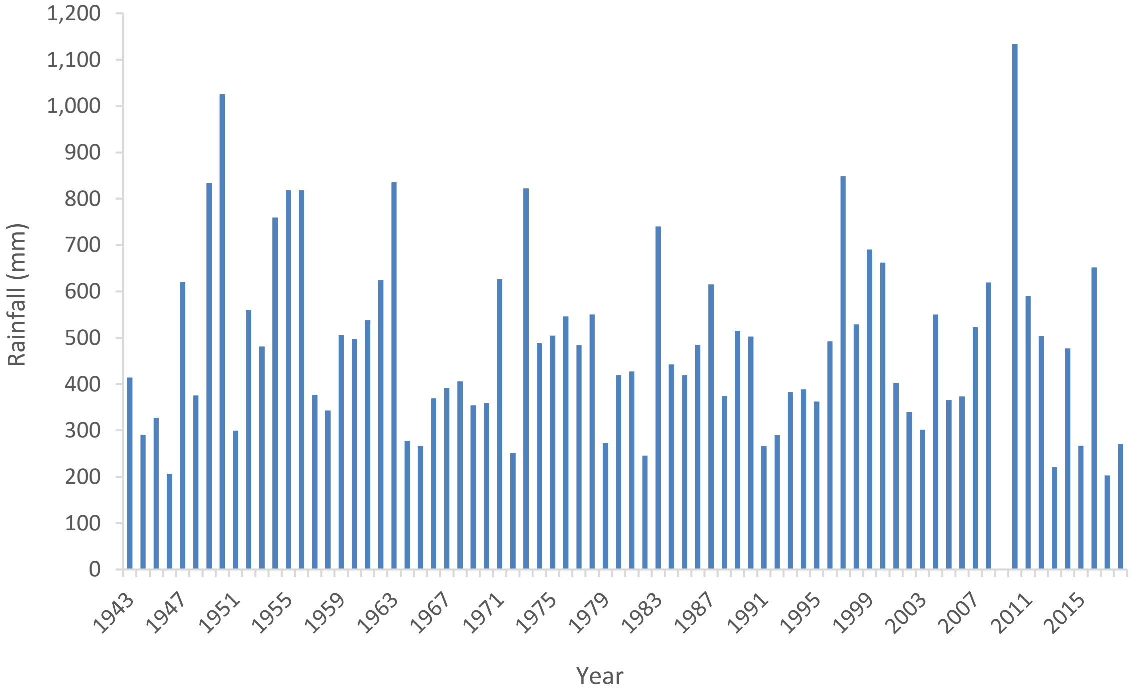


Table 8 - Mean annual rainfall (mm) and rainfall variability (coefficient of variation) at Charleville, Quilpie, Cunnamulla and Thargomindah for the 30-year 'climate normal' period 1961-1990 (BOM 2020a)

Town	Mean annual rainfall (mm)	Rainfall variability expressed as the Coefficient of variation (%)
Charleville	472	33
Quilpie	354	45
Cunnamulla	393	34
Thargomindah[A]	304	48

[A]Norley Station 23.6 km north of Thargomindah.

Figure 4 - Annual rainfall at Charleville over the 76-year period 1943-2018 (BOM 2020a)



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 2020a). 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 2020). 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 Charleville (Table 9). Using this definition, there have been 37 droughts at Charleville since 1900, the longest lasting 19 months. Figure 5 shows the percentage of time, over the period 1964-2019, that Queensland shires have been drought declared (The State of Queensland 2019b). The general area designated in the current report as Mulga Lands has been drought declared 40-50% of the time with the south east section of the Quilpie shire having the longest time in drought of all Queensland shires with drought declarations in place for 50-60% of the time.

Figure 5 - Map showing the percentage of time Queensland shires have been drought declared over the period 1964-2019 (The State of Queensland 2019)

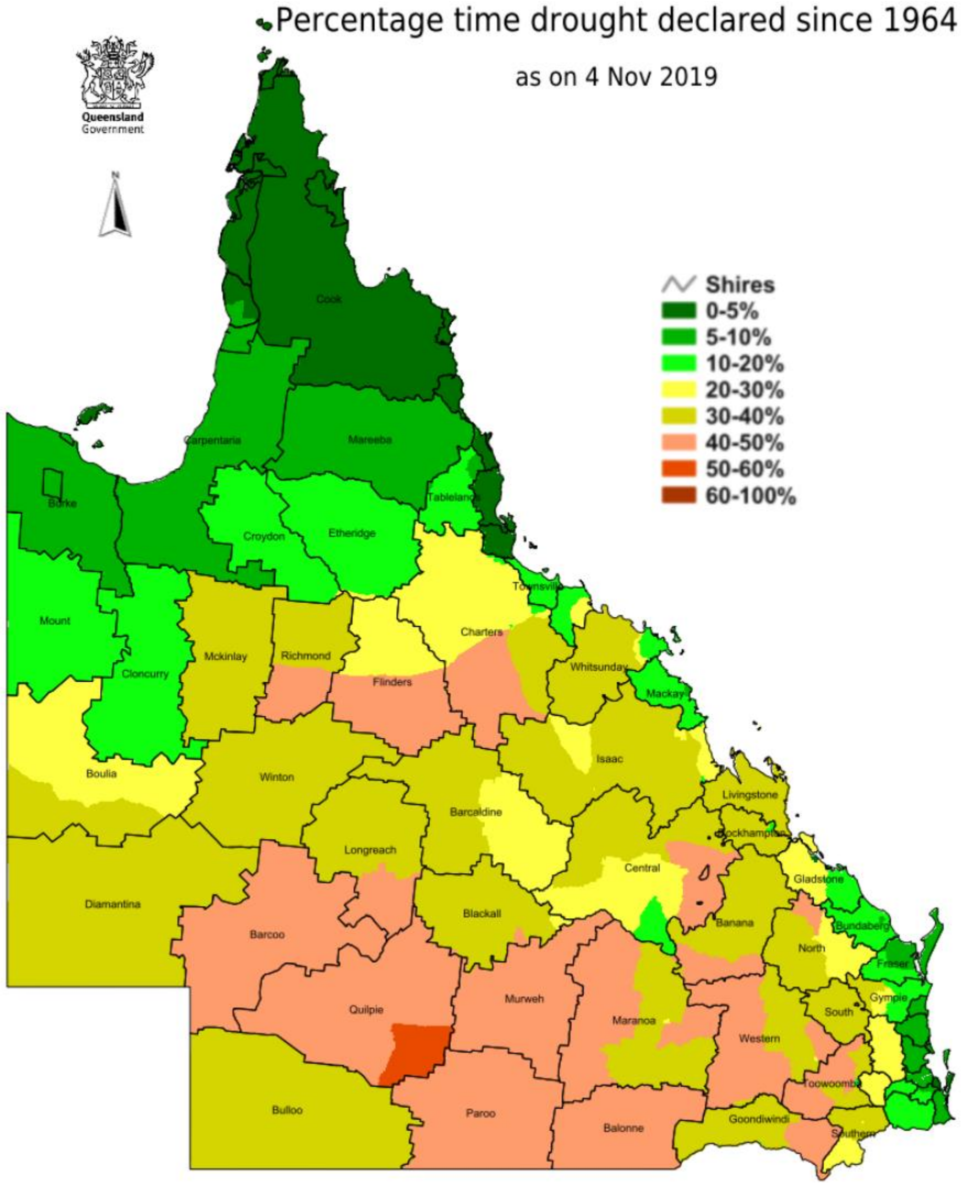


Table 9 - Historical droughts (1900–2020) at Charleville ranked by depth and duration and with subsequent recovery rainfall[A]

Rank	Drought period	Drought length (months)	Drought depth (percentile)	Subsequent recovery rainfall (mm)
1	Sep 2017 - Feb 2019	18	0	308
2	May 1991 - Nov 1992	19	0.8	299
3	Jan 1965 - Dec 1965	12	0	205
4	Apr 1902 - Nov 1902	8	0	117
5	Aug 1946 - Apr 1947	9	0	228
6	Feb 1912 - May 1912	4	0	26
7	Jan 2003 - Jul 2003	7	1.7	230
8	Dec 1900 - Mar 1901	4	1.7	67
9	Jun 1929 - Oct 1929	5	4.2	44
10	Mar 2014 - Aug 2014	6	3.4	119
11	Feb 1933 - Jun 1933	5	3.4	119
12	Sep 1922 - Nov 1922	3	3.4	55
13	Nov 1982 - Jan 1983	3	4.2	67
14	Dec 2013 - Jan 2014	2	3.4	54
15	Mar 1938 - Apr 1938	2	3.4	5
16	Jul 1985 - Oct 1985	4	5.9	100
17	Oct 1940 - Dec 1940	3	5.9	78
18	Mar - 1983	1	3.4	61
19	Apr 1980 - Jun 1980	3	5.1	36
20	Apr 1935 - May 1935	2	6.7	1
21	Aug 1919 - Nov 1919	4	6.8	25
22	Dec - 1929	1	5.9	10
23	Feb 1920 - Mar 1920	2	7.6	79
24	Dec 1972 - Jan 1973	2	6.7	57
25	Jun 1938 - Jul 1938	2	6.8	29
26	Feb - 1993	1	6.7	13
27	May 1993 - Jun 1993	2	8.5	6
28	Dec - 2015	1	7.6	55
29	Jan - 1967	1	7.6	21
30	Aug - 1940	1	7.6	17
31	Jul - 1935	1	7.6	34
32	Sep - 1980	1	7.6	0
33	Jan - 1906	1	8.4	33
34	Feb - 1929	1	8.4	18
35	Nov - 1915	1	8.5	5
36	Jul - 1915	1	8.5	16
37	Aug - 1969	1	8.5	10

[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 2020).

1.1.3 Mulga Lands beef production systems

Extensive grazing, primarily on native pastures, is the principal land use across the Mulga Lands. The region falls within the Southern Queensland Landscapes NRM region but was formerly designated as the South West Queensland NRM region which is a total of 16,923,328 ha and supports 396 meat cattle businesses and 157 sheep businesses (ABS 2020a). The South West NRM region has a total meat cattle herd size of ca. 412,805, representing 2% of Australia's and 4% of Queensland's meat cattle numbers and producing $216 million or 2% of Australia's and 4% of Queensland's gross value of cattle in 2018-19 (ABS 2020a,b). The meat and wool sheep flock in the region totals 396,319, representing 0.60% of Australia's and 19% of Queensland's total sheep flock and producing $24 million or 0.28% of Australia's and 19% of Queensland's gross value of sheep (ABS 2020a,b).

Historically, production of Merino sheep for wool was the dominant livestock production system in the Mulga Lands, and the Queensland mulga bioregion more broadly (Clarke 1991). However, cattle numbers increased during the 1990s as well as diversification into rangeland goat harvesting or managed production systems (Heywood *et al.* 2000). Economic factors as well as increases in wild dog numbers have contributed to the decline in sheep production in the region. With the increase in lamb and wool prices in recent years there has been some return to sheep production in the area. However, the requirement for substantial infrastructure redevelopment, particularly wild dog exclusion fences, to support sheep production has limited the extent of conversion back to sheep, and cattle are currently the dominant livestock in the region (ABS 2020a). The emerging industry of carbon farming has also provided an alternative income stream for producers in the mulga lands following the Carbon Farming Initiative which commenced operation in Australia in December 2011 and is currently operating through the Emissions Reduction Fund (ERF) established in 2014 (The State of Queensland 2020b). In January 2019 there were 122 vegetation projects in the south west Queensland shires, mostly related to the avoided clearing or regeneration of the Mulga Lands (principally the woody vegetation component), with Salter (2019) concluding that that in many instances in south west Queensland the project cashflow from these ERF projects over 10 years was greater than the value of the land on which the project was located.

Traditionally, beef cattle production in the Mulga Lands region has focussed on a store steer breeding enterprise with age of turnoff typically decreasing to production of young weaners in drought periods (Clarke 1991). Older ages of turnoff are often selected on properties with areas of more productive frontage country. Mortality rates, reproductive performance and annual liveweight gains reported for the region vary over a wide range, dependent on seasonal conditions and locality (Clarke 1991; O'Rourke 1992; Bortolussi *et al.* 1999, 2005; McGowan *et al*. 2014). Published beef cattle herd data, over a number of years at one site to indicate annual variability, is limited for the Mulga Lands. Clarke (1991) reported a range in annual growth rates of cattle in the Mulga Lands from 30-160 kg with an average of 95 kg/head. Weston (1988) suggested 109 kg/head.annum to be representative of beef production from mulga pastures.

Mulga top feed, or browse, is an essential part of beef production systems in the Mulga Lands. As well as forming a substantial part of the diet even in good seasons, it is considered to make the Mulga Lands 'safe' for beef production (Clarke 1991) by providing a maintenance diet for livestock during drought when stock would otherwise either die or need to be removed. It has been estimated that the optimal density of mulga for pasture production, preservation of mulga fodder as a drought reserve, and land stability is ca. 160 trees/ha (canopy cover of ca. 6%), (Everist 1949; Beale 1999 (cited in Page *et al.* 2008); Mills 1989). However, Beale (1971), cited in Burrows (1973), found that this level of tree density still depresses potential pasture yields. Studies with fresh and dried mulga leaves fed to sheep and cattle have shown that the nutritive value of mulga browse is low with *in vivo* dry matter digestibility (DMD) values reported as ranging within 35-60% (average 45%), resulting in intakes barely sufficient for maintenance of dry stock (e.g., Norton *et al.* 1972; McMeniman 1976; Gartner and Niven 1978; McDonald and Ternouth 1979; Miller and Pritchard 1988; Strachan *et al.* 1988). Despite a crude protein (CP) content of 10-14% (Everist *et al.* 1958; Everist 1969), the digestibility of this protein is low (30-40%) due to high levels of tannins (11-14% of the DM), (Harvey 1952; Gartner and Hurwood 1976; McMeniman *et al.* 1981; Brooker *et al.* 1994). In addition to reducing the digestibility of protein, the tannins, and possibly other anti-nutritive components in mulga, have been shown to reduce voluntary intake and result in inhibitory effects on abomasal and intestinal structure and function (Robins and Brooker 2005). Research with sheep has indicated that when the diet consists primarily of mulga browse, with no other addition of minerals from supplements or artesian bore water, the diet will be deficient in sulphur (S), P, N and sodium (e.g., McMeniman and Little 1974; Hoey *et al.* 1976; McMeniman 1976; McMeniman *et al.* 1981; Niven and McMeniman 1983). Loose licks supplying S, P and N have long been recommended for cattle and sheep consuming mulga browse to increase feed intake (by up to 20-30%) and thereby reduce rate of liveweight loss and mortality (O'Dempsey 1992; NSW Department of Primary Industries 2016; The State of Queensland 2020a). Breeders in late pregnancy or lactation will require supplementation with additional energy and protein to prevent considerable weight loss.

Enterprise and resource management in the Mulga Lands relies on fodder harvesting of mulga, which is considered an economic imperative without which grazing businesses are unlikely to be viable (Page *et al.* 2008). However, the ability to retain livestock through use of mulga fodder, even when grass biomass is limiting, has been the major contributor to pasture degradation in the region (Pritchard and Mills 1986; Mills *et al.* 1989; Johnston *et al.* 1990). Reports indicate the application of higher stocking rates and pasture utilisation rates in the Mulga Lands bioregion than indicated as 'safe' for maintaining pasture condition (McKeon *et al.* 2004; Commonwealth of Australia 2008) and that high pasture utilisation levels are leading to the necessity of recurrent and extensive fodder harvesting of mulga to maintain livestock numbers (Commonwealth of Australia 2008; Page *et al.* 2008). Additional contributors to pasture degradation include woodland thickening which decreases pasture growth, and large numbers of macropods, feral and semi-commercial goats contributing to high pasture utilisation (Burrows *et al.* 1990; Commonwealth of Australia 2008; Page *et al.* 2008).

The widespread pasture degradation in the Mulga Lands has been well documented (e.g., Mills 1989; Mills *et al.* 1989; McKeon *et al.* 2004) with this region recognised as the most extensively degraded landscape in Queensland (Wilson 1999). However, despite government and grazier-supported initiatives in the 1990s to (1) promote property amalgamation for improved enterprise efficiency, (2) control total grazing pressure and (3) objectively assess safe livestock carrying capacities (Johnston *et al.* 1996a,b; Rose 1998), and the more recent Queensland Vegetation Management Act 1999 (The State of Queensland 2018), the resource condition appears to be in continued decline (Commonwealth of Australia 2008). Recent droughts since the latest published survey of landscape function in 2008 would be expected to have only exacerbated this situation. Furthermore, it is considered unlikely that large areas of degraded rangeland pastures will be improved due to the difficulty in doing so, and the economic constraints (Foran *et al.* 1990a; MacLeod and Johnston 1990; Johnston *et al.* 1990; Commonwealth of Australia 2008).

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 Mulga Lands 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 and rangeland goat 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 net present value (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) and
- 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 Mulga Lands 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 adult equivalents (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.

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 internal rate of return (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.

Discounted cash flow (DCF) 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 (2020), except for livestock prices, which were calculated as the average over the past 10 years and 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 discounted cash flow 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.

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 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.

It is important to recognise that while gross margins are 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 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.

2.3 Constructed, base beef cattle property

The base property, herd and business characteristics were informed by industry surveys and research relevant to the region (Holmes 1980; Clarke 1991; O'Rourke 1992; Bortolussi *et al.* 1999, 2005; McGowan *et al*. 2014) as well as consultation with regional producers and experienced DAF staff. Due to the predominance of beef cattle enterprises, which have largely replaced Merino wool production in the Mulga Lands of Queensland, a beef cattle property was selected as most representative of the region. The example beef cattle property was developed based on very limited herd data. The assumptions were largely informed by the knowledge and experience of DAF research and industry extension staff who have worked across northern Australia's grazing regions as well as through consultation with regional producers. The production parameters assumed for the base property were intended to represent the current expectation for this region. However, there is an obvious challenge in adequately accounting for the high annual rainfall variability that occurs in this region given limited published data for beef cattle production. As there is an absence of contemporary beef cattle research data to validate the assumptions made for the Mulga Lands analysis, we strongly recommend that the results be considered as a guide only and that the assumptions be adjusted to suit the circumstances of individual properties and local managers. Regardless, 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 responses to these changes, and (3) an appropriate framework to support decision making.

The constructed, example property was located within 100 km of Charleville. The property was modelled as a total area of 20,000 ha of mulga and associated native pastures growing on primarily

Soft and Hard mulga (75% of property) and Black soil (Gidgee, Brigalow and Yapunyah; 25% of property) land types (The State of Queensland 2019a; Figure 2) with a currently applied stocking rate of ca. 600 AE. The assumption was that the starting point of the analysis would be a stocking rate typically applied by many local landholders. The first alternative management strategy considered was the impact on property performance of a reduction in the current stocking rate to what was assessed as the long-term, safe carrying capacity (500 AE). Although the three main land types were largely interspersed across the property, each land type was allocated an area and a current stocking rate (Table 10). The property was made up of six main paddocks and two smaller holding paddocks with a mix of land types in each paddock. The property had only one set of cattle yards and no laneways. Over the range of land types, the property was considered to be deficient in P on average (4-5 ppm bicarbonate extracted P (Colwell 1963); Bowen *et al.* 2020b)) in the top 100 mm soil (McCosker and Winks 1994; P. Zund, pers. comm.). The property relied on pulling or pushing mulga browse for a period of 6 months every 2 years (on average over 30 years) to provide sufficient cattle feed. Due to utilisation of mulga browse as a feed source it would be rare for this property to be completely destocked. It should be noted that due to the size of this property and its low productivity, it is not considered capable, by itself, of supporting the full expenses of the property and of the owners and hence off-farm income would be needed.

Table 10 - Land types, areas and current stocking rates on the Mulga Lands base property

Main land types	**Area (ha)**	**ha/AE**	**Total AE/land type**
50% Soft mulga	10,000	40	250
25% Hard mulga	5,000	50	100
25% Black soil (Gidgee/Brigalow/Yapunyah)[A]	5,000	20	250
Total	*20,000*	*33.3*	*600*

[A]Not contiguous; scatted through the mulga land types.

2.3.1 Starting herd performance and structure

A self-replacing *Bos indicus* crossbred breeding herd (ca. 50% *B. indicus*) primarily grazed the mulga land types which were considered deficient in P on average (4-5 ppm bicarbonate extracted P (Colwell 1963); Bowen *et al.* 2020b) in the top 100 mm soil (McCosker and Winks 1994; P. Zund, pers. comm.). The herd received no vaccinations for herd health. Replacement heifers were separated from the breeding herd until they were first mated at ca. 2 years of age. Although male calves were castrated, no steer weaning activities were undertaken, and steers were sold off their mothers at ca. 12 months of age. Continuous mating was practiced with two main musters of the breeding herd undertaken to castrate male calves, sell steers and identify cull (i.e., saleable) breeding cows. Due to the mix of land types in each paddock and the mulga regrowth, mustering was considered difficult and time consuming and a clean muster rarely achieved.

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 who apply lower levels of management input (Table 11). An average annual mortality rate was applied to the various classes of livestock (range 4-12.5%) to reflect industry expectations and other anecdotal evidence related to the general low nutritive value of available forage, P deficiency, absence of vaccination against botulism, and the impact of droughts across the region over the long term (average herd mortality 7.6%). There was no culling on reproductive status of younger female groups but in older groups (>4-6 years) possibly up to half of them were culled depending on their status and condition. More culling pressure was applied with age to the older cows, essentially to cull cows with higher liveweight and higher per head values. The herd bulls purchased each year as a percentage of 'herd bulls required' figure was set at 15% to reflect the expected retention of herd bulls in the breeding herd for more than 6 years on average. An overall proportion of bulls to cow was set at 2.5% and bull mortality was expected to average 5%/annum.

Table 11 - Initial reproduction parameters and mortality rates for the Mulga Lands base herd

Initial cattle age **Final cattle age**	**6 months** **1**	**1** **2**	**2** **3**	**3** **4**	**4** **6**	**6** **8**	**8** **13**
Expected conception rate for age group (%)	n/a	0	60	15	65	60	60
Expected calf loss from conception to weaning (%)	n/a	0	12	10	10	10	12
Female death rate (%)	4	6	12.5	12.5	12.5	12.5	12.5
Male death rate (%)	4	6	6	6	6	n/a	n/a

n/a: not applicable.

The application of the data for reproduction efficiency and mortality rates to the herd model produced an expected average branding rate of 47.53% (branded calves from all cows mated). This is substantially lower than the median 'contributed a weaner' figure of about 85% identified for the CashCow project, Southern Forest region (McGowan *et al.* 2014) but is seen as better representing the expected herd performance for properties that are predominately mulga land types with no weaning or vaccination programs in place, a P deficiency, and no adequate inorganic supplements regularly fed to the breeding herd, as well as the general low nutritive value of available forage in this region. The starting stocking rate for the property produced about 218 branded calves from 458 females mated and sold 152 head/annum. Cull (fat) female sales made up 30.53% 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 12.

Table 12 - Average herd structure for the Mulga Lands base property and starting stocking rate (600 AE per 20,000 ha)

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	76
Weaners 5 months	218	0	0.23	0.06	50
Heifers 1 year but less than 2	104	0	0.59	0.04	62
Heifers 2 years but less than 3	96	3	0.84	0.40	82
Cows 3 years plus	323	43	0.88	0.54	307
Steers 1 year but less than 2	0	104	0.62	0.04	4
Bulls all ages	11	1	1.54	0.90	19
Total number.	*752*	*152*	-	-	*600*

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

2.3.2 Steer and heifer growth assumptions

The pattern of growth over time for steers and heifers influenced the markets available for both steers and surplus heifers as well as the likely mating age and reproduction performance of the heifers as they entered the breeding herd. Some evidence exists that, where the same nutrition is available, male calves grow about 8% faster than female calves pre-weaning and steers grow about 5% faster than heifers post-weaning (Fordyce *et al.* 1993). To simplify the analyses, all growth rates for heifers were set at 5% lower than male calves and steers. The average daily liveweight gain from birth to 6 months of age was set at 0.75 kg/head.day for male calves. Birth weights were uniformly set at 35 kg/head for both male and female calves. The average weight at 6 months of age was estimated to be ca. 171 kg for steers and 164 kg for heifers. Steer and heifer calves were not weaned in the base property scenario and hence some benefit was gained from the mother during this period prior to sale compared to what would be achieved by weaned calves on this property. Steer liveweight gains were predicted to be 0.3 kg/head.day for the 7^{th}- 9^{th} months of age, 0.2 kg/head/day for the 10^{th}-11^{th} months of age, and 0.3 kg/head/day for the 12^{th} month of age to achieve an average sale weight of 220 kg (in the paddock) for steers. Few, if any, heifers would be sold at this age from the base herd. If any were sold, they were expected to average 5% lower liveweight at sale than steers at the same age.

2.3.3 Husbandry treatments applied to the herd

Table 13 shows the treatments applied to the various classes of cattle held for 12 months in the model. Sale stock may or may not have received the treatment depending upon the timing of sale. The initial base herd received no vaccinations for herd health.

Table 13 - Husbandry treatments applied and cost per head for the Mulga Lands base property

Treatments	Weaners	Females 1-2 years	Females 2-3 years	Females 3+ years	Bulls
Weaner hay pre-sale	$1.00	-	-	-	-
NLIS tags	$3.50	-	-	-	-
Management tag	$1.50	-	-	-	-

2.3.4 Cattle price data

The hypothetical, base property was located near Charleville with one main selling centre at Roma. Detailed price data is available for the Roma livestock selling centre (ca. 450 km distance) and south Queensland abattoirs (ca. 650-750 km distance). These centres are relevant indicators of market prices for beef producers in the Mulga Lands region.

Price data by sale class was analysed for Roma and for Queensland over-the-hooks markets (see Meat and Livestock Australia (MLA) market statistics database at http://statistics.mla.com.au/Report/List). Figure 6 shows price trends for selected classes of sale cattle from January 2010 to December 2019. Slaughter values based on dressed weights were converted to liveweight prices using a 54% dressing percentage for males and 52% for females. Prices for sale stock have shown large variability over the last 4 years with a substantial increase in the prices paid compared to the average of the previous years.

Figure 6 - Monthly cattle prices over time for slaughter and saleyards cattle in Queensland
A-E = carcass grading; cwt = carcass weight

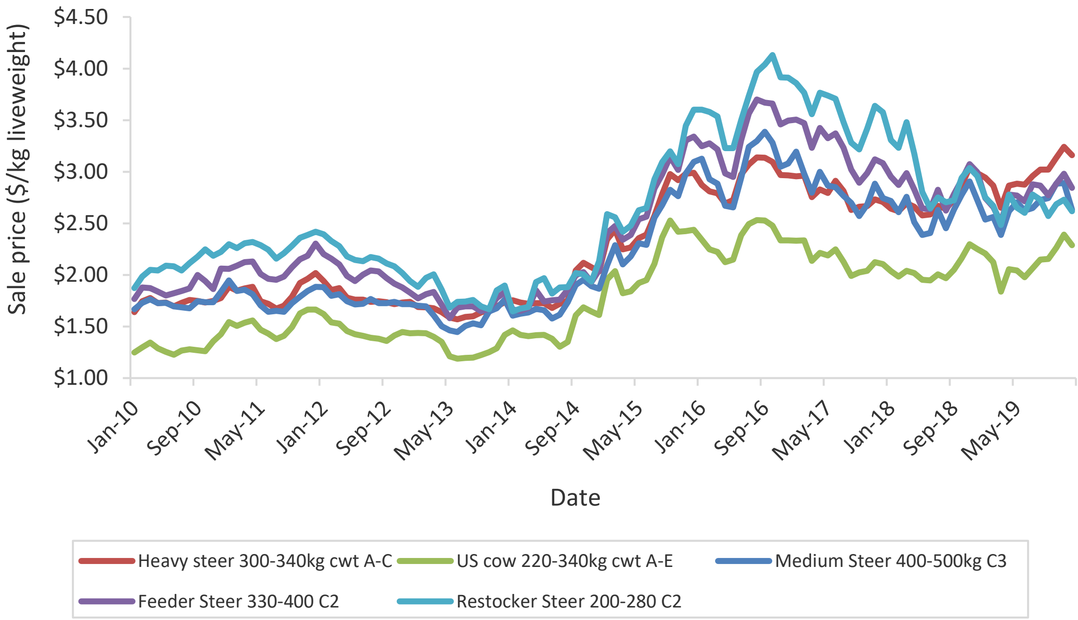


Table 14 indicates the range in average prices for relevant classes of slaughter cattle at Queensland abattoirs. Averages are calculated for the last 10, 5 and 2 years, respectively. Table 15 indicates the range in average prices for relevant classes of store cattle at the Roma sale yards for the last 10, 5 and 2 years, respectively.

Table 14 – Over-the-hooks cattle indicators for 2010 to 2019 from Queensland monthly prices in c/kg dressed weight (http://statistics.mla.com.au/Report/List)

Average price	Trade steer 240-260 kg A-C	Trade heifer 240-260 kg A-C	Medium steer 260-280 kg A-C	Heavy steer 300-400 kg A-C	US cow 220-240 kg A-E	Medium cow 260-280 kg A-E
Last 10 years	$4.11	-	$4.06	$4.16	$3.44	$3.55
Last 5 years	$5.01	$4.97	$4.99	$5.10	$4.17	$4.27
Last 2 years	$5.09	$5.04	$5.07	$5.18	$4.03	$4.13

Table 15 - Store cattle prices at Roma saleyards for 2010 to 2019

Average price over last	Steers (kg)				Heifers (kg)				Cows (kg)			
	<220	221-280	281-350	351-400	401-550	<220	221-280	281-350	351-400	300-400	401-500	>500
10 years	$2.57	$2.55	$2.47	$2.39	$2.34	$2.21	$2.19	$2.12	$2.07	$1.42	$1.65	$1.81
5 years	$3.16	$3.12	$3.03	$2.94	$2.86	$2.67	$2.65	$2.61	$2.56	$1.74	$2.02	$2.21
2 years	$2.76	$2.80	$2.79	$2.77	$2.75	$2.20	$2.29	$2.33	$2.35	$1.53	$1.85	$2.11

The recent volatility in prices, as well as the harvesting nature of some of the cattle sale activities applied to the base herd, made it very difficult to identify appropriate prices for budgeting purposes. In this analysis an ‘historical averages’ value for prices was calculated for use in the economic analysis

(Table 16). Recent livestock selling prices were averaged, for the period January 2010 to December 2019, and then applied to represent the real prices likely to be experienced in the future. No adjustment was made for the possible impact of inflation on the current value of the prices received in early years of the data. The price data was applied in the herd model to calculate the net price per head of stock sold (Table 16). Transport and other selling costs were estimated for each class of cattle to the Roma sale yards. It should be noted that the prices used in the analyses are lower than the average Roma store sale prices to account for lower weights and/or condition (e.g., Figure 7) of mulga-bred cattle run under the management conditions of the base property when compared to some of the cattle going through the Roma saleyards from better country around, and east of, Roma.

Table 16 - Sale prices applied in the analysis for the Mulga Lands base property (based on last 10 years of price data; January 2010-December 2019)

Class of cattle	Sale weight (kg)	Price ($/kg)	Comm. (% of value)	Other selling costs ($/head)	Freight ($/head)	Gross price	Total selling and freight costs	Net price
Heifer weaners	156	$1.80	3.00%	$17.00	$28.13	$280.44	$53.54	$226.90
Heifers 1 yr	200	$2.25	3.00%	$17.00	$28.13	$451.01	$58.66	$392.35
Heifers 2 yrs[A]	409	$2.25	3.00%	$17.00	$40.18	$874.24	$83.41	$790.83
Cows 3 yrs+[A]	428	$1.85	3.00%	$17.00	$43.27	$790.88	$84.00	$706.88
Steer weaners	162	$2.00	3.00%	$17.00	$28.13	$324.90	$54.88	$270.02
Steers 1 yr[A]	209	$2.45	3.00%	$17.00	$28.13	$512.05	$60.49	$451.56
Cull bulls[A]	665	$1.80	3.00%	$17.00	$70.31	$1,197.00	$121.22	$1,075.78

Comm., commission; yr, years.

[A]These are the only classes of cattle sold in the base model. The other classes are valued to allow the total herd investment to be estimated.

Figure 7 – Examples of cattle bred in the Mulga Lands and considered as representative of the base property

2.3.5 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 12 to produce the herd gross margin shown in Table 17.

Table 17 - Herd parameters and gross margin for the base property with 600AE

Parameter	Starting herd
Total AE	600
Total cattle carried	752
Weaner heifers retained	109
Total breeders mated	458
Total breeders mated and kept	418
Total calves weaned	218
Weaners/total cows mated	47.53%
Overall breeder deaths	12.50%
Female sales/total sales	30.53%
Total cows and heifers sold	46
Maximum cow culling age	13
Heifer joining age	2
Weaner heifer sale and spay	0.00%
One year-old heifer sales	0.00%
Two-year-old heifer sales	2.66%
Total steers and bullocks sold	104
Maximum bullock turnoff age	1
Average female price	$711.65
Average steer and/or bullock price	$451.56
Capital value of herd	$431,317
Imputed interest on herd value	$21,566
Net cattle sales	$79,859
Direct costs excluding bulls	$1,088
Bull replacement	$5,638
Herd gross margin	$73,132
Herd gross margin after imputed interest	$51,567
Gross margin/AE	$122
Gross margin/AE less interest on livestock capital	*$86*

AE, adult equivalent.

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

2.3.6 Expected property profit

The additional information required to complete an efficiency or profit analysis includes fixed, capital and finance expenses incurred, together with the opening and closing value of the land, plant and improvements. Fixed (or operating) 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 18 indicates 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 18 – Annual fixed cash costs for the base property

Item	Cost
Accounting	$3,500
Administration, computer, postage	$1,000
Electricity, power	$4,000
Fuel and oil	$25,000
Contract mustering	$10,000
Insurance	$10,000
Motor vehicle registration, repairs	$6,000
Rates	$5,000
Repairs and maintenance	$30,000
Telephone and internet	$1,500
Baiting	$600
Total	*$96,600*

Table 19 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 19. The replacement allowance was applied as part of the calculation of the expected 'return on total capital' (operating profit) shown in Table 20.

Table 19 - Plant inventory, replacement cost and salvage value for the base property

Item	Market value	Years to replacement	Replacement cost	Subsequent replacement	Salvage value	Replacement allowance
4wd ute	$20,000	5	$50,000	10	$10,000	$4,000
Old ute	$5,000	7	$10,000	15	$1,000	$600
Box trailer	$2,500	20	$5,000	25	$0	$200
Stock trailer	$8,000	15	$10,000	20	$1,000	$450
Tractor with bucket	$40,000	25	$60,000	35	$1,000	$1,686
Quad bike	$8,000	10	$17,000	15	$1,500	$1,033
Motor bikes x 2	$10,000	4	$12,000	10	$1,000	$1,100
Body truck	$20,000	25	$60,000	30	$10,000	$1,667
Grader/2nd dozer	$15,000	35	$40,000	45	$5,000	$778
Dozer	$30,000	35	$60,000	55	$10,000	$909
Workshop and tools	$50,000	25	$50,000	30	$0	$1,667
Total	*$208,500*	-	*$374,000*		-	*$14,089*

The allowance for operator's labour and management was set at $40,000. 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 $2,500,000. This resulted in an opening value of the total of land, plant and improvements for the property of $2,708,500. The profit analysis identified that the beef property returned about -2.47% on the capital invested over 30 years (Table 20). 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.

Table 20 - Expected value of annual outcomes for the base beef property

Parameter	Value
Adult equivalents (AE)	600
Return on total capital	-$78,213
Rate of return on total capital	-2.47%

3 Strategies to improve profitability and drought resilience

The constructed, base beef production system was used to test key strategies for their ability to improve the long-term profitability and drought resilience of the Mulga Lands property. The strategies examined in this section of the report have been identified by producers and industry as potentially useful when preparing for drought. They were assessed for their capacity to improve the drought preparedness of the base beef property through building resilience and profit over time. The results of this section relate to the hypothetical property outlined in this report and the associated assumptions made for the expected production responses to changing the management strategy. Different results may be gained 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 Implementing basic herd management

The constructed, base beef production system defined in section 2.3 was used to test the implementation of basic herd management strategies as initial steps to improve the profitability and resilience of the Mulga Lands property. As these strategies were seen as fundamental and essential to best-practice management of a beef property, they were implemented sequentially and additively. They were: (1) implementing the safe carrying capacity through herd reduction to 500 AE; (2) weaning, pregnancy testing and basic herd vaccinations; (3) targeting the optimum age of steer turnoff, and (4) inorganic supplements to address S, P and N deficiencies.

3.1.1 Managing to long-term safe carrying capacity

3.1.1.1 Introduction

Reports indicate the ongoing application of higher stocking rates and pasture utilisation rates in the Mulga Lands bioregion than indicated as ‘safe’ for maintaining pasture condition (McKeon *et al.* 2004; Commonwealth of Australia 2008). Government and grazier-supported initiatives in the 1990s south west Queensland promoted (1) property amalgamation, (2) control of total grazing pressure and (3) the objective assessment of safe livestock carrying capacities (Johnston *et al.* 1996a,b; Rose 1998). 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 (Johnston *et al.* 1996a). The safe carrying capacity (e.g., ha/AE) can be calculated by determining the expected long-term, average annual forage growth for each land type on the property (kg DM/ha), the safe level of forage utilisation (%) for that pasture and land type combination, and the expected forage intake of an AE or other livestock unit (kg DM/AE). 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 1996a). Reducing livestock numbers to match safe stocking rates (seasonal or annual) and safe carrying capacities (over 30-40 years) is expected to minimise continued pasture and soil degradation. An additional expected benefit is the improvement in livestock performance due to the ability to select a higher quality diet with proportionally higher intake of grass and herbage cf. mulga browse. However, there is a lack of relevant field research data for beef cattle in the Mulga Lands to quantify any anticipated improvements in livestock productivity which might result from implementing the safe carrying capacity at the property level. The only evidence for livestock and landscape benefits come from the observations of graziers who practice safe stocking (Stone 2004).

3.1.1.2 Methods

The representative, base property was considered to have a safe carrying capacity of ca. 500 AE, 16.7% lower than the 600 AE currently run on the property. The strategy considered was the reduction in the long-term, average stocking rate (through additional sales over the first 2 years of the analysis) to achieve stocking rates within what was considered the safe carrying capacity of the representative property. This involved the sale of a proportion of each class of female stock, at the average market price, in Year 1 to bring the herd size to the required target of 500 AE, while maintaining the herd structure. Steers were sold in Year 2 at their usual sale weight and age. The net effect of these sales over time was that the total herd size was reduced to 489 AE in Year 2 (i.e., below the target) and took until Year 10 before the herd increased to the 500 AE target.

In the absence of available data, the consensus view of local landholders and DAF staff was relied upon to derive assumptions of productivity improvements of individual livestock resulting from reducing grazing pressure from 600 to 500 AE. The productivity benefits resulting due to the reduction in grazing pressure were phased in over a 5-year period so that the stock sold in Year 5 reflected the improved performance parameters. The assumptions included:

- average breeder liveweight increased by 10 kg/head (ca. 0.5 body condition score; range 1-5), from 400 to 410 kg;
- no change in cull cow weight of 450 kg;
- female mortality rate reduced by 20% from 12.5% to 10%;
- steer mortality (5-12 months of age) reduced from 4% to 3%;
- weaning rate increased by 4.3% from 47% to 49%; and
- sale weight of steers at 10-12 months unchanged at 220 kg.

There was expected to be considerable variation around these parameters over time, but the assessment was that a reduction in the average stocking rate on the property of 16.7% would lead to these differences in herd performance on average.

The herd bulls purchased per year as a percentage of herd bulls required figure was unchanged from the starting herd at 15%. An overall proportion of bulls to cows of 2.5% was also maintained and bull mortality was remained at an average of 5%/annum. Table 21 shows the changed conception and mortality rates applied in the herd model following implementation of a safe carrying capacity of 500 AE.

Table 21 - Reproduction parameters and mortality rates for the Mulga Lands property following implementation of the safe carrying capacity of 500 AE

Initial cattle age **Final cattle age**	**6 months** **1**	**1** **2**	**2** **3**	**3** **4**	**4** **6**	**6** **7**	**7** **8**	**8** **13**
Expected conception rate for age group (%)	n/a	0	60	20	65	60	60	60
Expected calf loss from conception to weaning (%)	n/a	0	12	10	10	10	10	12
Female death rate (%)	3	6	10	10	10	10	10	10
Male death rate (%)	3	6	6	6	6	n/a	n/a	

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

3.1.1.3 Results and discussion

Table 22 provides a comparison of herd performance at the end of the 30-year period for two steady-state herd models representing 600 AE and 500 AE. The 600 AE herd data is for the starting herd prior to the change while the 500 AE (safe carrying capacity) herd data is for the end result following full implementation of the change. The 500 AE herd model was optimised for cow and heifer culling age.

Table 22 - Comparison of steady-state herd models for the 500 AE safe carrying capacity herd and the 600 AE herd on the Mulga Lands property

Parameter	500 AE herd (Safe carrying capacity)	600 AE herd (Base)	Difference
Total AE	500	600	-100
Total cattle carried	615	752	-137
Weaner heifers retained	91	109	-18
Total breeders mated	369	458	-89
Total breeders mated and kept	336	418	-82
Total calves weaned	182	218	-36
Weaners/total cows mated	49.16%	47.53%	1.63%
Weaners/cows mated and kept	54.02%	52.02%	2.00%
Overall breeder deaths	10.00%	12.50%	-2.50%
Female sales/total sales %	35.83%	30.53%	5.30%
Total cows and heifers sold	49	46	3
Maximum cow culling age	13	13	0
Heifer joining age	2	2	0
Weaner heifer sale and spay	0.00%	0.00%	0.00%
One-year-old heifer sales %	0.00%	0.00%	0.00%
Two-year-old heifer sales %	14.45%	2.66%	11.80%
Total steers and bullocks sold	88	104	-16
Maximum bullock turnoff age	1	1	0
Average female price	$727.31	$711.65	$15.66
Average steer/bullock price	$451.56	$451.56	$0.00
Capital value of herd	$349,272	$431,317	-$82,044
Imputed interest on herd value	$17,464	$21,566	-$4,102
Net cattle sales	$75,514	$79,859	-$4,345
Direct costs excluding bulls	$908	$1,088	-$181
Bull replacement	$4,546	$5,638	-$1,092
Herd gross margin	$70,060	$73,132	-$3,072
Herd gross margin less interest on livestock capital	$52,596	$51,567	$1,030
Gross margin/AE	$140	$122	$18
Gross margin/AE after interest	*$105*	*$86*	*$19*

AE, adult equivalent.

Figure 8 indicates that the cumulative cash flow of the property, for both the 600 and the 500 AE herd, was negative at the end of 10 years and was continuing to decline. Neither the safe carrying capacity scenario (additional cattle sales over Years 1 and 2 to achieve a reduction to 500 AE) nor the base scenario (600 AE) was sufficiently profitable to pay the total costs of the property. The safe carrying capacity scenario relied upon the initial release of capital associated with the herd reduction to provide improved cash flow in the early years of the analysis. However, the long-term herd output associated with the safe carrying capacity scenario was not capable of making the property substantially more profitable than the base scenario which had higher grazing pressure and lower assumed individual animal performance. Figure 8 indicates that the property manager who makes no other change, other than to reduce stocking rates in line with safe carrying capacity estimates, is likely to have the same low chance of remaining viable as the beef producer who utilises higher stocking rates.

Figure 8 – Cumulative cash flow over 10 years for the Mulga Lands property with 600 adult equivalents (AE) and with reduction to 500 AE (considered to be the safe carrying capacity) through additional cattle sales made over Years 1 and 2

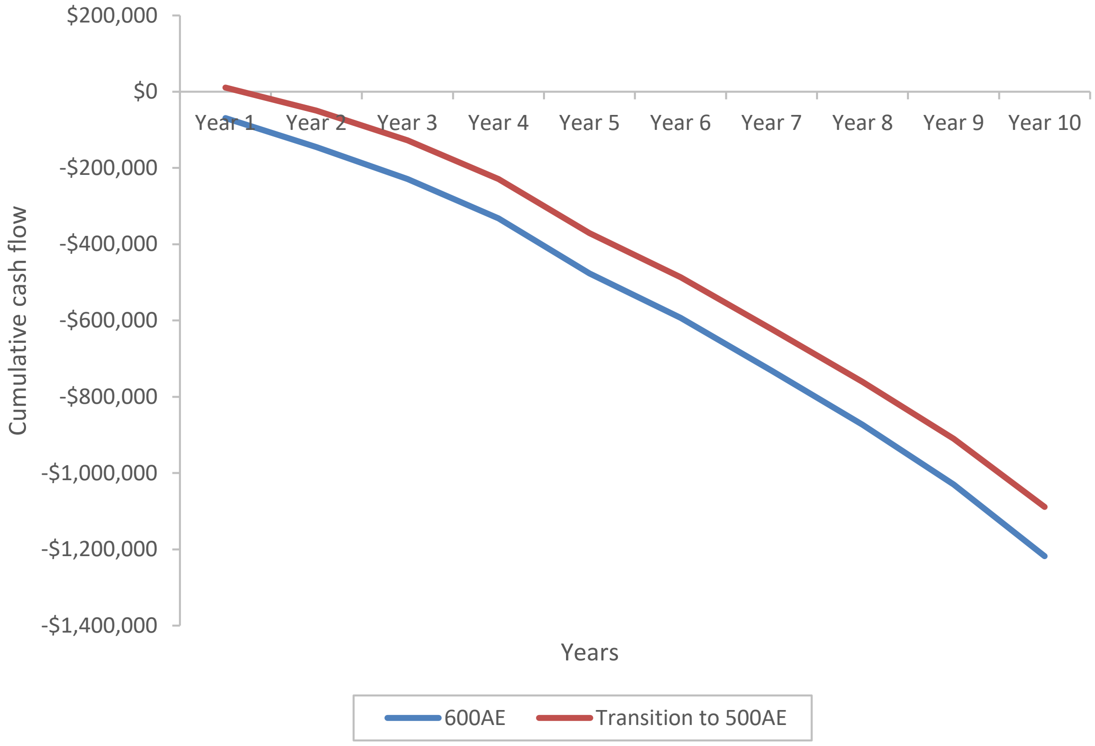


Table 23 shows the summary of the economic and financial impact resulting from the reduction in the long-term average stocking rate from 600 to 500 AE to match what was considered the safe carrying capacity of the representative property. The analysis period was 30 years with a 5-year, phase-in of the improved performance of the cattle herd. Although about $60,000 worth of livestock capital was freed up during the 2-year period of the adjustment to the new average stocking rate, the long-term economic and financial outlook for the property was not substantially improved with only $520/annum additional profit expected as a result of the change. The annual return on assets invested at the property-level remained similar to that when running 600 AE, at ca. -2.60%.

The use of the average market price to value the stock sold as part of the herd reduction may have overstated their value as they are unlikely to be in the same average condition as the normal sale cattle. An overstatement of the value of the stock sold as a part of the herd reduction would improve the returns accruing to the conversion and understate the peak deficit incurred. Another consideration is that the assumptions made here about animal performance parameters have been made in the absence of any field research to indicate likely change resulting from reduced grazing pressure in the Mulga Lands. This analysis should therefore be considered as a scoping exercise in the absence of data to validate these assumptions. Regardless, the outcome of this strategy is consistent with a similar scenario for a Northern Gulf property (30,000 ha; 2,500 initial AE) where reduction in stocking rate to match the long-term safe carrying capacity was estimated to result in $15,000/annum extra profit over 30 years but the property remained unviable as indicated by the negative and declining cumulative cash flow (Bowen *et al.* 2019a). As for the Northern Gulf property, it is evident that further improvements to herd and property management need to be identified and investigated for their ability to improve profitability and resilience of the representative Mulga Lands property.

Table 23 - Returns for the strategy of reducing the long-term, average stocking rate of the Mulga Lands property to match the safe carrying capacity of the property (500 AE), compared to the 600 AE base herd and property

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Discount rate for NPV	5%
NPV	$7,993
Annualised NPV	$520
Peak deficit (with interest)	-$16,988
Year of peak deficit	30
Payback period (years)	n/c
IRR	4.25%

3.1.2 Weaner management, pregnancy testing and basic herd vaccinations

3.1.2.1 Introduction

Weaning calves is a well-established practice in northern Australia and has long been advocated as the single most effective management strategy to manage breeder body condition and thus improve fertility and weaning rates, and reduce breeder mortalities (Dixon 1998; Tyler *et al.* 2012). In seasonally mated herds, calves in northern Australia are commonly weaned at 4-8 months of age between April and June. In continuously mated herds, the recommendation is to wean all calves over 100 kg at the first muster (April-June), (Tyler *et al.* 2012). While good quality hay is the minimum requirement for weaners while in the yard, calves weaned under 150 kg also require supplements of highly digestible protein and energy if pasture quality is poor. In difficult dry periods calves can be weaned earlier (<100 kg liveweight and 3 months of age) but will require adequate supplementation with calf meals or pellets, and with milk replacer if under 60 kg.

Pregnancy testing is also considered a valuable management tool in an extensive beef cattle enterprise (The State of Queensland 2021a). Pregnancy testing allows identification of non-productive breeders and heifers for culling (sale) and, in herds with uncontrolled mating, allows segregation and appropriate management of high-risk cows due to calve in dry periods. Additionally, pregnancy testing allows estimation of calving distribution so that the timing of weaning can be better planned, to manage cow body condition and supplementation programs.

In addition to weaning and pregnancy testing, basic vaccinations for herd health are also considered best-practice management to reduce mortality rates, and maximise fertility and weaning rates, of breeding herds (The State of Queensland 2020d). Cattle deaths from botulism due to osteophagia (bone-chewing) can be substantial in herds grazing P-deficient land types, even when supplemented with P (e.g., as outlined in Bowen *et al.* 2020b). Botulism is a disease caused by the botulinum toxin, which is produced by the bacterium *Clostridium botulinum* commonly present in rotting animal or vegetable material. In high-risk situations and environments, vaccination against botulism is the only effective way to prevent botulism from occurring. Hence the best-practice recommendation is that all herds grazing P-deficient land types receive botulism vaccination (The State of Queensland 2020d). Vaccination against clostridial diseases in calves and the reproductive diseases, leptospirosis and vibriosis, are also considered basic best-practice management to maximise fertility and weaning rates of breeding herds (The State of Queensland 2020d).

3.1.2.2 Methods

In the original base herd of 600 AE, and in the safe carrying capacity herd of 500 AE, sale steers were left on their mothers until they were sold at an average of 12 months of age. An alternative strategy considered here was to wean calves at about 6 months of age and then sell them at the same age as they were sold in the base herd. In this strategy, weaning activities were implemented twice a year with calves separated and weaned at an average weaning weight ca.167 kg liveweight. No additional mustering activities were required as the weaners were separated at the usual mustering events. Weaners were fed hay for a 10-day period post-weaning at a cost of $5/head. The extra labour required for post-weaning activities was costed at $50/day for 10 days, for each weaning. The total extra labour cost was calculated at $1,000/annum and added to the operating overheads, even though it would be unpaid on many similar properties. Pregnancy test expenses ($5/cow) were included in this strategy to enable cull cows to be identified for sale. In addition, a basic vaccination program for prevention of botulism ($1/head), leptospirosis ($2.20 for yearling heifers, $1.28 all other females), vibriosis ($12/bull) and clostridial diseases ($1.50/calf) was implemented concurrently. Weaning, pregnancy testing and basic herd vaccinations were introduced concurrently with the herd reduction (600 to 500 AE) that occurred over Years 1-2 of the analysis. The productivity benefits resulting due to these combined management strategies were phased in over a 5-year period so that the stock sold in Year 5 reflected the improved performance parameters. Compared to the 500 AE herd (i.e., the herd achieved after the first step of implementing basic herd management strategies), the following performance was achieved by the end of Year 5 due to implementing weaning, pregnancy-testing and basic herd vaccinations:

- average breeder liveweight increased by 10 kg/head (ca. 0.5 body condition score; range 1-5), from 410 to 420 kg;
- cull cow weight reduced by 60 kg from 450 to 390 kg;
- female mortality rate reduced by 40% from 10% to 6%;
- steer mortality (5-12 months of age) reduced from 3% to 2.5%;
- weaning rate increased by 16.3% from 49% to 57.28%; and
- sale weight of steers, at 10-12 months of age, reduced by 15 kg from 220 to 205 kg.

The improved reproduction efficiency allowed more cows to be culled on performance at weaning causing the sale of some lighter cows and hence a reduction in average cull cow liveweight. It should be noted that there was no capacity on the constructed property to hold cull cows until they were heavier unless they were spayed. Pregnancy testing was conducted to enable cull cows to be identified but spaying was not implemented.

Conception rates increased in mature breeders but the conception rates in the 2-3-year-old heifers and the first-calf heifers (3-4 years old) were expected to be unchanged and were retained at the same level as for the base herd. Table 24 indicates the parameters for conception rate, calf loss and mortality rates applied in the 500 AE herd model with weaning, pregnancy testing and basic herd vaccinations applied.

Table 24 - Reproduction parameters and mortality rates for the for the 500 adult equivalent (AE) steady-state herd, with weaning, pregnancy testing and basic herd vaccinations

Initial cattle age **Final cattle age**	**Weaners** **1**	**1** **2**	**2** **3**	**3** **4**	**4** **6**	**6** **8**	**8** **13**
Expected conception rate for age group (%)	n/a	0	60	20	75	75	75
Expected calf loss from conception to weaning (%)	n/a	0	12	10	10	10	12
Female death rate (%)	3	6	6	6	6	6	6
Male death rate (%)	2.5	6	6	6	6	n/a	n/a

n/a: not applicable.

The application of the data for reproduction efficiency and mortality rates to the herd model produced an expected average branding rate of 57.28% (branded calves from all cows mated). Although sale steers were expected to be 15 kg/head lighter than those sold from the base herd at the same age of sale (205 kg for weaner management vs. 220 kg for the base 600 AE herd and also the 500 AE herd without weaning) the sale prices were maintained at the same level in this scenario.

The allowance for operator's labour and management was increased (by $5,000/annum) to a total of $45,000, to compensate the manager for the increased workload and necessary increase in skill levels above that applied for the base herd.

3.1.2.3 Results and discussion

Table 25 compares two steady-state herd models: the 500 AE herd with and without weaning, pregnancy testing and vaccinations fully implemented. The herd model was optimised for cow and heifer culling age once the new strategy was implemented. The maximum age of cow culling remained at 13 years with additional culling pressure placed on the heifers 1-2 years of age. The culling percentage for the latter age group increased from 0% to 11.23%. Although the conception rates in mature cows increased, the conception rates for younger females were unchanged. The combined result was the percentage of weaners produced from cows mated increasing from 49.16% to 57.28%. The additional labour was not included in the gross margin calculation but was included in the investment analysis (Table 26).

Table 25 - Comparison of steady-state herd models for the 500 adult equivalent (AE) herd and the same herd after full implementation of weaning, pregnancy testing and basic vaccinations for herd health

Parameter	500 AE herd with weaning, pregnancy testing and basic vaccinations	500 AE herd safe carrying capacity	Difference
Total AE	500	500	0
Total cattle carried	625	615	10
Weaner heifers retained	106	91	15
Total breeders mated	370	369	1
Total calves weaned	212	182	31
Weaners/total cows mated	57.28%	49.16%	8.12%
Overall breeder deaths	6.00%	10.00%	-4.00%
Female sales/total sales %	43.21%	35.83%	7.38%
Total cows and heifers sold	79	49	30
Maximum cow culling age	13	13	0
Heifer joining age	2	2	0
One-year-old heifer sales %	11.23%	0.00%	11.23%
Two-year-old heifer sales %	40.00%	14.45%	25.55%
Total steers and bullocks sold	103	88	15
Maximum bullock turnoff age	1	1	0
Average female price	$646.32	$727.31	-$80.99
Average steer/bullock price	$417.69	$451.56	-$33.87
Capital value of herd	$323,286	$349,272	-$25,986
Imputed interest on herd value	$16,164	$17,464	-$1,299
Net cattle sales	$94,059	$75,514	$18,545
Direct costs excluding bulls	$5,932	$908	$5,024
Bull replacement	$4,560	$4,546	$14
Herd gross margin	$83,567	$70,060	$13,507
Herd gross margin less interest on livestock capital	$67,403	$52,596	$14,807
Gross margin/AE	$167	$140	$27
Gross margin/AE after interest	*$135*	*$105*	*$30*

Table 26 indicates the property-level returns resulting from implementing the safe carrying capacity plus a weaning strategy, pregnancy testing and basic herd-health vaccinations. The comparison was to the 600 AE base herd with low-level herd management. The benefit from implementing these combined strategies was minimal ($173 extra profit/annum) in relation to the $5,000/annum additional expense required for the increase in management skills and labour. Although a substantial improvement in gross margin was identified from implementing these combined strategies compared to implementing safe carrying capacity alone (Table 25), the extra benefits of the weaning, pregnancy testing and vaccinations did not offset all of the extra costs when the additional management skill and labour required was appropriately compensated.

Table 26 - Returns for implementing safe carrying capacity, weaning, pregnancy testing and basic herd vaccinations for the 600 AE base herd on the Mulga Lands property

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Discount rate for NPV	5%
NPV	$2,660
Annualised NPV	$173
Peak deficit (with interest)	-$14,976
Year of peak deficit	30
Payback period (years)	n/c
IRR	4.58%

3.1.3 Optimal age of steer turnoff

3.1.3.1 Introduction

The optimal age of male turnoff on beef properties in northern Australia is driven by the relative profitability of breeders and steers. This, in turn, is a function of breeder productivity, steer performance, available markets, and the relative price of steer and female beef (Holmes *et al.* 2017; The State of Queensland 2020e). 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 (The State of Queensland 2020e).

The annual weight gain of steers and heifers in regions of northern Australia with highly variable nutrition, both inter-annual and intra-annual, has been found to decline with increasing age (Cowley 2012). Additionally, there is evidence that growth during the first post-weaning dry season is influenced by weaning weight (Schatz 2011). Table 27 shows the expected impact of weaning weight on weight loss during the period after weaning in the seasonally dry tropics estimated by Schatz (2011).

Table 27 - Estimated dry season average daily gain of steers and heifers, for the first post-weaning dry season, in the seasonally dry tropics of northern Australia (Schatz 2011)

Weaning weight range (kg)	Dry season average daily gain (kg/day)
100-120	-0.022
121-140	-0.038
141-160	-0.054
161-200	-0.070
201-220	-0.086
221-240	-0.102
241-260	-0.118
261-280	-0.134

Table 28 shows the expected seasonal weight gain for steers and heifers from Cowley (2012) with different seasons of weaning. Round 1 weaners are normally weaned around May to early June and Round 2 weaners are those calves weaned later in the year during late September or October.

Table 28 - Post-weaning average daily gain average daily (kg/day) of steers and heifers in the seasonally dry tropics of northern Australia (Cowley 2012)

	Steers		**Heifers**	
Season	**Round 1 weaners**	**Round 2 weaners**	**Round 1 weaners**	**Round 2 weaners**
Wet 1	0.55	0.52	0.50	0.47
Dry 2	0.14	0.14	0.13	0.13
Wet 2	0.50	0.50	0.45	0.45
Dry 3	0.11	0.11	0.10	0.10
Wet 3	0.42	0.42	0.38	0.38
Dry 4	0.11	0.11	0.10	0.10
Wet 4	0.33	0.33	0.30	0.30

The combination of the potential weight gain during different growth periods from Cowley (2012) with the influence of weaning weight on the immediate post weaning weight loss shown by (Schatz 2011) indicates that:

- steers growing from 24 months to 36 months of age will achieve 88% of the potential weight gain of steers growing from 12 months to 24 months of age;
- steers growing from 36 months to 48 months of age will achieve 76% of the potential weight gain of steers growing from 12 months to 24 months of age; and
- steers growing from 48 months to 60 months of age will achieve 64% of the potential weight gain of steers growing from 12 months to 24 months of age.

This combined information can be used to estimate growth paths for steers in regions of northern Australia with similar nutrition and hence to inform calculations of optimal age of steer turnoff.

3.1.3.2 Methods

The effect of steer sale ages on the profitability of the Mulga Lands property was initially modelled by comparing the alternative ages in a steady-state herd model consisting of 500 AE on the property after full implementation of weaning, pregnancy testing and basic vaccinations. Steers that were weaned in the Mulga Lands analyses were assumed to have an annual rate of weight gain that fell as steers aged, similar to that found in the analysis of Cowley (2012) and Schatz (2011) even though the research was conducted in a different region with a monsoonal rainfall pattern. This approach was taken here due to the similarities between both regions in management of steers and the variability of paddock nutrition post-weaning, as well as the lack of local data from the Mulga Lands to support alternative assumptions. Table 29 shows the assumed annual weight gain for steers in the Mulga Lands herd model as they age.

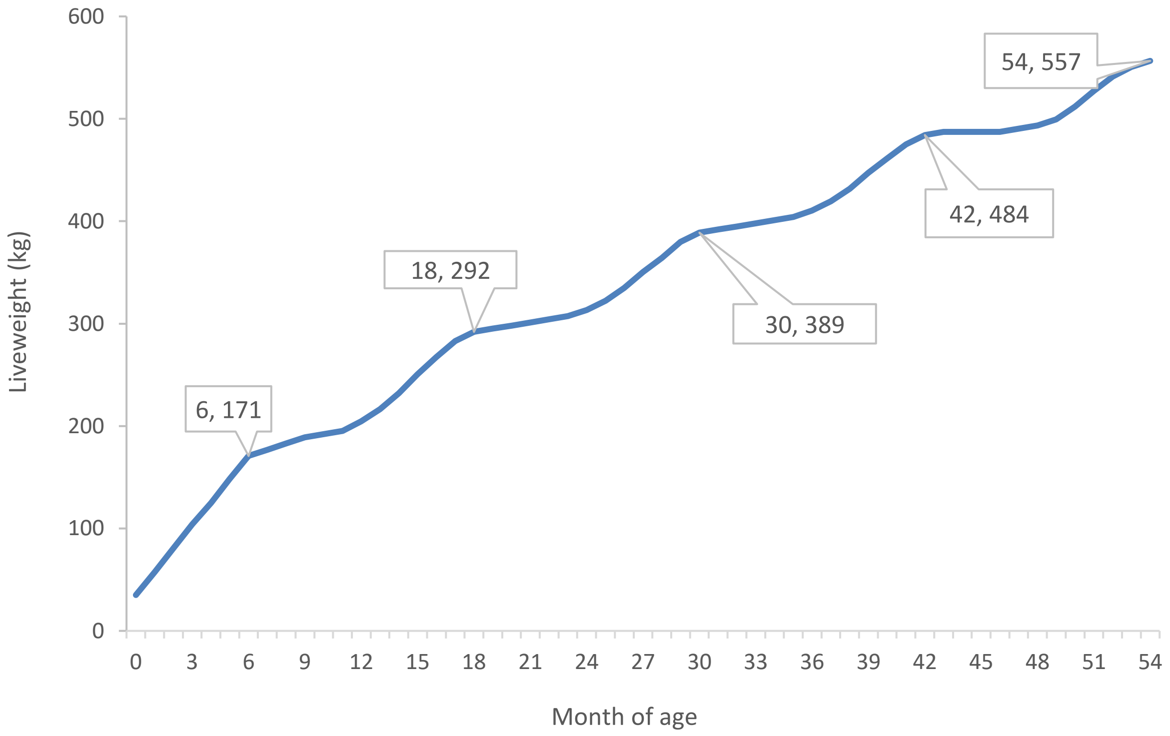
Table 29 – Assumed steer weight gain post-weaning on the Mulga Lands base property with basic herd management in place except inorganic supplementation

Month of age	Steer liveweight (kg)	Average daily gain for previous 12 months (kg/head.day)	Annual liveweight gain over previous 12 months (kg/head)	Liveweight gain as a % of 6-18-month weight gain
18	292	0.34	115	-
30	389	0.28	94	82%
42	484	0.28	92	80%
54	557	0.21	69	60%

Figure 9 shows the estimated growth path of steers on the Mulga Lands property and the potential average liveweight of the steers in May at weaning (6 months old) and in May in each subsequent year when they were 18, 30, 42 and 54 months old. These weights are based on the level of performance shown in Table 29.

Figure 9 - Steer liveweight from birth to point of sale, showing alternative steer sale ages and weights for the Mulga Lands base property with basic herd management in place except inorganic supplementation

Boxes on the graph give steer age (months) and sale liveweight (kg)



The effect on steady-state profit of selling steers at alternative ages (and restructuring the herd to maintain equivalent grazing pressure) was assessed to determine the optimum age of turnoff. The 500 AE herd currently turning off yearling steers directly from their mothers was used as a base for comparison (i.e., the first step in the transition to basic herd management strategies). Roma saleyards prices were adjusted to reflect the expected quality and condition of the Mulga Lands property steers at each age of sale, as described in section 2.3.4. The steer sale age scenarios were modelled as follows:

(1) All steers were sold as weaners when 6 months old at an average of 171 kg in the paddock. The sale price at the Roma yards was $2.00/kg liveweight.

(2) All steers were sold at 18 months of age at an average of 292 kg liveweight in the paddock. The sale price was $2.45/kg liveweight.

(3) All steers were sold at 30 months old at an average of 389 kg liveweight. The sale price was $2.35/kg liveweight.

(4) All steers were sold at 42 months old at an average of 484 kg liveweight. The sale price was $2.25/kg liveweight.

(5) All steers were sold at 54 months old at an average of 557 kg liveweight. The sale price was $2.20/kg liveweight.

Secondly, the 600 AE starting herd with minimal management was used as a base for conversion to the optimum age of turn-off determined in the initial stage of this analysis. The safe carrying capacity, weaning, pregnancy testing and herd vaccinations were also implemented concurrently.

3.1.3.3 Results and discussion

3.1.3.3.1 Optimising age of steer turnoff

The effect on herd gross margin of selling steers at five alternative ages: 6, 18, 30, 42 and 54 months-old, was considered for the 500 AE steady-state herd with weaning, pregnancy testing and basic vaccinations in place. As indicated in Table 30, a steer sale age of 18 or 30 months generated similar herd gross margins after interest with the 18-month sale age being the most profitable at $83,336. Selecting an 18-month or 30-month sale age for steers was substantially more profitable than the practice of selling steers off their mothers at 12 months of age which was the base scenario. The results of the gross margin analysis indicated that the number of breeders retained on the property fell as the age of turnoff of steers increased to maintain equivalent grazing pressure on the property.

Table 30 - Steer age of turnoff herd gross margin comparison for a 500 adult equivalent (AE) herd with weaning, pregnancy testing and basic herd vaccinations in place

The base for comparison was the 500 AE herd turning off 12-month-old steers

Parameter	**Age of steer turnoff**					
	6 months (Weaners)	**12 months (Base)**	**18 months**	**30 months**	**42 months**	**54 months**
Total AE	500	500	500	500	500	500
Total cattle carried	542	625	596	615	610	594
Weaner heifers retained	111	106	101	90	78	69
Total breeders mated	387	370	353	313	274	240
Total breeders mated and kept	326	312	298	263	231	202
Total calves weaned	222	212	202	179	157	137
Weaners/total cows mated	57.28%	57.28%	57.28%	57.28%	57.28%	57.28%
Overall breeder deaths	6.00%	6.00%	6.00%	6.00%	6.00%	6.00%
Female sales/total sales	42.59%	43.21%	43.21%	44.73%	46.26%	47.81%
Total cows and heifers sold	82	79	75	66	58	51
Maximum cow culling age	13	13	13	13	13	13
Heifer joining age	2	2	2	2	2	2
One-year-old heifer sales	11.23%	11.23%	11.23%	11.23%	11.23%	11.23%
Two-year-old heifer sales	40.00%	40.00%	40.00%	40.00%	40.00%	40.00%
Total steers and bullocks sold	111	103	99	82	67	56
Maximum bullock turnoff age	0	1	1	2	3	4
Average female price	$646.32	$646.32	$646.32	$646.32	$646.32	$646.32
Average steer/bullock price	$270.02	$417.69	$610.99	$786.60	$941.51	$1,061.07
Capital value of herd	$307,740	$323,286	$308,266	$326,148	$341,853	$355,348
Imputed interest on herd value	$15,387	$16,164	$15,413	$16,307	$17,093	$17,767
Net cattle sales	$83,036	$94,059	$108,753	$107,456	$101,091	$91,918
Direct costs excluding bulls	$6,085	$5,932	$5,657	$5,093	$4,529	$4,029
Bull replacement	$4,762	$4,560	$4,348	$3,848	$3,367	$2,951
Herd gross margin	$72,189	$83,567	$98,749	$98,515	$93,195	$84,938
Herd gross margin less interest on livestock capital	***$56,802***	***$67,403***	***$83,336***	***$82,207***	***$76,103***	***$67,170***
Difference to base herd	*-$10,602*	*Base*	*$15,933*	*$14,804*	*$8,699*	*-$233*

3.1.3.3.2 Moving from yearling steer production to an older age of turnoff

Table 31 shows the results of the 30-year analysis of the value of converting from yearling to 18-month-old steer sale age which was the most profitable age of turnoff identified in the steady-state analysis (Table 30). The base was for comparison was the 600 AE base herd. The optimum age of turnoff was implemented concurrently with the safe carrying capacity, weaning, pregnancy testing and basic herd vaccinations so the result was the combined effect of implementing these strategies. Implementing this combination of strategies added ca. $12,400 to the annual profit of the enterprise. However, despite this improvement the total property returns were still negative at -1.88%.

The results for the Mulga Lands region, indicating that 6-month, weaner steer production is the least profitable age of turnoff, are in accord with results for the Northern Gulf, Northern Downs and central Queensland regions (Bowen and Chudleigh 2018b; Bowen *et al.* 2019a; Bowen *et al.* 2020a). Moving from a 6-month weaner turnoff production system (or base situation of 12 months turnoff in the Mulga Lands) to one producing older steers improved profit and also improved drought resilience due to a reduction in the size of the breeder herd at the same grazing pressure. This result is, in part, due to low breeder efficiency (e.g., ranging from 47.5% branding rate for the Mulga Lands 600 AE base herd with low-level management to 78% weaning rate in central Queensland) as well as the relatively lower value of female beef compared to steer beef.

Table 31 - Returns for implementing the safe carrying capacity, weaning, pregnancy testing, basic herd vaccinations and an 18-month steer sale age compared to the initial 600 adult equivalent (AE) base herd with low-level management in the Mulga Lands

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Discount rate for NPV	5.00%
NPV	$190,689
Annualised NPV	$12,405
Peak deficit (with interest)	n/c
Year of peak deficit	n/c
Payback period (years)	n/c
IRR	n/c

3.1.4 Inorganic supplements

3.1.4.1 Introduction

Low levels of strategic, inorganic, supplements such as P and non-protein N (urea) constitute one of the few low-cost options for beef producers in northern Australia to reduce the effects of nutritional deficiencies in pasture and thus increase breeder productivity (McCosker and Winks 1994; Dixon 1998). Soils in the Mulga Lands are characterised as, in general, having a severe deficiency of available P and N (Dawson and Ahern 1973; Beale 1994; McLennan *et al.* 1999; P. Zund, pers. comm.). In the Mulga Lands, P and N deficiency is further exacerbated when the livestock diet contains high proportions of mulga browse (e.g., McMeniman and Little 1974; Hoey *et al.* 1976; McMeniman 1976; McMeniman *et al.* 1981; Niven and McMeniman 1983). Additionally, when consuming a large proportion of the diet as mulga browse, S and sodium also become limiting (e.g., McMeniman *et al.* 1986a; Clarke 1991). An additional limitation when consuming diets of primarily mulga browse is the low digestibility (ca. 45% dry matter digestibility (DMD)) and voluntary intake which severely curtails performance (e.g., Norton *et al.* 1972; McMeniman 1976; McDonald and Ternouth 1979; Miller and Pritchard 1988; Strachan *et al.* 1988). Studies with sheep fed a diet of mulga browse have indicated a low and variable daily DM intake within the range 23-58 $g/kg^{0.75}$ (Entwistle and Baird 1976; Pritchard *et al.* 1985; Miller *et al.* 1997). In addition to condensed tannins, mulga contains a range of secondary metabolites that can detrimentally affect DM intake and nutrient digestion (oxalates, Gartner and Hurwood 1976; terpenes and saponins, Pedrotti and Fox 1979). Previous research efforts to improve the nutritive value of mulga through alleviating the effects of the condensed tannins, via supplementation with polyethylene glycol (Pritchard *et al.* 1992; Robins and Brooker 2005) or inoculation with rumen fluid from mulga-fed feral goats (Miller *et al.* 1995, 1996, 1997), did not meet with commercial success. However, research to determine the appropriate formulation of inorganic supplements (e.g., Niven and McMeniman 1983) has allowed nutrient deficiencies to be alleviated in ruminants grazing the Mulga Lands through use of commercially available products.

In a large body of work conducted with sheep in both pens and in grazing studies, S was shown to be the primary limiting nutrient when a substantial proportion of the diet was mulga browse (e.g., Hoey *et al.* 1976; Gartner and Niven 1978). This was considered partially a result of the low digestibility of the protein, and as a consequence of the S, in mulga browse. The S content of mulga browse has been measured as 1.2-1.5 mg/g DM (Gartner and Hurwood 1976; Vercoe 1987). The dietary requirements for S are primarily determined by its essentiality for the synthesis of proteins by the ruminal microorganisms. Therefore, S requirements are commonly expressed as a fraction of the N supply from the feed. For efficient synthesis of rumen microbial protein, NRDR (2007) recommended a N:S ratio of no wider than 14.3 : 1 for cattle, or ca. 1.5 g S/kg DM. Sheep grazing mulga-grassland sites were found to consume a diet of 0.9 g S/kg DM (N:S ratio 16.8 : 1) in the dry period when mulga browse formed 35% of the diet DM (McMeniman *et al.* 1986a), indicating a S deficiency for cattle. In the same experiment, during pasture growing periods when mulga browse formed 6% or less of the diet DM the S supply from the diet appeared adequate for cattle: 1.8 g S/kg DM (N:S ratio 13.7-14.0 : 1).

During dry periods in northern Australia the N content of grazed 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, as in the Mulga Lands. 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). The situation in the Mulga Lands is complicated by the consumption of mulga browse. Despite a crude protein (CP) content of 10-14% (Everist *et al.* 1958; Everist 1969), the digestibility of this protein is low (30-40%) due to high levels of tannins (11-14% of the DM), (Harvey 1952; Gartner and Hurwood 1976; McMeniman *et al.* 1981). The evidence of a response to urea, in supplements for sheep consuming a solely mulga browse diet to imitate a drought feeding situation, is inconsistent (e.g., McMeniman 1976; Entwistle and Baird 1976; Pritchard *et al.* 1992). In some experiments, the efficiency of microbial protein production and faecal N content was greater than expected given the N availability in the feed (e.g., McMeniman *et al.* 1986b; Goodchild 1989) suggesting either a compensatory, tannin-induced increase in microbial growth or a tannin-induced damage to the gut epithelium. However, urea is commonly added to dry period, commercial mixes for the Mulga Lands, even when cattle are primarily consuming mulga browse, to balance the low level of available N in such diets.

In the Mulga Lands, as in many rangeland regions in 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, bone breakage and, in severe cases, bone deformities. In addition to such poor 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 Mulga Lands of south west Queensland (McCosker and Winks 1994; P. Zund, pers. comm.) indicate that most grazing properties are likely to be deficient to acutely deficient in P on average (defined by Bowen *et al.* (2020b) as <6 ppm bicarbonate extracted P (Colwell 1963) in the top 100 mm soil). Grazing studies with sheep in the Mulga Lands have shown that P concentrations in the diet were always low (0.7-

1.1 g/kg DM) regardless of seasonal conditions (McMeniman *et al.* 1986a) and limiting for animal production. Research with sheep consuming solely mulga browse (which contains ca. 0.7-0.9 g P/kg DM; e.g., McMeniman 1976; Pritchard *et al.* 1992) to imitate a drought feeding situation found that P supplementation increased digestibility of the mulga and hence increased intakes so long as a source of S was also provided (e.g., McMeniman 1976; Hoey *et al.* 1976).

Past 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 pasture 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 (Dixon *et al*. 2017; Anderson *et al*. 2017). Thus, when P supplements are fed during the dry season the P can be stored in bone and used later during the wet season. Supplementation programs during dry periods generally involve fewer practical and logistical difficulties than feeding supplements during the wet pasture growing season when access to wet and boggy paddocks to distribute supplements is often difficult. Additionally, it is often difficult to achieve voluntary intake of loose mix supplements in the amounts required to provide for P deficiencies in the pasture. 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 best-practice recommendation and there is extensive anecdotal information from the industry suggesting that this is effective to at least alleviate the low productivity from P deficiencies (Jackson *et al.* 2012).

In the Mulga Lands, provision of loose licks supplying S, N and P have long been recommended for both cattle and sheep consuming some component of their diet as mulga browse to increase feed intake (by up to 20-30%) and thereby reduce rate of liveweight loss and mortality (Clarke 1991; O'Dempsey 1992; NSW Department of Primary Industries 2016; The State of Queensland 2020a).

3.1.4.2 Methods

In this strategy, the improvement in animal performance due to whole-herd supplementation with appropriate inorganic supplements was examined for a 500 AE base herd with safe carrying capacity, weaning, pregnancy testing, basic vaccinations and optimal age of steer turnoff already in place as per section 3.1.3. The effect of inorganic supplements was compared to the new base herd, with initial basic management strategies already in place, over a 30-year analysis period. For the purposes of this exercise, and in the absence of better data, the whole herd was assumed to be P-deficient and to consume a diet of ca. 10% or less mulga browse during pasture growing periods and ca. 30%, or greater, of the diet as mulga browse during dry periods (extrapolated from McMeniman *et al.* 1986a).

Three scenarios were modelled, each with supplements (mineral loose mixes) designed to provide adequate S and P in the pasture growing periods and/or dry periods and in combination with N in dry periods:

1) S, P, N in dry periods (Dry period supplement)

2) S, P in growing periods (Growing period supplement)
3) S, P, N in dry periods and S, P in growing periods (Dry period supplement and Growing period supplement).

Supplement composition, supplement and nutrient intakes, estimated responses to supplementation strategies, and costs of supplementation were as described in Table 32 to Table 34. The dry period supplement was a custom mix for the mulga country produced by a commercial company. It contained protein meal to overcome practical difficulties with cattle eating target amounts of lower cost, dry period supplements. Additionally, the commercial mix contained gypsum and molasses. The growing period supplement was costed as a pre-mixed product made to requested specifications. Weaner cattle were assigned a feeding period of 130 days of dry period lick, only, with the assumption that (1) 50% were weaned on 1 May and fed for 199 days and (2) 50% weaned on 15 September and fed for 60 days. The quantities of key nutrients and supplement fed to achieve the assumed biological responses were extrapolated from the literature detailed above in section 3.1.4.1 and hence should be considered an estimate, only, for cattle grazing mulga-grasslands as outlined in this example. In contrast to responses estimated for cattle in other P-deficient land types (Bowen *et al.* 2020b), for the Mulga Lands similar biological responses to dry season and growing season supplements were assigned (Table 34). This approach was taken due to the major role that addressing a S deficiency has in dry periods when cattle are consuming large proportions of the diet as mulga browse and the longer period of feeding the dry period supplement (130-150 cf. 90 days for growing period supplement).

Table 32 – Supplement loose mix composition (as-fed basis[A]) and cost per tonne
Costs are GST exclusive, landed Charleville

Parameter	**Dry period supplement[B]**	**Growing period supplement**
Urea (g/kg)	150	0
Ammonium sulphate (GranAm), (g/kg)	75	0
Monodicalcium phosphate (MDCP), (g/kg)	180	780
Yellow sulphur (g/kg)	10	20
Salt (g/kg)	150	200
Crude protein (g/kg)	650	0
Phosphorus (g/kg)	41.5	170
Sulphur (g/kg)	60.9	20.0
Supplement cost including freight ($/t)	*$923*	*$1,088*

[A]The dry matter content of minerals was assumed to be 970 g/kg.
[B]The commercial supplement mix also contained two types of vegetable protein meals, gypsum and molasses.

Table 33 – Supplement and nutrient intakes for cattle in the Mulga Lands supplemented with mineral loose mix supplements in the pasture dry and/or growing periods

Scenario	**Days fed supplement**		**Supplement (g/head.day)**		**Crude protein (g/head.day)**		**Phosphorus (g/head.day)**		**Sulphur (g/head.day)**	
	Dry period	**Growing period**	**Dry period**	**Growing period**	**Dry period**	**Growing period**	**Dry period**	**Growing period**	**Dry period**	**Growing period**
Dry period supplement										
Breeders from 2 years	150	0	155	0	101	0	6.4	0	9.4	0
Weaners to 6-12 months	130	0	115	0	75	0	4.8	0	7.0	0
Steers, heifers (12-24 months)	150	0	115	0	75	0	4.8	0	7.0	0
Growing period supplement										
Breeders from 2 years	0	90	0	60	0	0	0	10.2	0	1.2
Weaners 6-12 months	0	0	0	0	0	0	0	0	0	0
Steers, heifers (12-24 months)	0	90	0	30	0	0	0	5.1	0	0.6
Dry period supplement, growing period supplement										
Breeders from 2 years	150	90	155	60	101	0	6.4	10.2	9.4	1.2
Weaners 6-12 months	130	0	115	0	75	0	4.8	0	7.0	0
Steers, heifers (12-24 months)	150	90	115	30	75	0	4.8	5.1	7.0	0.6

Table 34 – Estimated biological response to inorganic supplementation strategies for the Mulga Lands herd after already implementing initial basic management strategies including the safe carrying capacity (500 adult equivalents (AE)), weaning, pregnancy testing, basic herd vaccinations and optimal age of steer turnoff)

The base herd is the new base herd after implementing the initial basic management strategies

Parameter	Response
Average cow liveweight over 12 months (kg)	
1. Base herd	420
2. Dry period supplement	420
3. Growing period supplement	420
4. Dry period supplement, growing period supplement	430
Cull cow sale LW (kg)	
1. Base herd	390
2. Dry period supplement	410
3. Growing period supplement	420
4. Dry period supplement, growing period supplement	440
Female mortality rate (%)	
1. Base herd	6
2. Dry period supplement	4
3. Growing period supplement	4
4. Dry period supplement, growing period supplement	3
Steer mortality rate (%)	
1. Base herd	2.5
2. Dry period supplement	2
3. Growing period supplement	2
4. Dry period supplement, growing period supplement	1.5
Weaning rate (%)	
1. Base herd	57
2. Dry period supplement	63
3. Growing period supplement	63
4. Dry period supplement, growing period supplement	67
Sale liveweight of steers at 18 months (kg)	
1. Base herd	292
2. Dry period supplement	292
3. Growing period supplement	295
4. Dry period supplement, growing period supplement	299

Table 35 - Supplement feeding cost for cattle in the Mulga Lands supplemented with mineral loose mix supplements in the pasture dry and/or growing periods as per Table 33

Scenario	Seasonal feeding cost ($/head)		Total feeding cost ($/head.year)
	Dry period	Growing period	
Breeders from 2 years			
S, P, N dry season	$21.46	-	$21.46
S, P growing season	-	$5.88	$5.88
S, P, N dry season + S, P growing season	$21.46	$5.88	$27.33
Weaners 6-12 months			
S, P, N dry season	$13.80	-	$13.80
S, P growing season	-	-	-
S, P, N dry season + S, P growing season	$13.80	-	$13.80
Steers, heifers (12-24 months)			
S, P, N dry season	$15.92	-	$15.92
S, P growing season	-	$2.94	$2.94
S, P, N dry season + S, P growing season	$15.92	$2.94	$18.86

3.1.4.3 Results and discussion

The effect of feeding inorganic supplements on the modelled production outputs for the 500 AE base herd with weaning, pregnancy testing, basic vaccinations and the optimal steer sale age already implemented is given in Table 36.

Table 36 – Modelled production outputs for the Mulga Lands property with other basic management strategies in place and with inorganic supplementation in the dry and/or growing periods

Parameter	500 AE herd with weaning, pregnancy testing, basic vaccinations and optimal steer sale age of 18 months	Dry period lick	Growing period lick	Dry period lick, growing period lick
Total adult equivalents (AE)	500	500	500	500
Total cattle carried	596	593	591	583
Weaner heifers retained	101	108	108	111
Total breeders mated	353	343	342	330
Total breeders mated and retained	298	299	298	291
Total calves weaned	202	216	215	222
Weaners/total cows mated (%)	57.28	63.06	63.06	67.05
Overall breeder deaths (%)	6.00	4	4	3
Maximum cow culling age (years)	13	13	13	13
Total cows and heifers sold	75	90	90	97
Total steers and bullocks sold	99	106	106	109
Female sales/total sales (%)	43.21	45.96	45.96	47.02

Table 37 shows the added value of applying the different inorganic supplement strategies to the property after the full implementation of a lower carrying capacity, the weaning, pregnancy testing and basic herd vaccination programs and the change in steer sale age to the optimal of 18 months. Feeding S and P supplements during the growing period only, improved property profit by $7,080/annum over 30 years. Despite this additional improvement, the total property returns were still negative at -1.53%. Implementing dry period supplements decreased property returns when fed alone and decreased the benefit to growing period supplements when fed in combination. The ongoing lack of viability of the Mulga Lands property, even after implementing basic herd management strategies, highlighted the importance of identifying additional strategies to improve the performance of the property.

Table 37 - Returns for inorganic supplements for the whole herd compared to the 500 AE herd with weaning, pregnancy testing, basic herd vaccinations, and optimal age of steer turnoff already in place

All terms defined in the Glossary of terms and abbreviations

Factor	Dry period lick (S, P, N)	Growing period lick (S, P)	Dry period lick, growing period lick
Period of analysis (years)	30	30	30
Discount rate for NPV	5	5	5
NPV	-$31,280	$108,837	$62,629
Annualised NPV	-$2,035	$7,080	$4,074
Peak deficit (with interest)	-$102,233	n/c	-$33,527
Year of peak deficit	20	n/c	6
Payback period (years)	n/c	n/c	11
IRR	n/c	n/c	17.50%

3.2 Additional strategies that may build profit and resilience of a beef enterprise

The starting profit analysis identified that the original beef property running 600 AE and with only low-level management returned about -2.47% on the capital invested. The basic management strategies tested so far have revealed only two that could add measurably to the return on the investment (increasing age of steer turnoff and supplementation with S and P in the growing period). Unfortunately, the full and completely successful adoption of these two profitable management strategies did not substantially improve the outlook for the base property (Table 38).

The value of the land and fixed improvements for the example property did not substantially change with the implementation of the alternative management strategies, and livestock assets reduced with the change in property stocking rate. It is evident that the average return on the investment for such a property in the Mulga Lands is likely to be negative on average without a significant and ongoing increase in real land value that is unrelated to the productivity of the property.

To assess whether the property economic and financial performance could be improved further, the representative beef property after implementing the initial, basic best-practice management strategies of safe carrying capacity, weaning, pregnancy testing, basic herd vaccinations, optimal steer sale age, and growing period S and P supplements, was used as a new base to test additional strategies for their ability to improve long-term profitability and drought resilience. This approach was taken as implementing basic herd management strategies were seen as the first essential steps in improving the resilience and long-term profitability of the Mulga Lands property. The modified base herd had an average overall mortality rate of 2.45% and a 4% average female mortality rate. The average weaning rate from all cows mated was 63.06%. Weaned steer calves were sold to the saleyards at 18 months old and an average weight of about 295 kg in the paddock.

Table 38 - Expected value of annual outcomes for the initial base property with 600 adult equivalents (AE) and low-level management and the same property after implementation basic herd management strategies

Parameter	Original 600 AE base herd with low-level management	Herd after full implementation of safe carrying capacity (500 AE), weaning, pregnancy testing, basic herd vaccinations and optimal age of turnoff	Herd after full implementation of safe carrying capacity (500 AE), weaning, pregnancy testing, basic herd vaccinations, optimal age of turnoff and sulphur and phosphorus supplements in the growing period
AE	600	500	500
Allowance for operator's management and labour	$40,000	$45,000	$45,000
Return on total capital	-$78,213	-$57,948	-$47,455
Rate of return on total capital	-2.47%	-1.88%	-1.53%

3.2.1 Converting from breeding to steer turnover

3.2.1.1 Introduction

Unlike other regions in Queensland, few properties in the Mulga Lands region are used predominately for trading cattle or only growing steers to a weight and condition suitable for transfer or sale (backgrounding). This suggests that most local beef producers have rejected a steer trading or turnover enterprise as being either less profitable and/or riskier than running a breeding herd and turning off steers and cull females from the same property.

3.2.1.2 Methods

The relative profitability of a steer turnover activity was tested by converting the property from a breeding herd turning off yearling steers to a steer turnover operation. The purpose was to consider the property solely as a steer growing/turnover operation and identify the constraints and characteristics of such a property. The main difference between the two activities is that the steer turnover activity purchases all steers and has no breeders or female cattle on the property while the breeding activity has a self-replacing breeder herd on the property that produces (1) 18-month-old steers, (2) cull heifers and (3) cull cows.

The options for a steer turnover operation are numerous. The choices include the purchase of weaner steers, yearling steers or older steers and then keeping them for periods of 1, 2 or 3 years depending upon the target market. The relative steer prices for steer purchases and sales are critical to the profitability of a steer turnover operation. Table 39 indicates the range in average prices for relevant classes of (1) slaughter cattle at Queensland abattoirs and (2) store cattle at the Roma sale yards. Averages were calculated for the last 10-, 5- and 2-year periods, respectively, to the end of 2019.

Table 39 - Over the hooks cattle indicators for 2010-2019 and store cattle prices at Roma saleyards for 2010 to 2019 (http://statistics.mla.com.au/Report/List)

Prices averaged over last	**Over the hooks[A]**			**Store steers[B]**				
	Trade steer	**Medium steer**	**Heavy steer**					
	240-260 kg Butt shape A-C	**260-280 kg Butt shape A-C**	**300-400 kg Butt shape A-C**	**<220 kg**	**221-280 kg**	**281-350 kg**	**351-400 kg**	**401-550 kg**
10 years	$4.11	$4.06	$4.16	$2.57	$2.55	$2.47	$2.39	$2.34
5 years	$5.01	$4.99	$5.10	$3.16	$3.12	$3.03	$2.94	$2.86
2 years	$5.09	$5.07	$5.18	$2.76	$2.80	$2.79	$2.77	$2.75

[A]Queensland monthly prices in $/kg dressed weight.

[B]Roma store sale prices in c/kg liveweight.

As it is unlikely that steers grown or turned over on the Mulga Lands property will be sent to the abattoirs, the average store steer prices for each age and weight class at Roma, for the last decade, was taken to represent the relative average purchase and sale prices for steers going into, and coming out of, a steer turnover operation over an extended period of time.

Table 40 indicates the purchase weights, purchase prices, periods of time held, sale weights and sale prices applied in the model for a selection of the classes of steers that could potentially be traded or grown on the property. For simplicity, the purchase weights at each age and the expected average weight gain for the periods of time held were taken directly from the growth path of steers developed for the optimal age of steer turnoff scenario developed for the Mulga Lands property. This growth path did not reflect the benefit of feeding growing season S and P supplements to steers due to the difficulty in assigning growth responses to S and P for each age group in the absence of measured data. As the ranking of the gross margin results will be similar, with and without the supplementation of S and P, this was considered an appropriate approach. Sale weights were assumed to be 5% less than the paddock weight. Purchased steers incurred transport costs to the property and $5/head health and induction costs. Steer losses during the period of ownership were set at 6%/annum which was higher than the rate allocated to home-bred steers to allow for the inherent costs in transferring young steers to the Mulga Lands region. Sale steers incurred selling costs of transport to Roma (450 km), commission (3%), yard fees of $12/head and a livestock levy of $5/head.

Table 40 - Classes of steers available to be traded

Class purchased	Start weight (kg)	Purchase price ($/kg)	Time held	Class sold	Paddock weight (kg)	Annual weight gain (kg/head)[A]	Sale weight (kg)	Sale price ($/kg)
Weaners (6 m)	171	$2.57	12 m	18 m	292	121	277	$2.47
Weaners (6 m)	171	$2.57	24 m	30 m	389	109	370	$2.39
Weaners (6 m)	171	$2.57	36 m	42 m	484	104	460	$2.34
Weaners (6 m)	171	$2.57	48 m	54 m	557	96.5	529	$2.34
Yearlings (18 m)	292	$2.47	12 m	30 m	389	97	370	$2.39
Yearlings (18 m)	292	$2.47	24 m	42 m	484	96	460	$2.34
Yearlings (18 m)	292	$2.47	36 m	54 m	557	88	529	$2.34
Steers (30 m)	389	$2.39	12 m	42 m	484	95	460	$2.34
Steers (30 m)	389	$2.39	24 m	54 m	557	84	529	$2.34
Steers (42 m)	484	$2.34	12 m	54 m	557	73	529	$2.34

m, months

[A]The change in annual weight gain reflects the expected decreasing potential for steers to gain weight as they age on the Mulga lands property. No benefit to S and P supplementation was attributed.

Table 41 shows the expected average total gross margin for the Mulga Lands property when the different steer purchase and sale ages, expected purchase and selling costs, and weight gains per period held were combined. Each alternative turnover option was limited to the total grazing pressure of 500 AE. At the predicted annual weight gains, purchase and sale prices, it appeared that purchasing a large number of light weaners and holding them for 12 months (i.e., from 6 to18 months of age) was likely to produce the best gross margin. However, purchasing weaners and holding them for 2 years (i.e., from 6 to 30 months of age) resulted in a very similar gross margin to the optimal and was slightly less exposed to price risk over time.

Table 41 - Livestock gross margins for steer cohort turnover options

Parameter	**Steer cohort**									
	6-18 m	**6-30 m**	**6-42 m**	**6-54 m**	**18-30 m**	**18-42 m**	**18-54 m**	**30-42 m**	**30-54 m**	**42-54 m**
Number purchased	851	377	231	164	637	501	190	534	257	481
Total AE	500	500	500	502	500	501	500	501	500	500
Livestock sales	$548,142	$294,189	$206,771	$158,448	$528,915	$284,193	$195,514	$533,813	$277,920	$532,944
Livestock purchases	$373,989	$165,680	$101,518	$72,073	$459,430	$215,651	$137,036	$488,808	$235,250	$515,497
Freight in	$19,148	$8,483	$5,198	$3,690	$16,862	$7,915	$5,029	$17,164	$8,261	$16,650
Freight out	$25,000	$10,704	$6,646	$5,009	$19,254	$9,138	$6,183	$17,377	$8,883	$17,687
Treatment expenses	$4,255	$1,885	$1,155	$820	$3,185	$1,495	$950	$2,670	$1,285	$2,405
Selling expenses	$30,044	$14,487	$9,467	$6,929	$26,050	$13,014	$8,551	$24,548	$12,197	$23,672
Total expenses	$452,436	$201,238	$123,983	$88,521	$524,781	$247,213	$157,749	$550,567	$265,875	$575,912
Gross margin	$95,707	$92,951	$82,788	$69,927	$4,135	$36,980	$37,765	-$16,754	$12,045	-$42,968
Gross margin (after interest)	*$77,007*	*$76,383*	*$67,560*	*$55,512*	*-$18,837*	*$15,415*	*$17,210*	*-$41,195*	*-$11,480*	*-$68,743*

m, months

To investigate the value of converting from a breeding to steer turnover enterprise, the herd model was restructured to purchase weaner steers at the average weaner weight of the home-bred steers at 6 months of age. They were then held for 12 months and sold as 18-month-old steers (the optimal scenario identified above). The transition from a breeder herd to a steer turnover operation was completed over the first 12 months of the analysis and this required the entire female component of the existing herd be sold over a short period of time at 80% of their usual sale price. The existing steers were retained and added to the purchased steers to achieve the full stocking rate (500 AE) of the property.

The purchase price of the weaner steers was higher than the values applied to calculate the steer values in the breeder herd model. The steers were purchased for $2.57/kg liveweight at the yards whereas the home-bred weaners of the same age and class were valued at $2.00/kg liveweight. The landed value of the purchased weaners was $2.70/kg once purchase and transport costs from Roma to Charleville property (450 km) were added (Table 42). It was recognised that steers may be purchased across a number of regions but the cost to the enterprise was decided by identifying the purchase price at the major store selling centre in the region, adding the cost of transport to the property and settling the cattle on the property. All other husbandry, selling costs and sale weights for steers were maintained at the same value as the steers sold by the base breeder herd in the growing period supplementation scenario. The annual mortality rate in purchased steers was increased to 6% to cover some of the risks associated with purchasing weaner steers. Induction costs of $5/head included a station management tag, cross-branding and a botulism vaccination.

Table 42 – Landed cost of purchased turnover steers

Purchases are on a liveweight basis

Parameter	Value
Number purchased	530
Transport cost/head	$22.50
Average purchase liveweight (kg)	171
Buying cost/kg	$0.16
Nominal purchase price/kg at the yards	$2.57
Landed purchase cost/kg	$2.70
Cost per head on farm	*$461.97*

Removing the breeding herd and replacing them with steers changes the livestock schedule. Table 43 indicates the typical livestock schedule for the steer growing operation.

Table 43 – Livestock schedule for the steer turnover operation

Description	Opening number	Number purchased	Number sold	Closing number
Weaner steers (6-12 months)	-	851	0	800
Yearling steers (12-24 months)	800	0	800	0

Steers were sold at 292 kg liveweight (in the paddock) at 18 months of age on average. They lost 5% of their paddock weight to produce a sale weight of 277 kg at the saleyards. They sold for $2.47/kg on average, incurred 3% sales commission, $17/head MLA and saleyard levies, and $31.25 per head in transport costs to get from the property to the saleyards. Their gross and net sale prices were $685.18 and $616.15/head, respectively.

3.2.1.3 Results and discussion

Table 44 compares the livestock gross margins for a steer turnover vs. breeding operation on the Mulga Lands property with basic herd management strategies in place.

Table 44 - Livestock gross margin for steer turnover and breeding operations

Parameter	**Breeder herd**	**Steer turnover**
Net livestock sales	$121,722	$493,098
Livestock purchases	$4,000	$393,136
Variable expenses	$8,488	$3,830
Gross margin (before interest)	*$109,234*	*$96,132*

Table 45 indicates the extra returns generated by transitioning from the breeder herd to the steer turnover operation where the price basis relevant to the past decade was maintained. Implementing this change resulted in ca. $16,000 less profit/annum. Additional capital was required to establish the steer turnover operation and the alternative investment did not break-even with the current investment in the breeding operation. This additional capital was the difference between the capital tied up in the breeding herd and that tied up in the steer turnover herd. The peak deficit was the difference in funds received from the sell-down of the breeder herd and the costs involved in building up the purchased steer numbers over the first 2 years plus the opportunity cost of interest. This decrease in property profitability due to converting to a steer turnover operation, is in contrast to results for the representative property for the Northern Downs analysis (Bowen *et al.* 2020a) where an extra $62,500/annum profit resulted from implementing this strategy. The decreasing efficiency of steer weight gain over time in the low-productivity Mulga Lands region is the major cause of the negative result of this strategy in the current analysis. The poor result was also partly due to the higher mortality rate applied to purchased steers as well as the high transaction costs of holding each steer cohort for only 12 months due to the declining rate of weight gain.

Table 45 - Returns for converting from a breeding to a steer turnover operation at long term prices in the Mulga Lands

All terms defined in the Glossary of terms and abbreviations

Factor	**Value**
Period of analysis (years)	30
Discount rate for NPV	5%
NPV	-$247,965
Annualised NPV	-$16,130
Peak deficit (with interest)	-$718,466
Year of peak deficit	29
Payback period (years)	n/c
IRR	n/c

3.2.2 Controlled mating

3.2.2.1 Introduction

Breeding herds that practice continuous mating in regions with variable and generally poor nutrition have been shown to fall into a calving pattern that peaks around the main growing season (Cobiac 2006; McGowan *et al*. 2014; Kieren McCosker NTDPIR pers. comm). Table 46 shows the percentage of calves expected to be born in each calving season when data from the CashCow project (McGowan *et al.* 2014) and the Victoria River Research station herds (Cobiac 2006) were averaged, and summer was the main growing season. The pattern of calving over time for the base herd at Charleville in the Mulga Lands is unknown but anecdotal evidence suggests a November peak with breeding cows drifting into and out of the peak season due to locational anoestrus and climate variability. This pattern is similar to the rest of the northern beef industry where mating is continuous. The initial impact of removing the breeding bulls from a breeding herd with continuous mating for part of the year is expected to be a more concentrated calving period in the following year. Ongoing impacts can be highly dependent on herd nutrition and herd management after the first calving period with controlled mating. Little to no research data is available to identify what a typical response to controlled mating may be in the Mulga Lands region.

Table 46 - Percentage of calves born in each calving season

Season of calving	Cash Cow	Victoria River Research Station	Average
Jul Aug Sept	13%	12%	12%
Oct Nov Dec	53%	54%	54%
Jan Feb Mar	25%	30%	27%
April May June	8%	5%	7%

For reproduction efficiency to improve where a breeding herd moves from a continuous to a controlled mating scenario, cows that conceive and produce a calf will have to reconceive while they have a young calf at foot. As they generally failed to reconceive under these circumstances in the herd with continuous mating, there is no real likelihood of this changing if the only change is the removal of the bulls from the breeding herd for a period of time. This is because the available nutrition on the property has not changed due to implementation of this strategy (the same grazing pressure is applied). Evidence from cattle herds in more northern parts of Queensland (Chudleigh *et al.* 2016, 2017) indicates that implementing controlled mating, in the absence of additional management interventions, does not change the long-term reproductive efficiency of the breeding herd, but does change when the cows will calve. Thus, the impact of controlled mating in the Mulga Lands herd is not expected to be more weaners per 100 cows mated, only a more concentrated calving period. The frequency of mustering for the constructed property indicates that the bulls will likely be removed for a period of about 6 months and that two main musters will still be required to manage the herd.

Controlled mating can be implemented with or without other strategies. One common approach is to combine pregnancy testing with the removal of the breeding bulls. This allows non-pregnant breeders to be either segregated and managed differently or culled and sold. If a large proportion of non-pregnant breeders are culled and sold as a first step to moving to controlled mating, and the herd has low reproduction efficiency, the herd cannot quickly replace them from natural increase. Total herd numbers can only be returned to normal levels quickly by purchasing replacement breeding females.

3.2.2.2 Methods

This scenario considers the implementation of controlled mating for the Mulga Lands herd with basic herd management strategies already in place. The current management strategy allowed continuous mating with no attempt to remove herd bulls other than to cull them on age and faults. The outcome of this strategy was a continuous calving pattern with occasional peaks likely to occur after better seasonal conditions. Our current estimate of reproduction efficiency, expressed as the weaning rate achieved from the total number of cows mated, suggests that most mature breeding cows in the base herd wean a calf about every 18-24 months, or every 1.5 years on average. The average calving pattern shown in Table 46 was taken to be the expected calving pattern followed by the Mulga Lands base herd with continuous mating, over time.

The strategies tested were:

(1) removing the bulls from the herd for a period of the year,

(2) removing the bulls, pregnancy testing and selling the empties in the first year only, and

(3) removing the bulls, pregnancy testing, selling the empties and replacing them with PTIC cows annually.

For ease of modelling the impact of moving to controlled mating, the year was broken up into a series of main calving and mating periods. Table 47 indicates the main mating and calving periods for the continuously mated herd prior to the removal of the bulls that coincide with the calving periods predicted in Table 46. The percentage of calves expected to be born in each period was combined with the standard weaning dates to identify the shift of weaners across the calving periods once controlled mating was introduced.

Table 47 - Calving periods based on the number of days mated

Opening date mating period **Closing date mating period**	**17/09/2018** **17/12/2018**	**18/12/2018** **19/03/2019**	**20/03/2019** **17/06/2019**	**18/06/2019** **16/09/2019**
Days mated	91	91	89	90
Months mated	2.99	2.99	2.92	2.96
Days gestation	287	287	287	287
First calf	1/07/2019	1/10/2019	1/01/2020	31/03/2020
Last calf	30/09/2019	31/12/2019	30/03/2020	29/06/2020
Midpoint mating	1/11/2018	1/02/2019	3/05/2019	2/08/2019
Midpoint calving	15/08/2019	15/11/2019	14/02/2020	15/05/2020
Weaning date[A]	17/05/2020	17/05/2020	10/10/2020	10/10/2020
Months calving to weaning	9.18	6.12	7.95	4.93
Days to weaning	275	183	238	148

[A]1st weaning in May, calves born up until the end of December weaned; 2nd weaning October, calves born up until the end of June weaned.

The herd was modelled in a four-period calving model that mimicked the calving frequency shown in Table 46 and weaning dates and ages shown in Table 47. The bulls were removed from the herd for the period from June to December each year and the impacts allowed to flow through the model. This had the effect of all calves being born between October and the end of March.

Table 48 shows the number of cows calving in each calving period or status group leading into the start year of the controlled mating herd model, their expected rate of conception and the future calving period based on when they are expected to conceive. Controlled mating for the herd was achieved by preventing the cows from conceiving from June to December of each year.

Table 48 – Calving group by status for year 01-Jan-20 to 31-Dec-20, for the controlled mated herd

Parameter	Cows to calve[A]				Empty cows[B]
	Calving 01-Jul-19 to 30-Sep-19	Calving 01-Oct-19 to 31-Dec-19	Calving 01-Jan-20 to 31-Mar-20	Calving 01-Apr-20 to 30-Jun-20	
Cows as at end 2019	13	89	58	23	99
Number of cows available for mating	12	81	52	21	62
Proportion that conceive to calve July 2020 to September 2020 (%)	5%	0%	0%	0%	20%
Number conceived	1	0	0	0	12
Proportion that conceive to calve October 2020 to December 2020 (%)	30%	55%	0%	0%	55%
Number conceived	4	45	0	0	34
Proportion that conceive to calve January 2021 to March 2021 (%)	25%	25%	37%	0%	15%
Number conceived	3	20	19	0	9
Proportion that conceive to calve April 2021 to June 2021 (%)	0%	10%	10%	15%	0%
Number conceived	0	8	8	3	0
Empty cows (number that don't conceive)	5	8	25	18	6

[A]These cows are in calf and can provide a weaner.
[B]These cows are empty at this time.

Additional costs of removing the bulls from the herd were estimated to be an additional 3 days mustering for three people. It was assumed that the property had a paddock that could be used as a bull paddock and that the bulls did not receive additional supplements to those already fed. No other management strategy practised for the base herd was changed. That is, steers were still sold at the same average weight and age and two main musters were still required.

3.2.2.2.1 Sub scenario 1 - removing the bulls from the herd for a period of the year

The impact of removing the herd bulls was an initial delay in the re-conception time for some of the females that did not reconceive before the bulls were removed.

3.2.2.2.2 Sub scenario 2 – removing the bulls, pregnancy testing and selling the empties in the first year only

The impact of implementing controlled mating, pregnancy testing, and removing non-pregnant females in the first year only was tested by identifying the approximate average number of non-pregnant females and culling them in the 1st year. This was initially implemented as a one-off treatment undertaken in Year 1, with the effects on herd numbers allowed to flow through the subsequent years.

3.2.2.2.3 Sub scenario 3 – removing the bulls, pregnancy testing, selling the empties and replacing them with PTIC cows annually

The option of purchasing pregnancy tested in-calf (PTIC) cows to replace breeding cows that are empty and culled as part of a combined controlled mating/pregnancy testing strategy was assessed by replacing the culled females with sufficient purchased PTIC cows to maintain the number of weaners produced each year. This pattern was followed for the 30-year investment period with pregnancy tested empty (PTE) cows culled each year and replaced with PTIC cows. Additional costs of mustering, pregnancy testing and purchase of replacement stock were incurred. PTIC cows were purchased at 20% more than the gross sale price of mature cull cows for the base herd.

3.2.2.3 Results and discussion

3.2.2.3.1 Sub scenario 1 - removing the bulls from the herd for a period of the year

Maintaining a 6-month mating period initially reduced the proportion of cows conceiving, but the initial gap in conceptions was largely regained when the bulls re-entered the herd. Table 49 indicates that the total number of weaners fell over the first decade due to the reduced number of mature females that could run on the property with controlled mating at the same grazing pressure. A change in the efficiency of the replacement heifers due to the restricted mating period required a slightly larger number of empty heifers to be maintained thereby increasing the grazing pressure applied by the base herd. Once the total herd size was adjusted to return the grazing pressure to the same as the in the continuous mating scenario, the controlled mating strategy produced 204 weaners per annum on average by Year 30, compared to 209 in the continuous mating strategy, but maintained the same average weaning rate from cows mated.

Table 49 - Calving pattern for the base herd converting from continuous to controlled mating

Year	July to September calves	October to December calves	January to March calves	April to June calves	Total weaners
1	16	110	59	24	209
2	16	110	59	24	209
3	0	116	63	0	179
4	0	132	70	0	202
5	0	130	73	0	203
6	0	127	74	0	201
7	0	128	74	0	202
8	0	127	74	0	201
9	0	127	74	0	201
10	0	128	74	0	201

Table 50 indicates that the strategy of implementing controlled mating and doing nothing else was likely to have a negative impact on the profitability of the property. The benefit of selling down a few extra cows early in the period mostly offset the reduction in the number of weaners produced over time.

Table 50 - Returns for implementing controlled mating with no other change in management strategy

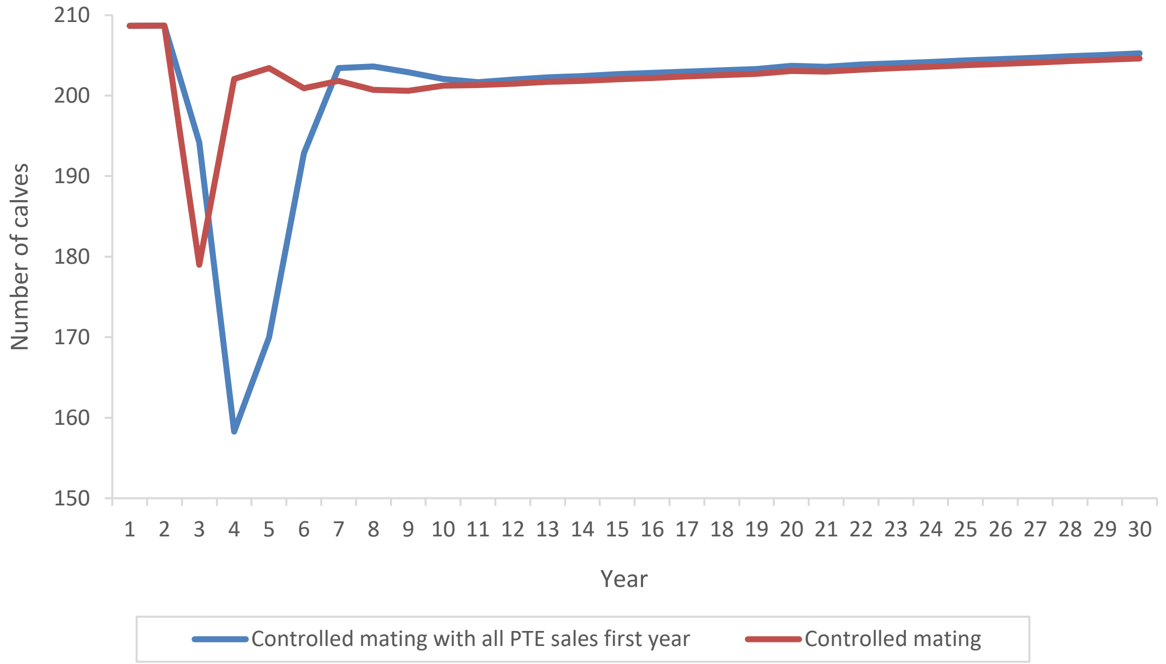
All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Discount rate for NPV	5%
NPV	-$45,671
Annualised NPV	-$2,971
Peak deficit (with interest)	-$99,731
Year of peak deficit	n/c
Payback period (years)	n/a
IRR	n/c

3.2.2.3.2 Sub scenario 2 – removing the bulls, pregnancy testing and selling the empties in the first year only

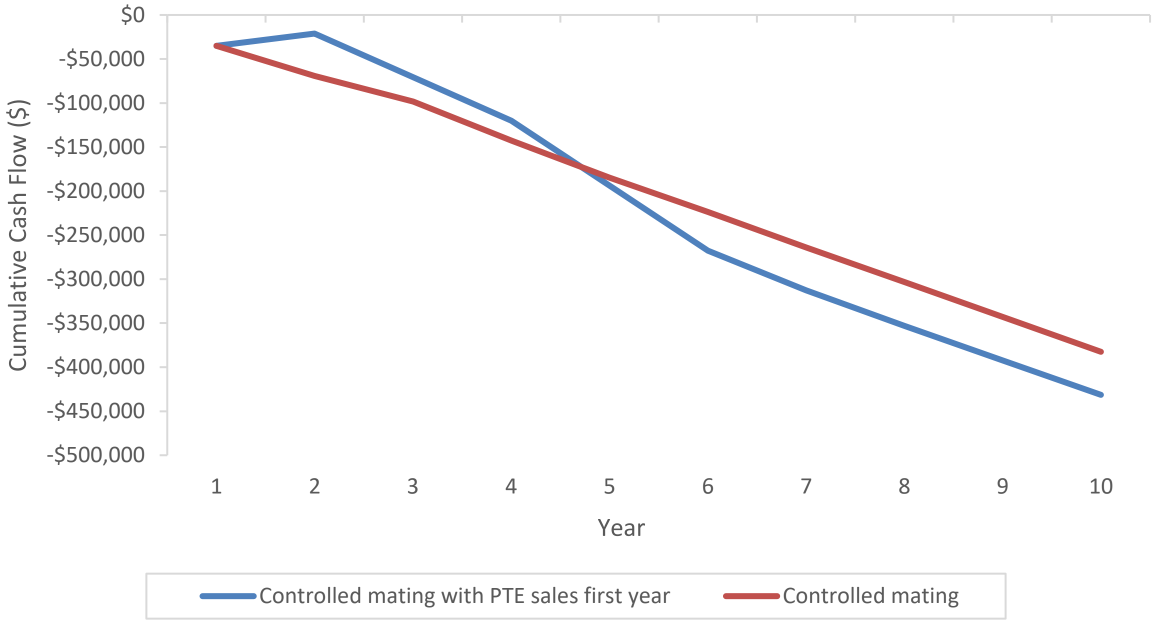
Figure 10 shows the impact on the numbers of calves produced by the base herd transitioning to controlled mating when the PTE females are culled in the first year and not replaced.

Figure 10 - Impact on the numbers of calves produced as a result of implementing controlled mating or implementing controlled mating and selling PTE females in Year 1 only



The outcome of removing the herd bulls, pregnancy testing the breeders and selling the PTE females (just in Year 1) in a herd with low reproduction efficiency is no improvement in herd reproduction efficiency over time, but gives a large decline in cash flow in the third or fourth year after the decision is made to remove the bulls (Figure 11). This is mainly due to the loss of the out-of-season calves that contributed to cash flow as well as the requirement to retain females to rebuild the herd. While the cash flow of the property is improved in the short term due to the sale of the PTE females in the first year, the long-term cash flow of the property is significantly reduced below the strategy of just implementing a controlled mating system.

Figure 11 - Cumulative cash flow for controlled mating and controlled mating with PTE sales in first year only



Unless there is a major improvement in herd nutrition in parallel with the decision to remove the herd bulls and sell the PTE cows, this cash deficit makes it very difficult for the beef property to continue. The problem is initially hidden by the cash surplus generated by the sale of the PTE cows in Year 1. Table 51 shows the impact on long-term returns of moving to a controlled mating scenario and selling the PTE cows in the first year only.

Table 51 - Returns for implementing controlled mating with PTE sales in the first year only

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Discount rate for NPV	5%
NPV	-$29,995
Annualised NPV	-$1,948
Peak deficit (with interest)	-$34,554
Year of peak deficit	n/c
Payback period (years)	n/c
IRR	n/c

3.2.2.3.3 Sub scenario 3 – removing the bulls, pregnancy testing, selling the empties and replacing them with PTIC cows annually

Incorporating the purchase of PTIC females to cover the sale of PTE cows each year did not improve the performance of the underlying strategy to move to controlled mating. Figure 12 indicates that if

PTE cows are replaced with PTIC cows due to calve at a favourable time of the year, both the herd efficiency and the number of calves produced by the herd will increase over the longer term.

Figure 12 - Number of calves with controlled mating and controlled mating with removal of PTE cows and replacement with PTIC cows to calve October, November and December

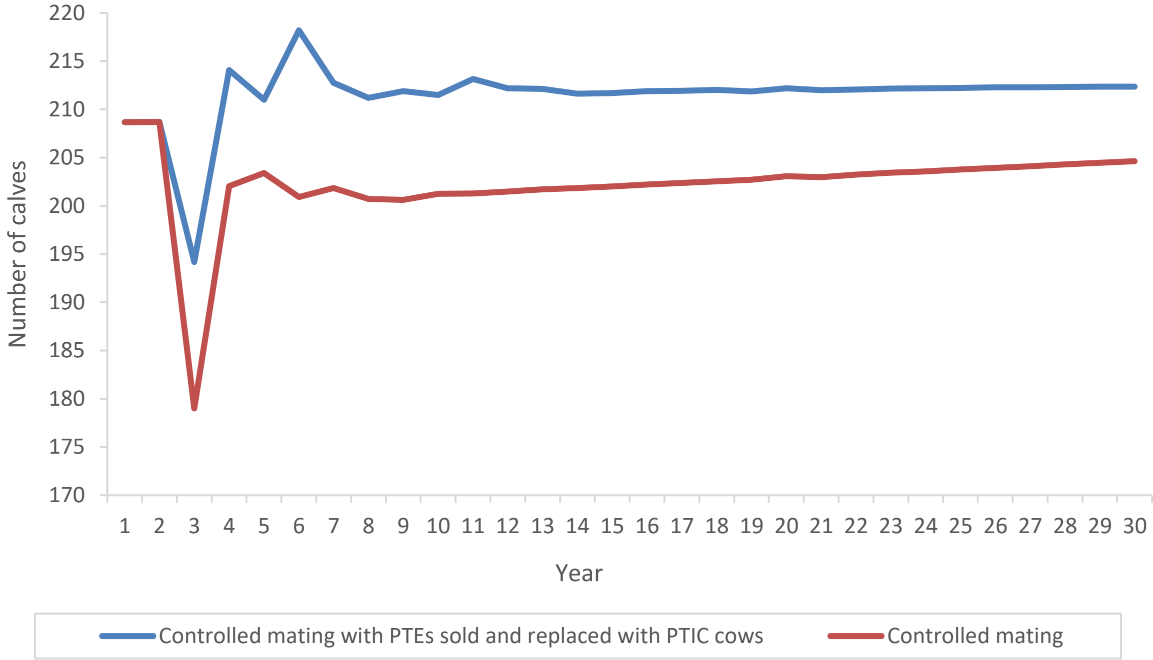


Table 52 indicates that the extra returns from replacing PTE empty cows with PTIC cows are likely to be breakeven at best. The critical parameter is the purchase cost for the PTIC cows purchased as replacements. It was estimated that they are likely to average 20% more than the cows they are replacing, based on market data for the Roma saleyards.

Each of these sub-scenarios relies upon significant interpretation of what may happen if a continuously mated herd is converted to a herd with controlled mating. Small changes in the parameters can change the negative returns into positives and vice versa. Previous analyses conducted for northern Australian cattle herds (Chudleigh *et al.* 2016, 2017) have indicated that where a breeding herd is poorly managed, but the underlying nutrition is sound (i.e. at higher level than that assumed for this Mulga Lands property), improving the management of the herd (tighter mating period or breeder segregation, better weaning management, closely targeted P supplements where needed) can improve the economics. However, the low levels of underlying nutrition in the Mulga Lands, and poor calf growth rates, precluded a similar response here.

Table 52 - Returns for controlled mating with PTIC purchases

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Discount rate for NPV	5%
NPV	$10,019
Annualised NPV	$651
Peak deficit (with interest)	n/c
Year of peak deficit	n/c
Payback period (years)	n/c
IRR	n/c

3.2.3 Feeding whole cottonseed to the breeder herd

3.2.3.1 Introduction

Whole cottonseed is readily available in tropical and subtropical areas of Australia and has been used for many years as a dry season or drought supplement for beef cattle and sheep, as well as in feedlot rations, due to its relatively attractive nutritional composition (high concentrations of protein and energy) and price (e.g., Bowen *et al.* 2007a,b; Tyler *et al.* 2008; The State of Queensland 2020c). An advantage of whole cottonseed as a dry period supplement includes the minimal requirement for infrastructure for storage and feeding out, as it can be stored and fed uncovered in the open, if necessary. Additionally, livestock regulate their own intake due to the high fibre content of the supplement (the lint).

3.2.3.2 Methods

In this strategy, the effect of feeding whole cottonseed to improve the nutrition of the breeder herd was compared to the steady-state, 500 AE herd with basic herd management strategies in place, including provision of S and P supplements in the growing period, over a 30-year analysis period. The strategy of feeding whole cottonseed to improve the nutrition of the breeder herd was examined to further improve herd productivity as the levels of nutrition of the herd were still considered to be low and limiting for reproduction efficiency (63.06% weaning rate) and average herd mortality rate (2.45%).

Whole cottonseed was fed to the breeder herd (including the heifers) every 2nd year on average to improve herd nutrition. The approximate nutrient composition of the whole cottonseed, on a DM basis, was considered to be:

- DM: 90-93%
- DMD: 80%
- energy: 14 MJ/kg DM
- crude protein: 22-24%
- crude fibre: 23-27% (largely from the lint retained on the seed)
- oil: 15-18%
- calcium: 0.15 %
- P: 0.75%.

The costs of feeding the whole cottonseed were kept to a bare minimum and included an increase in the allowance for the repairs and maintenance of machinery as well as the labour used to prepare and feed out the supplement, regardless of whether it would be paid or unpaid in reality. Breeders and replacement heifers were fed in the paddock with no additional expenditure on troughs or other feeding-out equipment. No sale cattle were fed the whole cottonseed as it was assumed that they would be sold prior to the start of feeding.

The rate of feeding was calculated at 180 days every 2nd year at 3 kg/day for a cow and calf and 2 kg/day for dry cattle. At the calving rate of the herd, this was assessed as an average feeding rate of 2.5 kg/head.day for mature females during the feeding period. Replacement heifers received 1.5 kg/head.day on average during the feeding period. The whole cottonseed was fed twice a week and cost $700/tonne landed on the property. Table 53 shows the average cost of feeding breeders and replacement heifers per head and per annum when the cattle were fed every 2nd year. The additional labour costs were incorporated in the costs of feeding. The cost of feeding out was less for heifers based on the assumption that there was one mob of heifers fed in one paddock cf. 2-3 paddocks of cows.

Table 53 - Feeding cost calculator for whole cottonseed

Feeding cost calculator	**Breeders**	**Heifers**
Number of breeders to be fed	298	70
Average liveweight (kg)	420	300
Whole cottonseed consumed (kg/head.day)	2.50	1.50
Number of days to be fed	180	180
Total intake of cottonseed (kg/head)	450	270
Cost of cottonseed (per tonne landed)	$700	$700
Total supplement fed (tonnes)	134	19
Total cost of supplement	*$93,870*	*$13,230*
Cost of feeding out		
Fed out (times a week)	2	2
Total number of times fed out	51.43	51.43
Wages and fuel for one feeding out	$150	$50
Total cost of feeding out the whole cottonseed	*$7,714*	*$2,571*
Total cost per herd of supplement and feeding	***$101,584***	***$15,801***
Total cost per head fed	*$341.00*	*$225.73*
Average cost per head per annum[A]	*$170.44*	*$112.87*

[A]Cattle were fed every 2nd year.

It was assumed that feeding an additional supplement such as whole cottonseed during periods when nutrition was limiting, to the breeding herd including the replacement heifers, would:

- improve the average body condition score by half a point, from 3 to 3.5;
- reduce the rate of female mortality by one third, from 4% to 2.7%;
- increase the weaning rate by about 4%, from 63.06% to 67%;
- improve paddock weights and sale weights by 10 kg/head for the breeding herd;
- increase the liveweight of sale steers by 10 kg at the same age of sale;
- result in no change to steer mortality rates.

These benefits to whole cottonseed supplementation reflect the gains already made by implementing basic levels of herd management (i.e., reduced stocking rate, weaning, pregnancy testing, vaccinations and appropriate inorganic supplementation of S and P in the growing season). Hence there is expected to be an effect of diminishing returns when increasing herd performance.

Sale prices were maintained at the same level in both the ‘with whole cottonseed’ and the ‘without whole cottonseed’ feeding activities. Table 54 shows the changed conception and mortality rates applied in the 500 AE herd model with basic herd management, plus whole cottonseed feeding.

Table 54 - Reproduction parameters and mortality rates for breeders fed whole cottonseed every 2nd year on average

Initial cattle age **Final cattle age**	**6 months** **1**	**1** **2**	**2** **3**	**3** **4**	**4** **7**	**7** **8**	**8** **13**
Expected conception rate for age group (%)	n/a	0	65	50	85	80	80
Expected calf loss from conception to weaning (%)	n/a	0	12	10	10	10	12
Female death rate (%)	3	2.7	2.7	2.7	2.7	2.7	2.7
Male death rate (%)	2	2	n/a	n/a	n/a	n/a	n/a

n/a: not applicable.

3.2.3.3 Results and discussion

Table 55 compares two steady-state herd models to show the effect of whole cottonseed feeding. The whole cottonseed data is for the end result after feeding whole cottonseed and full implementation of the changes to herd performance and structure. The herd model was optimised for cow and heifer culling age once the changes due to the feeding of the whole cottonseed were implemented. This led to the percentage of 1-year-old heifer sales increasing from 33.17% to 42.87%, an increase of 9.7% points. The percentage of weaners produced from cows mated increased from 63.06% to 67.10%, an increase of 4% points. The female mortality rate reduction was 33%. Although net cattle sales increased in value, the direct costs (excluding bulls) associated with herd management increased from $8,512/annum to $64,768/annum (on average), an increase of $56,256/annum. This greatly reduced the total gross margin for the herd.

Table 55 - Comparison of steady-state herd models for the base herd and the same herd with whole cottonseed feeding to females

Parameter	Base herd with whole cottonseed	Base herd	Difference
Total adult equivalents (AE)	500	500	0
Total cattle carried	580	591	-11
Weaner heifers retained	110	108	3
Total breeders mated	329	342	-13
Total breeders mated and kept	290	298	-8
Total calves weaned	221	215	5
Weaners/total cows mated	67.10%	63.06%	4.04%
Weaners/cows mated and kept	76.08%	72.36%	3.71%
Overall breeder deaths	2.70%	4.00%	-1.30%
Female sales/total sales %	47.43%	45.96%	1.47%
Total cows and heifers sold	98	90	8
Maximum cow culling age	13	13	0
Heifer joining age	2	2	0
One-year-old heifer sales %	42.87%	33.17%	9.70%
Two-year-old heifer sales %	35.00%	35.00%	0.00%
Total steers and bullocks sold	108	106	3
Maximum steer turnoff age	1	1	0
Average female price	$631.92	$627.82	$4.10
Average steer/bullock price	$638.50	$617.76	$20.74
Capital value of herd	$310,042	$313,939	-$3,897
Imputed interest on herd value	$15,502	$15,697	-$195
Net cattle sales	$130,643	$121,556	$9,087
Direct costs excluding bulls	$64,768	$8,512	$56,256
Bull replacement	$4,047	$4,205	-$158
Gross margin for herd	$61,828	$108,839	-$47,011
Herd gross margin less interest on livestock capital	$46,326	$93,142	-$46,816
Gross margin/AE	$124	$218	-$94
Gross margin/AE after interest	*$93*	*$186*	*-$94*

Table 55 indicates that feeding whole cottonseed to the herd generated a positive gross margin, although the gross margin was $94/AE less than for the herd that was not fed whole cottonseed. However, the gross margin, when viewed in isolation, does not identify the value of the strategy compared to the base situation or to other alternatives at the whole property level. To make this assessment it is necessary to conduct a marginal, property-level analysis which accounts for changes in unpaid labour, herd structure and capital, and which includes the implementation phase. The marginal economic and financial impact of feeding whole cottonseed to the breeder herd as a strategy to improve herd performance is summarised in Table 56. The sensitivity of the returns to the landed price of whole cottonseed was tested by reducing the estimated landed price by 50%. The return on the extra capital invested in feeding whole cottonseed was negative, even when the current price for whole cottonseed, associated with drought induced shortages, was halved. The breakeven landed price for whole cottonseed was less than $125/tonne.

Table 56 - Returns for feeding whole cottonseed to the breeder herd

All terms defined in the Glossary of terms and abbreviations

Factor	**Value (at $700/tonne landed)**	**Value (at $350/tonne landed)**
Period of analysis (years)	30	30
Discount rate for NPV	5%	5%
NPV	-$777,663	-$386,426
Annualised NPV	-$50,588	-$25,138
Peak deficit (with interest)	-$1,971,500	-$1,082,073
Year of peak deficit	n/c	n/c
Payback period (years)	n/c	n/c
IRR	n/c	n/c

3.2.4 Buffel paddock development

3.2.4.1 Introduction

Buffel grass, is the most drought tolerant introduced grass species available for northern Australia and is commonly sown in regions with an annual rainfall between 300 and 750 mm (Humphreys and Partridge 1995; Cook 2007). It is more productive than native grasses but requires a higher level of fertility. In particular, buffel grass requires available P levels above 10 mg/kg to establish and persist, and is also intolerant of high levels of soil aluminium and manganese (Cook 2007). These soil constraints are typical of Mulga Land soils (Dawson and Ahern 1973; Beale 1994; McLennan *et al.* 1999; P. Zund, pers. comm.). Hence, although some areas of cleared woodland within the Mulga Lands have been sown to buffel grass, its spread and persistence has been limited to the more fertile soil types such as heavier soils growing poplar box trees within the Soft mulga land type (Beale 1994; Partridge 1996; The State of Queensland 2019).

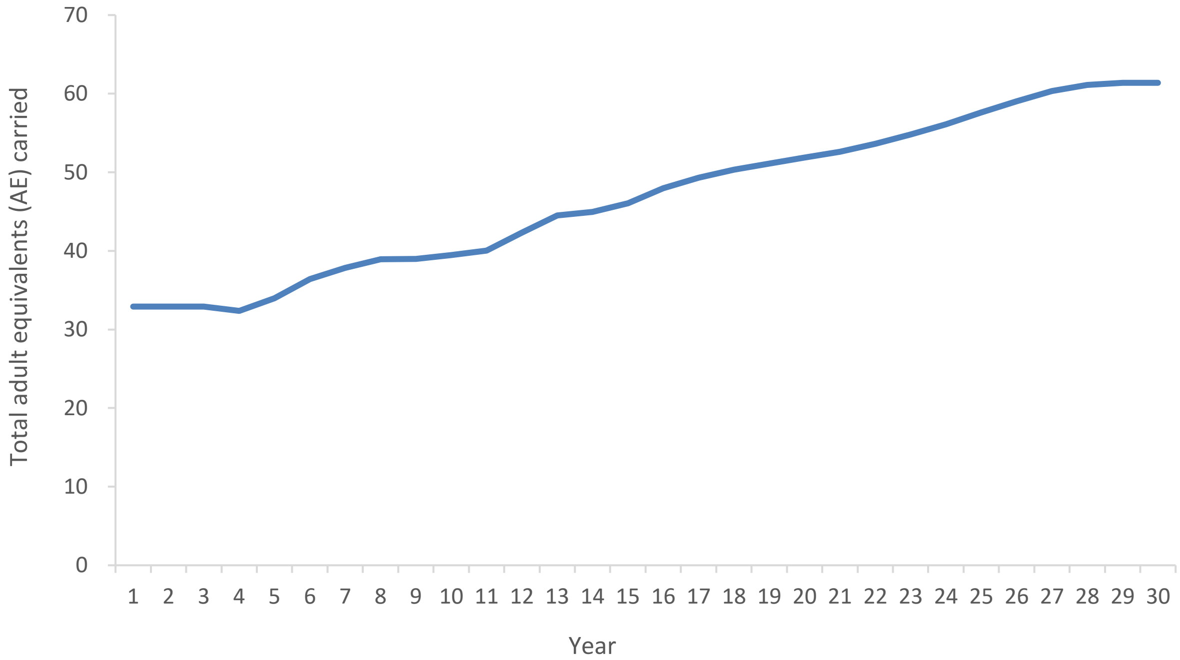
Buffel can be established by broadcasting seed from a ground-based machine or aircraft, generally after country is burnt or timber is pushed or pulled (Cavaye 1990). An ash seedbed or disturbed soil improves the reliability of establishment. In more arid western areas including the Mulga Lands, ‘microsites’, or natural depressions such as stump-holes or pushed or pulled trees on the ground, increase establishment success by providing moist areas for seed germination and protection of seedlings from grazing (The State of Queensland 2020f). The ‘fluffy’ nature of the seed makes it difficult to sow using conventional machinery and therefore rolling ‘drum seeders’ are commonly used. Pelleted or coated seed makes the seed easier to handle and spread; however, higher sowing rates are necessary, establishment is not necessarily improved, and the seed is much more expensive than uncoated seed (Cavaye 1990; The State of Queensland 2020f). A sowing rate of 2 kg/ha of uncoated seed is considered appropriate to establish a good sward of buffel within 1-2 years, given adequate rainfall. Lower sowing rates may delay the establishment of a good sward by 3-5 years (Cavaye 1990). Buffel grass germination relies on good rain after planting. The seed must maintain contact with wet soil for 4-5 days to produce a seedling (The State of Queensland 2020f). Sub-soil moisture is required to sustain the seedling until follow-up rainfall occurs. Similar conditions are required for the successful establishment of the native grass species endemic to the region.

3.2.4.2 Methods

This strategy considered the sowing of a 1,000 ha paddock to buffel and allowing it to increase in density over time. A paddock with more suitable soil types of predominantly Soft mulga and Black soil was selected. It was also assumed the timber in the paddock had been recently pulled for mulga-feeding, therefore providing an improved seed bed (compared to a paddock with no soil disturbance). The buffel seed was flown onto the paddock at a low rate (0.5 kg/ha) in the first year of the development. A germination rate of 15-20% was assumed, with the seed produced from the first germination 2-4 times the original amount of seed planted. The buffel grass was then allowed to self-seed over time to increase the density of the grass in the paddock. The stocking rate of the selected paddock was maintained at a low level (30 AE/1,000 ha) for the first 3 years to allow the buffel to set seed. The estimated cost of buffel seed and the application of the seed to the paddock was $5,000 for buffel seed (1,000 ha x 0.5 kg/ha at $10/kg) and $1,200 for plane hire (6 x 20-25 kg bags of seed takes four trips to the paddock and 2 hours flying time at $600/h).

It was estimated that the carrying capacity of the paddock would increase by 30% over the first 10 years of the development with the improvement in carrying capacity continuing until the carrying capacity of the paddock was doubled by Year 30 of the development. Additional livestock capital was required as the carrying capacity of the paddock increased over time. This was incorporated in the analysis, via retention of natural increase in the herd over time, at the paddock level. Figure 13 shows the rate of increase in carrying capacity over time for the paddock to be developed.

Figure 13 - Rate of increase in carrying capacity for a 1,000 ha paddock planted to buffel



3.2.4.3 Results and discussion

The buffel development was a long, slow process that provided a slightly positive return. The majority of the benefit was due to the cattle capital accumulated over the 30-year development period (Table 57). If additional areas of buffel were to be developed using the same approach, the return to each additional area of buffel would have the same rate of return as for this initial 1,000 ha, i.e., roughly an additional $1.72/ha.annum resulting from buffel development.

Table 57 - Returns for buffel development in a 1,000 ha paddock

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Discount rate for NPV	5%
NPV	$26,395
Annualised NPV	$1,717
Peak deficit (with interest)	-$10,578
Year of peak deficit	7
Payback period (years)	16
IRR	13.55%

3.2.5 Destocking through livestock sales

3.2.5.1 Introduction

Enterprise and resource management in the Mulga Lands relies on fodder harvesting mulga, which is considered an economic imperative without which grazing businesses are unlikely to be viable (Page *et al.* 2008). However, the ability to retain livestock through use of mulga fodder, even when grass biomass is limiting, has been the major contributor to pasture degradation in the region (Pritchard and Mills 1986). Reports indicate the application of higher stocking rates and pasture utilisation rates in the Mulga Lands bioregion than indicated as 'safe' for maintaining pasture condition (McKeon *et al.* 2004; Commonwealth of Australia 2008). Additionally, there is evidence that high pasture utilisation levels are leading to the necessity of recurrent and extensive fodder harvesting of mulga to maintain livestock numbers (Commonwealth of Australia 2008; Page *et al.* 2008). The long-term, ongoing harvesting of mulga fodder is constrained by the current vegetation management laws in Queensland.

The outcome of the maintenance of cattle numbers on a property via mulga feeding is expected to be (1) increased costs associated with fuelling and operating a bulldozer to push mulga, and (2) a requirement for a person to drive the bulldozer for extended periods. Although the time of the person driving the dozer may be unpaid, it has a significant opportunity cost to the property. One alternative to maintaining stock numbers during significant dry periods is to sell a large portion of the breeding herd and manage the remaining herd to reduce mulga feeding activities, thereby reducing property operating costs.

3.2.5.2 Methods

In this strategy, options were examined to allow destocking half of the breeding herd, stocked at the safe stocking rate of 500 AE, as a response to a significant dry period instead of continuing with the current management strategy that relies on feeding mulga to maintain stock numbers. It was predicted that dry periods of sufficient intensity to implement such a destocking strategy could occur once every decade on average. To test the impact of a destocking strategy on the relative economic and financial performance of the property, the following assumptions were made about the impact of destocking:

- Half of the replacement yearling heifers, all PTE females, and previously PTIC females that did not produce a weaner that year were sold on average every 10 years (Years 5, 15 and 25 in the 30-year model). The females were valued at 80% of the usual expected sale price for mature females due to the inability to select sale females on weight in this strategy. Normal sales in other years were made at normal prices. This provided a normal number of weaners in the year of the destocking.
- 18 months after the destocking, pastures and forage had responded sufficiently for herd numbers to return to normal levels.
- The annual fuel, oil, repairs and maintenance (FORM) allowance for the property was reduced by 20% from Year 5 to Year 30, despite destocking occurring in only 10% of years. This cost saving was due to a decrease in general mulga feeding resulting from the lower average stocking rate over time.
- The value of the labour saving was incorporated through a reduction of 10% in the operator's allowance.
- The average herd performance was maintained at the level of the base herd with basic management strategies including inorganic supplements during the growing season.

Following recovery from the dry period (in this example, 18 months following destocking) the choices considered were either:

(1) to allow the breeding herd to rebuild numbers through natural increase over time,

(2) the purchase of PTIC breeders to replace those that were sold during the destocking phase, or

(3) taking cattle on agistment to maintain income during the herd-rebuilding phase after drought.

The counterfactual to each destocking and subsequent recovery strategy combination was the herd with basic herd management strategies in place.

3.2.5.2.1 Recovery from destocking through natural increase in livestock numbers

In this 1st sub-scenario, no intervention was applied following destocking to maintain income or rebuild the herd numbers. The cattle herd was rebuilt over time through natural increase alone. Destocking involved sale of additional females, once every 10 years from Year 5, and then attempted to build numbers back to 500 AE through natural increase. The sensitivity of the property returns to the savings made in FORM allowance due to destocking was tested by halving the assumed level of savings (i.e., 10% savings cf. 20%) while the labour savings remained at 10% reduction in operator's allowance.

3.2.5.2.2 Recovery from destocking through purchase of replacement breeders

In the 2nd sub-scenario, the females were also sold once every 10 years from Year 5. However, sufficient pregnancy tested in calf (PTIC) females were purchased to achieve 500 AE on the property 2 years after the breeders were destocked. PTIC breeders were purchased to rebuild numbers at the end of each drought, at a cost equivalent to 20% more than the average gross sale price for cull mature females. This cost included an allowance for getting the cows to the property. The purchased PTIC cows produced a weaner in the year of purchase, and they were purchased in the 2nd year after the destocking took place. An allowance of 10% was made for calf loss in the PTIC cows.

3.2.5.2.3 Recovery from destocking by taking cattle on agistment

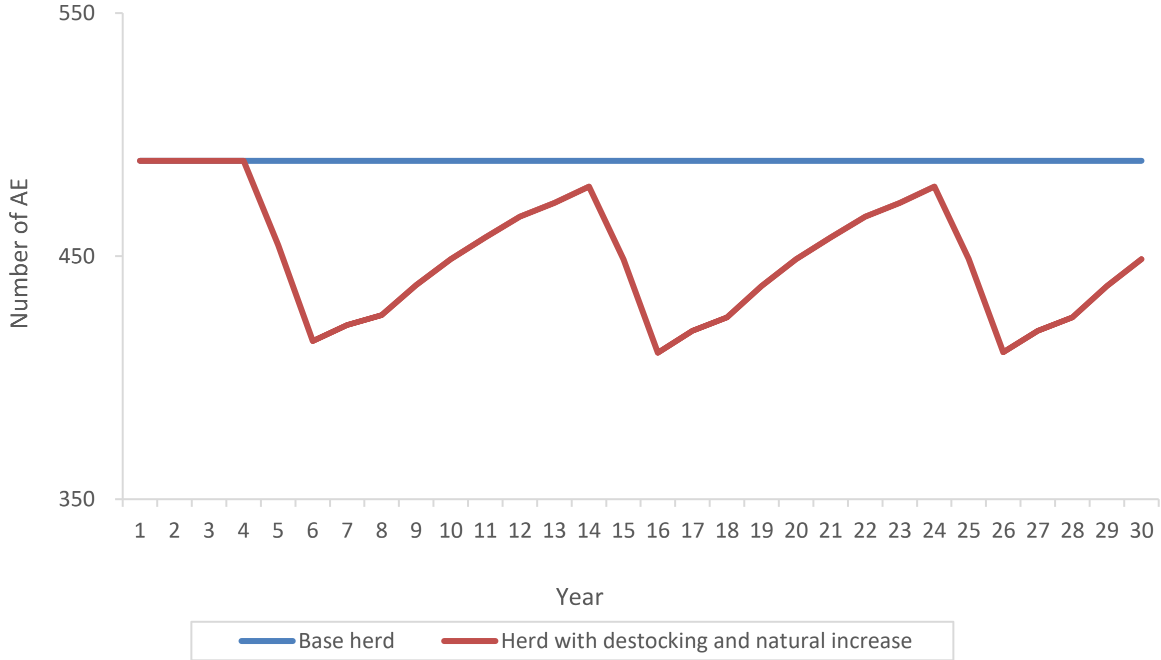
In the 3rd sub-scenario, cattle were taken on agistment to maintain income during the herd rebuilding phase following drought. As for first two sub-scenarios, a destocking frequency of once every 10 years on average was applied with 50% of the breeders sold and cattle taken on agistment during the herd rebuilding period. The income from cattle taken on agistment was valued at $3, $5 or $7/AE.week. The number of cattle taken on agistment was assessed as 90% of the available carrying capacity while herd numbers were being rebuilt through natural increase, starting 18 months after the destocking event took place. The number of cattle on agistment declined over time as herd numbers rebuilt through natural increase.

3.2.5.3 Results and discussion

3.2.5.3.1 Recovery from destocking through natural increase in livestock numbers

Figure 14 shows the impact on the total AE on the property, of the strategy to destock and sell 50% of the breeding females as a response to drought and then allow natural increase to rebuild herd numbers. Although the breeders were all sold in 1 year, the total AE on the property continued to fall as a result of a lower number of replacement stock and sale steers coming through the herd after the drought period. Although minimal cull female sales were made during the herd rebuilding period, it was expected to take about a decade for the grazing pressure to return to ca. 500 AE following destocking. This was predicted to be just before the next drought, and subsequent sell-down of breeders, occurring.

Figure 14 - Total adult equivalents (AE) over time for the property, managed (1) without periodic destocking (Base herd), and (2) with sale of 50% of breeding females every 10 years from Year 5 followed by natural increase in numbers during the recovery period



The capacity to reduce property FORM expenses by 20% on average from Year 5, in combination with the 10% reduction in operator's allowance, overcame the lack of cattle grazing the property over time and produced a positive marginal return ($5,100 extra profit/year; Table 58). However, if the

FORM cost savings were half the level expected (i.e., 10% FORM cost savings cf. 20%), the property would have similar profitability to the base situation of maintaining the stock numbers and feeding mulga fodder during drought ($880 extra profit/year).

Table 58 - Returns for destocking in response to drought followed by natural increase to rebuild numbers, and two levels of assumed cost savings from reduced mulga feeding

All terms defined in the Glossary of terms and abbreviations

Factor	Value (20% FORM cost savings from Year 5)	Value (10% FORM cost savings from Year 5)
Period of analysis (years)	30	30
Discount rate for NPV	5%	5%
NPV	$78,500	$13,500
Annualised NPV	$5,100	$880
Peak deficit (with interest)	n/c	n/c
Year of peak deficit	n/c	n/c
Payback period (years)	n/c	n/c
IRR	n/c	n/c

3.2.5.3.2 Recovery from destocking through purchase of replacement breeders

Figure 15 shows the impact on the total AE on the property of the strategy to destock and sell down 50% of the breeding females as a response to drought, and then purchase PTIC cows to rebuild herd numbers. A total of 55 breeders were purchased in Year 7 and 50 breeders were purchased in Years 17 and 27 to return numbers to an almost full stocking capacity of 500 AE. Although the breeders were all sold in 1 year in response to drought, the total AE on the property continued to fall as a result of a lower number of replacement stock and sale steers coming through the herd during the drought period.

Figure 15 - Total adult equivalents (AE) over time for the property with and without destocking followed by purchases of pregnancy tested in-calf (PTIC) cows

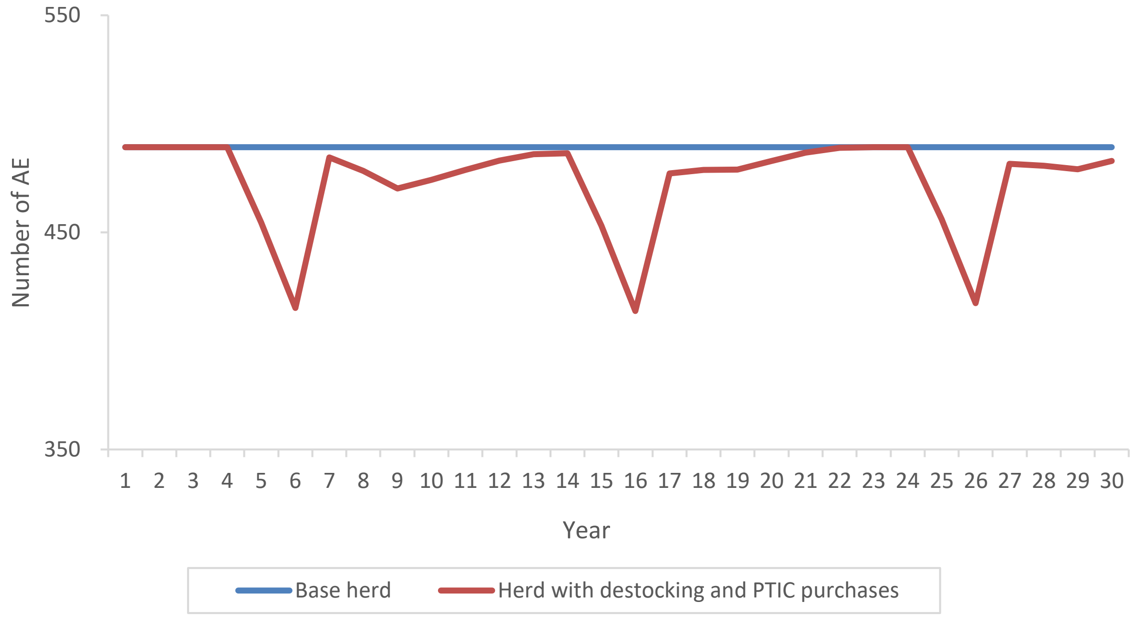


Table 59 indicates that the expected benefit of restocking with PTIC cows was about the same as allowing natural increase to rebuild numbers. It appears that the costs incurred in purchasing the PTIC cows reduce the benefit of maintaining stock numbers over time. Therefore, it appears that the main impact on the profitability of destocking is the assumed level of savings of FORM costs for the property. The previous sub-scenario indicates that at least a 20% reduction in ongoing FORM costs, and a nominal saving of 10% of the labour required to run the property, is necessary from Year 5 to Year 30 for a destocking strategy of this nature to be given consideration.

Table 59 - Returns for destocking in response to drought with recovery through purchase of pregnancy tested in-calf (PTIC) cows to rebuild numbers

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Discount rate for NPV	5%
NPV	$123,200
Annualised NPV	$8,000
Peak deficit (with interest)	n/c
Year of peak deficit	n/c
Payback period (years)	n/c
IRR	n/c

3.2.5.3.3 Recovery from destocking by taking cattle on agistment

Table 60 shows the expected gross income available from taking stock on agistment during the herd rebuilding period. The returns for taking stock on agistment during the herd rebuilding phase at three alternative rates of agistment income are shown in Table 61. The agistment strategy resulted in negative returns when the rate of agistment income was below $7/AE.week.

Table 60 - Assessment of agistment income during the herd rebuilding phase following destocking

Year	AE without destocking	AE with destocking	Difference	AE on agistment	Income at $3/AE.week	Income at $5/AE.week	Income at $7/AE.week
1	489	489	0				
2	489	489	0				
3	489	489	0				
4	489	489	0				
5	489	455	35				
6	489	415	74				
7	489	422	68	61	$9,495	$15,826	$22,156
8	489	426	64	57	$8,923	$14,872	$20,821
9	489	438	51	46	$7,186	$11,977	$16,768
10	489	449	41	36	$5,690	$9,484	$13,277
11	489	458	32	28	$4,427	$7,378	$10,330
12	489	466	23	21	$3,228	$5,379	$7,531
13	489	472	17	16	$2,437	$4,062	$5,686
14	489	479	11	10	$1,500	$2,499	$3,499
15	489	449	41				
16	489	410	79				
17	489	419	70	63	$9,827	$16,378	$22,930
18	489	425	64	58	$9,049	$15,082	$21,115
19	489	438	52	46	$7,239	$12,065	$16,891
20	489	449	41	36	$5,690	$9,484	$13,277
21	489	458	32	28	$4,427	$7,378	$10,330
22	489	466	23	21	$3,228	$5,379	$7,531
23	489	472	17	16	$2,437	$4,062	$5,686
24	489	479	11	10	$1,500	$2,499	$3,499
25	489	449	40				
26	489	410	79				
27	489	419	70	63	$9,821	$16,368	$22,915
28	489	425	64	58	$9,049	$15,082	$21,115
29	489	438	52	46	$7,239	$12,065	$16,891
30	489	449	41	36	$5,690	$9,484	$13,277

Table 61 - Returns for taking stock on agistment during the herd rebuilding phase

All terms defined in the Glossary of terms and abbreviations

Factor	Value at $3/AE.week	Value at $5/AE.week	Value at $7/AE.week
Period of analysis (years)	30	30	30
Discount rate for NPV	5%	5%	5%
NPV	-$46,500	-$11,600	$23,300
Annualised NPV	-$3,000	-$760	$1,500
Peak deficit (with interest)	-$152,600	-$52,200	n/c
Year of peak deficit	n/c	n/c	n/c
Payback period (years)	n/c	n/c	n/c
IRR	n/c	n/c	n/c

3.2.6 Destocking by sending breeders on agistment

3.2.6.1 Introduction

An alternative to sale of breeders in response to a significant dry period or drought, is a strategy of sending breeders on agistment. This section considers that option.

3.2.6.2 Methods

A destocking frequency of once every decade on average was applied, as for the previous strategy. The breeders and young females previously sold were sent on agistment for 18 months and then returned. The breeders sent on agistment achieved the same performance as if they had been maintained on the Mulga Lands base property. Transport costs were incurred to take the stock to the agistment property and return them from the agistment property at $2/km.deck (26 head/deck) for 500 km one way. Agistment was costed at $3, $5 or $7/AE.week. Management costs were incurred to check on the cattle during the agistment period with the stock visited every 2 months on average at a cost of $500/visit.

To test the impact of this agistment strategy on the relative economic and financial performance of the property, the following assumptions were made about the impact of destocking:

- The female cattle were sent on agistment in Years 5, 15 and 25 in the 30-year model.
- 18 months after sending the breeders on agistment, pastures and forage had responded sufficiently for herd numbers to return to normal levels or stock to be taken on agistment.
- The annual FORM allowance for the property was reduced by 20% from year 5 to year 30. This was a result of the lower average stocking rate applied to the property over time.
- The allowance for labour and management was reduced by 10% from year 5 due to the reduction in mulga feeding.
- The average herd performance was maintained at that achieved by the base herd with basic herd-management strategies in place.

The counterfactual to each destocking through agistment strategy was the herd with basic herd management strategies in place and no destocking.

3.2.6.3 Results and discussion

Table 62 shows the calculation of total costs each time part of the breeding herd was sent away on agistment. The assumption was that 80 head (1.2 AE/head) were sent on agistment for 72 weeks. A total of nine management trips at $500/trip were required.

Table 62 - Calculation of agistment costs

Parameter	**Agistment cost ($/AE.week)**		
	$3	**$5**	**$7**
Agistment	$20,736	$34,560	$48,384
Transport	$14,769	$14,769	$14,769
Management	$4,500	$4,500	$4,500
Total agistment costs	*$40,005*	*$53,829*	*$67,653*

Table 63 indicates the value of sending breeders on agistment three times over a 30-year period as a response to drought. The analysis suggests sending stock on agistment during drought may be a better option for the business than selling breeders and then taking cattle on agistment during the herd rebuilding phase (Section 3.2.5.3.3). Even so, consideration of the destocking strategies and the counterfactual of maintaining the stock and pushing mulga as a drought fodder suggests that destocking combined with 'something' will be better than not destocking. What the combination will be in each drought event will depend upon the availability of long-term agistment at a reasonable cost versus the expected availability of stock to take on agistment during the recovery phase and the income that can be earned from that activity.

Table 63 - Returns for sending breeders on agistment as a response to drought
All terms defined in the Glossary of terms and abbreviations

Factor	Value at $3/AE.week	Value at $5/AE.week	Value at $7/AE.week
Period of analysis (years)	30	30	30
Discount rate for NPV	5%	5%	5%
NPV	$115,000	$93,400	$71,900
Annualised NPV	$7,500	$6,100	$4,700
Peak deficit (with interest)	-$25,000	-$38,838	-$52,700
Year of peak deficit	5	5	5
Payback period (years)	6	7	8
IRR	n/c	n/c	n/c

3.3 Investments other than beef production

The previous sections (results summarised in Table 1, Table 2 and Table 3) have indicated very limited opportunity to improve the profitability, and hence viability, of the beef enterprise on the representative Mulga Lands property. This understanding led to examination of alternative investment options for the Mulga Lands property including production of rangeland goats and carbon farming. Although, historically, Merino wool sheep were the dominant livestock production system in the Mulga Lands, sheep production is now uncommon in the target region. For this reason, as well as the lack of interest by our local advisory group in examining sheep wool or meat enterprises, they were not included in this study. Merino wool and meat sheep enterprises were examined for the Longreach region with results presented in the 'Rangelands of central-western Queensland' report (Bowen and Chudleigh 2021b). This report can be accessed from the project internet page: Improving profitability and resilience of grazing businesses in Queensland - Preparing for, responding to, and recovering from drought - FutureBeef. Furthermore, the property-level, regionally specific herd and business models developed for that analysis are available for use by others and can be applied to assess sheep scenarios for the Mulga Lands, if required.

The results of this section relate to the hypothetical property outlined in this report and the associated assumptions made for the expected production responses to changing the management strategy. Different results may be gained for different properties or production systems and hence it is recommended that property owners, managers or their advisors use the tools and models developed in this study to conduct their own analyses specific to their circumstances.

3.3.1 Rangeland goats

3.3.1.1 Introduction

The Australian rangeland goat is a composite breed comprised of dairy, fibre and meat goat breeds. The rangeland goat has evolved over the past 200 years from animals that escaped domestication and formed small herds in more the arid areas in Australia, largely in western New South Wales and south western Queensland (MLA 2006; Hacker and Alemseged 2014). Rangeland goat production in the Mulga Lands (mostly through harvest of semi-feral or feral goats) has occurred since the 1980s (Heywood *et al.* 2000). Pople and Froese (2012) estimated that feral and rangeland goat populations in Queensland increased over a 20-year period to 2004, particularly in the Mulga Lands where goats increased almost five-fold over this period. However, the number of goats surveyed has been declining since 2006 (Pople and Froese 2012), which appears largely related to increased meat goat prices leading to increased harvest of feral goats.

As the value of the goat meat industry in Australia has increased over recent decades, so has the interest in managed production systems, rather than harvesting wild populations (Hacker and Alemseged 2014; Robertson *et al*. 2020). In the Queensland rangelands, various levels of management intensity are currently applied following containment of goats with suitable fencing. This may include (1) mating rangeland does with selected or introduced bucks including rangeland, Boer or Kalahari Red breeds, (2) control of mating period, (3) weaning and (4) supplementation.

Although currently there are few specialist rangeland goat producers in the Mulga Lands, interest appears to be increasing with a recent (October 2020) Cunnamulla field day discussing the management of meat goats run under rangeland conditions attracting 70 participants. The expansion of the area behind exclusion and cluster fences in the region, in combination with the recent high prices for rangeland goat meat on export markets, has encouraged some local landholders to consider goats as an alternative to beef cattle.

The more flexible diet of goats and their better ability to select for diet quality, as well as physiological and behavioural adaptions to harsh rangeland environments, allows a relatively higher reproductive rate and possibly better drought resilience compared to other livestock species (Hacker and Alemseged 2014). An advantage of goat production in the Mulga Lands is the preferential selection by goats of proportionally more browse, when it is available, relative to the other livestock species (Hacker and Alemseged 2014; Pahl 2019b). Furthermore, there is evidence that rangeland goats can digest and utilise mulga browse more effectively than cattle and sheep due to adapted micro-organisms in the rumen fluid which improve nitrogen digestion and retention (Brooker *et al.* 1994; Miller *et al.* 1995, 1996, 1997).

The complete conversion from a beef herd to a herd of rangeland goats on the constructed property is something we can examine in a modelling exercise. Whether it is a realistic proposition to convert an entire property to meat goat production in the Mulga Lands will be decided by time and by the building of experience in the management of rangeland goats run in large mobs under extensive and controlled (not semi-feral) conditions. To convert from beef to goat production, property managers would need to invest in an external exclusion fence to provide protection from wild dogs and to contain the goat herd. Investment in some internal fencing and infrastructure would also be required to manage goats.

3.3.1.2 Methods

Initially, the entire property was modelled as an existing rangeland meat goat enterprise, in a steady-state analysis, for comparison with the alternative self-replacing beef herd and steer turnover enterprises. Then the marginal returns were calculated for full conversion from the self-replacing beef enterprise to a rangeland goat enterprise. In the steady-state analysis, the initial assumption was made that internal fences were sufficient to contain goats on specific parts of the property and that classes of weaner goats could be separated from the breeding herd and maintained as separate mobs of goats. In the steady-state analysis, it was also assumed that the property had an exclusion fence as a boundary. These assumptions were removed when the transition from a beef to a rangeland goat enterprise was modelled.

The rangeland meat goat activity was a self-replacing breeding and growing activity that relied on the production of weaner kids by a breeding herd. Weaner bucks were not castrated and entered a growing system that varied in size with the period of time bucks were retained prior to sale. Weaner does maintained the breeding herd or were culled and sold. Breeding does were culled on age. Herd bucks were retained in the breeding herd for an average of 3 years, although allowance was made for some trading of herd bucks which led to the replacement expense being calculated at a 20% replacement per annum rate. Weaner does were separated from weaner bucks and were expected to have their first kids after a yearling mating. The goat enterprise modelled in this scenario is based on semi-feral or rangeland genetics underpinning the does with some crossbred (rangeland goats crossed with Kalahari, Nubian or Boer genetics) bucks used as sires. As for the beef enterprise, the rangeland goat enterprise employed no permanent labour other than the owner/manager. An allowance of an additional $10,000/annum was allocated to contract wages and other mustering expenses for the property when it was run solely as a rangeland goat enterprise. This doubled the mustering and hired labour expense compared to running the property solely as a beef enterprise. The allowance for operator’s labour and management was set at $45,000/annum, the same as the allowance for a self-replacing beef herd or a steer turnover enterprise.

The parameters applied were derived from discussion with one meat goat producer located in the Mulga Lands near Charleville and three meat goat producers located in the Mitchell grasslands further north near Longreach. The production parameters described by each of these producers had sufficient similarity for an initial model to be constructed for a Mulga Lands property. This model can be refined as more case studies and industry data becomes available.

To convert from beef to goats, the constructed property invested in an external exclusion fence estimated at ca. $500,000. Although the optimum way to run a large mob of goats is still under discussion, it is expected that significant changes and additions would be required to the existing internal fencing and livestock infrastructure on the beef property, even if useable sheep yards were available. In our analysis, an amount of $150,000 was allocated to capital expenditure to remediate internal fences and convert a set of sheep yards to handle goats. If no useable sheep yards were available for modification, additional expenditure would be required to install one or more sets of goat yards. Therefore, the minimum capital cost to convert from the constructed beef property, which had little sheep infrastructure still in place, to a goat property with an exclusion fence and suitable internal infrastructure was expected to be $650,000. Additionally, in our analysis we assumed that investment in specialist goat handling equipment was also required at a cost of $15,000.

The combined meat goat and beef model was structured to sell down the existing beef breeding herd in the first 2 years of a 30-year period. The steer component of the beef herd was sold as target weights were reached. The goats were established through the purchase of sufficient breeding does of mixed ages at the start of the 2nd year to provide a full complement of female goats for the property. The kids produced by the purchased breeding goats in their 1st and 2nd years on the property were retained to build up numbers. Once the herd of goats achieved the structure and size identified in the steady-state, self-replacing meat goat model structure, (Year 4 in the model), the expected culling and sale strategy was applied. The purchase price of the does was based on the value applied to calculate their sale value in each age class in the steady-state, meat goat model with the expected cost of transport to the property added.

3.3.1.2.1 Kid growth assumptions

To simplify the analyses, all pre-weaning and post weaning growth rates for female kids were set at 5% lower than male kids, consistent with assumptions for cattle in this analysis. Table 64 indicates the expected pre-weaning and post-weaning seasonal performance for young bucks up until 12 months of age. Weaner bucks were assumed to achieve 29 kg/head.annum post-weaning and weaner does to achieve 28 kg/head.annum post-weaning. There is some uncertainty about the average age of weaners, but it is expected most kids would be weaned by 4-5 months of age.

Table 64 - Expected pre-weaning and post-weaning growth rates for male rangeland goat kids

Month of age	Days	Liveweight (kg)
Birth	Apr	3
1	May	6
2	Jun	8
3	Jul	11
4	Aug	14
5	Sep	17
6	Oct	19
7	Nov	22
8	Dec	25
9	Jan	28
10	Feb	31
11	Mar	33
12	Apr	33

3.3.1.2.2 Husbandry costs and treatments

Table 65 shows the treatments applied to the various classes of goats held for 12 months in the herd model. Sale stock may or may not have received the treatment depending upon the timing of sale. Labour costs were deducted as an operating or overhead cost later in the analysis. The mineral block fed to goats cost $1,400/tonne landed and was fed for 180 days/annum with an average intake of 7.5 g/head.day.

Table 65 - Treatments applied and cost per head

Treatment	Kids	Does 1-2 years	Does 2-3 years	Does 3+ years	Herd bucks
Tags	$1.50	-	-	-	-
Weaner hay	$1.00	-	-	-	-
Weaner supplement	$0.50	-	-	-	-
6 in 1	$1.00	-	-	-	-
Mineral blocks	$1.89	$1.89	$1.89	$1.89	$1.89

3.3.1.2.3 Other herd performance parameters

There is little data available to describe the performance of rangelands goats and crossbreds in the Mulga Lands of Queensland. Data to describe the reproduction efficiency of the herd was based on the discussions held with local goat producers. The expected reproductive performance and mortality rates are summarised in Table 66. This data set was seen as being closest to the expected performance of a herd of rangeland goats located in the Mulga Lands near Charleville, run with a reasonable level of management input and with the use of purchased bucks with selection for performance and growth in this environment.

Table 66 - Reproduction performance and mortality rates for crossbred rangeland goats near Charleville

Goat age year start Goat age year end	Weaners 1	1 2	2 3	3 4	5 6	6 7	7 10
Expected conception rate for age group (%)	n/a	95	95	95	90	85	80
Expected kid loss from conception to weaning (%)	n/a	15	12	12	12	12	12
Proportion of empties (PTE) sold (%)	n/a	0	0	100	100	100	100
Proportion of pregnants sold (%)	n/a	0	0	0	0	0	0
% of does with twins	n/a	30	80	80	80	80	80
Kids weaned/does retained (%)	n/a	105	150.5	158.4	158.4	158.4	158.4
Female death rate (%)	5.0	5.0	5.0	5.0	5.0	5.0	6.0
Male death rate (%)	5.0	5.0	n/a	n/a	n/a	n/a	n/a

n/a, not applicable; PTE, pregnancy tested empty (i.e., not in kid).

3.3.1.2.4 Goat herd dry sheep equivalent (DSE) assumptions

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 grazing pressure. Maintaining equivalent grazing pressure across different species (e.g., cattle, sheep and goats) and 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 adult equivalent (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). Additionally, there is a paucity of information to indicate the appropriate ratings for the Australian rangeland goat, including incorporating consideration of the high reproductive rate of the species (e.g., Hacker and Alemseged 2014).

To determine grazing pressure equivalence of cattle and goats grazing in the Mulga Lands, we adopted the recommendations of McLennan *et al.* (2020) in their recent review of animal unit equivalence. These authors defined the AE or DSE rank assigned to a grazing animal as the ratio of its metabolisable energy (ME) requirements for a particular level of production to that of a 'standard animal' (cattle (AE) or sheep (DSE)). In doing this, ME requirements are determined using the Australian feeding standards for ruminants (NRDR 2007). While this approach was used in our analysis to determine grazing pressure equivalence (via assigning AE or DSE rank to animal species and the classes within), it was not used in the subsequent herd and economic modelling in BCD where a linear AE approach was adopted. To test the effect of applying the 'ME requirement' AE cf. the linear AE, in the subsequent herd and economic modelling, the equations of McLennan *et al.* (2020) were incorporated into a modified version of BCD and used to test the ranking of economic outcomes from this approach, with the traditional linear AE approach. As the ranking of outcomes was the same with both approaches (unpublished data) the application of the simplified, linear AE approach in the economic scenario analyses was justified in this study.

In our analysis, we have assumed equivalence between sheep and goats in DSE rating so that 1 DSE is a 45 kg wether goat with zero weight change, walking 7 km/day on level ground and with no fibre growth above that included in maintenance. Therefore, the ratio of DSE : AE, using NRDR (2007) unmodified equations, of 8.4 : 1 (73/8.7 MJ/day) was used to express the numbers of goats in modelled scenarios in DSE units to achieve uniform grazing pressure across species. Further justification of the adoption of this DSE ratings and approach used in this analysis are given in an accompanying report assessing alternative livestock enterprises in the central-western rangelands of Queensland (Bowen and Chudleigh 2021b).

The DSE ratings were calculated for a period of time, not for a point in time. Except for weaners and sale stock, this was 12 months, e.g., from age 12 to 24 months. The weaner group was rated for 7 months (age 5 to 12 months) for 'keepers', and less for those sold. This is even though the kids may be weaned at less than 5 months old. All sale stock were rated from their nominal birth month to their sale month, e.g., bucks sold at age 18 months were rated for 6 months (age 12 to 18 months) in their sale year. Table 67 shows the DSE ratings for all classes of goats retained in the herd for the entire 12-month period.

Table 67 – Dry sheep equivalent (DSE) ratings for goats held 12 months[A]

Description at start of rating period	Age at start (months)	Age at end (months)	Goats carried through whole year			
			Months rated	Lowest or start liveweight (kg)	Highest or end liveweight (kg)	DSE/head rating
Extra for does weaning a kid	n/a	n/a	n/a	n/a	n/a	0.476
Kids 5 months	5	12	7	16	33	0.32
Does 1-2 years	12	24	12	32	54	0.96
Does 2-3 years	24	36	12	54	65	1.32
Does 3 years +	n/a	n/a	12	65	65	1.44
Bucks 1 year	12	24	12	33	57	1.00
Herd bucks all ages	n/a	n/a	12	80	80	1.78

n/a, not applicable.

[A]In the herd and economic modelling the standard weight of one DSE = 45 kg; (AE : DSE of 1 : 8.4).

The DSE ratings for breeding stock are based on weight, plus a loading for a doe that weans a kid. This loading represents the extra nutritional requirement of a doe that rears a kid, relative to a dry doe. The loading for rearing one kid was 0.35 DSE. This covers the extra load of pregnancy, lactation, and pasture consumed for one weaner up to age 5 months, at which point the weaner begins to be rated in its own right. The loading was increased by the ratio of the herd weaning rate to 100% to allow for does that have multiple kids. Table 68 shows the DSE ratings for all classes of goats sold from the herd during the 12-month period.

Table 68 - Dry sheep equivalent (DSE) ratings for goats sold during the year[A]

Description at start of rating period	Sale stock carried past rating boundary				
	Sale month	Months rated	Start liveweight (kg)	Paddock liveweight at sale (kg)	DSE/head rating
Kids 5 months	4	7	16	33	0.32
Does 1-2 years	1	9	32	45	0.64
Does 2-3 years	5	1	54	45	0.09
Does 3 years+	5	1	65	50	0.11
Bucks 1 year	3	11	33	57	0.92
Herd bucks all ages	5	1	80	70	0.14

[A]In the herd and economic modelling the standard weight of one DSE = 45 kg; (AE : DSE of 1 : 8.4).

3.3.1.2.5 Prices

The hypothetical, constructed property was located near Charleville with a local abattoir available for sale stock. Slaughter values were underpinned by the MLA 'Queensland over the hooks (OTH)' goat prices database (MLA monthly market statistics database at http://statistics.mla.com.au/Report/List). The OTH indicators are calculated as a weighted average of Eastern States processor grids and saleyards. Transport and other selling costs were estimated for Charleville (ca.100 km distance).

Prices for sale goats have shown large variability over the last 4 years with a substantial increase in the prices paid compared to the average of previous years. Figure 16 shows the price of goat meat over time since 2010. Once carcass weights are above 8 kg there is little to no differentiation in prices. However, goats above 40 kg carcass weight incur a price penalty at the Charleville abattoir.

Figure 16 – Goat meat prices from 2010 to 2020

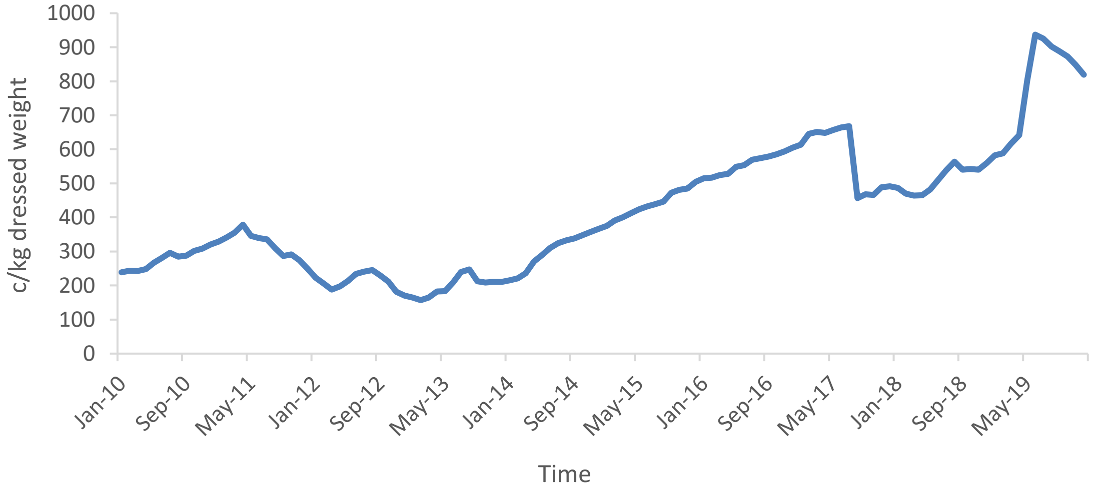


Table 69 shows the price data and selling costs for each class of stock retained in the goat meat models. All bucks were sold between 1 and 2 years old. No allowance for weight loss was made between the paddock weights and the sale weights. A dressing percentage of 45% was applied to convert dressed weight prices to liveweight prices.

Table 69 - Prices worksheet showing selling costs, gross and net prices for meat goats

Group description	Sale liveweight (kg/head)	Dressing %	Dressed price ($/kg)	Other selling costs ($/head)	Freight ($/head)	Net price
Does 1 year	45	45	$6.00	$0.37	$1.60	$119.53
Does 2 years	45	45	$6.00	$0.37	$1.60	$119.53
Does 3 years	50	45	$6.00	$0.37	$1.61	$133.02
Bucks 1-2 years	57	45	$6.00	$0.37	$1.61	$151.92
Cull herd bucks	70	45	$6.00	$0.37	$1.61	$187.02

3.3.1.3 Results and discussion

3.3.1.3.1 Profitability of the rangeland goat enterprise – steady-state analysis

Table 70 shows the initial parameters for the self-replacing rangeland goat system.

Table 70 – Steady-state rangeland goat parameters

Parameter	Value
Herd size (DSE)	4,200
Age at first mating (1 or 2 years)	1
Doe casting age	10
Total does joined	1,292
Total kids weaned	1,759
Kids weaned/does mated (%)	136.11
Doe weaners retained	879
Surplus doe weaners sold	0
Mature does sold	773
Weaner bucks sold	0
Mature kids sold	835

Table 71 indicates the herd gross margin after interest for (1) two buck culling ages (1-2 years or weaners), (2) two ages of culling surplus young does (1-2 or 2-3 years), and (3) three maximum ages of doe culling (10, 8 or 4 years). The age of buck turnoff producing the highest expected herd gross margin after interest was between 1 and 2 years of age. When the goat herd was optimised for both male and female sale ages, bucks were sold at 1-2 years of age and surplus young does at 2-3 years with the final cull age for herd does between 4 and 5 years of age.

As the price per kilogram for goat meat doesn't change with age, it appears that herd profit is optimised when the maximum number of does are sold at suitable slaughter weights. The maximum doe culling age for the Longreach rangelands case studies was also 4-5 years (Bowen and Chudleigh 2021b) and although the Charleville herd initially targeted a 9-10 year cull age (due to an initial objective of building up herd numbers), the model is suggesting a cull age similar to Longreach is the most profitable. However, the analysis indicates that those herds building up breeder numbers can keep breeder does until 9-10 years of age without impacting herd profitability greatly. A more rigorous culling of breeder does can be undertaken once the target herd size is achieved. Selling surplus does at 2-3 years old appears more profitable than selling surplus does at 1-2 years old.

Table 71 - Analysis of wether and doe culling age

Parameter	**Age of buck turnoff[A]**		**Age of culling does[B]**		**Optimised herd[C]**
	Yearling	**Weaner**	**Surplus young does, 2-3 years; maximum, 10 years**	**Surplus young does, 2-3 years; maximum 8 years**	
Total dry sheep equivalents (DSE)	4,220	4,200	4,200	4,200	4,200
Total goats carried	2,975	2,548	3 446	3,447	3,462
Weaner does retained	879	1069	951	951	953
Total breeders mated	1,292	1,571	1,575	1,576	1,541
Total breeders mated and kept	1,190	1,447	1,512	1,513	1,525
Total kids weaned	1,759	2,138	1,903	1,903	1,906
Weaners/total does mated	136.11%	136.11%	120.79%	120.75%	123.73%
Overall breeder deaths	5.26%	5.26%	5.13%	5.04%	5.00%
Female sales/total sales %	48.05%	46.78%	47.76%	47.80%	47.80%
Total does sold	773	940	826	828	829
Maximum doe culling age	10	10	10	8	4
Doe joining age	1	1	1	1	1
Weaner doe sales	0.00%	0.00%	0.00%	0.00%	0.00%
One-year-old doe sales %	75.07%	75.07%	0.00%	0.00%	0.00%
Two-year-old doe sales %	0.00%	0.00%	85.72%	83.89%	62.14%
Total bucks sold	835	1069	904	904	906
Maximum buck turnoff age	1	0	1	1	1
Average female price	$122.07	$122.07	$121.00	$121.28	$124.32
Average buck price	$151.92	$87.27	$151.92	$151.92	$151.92
Capital value of herd	$323,196	$299,664	$373,856	$373,791	$372,722
Imputed interest on herd value	$16,160	$14,983	$18,693	$18,690	$18,636
Net goat sales	$221,251	$208,017	$237,272	$237,676	$240,666
Direct costs excluding herd bucks	$15,710	$17,182	$17,409	$17,415	$17,464
Herd buck replacement	$4,444	$5,403	$5,417	$5,419	$5,298
Herd gross margin	*$201,097*	*$185,432*	*$214,446*	*$214,842*	*$217,903*
Herd gross margin less interest	***$184,938***	***$170,448***	***$195,753***	***$196,152***	***$199,267***
Difference to yearling buck turnoff	*Base*	*-$14,489*	*$10,815*	*$11,214*	*$14,330*
Gross margin/DSE	*$48*	*$44*	*$51*	*$51*	*$52*
Gross margin/DSE after interest	*$44*	*$41*	*$47*	*$47*	*$47*

[A]The surplus young female cull age for these analyses was 1-2 years with maximum doe culling age of 10 years.

[B]The male sale age for these analyses was the optimal of 1-2 years.

[C]The optimised herd had a male sale age of 1-2 years, a surplus young female cull age of 2-3 years and a final doe cull age of 4 years.

Table 72 shows the female herd structure for a buck sale age of 1-2 years, a young female cull age of 2-3 years and a final doe culling age of 4-5 years. Expected doe deaths were 162/annum or 5.00% of female breeding stock maintained for the year. The application of the data for reproduction efficiency and mortality rates to the herd model produced an expected average weaning rate of 123.73% (i.e., kids from all does mated). The herd of goats produced about 1,906 weaners from 1,541 females mated and sold 1,739 head/annum. Cull female sales made up 47.80% of total sales.

Table 72 – Female herd structure for the self-replacing goat enterprise

Doe age start year **Doe age end year**	**1** **2**	**2** **3**	**3** **4**	**4** **5**
Does available start year	906	860	309	279
Sales unmated, % start year does	0.00%	62.14%	0.00%	0.00%
Does sold	0	535	15	279
Does mated in each age group	906	326	309	-
Mated does retained in each group	906	326	294	-
Kids weaned from each group	951	490	466	-

Table 73 shows the buck herd structure for the self-replacing herd of goats. The total bucks sold per annum was 906 at an average price of $151.92/head.

Table 73 – Buck herd structure for the goat enterprise

Buck age in months **Buck age group**	**5 to 11** **0**	**12 to 23** **1**	**24 to 35** **2**	**36 to 47** **3**
Number available at start year	953	906	0	0
Number reserved as herd bucks	0	0	0	0
Optional sales %	0%	0%	0%	0%
Transfers to buck herd	0	0	0	0
Sales at each age	0	906	0	0

The estimated herd buck requirements are shown in Table 74.

Table 74 – Herd Buck requirements

Parameter	**Value**
Herd bucks/does to be used (%)	2
Herd bucks required per year	31
% of herd bucks replaced annually (6; $1,000/head)	20
Herd bucks sold per year ($187/head)	5
Herd bucks deaths or destruction (5%)	2
Net herd buck replacement costs/year	$5,298
Net herd buck cost/kid weaned	$2.78

Classes of goats in the herd culling 2-3-year-old surplus does and a final doe cull age of 4-5 years are presented in Table 75.

Table 75 - Classes of goats in the herd

Age at Start of Rating Period	Number kept whole year	Number Sold	DSE/Head Kept	DSE/Head Sold	Total DSEs
Extra for does weaning a kid	n/a	n/a	0.48	n/a	908
Weaners 5 months	1,906	0	0.32	0.32	605
Does 1 year but less than 2	906	0	0.96	0.64	865
Does 2 years but less than 3	326	535	1.32	0.09	480
Does 3 years plus	294	295	1.44	0.11	456
Bucks 1 year but less than 2	0	906	1.00	0.92	830
Herd bucks all ages	31	5	1.78	0.14	55
Total number	*3,462*	*1,739*	-	-	*4,200*

n/a, not applicable. DSE, dry sheep equivalent.

The herd gross margin for the self-replacing rangeland meat goat enterprise is presented in Table 76.

Table 76 - Herd gross margin for the self-replacing herd of rangeland meat goats

Parameter	$/herd	$/goat	$/DSE
Net goat sales	$241,370	$69.72	$57.47
Husbandry costs	$17,458	$5.04	$4.16
Net buck replacement	$6,000	$1.73	$1.43
Gross margin (before interest)	$217,912	$62.94	$51.88
Gross margin less interest	*$199,267*	*$57.56*	*$47.44*

DSE, dry sheep equivalent

The opening value of the land and fixed improvements for the example property was taken as $2,500,000. The opening value of the total value of land, plant and improvements for the goat enterprise investment was $2,708,500. The opening value of goats was $598,681.

Table 77 indicates the expected average annual performance parameters for the rangeland goat enterprise. The meat goat production activity resulted in a rate of return on total capital of about 1.59%. This result was based on the assumption that the property was already protected from wild dogs with appropriate fencing infrastructure and that internal fencing was adequate for managing rangeland goats. The costs of implementing cluster fencing, or similar, were not included in the steady-state analysis.

Table 77 - Expected value of annual outcomes for the self-replacing herd of rangeland goats

Parameter	Value
Dry sheep equivalents (DSE)	4,200
Operating profit	$52,223
Rate of return on total capital	1.59%

3.3.1.3.2 The value of converting from a beef herd to a rangeland goat herd

The transition from beef cattle to goats was implemented to maintain the total grazing pressure applied to the property at about 4,200 DSE and was completed over the first 24 months. Table 78 indicates change in the grazing pressure applied, the sale of the beef herd and the purchase of the goats over the initial years of the transition from beef to goats.

Table 78 – Grazing pressure applied, sales and purchases during the transition from a self-replacing beef cattle herd to a self-replacing rangeland meat goat herd

Herd and flock summary	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Total DSE carried	2,094	3,311	3,371	4,201	4,201	4,201
Cattle total sales number	666	102	0	0	0	0
Goats total purchase number	0	3,338	6	6	6	6
Total new kids	0	1,906	1,906	1,906	1,906	1,906
Net beef cattle sales	$386,822	$64,382	$0	$0	$0	$0
Net goat purchases	$0	$454,555	$6,000	$6,000	$6,000	$6,000
Net goat sales	$0	$103,070	$103,818	$241,306	$241,306	$241,306

DSE, dry sheep equivalent. In the herd and economic modelling, the standard weight of one DSE = 45 kg; (AE : DSE of 1 : 8.4).

Table 79 indicates the extra returns generated by transitioning from the breeder beef herd to the self-replacing rangeland meat goat operation. The transition to rangeland goat production generated an additional $48,326/annum which was substantially greater than the profit generated by implementing any strategies to improve the management of the beef enterprise. This increase in profitability when changing from beef to goat production was similar to that obtained for a comparable analysis for a hypothetical property in the central-western rangelands of Queensland, near Longreach: $45,686 extra profit/annum for a 16,200-ha property running 9,000 DSE (cf. 4,200 DSE in this analysis), (Bowen and Chudleigh 2021b). The IRR for changing from beef to goat production was also similar in both regions: 10.82% for the Mulga Lands property cf. 12.83% for the property near Longreach.

Table 79 - Returns for converting from a self-replacing beef cattle herd to a self-replacing rangeland meat goat operation

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Discount rate for NPV	5%
NPV	$742,888
Annualised NPV	$48,326
Peak deficit (with interest)	-$876,011
Year of peak deficit	3
Payback period (years)	14
IRR	10.82%

In addition to the improvement in returns from implementing this strategy, there are less tangible benefits associated with transitioning from a beef breeder operation to a meat goat operation that are difficult to quantify in an analysis such as this. Most importantly, rangeland goats have a more varied diet than either sheep or cattle and hence are considered to be more drought resilient (e.g., Hacker and Alemseged 2014). The common use of 'semi-feral' genetics as a base for the breeding does may make them more drought tolerant in this region, although the trade-off between possibly more productive genetics and drought tolerance is unknown. In our analysis we have not attempted to account for livestock 'substitution ratios' between cattle, sheep and goats which relate to differences in diet selection and digestion between species (Scarnecchia 1990). As reviewed by Pahl (2019a), relative energy requirements of herbivores grazing Australian rangelands may not be equivalent to relative dry matter intakes due to the differences in the structure of digestive tracts, and selective foraging capabilities resulting in differences in diet quality. Furthermore, there are differences between livestock species in the preferential selection of the forage component/s of the feed-base and foraging areas (Hacker and Alemseged 2014; Pahl 2019b). Pahl (2019b) concluded that equivalency in what and where different herbivore species eat is not quantifiable but appears to be high overall, particularly for perennial grass which is the dominant forage for all species in the rangelands. Selection of proportionally more browse in the diet of goats, in particular, relative to the other species (Hacker and Alemseged 2014; Pahl 2019b), could be assumed to result in less grazing pressure on the perennial grass pasture and therefore enable relatively more AE or DSE units of goats to be grazed in an area without causing pasture condition to decline. However, diet selection differences between livestock species will vary in magnitude according to many factors including (1) the proportion, palatability, stage of maturity or 'greenness' of grass, forbs and browse in a particular grazing area, and (2) the breed, size and stage of maturity of the animals. In this analysis, in the absence of better information to quantify the diet selected by different livestock species under practical grazing situations, we have assumed grazing pressure equivalency of cattle and goat animal units, based on energy requirements.

A self-replacing herd of meat goats is likely to require more labour, especially during the steep learning curve phase at the beginning of the changeover, than a self-replacing beef herd on the same property. We have accounted for the additional expense in the budget by allowing for an increase in casual labour. Even so, the complete set of skills and knowledge needed to manage a property entirely running meat goats are yet to be fully defined in this region and a less effective level of management than applied in this analysis would make the payback period longer and risks greater.

Even though the returns and the level of resilience expected for a meat goat enterprise appear positive, it is unknown whether many managers would be likely to convert their entire production system to rangeland meat goats. The unknown aspects of managing and producing large numbers of goats in this environment suggests that adoption of a conservative 'trial and error' approach, with small mobs of goats initially, would be most appropriate.

3.3.2 Carbon farming

3.3.2.1 Introduction

Carbon farming is a relatively new land use option available in the Australian rangelands which is rapidly increasing in significance and extent (Baumber *et al.* 2020). Due to the comparatively recent emergence of this land use option, we have summarised the available literature in this section to provide background and justification for the approach that we have adopted in our analysis to estimate the potential economic benefits to the landholder of investing in carbon farming in the Mulga Lands region.

Carbon farming encompasses land management activities designed to either increase the amount of carbon stored in the soil and vegetation (sequestration) or to reduce greenhouse gas emissions from livestock, soil or vegetation (avoidance), (DAWE 2021). The Australian Government's ERF is the program through which landholders can earn income from carbon farming (DISER 2021). Since being established in 2014, the majority of ERF projects have been awarded under either one of two methodologies: Avoided Deforestation, or Human Induced Regeneration' (Cockfield *et al.* 2019).

Avoided Deforestation projects require a commitment not to clear areas of vegetation that landholders are otherwise legally entitled to clear and thereafter to maintain a natural increase in biomass. Human Induced Regeneration projects require a commitment to allow woody vegetation to regrow on areas on which there has been long-term vegetation suppression, with ongoing carbon stock maintenance requirements. Both methodologies are applicable to the Mulga Lands region. Baumber *et al.* (2020) reported that as of February 2020, Avoided Deforestation and Human Induced Regeneration projects accounted for 24 and 23%, respectively, of all Australian carbon credit units (ACCUs) issued. The contract periods of these agreements (i.e., the period of time over which payments are made, and the project holder commits to deliver ACCUs for the project), vary widely (e.g., 1-10 years; Cockfield *et al.* 2019). Additionally, there is variation in the length of time over which vegetation management obligations extend beyond these contract periods. The total 'permanence' periods, whereby the project holder undertakes to maintain the stored carbon, have been reported as either 25 (17% of the total) or 100 years (83% of the total) for projects in the Western Land Services region in north-west New South Wales (Cockfield *et al.* 2019).

In Australia, all carbon farming projects looking to gain financial benefit from the ERF need to be registered with the Clean Energy Regulator and comply with legislated rules known as 'methods' to earn ACCUs. One ACCU is earned for each tonne of carbon dioxide equivalent (tCO_2-e) stored or avoided by a project. Businesses can sell ACCUs to generate income, either to the Australian government through a carbon abatement contract, or in the secondary market (DISER 2021).

The Queensland Government's Land Restoration Fund (LRF) aims to expand carbon farming in Queensland by supporting carbon projects that deliver benefits additional to those sought by the Commonwealth Government (The State of Queensland 2021b). The LRF Trust contracts carbon-offset projects which deliver defined environmental, economic and social co-benefits. The payment by the Queensland government for co-benefits means that farmers, landholders and land managers may earn more for LRF projects than through other schemes prioritising lowest cost abatement. All LRF participants must follow the Commonwealth ERF-approved method for their carbon farming project and all LRF projects need to be registered with the ERF and generate ACCUs. Priority regions for investment have been identified as the catchments draining into the Great Barrier Reef lagoon and south east Queensland bioregions (The State of Queensland 2021b).

Baumber *et al.* (2020) concluded that, as carbon farming is relatively recent in the Australian rangelands, most research into benefits and disbenefits has relied on stakeholder perceptions, modelling or speculation by rangeland experts based on similar practices rather than empirical evidence from carbon farming sites. They identified a range of potential 'disbenefits' that could pose threats to the future expansion of the industry as well as affecting the socioecological resilience of rangeland systems. These disbenefits include the potential for: increases in invasive native scrub, reduced land use flexibility due to long-term land management commitments, decreased land value, increased wildfire and pest occurrence due to absenteeism, social divisions between those who have eligible land for carbon farming and those who do not, and reduced ecological, economic and social diversity reducing the resilience of the rangelands.

Various risks and uncertainties in undertaking a carbon farming project in the rangelands have also been identified (Baumber *et al.* 2020); examples are listed below.

- Uncertainty relating to the opportunity cost of changing land use, the long-term price of carbon, the rate at which carbon is sequestered (tree growth) and the ongoing costs associated with establishing and managing the vegetation.

- Revegetation projects stop being a net carbon sink when the vegetation reaches carbon equilibrium. At this time the amount of carbon being sequestered is equal to the amount being emitted as vegetation senesces and rots or soil carbon is oxidised. This means that the administrative and operational costs associated with maintaining a sequestration project may continue well after income from carbon abatement has ceased.
- Capital gains for land with carbon rights registered on the title may be less than for unencumbered land.
- Mitigation rates are highly variable and achieving the highest potential rates will depend on a thorough understanding of the productive capacity of various biological systems at a paddock scale combined with careful project planning and management. Also, any leakage criteria will have to be met and the 'permanence obligations' for sequestration projects present new and unique risks for land managers.
- Participation in the ERF comes with an obligation to proactively protect carbon stores for the permanence period. This includes managing for the risk of fire. Fire and other disturbances can release carbon stored in vegetation back into the atmosphere, thereby reversing the sequestration of carbon for which project proponents have been issued credits. The ERF proponents must replace carbon stores that have been credited and are lost in significant reversals – either by paying back the ACCUs that have been issued for the lost carbon (relinquishment) or restoring the vegetation on the project.

Blakers and Considine (2016) determined that more than 75% of all carbon credits purchased by the government at the time of their analysis (equating to over half of total ERF-contracted abatement to that time) had been supplied by just two mulga-dominated bioregions in south west Queensland and western New South Wales (The Mulga Lands and the Cobar Peneplain bioregions). Further, the value of contracted vegetation projects at that time was over $1.2 billion, of which $1 billion was committed to projects in and around the mulga bioregions. Cockfield *et al.* (2019) estimated that up to the end of 2018, greater than 3.5 million ha of the Western Land Services NRM region of NSW (encompassing the Mulga Lands and Cobar Peneplain bioregions) had been committed to revegetation contracts with permanence periods of up to 100 years.

The concentration of carbon farming projects around and within the Mulga Lands of Queensland and New South Wales appears not to have changed since Blakers and Considine (2016) compiled their analysis. The Clean Energy Regulator maps registered vegetation projects by postcode. As of January 2021, the Clean Energy Regulator identified 165 vegetation projects with 12,318,940 attached ACCUs for Queensland. Approximately 132, or 80%, of the vegetation projects were mapped to postcodes in south west Queensland (Figure 17; Clean Energy Regulator (2021a)).

Figure 17 – Emissions Reduction Fund (ERF) vegetation projects by postcode (Clean Energy Regulator 2021a)

The numbers within the markers indicate the number of projects registered in each postcode

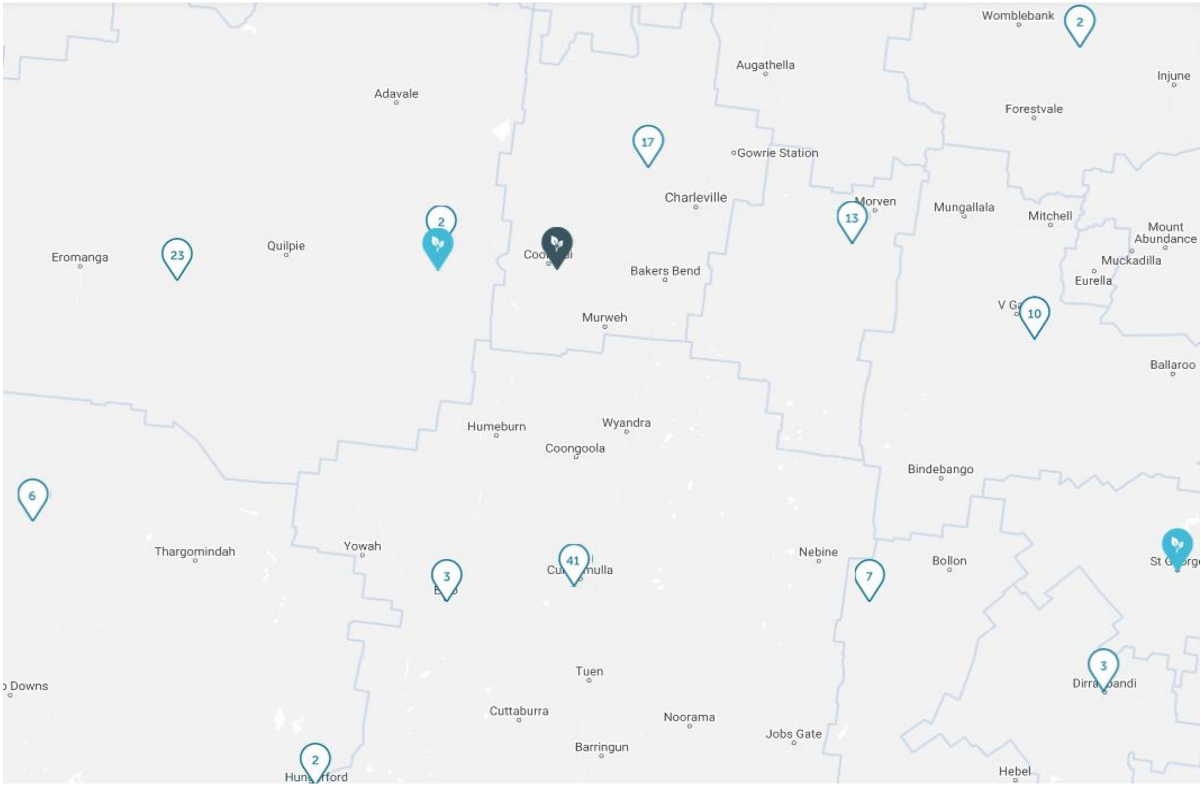


Figure 18 shows the distribution of carbon farming projects in Queensland in 2020 (Baumber *et al.* 2020). The greatest concentration of Avoided Deforestation and Human Induced Regeneration projects occurred on the rangelands of south-western Queensland, primarily in the Mulga Lands. Savannah burning projects covered a large area but accounted for a much smaller proportion of total ACCUs (9% as of February 2020) than either Avoided Deforestation or Human Induced Regeneration projects (Baumber *et al.* 2020).

Figure 18 - Distribution of carbon farming projects in Queensland (Baumber et al. 2020)

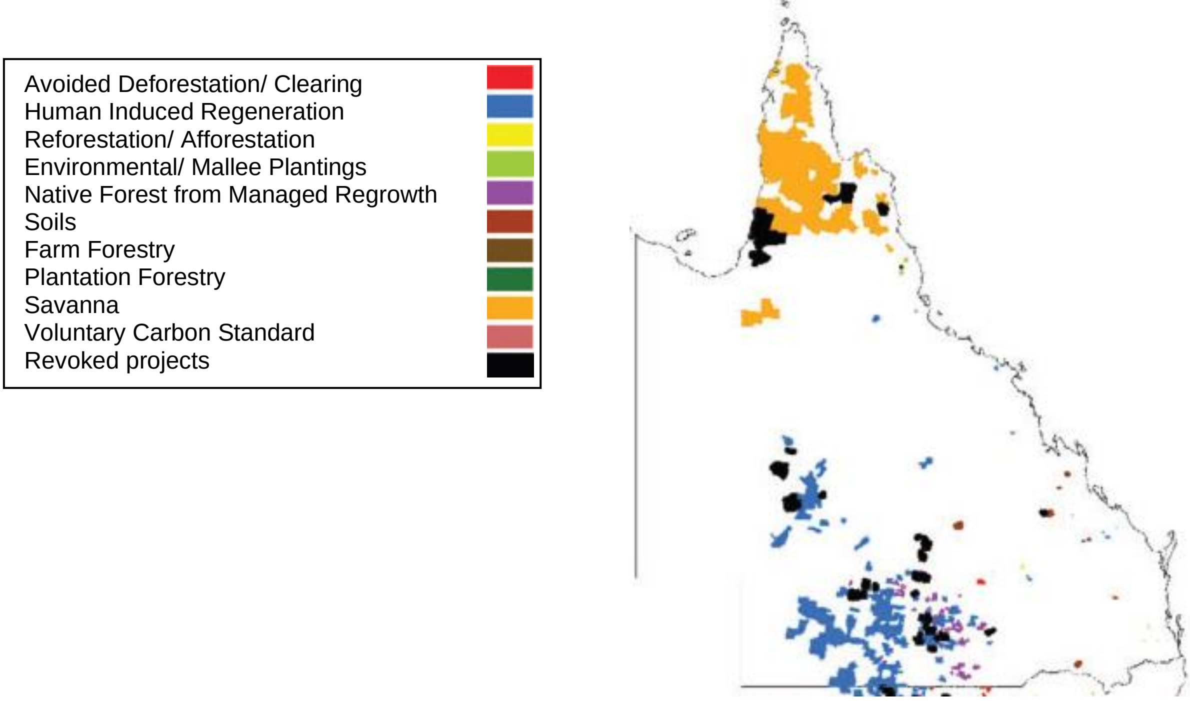


Figure 19 indicates the location of most of the carbon farming projects registered with the Clean Energy Regulator for the Murweh local government area in south west Queensland for which Charleville is the administrative centre. Two of the identified projects are partly in the Quilpie local government area. Three of the mapped projects have been revoked and three have been completed (Clean Energy Regulator 2021d).

Figure 19 - Sample geographic spread of carbon farming projects around Charleville (Clean Energy Regulator 2021d)

The distance from Charleville to Cooladdi is about 80 km by road.

Above-ground carbon in mulga vegetation is stored in living trees and shrubs, but also in dead standing trees, fallen timber and litter (Peters and Butler 2014). Carbon in soil stocks is also expected to accumulate in proportion to above-ground plant biomass but is less stable and less readily verified than above-ground carbon stocks. The maximum amount of carbon stored by mature mulga at a given site depends on the site's average annual rainfall, with greater carbon storage capacity in locations with higher average annual rainfall. Fensham *et al.* (2012) found a site with 400 mm average rainfall (which is within the range expected in the Mulga Lands) could store a total 30-150 tCO_2-e/ha. Peters and Butler (2014) concluded the peak carbon accumulation rate for mulga sites with average annual rainfall above 400 mm was 1-2 tCO_2-e/ha.year. The rates of carbon accumulation were greatest in young, regrowing mulga forests with relatively high rainfall.

In management guidelines developed for carbon farming in the Mulga Lands, by Peters and Butler (2014), it was concluded that that carbon storage could be optimised by:

- Maximising the height and diameter of existing trees (mulga and/or eucalypts) within the productivity constraints of the site.
- Increasing the density of large trees (mulga and/or eucalypts) to reach the typical tree density for the vegetation type. Managers can choose a lower target tree density, but this will prevent the site reaching its maximum carbon state.

- Ensuring that the mortality rate of large trees (mulga and/or eucalypts) is equal to the recruitment of new trees into the canopy, by allowing seedlings and saplings to develop into trees.

The limits to carbon accumulation in the Mulga Lands were summarised as (Peters and Butler 2014):

- Rainfall - drought can kill both young and mature mulga trees.
- Grazing pressure – levels of grazing pressure that remove native grasses, shrubs and small trees, and prevent the recruitment of trees and shrubs will result in a net carbon loss (Witt *et al.* 2011).
- Clearing – clearing mulga, including fodder harvesting, will produce a net carbon loss.
- Fire – large and intense fires result in net carbon loss. Repeated small fires reduce the rate of carbon gain.

Uncontrolled bushfire is considered a major risk to the storage of carbon in the Mulga Lands. The Clean Energy Regulator (2021b) indicates that as part of permanence obligations it may be necessary to undertake hazard reduction burns in project areas thereby reducing carbon credits and indicates reasonable and/or mandated fire prevention activity must be undertaken. Managers of ERF projects have a responsibility to manage and to report fire incidences if fire affects >50 ha or 5% of the total project area, whichever is smaller.

A 'risk of reversal buffer' applies to all sequestration projects managed by the Clean Energy Regulator and reduces the carbon abatement issued during a reporting period by 5% (Clean Energy Regulator 2021b). This means that for every 100 t of carbon stored by a sequestration project only 95 ACCUs will be issued if the project has a 100-year permanence period. A further 20% deduction of ACCUs is be made for projects with a 25-year permanence period. However, the risk of reversal buffer does not insure participants against loss of income from the sale of ACCUs, following fire or other natural disturbance or for the costs of re-establishing carbon stores.

Most carbon sequestration projects registered under the ERF in the Charleville region of the Mulga Lands are managed by Devine Agribusiness Carbon Pty Ltd, part of the Leichardt Group. Although other brokers have different requirements and new guidelines and methods are being developed, the carbon farming guidelines provided by the Leichardt Group (2021) will be taken as identifying key eligibility criteria and concepts for the present analysis. To be eligible for inclusion in a Devine Agribusiness Carbon project to sell ACCUs, land must meet the following criteria (as a minimum):

- Consist of private property, i.e., freehold land or a lease under the Queensland Land Act 1994.
- Be currently classified as non-remnant (white) on regional ecosystem mapping.
- Be currently classified, or be able to be classified, as Category X on a Property Map of Assessable Vegetation.
- Carried a reasonably substantial forest as at 31st December 1989.
- Have been cleared at least once during the period 1990–2006.

The Leichardt Group state that their role, in the carbon farming projects that they manage, includes:

- Obtaining registration for the project.
- Developing and seeking approval of yield verification methods applicable to the project.
- Acquiring carbon rights from landholders.
- Drafting required landholder agreements.

- Arranging for the necessary consents (mortgagee, Land Titles Office).
- Attending to registration of the project area on title.
- Verifying carbon yields.
- Reporting to the Domestic Offsets Integrity Committee.
- Applying for ACCUs.
- Marketing ACCUs to the customer.
- Distributing funds to participating landholders in accordance with the agreements.
- Ongoing monitoring of the project areas.
- Submitting to the audit requirements of the Clean Energy Regulator.

Two main methods have been applied to calculate the amount of carbon sequestered by ERF projects in the Mulga Lands region around Charleville:

(1) Carbon Credits (Carbon Farming Initiative) (Human-Induced Regeneration of a Permanent Even-Aged Native Forest - 1.1) Methodology Determination 2013. (Clean Energy Regulator 2021c).

(2) Carbon Credits (Carbon Farming Initiative) (Native Forest from Managed Regrowth) Methodology Determination 2013 (Clean Energy Regulator 2021c).

Both methods can be applied in the Full Carbon Accounting Model (FullCAM; Commonwealth of Australia 2021) to determine the carbon productivity of a described site. FullCAM is a calculation tool for modelling Australia's greenhouse gas emissions from the land sector and is also used to generate abatement estimates for vegetation methodology determinations (methods) under the ERF.

Fensham and Guymer (2009) estimated the average values (standard deviation in brackets) of above ground biomass carbon stores as 14 (23) t and 23 (15) t carbon/ha for acacia open woodland and for acacia woodland respectively. The potential rates of carbon sequestration in a mulga woodland have been estimated by Witt *et al.* (2011) as 1.1 tCO_2-e/annum (Table 80).

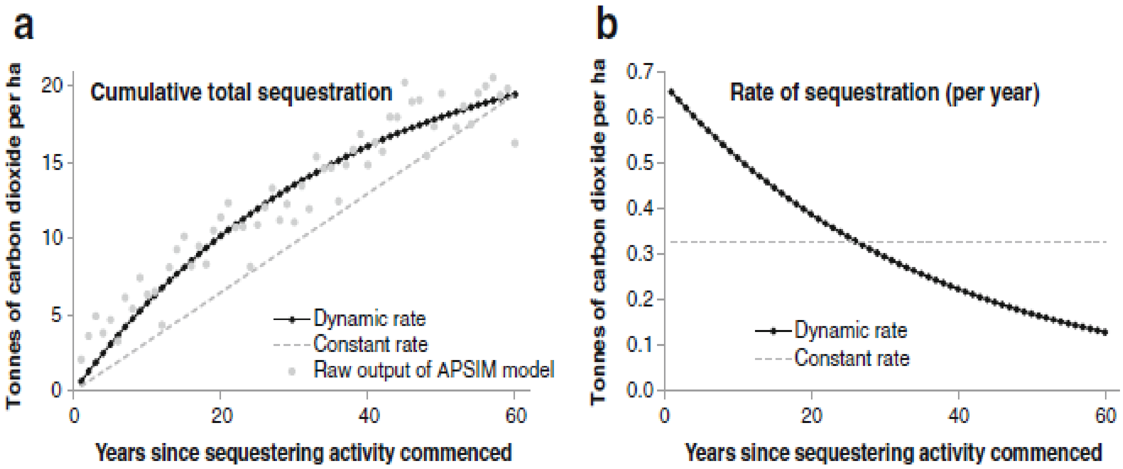
Table 80 – Measured carbon sequestration rates and time to equilibrium for soil, biomass and whole landscape in mulga woodland in Queensland (Witt et al. 2011)

Management intervention	Soil tCO2-e/ha.year	Biomass tCO_2-e/ha.year	Total tCO2-e/ha.year	Time period (years)
Destocking	0.18	0.73 – 0.9	0.92 – 1.1	25

The rates of carbon sequestration described by Witt *et al.* (2011) are below the expected rates of sequestration applied in some carbon contracts currently registered in the Murweh Shire. (Clean Energy Regulator 2021a). The difference is likely due to specific sites showing higher expected short-term rates of sequestration when modelled in FullCAM than identified by Witt *et al.* (2011) as a long term, expected value.

The economic value of carbon sequestration can be impacted by whether a dynamic or long-term constant rate of sequestration is applied in the analysis. Figure 20 is taken from (Thamo *et al.* 2017) and demonstrates that rates of sequestration in soil and vegetation can be highest soon after a sequestration activity has commenced, declining over time as the system approaches a new steady state. Although the total carbon sequestered is the same at the end of the period, the discounting procedures applied in the economic analyses will change the value of the carbon sequestered depending upon whether dynamic or constant sequestration is assumed.

Figure 20 - Total accumulation of sequestered carbon (a) and (b) the annual rate of sequestration (Thamo et al 2017)



As summarised in Cockfield *et al.* (2019) from data collated by the Clean Energy Regulator (2018), the average price for each auction round, for all regional vegetation projects, varied over time from $13.95 (April 2015), to a low of $10.23 (April 2016) and back up to $13.52 (June 2018).

There are a range of carbon sequestration contracts available to landholders in the Mulga Lands. Some exclude grazing and some allow grazing. Some are for parts of a property and some are for all lands within the boundaries of a property. It is typical that contracts are for a set number of years, with the broker identifying the amount of carbon to be sequestered over the period and the price sought. This is lodged as a bid in an auction with the Clean Energy Regulator or as a tender with a third party. Successful bidders are contracted to deliver the amount of carbon and are paid at the agreed price per tonne over the contract period. Typically, the broker contracts with the carbon purchaser and the landholder has a contract with the broker. At the end of the contract period, landholders can have the land area reassessed and seek further contracts for the sequestration of additional carbon. The carbon price is set for the period of each contract and can vary with new contracts over the same parcel of land.

3.3.2.2 Methods

In this analysis we have assessed two relatively straight forward contracts where the portion of the constructed Mulga Lands property put under contract was either:

(1) 50% of the total area, taken as equivalent to 10,000 ha and 50% of the long-term carrying capacity of the property; or

(2) 75% of the total area, taken as equivalent to 15,000 ha, and 80% of the long-term carrying capacity of the property. The level of 80% was selected to account for likely inclusion of some higher-carrying capacity land types in this proportion of the property area.

The assumption was made that the area not put under carbon farming would maintain livestock carrying capacity over time and not be subject to ongoing mulga thickening. The 'without change' property scenario assumed that the property was fully stocked with either (1) beef cattle or (2) rangeland goats at the start of the conversion to carbon farming.

As the location of our hypothetical, constructed property is indeterminate, and FullCAM requires precise location, climate, vegetation and management event data to calculate carbon sequestration, more generic estimates of carbon sequestration in mulga woodlands were applied in our study, based on the literature, and particularly the estimates of Witt *et al.* (2011). Short term contracts (4-5 years) taken in sequence in the Mulga Lands may reflect a more dynamic rate of carbon sequestration with some of the current contracts indicating rates up to 4 tCO_2-e/ha.annum (Clean Energy Regulator 2021d). However, as no data was available to model a dynamic rate of sequestration, we applied a constant rate of sequestration of 1.2 tCO_2-e/ha.annum for 25 years with a total of 30 tCO_2-e/ha accumulated in this time. The total carbon accumulated per hectare is likely to be greater than 30 tCO_2-e but 30 tCO_2-e was taken to be the total amount eligible for sale as ACCUs over the crediting period (period of time the project can apply to claim ACCUs) of 25 years. The assumption of 30 tCO2-e sequestered allowed for the potential negative impact on carbon sequestration of any disturbance events. The 25-year period for income (the crediting period) broadly aligns with the finding of Witt *et al.* (2011) that mulga carbon balances are likely to be in equilibrium after 25 years. Additionally, 25 years is the maximum crediting period currently allowed by the Clean Energy Regulator (2021e).

The area of the constructed property contracted for carbon sequestration was set aside from tree clearing for a 100-year period. This aligns with the most common practice in the Murweh shire where 11 of 13 current contracted projects have a permanence period of 100 years (Clean Energy Regulator 2021d). This also aligns with carbon farming projects in Western NSW were >80% had permanence periods of 100-year periods (Cockfield *et al.* 2019). To simplify the analysis, and match the carbon sequestered to the estimates gained from exclosures by Witt *et al.* (2011), livestock grazing was excluded from the contract area for the entire 100-year period.

The initial gross carbon price was assumed to be \$12.50/tCO_2-e as per Cockfield *et al.* (2019) and was maintained at that level in real terms for the period of the analysis. Also following Cockfield *et al.* (2019), and the advice of local landholders in the Charleville region, the carbon price achieved at auction was reduced by 25% for an on-farm return of \$9.30/tCO_2-e. The 25% reduction is due to fees for project management, with most projects having a third-party broker/project manager, and a risk margin for potential non-delivery of sequestration obligations. Cockfield *et al.* (2019) indicated that project managers hold back some funds as a contingency against the project under-performing against expectations, as might be revealed by later estimations. The retention of 5% of value by the Clean Energy Regulator was taken to be part of the 25% retained by the broker in our analysis.

Transaction or operational costs are incurred to maintain the sequestered carbon and the contracts over time. They include components for planning/accreditation, monitoring, auditing (including compliance) and trading (including pooling and brokerage fees). Cockfield *et al.* (2019) set initial project management costs for the landholder to \$2/ha.year for Avoided Deforestation projects and \$1/ha for Human Induced Regeneration, decreasing in later years. That approach was followed here with the 10,000-ha project incurring expenditure of \$15,000/year over the first 5 years for setting up and maintaining the project area including (1) machinery operation to maintain firebreaks and access to fences, (2) fencing materials and labour, and (3) removal of unwanted species. After 5 years, annual maintenance costs were halved. The assumption was made that existing fences were sufficient with only minimal upgrading necessary to meet the requirements of the carbon farming contract and that better-quality fencing was not required. Transaction costs were incurred for the 100-year permanence period.

The contracting of a significant portion of the constructed Mulga Lands property to carbon farming is expected to impact more than the variable costs associated with the enterprise forgone, making a gross margin analysis inappropriate to assess the value of this investment decision. Returns were initially calculated at the property level on an annual basis where: operating profit = (total receipts – variable costs = total gross margin) – overheads as defined in the General methods section of this report (Section 2). The calculation of operating profit with and without carbon farming allows overheads or other property expenses that change with the implementation of a carbon farming strategy to be identified and accounted for where necessary. The annual estimates of operating profit were adjusted for use in the DCF.

The returns from the property under its current use were taken as the opportunity cost of the carbon farming project. The returns forgone were tested as either beef cattle or meat goat production (described in previous sections of this report) to estimate the impact of the alternative enterprises on the net returns resulting from the investment in carbon farming. The returns to the property under carbon farming were (1) the returns to carbon farming plus (2) the returns to the residual livestock enterprise plus (3) the capital released by the reduction in livestock numbers in the first year of the contract. The property was taken to be fully stocked at the start of the contract period.

The model compared the ‘without change’ scenario (either beef cattle or meat goat production) to an alternative ‘with carbon farming’ scenario that gained income from carbon farming for the first 25 years (the crediting period) and then maintained the area under contract for the remainder of the 100-year period (the permanence period). To simplify the modelling, the 100-year period was broken into a first period during which income from carbon farming was received (first 30 years) and a second period when no net income from carbon farming was expected to be received (the final 70 years). The 30-year investment analysis period was chosen to match other analyses compiled for this report, even though the carbon farming income was only received for 25 years. The present value of the second period of the investment for both the ‘with’ and ‘without carbon farming’ scenarios was represented as the likely sale value of the property at the end of the first period (Year 30 of the analysis). The present value of ongoing costs of maintaining that part of the property subject to the carbon farming project for the 70 years after the first 30-year period was also deducted from the residual value of the property in Year 30 of the DCF analysis.

The assumption was made that the value of an investment property is equivalent to the discounted value of the expected future net income streams including growth in capital value. The ‘without change’ scenario applied the current market value of the property as the real value of the property in Year 30 of the analysis. The ‘with change’ scenarios applied either 50% or 20% of the current market value of the property as the residual real value, to match the assumed reduction in carrying capacity due to carbon farming. This was done to represent the long-term fall in income earning capacity of the property once carbon farming income ended from the project area. As previously identified, the ‘without carbon farming’ property held stock numbers over time due to the assumption that the property was stocked at the safe carrying capacity.

All costs and benefits, including into the future, were expressed in constant dollar terms with 2020 as the base year. No real capital gain for either the ‘without change’ or ‘with change’ scenarios for the property was included. The opportunity cost of funds invested in the project was set at 5%, matching the value set for other analyses in this series.

3.3.2.1 Results and discussion

Table 81 indicates the returns to an investment in carbon farming for different proportions of the representative Mulga Lands property. In the 'without change' property scenario, the assumption was that the property was fully stocked with (1) either beef cattle or (2) meat goats at the start of the investment period. In the 'with change' property scenario, the assumption was that the payable carbon sequestration rate averaged 1.2 tCO_2-e/ha.annum for 25 years with a gross contract price of \$12.50/tCO_2-e (on-farm price of \$9.30/tCO_2-e). Partial conversion of a beef enterprise to carbon farming, substantially improved the profitability of the property, with 75% conversion adding more profit than 50% (ca. \$37,000 or \$27,000 extra profit/annum, respectively). However, partial conversion of a rangeland meat goat enterprise to carbon farming decreased the profitability of the property.

Table 81 - Returns for investing in carbon farming on 50% or 75% of the Mulga Lands property area which was fully stocked with either (1) beef cattle or (2) meat goats at the start of the investment period[A]

All terms defined in the Glossary of terms and abbreviations

Factor	Convert from self-replacing beef herd to carbon farming on		Convert from self-replacing rangeland meat goat herd to carbon farming on	
	50% of the property	75% of the property	50% of the property	75% of the property
Period of analysis (years)	30	30	30	30
Discount rate for NPV	5%	5%	5%	5%
NPV	$408,981	$586,221	-$267,554	-$566,323
Annualised NPV	$26,605	$36,834	-$17,405	-$36,840
Peak deficit (with interest)	n/c	n/c	-$1,542,488	-$2,834,930
Year of peak deficit	n/c	n/c	30	30
Payback period (years)	n/c	n/c	n/c	n/c
IRR	n/c	n/c	n/c	n/c

[A]The self-replacing beef herd was the herd after implementation of the safe carrying capacity, weaning, pregnancy testing and basic vaccinations, the optimal age of steer turnoff, and phosphorus and sulphur supplements fed in the growing season.

It should be noted that our analysis did not incorporate any potential impacts on the level of tax payable when carbon farming is added to the income mix of the hypothetical property. Income from carbon farming is not treated as income from primary production and specialist taxation advice should be sought by any landholder considering an investment in carbon farming. If income from carbon farming was treated as primary production income for taxation purposes, as was not the case here, this could change the outcomes further in favour of carbon farming as landholders, with part of the business allocated to grazing enterprises, would be able to offset farm business losses against some of that additional income.

Additionally, the potential impact of carbon farming on (1) the level of operating overheads (the fixed costs) of the property or (2) the opportunity to earn additional off-farm income, was not incorporated in the analysis. The overhead expenses allocated in the budgets for this analysis suggest that a reduction is possible if a significant area of carbon farming is implemented. However, the extent and timing of such a reduction, and the possibility that this may be compensated for by expenditure in other areas, is difficult to identify without undertaking case studies with landholders in the region who have adopted carbon farming.

It is likely that the riskiness of a mulga property investment will be reduced after allocating part of the land to producing an income from a non-agricultural commodity source. This aspect has also been identified by others including Cockfield *et al.* (2019) and Baumber *et al.* (2020). This could be an important factor influencing the decision of a landholder to farm carbon even though the income from carbon farming will fluctuate with each new contract and also has inherent risks.

The discount rate applied by an investor can change the value of returns from a very long-term investment like carbon farming. As identified by Thamo *et al.* (2017), real discount rates can be over 10%, or even 20%, for landholders in a range of circumstances, particularly those whose survival is under threat. The application of high discount rates in a carbon farming analysis would significantly reduce the impact of events after the first 15-20 years of the investment. Landholders applying this frame of reference (cash flow for survival and a high discount rate applied to future events) would not see the lack of carbon income after sequestration gained equilibrium, or the potential long-term impact of a carbon contract and its permanence period on the value of the land asset, as major issues.

The net income from carbon farming, at each level of the property assigned to carbon farming, is the same whether the property transitions from (1) all beef to part carbon and part beef, or (2) from all goats to part goats and part carbon. Therefore, the opportunity cost of the enterprise foregone is the principal factor determining the value of investing in carbon farming. Where an inefficient enterprise is in place, in this case beef production, the opportunity costs of investing in carbon farming are low and hence there is a greater incentive for a large part of the property to be allocated to carbon farming. Where a more efficient enterprise is in place (i.e., rangeland goat production), it appears less of the property area would likely to be allocated to carbon farming. Our findings are broadly in agreement with the conclusions of Cockfield *et al.* (2019) for their analysis of carbon farming in the dry, semi-arid area of western New South Wales which included the Mulga Land bioregion characterised by low carrying capacity and hence low opportunity costs. However, the carrying capacity of the property in our analysis did not change with the scenarios (beef vs. goat production); only the profitability of the enterprise changed. This indicates that while correctly identifying the opportunity cost of the carbon farming enterprise at the property level is critical for this type of analysis, identifying the relative carrying capacity of the property is less important (given that it does not change whether goats or cattle are run).

It is also evident that the price required for the tCO2-e sequestered, that would make carbon farming the better investment option, varies with the opportunity cost. This aspect was also highlighted in the study of Cockfield *et al.* (2019). Although a gross contract price of $12.50/tCO2-e may be attractive for a beef producer on our constructed Mulga Lands property, the price per tCO2-e would have to almost double before an efficient goat producer on the same property would be compelled to allocate a large part of the property to carbon farming.

Our findings concur with Thamo *et al.* (2017) who concluded that the value of carbon sequestration cannot be estimated without making assumptions about the fate over time of three key factors: (1) the price of carbon; (2) the opportunity cost of diverting land from its current use to one with higher carbon sequestration; and (3) the rate of sequestration on land that has been converted. They found that, depending on the combination of assumptions made about the dynamics of the sequestration rate, opportunity cost and carbon price, the breakeven carbon price for their scenario analysis could vary by a factor of almost four, from \$14/tCO_2-e to \$53/tCO_2-e.

Carbon farming is a relatively new phenomena in the Mulga Lands. The rapid expansion of the activity indicates that the recent run of droughts, and low commodity prices, significantly reduced the opportunity cost of converting to carbon farming for some landholders. Continued expansion of carbon farming activities seems likely, given the results of the economic analysis shown in Table 81.

Figure 21 indicates the cumulative cash flow over the first 30 years of the investment in carbon farming by a beef producer on the hypothetical property in the Mulga Lands. Carbon farming on 50-75% of the property would improve the relative cash flow of the property for a substantial period of time. The choice for the beef producer (at a long-term beef price) appears to be between (1) insolvency and (2) maintenance of an acceptable property cash flow by incorporating carbon farming. The improved capacity to earn additional off-farm income with 50% or 75% of the property locked up for carbon farming has not been identified, but could be an additional incentive for younger landholders.

Figure 21 - Cumulative cash flow for the Mulga Lands property run as a beef enterprise with and without carbon farming

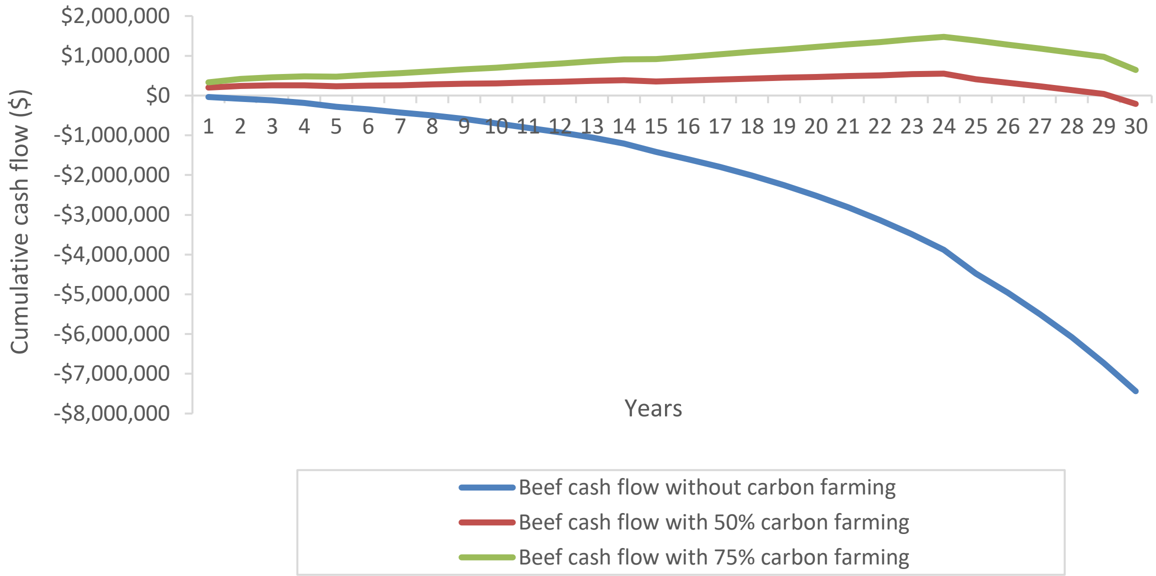
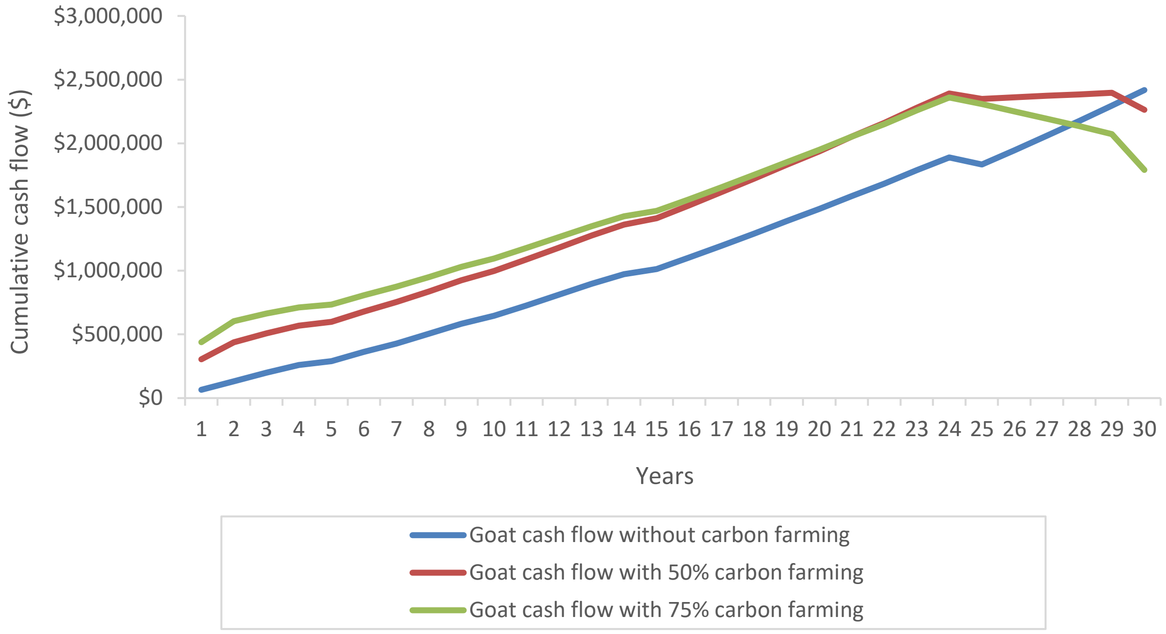


Figure 22 indicates the cumulative cash flow over the first 30 years of the investment in carbon farming by a meat goat producer on the hypothetical property in the Mulga Lands. Even where it is more profitable over the longer term to not carbon farm, the improved cash flow available from carbon farming in the short to medium term may encourage some landholders to allocate significant resources to carbon farming. The net cash flow may be significantly changed depending upon the effect of taxation on net income from carbon farming and additional livestock sales in the initial years of the commitment. Most of the immediate benefit arises from the release of capital associated with additional livestock sales when the move to carbon farming is made. The economic analysis (Table 81) is a better representation of the long-term benefits of the investment in carbon farming than the cash flow analysis for a goat producer as it includes the expected fall in asset value at the end of the sequestration period. Even so, a cash flow analysis of the benefits of carbon farming compiled for the first decade could encourage some goat producers to take that option on a significant scale.

Figure 22 - Cumulative cash flow for Mulga Lands property run as rangeland goat enterprise with and without carbon farming



It is evident that the key factors determining whether carbon farming will be attractive to a landholder are dynamic and quite dependent upon the circumstances and goals of the landholder. Our analysis indicates that the widespread adoption of carbon farming in the rangelands is likely to be largely due to the extended droughts and lower commodity prices of the last decade reducing the opportunity costs and increasing the discount rates of some landholders to the point that carbon farming became quite attractive. A return to better seasonal conditions and the continuation of higher commodity prices for beef cattle could slow the conversion of the Mulga Lands to carbon farming. Even so, the relative profitability of carbon farming, on suitable land types and paddocks in the Mulga Lands, indicates that carbon farming on portions of properties is likely to be considered closely by many landholders who have not yet adopted the enterprise. This is particularly likely if carbon prices show increases, in real terms, over time.

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 Mulga Lands 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 Mulga Lands and, secondly, to indicate the potential level of response to change revealed by relevant research. 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 production parameters assumed for the base 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. Additionally, there is currently a lack of measured data available to adequately describe contemporary beef cattle enterprises and managed rangeland goat production systems in this environment. This necessitated a reliance on producer experience, expert opinion, and extrapolation from the documented sheep production data for the 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. Our analysis was based on a hypothetical property located entirely within the Mulga Lands region. The results of our analysis reflect the mix of land types and other assumptions for the representative property. Properties with different characterises, including areas of more productive land types, are likely to have improved productivity and profitability outcomes relative to the representative property in our study.

The major challenges facing beef producers in the Mulga Lands are associated with the inherently low productivity and profitability of the region exacerbated by widespread, and well documented, pasture degradation (Foran *et al.* 1990a; MacLeod and Johnston 1990; Johnston *et al.* 1990; Commonwealth of Australia 2008). Additionally, the Mulga Lands have high levels of climate variability and a history of extended and extensive droughts. To remain in business, and to build resilience to droughts, floods and market shocks, beef producers need to increase profit and equity. 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.* 1990b). 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.

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 Mulga Lands were consistent with findings for other regions across Queensland and the Northern Territory and included increasing age of steer turnoff from weaners to the optimal, and inorganic supplements (particularly P) in the pasture growing season where deficiencies exist (Bowen and Chudleigh 2018b; Bowen *et al.* 2019a, 2020a; Chudleigh *et al.* 2019). However, as indicated in Table 1 through to Table

3, there was in general very limited opportunity to improve profitability, and hence viability, of the beef enterprise overall. The assumption for our study, was that the starting base beef property had only low levels of management, below what was considered basic best-practice in Queensland rangelands. The cumulative effect of implementing basic levels of herd management and other available strategies to improve profitability of the beef enterprise, was a property with negative total returns and declining cumulative cash flow over the 30 years of the analysis. This finding, of poor profitability of livestock enterprises in the Mulga Lands and limited opportunity to improve upon this situation, is in accord with earlier studies in the 1980s and 1990s (e.g., Pressland 1984; Johnston *et al.* 1990). This understanding led to examination, in the present study, of the alternative investments, of rangeland goat production and carbon farming.

Although, historically, Merino wool sheep were the dominant livestock production system in the Mulga Lands, sheep production is now uncommon in the target region. For this reason, as well as the lack of interest by our local advisory group in examining sheep wool or meat enterprises, they were not included in this study. Merino wool and meat sheep enterprises were examined for the Longreach region with results presented in the 'Rangelands of central-western Queensland' report (Bowen and Chudleigh 2021b). This report can be accessed from the project internet page: [Improving profitability and resilience of grazing businesses in Queensland - Preparing for, responding to, and recovering from drought - FutureBeef](). Furthermore, the property-level, regionally specific herd and business models developed for that analysis are available for use by others and can be applied to assess sheep scenarios for the Mulga Lands, if required.

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.

In the present study, where the constructed property was (1) operated as a beef property, (2) had some existing infrastructure to manage goats, but (3) required the construction of an exclusion fence and some improvements to internal fencing to operate a goat enterprise, the relative profitability of the property could be improved over the long term with an investment in an exclusion fence and a switch to a rangeland meat goat enterprise (Table 5). The significant constraint on this investment was the level of additional debt required to make the change (-$876,011 peak deficit) and the number of years (14) before the property would be back to the same financial position that it would have maintained without the investment. In our study, the construction of the exclusion fence was costed at $500,000, which is ca. 20% of actual land value. Given the variable and low income from the existing beef enterprise, and the likelihood of pre-existing high debt levels, the investment in exclusion fences appears unlikely to be widely adopted by existing beef producers in the Mulga Lands if the investment is to be fully funded by the property.

Our analysis of rangeland goat production systems was intended to reflect the level of performance and profitability possible when goats were managed to prevent overutilisation of the pasture resource, despite the relatively higher reproductive rates (123.7% weaning rate from females mated, in this analysis), and possibly better drought resilience compared to other livestock species due to their more flexible diet and better ability to select for diet quality (Hacker and Alemseged 2014). In our analyses we applied a sufficient standard of management to ensure continuity of sale of goats so as to maintain equivalent grazing pressure on the pasture compared to other livestock enterprises. In the absence of better information to quantify the diet selected by different livestock species under practical grazing situations, we assumed grazing pressure equivalency of cattle, sheep and goat animal units, based on energy requirements (as per McLennan *et al.* (2020)). Hence, our estimate of the number of goats able to run on the constructed property was likely conservative, given the preferential selection of proportionally more browse, when it is available, in the diet of goats relative to the other species (Hacker and Alemseged 2014; Pahl 2019b) and the prevalence of the edible mulga browse on the constructed property.

Partial conversion of a beef enterprise to carbon farming, substantially improved the profitability of the property over 30 years, with 75% conversion adding more profit than 50% conversion (Table 6). However, partial conversion of a rangeland meat goat enterprise to carbon farming decreased the profitability of the property over 30 years. Despite carbon farming improving cash flows in the short to medium term for both enterprises, the implications of the 30-year economic analysis are that where a more efficient enterprise is in place (i.e., rangeland goat production), it appears less of the property area would likely to be allocated to carbon farming. Where an inefficient enterprise is in place, such as beef production, the opportunity costs of investing in carbon farming are low and hence there is a greater incentive for a large part of the property to be allocated to carbon farming.

The analysis of investment in carbon farming indicated that the opportunity cost, and other key factors determining whether carbon farming is attractive to a landholder, are dynamic and uncertain. Each part of a property eligible to be allocated to a carbon farming project will have different characteristics leading to different assumptions and different investment returns. It is critical that managers not only apply the correct methodology when assessing the potential for carbon sequestration, but also apply an appropriate framework to assess the economic and financial value of carbon farming. Furthermore, our analysis did not incorporate any potential impacts on the level of tax payable when carbon farming is added to the income mix of the hypothetical property. Income from carbon farming is not treated as income from primary production and specialist taxation advice should be sought by any landholder considering an investment in carbon farming. The potential implications of carbon agreements on future sale of the property also needs to be considered.

The widespread adoption of carbon farming in the rangelands to date has been due predominately to the extended droughts and lower commodity prices of the last decade reducing the opportunity costs and/or increasing the discount rates of some landholders to the point that carbon farming became quite attractive. A return to better seasonal conditions and the continuation of higher commodity prices could slow the conversion of large parts of the Mulga Lands to carbon farming. Even so, the relative profitability of carbon farming, on suitable land types and paddocks in the Mulga Lands, indicates that carbon farming on portions of properties is likely to be considered closely by many landholders who have not yet adopted the enterprise. This is particularly likely if carbon prices show increases, in real terms, over time.

An important consideration is that income from carbon farming and rangeland goat production provides a diversification of income streams for a beef property, allowing potential stabilisation of income over time. Diversifying sources of income can have the effect of both smoothing income over time and improving average profitability which, consequently, can reduce risks from climate variability and assist with drought preparedness and resilience (Buxton and Stafford Smith 1996; Freebairn 2019). The benefits to the rangelands livestock producer, of diversifying the enterprise mix and income streams on-farm, was also highlighted in our analysis of alternative livestock enterprises in the rangelands of central-western Queensland (Bowen and Chudleigh 2021b).

It is recognised that in the Mulga Lands some livestock producers rely on non-farm income for business survival, particularly during drought periods. This aspect was not examined in the current study but has been identified as particularly important in inherently low-productivity, extensive regions that have an early history of subdividing large properties (e.g., Johnston et al. 1990). This same issue was evident in the Northern Gulf of Queensland (Bowen *et al.* 2019a) but not was not apparent in regions of the Northern Territory with similar extensive, low-productivity land types that have not been subject to the same level of subdivision (Chudleigh *et al.* 2019). There may be a case for the amalgamation of properties in low-productivity regions such as the Mulga Lands as a way of improving drought preparedness but the ongoing disconnect between land value and production potential in these regions will limit the capacity of local landholders to achieve such an outcome. Additional work and analysis would be required to appropriately examine the economic impacts of property and herd or flock size relevant to each Queensland region examined in this series of reports to enable identification of the size at which real efficiencies are achieved for each. Such analysis was beyond the scope of the current project. For low-productivity regions such as the Mulga Lands, others, such as Hamblin (2009), argue that more effective agricultural policies are required to instead retire these low-productivity areas from agricultural land use where environmental and social decline are endemic.

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), Bowen and Chudleigh (2018a,b,c, 2021a,b), and Bowen *et al.* (2019a,b, 2020a,b, 2021). 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.* (1990b) 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 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 preparing for drought and frequently monitor their pastures, livestock, financial position, markets, options and wellbeing. 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

The central finding of these analyses was that the representative beef property had low inherent productivity and profitability with very limited opportunity to improve upon this base situation. When combined with the apparent disconnect between land value and the possible returns from the investment, this suggests that low profitability and debt servicing pressures will make investment in alternative beef management strategies unaffordable for many Mulga Land region beef cattle businesses. This understanding led to examination of alternative investment options for the Mulga Lands property including production of rangeland goats and carbon farming. The modelling approach applied in this study allowed the integration of alternative investments to beef cattle within the one investment model and enabled a whole-of-business analysis of the impact of change on productivity and profitability at the property level.

The steady-state analysis of alternative livestock enterprises indicated that the rangeland goat enterprise produced a positive operating profit and rate of return on total capital in comparison to the negative profitability of both the self-replacing beef herd and steer turnover operations. However, where full investment in an exclusion fence around the majority of the property was required to facilitate a shift from beef to rangeland goat production, the investment was likely to increase the riskiness of the overall enterprise. This was the case even although the long-term profitability and resilience of the property could be substantially improved by a change to production of rangeland meat goats. The lack of reliable data for managed rangeland meat goat production in this region limits the confidence in conclusions about the role of rangeland goats, long-term. However, maintenance of the demand for goat meat, together with increased knowledge of effective goat management strategies, could see rangeland goats play a very important role in maintaining profitable and resilient production systems in the future.

The potential returns to the investment in differing levels of carbon farming, through carbon sequestration, on the modelled Mulga Lands property when initially fully stocked with either (1) beef cattle or (2) rangeland goats at the start of the conversion, produced different results depending on the starting enterprise in place. Partial conversion of a beef enterprise to carbon farming, substantially improved the profitability of the property, with 75% conversion adding more profit than 50%. However, partial conversion of a rangeland meat goat enterprise to carbon farming decreased the profitability of the property. Importantly, each part of a property eligible to be allocated to a carbon farming project will have different characteristics, leading to different assumptions and different investment returns which may or may not be the same as those in our analysis. It is critical that managers not only apply the correct methodology when assessing the potential for carbon sequestration, but also apply an appropriate framework to assess the economic and financial value of carbon farming. The tax implications of this non-primary production income stream, and potential implications for property sale value, should also be considered.

Regardless, the application of a logical, rational 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.

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7 Glossary of terms and abbreviations

ACCUs	Australian carbon credit units.
AE	Adult equivalent. In the Breedcow and Dynama (BCD) software 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 AE, not adjusted for metabolic weight). 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. To estimate grazing pressure equivalence between cattle and goats in our analysis 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.
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. This software can be downloaded free from https://breedcowdynama.com.au/. In the analyses documented in this report, herd models and analyses were also compiled in a modified version of the Breedcow and Dynama suite of programs to allow comparison of beef and goat enterprises. Please contact the authors if you would like a copy of any of these files.
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 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. The factor of 6.25 is based on the assumption of 16% N in proteins which is a generalisation that ranks the N in amides, nucleic acids and other compounds equally with the N in amino acids. However, 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). Regardless, the factor of 6.25 is the generally agreed convention in the practical feeding of ruminants in Australia and overseas.
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.
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).
DSE	Dry sheep equivalent. This standard 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 was calculated, i.e., not adjusted for metabolic weight. To estimate grazing pressure equivalence between cattle and goats in our analysis 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.
ERF	Emissions Reduction Fund. An Australian Government program, established in 2014, to incentivise Australian businesses to cut the amount of greenhouse gases they create and to undertake activities that store carbon.
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.
FullCAM	Full Carbon Accounting Model
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****.*
LRF	Land restoration fund. A Queensland Government initiative with the objective of expanding carbon farming in the state by supporting land-sector carbon projects that deliver additional environmental, social and economic, and First Nations co-benefits.
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.
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.*
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 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.
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. 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).
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.
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.

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9 Appendix 1. Breedcow and Dynama software

The Breedcow and Dynama herd budgeting software (BCD) was developed for cattle herds. For the current analyses, we developed similar models, to those in the BCD software, to assess the alternative livestock enterprise of rangeland goats for meat production. Using these spreadsheets tools beef and goat enterprises can be modelled individually or as components of a mixed rangelands enterprise. The BCD software is described below but the same principles were applied in models developed for rangeland goats. The software is described in more detail in Holmes *et al.* (2017).

9.1 Brief description of the Breedcow and Dynama software

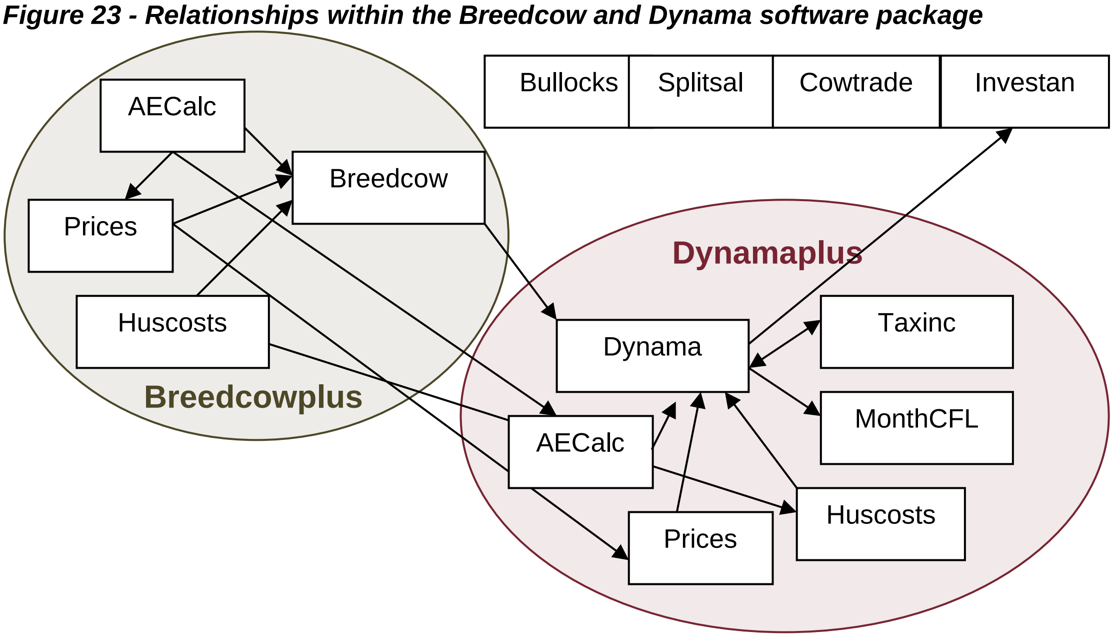
The BCD package of software programs is used to assess choices for the management of beef cattle herds run under extensive conditions. **It is not an accounting package or a paddock records package and does not record individual animals**. It presents budgeting processes, adapted to the special needs 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); and
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 23 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 23.

Figure 23 - 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:

$$\text{present value} = A / (1+i)n$$

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 (PV) of the investment inflows and the PV of the investment outflows. An investment is acceptable if the NPV is positive.
- Benefit-cost ratio (B/C ratio) - the PV of the investment inflows divided by the PV of the investment outflows. An investment B/C ratio greater than one is required.

- The internal rate of return (IRR) - the discount rate at which the PV of inflows equals the PV 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 82 presents an example of the range of values expected for each profitability criteria at a discount rate of 8%.

Table 82 - Relationship between profitability measures at a discount rate of 8%

Factor	Relative value		
NPV	Negative	Zero	Positive
IRR	< 8%	8%	>8%
B/C 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 B/C 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 (BCA). A calculated B/C 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 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.

NPV 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 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 (IPDs) 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 IPD seems applicable, a general deflator such as the Gross Non-Farm Product IPD 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.