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Fitzroy beef production systems

Preparing for, responding to, and recovering from drought

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Summary

The work reported here represents a comprehensive analysis of the economic implications of management decisions that can be applied to prepare for, respond to, or recover from drought in the Fitzroy Natural Resource Management (NRM) region of central Queensland. 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 businesses in the Fitzroy region. In doing this, we developed property-level, regionally-specific herd and business models for a representative, case-study beef cattle enterprise which was based on the median herd data from relevant industry surveys and research. The Breedcow and Dynama herd budgeting software was used to develop integrated herd models and discounted cash flow budgets for each alternative scenario.

Production systems that can be applied to improve profitability and hence resilience of a beef business to drought are generally of a strategic nature. The economic and financial effect of implementing each strategy was assessed by comparison to the baseline production system for the case-study property. Whole-of-business productivity and profitability was assessed over a 30-year investment period.

Management decisions which are considered in response to, or recovery from, drought tend to need consideration of both short term and long term implications and were examined using herd models in conjunction with spreadsheets designed to assess tactical decisions.

Preparing for drought

Preparing for drought by improving profit and business resilience

The results of the investigation of strategies for their ability to improve profitability and business resilience, and hence prepare for drought, are summarised in Table 1. These results are the difference in returns between the baseline, case-study property and the same property after implementing the specified management strategy. They are a guide to possible strategies that may build profit and resilience prior to drought. It is important to note that a negative marginal NPV does not necessarily indicate that a business implementing such a strategy is unprofitable, just that the strategy causes the business to be less profitable than the baseline scenario. It should also be noted that while the baseline property and herd was typical of the Fitzroy NRM region it was already a relatively efficient and high-performing herd compared to other less productive regions of northern Australia. A summary of the key findings of this part of the analysis is given below. The annualised NPV results can be considered an approximation of the change in profit per year resulting from the management strategy and are expressed as such below.

a) Improving steer growth rates

1. Optimising steer growth path performance with investment in leucaena-grass pastures, planted in strips into existing buffel grass pastures, substantially improved the profit of the beef business and was the most profitable of all strategies assessed when the breeder herd was phosphorus (P) -adequate ($40,336-$46,135 extra profit per annum). Purchase of additional breeders to match weaner numbers to the supply of leucaena, rather than waiting for natural increase in breeder numbers, resulted in the greatest improvement in profit. However, implementing a leucaena-grass system substantially increased peak deficit levels (-$145,722 or -$190,539, with

natural breeder increase or purchase of additional breeders, respectively) and financial risk, with a payback period of 7 years.

2. Improving steer growth path performance with investment in a shrubby legume such as desmanthus, planted in strips into existing buffel grass pastures, substantially improved the profit of the beef business ($26,779 extra profit per annum). As for leucaena, peak deficit levels were substantially increased (-$103,212) and a considerable payback period was required (8 years).
3. Investing in a strategy of growing forage oats to sell feed-on steers at a younger age than if grazed only on buffel grass substantially reduced the economic and financial performance of the beef business resulting in $34,521 less profit/annum than the baseline scenario with no forage oats. The use of forage oats also substantially increased financial risk with the strategy not generating sufficient returns to repay the additional borrowings required to implement the system within the 30 years of the analysis. In this example it was assumed that conditions would be suitable for planting a forage oats crop in 67% of years.
4. Implementing a strategy of custom feedlotting, feed-on steers to slaughter weight substantially reduced the economic and financial performance of the beef business resulting in $48,841 less profit/annum than the baseline scenario. The large negative gross margin per head of ca -$244 indicated that grain prices would have to decrease substantially and/or the price margin ($/kg) between cattle entering and exiting the feedlot improve substantially, relative to current prices, for this strategy to be profitable. The results of this analysis will equally apply to the use of custom feedlotting as a drought response strategy.
5. Using hormonal growth promotants (HGP's) on a long term basis will change the weight for age for steers, the range of accessible markets and the structure of the total herd. Implementing a strategy of HGP use from weaning until sale of feed-on steers at the same age as for the baseline herd (27 months) resulted in positive returns but only if the same sale price was received as for the feed-on steers in the baseline herd despite the HGP-treated steers exceeding the target feed-on weight: $10,794 extra profit per annum. When these same HGP-treated steers received a price discount of 10c/kg liveweight, as a result of exceeding the target weight for feed-on steers at 27 months, the HGP strategy reduced profit: $806 less profit/annum. Alternatively, if the HGP-treated steers were sold at a younger age than steers in the baseline herd, in order to meet the target weight for feed-on steers and avoid price discounts, the profit of the beef business was also reduced ($5,494 less profit/annum). This was predominantly due to the herd structure changes associated with selling younger steers which, in effect, caused proportionally more (less valuable) cow beef to be sold out of the herd as the sale age of the steers reduced. These results demonstrate the importance of getting the target market and herd structure right when applying HGPs to improve steer growth rates.

b) Improving breeder reproductive performance

1. Improving breeder reproductive performance by investment in genetically superior bulls to improve the average weaning rate by 6% reduced economic and financial performance of the beef business resulting in $3,265 less profit/annum. Peak deficit levels were increased (-$135,215) and the strategy did not generate sufficient returns to break-even within the 30 years of the analysis. The poor economic performance was due to the extended period of time before

the improved genes predominated in the herd as well as the pre-existing reproduction efficiency in the baseline herd (77% weaning rate).

2. To achieve a 50% reduction in calf loss in heifers and first lactation cows, no more than \$5/head.annum should be spent if a return on funds invested is to be achieved. At \$5/head investment, additional profit generated was only ca. \$474/annum over the 30 years of the analysis. For this enterprise, supporting 1,500 adult equivalents (AE), expenditure of up to \$20,000 as an upfront capital expenditure with no additional ongoing expenditure would result in an extra \$1,019 profit/annum if calf/foetal loss could be reduced by 50% in heifers and first lactation cows. Increasing capital expenditure above \$30,000, to achieve the same improvement in reproductive performance reduced returns. These results demonstrate the diminishing returns available from investing to improve reproduction efficiency in a herd that has the median level of performance of 10.2% foetal/calf loss in heifers and 7.3% in first lactation cows.
3. A beef property with a high prevalence of pestivirus and a 2% reduction in average conception rate was only slighter better off with a long term vaccination program that treated all breeding females (\$1,025 extra profit/annum), with 15 years required before the investment in annual vaccination was repaid. If the same high prevalence herd could recover the 2% reduction in average conception rate by vaccinating only the heifers, then the benefits of the vaccination program would more than double (\$3,683 extra profit/annum). If the beef herd was assumed to be naive to pestivirus, the marginal returns from implementing a full vaccination program were -\$2,436 annualised NPV/annum.
4. Analysis of investments in inorganic supplements to improve the performance of low P status breeder herds showed that where a biological response to supplements can be identified, wet season P supplementation alone appears to be more efficient than either supplementing with N+P during the dry season or supplementing with N+P during the dry season combined with P supplements during the wet season. However, for herds considered ‘deficient’ and ‘acutely deficient’ in P, supplementation with P in any season substantially increased profitability (range \$9,025-\$48,216 extra profit/annum). The maximum response (\$48,216 extra profit/annum) resulted from supplementing an acutely P deficient herd with P in the wet season only.
5. Supplementing first calf heifers with an M8U (molasses with 8% urea by weight) supplement to improve their re-conception rates from 78 to 80% reduced the returns of the business by \$9,684/annum. This demonstrates that although maintaining body weight is critical to the performance of young breeders, the extra costs associated with achieving extra weaners through supplementing first calf heifers will not be repaid.

c) Marketing options

1. Targeting the certified organic beef market with steers and cull heifers was only marginally more profitable than the baseline production system, resulting in an extra profit of \$2,436/annum. Over the longer term (i.e. after the initial 30 years examined in this analysis) the 25% price premium for organic cattle would not be adequate to offset the 20% reduction in grazing pressure which was assumed to remove the need for supplementation or drought feeding.
2. Targeting the European Union (EU) beef market and selling steers at the same age as for the baseline herd, with 67% going to slaughter and the remainder to the feed-on market, resulted in an extra profit of \$5,949/annum. If EU steers were sold at a younger age than the baseline

herd and in two cohorts as feed-on steers, the annualised NPV was a similar amount: $5,338/annum. However, these results were very dependent on the price premium received for EU cattle (15 c/kg LW). If the price premium was reduced by half, the sale of EU steers as two cohorts of feed-on steers resulted in -$3,845 annualised NPV.

3. Converting to a purebred Wagyu herd substantially improved the profitability of the beef enterprise if the price premium of 100% for Wagyu cattle was maintained from Year 7 of the transition until Year 30 years of the analysis: $32,943 extra profit/annum. However, when price premiums were reduced from Year 20 of the analysis (to $0 by Year 25) the investment in Wagyu cattle was only marginally profitable: $3,218 extra profit/annum. When price premiums were reduced from Year 10 of the analysis (to $0 by Year 15) the investment in Wagyu cattle was not profitable: $42,071 less profit/annum than the baseline herd.

Table 1 - Profitability and financial risk of implementing alternative strategies to improve profitability and drought resilience of beef enterprises in the Fitzroy region

Terms are defined in the Glossary of terms and abbreviations. All scenarios described in full in the report

Strategy	NPV of change	Annualised NPV	Peak deficit (with interest)	Year of peak deficit	Payback period (years)
Improving steer growth rates					
Leucaena	$620,063	$40,336	-$145,722	4	7
Leucaena + purchased breeders	$709,207	$46,135	-$190,539	4	7
Desmanthus	$411,659	$26,779	-$103,212	4	8
Forage oats	-$530,671	-$34,521	-$1,544,320	never	never
Feedlotting steers	-$720,062	-$48,841	-$2,166,733	never	never
HGP - same price, heavier weight	$196,935	$10,794	-$5,063	1	2
HGP - lower price, heavier weight	-$12,386	-$806	-$33,182	never	never
HGP - same price, younger age	-$84,452	-$5,494	-$231,803	never	never
Improving reproductive performance					
Better genetics for fertility	-$50,196	-$3,265	-$126,309	never	never
Benefit of reducing foetal/calf loss in young females by 50%					
$5/head	$7,289	$474	-$1,829	5	6
$7.50 /head	-$6,427	-$418	-$17,502	never	never
$10/head	-$20,142	-$1,310	-$55,927	never	never
$20,000 capital	$15,672	$1,019	-$20,000	2	12
$30,000 capital	$6,148	$400	-$30,000	2	n/a
$40,000 capital	-3,376	-$220	-$40,451	4	never
Pestivirus, high prevalence, vac all	$15,750	$1,025	-$21,219	7	15
Pestivirus, high prevalence, vac heifers	$56,614	$3,683	-$3,276	6	6
Pestivirus, naïve herd vaccination	-$37,446	-$2,436	n/a	n/a	n/a
Inorganic supplements for breeders					
Marginal P herd, P wet season	$121,714	$7,918	-$1,365	1	1
Marginal P herd, N+P dry season	$23,706	$1,542	-$21,252	8	14
Marginal P herd, N+P dry, P wet	$5,765	$375	-$33,892	8	1
Deficient P herd, P wet season	$276,190	$17,967	-$4,251	1	1
Deficient P herd, N+P dry season	$138,729	$9,025	-$10,692	1	1
Deficient P herd, N+P dry, P wet	$249,128	$16,206	-$14,943	1	1
Acute P herd, P wet season	$741,195	$48,216	-$7,136	1	1
Acute P herd, N+P dry season	$176,436	$11,477	-$13,769	1	1
Acute P herd, N+P dry, P wet	$687,365	$44,714	-$20,839	1	1
Feeding first calf heifers	-$148,860	-$9,684	-$416,285	never	never
Marketing options					
Organic beef	$37,445	$2,436	n/a	n/a	n/a
EU slaughter and feed on	$84,449	$5,494	-$10,500	2	2
EU feed on only	$82,059	$5,338	-$10,500	2	2
EU feed on only, lower premium	-$59,109	-$3,845	-$183,713	never	never
Wagyu beef, price premium maintained	$506,411	$32,943	-$269,104	4	12
Wagyu beef, price premium reduces from year 20	$49,471	$3,218	-$269,104	4	n/a
Wagyu beef, price premium reduces from year 10	-$646,738	-$42,071	-$1,927,459	never	never

NPV is the net present value of an investment, referring to the net returns (income minus costs) over the 30-year life of the investment and represents the extra return added by the management strategy, i.e. it is the difference between the baseline, case study property and the same property after the management strategy is implemented. The annualised NPV represents the average annual change in NPV over 30 years, resulting from the management strategy and can be considered as an approximation of the change in profit per year.

Peak deficit is the maximum difference in cash flow between the implemented strategy and the base scenario over the 30-year period of the analysis. It is a measure of riskiness.

Payback period is 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.

n/a: not applicable.

The analysis indicates that a number of the alternative management strategies or technologies that could be applied to beef businesses in the Fitzroy region are unlikely to substantially improve resilience or add to profit. This is due to the representative, regional case-study model already being an efficient beef production system with existing production targets well considered by beef producers for their impact on risk and profit. For example, the available data for reproduction efficiency for the Fitzroy identifies a relatively high level of performance compared to other regions in northern Australia This reduces the economic benefit of marginal improvements in strategies like the genetic improvement of fertility and reducing pre-weaning calf loss. Higher cost strategies aimed at improving reproduction efficiency, such as providing energy rations to first calf heifers prior to calving, appear unlikely to ever be economic due to the changes in herd structure that occur when one component of an already efficient system is targeted in such a manner.

There are available strategies that target growth rates of the steer component of the herd that will improve efficiency and resilience as long as they are initially selected for their likely impact on profit at the property level. It is clear that the incorporation of perennial legumes, especially leucaena, into the diet of steers provides a substantial step forward in profitability and therefore resilience. Even so, the long payback periods for these perennial legume-grass pastures suggest that investments will have to be targeted closely with a staged development process applied to reduce the riskiness of the investment.

In contrast to the investment in perennial legumes, other strategies targeting steer nutrition reduced both the profitability and resilience of the beef production system. One strategy often used in the Fitzroy is to send steers to a feedlot to be custom fed and then slaughtered, either as a strategy to increase output or in preparation for drought. This action substantially reduced the profitability of the beef production system. Likewise, targeting the use of annual forages such as forage oats to increase steer growth rates has been shown in this analysis to be both a high risk and low profit venture. When considering a strategy of HGP use from weaning until sale producers need to ensure they will meet the specifications for the market they are targeting and need to consider effects on the overall herd structure if the age of turn-off changes. A relatively small change in price can make this strategy either profitable or unprofitable.

The one strategy that considered disease management in the breeder herd indicated that potentially high impact, episodic events, such as an outbreak of pestivirus in a naive breeder herd, are difficult to assess for their impact on profit and risk. This makes a recommendation of change to the current strategy (of no treatment) difficult to justify. Treatment of diseases that have an ongoing, low level of impact is also difficult to justify given the often high cost of treatment and the difficulty of isolating and measuring the impact of treatment. Regional survey data indicates that producers are capable of assessing these risks within the context of the circumstances of their property if they are provided with adequate information about the risks of the disease and its aetiology. A decision not to prevent a disease can be shown to be equally as rational as taking action to prevent disease, depending upon the circumstances of the beef production system under threat.

Phosphorus deficiency has been shown to be widespread across northern Australia and is considered to be a major constraint to the performance of beef cattle. In this analysis we looked at the breeder herd in isolation and found that the value of providing supplements to reduce the impact of varying levels of P deficiency depended very much on the marginal benefits of providing an efficient supplementation program. Rigorous analysis of the existing level of P deficiency and its impact, the appropriate method of overcoming the deficiency and the value of fixing the deficiency need to be undertaken prior to implementation of any supplementation program. Breeder herds that are performing at the median level indicated in regional surveys (Adequate P status) are unlikely to show an economic response to nutritional supplements whereas breeder herds running on country with an acute level of P deficiency are likely to show a strong economic response to appropriate levels of P supplementation. Breeder herds that run exclusively on Marginal P country appear likely to only show a measureable economic response to P supplements delivered in the wet season. However, breeder herds run on Deficient P and Acute P country are expected to show a measureable economic response to P supplementation delivered either in the wet season only, in the dry season only and in combination with N supplements, or in both the wet season and dry seasons. For all herds with a measureable P deficiency, response to supplementation is likely to be more profitable if delivered in the wet season only.

Strategies that target different markets such as the EU market for steers, organic production and Wagyu beef may offer short term opportunities to improve profitability but also appear to increase drought risk due to the focus on a more narrow production system. Production systems that reduce flexibility over the longer term have been shown to be inherently more risky and therefore likely to expose the property to greater variation in returns.

Assessing the potential impact of drought on the herd as well as the effect of herd structure on drought risk and profitability

The results of our study of the Fitzroy representative property suggest that, other than P supplementation when appropriate, strategies focused on improving the performance of the breeder component of the herd in isolation are unlikely to improve business profit and resilience. This lack of capacity to identify alternative strategies that improve breeder herd efficiency highlights the critical importance of implementing the usual low cost strategies to get body condition and herd structure right as key factors in being drought prepared. The analysis of the impact of breeder condition score on mortality, due to falling body condition and weight loss during a drought, demonstrates the importance of the day-to-day management of the breeder herd and its nutrition in preparing for drought. Selecting the appropriate age for female culling and steer sale can also reduce drought risk. A summary of the key findings from this part of the analysis is given below.

1. As breeders age they have a greater expected mortality if they suffer liveweight loss during a drought. Having breeder BCS in better than a forward store condition (better than score 5 on a 9 point scale) going into a drought could substantially reduce the mortality rate of mature and aged cows who are considered likely to lose more than 10% of their starting liveweight. Reducing the age of cow culling from 12-13 years to 9-10 years of age, and consequently reducing the percentage of 2 year old heifers sold as culls, only marginally reduced the profit (by less than $1,000/annum). This reduction is more than likely to be offset by the breeding herd having a substantially reduced number of mature cows, and no aged cows, going into a drought and consequent reduced mortality rates.

2. Targeting the production (sale) of 1-2 year old feed-on steers resulted in the optimum profitability for the baseline herd. Changing the age of steer turnoff to older or younger than 1-2 years of age reduced profit but also changed drought risk due to changing the number of wet cows in the herd. Over the longer term, a strategy of turning off 2-3 year old steers appears to

be worth consideration to reduce drought risk. This increased age of steer turnoff only marginally reduced profit (by 1.4% for herd gross margin) whilst reducing drought risk due to decreasing the number of wet cows in the herd (35% of the herd vs. 40% in the baseline herd). Re-structuring the herd to turn off 3-4 year old steers reduced drought risk further (30% of the herd now wet cows) but also reduced profit more substantially (5% decrease in herd gross margin). When the herd was restructured to turn off weaner steers drought risk increased due to 51% of the total herd being breeders mated and kept whilst profit also decreased substantially (by 23% for herd gross margin).

Responding to drought

Drought response strategies are often seen as tactical, short-term decisions which are highly dependent on the individual circumstances prevailing at the time. This is not always correct as the options available to respond to drought are often determined by the decisions made prior to the drought and the actions taken in response to drought will often determine the medium term outcomes for the beef property once the drought breaks. The consideration of alternative responses should initially be undertaken by looking at impacts on components of the herd in isolation together with the marginal costs and benefits. This analysis revealed a need to often also identify the outcomes of the response in terms of property level impacts if a full picture of the impact of the response decision were to be gained.

As it is not possible or practical to create scenarios to reflect every possible combination of assumptions, expected ‘answers’ cannot be given – the strategies need to be assessed using the relevant input figures at the time of the decision. Hence, examples were developed to demonstrate a) the key strategies which may be considered in response to drought, and b) how to assess strategies using tools available in the Breedcow and Dynama suite of programs.

The capacity of the representative property to respond to drought is initially defined by the way the breeder herd is already segregated on age and managed. In this analysis the case study breeder herd had been culled on pregnancy status with all empties removed during the previous season. This reduced the opportunity for the manager to take decisive action, in rapidly reducing grazing pressure, if the following season was below average and hence complicated the decision making process when forced sales were being considered. These difficulties are part and parcel of having an efficient production system in place prior to drought but are less challenging than those faced by the producer that does not pregnancy test and has in place a breeder herd structure that exposes them to increased drought risk.

The analysis showed that an efficient system has no easy decisions when it comes to substantially reducing grazing pressure. The initial tweaks to herd numbers that can be made when responding to drought do not make large reductions in numbers or grazing pressure and the remaining choices involve the sale of classes of cattle that will substantially impact the future earning capacity of the property. At this time, detailed analysis of the options available needs to be made as each set of circumstances will be different and a successful action taken at the start of the last drought may not meet with success this time around. The finding from this study was that assessing the sale of alternative classes of cattle should be done on the basis of the impact of either future profit or future cash flow, depending upon the immediate needs of the property, and that all classes of cattle should be incorporated in the assessment.

A summary of the key findings from this part of the analysis is given below.

1. Drafting off and culling PTIC empties (females that were pregnancy tested in calf the previous year but subsequently lost a calf prior to branding) at the branding muster is an easy way to reduce grazing pressure early in the year in response to poor seasonal conditions and outlook. In a well-managed herd that has a lower rate of foetal/calf loss, the number available for sale are not likely to be a substantial portion of the herd or grazing pressure but sale of these females may also remove sub fertile cows.
2. Early weaning at branding in February (rather than the usual weaning in mid-May) will reduce liveweight loss of breeders during poor seasonal conditions and hence reduce breeder mortality rates and improve reproductive efficiency. The weaners will need to be segregated on weight (>/< 100 kg) and fed supplements suitable for each group. The Splitsal program (within the Breedcow and Dynama package) can be used to indicate the expected weight distribution of weaners in February, allowing feeding costs to be calculated. The Cowtrade program (within the Breedcow and Dynama package) can then be used to compare these costs to the anticipated benefits of a reduction in breeder mortality rate and improved reproductive efficiency.
3. Selling PTIC cows at pregnancy testing in early May and then re-purchasing cows and calves 12 months later is another strategy that can be considered using the Cowtrade program. This strategy is aimed at maintaining the number of weaners available to the property over time and can be compared to the expected feeding costs if the cows are retained to produce weaners as normal. A table can be produced to indicate the sensitivity of the exercise to variation in the sale price for PTIC cows, the cost of feeding, and the replacement costs of cows and calves. The break-even level for the drought feeding strategy can be determined using the Cowtrade program.
4. The sale of other classes of dry stock as an alternative to selling breeding females can be evaluated by comparing the outputs of the Bullocks and Cowtrade programs. The Bullocks program (within the Breedcow and Dynama package) can be used to test the same options for non-breeding cattle as the Cowtrade program does for breeder groups. In many cases a drought response can include ‘either or’ options where different classes of cattle can be sold to achieve the same level of reduction in grazing pressure. The criteria for deciding which class of cattle needs to be sold first is usually the ‘gross margin per AE after interest’ calculated over the selected period of time with the class achieving the lowest gross margin sold first. The class of cattle chosen for sale could change over time due to changing market opportunities and feeding costs.
5. The direct costs of agistment can be determined using spreadsheets and compared to the costs of alternative management responses.

Recovering from drought

The choices available during the drought recovery phase depend partly upon the decisions previously made during the drought response phase. Each alternative strategy implemented during a drought will result in a different herd structure on the property at the end of the drought and different options available for recovery. As it is not possible or practical to create scenarios to reflect every possible combination of assumptions, expected ‘answers’ cannot be given – the strategies need to be assessed using the relevant input figures at the time of the decision. Hence, examples were developed to demonstrate a) the key strategies which may be considered in the drought recovery phase, and b) how to assess strategies these using tools available in the Breedcow and Dynama suite of programs.

Drought recovery strategies should be targeted at returning business cash flow and profit to their long term trend as quickly as possible. The analysis makes it clear that drought recovery and drought response actions are closely linked and that the impact of response actions on the choices available for recovery action at the end of the drought need to be fully considered. Even so, deciding prior to drought upon the recovery action that is considered most likely to return the property to a positive cash flow, and profitable operation, the quickest will often determine the response actions which should be considered first. However, this may not be the best management mindset to take into a drought. Flexibility is the key when responding to drought and setting a drought response (and recovery) plan prior to drought may prevent the consideration of more viable alternatives that are revealed as the drought progresses. It is necessary to apply the right planning framework and to reassess the strategy as change occurs. The best recovery option will only be identified after a number of strategies are compared for both their short term and medium term impact on the cash flow and profit outlook for the property.

A summary of the key findings from this part of the analysis is given below.

1. Where a substantial herd reduction has been carried out, allowing herd numbers to rebuild slowly from retained progeny, and taking no other action, is likely to seriously impact the ongoing viability of the business.
2. If breeders had been sent on agistment for the period of a short term drought (12 months) cash flow deficits would be increased in the short term compared to the sale of breeders but cash flow and profit could be more rapidly returned to the long term trend.
3. Purchasing PTIC (pregnancy tested in calf) cows to rapidly restore the breeder herd at the conclusion of the drought would increase and extend cash flow deficits in the short term but potentially provide a better outcome than just allowing the herd to return to normal numbers through foregoing sales.
4. If the spare grazing capacity created by selling cattle at the start of the drought can be filled by stock on agistment at a suitable price once the drought breaks this strategy improves the cash balances in the early years while the herd is rebuilding and hence appears to be more profitable than purchasing PTIC cows.
5. Cattle trading can be initially considered as part of a drought recovery strategy by using the Bullocks program to assess the purchase of dry stock and the Cowtrade program to assess the purchase of cows and calves or PTIC cows. The resulting gross margins need to be incorporated into a cash flow budget for the property over the medium term future to identify the impact of interest and other costs associated with funding stock purchases. It appears the short term trading of large numbers of stock when recovering from drought may be a risky venture that needs close consideration if benefits above those available from other recovery strategies are to be gained.
6. Another recovery option is ‘buying back the herd’. This relies on returning the herd to its long term structure as soon as possible through the purchase of replacement steers, heifers and PTIC cows. It appears to be a risky strategy that is likely to take a considerable period of time

before the cash balances of the property achieve the level of some of the potentially less risky recovery options.

Conclusions

This study represents the first known attempt to assess the economic implications of a comprehensive range of management decisions that can be applied to prepare for, respond to, or 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 businesses in the Fitzroy NRM region of Queensland. The scenarios modelled here are aimed at providing a broad understanding of the range of opportunities available for improvement, the potential response functions in a production system and an appropriate framework to support decision making. The property-level, regionally-specific herd and business models that we have developed can be used by consultants, advisors and producers to assess both strategic and tactical decisions for their own businesses.

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1 Introduction

1.1 General introduction

More than 80% of Queensland's total area of 173,047,559 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 with introduced (sown) pastures constituting less than 10% of the total grazing area and occurring on the more fertile land types (McIvor 2005; QLUMP 2017). Grazing industries, and particularly beef cattle, make an important contribution to the Queensland economy. In 2016-17 the beef cattle industry accounted for ca. 41% ($5.7 billion) of the total gross value of Queensland agricultural production while sheep meat and wool accounted for ca. 1% ($0.1 billion), (ABS 2018*b*).

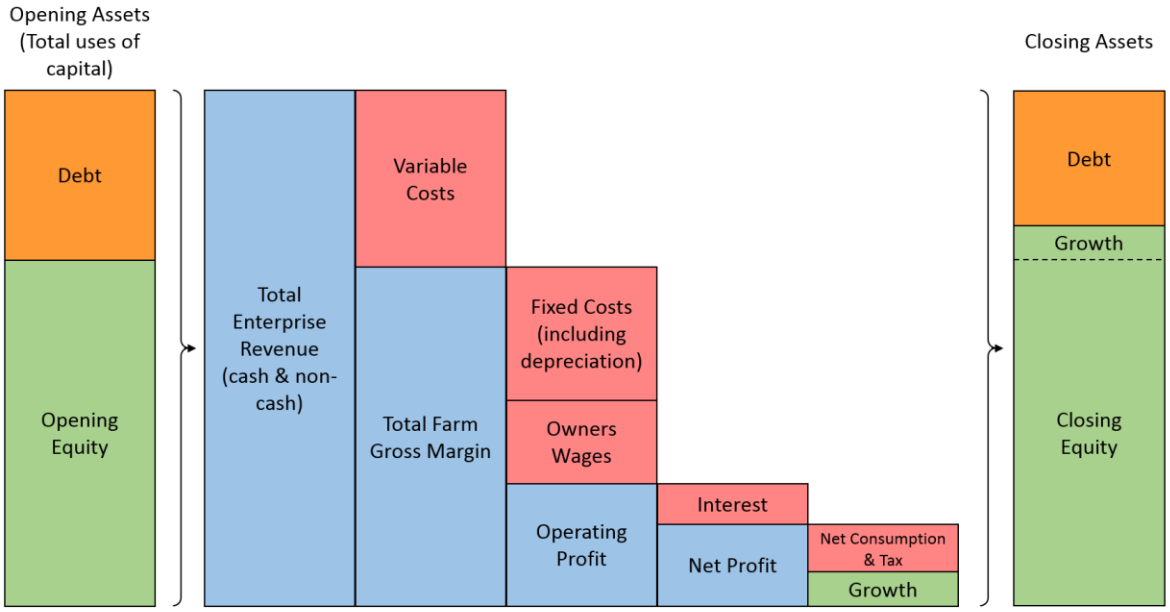
Queensland's variable rainfall, especially long periods of drought, is one of the biggest challenges for grazing land managers. As well as the potential for causing degradation of the grazing resource, drought has a severe impact on business viability, is a regular occurrence, and provides the context 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' (McCosker *et al.* 2010; McLean *et al.* 2014).

To remain in business, and to build drought resilience, beef and sheep enterprises need to be profitable and to build equity (Figure 1). Building resilience usually means investments have to be made and alternative management strategies considered. To make profitable management decisions graziers need to be able to appropriately assess the impact of the strategy on business profitability, the associated risks, and the period of time before benefits can be expected. The effect of such alternative management strategies is best assessed using property-level, regionally-relevant herd models that determine whole-of-business productivity and profitability (Malcolm 2000).

Decision making during drought often has a much more tactical, short term focus but once again relies upon the application of a framework that can rapidly highlight the relative value of the alternatives available over both the short and medium term. Simple spreadsheets that apply a farm management economics framework can be used to gather the relevant information and highlight the possible outcome of any decision. These tools can be applied quickly and greatly assist decision making during drought.

Recovery from drought is also a challenging period where much is changing and uncertainty is great. Decision making at this time has to be a suitable blend of the strategic – how to get back to the most profitable herd structure and production system, and tactical - how to survive while the system is being rebuilt.

Figure 1 – The link between profit and growth in equity



The objective of this project, 'Delivering integrated production and economic knowledge and skills to improve drought management outcomes for grazing enterprises', was to improve knowledge and skills of advisors and graziers in assessing the economic implications of management decisions which can be applied to prepare for, respond to, or 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 businesses for a number of disparate regions across Queensland. In doing this we have developed property-level, regionally-specific herd 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 which can be applied to prepare for, respond to, or recover from drought for beef production systems in the Fitzroy region of central Queensland.

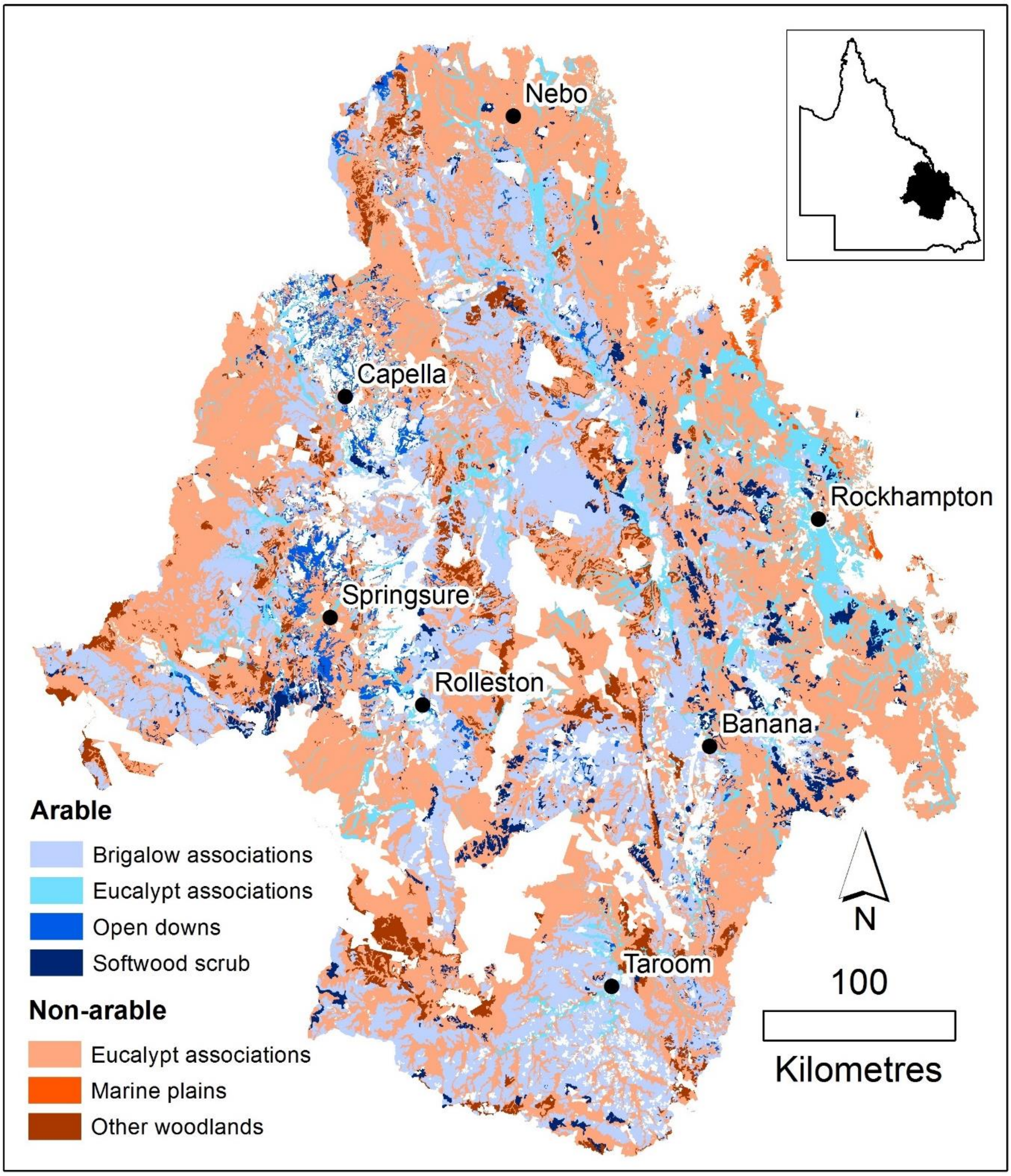
1.2 The Fitzroy region of central Queensland

1.2.1 The land resource

The Fitzroy Natural Resource Management (NRM) region encompasses 12.2 million ha of grazing land (DNRM 2017*b*). The region falls largely within the Brigalow Belt bioregion with ca. 42% of the land area used for grazing having arable soils capable of supporting sown forages suitable for beef cattle finishing (slaughter) or backgrounding (preparing for feedlot entry), (DNRM 2010; DNRM 2017*b*; Figure 2). In the Fitzroy region the less productive, non-arable land (58% of the grazing lands) is largely open Eucalypt woodlands which are primarily used for running breeder herds.

Figure 2 – Map of the Fitzroy Natural Resource Management Region of central Queensland showing the distribution of major arable and non-arable land types on land used for grazing

Note: land used for purposes other than grazing, including cropping and national parks, is marked white on the map



1.2.2 Rainfall and drought

The Fitzroy region is characterised by a sub-tropical, semi-arid climate with high rainfall variability. The amount and distribution of rainfall are primary determinants of pasture and forage growth. The ratio of summer to winter rainfall decreases from north to south, with an average ratio of 70:30 (Bowen et al. 2015*a*). Examples of seasonal distribution of rainfall are shown for seven locations from north to south across the Fitzroy region (BOM 2017; Table 2). The variability of annual rainfall in the Fitzroy region ranges from 'moderate' in the north-west to 'low to moderate' in the south-east (scale low to extreme) based on an index of variability determined by percentile analysis (BOM 2018; Figure 3).

Queensland's variable climate, especially long periods of drought, is one of the biggest challenges for beef enterprise managers. Drought has a severe impact on viability, is a regular occurrence, and provides the context for many of the production and investment decisions made by managers of beef properties. While there is no universal definition of drought, one that is common in agriculture is the 'drought percentile method' (BOM 2017). 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 2017). 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 in (Table 3) for Rolleston which is centrally located within the Fitzroy region. Using this definition, there have been 35 droughts at Rolleston since 1900, the longest lasting 14 months.

Table 2 - Median seasonal distribution of rainfall (mm) at Nebo, Capella, Rockhampton, Springsure, Rolleston, Banana and Taroom for the 30-year 'climate normal' period 1961-1990

Town	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Nebo	88.5	107.8	79.8	25.0	26.7	27.5	16.2	12.5	5.8	26.6	51.5	91.2	691.4
Capella	86.5	76.2	49.1	17.6	31.5	11.9	18.6	7.7	7.0	17.9	54.0	81.2	595.4
Rockhampton	82.1	77.8	72.3	33.5	34.9	29.3	18.5	19.7	12.9	31.0	84.4	104.9	753.8
Springsure	90.3	91.6	47.7	32.2	26.2	16.9	12.7	12.1	8.3	35.9	66.0	90.0	734.1
Rolleston	82.9	73.6	42.2	26.0	32.4	12.7	18.1	13.6	9.9	28.6	66.2	94.4	621.3
Banana	63.9	81.0	46.7	20.0	29.9	18.7	23.6	14.1	15.3	37.4	82.7	85.1	616.9
Taroom	89.6	57.1	55.5	19.8	33.8	22.4	28.1	19.8	21.0	46.6	53.3	93.6	627.6

Figure 3 – Map of the annual rainfall variability across Australia determined using the percentile analysis (BOM 2018)

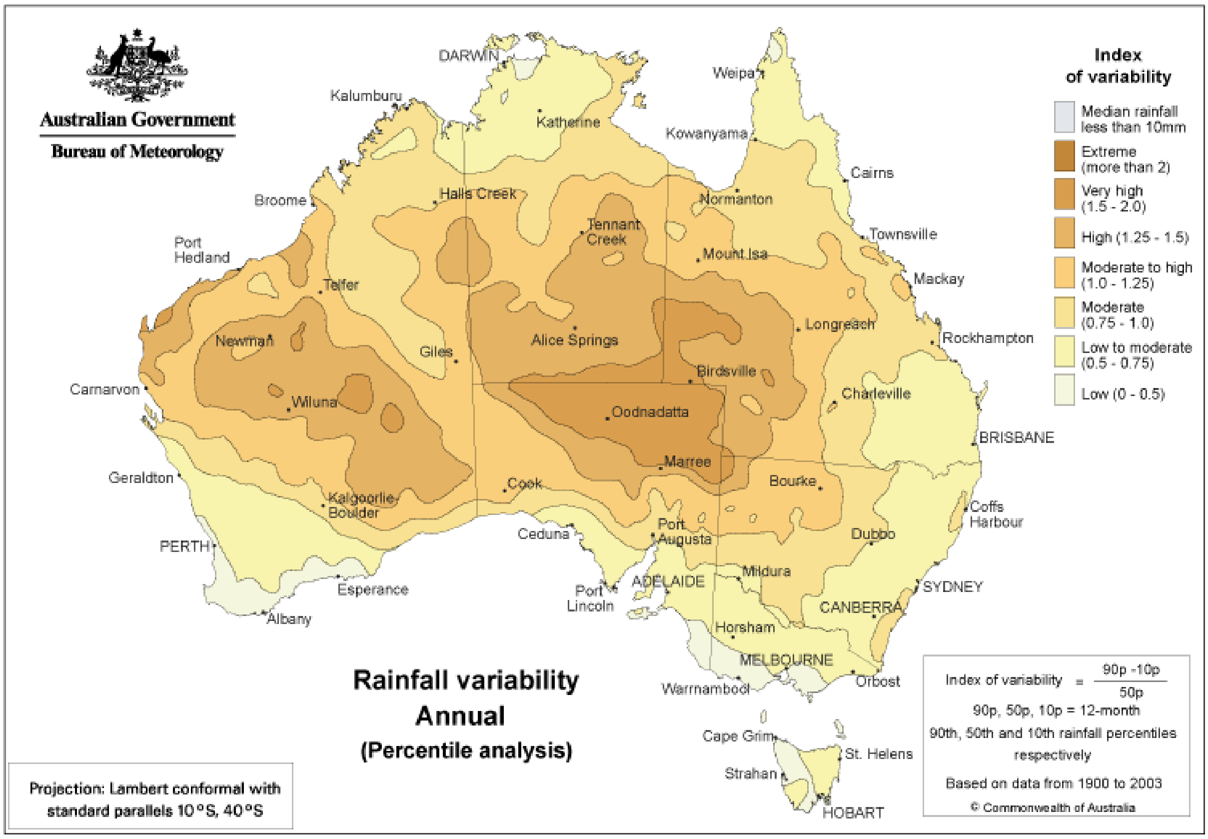


Table 3 – Historical droughts (1900 – 2017) at Rolleston ranked by depth and duration and with subsequent recovery rainfall[A]

Rank	Drought period	Drought length (months)	Drought depth (percentile)	Subsequent recovery rainfall (mm)
1	Mar 1902 - Apr 1903	14	0	236
2	Jan 1919 - Jan 1920	13	0.9	399
3	Apr 1969 - Jan 1970	10	0.9	310
4	Mar 1915 - Feb 1916	12	0	376
5	Mar 1995 - Sep 1995	7	1.7	130
6	Nov 1951 - Mar 1952	5	0	265
7	Feb 1912 - May 1912	4	0	118
8	Jun 2003 - Nov 2003	6	3.4	131
9	Jan 2014 - Sep 2014	9	4.3	279
10	Feb 1923 - Aug 1923	7	1.7	211
11	Feb 2016 - Jun 2016	5	2.6	131
12	Nov 1982 - Mar 1983	5	4.3	277
13	Jun 1931 - Oct 1931	5	5.2	121
14	Aug 1965 - Nov 1965	4	3.4	77
15	Dec 2002 - Feb 2003	3	2.6	155
16	Nov 1926 - Feb 1927	4	3.4	247
17	Sep 2013 - Nov 2013	3	4.3	81
18	Dec 1957 - Feb 1958	3	4.3	148
19	May 1970 - Aug 1970	4	6.9	30
20	Mar 1938 - Apr 1938	2	6	61
21	Jan 1947	1	3.4	32
22	Sep 1948 - Dec 1948	4	8.6	203
23	Oct 1970	1	6	21
24	Dec 2009	1	6	76
25	Sep 1927	1	6.9	0
26	Oct 1972	1	7.8	33
27	Apr 2007 - May 2007	2	8.6	19
28	Dec 1932	1	8.6	56
29	Jul 1953	1	8.6	0
30	Aug 2004	1	8.6	0
31	Jun 1973	1	9.5	29
32	Nov 2014	1	9.5	30
33	Oct 1953	1	9.5	57
34	Jul 2007	1	9.5	0
35	May 1948	1	9.5	9

[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 2017).

1.2.3 Fitzroy region beef production systems

The Fitzroy NRM region of central Queensland is an important beef producing region of Australia, supporting 12% of Australia's (25% of Queensland's) cattle numbers and producing 12% of Australia's (25% of Queensland's) gross value of cattle in 2016-17 (ABS 2018*a*,*b*). The region supports the greatest number of cattle of all NRM regions in Australia (ABS 2018*a*).

A beef industry survey of 94 enterprises undertaken during 2011-2014 in the Fitzroy NRM area determined property characteristics and herd management practices representative of the region (Barbi *et al*. 2016). The survey data indicated:

- Median property area of beef enterprises: 7,100 ha
- Median beef herd size: 800 head
- 85% of the surveyed enterprises had a breeding herd
- 56% of enterprises sold the majority of their output direct to the meatworks
- 29% of enterprises mostly sold store cattle (cattle not yet at slaughter weight or condition)
- Target slaughter markets were:
    - heavy weight, grass-fed steers (55% of respondents)
    - domestic market for surplus heifers (62% respondents)
    - American market for surplus cows (81% of respondents).
- Target carcass weights for stock sent to the abattoirs:
    - steers: 346 kg
    - heifers: 278 kg
    - cows: 315 kg
- Weaning weight range (poor season to good season): 166-221 kg liveweight
- Weaning percentages depended upon the seasonal conditions:
    - replacement heifers: 77-80%
    - first calf heifers: ca. 70%
    - breeders: 80-85%.
- Most enterprises (80%) segregated their heifers with 50% first joining heifers at 18 months of age.
- Many enterprises (ca. 70%) removed bulls from the breeding herd for part of the year and most (>80%) used pregnancy testing as a herd management tool. About 17% of enterprises also applied foetal aging as a herd management tool. A smaller percentage of enterprises (61%) applied bull soundness examinations as a management tool with a smaller proportion again (42%) using EBV's when selecting bulls. The average bull joining percentage was calculated as 3.2%
- Health treatments applied to weaners included:
    - botulism vaccination: 16% of enterprises

    - 5 in 1 vaccination: 53% of enterprises
    - 7 in 1 vaccination: 26% of enterprises
    - leptospirosis vaccination: 5% of enterprises
    - pestivirus vaccination: 3% of enterprises
    - tick fever vaccination: 28% enterprises
- Health treatments applied to bulls included:
    - vibriosis vaccination: 35% of enterprises
    - 3-day fever vaccination: 17% of enterprises
- Most enterprises (94%) fed supplements of some form and incurred an average supplement cost of ca. $17/head
- Almost half (46%) the enterprises recorded data for individual animals with stock handled four to five times per annum on average.

1.2.4 Strategies available to prepare for drought by improving profitability and business resilience

1.2.4.1 Improving steer growth rates

1.2.4.1.1 Improving steer growth path performance with perennial legume-grass pastures

A major constraint to beef production in the Fitzroy region is the declining productivity of sown pastures. Although the Brigalow Belt bioregion has been regarded as a highly productive agricultural area due to its inherent soil fertility and moderate rainfall environment, pasture and beef cattle productivity have appreciably declined since pasture establishment due to a ‘run-down’ or decline in available nitrogen in the soil with increasing age of the pasture stand since tree clearing (Peck *et al.* 2011, 2017). Furthermore, this decline in productivity of the largely buffel grass (*Cenchrus ciliaris*) pastures has been exacerbated in some cases by sustained heavy grazing pressure, causing a decline in land condition (Beutel *et al.* 2014), as well as by invasion by the less productive pasture species, Indian couch (*Bothriochloa pertusa*; Spiegel 2016) and the increasing but poorly understood phenomenon of pasture dieback (Buck 2017).

The more productive land types in the Fitzroy (largely Brigalow land types) were generally cleared of timber and sown to primarily buffel grass pasture during the 1960-80s (Thornton and Elledge 2013; DNRM 2017*a*). Although these sown grass pastures were very productive when they were planted after clearing virgin forest, the productivity of these pastures has declined over time, a phenomenon often described as ‘pasture run down’. Pasture run down is caused by a lack of available nutrients, mainly nitrogen (N). It is not caused by a net loss of nutrients from the system unless nutrients have been removed as grain, hay or silage production from the paddock. The high intake of available N by sown grasses, coupled with a low rate of N cycled back into the system in a plant-available form over time (through organic matter breaking down) reduces grass production over time after establishment. Data collated by Peck *et al.* (2011) showed the annual dry matter (DM) production from sown grass pastures to decline by 50-60% within 5-10 years of establishment. Animal production followed a similar trend with a linear decline of 20-70% in annual liveweight gain over the first 5 years after pasture establishment, when stocking rates were held constant.

Establishment of adapted legumes into the existing grass-only pastures has been identified as the best long-term option to increase both the productivity and returns from run-down, sown grass pastures due to their ability to biologically fix atmospheric nitrogen if nodulated with the correct rhizobium (Peck *et al.* 2015, 2017). When the high-N legume plant material decomposes and N is released into the soil it provides additional N which can be used by adjacent grass plants. The amount of N a legume adds to the soil is directly related to how much dry matter it produces. Modelling suggests that ccurrently available legumes, with good agronomy and management, can potentially reclaim 30-50% of grass production lost through pasture run down (Peck *et al.* 2017). Legumes also increase the quality of the diet for grazing cattle by providing a diet higher in N and digestibility which result in increased nutrient intake and animal performance (Bowen *et al.* 2015*a)*.

Of the commercially available perennial legumes suited to the arable land types of central Queensland, the tree leucaena (*Leucaena leucocephala* spp. *glabrata*) has been identified as the most productive and profitable, increasing beef production per ha by ca. 2.5 times and doubling gross margin per ha, compared to perennial grass pastures (Bowen *et al.* 2018*a*). The area planted to leucaena in the prime leucaena-growing areas of Queensland which primarily fall within the Fitzroy NRM region, is currently estimated to be ca. 123,500 ha (Beutel *et al.* 2018). Assessments of suitable soil and climatic conditions indicate that there is considerable scope to expand plantings within this region as well as across Queensland (Beutel *et al.* 2018) with Peck *et al.* (2011) estimating that leucaena has been sown to only 2.5% of the area to which it is adapted in Queensland.

The shrubby legume, butterfly pea (*Clitoria ternatea)* has also been shown to be a profitable legume option for arable land types in central Queensland (Bowen *et al.* 2018*a*). Furthermore, recent research has demonstrated that the shrubby legumes, desmanthus (*Desmanthus virgatus*) and Caatinga stylo (*Stylosanthes seabrana*), can also be persistent and productive in central Queensland although they have not been widely adopted commercially (Peck *et al.* 2017).

Leucaena and other legume options remain an under-exploited resource in the Fitzroy region due to a number of constraints, primarily the difficulty, cost and risk of establishment as well as the additional management expertise required to productively utilise the resource (Shelton *et al.* 2005; Peck *et al.* 2011; Bowen *et al.* 2015*a*). Regardless, the general, low adoption rates of pasture legumes in the Fitzroy, and northern Australia more broadly, indicate a significant opportunity to increase beef production, and potentially profitability, through incorporation of adapted legumes into sown grass pastures.

1.2.4.1.2 Improving steer growth path performance with forage oats

While perennial legumes, especially leucaena, have been identified as the most profitable high quality forage option for beef cattle production in central Queensland, annual forage cropping is common despite the marginal contribution to business profit when alternatives are considered (Bowen *et al.* 2015*a*, 2015*b;* Bowen and Chudleigh 2017). Studies of commercial beef production systems in central Queensland showed oats (*Avena sativa*) to be the most profitable, of the commonly applied annual forage crop options in central Queensland, in terms of gross margin per hectare (Bowen *et al.* 2015*b*, 2016). Being a C_3, winter growing plant, forage oats produces high quality, highly digestible feed resulting in high levels of animal performance. It is productive at the time of the year when C_4 perennial grass pastures are dormant, enabling good weight gains (ca. 1 kg/head.day) when cattle would otherwise be maintaining or losing weight (Bowen *et al*. 2015*a*).

1.2.4.1.3 Custom feedlotting steers

Other nutritional interventions to improve growth rates of steers, increase output of beef, and potentially increase profitability involve provision of energy supplements either on or off farm. Custom feeding in a commercial feedlot, off-farm, has been a common strategy in the Fitzroy region and has been viewed as an insurance against deteriorating rainfall outlook conditions. A major influence on the cost of grain feeding cattle is the feed conversion efficiency (the ratio of feed consumed to liveweight gain). Older, heavier cattle are less efficient (require more feed to produce each kg of liveweight gain) than younger, lighter cattle due to their greater maintenance energy requirements and greater proportion of fat in the liveweight gain (NRDR 2007). The profitability of a custom feedlotting strategy is sensitive to the cost of grain as well as the price margin ($/kg) between cattle entering and exiting the feedlot.

1.2.4.1.4 Hormonal growth promotants for steers

Hormone growth promotants (HGPs) can increase growth rates of cattle by 10-30% and feed conversion efficiency by 10-15% with the result dependant on the period over which the cattle were treated and the nutrition available (Hunter 2009). The increased growth rates can have a substantial benefit, enabling the weight-for-age specifications of the target market to be met, particularly when cattle are grazing perennial grass-only pastures. However, cattle treated with HGPs are excluded from the European Union (EU) and the Pasturefed Cattle Assurance System (PCAS) markets. In addition, HGP treatment can make it more difficult to achieve the MSA grading specifications required to achieve maximum price per kg carcass weight as HGP-treated cattle have a higher ossification score and also receive an additional penalty in the MSA grading system. HGPs can also increase carcass leanness by 5-8% and thus may not be beneficial when late-maturing genotypes are used to produce beef for markets requiring substantial fat levels at light carcass weights (Bowen *et al.* 2015*a*). McLennan (2014) found that use of HGP implants continuously from weaning in *B. indicus* steers grazing native pastures in north Queensland, with or without molasses supplements, increased the net value added to the steers despite impeding compliance with MSA.

1.2.4.2 Improving breeder reproductive performance

1.2.4.2.1 Better genetics for breeder fertility

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

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

1.2.4.2.2 Investing to reduce foetal/calf loss

The CashCow project (McGowan *et al.* 2014) identified median values of 10.2% foetal/calf loss in heifers and 7.3% in first lactation cows for the Central Forest region, which is applicable to the Fitzroy region study area. (Table 4). These losses occurred sometime between conception (pregnancy testing) and weaning. Calf losses were identified in the CashCow project if a heifer or cow was diagnosed as pregnant in one year and was recorded as dry (non-lactating) at an observation at least one month after the expected calving month the following year. This measure of foetal/calf loss, as it was derived in the CashCow project, excludes cow mortality during the same period and subsequent calf loss due to that source.

Table 4 - Median reproduction performance for Central Forest data (McGowan et al. 2014)

Reproduction performance indicator	Heifers	First lactation cows	2nd lactation cows	Mature	Aged	Overall
P4M*		49%	64%	77%	71%	68%
Annual pregnancy**	80%	78%		89%	86%	85%
Foetal / calf loss	10.20%	7.30%		5.90%	4.90%	6.70%
Contributed a weaner^	67%	71%		80%	86%	77%
Pregnant missing#		11.80%		6.60%	6.30%	7.90%

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

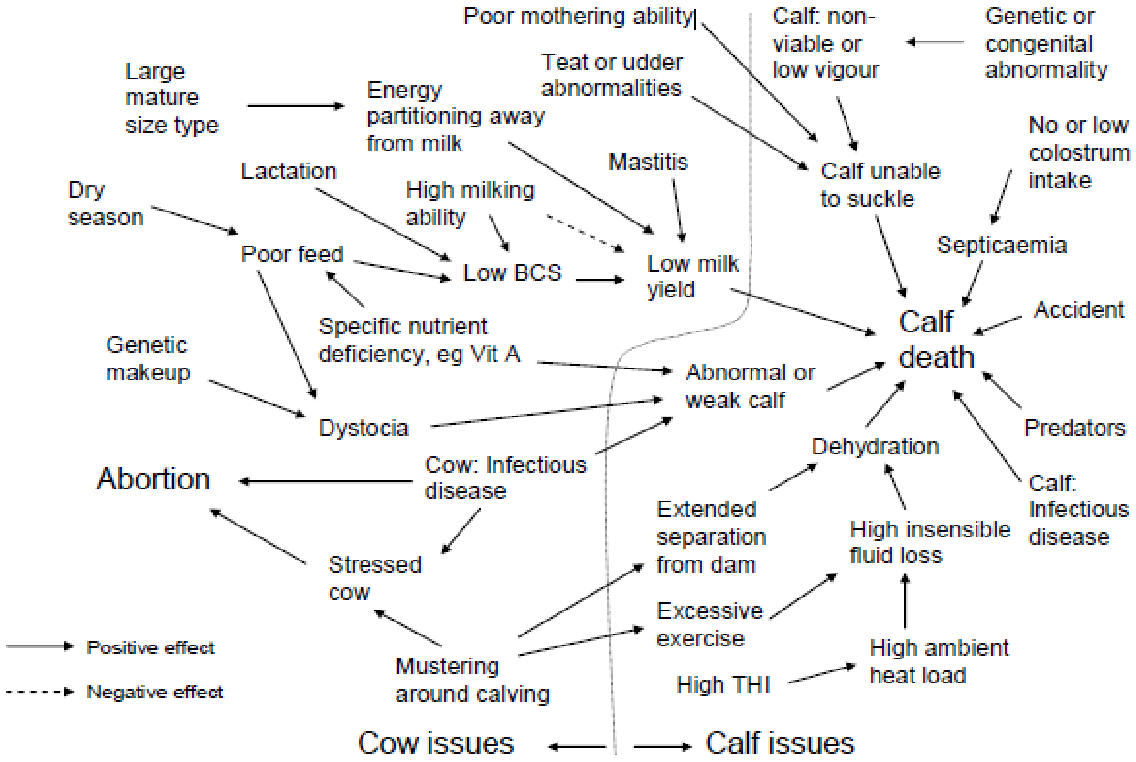
** Percentage of cows in a management group (mob) that became pregnant within a one-year period. For continuously mated herds, this included cows that became pregnant between September 1 of the previous year and August 31 of the current year

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

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

The CashCow project developed a possible causal pathway for calf loss (Figure 4). Each property manager would need to work their way through the factors likely to be affect calf/foetal loss in their herd based on the modelling of the CashCow project and the causal pathways identified in Figure 4 if a relatively high value for loss in any age class of females was identified. From there an analysis based on the identified cause and effect pathway could proceed.

Figure 4 - Possible causal pathway for foetal and calf loss in northern Australia (McGowan et al. 2014)



1.2.4.2.3 Pestivirus management

Bovine pestivirus, taxonomically known as bovine viral diarrhoea virus (BVDV), is ubiquitous in cattle populations around the world and considered an economically important cause of disease in beef cattle in Australia (Kirkland *et al.* 2002; GHD Pty Ltd *et al.* 2015). As reviewed by Kirkland *et al.* (2002), the major impact of pestivirus is reproductive loss in breeder cattle, from conception through to calving. This is a result of reduced conception rates, early embryonic deaths, abortion, congenital defects, stillbirths and perinatal mortality. Cattle born after exposure to the disease *in utero* during the first trimester of gestation, known as persistently infected (PI) animals, usually succumb to diseases such as chronic ill-thrift and wasting, gastroenteritis or pneumonia during the first 12-18 months of life due to virus-induced immunosuppression. Cattle exposed postnatally and undergoing a transient pestivirus infection are more susceptible to other diseases, especially under intensive conditions such as feedlots, but often only develop mild flu-like symptoms with low mortality rates. Once recovered, infected animals develop a long lasting immunity to the disease. Pestivirus is believed to be spread almost exclusively by PI animals who shed extreme amounts of virus for their entire lives, with some animals not displaying any clinical signs of ill-health and entering the breeding herd undetected.

A killed vaccine against BVDV is available in Australia with efficacy of ca. 80% (GHD Pty Ltd *et al.* 2015). The vaccine requires 2 initial injections and may be recommended for annual use in some herds. Other strategies to control infection include control and eradication through identifying immune animals and PIs via diagnostic testing.

GHD Pty Ltd *et al.* (2015) report the results of modelling that uses an understanding of BVDV epidemiology in Australia and the known incidence of PI animals to suggest that, depending on the relative prevalence of BVDV strains with varying abortigenic effect, weaning rate is conservatively estimated to be lower by between 1% and 4.5% as a result of between 3% and 7% of cows being infected in early pregnancy each year.

McGowan *et al*. (2014) reported that 15-21%, 39-50% and 35-40% of north Australian cow herds had prevalence of cows sero-positive to BVDV of <20%, 20-80% and >80%, respectively; recent infection was found in 4-16% of cow herds. St George *et al*. (1967) had previously reported that 61% of Australian cattle were seropositive and 79% of herds infected, indicating little change in prevalence in 45 years. In line with the finding of McGowan *et al.* (2014), both Kirkland *et al*. (2012) and Morton *et al*. (2013) reported a low proportion of cattle herds having recent BVDV infection. Both the latter research groups reported that half the herds they studied had 0-30% sero-positive animals, indicating high susceptibility to the virus. The timing and impact of a pestivirus infection on any herd is difficult to predict.

A herd that does not have BVDV would be at risk of it rapidly spreading through susceptible cattle. The impact of any disease outbreak depends upon the frequency of the infection, the level of impact and the proportion of the herd impacted. Estimates of potential loss associated with a rapid infection of pestivirus in a naive herd have been placed at a 10-50% reduction in the herd weaning rate in the year of occurrence with an expectation that it would be many years before a similar crash could be expected to reoccur (M. Sullivan, pers. comm.).

Once a heifer or cow has been exposed to pestivirus and developed immunity, future pregnancies will not be affected even if she is re-exposed to the virus later on. On a limited survey carried out on thirteen properties in the NT, it was found that 63% of animals had been infected with BVDV by the time they were 3 years old (Schatz *et al.* 2008). In some areas, around Alice Springs and the Sturt Plateau, it was found that 90%+ of the heifers had been infected with the virus before they were 2 years of age and thus vaccination against BVDV would be unnecessary in these mobs. However, in herds with high numbers of non-immune animals, the introduction of bovine pestivirus can result in massive losses through abortion storms, where a high proportion of breeding cows will abort their pregnancies.

1.2.4.2.4 Improving reproductive performance with inorganic supplements

Low levels of strategic, inorganic, supplements such as phosphorus (P) and non-protein N (urea) constitute one of the few 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).

Phosphorus deficiency occurs in cattle grazing many rangeland regions of northern Australia due to low soil P, and may severely reduce cattle growth and breeder productivity (Winks 1990; McCosker and Winks 1994). Phosphorus deficiency results in poor appetite and feed intake, poor growth, high breeder mortality, reduced fertility and milk production, bone breakage and, in severe cases, bone deformities. In addition to such poor performance there is an increased risk of deaths from botulism when cattle chew bones in their craving for the mineral. Feeding a P supplement to P-deficient cattle will increase feed consumption by 10–60%, growth rates of young stock by 30-40 kg/year and weaning rates by 10-30% (Jackson *et al.* 2012). The biological response to P supplements is related to soil P status (Table 5). Maps showing the P status of land in the Fitzroy NRM area of central

Queensland indicate that most grazing lands fall in to the ‘adequate’ or ‘marginal’ categories, with smaller areas identified as ‘deficient’ or ‘acute’ (McCosker and Winks 1994).

Past research from the 1970’s to the 1990’s concluded that P supplementation is most effective when fed during the wet 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, in the 1990’s, of evidence to the contrary 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 wet season and not the dry season 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 a*l. 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.

Dry season supplementation programs generally involve fewer practical and logistical difficulties than feeding supplements during the wet season when access to paddocks 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. During the dry season in northern Australia the N content of grazed pastures is also generally limiting for optimal production of cattle, and the N deficiencies are likely to be more severe on less fertile country types which are also those most likely to be deficient in P. Urea-based (non-protein N) supplements fed during the dry season have been shown to substantially reduce breeder liveweight loss and increase fertility during severe dry seasons (Dixon 1998). 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).

Table 5 – Definition of categories of phosphorus (P) deficiency in terms of soil P (ppm) from 1) McCosker and Winks (1994), 2) Jackson et al. (2012) and 3) a modified definition adopted in this report

Category of P deficiency	**Soil P (ppm)**		
	McCosker and Winks (1994) definition	**Jackson *et al.* (2012) definition**	**Modified ranges – adopted in this report**
Very severely deficient (e.g. South Africa)	-	-	</=2
Acute	<2	<4	2-3
Deficient	3-5	5	4-5
Marginal	6-8	6-8	6-8
Adequate	>8	-	>8

1.2.4.2.5 Supplementing first calf heifers to improve re-conception rates

Energy and protein supplements for first calf heifers are often are often recommended as best management practice to increase re-conception rates (Dixon 1998; DAF 2018). Recent research by Schatz (2010) investigated whether pre-partum supplementation during the dry season with a suitable supplement could reliably increase re-conception rates in first-lactation heifers in the Victoria River District (VRD) of the Northern Territory. Schatz (2010) concluded that feeding pre-partum protein supplements for a period of at least 100 days until green grass is available at the start of the wet season is a reliable method of changing re-conception rates in first-lactation heifers in the VRD. Although the trial groups achieved a 42% improvement in re-conception rates, analysis of the trial data identified that the predicted pregnancy rate changed by between 4- 4.6% (average 4.4%), for each 10 kg change in the pre-calving weight corrected for stage of pregnancy, for heifers with pre-calving body weights between about 380 and 460 kg.

1.2.4.3 Marketing options

1.2.4.3.1 Organic beef

The organic beef market is a premium market for beef ‘certified organic’ through being produced according to standards administered by the Australian Department of Agriculture. These include the requirement that beef be produced without use of synthetic chemicals and fertilisers, antibiotics or growth promoting hormones and with an emphasis on animal welfare, sustainability and the environment. Australian organic beef sales grew by 127% from 2011 to 2014 with a total value of $198 million in 2014 (OAMR 2014). Exports of organic beef continued to grow in 2017 with organic red meant considered to be in undersupply (OAMR 2017). The certified organic beef market offers higher premiums but at the expense of a higher cost of production and potentially lower productivity per hectare dependent on location (Wynen 2006; Will 2015). Whether organic beef will be a profitable enterprise for an individual producer will depend on product premiums (quoted as ca. 25% in 2015; Will (2015)), total production and any change in input prices (Wynen 2006). As for other specialised markets, sound business management skills are required by producers to capitalise on the opportunities.

1.2.4.3.2 EU market

The European Union (EU) beef market offers a reliable, high-value opportunity for Australian beef, despite access to the market traditionally being restricted due to tariffs and quotas. Cattle production in the EU is declining, whilst consumption has remained steady, causing a growing beef supply deficit that has been forecast to approach one million tonnes by 2020 (MLA 2016). Despite limited access to the EU market due to low volume tariff rate quotas, the EU is Australia’s highest value export market on a per tonne basis, reaching $13,430/t in 2016 (MLA 2016). To be eligible for the EU market, beef must meet the market's requirements around traceability and HGP-free status (Bowen *et al.* 2015*a*). Carcasses must also meet specifications for weight, fat depth and colour, dentition and muscle score.

Beef destined for the EU must have been supplied through an EU accredited supply chain, including producers, feedlots and saleyards. The European Union Cattle Accreditation Scheme (EUCAS) requires individual animal trace back capability on all animals slaughtered for the EU market. Producers wanting to supply the EU market must have their properties accredited under the EUCAS. The Australian Quarantine and Inspection Service (AQIS) administers EUCAS. This is a voluntary scheme and there is no application fee.

EUCAS requires accredited farms to:

- have only eligible cattle on their property at all times; that is cattle that have lifetime traceability and have never been treated with HGPs (with the exception of breeding bulls and a small number of house cows);
- only purchase cattle from other accredited properties or saleyards (with the exception of approved non-EU breeding females and bulls);
- identify all cattle on the property with NLIS devices. For cattle born on the property this is to be done at the time of or before weaning (this requirement is different to state or territory National Livestock Identification Scheme (NLIS) requirements);
- use LPA European Union Vendor Declaration (EUVD) forms and specific Scheme transaction tail tags to identify Scheme cattle that are being moved;
- ensure their NLIS database account is kept up to date.

The terms of EUCAS accreditation are strict. With the exception of breeding bulls, only cattle that have never have been treated with HGPs in their lifetime are eligible to remain on a EUCAS property. Properties with a history of HGP use will have to remove any HGP treated cattle and demonstrate through records the disposal of HGP treated cattle and any unused HGP doses. Cattle with an unknown HGP status or that do not have lifetime traceability must be removed from the property. Accredited feedlots and accredited saleyards are allowed to have HGP treated cattle on the property; however, stringent EUCAS approved management plans must be in place to ensure these cattle are segregated from EUCAS cattle at all times. Once accredited, cattle must only be purchased from other accredited properties or through accredited saleyards, and these cattle must be accompanied by EUVDs.

Prices for cattle eligible for the EU market have consistently been above that for other markets but there is more work involved in meeting the stringent requirements.

1.2.4.3.3 Wagyu beef

The Wagyu is a Japanese beef cattle breed characterised by high marbling and eating quality attributes (AWA 2018). Australia has the highest fullblood Wagyu beef cattle population outside of Japan (Wagyu International 2018). However, Wagyu breeding and feeding in Australia is dominated by crossbreeding, with a small fullblood segment expanding from a tiny base (AWF 2018). The industry is growing rapidly due to historically high price premiums for Wagyu-infused cattle, although estimated to be only 1-2% of the total Australian cattle herd (AWF 2018).

The first cross of a Wagyu fullblood (100% Wagyu genetic content) over another breed is referred to as an F1. Further crossing of Wagyu is referred to as ‘breeding up’. A purebred Wagyu is achieved after at least four generations of crossbreeding using Wagyu fullblood sires and has greater than 93% Wagyu genetic content. No amount of crossbreeding can result in a fullblood Wagyu being produced as fullblood animals can only be produced from the mating of a 100% fullblood male Wagyu and a 100% fullblood female Wagyu (AWA 2018).

Most crossbred Wagyu cattle are sold to the feed-on market at ca. 340-400 kg liveweight where they are commonly fed for ca. 450 days. Around 80-90% of Wagyu-infused beef is sold to export markets with the remainder consumed domestically (AWA 2018). As most Wagyu-infused beef is produced for export in relatively long feedlot programs, the segment is historically vulnerable to both feed price and currency fluctuation.

1.2.5 Assessing the potential impact of drought on the herd as well as the effect of herd structure on drought risk and profitability

Another aspect of being prepared for drought is to assess the potential impact of drought on the components of the cattle herd. The weight loss associated with drought will affect different age classes as well as the lactating (hereafter 'wet') and non-lactating (hereafter 'dry') breeders differently and hence the proportion of these groups in the herd is an important factor to consider. The herd structure itself will also likely have effects on the capacity of the enterprise to respond to drought which will be related to the proportion of breeders in the herd. Assessing these aspects well prior to drought can enable adjustments to herd structure to be made that increase the drought resilience of the business.

1.2.6 Responding to, and recovering from, drought

The combination of drought and heavy utilisation of pasture by both domestic livestock and other herbivores (rabbits and macropods) has led to a series of historical degradation episodes in Australia's grazing lands manifested in the accelerated death of desirable perennial pasture species, soil surface erosion and delayed recovery from drought (McKeon *et al.* 2004). McKeon *et al.* (2004) state that the three major causes of degradation include:

1) over-utilisation of pasture by domestic and other herbivores in the pre-drought period resulting in damage to 'desirable' perennial pasture species;
2) extreme pasture utilisation in the first years of drought caused by retaining livestock (and continued presence of other herbivores) that result in loss of perennial pasture species and soil cover; and
3) continued retention of stock through a long drought period, compounding damage to the land resource and delaying pasture recovery.

Scientists and government departments have long emphasised the adoption of conservative stocking rates, and/or highly responsive stock management strategies to prevent degradation. Regardless, financial and economic pressures have historically, and will continue, to result in many graziers pushing their grazing land resources to the limits to maximise returns in the short to medium term (e.g. McKeon *et al.* 2004; Rolfe *et al.* 2016; Bowen and Chudleigh 2017). Knowledge and tools to assess relative short and longer-term profitability of various strategies that can be applied prior to, during, and after a drought would assist producers to evaluate various destocking options for relative profitability and risk and hence to make more informed decisions.

Graziers in western Queensland have recommended two key actions required to better manage droughts:

1) developing a strategic drought plan prior to a drought, and
2) participating in an 'after action review' process following a drought in which drought plans are reviewed and improved in readiness for subsequent droughts (Counsell and Houston 2017).

A key component of planning for, and then responding to and recovering from, drought is to have a clear understanding of the options or strategies available, the potential interactions between them and being able to assess the relative value of each at critical points in time. These strategies are often tactical in nature and are highly dependent on the individual circumstances specific to a beef business at a given point in time. Therefore, we propose that is more efficient to provide a knowledge of available strategies and their likely response functions, together with a framework within which individual managers can assess their options, rather than to provide ‘answers’. The premise is that providing both a better understanding of complex interactions, as well as a framework and tools to support appropriate decision making, should improve the outcomes and timeliness of decisions made by managers of grazing enterprises. In this report we have provided some examples of response options for the baseline, case-study herd.

In responding to drought in the Fitzroy region, the following key strategies are available to reduce grazing pressure and/or protect livestock capital:

- reducing grazing pressure and herd numbers by culling pregnant but dry females,
- reducing liveweight loss of breeders by early weaning,
- reducing grazing pressure and herd numbers by culling from within groups of remaining herd classes (cows, heifers and steers),
- drought feeding, or
- agistment.

Drought recovery strategies are often seen as the opposite of the response strategies but the choices made during the response phase will be somewhat decided by what is seen as the best recovery strategy and vice versa. The interactions between tactical decisions made in response to a drought and the more strategic decisions considered when recovering from drought are numerous and one set of decisions may rely entirely upon the other. This can apply whether the drought is broken by extended rainfall that recovers the carrying capacity of the property back to a more expected level or if the drought is just interrupted by a short lived, seasonal break.

2 Methods

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 representative beef cattle property in the Fitzroy region of Queensland using a combination of case-study method (Yin 1994) and scenario analysis. The levels of production associated with this baseline, case study 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 staff. An exhaustive approach, of conducting workshops, training events and discussions with skilled and experienced scientific and extension colleagues, has been applied over recent years 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 baseline property and for each scenario.

The Breedcow and Dynama programs (Version 6.02; Holmes *et al.* 2017) were applied to test the relative and absolute value of changing herd management strategy. In all cases, a change in the current 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 the existing beef production system. Hence the scenario analysis was undertaken as a marginal analysis, over a uniform investment period of 30 years.

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

- the current wealth of the beef property (net present value; NPV);
- 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 Breedcow and Dynama programs can be used to consider changes in management strategies such as different ways of financing the beef property or the impact of different levels of equity on farm risk, these other equally critical aspects of managing a beef property were not considered here.

Components of the Breedcow and Dynama suite of programs were applied in an integrated manner during the model building process. Initially Breedcowplus was used to identify the herd target, optimal herd structure and the most profitable age of sale for steers and age of culling for heifers and cows. 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 in the northern beef industry 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 a) optimal or current herd structures for the start of each scenario, and b) 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 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 marginal difference between the two Dynamaplus models was identified with the Investan program (also within the Breedcow and Dynama 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 and the analysis undertaken at the property level. Additional detail and description of the Breedcow and Dynama suite of programs is provided by Holmes *et al*. (2017).

In summary, for each scenario, the regionally-relevant herd was applied in the Breedcow and Dynama suite of programs to determine the expected and alternative whole-of-business productivity and profitability over a 30-year investment period. Change was implemented by altering the herd performance and inputs of the baseline 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 to look at the marginal returns associated with any additional capital or resources invested within farm operations. The DCF analysis was compiled in real (constant value) terms, with all variables expressed in terms of the price level of the current year (2018). It was assumed that future inflation would affect all costs and benefits even-handedly.

The discounted cash flow analysis was calculated at the level of operating profit which, in turn, was calculated as: *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 reward to all of the capital managed by the business. 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 a fixed cost. Our definition of an operators 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 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 to extend their impact past 30 years in the form of an increase in closing land value.

The examination of short-term, tactical strategies that can be applied in the response or recovery phases of drought were also analysed using a farm management economics framework (Malcolm 2000). These analyses were conducted with reference to Breedcow baseline herd model and with use of the ‘Cowtrade’, ‘Bullocks’ and ‘Splitsal’ programs from within the Breedcow and Dynama suite where applicable (Version 6.02; Holmes *et al.* 2017). The Cowtrade program was used to calculate the relative profitability of breeder groups while the Bullocks programs was used to calculate the relative profitability for groups of steers and empty cows or heifers. The Splitsal program was used to estimate potential weight distributions and averages for groups within the herd.

The Breedcow and Dynama herd models can be downloaded free from: https://www.daf.qld.gov.au/animal-industries/beef/breedcow-and-dynama-software. The 30 year version of the models applied in this analysis are available from the authors of the report.

2.2 Criterion used to compare the strategies

The economic criterion were net present value (NPV) at the required rate of return (5%; taken as the real opportunity cost of funds to the producer) and the internal rate of return (IRR). NPV was calculated as the net returns (operating profit as adjusted) over the life of the investment, expressed in present day terms. 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). The NPV was amortised at a 5% discount rate over the life of the investment to identify the annual average improvement in profit generated by the implementation of the alternative growth path. An amortised NPV was calculated at the discount rate over the investment period to assist in communicating the difference between the baseline case-study property and the property after the management strategy was implemented. This measure is not the same as the annual difference in operating profit between the two strategies but is automatically calculated in the Investan program and is therefore already presented to users of the program as a metric.

The financial criterion were peak deficit, the number of years to the peak deficit, and the payback period in years. The beef enterprise started with no debt but 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 continues into the investment period. The payback period was calculated as the number of years taken for the cumulative present value to become positive.

For tactical strategies, the break-even point of alternative courses of action was usually the key decision criteria. However, alternatives were also considered on the basis of least cost and the lowest impact on the future productivity of the herd.

2.3 Representative case-study, beef cattle enterprise

2.3.1 The beef enterprise

The property and herd characteristics were informed by recent industry surveys and research relevant to the region (McGowan *et al.* 2014; Bowen *et al.* 2015*b*; Barbi *et al.* 2016). The case-study property was located centrally in the Fitzroy NRM region and considered to be a total area of 8,700 ha and to consist of a mixture of native and sown grass pastures, giving an assumed carrying capacity of 1,500 AE considered to be appropriate long term carrying capacity designed to maintain land condition in non-drought years. The baseline activity was a self-replacing breeding and growing activity that relied on the production of weaners by a breeding herd. Weaner steers entered a growing system that varied in size with the period of time steers were retained prior to sale. Heifers were used to maintain the breeding herd or were culled and sold. Breeding cows were culled on reproductive performance and age. Herd bulls were retained in the breeding herd for an average of 5 years. The target was to sell feed on steers through the sale yards, surplus heifers and cull cows to the abattoirs.

The self-replacing *Bos indicus* crossbred breeding herd generally grazed less productive, non-arable land types. Replacement heifers were separated from the breeding herd until they were first mated at about 2 years of age. *B. indicus* crossbred steers mostly grazed more productive and arable Brigalow land types supporting sown, buffel grass pastures, until they were sold to the feed-on (feedlot entry) market (470 kg at the feedlot) which was identified as the most profitable market target by Bowen and Chudleigh (2017). Feed-on steers were required to reach 495 kg liveweight in the paddock prior to sale to allow for an assumed loss of 5% liveweight during transit to the feedlot.

2.3.2 Reproduction, mortality and culling parameters and resulting herd structure

Reproduction, mortality and culling parameters were informed by Henderson *et al.* (2012), McGowan *et al.* (2014) and Chudleigh *et al.* (2017). Data to describe the reproduction efficiency of the breeder herd was based on the data collected by the CashCow project (McGowan *et al.* 2014). The median reproductive performance values for the CashCow project country type termed 'Central Forest' are summarised in Table 6. This data set was seen as being closest to the expected median performance of a beef breeding herd in the Fitzroy catchment.

Table 6 - Median reproduction performance for 'Central Forest' data (McGowan et al. 2014)

Reproduction performance indicator	Heifers	First lactation cows	2nd lactation cows	Mature	Aged	Overall
P4M*		49%	64%	77%	71%	68%
Annual pregnancy**	80%	78%		89%	86%	85%
Foetal / calf loss	10.20%	7.30%		5.90%	4.90%	6.70%
Contributed a weaner^	67%	71%		80%	86%	77%
Pregnant missing#		11.80%		6.60%	6.30%	7.90%

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

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

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

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

Table 7 shows the level of reproductive performance of each class of females required to achieve an average weaning rate of 77% for all cows mated in the Breedcowplus model. The values retained produced a weaning rate equivalent to CashCow's 'contributed a weaner' figure of 77% while maintaining a strong relationship to the annual pregnancy (conception), calf loss and missing data provided by the CashCow project. Heifers were first mated at 2 years of age.

Table 7 - Calving rate and death rate assumptions

Cattle age year start **Cattle age year end**	**Weaners** **1**	**1** **2**	**2** **3**	**3** **4**	**4** **5**	**5** **6**	**6** **7**	**7** **8**	**8** **9**
Expected conception (%)	n/a	0	80	78	87	87	87	87	84
Expected calf loss from conception to weaning (%)	n/a	0	10	7	6	6	6	6	5
Proportion of empties (PTE) sold (%)	n/a	0	100	100	100	100	100	100	100
Proportion of females sold (%)	n/a	0	0	0	0	0	0	0	0
Calves weaned/cows retained (%)	n/a	0	90	93	94	94	94	94	95
Female death rate (%)	3	3	5	4.	4	4	4	4	5.5
Spayed or unmated female death rate (%)	4	4	6	5	5	5	5	5	6.5
Male death rate (%)	4	4	4	4	n/a	n/a	n/a	n/a	n/a

n/a: not applicable.
PTE, pregnancy tested 'empty'.

The culling strategy for the baseline herd removed cows that did not show as pregnant after mating or after they had produced a calf at 12-13 years old. The mortality rates are based on the CashCow project data for missing pregnant females and also reflect the mortality data analysed by Henderson *et al.* (2012) for the northern beef industry. Although data from Henderson *et al.* (2012) was not collected from the Fitzroy NRM region, the mortality rates applied in the Breedcowplus herd model are a seen as a balance between the CashCow estimates of missing pregnant females and the values identified by Henderson *et al*. (2012) for steers and breeding females and contribute to achieving the median reproduction performance identified by the CashCow project.

The compiled herd model resulted in average breeder mortality rates of 4.53% and a weaning rate of 77.6% (weaners from all cows mated). The property produced about 500 weaners from the 642 females mated and sold 444 head per annum. Cull female sales made up 48% of total sales. The average herd structure of the baseline beef cattle enterprise is given in Table 8.

Table 8 - Herd structure (on average)

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	174
Weaners 5 months	498	0	0.26	0.07	129
Heifers 1 year but less than 2	242	0	0.70	0.33	168
Heifers 2 years but less than 3	115	119	1.07	0.52	185
Cows 3 years plus	419	91	1.21	0.69	570
Steers 1 year but less than 2	239	0	0.73	0.34	174
Steers 2 years but less than 3	0	230	1.13	0.25	58
Bulls all ages	22	4	1.65	0.96	41
Total number.	*1,537*	*444*	-	-	*1,500*

AE, Adult equivalent. A 2.25 year old, 450 kg steer at maintenance.
n/a, not applicable.

2.3.3 Steer and heifer growth assumptions

The pattern of growth over time for steers and heifer underpins the markets available for both steers and surplus heifers and the likely mating age and reproduction performance of the heifers as they enter the breeding herd. Table 9 shows the expected “average” birthdate and weaning date plus the pre-weaning performance of the steers and heifers on the breeding and finishing property.

Table 9 - Birthdate, weaning and pre weaning performance

Parameter	**Value**	**Units**
Average calving date	15/11/2017	
Average weaning date	17/05/2018	
Age at weaning	6.0	months
Days to weaning	183	days
Birth weight	35	kg
Male calf average daily gain birth to weaning	0.9	kg/day
Reduction in growth rate of heifers compared to steers	5	%
Heifer average daily gain birth to weaning	0.86	kg/day

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 pre-weaning growth rates for female calves were set at 5% lower than male calves, the same as the post-weaning growth rate difference between steers and heifers. This only applied to the baseline herd model as the relationship between steer and heifer growth rates changed with the implementation of the alternative management strategies.

Table 10 indicates the expected post weaning seasonal performance for steers. Seasonal steer growth rates for buffel grass pasture were assigned with reference to available measured data for diet dry matter digestibility (DMD), seasonal rainfall data and liveweight gain (QDPI 2003; Bowen *et al.* 2010; Bowen *et al.* 2015*a*,*b*). Steers were assumed to gain weight at about 0.49 kg/head.day on buffel grass pastures to achieve 180 kg/head.annum post weaning and heifers to gain ca. 0.47 kg/head.day to achieve 171 kg/head.annum post weaning. Table 11 shows the expected month by month growth pattern for steers on buffel grass. Expected liveweight at birth, weaning and birthdays are highlighted (orange, green and orange, respectively). The baseline sale weight target for steers is highlighted in red. Figure 5 shows the estimated average growth path for steers and heifers grazing buffel grass pastures with similar levels of productivity. Steers were assumed to grow at a rate 5% greater than heifers at the same level of nutrition.

Table 10 - Expected post weaning steer growth rates for the baseline scenario

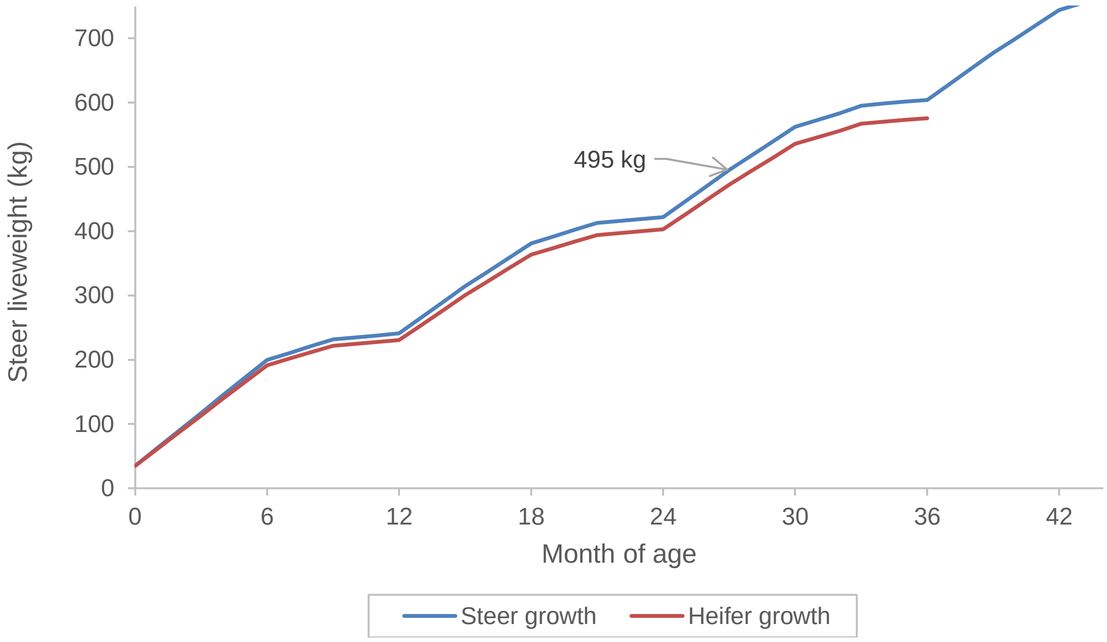
Season	**Days**	**Daily liveweight gain (kg/d)**	**Total liveweight gain (kg)**
Summer (D-J-F)	90	0.80	72
Autumn (M-A-M)	92	0.73	67
Winter (J-J-A)	92	0.35	32
Spring (S-O-N)	91	0.10	9
Average/Annual	*365*	*0.49*	*180*

Table 11 - Expected growth of steers for the baseline scenario

Date	**Daily gain (kg/d)**	**Age (months)**	**Liveweight (kg)**
15/11/17	0	0	35
15/12/17	0.90	1	62
15/01/18	0.90	2	90
14/02/18	0.90	3	117
17/03/18	0.90	4	145
16/04/18	0.90	5	172
17/05/18	0.9	6	200
16/06/18	0.35	7	210
17/07/18	0.35	8	221
16/08/18	0.35	9	232
16/09/18	0.1	10	235
16/10/18	0.1	11	238
16/11/18	0.1	12	241
16/12/18	0.8	13	265
16/01/19	0.8	14	290
15/02/19	0.8	15	314
18/03/19	0.73	16	336
17/04/19	0.73	17	359
18/05/19	0.73	18	381
17/06/19	0.35	19	392
18/07/19	0.35	20	402
17/08/19	0.35	21	413
17/09/19	0.1	22	416
17/10/19	0.1	23	419
17/11/19	0.1	24	422
17/12/19	0.8	25	446
17/01/20	0.8	26	471
16/02/20	0.8	27	495

Figure 5 - Estimated steer and heifer growth paths

Steer sale target weight of 495 kg in the paddock is shown



2.3.4 Cattle prices

It was assumed that 100% of steers were sold at less than 30 months old at ca. 495 kg liveweight as this target market of feed-on steers has been identified as the most profitable target market for the central Queensland region (Bowen and Chudleigh 2017). Detailed price data over time is available for the Roma stock selling centre (ca. 350 km from the property) and Dinmore abattoirs (ca. 650 km from the property). As both of these selling centres are considered relevant indicators of market prices for beef producers in the region, these two selling centres were used to calculate net sale values.

Figure 6 shows the relationship between the prices of medium sized store steers at Roma and grass fed Jap Ox at Dinmore since mid-2009. Prices for most classes of cattle have risen dramatically over recent times. Roma store sale data were used to estimate the values of store stock classes and Dinmore prices were used to estimate slaughter prices. Selling costs relate to the selected selling centre. Table 12 shows average price data (July 2008 – November 2015) for a range of slaughter stock at Dinmore abattoirs. Table 13 indicates the price variation for sale weights for steers and heifers at the Roma store sale between 2008 and 2015.

Figure 6 - Steer prices over time from 2009 to 2016

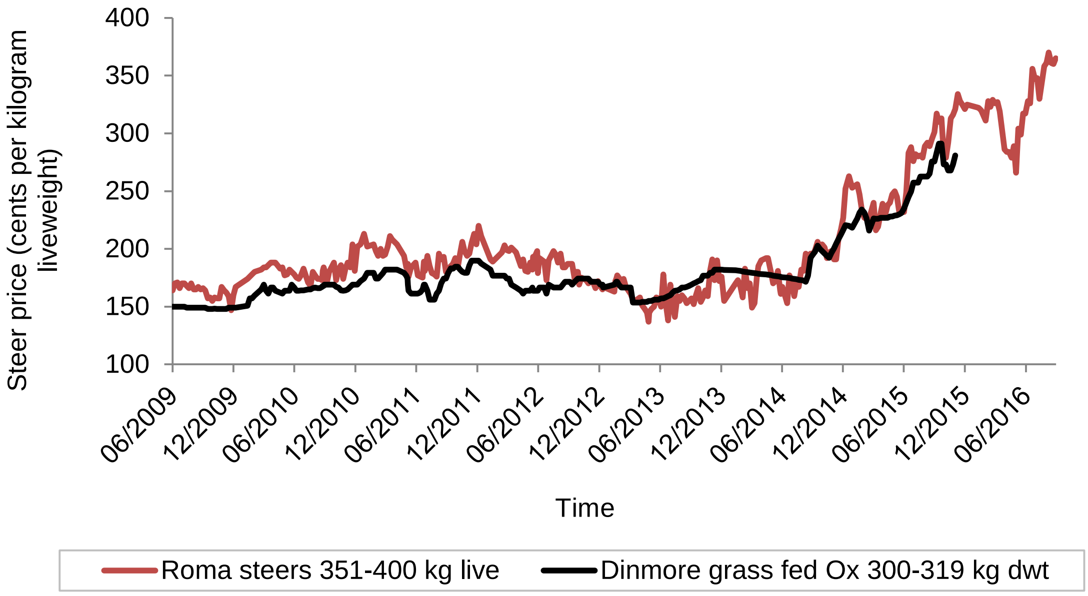


Table 12 - Price ranges for Dinmore abattoir (July 2008 – November 2015)

Parameter	**Grass Fed Jap Ox**	**Grass Fed Jap Heifer**	**Cow**	**Bull**
Grade	J	I1	L/M/M9	Q
Weight (kg)	300-319	200-219	220-239	320-499
Teeth	0-6	0-4	8	0-8
Fat (mm)	5-22	5-22	3-12	0-32
$/kg dressed weight				
Mean	$3.59	$3.29	$3.22	$3.18
Median	$3.30	$3.00	$2.92	$2.95
Max	$5.60	$5.35	$5.30	$5.10
Min	$2.85	$2.45	$2.35	$2.25
Dressing %	52%	52%	50%	52%
$ / kg live equivalent	$1.87	$1.71	$1.61	$1.65

Table 13 - Price ranges at Roma sale yards (July 2008- November 2015) expressed as cents per kilograms liveweight

Parameter	**Liveweight range (kg)**					
	Steers					**Heifers**
	<220	**221-280**	**281-350**	**351-400**	**401-550**	**281-350**
Mean	205	204	196	190	189	169
Median	199	197	189	181	178	164
Max	370	355	341	334	320	316
Min	136	142	136	137	137	106

The average of the values (July 2008-November 2015) were applied to reflect the expected real average for prices into the future, therefore they are taken to represent the real value of prices in 2018. Not all of the recent price spike was included in the average as its long term effect on prices is unknown. Table 14 shows the price data and selling costs for each class of stock retained in the herd models. An allowance for 5% weight loss was made between the paddock weights and the sale weights. The expected selling costs of each class of stock varied due to whether they were sold in Roma or at Dinmore. Freight costs for steers were calculated as described in Bowen *et al.* (2015*b*).

Table 14 - Prices worksheet showing selling costs, gross and net prices

Group Description	Paddock weight (kg/head)	Weight loss to sale (%)	Sale weight (kg/head)	Price ($/kg)	Commission (% of value)	Other selling costs ($/head)	Freight ($/head)
Heifers 1 year	364	5	346	$1.69	4.00	$17.00	$22.56
Heifers 2 years	536	5	509	$1.61	0.00	$5.00	$53.70
Cows 3 years plus	520	5	494	$1.61	0.00	$5.00	$53.70
Steer weaners 5-11 months	190	5	181	$2.04	4.00	$17.00	$18.05
Steers 1 year	381	5	362	$1.96	4.00	$17.00	$24.07
Steers 2 years	495	5	470	$1.87	4.00	$17.00	$29.71
Cull bulls	750	5	713	$1.65	0.00	$5.00	$77.19

2.3.5 Husbandry costs and treatments

Table 15 shows the husbandry costs and treatments applied to the various classes of cattle held for 12 months in the breeder herd model. Sale stock may or may not have received the treatment depending upon the timing of sale. Steers grazing leucaena were dosed with leucaena inoculum at a cost of $2.80 per head.

Table 15 - Treatments applied and cost per head

Treatment	Weaners	Females 1-2 years	Females 2-3 years	Females 3+ years	Steers	Bulls
Weaner feed	$15					
NLIS tag	$3.5	$0.20	$0.20	$0.20	$0.20	$0.20
5 in 1 calves	$0.80					
Leptospirosis vaccine breeders		$2.34	$1.17	$1.17		
Tick treatment	$4	$6	$10	$10	$6-$10	$10
Vibrio vaccine bulls						$10
Drought feeding (1 year in 7)		$5	$6	$7.5		$10
Pregnancy testing		$5	$5	$5		

2.3.6 Herd gross margin

The combination of reproductive efficiency, mortality rates, growth rates, treatment costs and selling costs provided the herd gross margin shown in Table 16. For a change to management to be considered it must not substantially increase the exposure of the property to production or financial risk and must also improve profitability.

Table 16 –Herd gross margin for the baseline, case-study property

Parameter	$
Net cattle sales	$344,438
Husbandry costs	$31,992
Net bull replacement	$18,548
Gross margin	$293,898

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

2.3.7 Operating expenses and asset value

The additional information required to complete an investment analysis includes fixed or operating expenses and capital expenditure incurred together with the opening 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 17 indicates the expected fixed cash costs for the property. Non-cash fixed costs include depreciation and, sometimes part or all of, the operators allowance, which will be identified later.

Table 17 - Fixed cash costs for the baseline property

Item	Cost
Accountant	$5,000
Administration	$2,000
Bank charges other than interest	$500
Blade ploughing	$10,000
Casual labour	$0
Electricity - farm	$5,000
Farm rates	$9,500
Fuel and oil	$25,000
Insurance - farm	$4,500
Motor vehicle expenses	$3,000
Plant repairs	$14,675
Property repairs	$5,125
Telephone – farm	$1,278
Total	*$85,578*

Table 18 shows the plant inventory for the baseline beef enterprise and the calculation of depreciation. It should be noted that this depreciation allowance is not the one found in the tax returns of the enterprise. The depreciation allowance calculated here is used as a cost in the calculation of the annual operating profit (not reported in this analysis) and it is therefore related to the economic life rather than the depreciation life of the item for taxation purposes. The allowance calculated in Table 18 essentially allows for the annual use and fall in value of assets that have a life of more than one production period. It is not a cash cost but is an allowance that is deducted from gross revenue each year so that all of the costs of producing an output in that year are set against all of the revenues produced in that year to estimate the operating profit of the enterprise.

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 minus salvage value’ divided by the ‘remaining life in years’. 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 18. The estimate of depreciation is not applied in the DCF analysis as that would double count the cost of the plant to the property

Table 18 - Plant inventory and depreciation allowance

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

The allowance for operators labour and management was set at $80,000. The value of the land and fixed improvements for the example property was taken to be $5,872,500. This resulted in an opening value of the total value of land, plant and improvements for the beef enterprise investment of $6,075,740. The investment analysis identified that the baseline beef property returned an IRR of 1.2% on the capital invested over the investment period. No allowance for any potential change in the real value of the land asset was included. Although some of the things that impact the underlying value of the land asset are outside the influence of the manager, it must be remembered investments that increase (or decrease) the capital value of the property or other assets will be captured by the DCF analysis equally as well as investments that only seek to increase cash flow, hence allowing them to be compared. The expected annual value of outcomes for the baseline property is shown in Table 19.

Table 19 - Expected annual value of outcomes for the property

Parameter	**Value**
Adult equivalents	1497
Cash flow for debt service	$128,942
Return on total non-cash assets	$109,704
Percentage return on total non-cash assets	1.53%

2.4 Alternative management strategies

2.4.1 Strategies available to prepare for drought by improving profit and business resilience

2.4.1.1 Improving steer growth rates

2.4.1.1.1 Improving steer growth path performance with leucaena

The strategy considered was the establishment of a sufficient area of leucaena-grass pastures to provide grazing for all steers produced by the beef enterprise from weaning until reaching the feed-on target weight (495 kg liveweight in the paddock).

It was assumed that a buffel grass paddock, capable of being planted to leucaena, already existed in a ‘fenced and watered’ state. The expected development costs for leucaena are shown in Table 20. The pasture was developed on the basis of cultivating 5 m wide strips across the paddock on 10 m centres (i.e. alternating 5 m wide strips of grass and cultivation). Leucaena seed was planted in double rows in the center of the 5 m strips of cultivation. No grass seed was sown as it was assumed that the buffel grass pasture in the non-cultivated strips would readily spread into the adjacent cultivated strips.

Compared to sowing into a cultivated paddock previously used for cropping, additional expenses were incurred in this scenario to prepare an adequate seed bed as the paddock was being converted from buffel grass pasture. Different establishment costs may be incurred if converting from previously cultivated land to leucaena or if a different approach is taken. Different approaches to establishing leucaena may also impact the productivity of the pasture and that of the steers and require different assumptions to those we have made in this example. Contract rates were used for the fallow costs and planting the leucaena as the pasture only needs to be planted once in the 30-year investment period of the analysis.

Leucaena has a high requirement for soil phosphorus (P; Bowen *et al.* 2015*a*) but it was assumed that a soil test revealed a currently adequate state (ca. 15-20 mg/kg Colwell P in the top 10 cm of soil) and that no additional P was required to maintain the productivity of the leucaena over period of the investment. The leucaena was assumed to receive maintenance in the form of mechanical cutting at the end of each decade, costing $81.50/ha on each occasion.

Table 20 - Leucaena development costs using contract rates

Item or treatment	Rate of application	Cost / unit	Number of applications	% of area treated	Cost per hectare
Pre planting costs					
Chisel plough	1	$61.44	2	50	$61.44
Tyne cultivator	1	$36.91	2	50	$36.91
Linkage spray rig	1	$8.35	2	50	$8.35
Roundup CT	2 L/ha	$4.50	2	50	$9.00
Amicide 625	0.5 L/ha	$6.83	2	50	$3.42
Planting Costs					
Leucaena planter	1	$21.23	1	100	$21.23
Leucaena seed	2 kg/ha	$30.00	1	100	$60.00
Leucaena inoculant	1	$0.24	1	100	$0.24
Beetle bait	1	$7.00	1	100	$7.00
Linkage spray rig	1	$8.35	1	50	$4.18
Spinnaker	0.14 kg/ha	$255.00	1	50	$17.85
Roundup CT	1.5 L/ha	$4.50	1	50	$3.38
Post Planting Costs					
Linkage spray rig	1	$8.35	1	50	$4.18
Fusilade	1.5 L/ha	$69.27	1	50	$51.95
Total					*$289*

The development process for the leucaena-grass pasture is given in Table 21. Once fully established (by Year 4) the leucaena-grass pasture was grazed by the steers from weaning until they reached a feed-on target weight. From Year 5 the steers were expected to grow about 40% faster per annum than steers grazing the buffel pasture without leucaena.

Table 21 - Leucaena development process for buffel grass in the Fitzroy

Year 1	Year 2	Year 3	Year 4	Year 5
9 months fallow; plant after Christmas	year of sowing; no grazing	spell until end of the wet season then graze at 50% of stocking rate for fully established pasture	100% stocking rate; half extra weight gain per head anticipated from Year 5	full stocking rate; full weight gain

Table 22 indicates the assumed forage and steer growth parameters for buffel grass-only pastures and for leucaena-grass pastures planted in the same paddock. The GRASP pasture growth model (McKeon *et al.* 2000; Rickert *et al.* 2000) was used to simulate median pasture (assumed to be primarily buffel grass) biomass production for the location using 100 years of historical rainfall and climate data to June 2016. For buffel grass pastures assumed to be grown on Brigalow softwood scrub land type in A land condition (scale A-D; Quirk and McIvor 2003; DAF 2011) the median, long-term annual pasture biomass production was estimated as 5,100 kg dry matter (DM)/ha. The buffel grass pasture was assigned a pasture utilisation of 30% of annual pasture biomass growth, which is suggested as a safe level of pasture utilisation for this land type for long-term sustainability (Whish 2011) based on research for native pasture communities (Silcock *et al.* 2005; Orr *et al.* 2010; Orr and Phelps 2013; O'Reagain *et al.* 2014; Hall *et al.* 2017), and in the absence of any data for buffel grass utilisation rates in central Queensland Brigalow land types. Perennial grass biomass production in the leucaena-grass pasture was assumed to be the same as that for the grass-only pastures in A condition and with 30% utilisation (5,100 kg DM/ha.year), which is in line with comparative measured data on commercial properties in the central Queensland region (Bowen *et al.* 2015*b*). Edible leucaena biomass production was assumed to be 1,800 kg DM/ha.year with 85% of this utilised (consumed) by the grazing cattle (adapted from Dalzell *et al.* 2006; Elledge and Thornton 2012; Bowen *et al*. 2018*a*; and data obtained from DAF producer demonstration sites (S. Buck pers. comm.)). At these yields and utilisation levels, the resultant average proportion of leucaena forage in the diet of grazing steers would be about 0.50, which was the measured proportion for cattle on commercial properties in central Queensland (Bowen *et al.* 2018*a*).

Seasonal steer growth rates for buffel grass and leucaena-grass pastures were assigned with reference to available measured data for diet dry matter digestibility (DMD), seasonal rainfall data and liveweight gain (QDPI 2003; Bowen *et al.* 2010; Bowen *et al.* 2015*a*). Daily growth rates of steers grazing buffel grass pastures were assumed to be 0.80 kg/d over the summer period (December to February), 0.73 kg/d over autumn (March to May), 0.35 kg/d over winter (June to August), and 0.10 kg/d over spring (September to November). Daily growth rates of steers grazing leucaena-grass pastures were assumed to be: 1.1 kg/head over the summer period (December to February), 0.8 kg/head during early-mid autumn (March and April), and 0.5 kg/head during late autumn, winter and spring (May to November).

The carrying capacity of each pasture was calculated by multiplying the median annual pasture biomass production by the specified utilisation level and then dividing by the annual pasture consumption of a standard animal unit or AE. An AE was defined here in terms of the forage dry matter intake at the specified diet DMD, of a standard animal which was defined by McLean and Blakeley (2014) as a 2.25 year old, 450 kg *B. taurus* steer at maintenance, walking 7 km/day. The spreadsheet calculator, QuikIntake (McLennan and Poppi 2016), which is based on the Australian Feeding Standards (NRDR 2007) with some modifications for tropical feeding systems (McLennan 2014), was used to calculate daily cattle dry matter intakes for the specified pasture DMDs. Note that although the commonly quoted industry figures for stocking rates of leucaena-grass pastures are in the range of ca. 0.67 AE/ha (Bowen *et al*. 2015*a*), which are much less than our calculated carrying capacity, our carrying capacity method results in a stocking rate of growing animals which is in the range of the industry figure, i.e. 450 kg steers gaining 0.7 kg/day (cf. 0 kg/day) would be run at 0.74 animals/ha.

Table 22 – Assumed forage and steer growth parameters for buffel grass and leucaena-grass pastures grown in central Queensland

Biological parameter	Buffel grass	Leucaena-grass pasture	
		Edible leucaena[B]	Grass
Median, annual pasture biomass production (kg DM/ha)	5,100	1,800	5100
Utilisation of annual biomass growth (%)	30	85	30
Average, annual diet DMD of grazing cattle (%)	57	63	
Average, annual steer LWG (kg/head)	180	255	
Carrying capacity (AE/ha)[A]	0.47	1.10	

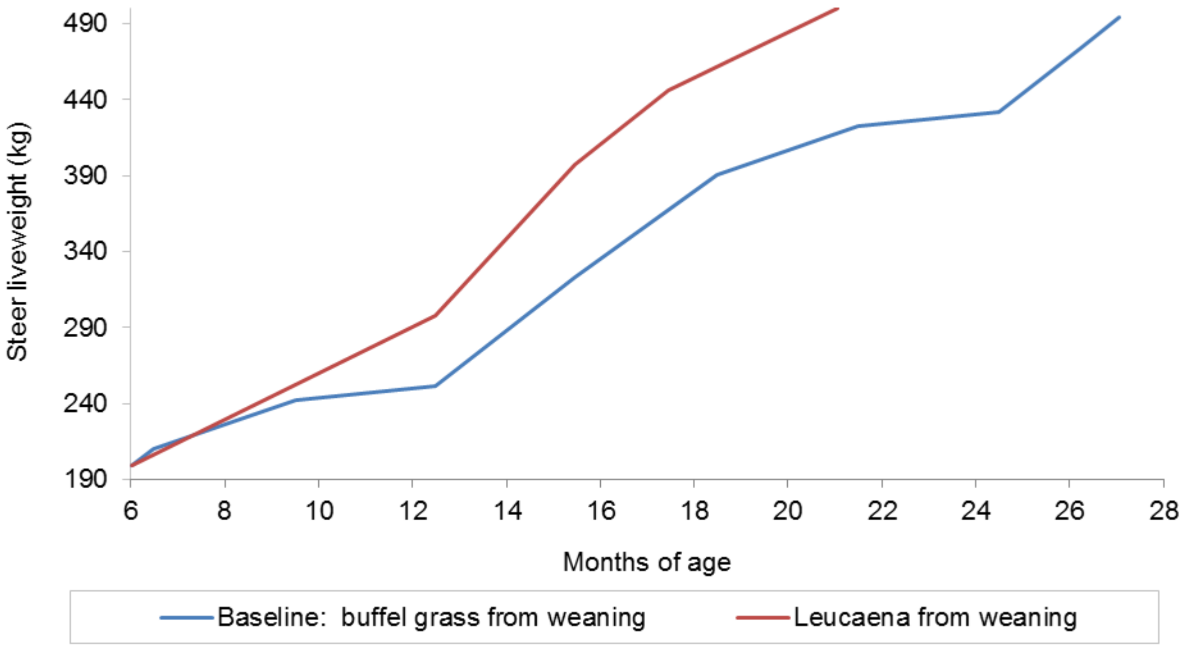
DM, dry matter; DMD, dry matter digestibility; LWG, liveweight gain.

[A] AE (adult equivalent); defined in terms of the forage intake of a 2.25 year old, 450 kg *Bos taurus* steer at maintenance, consuming a diet of the specified DMD and walking 7 km/day (McLean and Blakeley 2014).

[B] The edible leucaena component includes leaves and stems <5 mm in diameter.

Figure 7 shows the estimated average growth path for steers grazing either buffel grass or leucaena-grass pastures. Steers grazing leucaena-grass pastures reached the target sale weight about 6 months earlier than the buffel grass-only pasture.

Figure 7 – Estimated steer growth paths from weaning when grazing either buffel grass or leucaena-grass pastures



The stocking rate (and hence number of ha required) to run a steer from weaning until reaching feed-on sale weight, for either buffel grass pasture or leucaena-grass pasture was determined by calculating available pasture biomass for consumption per hectare (based on the specified forage utilisation rate for that scenario) and then dividing by the calculated steer intake of pasture dry matter over that period. For leucaena-grass pastures, the respective annual biomass production and utilisation levels of the buffel grass and edible leucaena components were summed to determine total biomass available. It was assumed that cattle consumed 50% of their diet DM as leucaena biomass, as per data from Bowen *et al.* (2018*a*). The pasture biomass available for consumption during a defined growth path was adjusted proportionally for days greater or less than the full annual period. As described previously for calculation of representative carrying capacity figures (AE/ha), the average DM intake by steers of each forage type within each growth path was estimated using the QuikIntake Excel spreadsheet calculator (McLennan and Poppi 2016) modified from the Australian ruminant feeding standards (NRDR 2007) to better predict intake for *B. indicus* content cattle and tropical diets (McLennan 2014). In the prediction of average DM intake, the average diet DMD of buffel grass or leucaena-grass forage for the relevant period was assigned based on data from Bowen *et al.* (2015*b*). The average liveweight of the cattle (i.e. liveweight at the mid-way point) and the assumed average daily gain over the relevant period were used as key inputs. The steers were assumed to be 50% *B. indicus*, to have a standard reference weight (SRW) of 660 kg, to walk 7 km/day (as per McLean and Blakely 2014) and the terrain to be 'level 1'.

Table 23 shows the assumed parameters used in the calculation of the area required to run a steer from weaning to feed-on sale weight on buffel grass and on an established leucaena-grass pasture. The higher DM production and the higher digestibility of the leucaena-grass pasture result in a lesser area of leucaena-grass pasture required. The steers grazing buffel pastures (to feed-on weight; ca. 495 kg) will need access to about 1,031 ha from weaning to sale at 27 months of age (239 head x 4.31 ha). If the same number of steers graze a paddock of leucaena-grass pasture from weaning to 21 months old it is expected that about 340 ha (239 head x 1.42 ha) would be required to run the same number of steers to the earlier point of sale. The steers will average ca. 501 kg at 21 months old at the end of this grazing period on leucaena-grass pastures.

If all of the yearling steers are grazed on leucaena-grass pastures this would free up about 690 ha of land to be grazed by other classes of stock in the breeding herd. If 2.1 hectares is allocated per AE, then the breeder herd component of the overall beef herd can expand in size by about 325 AE once the leucaena is fully established. Proportionally expanding the breeding herd and replacement heifers to graze this spare pasture allows the breeders to produce more weaner steers, increasing the area of leucaena required but also reducing the spare grass available for breeder herd expansion. An iterative process was used to approximately identify the relationship between the size of the breeder herd and the numbers of steers grazing the leucaena-grass pasture, which optimised the size of each. Table 24 and Table 25 show the change in herd structure enabled by the planting of leucaena-grass pastures in this example. A leucaena paddock of ca. 433 ha was required to provide an appropriate balance between an expanded breeder herd and suitably sized leucaena paddock for the steers. This paddock was planted at the start of the second year of the 30-year analysis period as per Table 21. The cost of preparing and planting the leucaena paddock (at contract rates) was $154,000.

Table 23 – Assumed parameters used in the calculation of the grazing area required for a steer from weaning to feed-on sale weight, for buffel grass and leucaena-grass pasture

Figures are the average or total for the entire grazing period

Parameter	**Buffel grass pasture**	**Leucaena-grass pasture**
Days on forage (post weaning)	640	457
Average LWG (kg/d)	0.46	0.66
Average age (years)	1.4	1.1
Average liveweight (kg)	347	350
Average DMD of diet (%)	57	63
DMI (kg/head.day)	10.3	9,533
Total biomass consumed per head (kg DM)	6,660	4,357
% of DM consumption as grass	100	50
% of DM consumption as leucaena	-	50
Total grass consumed per head (kg DM)	6,660	2,178
Total leucaena consumed per head (kg DM)	0	2,178
Utilisation of grass biomass growth (% of DM)	30	30
Utilisation edible leucaena biomass growth (% of DM)	-	85
Annual grass biomass production (kg DM/ha)	5,100	5,100
Annual edible leucaena biomass production (kg DM/ha)	-	1,800
Annual paddock biomass production (kg DM/ha)	5,100	6,900
Total grass yield for grazing days (kg DM/ha)	8,942	6,385
Total edible leucaena yield for grazing days (kg DM/ha)	-	2,254
Grass biomass available for consumption (kg DM/ha)	2,683	1,916
Edible leucaena biomass available for consumption (kg DM/ha)	-	1,916
Area required to meet steer demand for 1 year (ha)	2.46	1.14
Total area required for the grazing period (area adjusted for number of days > 365), (ha)	4.31	1.42

DM, dry matter; DMD, dry matter digestibility; DMI, dry matter intake; LWG, liveweight gain.

Table 24 - Change in herd AEs due to implementing leucaena-grass pastures for the steers

Age at start of rating period	**Baseline herd breeder component AEs (no leucaena)**	**Leucaena breeder component AEs**
Extra for cows weaning a calf	174	213
Weaners 5 months	129	158
Heifers 1 year but less than 2	168	206
Heifers 2 years but less than 3	185	227
Cows 3 years plus	570	696
Bulls all ages	41	50

Table 25 - Breeder herd components without the leucaena development and with the leucaena development once established

Breeder herd components	Baseline herd (no leucaena)	With leucaena
Total cows and heifers mated	642	785
Calves weaned	498	609
Weaner steers	249	304

The conversion from buffel grass pastures to leucaena grazing for all steers from weaning requires the breeder herd to increase in size (from 642 to 785 cows mated) to supply sufficient steers to graze the total area of leucaena planted. Table 26 shows that it takes about a decade for the new optimum herd size to be reached and about 12 years for the new level of sales to be achieved if additional heifers are held and the current cow culling strategy is slightly altered to build up the herd over time. Given that the leucaena can be fully stocked from Year 5 (Table 21), it is likely that the leucaena is not being fully utilised for about 5 years and that some of the potential benefit of the investment may be foregone. Therefore, to look at the impact (in investment returns) of the delay in fully stocking the leucaena, the effect of purchasing sufficient breeding cows and replacement heifers in the 4th year of the development to stock the leucaena fully with weaner steers from Year 5, was examined. The additional cows and heifers were purchased at the beginning of Year 4 and mated to produce calves in that year. The additional weaner steers went onto the leucaena in Year 5 and were sold in Year 6. The number of additional breeding stock purchased in order to fully stock the leucaena with steers from Year 5 was: 32 x 12-24 month old heifers, 38 x 3-4 year old cows, 50 mature cows, and one bull. The total landed purchase price for the cows, heifers and bull was $81,300.

Table 26 – Years taken to achieve the calf numbers required to fully stock the leucaena-grass pastures, with natural increase (i.e. no additional breeder purchase)

Herd Summary	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Total sales	655	432	446	513	530	532	555	555	555	554	555	555	555
Total new calves	522	541	557	609	609	609	609	609	609	609	609	609	609

2.4.1.1.2 Improving steer growth path performance with shrubby legumes such as desmanthus

The strategy considered was the establishment of a sufficient area of desmanthus-grass pastures to provide grazing for all steers produced by the beef enterprise from weaning until reaching the feed-on target weight (495 kg liveweight in the paddock). Desmanthus was considered as an example of a shrubby legume but Caatinga stylo would be expected to have similar planting requirements and result in similar animal performance. As there have been no grazing trials yet conducted to measure grazing animal performance on these legumes in central Queensland the pasture and animal performance was estimated in this analysis.

It was assumed that a buffel grass paddock, capable of being planted to desmanthus, already existed in a ‘fenced and watered’ state. The expected development costs for desmanthus are shown in Table 27. The pasture was developed on the basis of cultivating 5 m wide strips across the paddock on 10 m centres (i.e. alternating 5 m wide strips of grass and cultivation). Desmanthus seed was applied using a drum seeder within the 5 m, cultivated strips. No grass seed was sown as it was assumed that the buffel grass pasture in the non-cultivated strips would readily spread into the adjacent cultivated strips.

Compared to sowing into a cultivated paddock previously used for cropping, additional expenses were incurred in this scenario to prepare an adequate seed bed as the paddock was being converted from buffel grass pasture. Different establishment costs may be incurred if converting from previously cultivated land to desmanthus or if a different approach is taken. Contract rates were used for he fallow costs and planting of desmanthus as the pasture only needs to be planted once in the 30-year investment period of this analysis.

Desmanthus (and Caatinga stylo) have a lower requirement for soil P than leucaena (S. Buck, pers. comm.) and as it was assumed that a soil test revealed a currently adequate state (ca. 15-20 mg/kg Colwell P in the top 10 cm of soil) no additional P was considered necessary in this scenario to maintain productivity of the legume over time.

Table 27 - Desmanthus development costs in 5 m strips using contract rates

Item or treatment	**Rate of application**	**Cost / unit**	**Number of applications**	**% of area treated**	**Cost per hectare**
Pre planting costs					
Chisel plough	1	$61.44	2	50	$61.44
Tyne cultivator	1	$36.91	2	50	$36.91
Linkage spray rig	1	$8.35	2	50	$8.35
Roundup CT	2 L/ha	$4.50	2	50	$9.00
Amicide 625	0.5 L/ha	$6.83	2	50	$3.42
Planting Costs					
Drum Seeder	1	$20.89	1	50	$10.44
Legume seed	2 kg/ha	$28.00	1	50	$28.00
Rhizobia	1	$2.00	1	50	$1.00
Linkage spray rig	1	$8.35	2	50	$8.35
Spinnaker	0.14 kg/ha	$255.00	2	50	$35.70
Total					*$203.00*

The recommended development process for the desmanthus is given in Table 28 (G. Peck, pers. comm.). Once fully established (by Year 5) the legume pasture was grazed by the steers from weaning until they reached a feed-on target weight. From Year 5 the steers were expected to grow about 30% faster per annum than steers grazing the same buffel pasture without legume. Steer weight gains were adjusted in the herd model to allow for periods of spelling during the development phase.

Table 28 - Desmanthus development process for buffel grass in the Fitzroy

Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**
9 months fallow; plant after Christmas	year of sowing; stock at 50% of baseline, buffel grass pasture post July	stock at 75% of baseline pasture; 3 months spell to allow seeding	stock at 80% of baseline pasture; 2 months spell to allow seeding	full stocking rate; full weight gain

Table 29 indicates the assumed forage and steer growth parameters for buffel grass-only pastures and for desmanthus-grass pastures if planted in the same paddock. The GRASP pasture growth model (McKeon *et al.* 2000; Rickert *et al.* 2000) was used to simulate median pasture (assumed to be primarily buffel grass) biomass production for the location using 100 years of historical rainfall and climate data to June 2016. For buffel grass pastures assumed to be grown on Brigalow softwood scrub land type in A land condition (scale A-D; Quirk and McIvor 2003; DAF 2011) the median, long-term annual pasture biomass production was estimated as 5,100 kg dry matter (DM)/ha. The buffel grass pasture was assigned a pasture utilisation of 30% of annual pasture biomass growth, which is suggested as a safe level of pasture utilisation for this land type for long-term sustainability (Whish 2011) based on research for native pasture communities (Silcock *et al.* 2005; Orr *et al.* 2010; Orr and Phelps 2013; O'Reagain *et al.* 2014; Hall *et al.* 2017), and in the absence of any data for buffel grass utilisation rates in central Queensland Brigalow land types. Perennial grass biomass production in the desmanthus-grass pasture was assumed to be the same as that for the grass-only pastures in A condition and with 30% utilisation (5,100 kg DM/ha.year), which is in line with comparative measured data on commercial properties in the central Queensland region (Bowen *et al.* 2015*b*). Desmanthus biomass production was assumed to be 1,500 kg DM/ha.year with 45% of this utilised (consumed) by the grazing cattle. At these yields and utilisation levels, the resultant average proportion of desmanthus forage in the diet of grazing steers would be about 0.3.

Seasonal steer growth rates for buffel grass and desmanthus-grass pastures were assigned with reference to available measured data for diet dry matter digestibility (DMD), seasonal rainfall data and liveweight gain (QDPI 2003; Bowen *et al.* 2010; Bowen *et al.* 2015*a*). Daily growth rates of steers grazing buffel grass pastures were assumed to be 0.80 kg/d over the summer period (December to February), 0.73 kg/d over autumn (March to May), 0.35 kg/d over winter (June to August), and 0.10 kg/d over spring (September to November). Daily growth rates of steers grazing desmanthus-grass pastures were assumed to be: 1.0 kg/head over the summer period (December to February), 0.70 kg/head during early-mid autumn (March and April), 0.50 kg/head during late autumn, winter and early spring (May to September), and 0.43 kg/head during mid-late spring (October to November).

The carrying capacity of each pasture was calculated by multiplying the median annual pasture biomass production by the specified utilisation level and then dividing by the annual pasture consumption of a standard animal unit or 'adult equivalent' (AE). An adult equivalent was defined here in terms of the forage dry matter intake at the specified diet DMD, of a standard animal which was defined by McLean and Blakeley (2014) as a 2.25 year old, 450 kg *B. taurus* steer at maintenance, walking 7 km/day. The spreadsheet calculator, QuikIntake (McLennan and Poppi 2016), which is based on the Australian Feeding Standards (NRDR 2007) with some modifications for tropical feeding systems (McLennan 2014), was used to calculate daily cattle dry matter intakes for the specified pasture DMDs.

Table 29 – Assumed forage and steer growth parameters for buffel grass and desmanthus-grass pastures grown in central Queensland

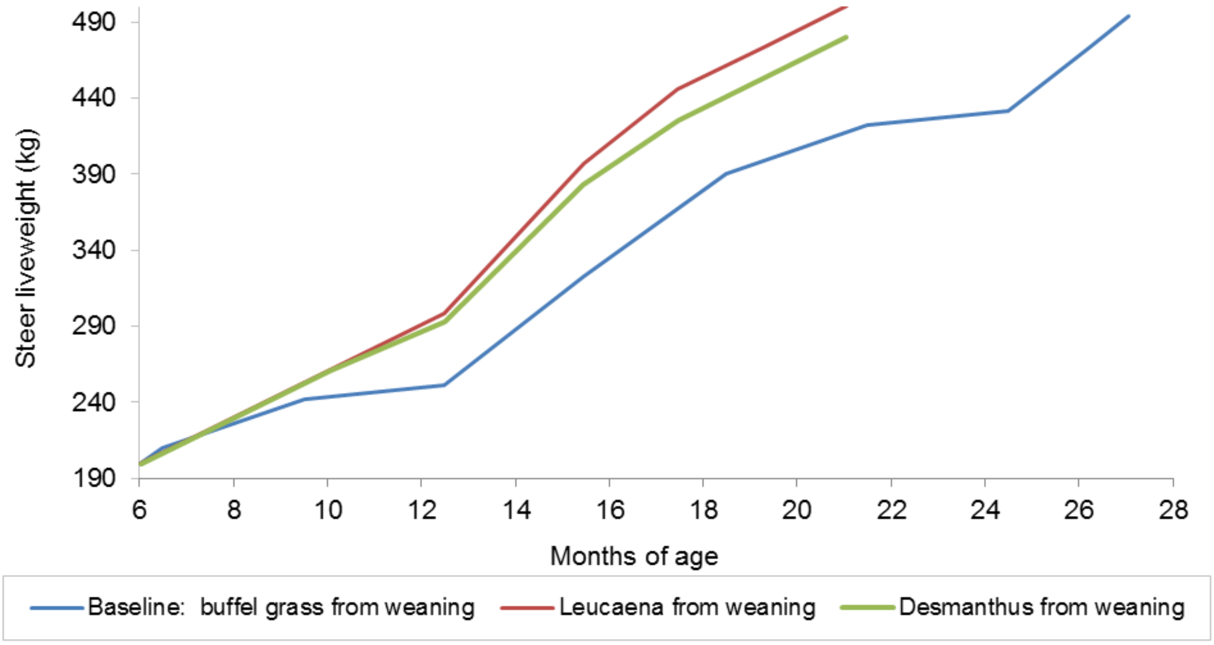
Biological parameter	Buffel grass	Desmanthus-grass pasture	
		Desmanthus	Grass
Median, annual pasture biomass production (kg DM/ha)	5,100	1500	5100
Utilisation of annual biomass growth (%)	30	45	30
Average, annual diet DMD of grazing cattle (%)	57	60	
Average, annual steer LWG (kg/head)	180	235	
Carrying capacity (AE/ha)[A]	0.47	0.74	

DM, dry matter; DMD, dry matter digestibility; LWG, liveweight gain.

[A] AE (adult equivalent); defined in terms of the forage intake of a 2.25 year old, 450 kg *Bos taurus* steer at maintenance, consuming a diet of the specified DMD and walking 7 km/day (McLean and Blakeley 2014).

Figure 8 shows the estimated average growth path for steers grazing either buffel grass, leucaena-grass or desmanthus-grass pastures. Steers grazing desmanthus-grass pastures reached the target feed-on sale weight about 6 months earlier than for the buffel grass-only pasture but were 21 kg lighter than steers that had grazed leucaena-grass pastures.

Figure 8 - Estimated steer growth paths from weaning when grazing either buffel grass, leucaena-grass or desmanthus-grass pastures



The stocking rate (and hence number of ha required) to run a steer from weaning until reaching feed-on sale weight, for either buffel grass pasture or desmanthus-grass pasture was determined by calculating available pasture biomass for consumption per hectare (based on the specified forage utilisation rate for that scenario) and then dividing by the calculated steer intake of pasture dry matter over that period. For desmanthus-grass pastures, the respective annual biomass production and utilisation levels of the buffel grass and desmanthus components were summed to determine total biomass available. It was assumed that cattle consumed 31% of their diet DM as desmanthus biomass. The pasture biomass available for consumption during a defined growth path was adjusted proportionally for days greater or less than the full annual period. As described previously for calculation of representative carrying capacity figures (AE/ha), the average DM intake by steers of each forage type within each growth path was estimated using the QuikIntake Excel spreadsheet calculator (McLennan and Poppi 2016) modified from the Australian ruminant feeding standards (NRDR 2007) to better predict intake for *B. indicus* content cattle and tropical diets (McLennan 2014). In the prediction of average DM intake, the average diet DMD of buffel grass or desmanthus-grass forage for the relevant period was assigned based on data from Bowen *et al.* (2015*b*). The average liveweight of the cattle (i.e. liveweight at the mid-way point) and the assumed average daily gain over the relevant period were used as key inputs. The steers were assumed to be 50% *B. indicus*, to have a standard reference weight (SRW) of 660 kg, to walk 7 km/day (as per McLean and Blakely 2014) and the terrain to be 'level 1'.

Table 30 shows the assumed parameters used in the calculation of the area required to run a steer from weaning to feed-on sale weight on buffel grass and on an established desmanthus-grass pasture. The higher DM production and the higher digestibility of the desmanthus-grass pasture result in a lesser area of desmanthus-grass pasture required. As identified previously, the steers grazing buffel pastures (to feed-on weight; ca. 495 kg) would need access to about 1,030 ha from weaning to sale at 27 months of age (239 head x 4.31 ha). If the same number of steers graze a paddock of desmanthus-grass pasture from weaning to 21 months old it is expected that about 479 ha (239 head x 2 ha) would be required to run the same number of steers to the earlier point of sale. The steers will average ca. 480 kg at 21 months old at the end of this grazing period on desmanthus-grass pastures whereas they would have averaged 501 kg at the same age if they had grazed leucaena.

If all of the yearling steers are grazed on desmanthus-grass pastures this would free up about 552 ha of land to be grazed by other classes of stock in the breeding herd. If 2.1 hectares is allocated per AE, then the breeder herd component of the overall beef herd can expand in size by about 260 AE once the desmanthus is fully established. Proportionally expanding the breeding herd and replacement heifers to graze this spare pasture allows the breeders to produce more weaner steers, increasing the area of desmanthus-grass pasture required but also reducing the spare buffel grass pasture available for breeder herd expansion. An iterative process was used to approximately identify the relationship between the size of the breeder herd and the numbers of steers grazing the desmanthus-grass pasture, which optimizes the size of each. Table 31 and Table 32 show the change in herd structure enabled by the planting of desmanthus-grass pastures in this example. A desmanthus-grass paddock of ca. 583 ha was required to provide an appropriate balance between an expanded breeder herd and suitably sized desmanthus-grass paddock for the steers. This paddock was planted at the start of the second year of the 30-year analysis period. The cost of preparing and planting the desmanthus-grass paddock (at contract rates) was $118,349.

Table 30 – Assumed parameters used in the calculation of the grazing area required for a steer from weaning to feed-on sale weight, for buffel grass and desmanthus-grass pasture

Figures are the average or total for the entire grazing period

Parameter	**Buffel grass pasture**	**Desmanthus-grass pasture**
Days on forage (post weaning)	640	457
Average LWG (kg/d)	0.46	0.61
Average age (years)	1.4	1.1
Average liveweight (kg)	347	340
Average DMD of diet (%)	57	60
DMI (kg/head.day)	10.3	9.7
Total biomass consumed per head (kg DM)	6,660	4,418
% of DM consumption as grass	100	69
% of DM consumption as desmanthus	-	31
Total grass consumed per head (kg DM)	6,660	3,048
Total desmanthus consumed per head (kg DM)	0	1,370
Utilisation of grass biomass growth (% of DM)	30	30
Utilisation desmanthus biomass growth (% of DM)	-	45
Annual grass biomass production (kg DM/ha)	5,100	5,100
Annual desmanthus biomass production (kg DM/ha)	-	1,500
Annual paddock biomass production (kg DM/ha)	5,100	6,600
Total grass yield for grazing days (kg DM/ha)	8,942	6,385
Total desmanthus yield for grazing days (kg DM/ha)	-	1,878
Grass biomass available for consumption (kg DM/ha)	2,683	1,916
Desmanthus biomass available for consumption (kg DM/ha)	-	845
Area required to meet steer demand for 1 year (ha)	2.46	1.6
Total area required for the grazing period (area adjusted for number of days > 365), (ha)	4.31	2.00

DM, dry matter; DMD, dry matter digestibility; DMI, dry matter intake; LWG, liveweight gain.

Table 31 - Change in herd AEs due to implementing desmanthus-grass pastures for the steers

Age at start of rating period	**Baseline herd breeder component AEs (no leucaena)**	**Leucaena breeder component AEs**
Extra for cows weaning a calf	174	203
Weaners 5 months	129	151
Heifers 1 year but less than 2	168	196
Heifers 2 years but less than 3	185	216
Cows 3 years plus	570	664
Bulls all ages	41	47

Table 32 - Breeder herd components without the desmanthus development and with the desmanthus development once established

Breeder herd components	Baseline herd (no desmanthus)	With desmanthus
Total cows and heifers mated	642	749
Calves weaned	498	581
Weaner steers	249	291

2.4.1.1.3 Improving steer growth path performance with forage oats

For the strategy where steers were grazed on forage oats, the baseline, ‘without change’ system that did not grow forage oats was compared to a ‘with change’ system that invested in machinery to grow forage oats. It was assumed that no development costs were required as a suitable cultivated paddock capable of being planted to oats with minimal extra expense already existed in a ‘fenced and watered’ state.

Table 33 lists the plant and equipment required to grow about 100 to 200 ha of oats per annum using a minimum tillage farming system. The purchase cost of the equipment was $152,000 second hand. The equipment incurred a depreciation allowance of $8,575 per annum. Table 34 lists the expected variable costs of growing oats. Extra labour costs were incorporated in the allocation for machinery operations at $25/h. The machinery operating costs of fuel, oil, repairs and maintenance were initially calculated on an hourly basis then converted to a cost per hectare based on the expected rate of use. Any steers grazing the oats were treated with 5-in-1 vaccine at a cost of $0.50/head.

Table 33 - Machinery investment required to grow oats

Item	Cost (second hand)	Replacement cost	Time to replacement	Salvage value	Depreciation allowance
Tractor	$65,000	$65,000	10	$25,000	$4,000
Spray rig	$17,000	$20,000	10	$5,000	$1,500
Planter	$45,000	$45,000	20	$5,000	$2,000
Tyne cultivator	$10,000	$10,000	20	$1,000	$450
Chisel plough	$15,000	$15,000	20	$2,500	$625
Total	*$152,000*				*$8,575*

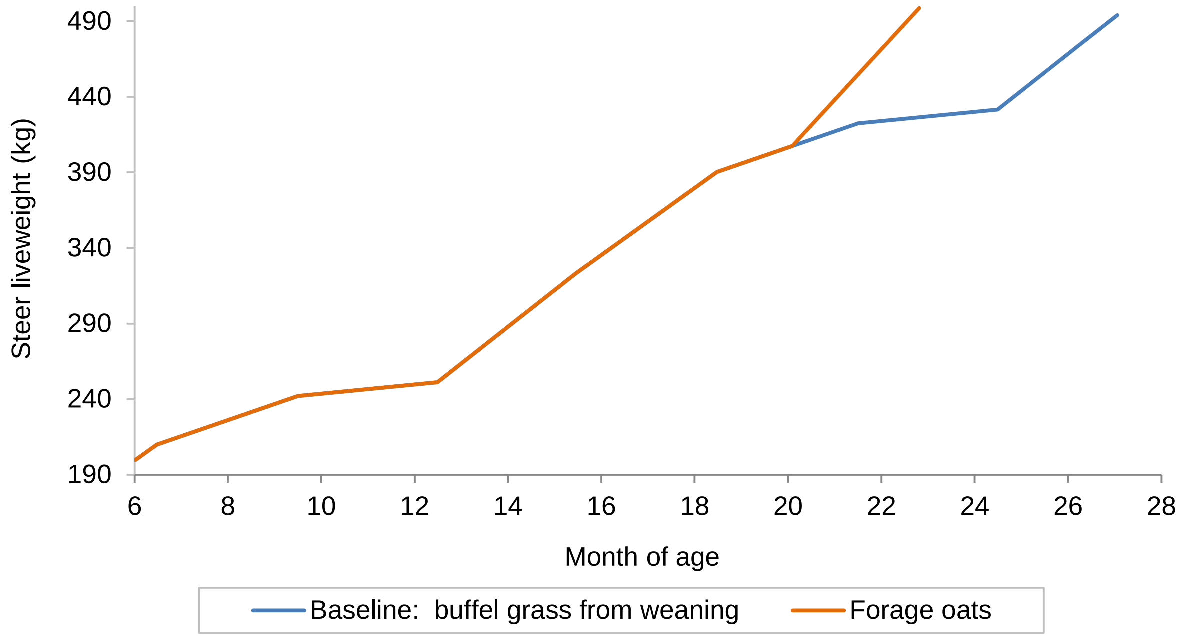
Table 34 - Variable costs associated with growing oats using owned machinery

Item or treatment	Rate of application	Cost / unit	Number of applications	Cost per hectare
Pre planting costs				
Chisel plough	10	$34.41	1	$34.41
Tyne cultivator	10	$17.74	1	$17.74
Linkage spray rig	10	$3.66	2	$7.33
Amicide 625	0.75 L/ha	$6.83	2	$10.25
Glyphosate 450 CT	1.50 L/ha	$4.64	2	$13.91
Planting Costs				
No till seeder	1	$13.66	2	$13.66
Oats seed	40 kg/ha	$1.80	1	$72.00
Urea	43.47	$0.50	1	$21.74
Post Planting Costs				
Linkage spray rig	1	$3.66	1	$3.66
MCPA LVE	1 L/ha	$10.75	1	$10.75
Total forage annual costs				*$219.09*

The oats was assumed to provide grazing for 83 days from mid-July, providing an average diet DMD of 65% and resulting in an average steer growth rate over this period of 1.1 kg/day (Bowen *et al.* 2015*a*, 2015*b*). The APSIM modelling framework (The Agricultural Production Systems Simulator; McCown *et al.* 1996; Keating *et al.* 2003) was used to simulate median annual forage biomass production for the location using 117 years of climate data and assuming 100 kg N/ha as a base N level (Cox 2009): 5432 kg DM/ha. It was assumed that 30% of the annual oats biomass was utilised (from data collected from commercial properties; Bowen *et al.* 2015*b*). The carrying capacity of oats forage (2.73 AE/ha) was calculated by dividing the utilisable biomass component by the annual forage DM intake of an AE. An AE was defined here in terms of the forage dry matter intake at the specified diet DMD, of a standard animal which was defined by McLean and Blakeley (2014) as a 2.25 year old, 450 kg *B. taurus* steer at maintenance, walking 7 km/day. The spreadsheet calculator, QuikIntake (McLennan and Poppi 2016), which is based on the Australian Feeding Standards (NRDR 2007) with some modifications for tropical feeding systems (McLennan 2014), was used to calculate daily cattle dry matter intake for the specified forage DMD.

Figure 9 shows the effect of providing forage oats on the steer growth path, as a divergence to the underlying steer growth path on buffel grass pastures. The forage oats allowed steers to reach the feed-on target weight 5 months earlier, on average, than the steers grown from weaning on buffel grass pastures (baseline scenario).

Figure 9 – Estimated steer growth paths from weaning when grazing buffel grass pastures only or when providing forage oats in the second dry season after weaning



The baseline, ‘without change’, herd model turned off 230 steers in the 2-3 year age group but this number required modification when implementing the forage oats strategy as the area planted to oats reduced the area available for the breeding herd and for steers up to the point they go onto the oats. The age steers leave the herd (to enter the oats paddock) is also younger than the sale age of steers in the baseline herd. Table 35 shows the baseline herd model reconfigured to turn off steers in mid-July at 408 kg ready to go onto oats but without a reduction in buffel grass grazing area due to oats production. A total of 260 steers were produced by the breeding herd when it was reconfigured to focus on selling steers off oats. However, this figure does not allow for the area of grazing land lost to oats production.

Table 35 - Herd structure when steers graze oats in their dry season after weaning (no AE reduction due to loss of grazing land due to oats production)

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	190
Weaners 5 months	542	0	0.26	0.07	141
Heifers 1 year but less than 2	263	0	0.70	0.33	183
Heifers 2 years but less than 3	125	129	1.07	0.52	202
Cows 3 years plus	456	99	1.21	0.69	619
Steers 1 year but less than 2	0	260	0.73	0.34	122
Bulls all ages	24	4	1.65	0.96	44
Total number.	*1,410*	*492*	-	-	*1,500*

The spreadsheet calculator, QuikIntake (McLennan and Poppi 2016), which is based on the Australian Feeding Standards (NRDR 2007) with some modifications for tropical feeding systems (McLennan 2014), was used to calculate daily cattle dry matter intakes for the specified forage oats DMD. For steers with an average weight of 453 kg and gaining 1.1 kg/day grazing oats with a DMD of 65% will require 12.6 kg DM/day (the steers go onto the oats at ca 408 kg liveweight and leave the paddock at ca.499 kg liveweight). A total paddock size of 190 ha (forage area 166 ha) was required for the 260 steers. The average stocking rate on the oats was 1 steer per 0.64 ha of forage.

The herd model was adjusted for the amount of land lost to the oats paddock. Removing an area of grass to grow oats reduces the area available to the breeding herd and other stock. Implementing the oats paddock allowed a carrying capacity for the rest of the property of 1,410 AE (1,500 AE's without change; 90 AE's lost to the oats paddock). This reduced the size of the paddock required for oats to 175 ha with 160 ha planted.

The machinery was purchased, and oats produced, in the first year of the investment period with adjustments to herd numbers made. Two age groups of steers were sold in the first year: the 2-3 year old steers were sold as usual and then the first group of 1-2 year old steers were sold off oats at the end of October in the same year. Only the steers produced off oats were sold in following years. The number of cows mated was increased from 642 to 656 to adjust for the younger age of turnoff associated with incorporating oats in the growth path of the steers.

The frequency of suitable planting conditions for oats must be considered as production from forage oats is more variable than production from a grass pasture that could be utilised in this paddock. The percentage of years with conditions suitable for sowing oats in central Queensland is expected to be ca. 67% based on data derived from the plant production model, APSIM (Agricultural Production Systems Simulator (McCown et al 1996)) using regional soil characteristics and 108 years of historical climate data. (Bowen *et al*. 2015*a*). Hence, adjustment was made to the expected income from steer sales and forage growing costs to allow for oats only being able to be sown in 67% of years. In those years in which oats was planted, the average steer weights and oats growing costs applied. When a planting opportunity didn't occur, the steers were sold in July at their oats paddock entry weight less 5% for weight lost during the selling process. In years when crops were not planted the planting costs were set at 44% of the costs incurred when oats was planted. That is, only fallow costs were incurred in a year when no planting opportunity arrived (Table 36).

Table 36 - Calculation of expected total variable costs for the forage oats enterprise

Oats planting occurrence	**Proportion of years**	**Variable costs per hectare**	**Total variable costs**
Oats not planted	0.33	$83.62	$13,406
Oats planted	0.67	$219	$35,040
Weighted average value	*1.00*	*$174.32*	*$27,892*

Table 37 shows the calculation of the expected sale value received for steers when the forage oats enterprise investment is made and showing the effect of the likely missed planting opportunities.

Table 37 - Calculation of expected steer weight, price and selling costs when the forage oats strategy is implemented

Oats planting occurrence	**Proportion of years**	**Steer sale weight (kg)**	**Steer price**	**Gross price/head**	**Selling costs**	**Net price/head**
Oats not planted	0.33	408	$1.87	$762	$58.48	$704
Oats planted	0.67	499	$1.87	$933	$70.31	$862
Weighted average value	*1.00*	*469*	*$1.87*	*$876*	*$66*	*$810*

2.4.1.1.4 Custom feedlotting steers

In the feedlotting strategy, the sale steers were sent from the property in central Queensland to a feedlot on the Darling Downs and arrived there at a liveweight of 470 kg (feed-on sale weight of 495 kg less 5% transport weight loss). The custom feeding assumptions were:

- fed for 105 days
- average liveweight gain of 1.94 kg/head.day
- consumption of 14.8 kg/head.day of feed on average
- steers achieved 377 kg dressed weight at slaughter.

Table 38 shows the detailed calculation of weight gain, costs and profit margin for the expected value of custom feeding the steers. The costs and prices were derived with reference to the ‘Beef Central’ website. It cost $40/head to transport the steers to the feedlot ($9,200/annum), $15/head for induction into the feedlot ($3,450/annum), $310/t for combined feed and custom feeding charges ($535 per head, $123,206/annum) and $30.56/head to move the steers from the feedlot to the abattoirs ($7,010/annum). The steers were expected to weigh 674 kg liveweight at the end of the feeding period. The average price for 100-day, grain fed ox at Dinmore abattoirs between 2008 and the end of 2015 was $3.60 c/kg dressed. The average dressing percentage was 54% indicating a liveweight equivalent price of $1.94 per kilogram. There was no change to herd structure due to implementing this strategy as the feed-on steers were removed from the property at the same age, but sent to the feedlot, rather than the saleyards.

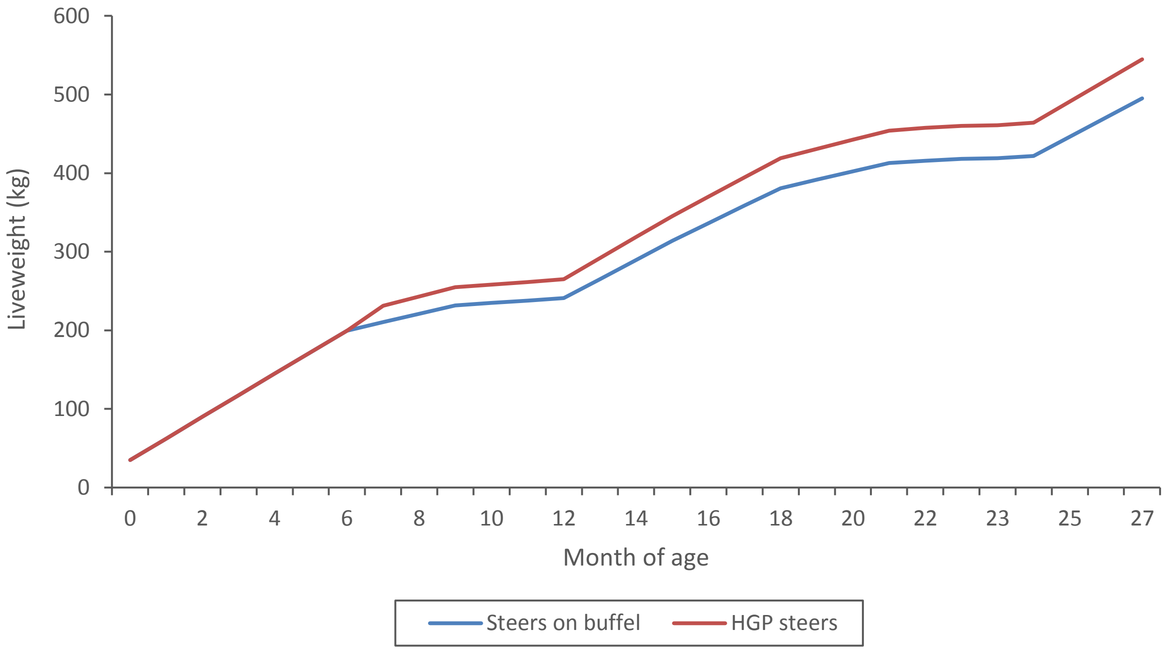
Table 38 – Calculation of feedlot costs and returns

Parameter	**Parameter value**	**$ per head**	**Total $**
Number of livestock to be fed	230		
Value of livestock into the feedlot			
Initial liveweight (kg)	470		
Price ($/kg liveweight)	$1.89		
Cost of stock into the feedlot		$888	$204,309
Costs of accessing the livestock			
Trucking (25 head/deck; 500 km), (per km)	$2.00	$40.00	$9,200
Induction		$15.00	$3,450
Final liveweight			
Expected average weight gain (kg/head.day)	1.94		
Estimated number of days in the feedlot	105		
Total expected gain (kg)	203.7		
Final weight (kg)	673.7		
Feed consumption			
Average weight during time in the feedlot (kg)	571.85		
Average daily feed consumption (kg DM/head)	14.8		
Total consumption at 3% of liveweight (kg DM/head)	1,555		
As-is feed consumed (90% DM), (kg)	1728		
Feed cost ($/t)	$310.00		
Total feed cost		$535.68	$123,206
Other feedlot costs			
Interest on steer cost (5%)		$12.78	$2,939
Interest on feed cost (5%)		$3.85	$886
Total costs		*$1,495.42*	*$343,990*
Number of cattle sold (0.25% losses)	229		
Final liveweight (kg)	674		
Steer selling price ($/kg)	1.94		
Value of stock out of feedlot		$1,306.98	$299,854
Livestock levy		$5.00	$1,147
Freight to abattoir (18/deck; 250 km), (per km)	$2.20	$30.56	$7,010
Net income from sales		*$1,271.42*	*$291,697*
Gross margin		*-$224.18*	*-$52,294*

2.4.1.1.5 Hormonal growth promotants for steers

The HGP strategy involved provision of HGPs continuously from weaning until sale as feed-on steers. This required two treatments with HGP that have effect over 400-day and 200-day periods, respectively. Steers implanted with HGPs were assumed to have a 10% greater growth rate than for steers in the baseline herd as per results of McLennan (2014) for *B. indicus* crossbred cattle grazing tropical pastures. Figure 10 shows the expected growth path of steers treated with HGP.

Figure 10 – Estimated steer growth paths from birth when grazing buffel grass pastures with or without HGP implants



In the first HGP scenario steers were sold at the same time as for steers in the baseline case-study herd (ca. 27 months of age) but were 545 kg liveweight in the paddock (cf. 495 kg) and maintained the same price point. The herd model was adjusted to reflect the greater weight of steers in the herd and also the increased feed efficiency. It was assumed that the implanted steers had an increase in average feed conversion efficiency of 4.5% compared to non-implanted steers, meaning that implanted steers required 4.5% less feed than non-implanted steers to achieve the expected weight gain (Hunter 2009; McLennan 2014). The cost of HGP treatment was $9 (400-day implant) and $5 (200-day implant) per head including treatment costs.

The use of HGPs in the steers resulted in allocation of proportionally more of the total property feed resources to the steers and hence reduced the number of breeders proportionally so that the same overall grazing pressure was applied (Table 39). Although this reduced the number of weaner steers produced it also resulted in the property to selling proportionally more steer beef.

Table 39 - Herd components for the baseline herd and with steers treated with HGP's

Herd component	Baseline herd	With HGP
Total cows and heifers mated	642	636
Calves weaned	498	493
Weaner steers	249	247

As it is possible that selling steers at a heavier weight than the target weight for feed-on steers may lead to price discounts. The impact of receiving a lower price for the treated steers was tested in a second scenario by reducing their expected sale price by 10 c/kg liveweight on average.

Selling steers at the target weight for feed-on steers but at a younger age than the steers in the baseline herd should prevent price discounts. The impact of selling the treated steers at a younger age was tested by reducing the sale age and rebalancing the herd model to restructure the herd to meet the younger age of turnoff.

2.4.1.2 Improving breeder reproductive performance

2.4.1.2.1 Better genetics for breeder fertility

The benefits expected to arise from converting the baseline female herd to a breeding herd with different genes for reproduction that provide a 6% improvement in overall weaning rates (as per Burns *et al*. (2014) were tested. It was assumed that the property manager converted all of the current breeding bull herd to one with different genes in the first year of the analysis with the first group of genetically different calves born in the second year. The calendar year was used in the analysis which resulted in calves being born around November of the first year from the mating prior to the changeover of the bulls.

On this basis it was Year 4 before heifers with different genes were first mated and calved. Heifer culling and mating strategies were maintained as the genes for reproductive efficiency spread through the breeder herd. This meant that ca. 1/3 of replacement heifers were culled before mating and empty replacement heifers were all culled after their first mating. Mature cows were culled on the basis of their pregnancy status.

The cost of replacement herd bulls was set at the same price used in the baseline herd, i.e. $5,000. The net cost of the changeover of all of the herd bulls at the beginning of the investment period was $55,000 (22 x $5,000 for the new bulls less 22 x $2,500 for the old ones). A total of 50% of the existing herd bulls were sold on to industry while 50% went to the abattoirs.

No other parameters of herd performance were changed. The herd structure was rebalanced to maintain grazing pressure as the genes for reproductive efficiency flowed through the breeding herd. The age for final culling for mature breeders was maintained at the same age as the baseline herd. Table 40 shows the change in weaning rate and other factors as the genes flowed through the breeding herd. The herd modelling indicates that it is likely to take at least 13 years for the overall weaning rate to improve by 6% if all of the bull herd is replaced in the first year. The cow culling strategy of the baseline herd was maintained to allow identification of the net benefits of the change in weaning rates. It is possible that some minor benefits may be gained by a reduction in the cow culling age freeing up some livestock capital during the transition process, but this was not examined here.

Table 40 - Modelled steps in genetic change of weaning rate (from Breedcowplus analysis)
The herd weaning rate is shaded grey

Herd component	**Base herd (Year 1)**	**Year 4**	**Year 6**	**Year 8**	**Year 10**	**Year 12**	**Year 13**
Total adult equivalents	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Total cattle carried	1,537	1,537	1,538	1,539	1,1539	1,1539	1,540
Weaner heifers retained	249	249	250	250	250	250	250
Total breeders mated	642	633	619	611	605	601	599
Total breeders mated & kept	535	535	535	535	535	535	535
Total calves weaned	498	499	499	500	500	500	500
Weaners/total cows mated	77.60%	78.83%	80.62%	81.79%	82.64%	83.27%	83.53%
Weaners/cows mated and kept	93.19%	93.19%	93.28%	93.35%	93.41%	93.44%	93.45%
Overall breeder deaths	4.53%	4.53%	4.52%	4.53%	4.56%	4.58%	4.59%
Female sales/total sales %	47.79%	47.79%	47.80%	47.80%	47.78%	47.77%	47.77%
Total cows and heifers sold	210	210	211	211	211	211	211
Maximum cow culling age	13	13	13	13	13	13	13
Heifer joining age	2	2	2	2	2	2	2
Weaner heifer sale and spay	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
One year old heifer sales %	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Two year old heifer sales %	58.48%	56.77%	62.34%	65.50%	67.39%	68.40%	68.65%
Total steers & bullocks sold	230	230	230	230	230	231	231
Max bullock turnoff age	2	2	2	2	2	2	2

2.4.1.2.2 Investing to reduce foetal/calf loss

In this strategy an investment to reduce foetal/calf loss in heifers and first lactation cows was investigated. These losses occurred sometime between conception (pregnancy testing) and weaning and have been applied to the baseline herd model according the CashCow data for the Central Forest region (McGowan *et al.* 2014). The wide range of possible agents and combinations of agents identified by the CashCow project together with a lack of other research data indicating a ‘typical’ cause and effect relationship for our beef enterprise limits the identification of appropriate examples for analysis and requires us to rephrase the question.

1) The question was rephrased to look at what level expenditure could be incurred on a per head per annum basis to resolve a calf loss problem. Hence, the first question was:
    - if $5, $7.50 or $10 was spent per head, and calf/foetal loss in first calf and second calf cows was reduced by half, what would be the return on the funds spent?
2) As the CashCow project (McGowan *et al.* 2014) also identified that additional capital costs (such as effective fencing, good paddock design, appropriate segregation, training of cattle, and selection for temperament) could be required to address the problem of calf/foetal calf loss a second question was assessed:
    - what amount of capital could be spent (upfront) to reduce calf mortality in first and second calf heifers by 50% on this property?

To answer these questions the baseline herd model was modified and optimised by:

- halving the calf loss values for the first calf heifers (2 to 3 year old females) and the first lactation cows (3-4 year old females),

- calculating the new weaning percentage and the new number of sales after mating, and
- balancing the herd structure for the new level of reproduction efficiency and selling any surplus heifers in the 2-3 years age group.

The data from the new steady-state herd model with 50% lower rates of calf loss in young females were then imported as the new herd culling target for the base investment herd model and the additional treatment costs inserted from the first year.

Where the examples considered additional capital expenditure, the capital costs were added to the capital purchases section of the first year of the investment model. This reflected the expectation that a 1-year (minimum) lag between expenditure and receipt of benefits would be expected for any strategy aimed at improving calf/foetal loss. The treatment cost allocated included the cost of any treatment plus any additional labour required to undertake the treatment. The effective economic life of additional capital invested was taken to be 30 years with no residual value. The baseline herd model (without change) and the 'with change' herd models were compared to identify the marginal returns achieved.

2.4.1.2.3 Pestivirus management

In this section a number of alternative investments are considered that could be applied to prevent potential losses due to pestivirus infection.

Vaccinating for pestivirus in a high prevalence herd

In the first scenario a baseline cattle herd was applied that was assumed to have a high prevalence of the pestivirus disease. This herd was developed by reducing the conception rates of the original baseline herd by a uniform 2% for each class of females mated, the same impact as applied by GHD Pty Ltd *et al.* (2015) for high prevalence herds.

a) Annual vaccination of all breeding females

The long term benefit of a vaccination program in which all breeding females were treated each year was set at a 2%/annum improvement in the herd pregnancy rate – the reversal of the disease impact. The vaccine was applied to all breeding age females in the first year of the analysis with the conception rates improving from the second year. The cost of the vaccine was $4.75/dose with two doses being applied to heifers entering the breeding herd and all cows retained in the breeding herd receiving an annual booster. Although the vaccination program can often be incorporated in the normal mustering activities, the cost of the vaccine per head was increased to $5 per dose applied to allow for additional labour and time required to apply the vaccine. In this scenario the vaccination program was continued for the entire 30-year investment period to prevent reinfection of the herd with pestivirus.

b) Vaccination of heifers only

The long term benefit of a vaccination program in which only heifers were treated prior to entering the breeding herd was also assessed. This vaccination program was assessed by adjusting the costs of treatment for the previous model so that only the heifers were treated. The same level of benefits achieved as for annual vaccination of all breeding females (a 2%/annum improvement in the average weaning rate) was assumed.

Vaccinating for pestivirus in a naive herd

In the second scenario the baseline cattle herd was assumed to have be naive to pestivirus. We assumed a 30% reduction in the herd weaning rate in the year of rapid spread of the virus (M. Sullivan, pers. comm.). The impact of a one-off 30% reduction in weaning rate on the number of weaners produced is shown in Table 41.

Table 41 - Calves weaned in a naive herd with and without a one-off impact of pestivirus

Herd component	Base herd	Naive herd impacted by pestivirus
Total cows and heifers mated	642	642
Calves weaned	498	349

Following the method outlined by Malcolm (2003) and McInerney (1996) it was assumed that the cost of the outbreak of the disease could happen with a given probability each year and the occurrence in one year is independent of its occurrence in any other year. That is, the problem is a ‘one-off’ event with an estimated total cost and an associated probability of occurring sometime in a defined planning horizon. It was also assumed that when the loss occurs, it is very unlikely that the impact of the one off event would reoccur within the planning horizon or that practices would be put in place to ensure that it does not happen again. In other words, the costs due to this cause can happen once and once only in the planning period – the probability of re-occurrence is zero (or some very small probability). Our planning period in this analysis was 30 years.

This type of situation appears to create a problem for benefit-cost analysis because the year in which the costs occur is unknown, which makes it difficult to obtain an expected present value by discounting the future loss. In our analysis the discount factor was applied to the probability component of the formula for the expected present value rather than the benefit and cost components to overcome this difficulty (Read Sturgess and Associates 1992). At a discount rate of 5%, an event with a 1 in 30 year probability is equivalent to a (discounted) probability of it occurring ‘now’, of 0.4. This result is achieved by combining the discounting formula (PV= $Cost/ ((1=discount rate)/100) x the number of years), and the formula for the probability of the random event. The algebra reduces to: 100/ ((number of years x discount rate) +100). For a 30 year period and discount rate of 5%, the solution is 100/ ((30 x5) +100) = 0.4

2.4.1.2.4 Improving reproductive performance with inorganic supplements

The alternatives modelled were are a ‘without change’ property that ran a breeder herd on country with varying levels of P status but no effective supplements, and the same property with inorganic supplements fed to breeders. This is a different base scenario to the previously applied ‘without change’ herd model where the assumption was that the breeders were running on P-adequate country, as inferred from the Cash Cow, Central Forest data for reproductive efficiency (McGowan *et al.* 2014). The steers and heifers were assumed to graze the same land types as described previously for the case study enterprise, i.e. the more productive and arable Brigalow land types supporting sown, buffel grass pastures. Hence the weaned steers and heifers required no supplementation and had the same growth paths as described previously. The heifers were assumed to be mated whilst grazing buffel grass pastures and then to calve down on forest country with the designated level of P status.

A total of 12 scenarios were modelled encompassing a range of categories of P status (Marginal, Deficient and Acute, as per Table 5) and various supplementation regimes designed to provide P in wet and/or dry seasons and in combination with N in the dry season:

1) Marginal P herd – no supplement
2) Marginal P herd – wet season P
3) Marginal P herd – dry season (N+P)
4) Marginal P herd – dry season (N+P), wet season P
5) Deficient P herd – no supplement
6) Deficient P herd – wet season P
7) Deficient P herd – dry season (N+P)
8) Deficient P herd – dry season (N+P), wet season P
9) Acute P herd – no supplement
10) Acute P herd – wet season P
11) Acute P herd – dry season (N+P)
12) Acute P herd – dry season (N+P), wet season P.

Table 42 identifies the main components of the supplements fed in the various scenarios to provide adequate N and/or P. The supplement composition and nutrient content were expressed on an as-fed basis. The dry season supplements were based on supplying 150 g crude protein/head.day. The Kynofos percentage was adjusted in the supplements to achieve the target P intake for the different deficiency scenarios. The same wet season supplement was used for all scenarios but the supplement intake was adjusted to achieve the target P intake for the different P deficiency scenarios. Supplement prices were expressed on a GST exclusive basis. The change in cost of each supplement was mostly related to the P content of the final mix.

Table 42 - Supplement composition (as-fed basis) and cost per tonne for country with different levels of P status

Supplement	**Wet season lick - Marginal, Acute and Deficient P herds**	**Dry season lick – Marginal P herds**	**Dry season lick – Deficient P herd**	**Dry season lick - Acute P herd**
Urea (%)	-	30	30	30
GranAm (%)	-	8	8	8
Copra meal (%)	-	10	10	10
Kynofos (%)	80	10	10	15
Salt (%)	20	46	42	37
Crude protein (%)	-	98.50	98.50	98.50
P (%)	16.80	1.31	2.15	3.20
Supplement cost ($/t)	*$1,056*	*$744*	*$773*	*$809*

It was assumed that each mix, when appropriately fed, met the rate of intake targeted. Table 43 identifies the expected rate of intake and the number of days that the supplements were assumed to be fed in each of the scenarios.

Table 43 - Supplement and nutrient intakes for breeders supplemented in the wet and/or dry season for 12 different scenarios covering Marginal, Deficient and Acute P status country and breeder herds

Scenario	**Days fed supplement**		**Supplement (g/head.day)**		**Crude protein (g/head.day)**		**P (g/head.day)**	
	Wet season	**Dry season**	**Wet season**	**Dry season**	**Wet season**	**Dry season**	**Wet season**	**Dry season**
1. Marginal P herd, no supplement	0	0	0	0	0	0	0	0
2. Marginal P herd, wet season P	90	0	18	0	0	0	3	0
3. Marginal P herd, dry season (N+P)	0	120	0	155	0	153	0	3
4. Marginal P herd, dry season (N+P), wet season P	90	120	18	155	0	153	3	3
5. Deficient P herd, no supplement	0	0	0	0	0	0	0	0
6. Deficient P herd, wet season P	120	0	42	0	0	0	7	0
7. Deficient P herd, dry season (N+P)	0	150	0	155	0	153	0	3
8. Deficient P herd, dry season (N+P), wet season P	120	150	42	155	0	153	7	3
9. Acute P herd, no supplement	0	0	0	0	0	0	0	0
10. Acute P herd, wet season P	120	0	65	0	0	0	11	0
11. Acute P herd, dry season (N+P)	0	150	0	155	0	153	0	5
12. Acute P herd, dry season (N+P), wet season P	120	150	65	155	0	153	11	5

Table 44 identifies the cost of the supplements in each scenario.

Table 44 – P Supplement feeding cost for 12 scenarios where breeders grazed country with different levels of P status and with a range of supplementation regimes

Scenario	**Seasonal feeding cost ($/breeder)**		**Total feeding cost ($/breeder.annum)**
	Wet season	**Dry season**	
1. Marginal P herd, no supplement	0	0	0
2. Marginal P herd, wet season P	1.71	0	1.71
3. Marginal P herd, dry season (N+P)	0	13.84	13.84
4. Marginal P herd, dry season (N+P), wet season P	1.71	13.84	15.55
5. Deficient P herd, no supplement	0	0	0
6. Deficient P herd, wet season P	5.32	0	5.32
7. Deficient P herd, dry season (N+P)	0	17.97	17.97
8. Deficient P herd, dry season (N+P), wet season P	5.32	17.97	23.29
9. Acute P herd, no supplement	0	0	0
10. Acute P herd, wet season P	8.24	0	8.24
11. Acute P herd, dry season (N+P)	0	18.81	18.81
12. Acute P herd, dry season (N+P), wet season P	8.24	18.81	27.05

Biological responses to each of the supplement regimes were assigned with reference to existing data and publications as well as the expert opinion of and QAAFI and DAF staff, particularly R. Dixon and M. Sullivan. A key assumption was that although P is the major factor limiting breeder performance at each level of P status, the supplementation program may not return breeder herd performance to the level of 'P-adequate', on 'Deficient' and 'Acute' P country due to other nutritional constraints expected to be associated with land types typical of each level of P status.

Table 45 and Table 46 show the expected impact on breeder liveweight of the modified categories of P status and the expected level of response to supplement programs for each class of country/status of P. In the analysis, cull cows were sold at the weights nominated for each level of P status and supplement less an allowance of 5% weight loss to the point of sale.

Table 45 - Expected conceptus-free liveweight loss of breeders during pregnancy and lactation without supplementation for different levels of P status

P status of country	**Conceptus-free liveweight loss during pregnancy and lactation, No P or N supplementation**
Adequate	12.5 (0.25 BCS)
Marginal	25 kg (0.5 BCS)
Deficient	50 kg (1 BCS)
Acute	80 kg (1.6 BCS)

Table 46 - Predicted breeder liveweight (LW) response to P or N+P supplementation in the wet and and/or dry seasons

P status of country	**Average cow LW (kg)**				**Cull cow LW in June (kg)**			
	No P or N	**Wet: P**	**Dry: N+P**	**Dry: N+P, Wet: P**	**No P or N**	**Wet: P**	**Dry: N+P**	**Dry: N+P, Wet: P**
Adequate	460	460	460	460	440	440	440	440
Marginal	450	460	460	460	430	440	440	440
Deficient	435	450	445	455	410	425	420	430
Acute	428	445	435	450	400	418	412	425

Table 47 identifies the expected impact on breeder mortality rate and weaning rate of the various categories of P status and the expected level of response to supplement programs for each class of country/status of P.

Table 47 - Predicted impact on breeder mortality and weaning rate of varying levels of P deficiency

P status of country	**Mortality rate (%)**				**Weaning rate (%)**			
	No P or N	**Wet: P**	**Dry: N+P**	**Dry: N+P, Wet: P**	**No P or N**	**Wet: P**	**Dry: N+P**	**Dry: N+P, Wet: P**
Adequate	2	2	2	2	77	77	77	77
Marginal	4	2	2	2	72	77	77	77
Deficient	8	5	6	3	67	73	72	75
Acute	12	7	8	5	57	72	67	73

Table 48 identifies the weaner liveweight at 6 months of age for each level of P status and supplementation. It is assumed that weaners will compensate for the lower weaning weight by the time of sale and thus cull heifers and 2-3 year old steers will sell at the same average weight in all scenarios.

Table 48 - Predicted impact on weaner liveweight of varying levels of P deficiency

P status of country	**Weaner liveweight (kg)**			
	No P or N	**Wet: P**	**Dry: N+P**	**Dry: N+P, Wet: P**
Adequate	200	200	200	200
Marginal	190	200	200	200
Deficient	175	190	190	195
Acute	168	180	180	190

Tudor and O'Rourke (1980) found that compensatory gain effects (increased growth rate of restricted cattle when grazed on good quality pasture from 200 d of age) overcame the effects of highly restricted diets prior to weaning. Growth rates of the previously restricted cattle were 48% higher over the 400 days post-weaning compared to calves which were on a high plane of nutrition prior to weaning. This indicates that weaners from low P status herds in our example scenario are likely to compensate sufficiently to achieve the same growth path as weaners from adequate P status herds within six months post weaning as long as they both have access to the same level of improved nutrition post weaning.

Therefore the differences in weaning weight shown in Table 48 have no impact on the final sale weights of steers and cull heifers in this analysis. Producers who sell weaners directly off cows running on P deficient country would need to incorporate the expected impact on weaning weights in their calculation of the benefit of supplementation. Differences in pre-weaning growth rates expected in herds with different P status and different levels of P supplementation are incorporated in the AE rating of stock up to 12 months of age in the respective herd models.

The scenarios applied place all weaners back onto the same Brigalow country post-weaning. They stay there until they are either sold or mated. Heifers are first mated on the Brigalow country and then returned to the breeder herd. Given that weaners were expected to compensate fully so that they recovered any weight differences at weaning by the time they were sold or enter the breeding herd, the main impacts of the different levels of P status, breeder nutrition and supplements for the breeders were cull cow sale weights, breeder herd mortality rates and weaning rates. The number of breeders in the supplemented scenarios was reduced in line with their higher average liveweight (reflecting the higher pasture intakes resulting from the supplement) so that grazing pressure was kept constant across scenarios.

Each supplementation scenario was modelled to include the impacts of implementing the change. Cows were fed the supplement in the first year, their reproduction efficiency and body weight did not change until the second or subsequent years and extra weaners produced by the supplement feeding program did not add to the returns of the property until they were sold. Herd structures changed as reproduction efficiency and mortality rates changed and cows and heifers were either culled or retained to maintain the same grazing pressure while adjusting to the new herd target

Effect of supplementing a Marginal P herd

Table 49 indicates the performance of the Marginal P breeding herd without a supplement. Breeders in a Marginal P herd without supplement had an average weight in the paddock of 450 kg, an average sale weight of 430 kg and a mortality rate of 4%. Conception, mortality and calf loss rates combine to achieve an average weaning rate of 72.06%.

Table 49 - Reproduction performance for a Marginal P breeding herd without supplement (Scenario 1)

Parameter	Heifers	1st lactation cows	2nd lactation cows	Mature	Aged
Conception rate	80%	69%	80%	80%	79%
Foetal / calf loss	10%	7%	6%	6%	5%
Mortality	-	4%	4%	4%	4%

a) Supplementing with P in the wet season (Scenario 2)

The assumptions for the improvement applied in the wet P supplemented herd model were:

- conception rates in the maiden heifers were unchanged as they have been run on buffel to first mating,
- 5% greater conception rates were achieved in the remaining breeders (77%),
- mortality rates fell from 4 to 2% in all breeder classes fed the supplement,
- cull cows achieved 10 kg heavier liveweights at sale (430 cf. 440 kg) and were 10 kg heavier in the paddock on average (450 cf. 460 kg),

- steers and cull heifers achieved the same sale weights with or without the supplement,
- other than the supplement costs incurred by the marginal P herd all other treatment costs and prices were identical on per head or per treatment in the 'with' and 'without' supplement models,
- the supplements were fed to all breeding cows retained or sold.

b) Supplementing with N and P in the dry season (Scenario 3)

The assumptions for the improvement applied in the dry season N+P supplemented herd model were:

- conception rates in the maiden heifers were unchanged as they were run on buffel to first mating,
- 5% greater conception rates were achieved in the remaining breeders (77%),
- mortality rates fell from 4 to 2% in all breeder classes fed the supplement,
- cull cows achieved 10 kg heavier liveweights at sale (430 cf. 440 kg) and were 10 kg heavier on average in the paddock (450 cf. 460 kg),
- steers and cull heifers achieved the same sale weights with or without the supplement,
- the dry season only supplement was fed to breeding cows retained in the herd and not to cows that were culled and sold.

c) Supplementing with N and P in the dry season and P in the wet season (Scenario 4)

The assumptions for the improvement applied in the dry season (N+P), wet season P supplemented herd model are the same as the previous responses for supplements fed to breeders in a marginal P herd. That is:

- conception rates in the maiden heifers were unchanged as they were run on buffel to first mating,
- 5% greater conception rates were achieved in the remaining breeders (77%),
- mortality rates fell from 4 to 2% in all breeder classes fed the supplement,
- cull cows achieved 10 kg heavier liveweights at sale (430 cf. 440 kg) and were 10 kg heavier in the paddock (450 cf. 460 kg),
- steers and cull heifers achieved the same sale weights with or without the supplement,
- the dry season supplement was fed to all breeding cows retained in the herd and the wet season supplement was fed to cows either retained or sold.

Effect of supplementing a Deficient P herd

Breeders in a Deficient P herd without supplement had an average weight in the paddock of 435 kg, an average sale weight of 410 kg and a mortality rate of 8%. Table 50 indicates the performance of the Deficient P breeding herd without a supplement program. Conception, mortality and calf loss rates combine to achieve an average weaning rate of 67.24%.

Table 50 - Reproduction performance for a Deficient P breeding herd without supplement (Scenario 5)

Parameter	Heifers	1st lactation cows	2nd lactation cows	Mature	Aged
Conception rate	80%	80%	65%	75%	70%
Foetal / calf loss	10%	7%	6%	6%	5%
Mortality	-	8%	8%	8%	8%

a) Supplementing with P in the wet season (Scenario 6)

The assumptions for the improvement applied in the Deficient P herd model supplemented only in the wet season with a P supplement were:

- conception rates in the maiden heifers were unchanged as they were run on buffel to first mating,
- 6% greater conception rates were achieved in the remaining breeders (73%),
- mortality rates fell from 8 to 5% in all breeder classes fed the supplement,
- 15 kg heavier liveweights were achieved at sale for cull cows and breeders (410 cf. 425 kg) and they were 15 kg heavier in the paddock (435 cf. 450 kg),
- steers and heifers achieved the same sale weights with or without the supplement,
- the supplement was fed to all breeding cows retained or sold.

b) Supplementing with N and P in the dry season (Scenario 7)

The assumptions for the improvement applied in the dry season N+P supplemented herd model were:

- conception rates in the maiden heifers were unchanged as they were run on buffel to first mating,
- 5% greater conception rates were achieved in the remaining breeders (72%),
- mortality rates fell from 8% to 6% in all breeder classes fed the supplement,
- cull cows achieved 10 kg heavier liveweights at sale (410 cf. 420 kg) and were 10 kg heavier on average in the paddock (435 cf. 445 kg),
- steers and cull heifers achieved the same sale weights with or without the supplement,
- the dry season supplement was fed only to cows kept after post weaning culling.

c) Supplementing with N and P in the dry season and P in the wet season (Scenario 8)

The assumptions for the improvement applied in the Deficient P herd model supplemented both wet and dry seasons were:

- conception rates in the maiden heifers were unchanged as they were run on buffel to first mating,
- 8% greater conception rates were achieved in the remaining breeders (75%),

- mortality rates fell from 8 to 3% in all breeder classes fed both supplements,
- 20 kg heavier liveweights were achieved at sale for cull cows (410 cf. 430 kg) and they were 20 kg heavier in the paddock (435 cf. 455 kg),
- steers and heifers achieved the same sale weights with or without the supplement,
- the dry season supplement was fed to all breeding cows retained in the herd and the wet season supplement was fed to cows either retained or sold.

Effect of supplementing an Acute P herd

Breeders in an Acute P herd without supplement had an average weight in the paddock of 428 kg, an average sale weight of 400 kg and a mortality rate of 12%. Table 51 indicates the performance of the Acute P breeding herd without a supplement program. Conception, mortality and calf loss rates combined to achieve an average weaning rate of 57.04%.

Table 51 - Reproduction performance for an Acute P breeding herd without supplement (Scenario 9)

Parameter	Heifers	1st lactation cows	2nd lactation cows	Mature	Aged
Conception rate	80%	45%	60%	60%	55%
Foetal / calf loss	10%	7%	6%	6%	5%
Mortality		12%	12%	12%	12%

a) Supplementing with P in the wet season (Scenario 10)

The assumptions for the improvement applied in the Acute P herd model supplemented over the dry season were:

- conception rates in the maiden heifers were unchanged as they were run on buffel to first mating,
- 15% greater conception rates were achieved in the remaining breeders (72%),
- mortality rates fell from 12 to 7% in all breeder classes fed the supplement,
- 18 kg heavier liveweights were achieved at sale for cull cows (400 cf. 418 kg) and they were 17 kg heavier in the paddock (428 cf. 445 kg),
- steers and heifers achieved the same sale weights with or without the supplement,
- the wet season supplement was fed to all cows whether culled or retained.

b) Supplementing with N and P in the dry season (Scenario 11)

The assumptions for the improvement applied in the dry season N+P supplemented herd model were:

- conception rates in the maiden heifers were unchanged as they were run on buffel to first mating,
- 10% greater conception rates were achieved in the remaining breeders (67%),
- mortality rates fell from 12 to 8% in all breeder classes fed the supplement,

- cull cows achieved12 kg heavier liveweights at sale (400k cf. 412 kg) and were 8 kg heavier on average in the paddock (428 cf. 435 kg),
- steers and cull heifers achieved the same sale weights with or without the supplement,
- the dry season-only supplement was fed to breeding cows retained in the herd.

c) Supplementing with N and P in the dry season and P in the wet season (Scenario 12)

The assumptions for the improvement applied in the Acute P herd model supplemented over both the wet and dry season were:

- conception rates in the maiden heifers were unchanged as they were run on buffel to first mating,
- 16% greater conception rates were achieved in the remaining breeders (73%),
- mortality rates fell from 12 to 5% in all breeder classes fed the supplement,
- 25 kg heavier liveweights were achieved at sale for cull cows (400 cf. 425 kg) and they were 22 kg heavier in the paddock (428 cf. 450 kg),
- steers and heifers achieve the same sale weights with or without the supplement,
- the wet season supplement was fed to all breeding cows and the dry season supplement was fed to cows kept after culling.

2.4.1.2.5 Supplementing first calf heifers to improve re-conception rates

In this strategy, a change in the re-conception rate of first calf, lactating heifers was sought by improving their body weight (relative to the baseline herd) prior to calving with an M8U supplement (molasses with 8% urea by weight). The baseline herd model indicates 78% of first lactation heifers are likely to conceive in the 3-4 year age group compared to 89% and 86% for mature and aged cows respectively, based on CashCow data (McGowan *et al.* 2014). The growth model for the Fitzroy region baseline herd identifies that first calf heifers are likely to average about 550 kg liveweight just prior to calving. The analysis of trial results (Schatz 2010) indicates that feeding these heifers so they are 20 kg heavier in bodyweight at the same time should lift their subsequent conception rates from 78% to 80%. This new conception rate was applied to the base model to identify the investment returns that may be gained by feeding first lactation heifers with a suitable protein supplement.

The adjustment to the first calf heifer conception rate was made and the additional surplus weaner heifers created by the change in reproduction efficiency were sold as 2-3 year olds to maintain the same grazing pressure and culling strategy as the baseline herd. The existing conception rates for heifers and age groups older than the 3-4 year age group were maintained at the same level. Feeding the M8U supplement was considered unlikely to change the overall average sale weight of culls cows from the herd or the grazing pressure applied.

The overall weaning rate (from cows kept) for the herd changed from 77.6% to 77.96%. The breeder herd with the heifer feeding strategy produced about three more weaners/annum on average and total female sales increased by 2/annum due to the improved efficiency of the breeding herd.

The calculation of the expected feeding cost of the M8U supplement is shown in Table 52. Capital expenditure of $5,000 was required for troughs and feeding out equipment.

Table 52 – Calculation of feeding costs for pregnancy tested in calf (PTIC), 2-3 year age group heifers

Parameter	**Value**
Number of PTIC heifers to be fed	110
Average body weight (kg)	550
Food consumed (0.4% liveweight; kg/head.day)	2.2
Number of days to be fed	100
Total intake of supplement (kg/head.day)	220
Cost of supplement ($/t landed)	$280
Total supplement fed (t)	24
Total cost of supplement ($)	$6,776
Cost of feeding out (twice/week)	
Wages and fuel for 1 feeding out	$50
Total cost of feeding out the supplement	$1,429
Total cost of the supplement and the feeding out	*$8,205*
Cost per head fed	*$74.59*

2.4.1.3 Marketing options

2.4.1.3.1 Organic beef

This organic beef scenario investigated the implementation of organic certification and subsequent economic outcomes for a grazing business. Adaptations from the baseline herd included the following:

- a reduction in grazing pressure by reducing total AE carried by 20%,
- removal of the costs of chemical control of cattle tick and drought feeding,
- adding the one-off cost for certification ($3,500) and the annual cost of auditing ($1,182),
- Changing the prices of steers and heifers from the third year to reflect an estimated organic market price premium of 25%.

Reducing the grazing pressure was assumed to remove the requirement for supplementation or drought feeding. The reduction in AEs of 20% has been previously seen as reasonable in other economic analysis undertaken by DAF economists and beef producers assessing the conversion from traditional production to organic production. The reduction in stocking rate was predicted to improve diet quality of cattle and allowed the herd to be fully sufficient on pastures without mineral supplements.

The organic steer prices were based on the JBS Rockhampton abattoir organic price grid. Cull cow sale prices were kept the same in both models as organic cow prices have been variable and the ability of the cow herd to achieve organic status in the medium term was unknown.

The overall herd productivity in terms of weaning rates, growth rates, mortality rates, sale weights were assumed to be unchanged.

2.4.1.3.2 EU market

This strategy considers the benefits of producing slaughter and feed-on steers and heifers specifically for the EU market. Two options were examined (1) split the steers at their current sale weight and sale date and sell the lead to the abattoirs and the tail through the sale yards, and (2) sell the steers earlier and lighter at the saleyards.

The first sale option required the current baseline herd steers to be split into two groups at the current paddock sale weight of 495 kg. The lead were sent to the abattoirs with the tail sent to the sale yards. Table 53 shows the expected split up of the sale steers based on a cut-off weight of 475 kg for the slaughter steers. This cut-off weight was assumed to achieve a minimum carcass weight for the group of 240 kg after transport weight losses were accounted for. Approximately 67% of the steers were sent to slaughter with 33% sent to the sale yards.

The slaughter steers were expected to average 522 kg in the paddock, lose 5% of that weight in transport to the abattoirs, have a dressing percentage 53% and achieve an average carcass weight of 263 kg. The expected price at slaughter was $3.678/kg dressed weight or $1.95/kg liveweight, which was 15 c/kg liveweight price premium, consistent with long term JBS Dinmore data.

The steers sent to the saleyards were expected to have an average weight in the paddock of 441 kg liveweight. They lost 5% of paddock liveweight in transit and achieved $2.02/kg liveweight at the saleyards. This saleyards price was 15 c/kg more than the steers sold in the baseline scenario that were not EU accredited. The usual selling costs associated with the saleyards were applied.

Table 53 - Splitsal analysis of EU steer sale groups when sold at the same weight and sale date as for the baseline herd

Parameter	**Value**
Average liveweight of total group (kg)	495
Standard deviation of weights (kg)	50
Liveweight range in total group for 95% of group, assuming a normal distribution (kg)	397-593
Cut-off weight for slaughter steers (kg)	475
% of total group above cut-off weight	67
Average weight of heavier group (kg)	522
Average weight of lighter group (kg)	441

For heifers to achieve the EU premium they have to be culled 12 months earlier than assumed to occur for the baseline herd. At this age they achieve a 15 c/kg premium but the herd had to be restructured to account for the change in grazing pressure brought about by the reduced sale age for cull heifers. On average, about 38% of the yearling heifers were be culled. Cull cows were sold at unchanged weights and prices compared to the baseline herd.

There was a 2 year lag between the decision to gain EU accreditation and when the improved prices were received (Table 54). This allowed time for all steers potentially treated with HGP at weaning to leave the property. It was expected to cost about $10,000 in time and effort to get the property and herd accredited to EU status.

Table 54 - EU steers sale price

Category	**Paddock weight (kg)**	**Percentage (%)**	**Sale weight (kg)**	**Total kg**	**Price ($/kg liveweight)**
EU slaughter steers	522	67	495.90	33,225	$1.95
EU feed-on	441	33	418.95	13,825	$2.02
Weighted average	**495**		**470**	**47,050**	

Table 55 indicates the calculation of the average selling price and selling costs for the two groups of steers turned off.

Table 55 - Calculation of net price for EU steers

Category	**Sale value per head**	**Total selling costs per head**	**Average sale value less selling costs per head**
EU slaughter steers	$967.01	$58.70	-
EU feed-on steers	$846.28	$76.13	-
Weighted average	$927.17 ($1.97/kg liveweight)	$64.45	$862.71

The second option with the EU strategy was to gain EU accreditation and sell the steers in two cohorts as feed-on steers. Table 56 shows the lead of the steers (29%) of the mob being sold in August when the steers were 21 months old. They were expected to average 471 kg. The remaining steers were held for a further 183 days when they were also sold with an average weight of 471 kg. The feed-on steers were sent to the saleyards and had an average weight in the paddock of 471 kg liveweight. They lost 5% of this in transit and achieved $2.02/kg liveweight at the saleyards. This was 15 c/kg more than the steers sold in the baseline scenario that were not EU accredited. The usual selling costs associated with the sale yards were applied. The heifer cull age was also reduced by 12 months and the herd restructured to account for the younger age of sale for 29% of the steers and the cull heifers. For Option 2, in addition to a scenario where the price premium for sale steers and heifers was maintained over 30 years, a scenario where the price premium was reduced by half, or 7.5 c/kg liveweight for the period of the analysis, was examined.

Table 56 - Splitsal analysis of EU steer sale groups for a younger age of turn-off compared to the baseline herd

Parameter	**Value**
Average liveweight of total group (kg)	413
Standard deviation of weights (kg)	50
Liveweight range in total group for 95% of group, assuming a normal distribution (kg)	315-511
Cut-off weight for first sale group (kg)	440
% of total group above cut-off weight	29
Average weight of heavier group (kg)	471
Average weight of lighter group (kg)	389
Expected weight gain of lighter group (kg)	82
Weight of lighter group by next age (kg)	471

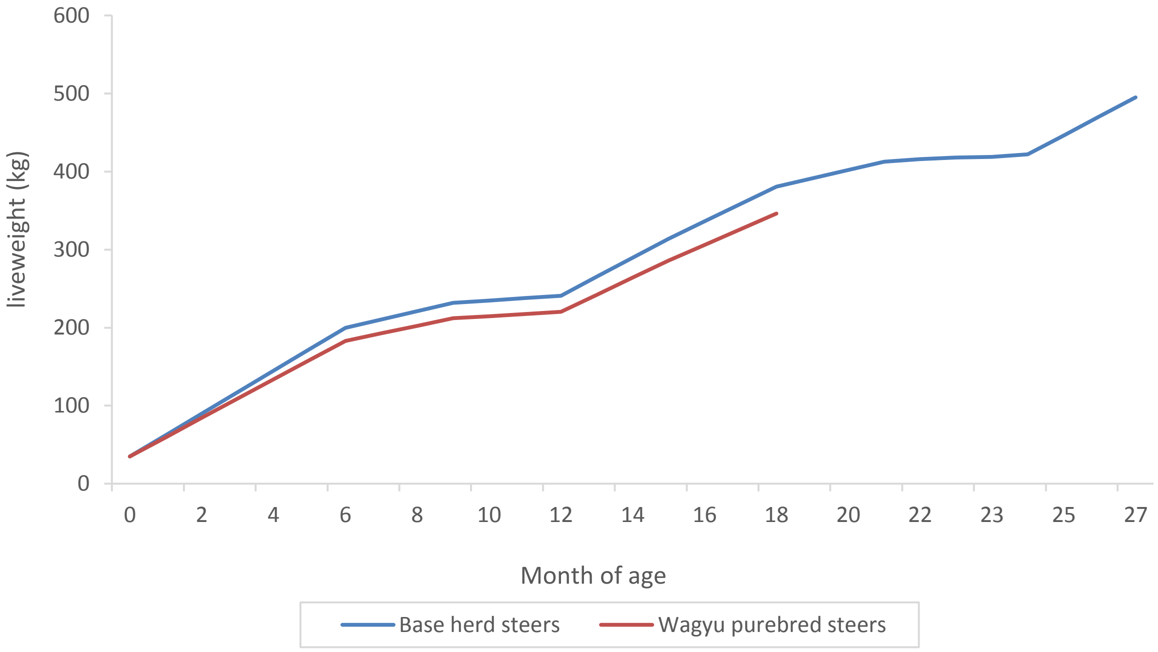
2.4.1.3.3 Wagyu beef

This scenario converted the *B. indicus* crossbred breeding herd to Wagyu genetics over time by replacing the current bull herd with fullblood Wagyu bulls. No Wagyu females were purchased and the Wagyu content of the breeding herd changed as replacement heifers with Wagyu content were retained with the objective of changing the baseline herd to a purebred Wagyu herd. A purebred Wagyu is one which has been bred up from another breed whilst a fullblood Wagyu consists of 100% Wagyu genetics and results of a mating between two fullblood parents. A purebred Wagyu is achieved after four generations of using a fullblood parent crossed with another breed.

The normal culling strategy was continued and replacement heifers were first mated at 18- 24 months old. It was assumed that purebred Wagyu steers and heifers had growth rates 10% lower than the baseline herd average growth rates. Growth rates of Wagyu crossbred cattle remained the same as the baseline herd until the 4th generation when considered a purebred.

The average price of the Wagyu fullblood bulls was set at $7,000/head, ca. 40% more on average than the baseline herd replacement bull price. Purchasing the 22 Wagyu bulls cost $160,000, including transport costs. The current breeding bull herd was sold for $2,500 per bull giving a net cost of replacing the bull breeding herd of $105,000. The assumption was that half the current bulls were sold to industry and half sold to the abattoir. Purebred Wagyu steers were sold at a younger age (18 months) and lighter weight (346 kg) than the baseline herd feed-on steers (27 months and 495 kg, respectively; Figure 11).

Figure 11 - Estimated growth path for Wagyu purebred steers and the baseline herd B. indicus crossbred steers



Additional treatment costs were incurred to maintain the productivity of the purebred Wagyu herd (Table 57). Tick control costs were increased plus additional supplements and vaccines were required. A DNA test to confirm Wagyu genetic content prior to sale were required at a cost of $50/weaner.

Table 57 - Wagyu purebred treatment costs

Treatment	Weaners		Females						Steers		Bulls
	Heifers	**Steers**	**1-2 yrs kept**	**1-2 yrs sold**	**2-3 yrs kept**	**2-3 yrs sold**	**3 yrs+ kept**	**3 yrs+ sold**	**1-2 yrs kept**	**1-2 yrs sold**	**kept**
Weaner feed	$15	$15									
NLIS and station tags	$6.50	$6.50	$0.20	$0.20	$0.20	$0.20	$0.20	$0.20	$0.20	$0.20	$0.20
Clostridial vaccines	$3.04	$1.10									
Leptospirosis vaccine			$2.34		$1.17		$1.17				$1.20
Tick control	$9.67	$9.67	$13.75	$13.75	$17.00	$17.00	$17.00	$17.00	$13.75	$11.20	$20.00
Vibrio vaccine bulls											$10.00
Drought feeding			$5.00		$6.00		$7.50				$10.00
Pregnancy testing			$5.00	$5.00	$5.00	$5.00	$5.00	$5.00			
Tick fever vaccine	$4.93	$4.93									
Three day vaccine											$10.00
Supplements	$8	$8	$10.00		$10.00		$10.00				$10.00
DNA test	$50	$50									
Cost/group	*$106.80*	*$96.54*	*$41.49*	*$18.95*	*$44.57*	*$22.20*	*$46.07*	*$22.20*	*$13.95*	*$11.40*	*$66.60*

Compared to the baseline herd, the reproductive efficiency of the Wagyu purebred herd was unchanged but the mortality rates were increased by 25% across all classes of livestock. The change of age of turnoff of steers resulted in a change in herd structure as shown below in Table 58.

Table 58 - Breeder herd components for the baseline herd and the alternative herd with purebred Wagyu

Breeder herd component	**Base herd**	**With Wagyu**
Total cows and heifers mated	642	794
Calves weaned	498	616
Weaner steers	249	308

Cull heifers attracted a price premium from Year 5 of the transition which increased in equal increments to a 100% price premium by Year 10. Sale steers achieved a 100% price premium in year 7 of the transition and this was maintained to the end of the investment period. Cull cows did not receive a price premium. Labour costs were increased by $10,000 per annum to cover the additional mustering and handling costs associated with Wagyu cattle in this region.

As it is difficult to have confidence in significant price premiums being continued into the long term future, with any form of beef production, the impact of a reduced price premium was tested by reducing the price premium back to zero over 6 years, from year 10 and from year 20 of the analysis.

2.4.2 Assessing the potential impact of drought on the herd as well as the effect of herd structure on drought risk and profitability

The potential effect of the drought on the mortality and conception rates of components of the baseline, case-study herd was assessed by applying the prediction equations developed by Mayer *et al.* (2012), for breeding cattle in northern Australia, to the herd output data from the Breedcow model (Holmes *et al.* 2017). While breeder liveweight, body condition score (BCS; range 0-9)) and age were key factors affecting mortality and conception rates, Mayer *et al.* (2012) identified that variation in the parameter ‘body condition ratio’ (BCR) could be used to model the effect of a change in BCS on mortality and conception rates in mature female cattle. BCR is defined as the ratio of current liveweight to expected body weight for age of animals in average condition (‘N’). ‘N’, in turn, is calculated using an exponential equation describing weight from birth to maturity, given adequate nutrition and relies on use of a ‘standard reference weight’ (SRW) which is defined as the weight of a mature animal of average body condition. The relationship between breeder BCS and BCR derived by Mayer *et al.* (2012) was used to determine the expected liveweight at each BCS and BCR increment, for a herd with an assumed SRW of 500 kg which was indicated as representative for contemporary Brahman cattle in Queensland by Mayer *et al.* (2012); (Table 59). Potential effects of drought on steer mortality were assessed with reference to available literature. The effects of herd structure on the capacity of the enterprise to respond to drought and on profitability were examined by changing the age of turnoff of the steer component on the herd within the Breedcow model (Holmes *et al.* 2017).

Table 59 – Equivalence of breeder body condition score (BCS) to body condition ratio (BCR) and calculated liveweight based on a breeder standard reference weight (SRW) of 500 kg liveweight; calculated using equations from Mayer et al. (2012)

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

Description of animal	BCS value (scale 0-9)	Nominal BCR range	Calculated BCR	Calculated liveweight (kg)
Emaciated	0	0.5–0.6	0.50	250
Very poor	1	0.6–0.7	0.60	300
Poor	2	0.7–0.8	0.70	350
Backward store	3	0.8–0.9	0.80	400
Store	4	0.9–1.0	0.90	450
Forward store	5	1.0–1.1	1.00	500
Prime	6	1.1–1.2	1.10	550
Fat Prime	7	1.2–1.3	1.20	600
Fat	8	1.3–1.4	1.30	650
Over-fat	9	1.4–1.5	1.40	700
Over-fat	9	1.4-1.5	1.50	750

2.4.3 Decision making in response to drought and in the drought recovery phase

These choices were assessed with reference to the Breedcow herd model output for the baseline herd and with use of the Cowtrade, Bullocks and Splitsal programs within the Breedcow and Dynama suite (Holmes *et al.* 2017), where relevant.

3 Results and discussion

3.1 Strategies available to prepare for drought by improving profit and business resilience

3.1.1 Improving steer growth rates

3.1.1.1 Improving steer growth path performance with leucaena

The effect of the leucaena strategy on returns to the business over the longer term (30 years) was that the profitability of the beef system was substantially improved compared to the baseline, case-study property, with an NPV of $620,063 generated over 30 years; (Table 60). The annualised NPV of $40,336 approximately represents the average annual change in profit over 30 years resulting from the management strategy. The implementation of leucaena for steers resulted in a substantial peak deficit for the enterprise of -$145,722 and a payback period of 7 years.

Table 60 - Marginal returns from an investment in leucaena

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Interest rate for NPV	5.00%
NPV	$620,063
Annualised NPV	$40,336
Peak deficit (with interest)	-$145,722
Year of peak deficit	4
Payback period (years)	7
IRR	33.51%

If additional breeders were purchased at the beginning of Year 4 to fully utilise the leucaena from Year 5 of the analysis (rather than waiting for natural herd increase to occur) then the NPV and IRR were improved (Table 61). However, the peak deficit was also increased with strategy.

Table 61 - Marginal returns for an investment in leucaena and additional females

Factor	Value
Period of analysis (years)	30
Interest rate for NPV	5.00%
NPV	$709,207
Annualised NPV	$46,135
Peak deficit (with interest)	-$190,539
Year of peak deficit	4
Payback period (years)	7
IRR	36.91%

These results for investment in leucaena-grass pastures are in agreement with those from gross margin analysis conducted for commercial properties, and whole-farm case study analyses, where leucaena-grass systems were identified as the most profitable forage option for beef cattle production in central Queensland (Bowen *et al.* 2015*b*; 2016). The modelling study of Bowen and Chudleigh

(2017) also showed that purchase of additional breeders was necessary to optimise the profitability of leucaena-grass investments.

3.1.1.2 Improving steer growth path performance with shrubby legumes such as desmanthus

The effect of the desmanthus strategy on returns to the business over the longer term (30 years) was that the profitability of the beef system was substantially improved compared to the baseline, case-study property, with an NPV of $411,659 over 30 years; (Table 62). The annualised NPV of $26,779 represents the approximate average annual change in profit over 30 years resulting from the management strategy. The implementation of desmanthus for steers resulted in a substantial peak deficit for the enterprise of -$103,212 and a payback period of 8 years.

It should be noted that these predicted returns are dependent on largely untested assumptions concerning the productivity of shrubby legumes under grazing conditions in central Queensland. However, these results for desmanthus are in line with positive gross margin results for the more established shrubby legume, butterfly pea, when grown commercially on producer properties in central Queensland. As reported in Bowen *et al.* (2018*a*) the average paddock gross margin for butterfly pea was 1.5 times that for perennial grass-only pasture and 0.77 that of leucaena-grass pastures.

Table 62 - Marginal returns from an investment in desmanthus
All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Interest rate for NPV	5.00%
NPV	$411,659
Annualised NPV	$26,779
Peak deficit (with interest)	-$103,212
Year of peak deficit	4
Payback period (years)	8
IRR	25.80%

3.1.1.3 Improving steer growth path performance with forage oats

Investing in a strategy of growing forage oats to sell feed-on steers at a younger age appears likely to substantially reduce profitability of the beef enterprise compared to selling the steers later off buffel, with a -$530,671 NPV over 30 years); (Table 63). These results are in agreement with our previous gross margin and whole farm analysis conducted for commercial properties in central Queensland (Bowen *et al.* 2015*b*, 2016). They are also in agreement with modelled whole farm scenario analysis for central Queensland conducted by Bowen and Chudleigh (2017) where the incorporation of forage oats into a buffel grass-only growth path for steers always reduced the profitability of both a steer turnover and breeding and finishing enterprise. In contrast to the present study, the analysis of Bowen and Chudleigh (2017) did not account for the proportion of years unlikely to be suitable for planting oats (33% of years) but still found investing in forage oats to reduce the profitability of beef enterprises. Furthermore, as also found by Bowen and Chudleigh (2017), investment in forage oats substantially increased peak deficit levels and financial risk with the investment failing to general sufficient returns to repay the additional borrowings during the 30 years of the investment period. Our results are in contrast, however, with results of enterprise-scale bio-economic modelling, which indicated potentially large economic benefits from utilising small areas of irrigated annual forages, including oats, as part of beef production systems in central Queensland and northern Australia in general (Bell *et al*. 2014; Hunt *et al*. 2014*a*). The latter studies did not consider the implementation phase for the forage strategies or the marginal returns on the investment at the property level. The results of the present study are in line with results and conclusions of Bowen and Chudleigh (2017) and Bowen *et al.* (2018*a*) in indicating that investment in annual forage crops such as forage oats result in lower profitability than perennial legume-grass pastures and, particularly, leucaena-grass pastures under central Queensland conditions. Relatively high forage costs (compared with perennial legume-grass pastures), combined with lower productivity, appear to be the primary factors.

Table 63 - Marginal returns from an investment in forage oats

All terms defined in the Glossary of terms and abbreviations

Factor	**Value**
Period of analysis (years)	30
Interest rate for NPV	5.00%
NPV	-$530,671
Annualised NPV	-$34,521
Peak deficit (with interest)	-$1,544,320
Year of peak deficit	never
Payback period (years)	never
IRR	n/a

3.1.1.4 Custom feedlotting steers

The predicted investment returns from implementing a strategy of custom feedlotting, feed-on weight steers suggest that this strategy is not likely to be a worthwhile ongoing venture for this property (Table 64). The large negative gross margin per head of ca -$244 indicates that grain prices would have to decrease substantially and/or the price margin ($/kg) between cattle entering and exiting the feedlot improve substantially, relative to current prices, for this strategy to be profitable.

Table 64 - Marginal returns from an investment in custom feedlotting

All terms defined in the Glossary of terms and abbreviations

Factor	**Value**
Period of analysis (years)	30
Interest rate for NPV	5.00%
NPV	-$720,062
Annualised NPV	-$48,841
Peak deficit (with interest)	-$2,166,733
Year of peak deficit	never
Payback period (years)	never
IRR	n/a

3.1.1.5 Hormonal growth promotants for steers

The predicted investment returns from implementing a strategy of HGP use from weaning until sale as feed-on steers at 27 months of age and using the same price for sale steers as for the baseline herd were positive (Table 65). The small peak deficit was caused by the requirement to adjust breeder numbers and the delay between spending on HGP's and selling the first lot of heavier steers.

Table 65 - Marginal returns for HGP use – heavier weight at 27 months and same price for sale steers as for baseline herd

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Interest rate for NPV	5.00%
NPV	$196,935
Annualised NPV	$10,794
Peak deficit (with interest)	-$5,063
Year of peak deficit	1
Payback period (years)	2
IRR	140.32%

The predicted investment returns from implementing a strategy of HGP use from weaning until sale as feed-on steers at 27 months of age but using a reduced price for sale steers (10 c/kg liveweight reduction) is shown in Table 66. The reduced sale price for steers, resulting from steers exceeding the feed-on market weight range (i.e. getting too heavy), made the use of HGPs unprofitable in this scenario.

Table 66 - Marginal returns for HGP use – heavier weight at 27 months and reduced price for sale steers compared to the baseline herd

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Interest rate for NPV	5.00%
NPV	-$12,386
Annualised NPV	-$806
Peak deficit (with interest)	-$33,182
Year of peak deficit	never
Payback period (years)	never
IRR	-14.01%

The predicted investment returns from implementing a strategy of HGP use from weaning until sale as feed-on steers at the same weight (rather than age) as the steers in the baseline herd is shown in Table 67. Selling younger steers caused proportionally more cow beef to be sold out of the herd. This resulted in some higher priced steer beef being substituted in sales by some lower priced cow and heifer beef. The result was, that if the steer beef from younger HGP-treated steers was assumed to sell at the same price as for the baseline herd, then incurring the additional cost of treating steers with HGP reduced the economic performance of the beef herd. Given the relatively small difference in steer sale weight and age between the baseline herd and the herd with steers treated with HGP but sold younger, it seems that the assumption that prices will not change is likely to be correct.

Table 67 - Marginal returns for HGP use – younger sale age but same price for sale steers compared to the baseline herd

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Interest rate for NPV	5.00%
NPV	-$84,452
Annualised NPV	-$5,494
Peak deficit (with interest)	-$231,803
Year of peak deficit	never
Payback period (years)	never
IRR	n/a

These results demonstrate the importance of getting the target market and the herd structure right when applying HGPs to improve steer growth rates. If the steers are sold earlier at the same target feed-on weight, the associated herd structural changes (proportionally more female beef being sold) could make the economics unattractive. If a lower price is achieved at a heavier sale weight, the economics would also be severely challenged.

3.1.2 Improving breeder reproductive performance

3.1.2.1 Better genetics for breeder fertility

The beef enterprise was worse off with the investment in genetically superior bulls to change the average weaning rate by 6%, when changeover costs were incurred (Table 68). The extended period of time to the peak deficit and the lack of a payback year in the first 30 years suggests that investment returns would not substantially improve with further extension of the analysis. It appears that if bulls capable of providing the level of change applied in the scenario analysis were available, and a changeover cost was incurred, their introduction would reduce economic performance and the producer would be unable to justify a premium for the different genetics. Seed stock producers would therefore also need to be careful about incurring extra costs to identify the genetically different bulls. Furthermore, beef producers have to be aware that the time taken to change the reproduction efficiency of the herd through selecting only replacement bulls with the characteristics described by Burns *et al.* (2014) would be many decades and any reduction in other herd performance parameters due to the introduction of the genes for changed reproduction efficiency would quickly negate any potential for economic gains.

There appears to be an effect of diminishing returns in this analysis. The weaning rates (77% from cows mated, as per the median CashCow data of McGowan *et al.* (2014) for the Central Forest region) prior to the introduction of the genetically superior bulls is a contributor to this effect. When the same analysis was conducted for a herd with 65% weaning rate which is less than the bottom 25th percentile reproduction performance for the Central Forest region of McGowan *et al.* (2014), the annualised NPV was -$3,178 (data not presented) indicating no change in the ranking of scenarios, or the conclusion, when a lower baseline performance was used within the range measured for the Fitzroy NRM region in survey data. However, when a much lower baseline than that relevant to the Fitzroy was examined for the Northern Gulf region (58% weaning rate and lower steer and heifer growth rates) the beef enterprise was slightly better off with the investment in better genetics for breeder fertility (annualised NPV: $4,114; Bowen *et al.* (2018*b*)). Regardless, the marginal return on extra capital (9.17%) was not inviting for what could be considered to be a fairly risky investment with uncertain outcomes and long payback period (17 years for Northern Gulf example). This effect of diminishing returns is further illustrated by comparing the % change in herd gross margins resulting from implementing the genetic improvement strategy. The increase in herd gross margin for the Northern Gulf property was ca. $15,000/annum (8.8% improvement) between Year 1 and Year 12 as a result of the 5.1% point increase in herd weaning rates. The corresponding increase in herd gross margin for the Fitzroy NRM region property was ca. $3,000/annum (1.2% improvement) resulting from a 5.9% point improvement in weaning rates. This eventual additional benefit for the Fitzroy NRM property was insufficient to ever offset the changeover costs incurred at the beginning of the period plus the reduced value of the herd at the end of the analysis and led to the negative marginal return.

If, instead of replacing all herd bulls in Year 1 of the analysis, bulls were replaced at the usual rate but with genetically different bulls and no extra cost, a small positive annualised NPV was obtained: $685 with a 9-year payback period (data not presented). This result doesn't change the conclusion that genetic improvement of breeder fertility in the Fitzroy will not result in a substantial improvement in economic performance of beef enterprises. However, the results indicate that it is not an unreasonable strategy to replace herd bulls as they come due with genetically superior bulls for breeder fertility, given they can be purchased for the same price as regular bulls and no changeover costs are incurred.

Table 68 - Marginal returns for investment in genetically superior bulls to improve breeder fertility

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Interest rate for NPV	5.00%
NPV	-$50,196
Annualised NPV	-$3,265
Peak deficit (with interest)	-$126,309
Year of peak deficit	never
Payback period (years)	never
IRR	-11.65%

3.1.2.2 Investing to reduce foetal/calf loss

Table 69 presents the results of the investment analysis to achieve a 50% reduction in calf loss in heifers and first lactation cows at cost levels of $5, $7.50 and $10 per female treated per annum plus upfront capital expenditure of $20,000, $30,000 and $40,000.

Table 69 - Marginal returns for investing to achieve a 50% reduction in calf loss in heifers and first lactation cows

All terms defined in the Glossary of terms and abbreviations

Factor	**Investment type**					
	$5/head. annum	**$7.50/head. annum**	**$10/head. annum**	**$20,000 capital**	**$30,000 capital**	**$40,000 capital**
Period of analysis (years)	30	30	30	30	30	30
Interest rate for NPV	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
NPV	$7,289	-$6,427	-$20,142	$15,672	$6,148	-$3,376
Annualised NPV	$474	-$418	-$1,310	$1,019	$400	-$220
Peak deficit (with interest)	-$1,829	-$17,502	-$55,927	-$20,000	-$30,000	-$40,451
Year of peak deficit	5	never	never	2	2	4
Payback period (years)	6	never	never	12	n/a	never

The analysis indicates that no more than $5/head.annum should be spent on reducing calf/foetal loss by 50% in the heifers and first lactation cows if a return on the funds invested was being sought. Even then, a successful treatment would only increase the annualised NPV by about $500/annum over the longer term. Spending more than $7.50 per treated female per annum, or gaining a reduction in calf loss of less than 50% in the classes of female treated, would make any investment unlikely to produce a positive return on funds invested.

For this size of herd and enterprise, expenditure of up to $20,000 as upfront capital expenditure with no additional ongoing expenses appears worth further consideration on the basis that calf foetal loss in the two classes of females is reduced by at least 50%. The maximum amount of capital that can be invested upfront to resolve a calf loss issue is directly related to the size and current productivity of the herd together with the level of change in productivity achieved. On the other hand, the size of the herd would not impact the benefits arising from applying per head treatment costs as only by the current level of herd productivity and the change in herd productivity would impact benefits. It is very important to recognise that the likely benefit of any combination of upfront capital and expenditure on additional livestock treatments should not be inferred from this analysis.

3.1.2.3 Pestivirus management

3.1.2.3.1 Vaccinating for pestivirus in a high prevalence herd

Annual vaccination of all breeding females

The beef enterprise with a high prevalence of pestivirus was slightly better off with a long term vaccination program that treated all breeding females, although it did take 15 years for the investment in the vaccine to break-even (Table 70). The assumptions required a changeover from the performance of a herd with a high prevalence of pestivirus to a new level of reproduction efficiency. This caused more heifers and cows to be retained as proportionally more became pregnant. The result of this change in herd structure was that the peak deficit occurred 6 years after the vaccination program commenced. It can be inferred that herds that have a lower impact of the disease, than the 2% reduction in average conception rate assumed here, would be unlikely to gain a positive benefit from an ongoing vaccination program.

Table 70 - Marginal returns for investment to reduce the incidence of pestivirus in a high prevalence herd – annual vaccination of all breeding females

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Interest rate for NPV	5.00%
NPV	$15,750
Annualised NPV	$1,025
Peak deficit (with interest)	-$21,219
Year of peak deficit	7
Payback period (years)	15
IRR	9.22%

Vaccination of heifers only

A long term vaccination program that just treated the replacement heifers resulted in the beef enterprise being better off, with 6 years required for the investment in the vaccine to break-even (Table 71). Hence, if a herd with a high prevalence of pestivirus could eliminate losses due to BVDV by vaccinating just the heifers, the benefits of the vaccination program are likely to more than double the option of vaccinating the entire breeding herd. It can be inferred that herds that do not show an immediate reduction in the impact of the disease in the remainder of the herd when just the heifers are vaccinated are likely to show benefits of a vaccination program somewhere between the two options examined above.

Table 71 - Marginal returns for investment to reduce the incidence of pestivirus in a high prevalence herd – vaccination of heifers only

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Interest rate for NPV	5.00%
NPV	$56,614
Annualised NPV	$3,683
Peak deficit (with interest)	-$3,276
Year of peak deficit	6
Payback period (years)	6
IRR	n/a

3.1.2.3.2 Vaccinating for pestivirus in a naive herd

Reducing the number of weaners produced from 498 to 349 in the baseline herd model in 1 year resulted in an expected impact on herd profit of ca. $102,000 (un-discounted). This total value included reduced steer sales sometime after the outbreak and the retention of additional heifers to maintain breeder numbers. In this example the annual probability of the occurrence of the costs associated with a disease outbreak is once in 30 years and it is assumed that if it occurs in the planning period it will not re-occur. Therefore, the net revenue losses from a virus outbreak would be $102,000 in total, regardless of when it occurred over the planning period. With the given assumptions about the discount rate and the probability of occurrence in the absence of the investment in disease reduction, prevention or control, this would mean that the expected Present Value of costs of the virus causing the level of impact predicted in a naive herd over the planning period is $40,800.

The alternative for this naive herd is to vaccinate the entire breeding herd and prevent the impact of the virus suddenly spreading through a naive herd. The Present Value of costs for this can be estimated by adding the vaccine cost into the analysis for the full breeding herd from the first year and comparing a treated herd with the (naive) baseline herd without the vaccine cost. In this case the Present Value of the preventative vaccination program for the 30 year investment period is -$78,246. That is the property would be $78,246 worse off in present value terms if it vaccinated to prevent pestivirus compared to not vaccinating and not getting an outbreak.

However, as an expected cost avoided is an expected benefit, the expected benefit of the investment is the difference between the expected additional costs associated with the disease outbreak and the additional costs of preventing the disease. Given these assumptions, a full vaccination program in a naive herd has an expected Net Present Value of -$37,446. This is the difference between the cost of the full vaccination program and the expected cost of a disease outbreak.

Table 72 - Marginal returns for investment to reduce the incidence of pestivirus in a naive herd with a full vaccination program

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Interest rate for NPV	5.00%
NPV	-$37,446
Annualised NPV	-$2,436
Peak deficit (with interest)	n/a
Year of peak deficit	n/a
Payback period (years)	n/a
IRR	n/a

The impact of discounting on the cost and timing of the pestivirus outbreak

A key component of the pestivirus analysis for a naive herd is the lack of knowledge of the timing of a potential outbreak leading us to conclude that we expect it to happen sometime in the next 30 years. If we knew the timing of the event it would be placed in the discounted cash flow budget at the appropriate time with the costs (and benefits) discounted to create a Present Value of the expected impact. For example:

- if the outbreak occurred in Year 1, the Present Value of the costs of an outbreak of the virus would be -$84,963,
- if it occurred in the 15th year, the Present Value of the costs would be -$42,912 and
- if the outbreak did not occur within the 30 year investment horizon, the Present Value of the costs of an outbreak would be $0 as it has no impact on sales within the period of the analysis.

Extending the analysis past a 30 year investment horizon will not substantially change the results. The impact of a 5% discount rate on the Present Value of benefits or costs occurring after year 30 means that their potential occurrence will probably not substantially impact the strategy considered by a decision maker. It may also be difficult to convince beef producers to take into account risks that may randomly occur sometime well into the future when their production system is notoriously dynamic and risky in the short to medium term.

The method of applying a probability weighting to the cost of the outbreak provides a way of comparing alternative courses of action where the timing of events are unknown and they are only likely to occur once in the planning period.

3.1.2.3.3 Summary of profitability of pestivirus management options

The strategies available to address bovine pestivirus include:

1. Do nothing and accept current losses or the risk of an abortion storm.
2. Vaccinate all heifers prior to joining (immunity lasts 12 months). This protects the heifers during their first pregnancy, during which time they should be exposed to the virus and develop their own natural immunity which is lifelong. This should be sufficient for properties with high levels of infection. A course of two vaccinations 4 weeks to 6 months apart is required. Immunity does not develop until after the second dose is administered. The second dose must occur 4 weeks prior to joining begins and the current cost of vaccination is approximately $5 per dose and can be purchased ‘over the counter’.
3. Vaccinate heifers as above and continue to administer annual vaccination to entire breeding herd. This may be necessary for properties with low levels of underlying infection where heifers may not be exposed to the virus naturally and develop their own immunity during their first pregnancy. Annual vaccination provides ongoing insurance against an abortion storm.
4. Autovaccination program using PI animals: This requires the identification of PI animals through blood or ear notch testing and then locking heifers with PI animals at a rate of 3-4% in close contact for 24-48 hours.

The results of the pestivirus analysis are challenging, especially given previous conclusions about the economic importance of the disease by GHD *et al*. (2015). The results indicate that if you have a high prevalence herd you are slightly better off by implementing a vaccination program, but the benefit is probably not measureable. Managers of herds with a high prevalence of the virus probably need to assess the losses occurring due to the virus before they take action. If calf loss is well above expectations and no other likely causes can be identified, then a vaccination program may be worthwhile.

It appears that the manager of a naive breeder herd may be better off closely managing herd biosecurity and taking the risk of an outbreak. There has to be a good reason why the herd is naive given that most herds are not. The manager would need to identify why their herd has that status and then assess whether those factors will continue. More risk averse managers may contemplate a vaccination program starting with the heifers.

3.1.2.4 Improving reproductive performance with inorganic supplements

3.1.2.4.1 Effect of supplementing a Marginal P herd

The expenditure of a relatively small amount to fix a marginal P deficiency, by providing P in the wet season, produced a relatively large return (Table 73). Doubling the cost of the supplement did not substantially reduce the additional benefits achieved. The 50% reduction in mortality rates in the breeder herd, together with the large improvement in conception rates, made the investment highly profitable.

Table 73 - Marginal returns from supplementing breeders with a Marginal P deficiency: P in the wet season (Scenario 2)

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Interest rate for NPV	5%
NPV	$121,714
Annualised NPV	$7,918
Peak deficit (with interest)	-$1,365
Year of peak deficit	1
Payback period (years)	1
IRR	2796.31%

The feeding of the N+P dry season-only supplement to a Marginal P herd increased the net costs of feeding without any performance improvement above and beyond the feeding of wet season P supplement alone (Table 74). This is even though the cull breeders do not receive the supplement. Although minimal additional funds were invested, the payback period would be a significant deterrent to investment.

Table 74 - Marginal returns from supplementing breeders with a Marginal P deficiency: N and P in the dry season (Scenario 3)

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Interest rate for NPV	5%
NPV	$23,706
Annualised NPV	$1,542
Peak deficit (with interest)	-$21,252
Year of peak deficit	9
Payback period (years)	14
IRR	317.32%

The feeding of the dry season (N+P) and wet season P supplement to a Marginal P herd also increased the net costs of feeding without any performance improvement above and beyond the feeding of wet season P-only supplements (Table 75). The feeding of supplements brought about an early readjustment in herd numbers which released capital.

Table 75 - Marginal returns from supplementing breeders with a Marginal P deficiency: N and P in the dry season and P in the wet season (Scenario 4)

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Interest rate for NPV	5%
NPV	$5,765
Annualised NPV	$375
Peak deficit (with interest)	-$33,892
Year of peak deficit	9
Payback period (years)	1
IRR	243.96%

3.1.2.4.2 The effect of supplementing a Deficient P herd

Table 76 indicates the impact on returns of supplementing cows in a Deficient P herd with wet season P only.

Table 76 - Marginal returns from supplementing breeders in a Deficient P herd: P in the wet season (Scenario 6)

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Interest rate for NPV	5%
NPV	$276,190
Annualised NPV	$17,967
Peak deficit (with interest)	-$4,251
Year of peak deficit	1
Payback period (years)	1
IRR	1162.5%

The feeding of the N+P dry season-only supplement to a Deficient P herd increased the net costs of feeding compared to the feeding of a wet season-only P supplement with all performance parameters lower than those achieved by just feeding a P supplement over the summer (Table 77).

Table 77 - Marginal returns from supplementing breeders in a Deficient P herd: N and P in the dry season (Scenario 7)

All terms defined in the Glossary of terms and abbreviations

Factor	**Value**
Period of analysis (years)	30
Interest rate for NPV	5%
NPV	$138,729
Annualised NPV	$9,025
Peak deficit (with interest)	-$19,692
Year of peak deficit	1
Payback period (years)	1
IRR	347.50%

Table 78 indicates the impact on returns of supplementing cows over the wet and dry seasons in a Deficient P herd. The economic benefits appear likely to be lower than those available if an appropriate supplementation program is implemented in the wet season alone.

Table 78 - Marginal returns from supplementing breeders in a Deficient P herd: N and P in the dry season and P in the wet season (Scenario 8)

All terms defined in the Glossary of terms and abbreviations

Factor	**Value**
Period of analysis (years)	30
Interest rate for NPV	5%
NPV	$249,128
Annualised NPV	$16,206
Peak deficit (with interest)	-$14,943
Year of peak deficit	1
Payback period (years)	1
IRR	463.15%

3.1.2.4.3 The effect of supplementing an Acute P herd

Table 79 indicates the impact on returns of supplementing cows in an Acute P herd during the wet season only.

Table 79 - Marginal returns from supplementing breeders with an Acute P deficiency: P in the wet season (Scenario 10)

All terms defined in the Glossary of terms and abbreviations

Factor	**Value**
Period of analysis (years)	30
Interest rate for NPV	5%
NPV	$741,195
Annualised NPV	$48,216
Peak deficit (with interest)	-$7,136
Year of peak deficit	1
Payback period (years)	1
IRR	1279.53%

The feeding of the N+P dry season-only supplement to an Acute P breeder herd increased the net costs of feeding without any performance improvement above and beyond the feeding of wet season only P supplements (Table 80). This is even thought the cull breeders did not receive the supplement.

Table 80 - Marginal returns from supplementing breeders with an Acute P deficiency: N and P in the dry season (Scenario 11)

All terms defined in the Glossary of terms and abbreviations

Factor	**Value**
Period of analysis (years)	30
Interest rate for NPV	5%
NPV	$176,436
Annualised NPV	$11,477
Peak deficit (with interest)	-$13,769
Year of peak deficit	1
Payback period (years)	1
IRR	521.63%

Table 81 indicates the impact on returns of supplementing cows in an Acute P herd during both wet and dry seasons. The benefits, although substantial, appear likely to be lower than those available if an appropriate supplementation program is implemented in the wet season alone.

Table 81 - Marginal returns from supplementing breeders with an Acute P deficiency: N and P in the dry season and P in the wet season (Scenario 12)

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Interest rate for NPV	5%
NPV	$687,365
Annualised NPV	$44,714
Peak deficit (with interest)	-$20,839
Year of peak deficit	1
Payback period (years)	1
IRR	432.65%

3.1.2.5 Supplementing first calf heifers to improve re-conception rates

Table 82 shows the predicted investment returns for feeding M8U supplement to first calf, lactating heifers to achieve an improved re-conception rate of 80% (cf. 78%). The investment produced an annualised NPV of ca. -$10,000. This demonstrates that although maintaining body weight is critical to the performance of young breeders, the extra costs associated with achieving extra weaners through supplementing first calf heifers will not be repaid.

Table 82 - Marginal returns for investment in M8U supplement for first calf heifers to improve re-conception rates

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Interest rate for NPV	5.00%
NPV	-$148,860
Annualised NPV	-$9,684
Peak deficit (with interest)	-$416,285
Year of peak deficit	never
Payback period (years)	never
IRR	n/a

3.1.3 Marketing options

3.1.3.1 Organic beef

The predicted investment returns from targeting the certified organic beef market with steers and cull heifers indicate that this strategy is only marginally more profitable than the baseline production system (Table 83). The slightly improved profitability was caused by the capital released by the herd reduction as after this adjustment had occurred the organic property was less profitable than the baseline herd operation. Over the longer term, the 25% price premium for steers and heifers was not adequate to offset the 20% reduction in grazing pressure. The negative IRR result in Table 83 was generated due to a positive return (herd reduction) followed by a long sequence of negative annual returns. Theoretically it is incorrect to have a negative IRR when the NPV is positive but the IRR value is retained here to indicate the underlying nature of the long term cash flows for this scenario.

Table 83 - Marginal returns for converting to the certified organic beef market for steers and cull heifers

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Interest rate for NPV	5.00%
NPV	$37,445
Annualised NPV	$2,436
Peak deficit (with interest)	n/a
Year of peak deficit	n/a
Payback period (years)	n/a
IRR	-0.28%

3.1.3.2 EU market

The investment returns indicate that a change to EU accreditation for steers and heifers, and a strategy of selling steers at the same age as the current baseline herd, is likely to improve the profitability of the property (Table 84). However, as the benefits likely to be gained by EU accreditation were not substantial, maintenance of the price premium is critical to the success of the strategy.

Table 84 - Marginal returns for EU steers and cull heifers – 67% of steers sent to slaughter, the remainder sold as feed-on steers

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Interest rate for NPV	5.00%
NPV	$84,449
Annualised NPV	$5,494
Peak deficit (with interest)	-$10,500
Year of peak deficit	2
Payback period (years)	2
IRR	104.75%

If a strategy was adopted of selling EU steers at a younger age than the baseline herd and in two cohorts as feed-on steers, profitability is likely to be improved by a similar amount to the strategy of selling steers at the same age as the baseline herd with 67% going to slaughter (Table 85). Again, maintenance of the price premium is critical to the success of this strategy.

Table 85 - Marginal returns for EU steers and cull heifers – all sold as feed-on

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Interest rate for NPV	5.00%
NPV	$82,059
Annualised NPV	$5,338
Peak deficit (with interest)	-$10,500
Year of peak deficit	2
Payback period (years)	2
IRR	198.81%

Table 86 shows the expected returns when the price premium was reduced by half, or 7.5 c/kg liveweight, in the scenario involving sale of younger feed-on steers and heifers. It is evident that a small change in the price premium dramatically reduces the value added to the beef property by converting to EU production status.

Table 86 - Marginal returns for EU steers and cull heifers – all sold as feed-on at reduced premium

Factor	Value
Period of analysis (years)	30
Interest rate for NPV	5.00%
NPV	-$59,109
Annualised NPV	-$3,845
Peak deficit (with interest)	-$183,713
Year of peak deficit	never
Payback period (years)	never
IRR	n/a

3.1.3.3 Wagyu beef

The investment returns indicate that converting to a purebred Wagyu herd is likely to substantially improve the profitability of the property if the price premium of 100% is maintained from Year 7 of the transition until Year 30 of the analysis (Table 87). When price premiums were maintained up to Year 20 of the analysis and then reduced to zero over the following 6 years, the investment in converting to a purebred Wagyu herd was only marginally profitable (Table 88). When price premiums were reduced from Year 10 of the analysis to zero over the following 6 years, the investment in converting to a purebred Wagyu herd was not profitable (Table 89).

Table 87 - Marginal returns converting to a purebred Wagyu herd with the price premium maintained for the life of the investment

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Interest rate for NPV	5.00%
NPV	$506,411
Annualised NPV	$32,943
Peak deficit (with interest)	-$269,104
Year of peak deficit	4
Payback period (years)	12
IRR	13.72%

Table 88 - Marginal returns converting to a purebred Wagyu herd with the price premium reduced after Year 20

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Interest rate for NPV	5.00%
NPV	$49,471
Annualised NPV	$3,218
Peak deficit (with interest)	-$269,104
Year of peak deficit	4
Payback period (years)	n/a
IRR	n/a

Table 89 - Marginal returns converting to a purebred Wagyu herd with the price premium reduced after Year 10

All terms defined in the Glossary of terms and abbreviations

Factor	Value
Period of analysis (years)	30
Interest rate for NPV	5.00%
NPV	-$646,738
Annualised NPV	-$42,071
Peak deficit (with interest)	-$1,927,459
Year of peak deficit	never
Payback period (years)	never
IRR	n/a

3.2 The potential impact of drought on the herd

Figure 12 demonstrates the relationship of mortality rate to BCR and weight change in either 1 year old or 12 year old breeders, calculated by applying the equation of Mayer *et al.* (2012). It can be seen that 12 year old cows that have a low starting BCR and then lose weight will have a substantially greater rate of mortality than yearling heifers that have a similar body condition ratio and lose a similar amount of weight. Table 90 shows the expected rate of mortality in breeders as predicted by the Mayer *et al.* (2012) mortality equation. The values were calculated for female stock that start the calendar with a BCR of either 1 or 1.1 (i.e. in ‘forward store’ or ‘prime’ condition) and then lose 60 kg liveweight during the next 12 months.

The data indicates a serious risk of high rates of mortality if a breeding herd has a high proportion of aged cows and they begin a drought in store or below body condition. Having breeder BCS in better than a forward score condition (better than score 5 on a 9 point scale or 3 on a 5 point scale) going into a drought could substantially reduce the mortality rate of mature and aged cows who are considered likely to lose more than 10% of their starting liveweight.

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

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

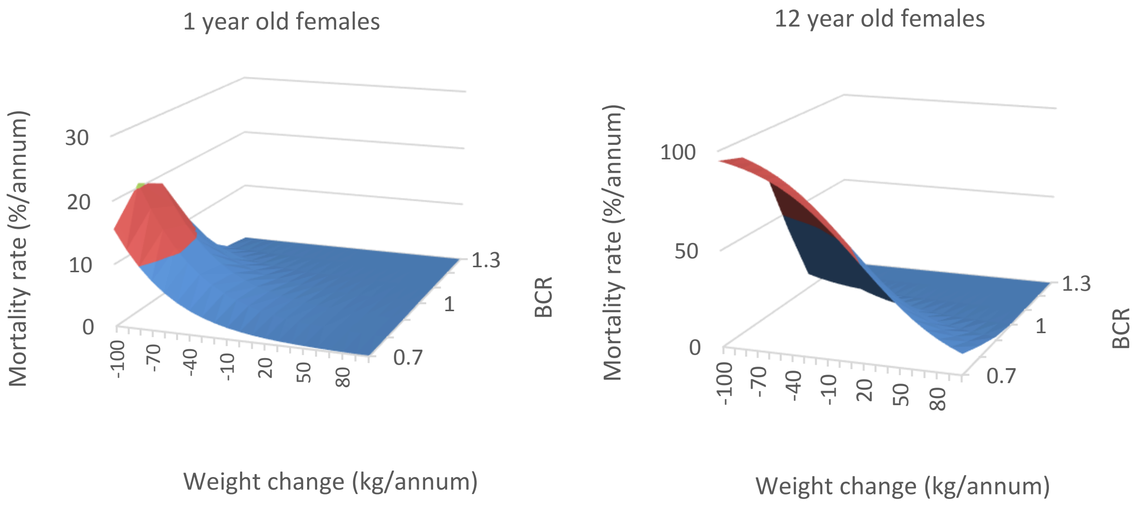


Table 90 - Rate of mortality by class of female stock starting with a body condition ratio (BCR) of 1.1 or 1 at the start of the calendar year and then losing 60 kg liveweight

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

Female age class	Rate of mortality at starting BCR 1.1	Rate of mortality at starting BCR 1	% increase in mortality rate with starting BCR decrease from 1.1 to 1
Heifer weaners	1.46%	4.26%	192%
Heifers 1 year	1.56%	4.95%	217%
Heifers 2 years	1.56%	4.95%	217%
Cows 3 years	1.66%	5.74%	246%
Cows 4 years	1.78%	6.65%	274%
Cows 5 years	1.90%	7.69%	305%
Cows 6 years	2.03%	8.88%	337%
Cows 7 years	2.17%	10.24%	372%
Cows 8 years	2.32%	11.77%	407%
Cows 9 years	2.48%	13.51%	445%
Cows 10 years	2.65%	15.45%	483%
Cows 11 years	2.83%	17.61%	522%
Cows 12 years	3.02%	20.00%	562%

This data indicates that the age structure of the females in a breeding herd may increase (or decrease) the risk of mortality rates increasing in a drought. Table 91 indicates the age structure of the baseline herd applied in this analysis and identifies that approximately 15% of the retained cow herd could be 9-10 years old, or older, going into a drought.

Table 91 - Age structure of the baseline herd in the case-study, beef cattle enterprise

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

Parameter	Number of females in each age class (1-13)												
Cow age start of calendar year	1	2	3	4	5	6	7	8	9	10	11	12	13
Cows/heifers available at start of year	242	234	110	82	69	57	48	40	32	25	20	16	13
Cows mated in each age group	0	144	110	82	69	57	48	40	32	25	20	16	0
Mated cows retained in each group	0	115	86	71	60	50	42	34	27	21	17	13	0
Calves weaned from each group	0	104	80	67	56	47	39	32	25	20	16	13	0

The baseline breeding herd structure and cow culling strategy for the case-study herd was optimised to identify the highest herd gross margin. This optimisation processes was influenced primarily by the relationship between age, conception rates, calf loss and the chance of pregnant females going missing as identified in the CashCow project for the 'central forest region' which was deemed representative of the Fitzroy region (McGowan *et al*. 2014). In addition, the sale prices and weights for the various classes of females, and the heifer culling strategy, contributed to the determination of the optimal maximum culling age for females which resulted in last mating at 12-13 years old. It appears likely that a reasonable portion of the CashCow data for the 'central forest region' may have been collected from breeding herds which placed a high selection pressure on breeder performance leading to the aged and mature cow median data representing cows with very good performance and little difference to the mortality rates of younger females. Therefore, we suggest that the risk of mortality for mature and aged cows going into a drought is likely to be better represented by the equations developed by Mayer *et al.* (2012) as they are based on a wider range of herds from northern Australia and a larger number of data sets.

The maximum age of culling was reset in the herd model, and the herd model rebalanced, to identify the average impact on the herd gross margin of reducing the current optimum age of cow culling in this herd. Table 92 indicates that culling all cows at 9-10 years of age and reducing the percentage of 2 year old heifers sold as culls will only marginally reduce the herd gross margin. The average reduction of less than $1,000/annum is likely to be more than offset by the benefits of a reduced number of mature and aged cows going into the drought and consequent benefits in potential mortality rates.

Table 92 - Comparison of the baseline herd with 13 year old cull cow strategy and a 9 year old cull cow strategy

Parameter	**Base herd with 13 year cull age**	**Base herd with 9 year old cull age**
Total adult equivalents	1500	1500
Total cattle carried	1537	1535
Weaner heifers retained	249	249
Total breeders mated	642	644
Total breeders mated & kept	535	535
Total calves weaned	498	497
Weaners/total cows mated	77.60%	77.23%
Overall breeder deaths	4.53%	4.36%
Female sales/total sales (%)	47.79%	47.89%
Total cows and heifers sold	210	211
Maximum cow culling age	13	9
Heifer joining age	2	2
2 year old heifer sales (%)	58.48%	47.75%
Total steers and bullocks sold	230	229
Maximum bullock turnoff age	2	2
Average female price	$750.50	$748.11
Average steer/bullock price	$812.62	$812.62
Capital value of herd	$895,998	$895,990
Imputed interest on herd value	$44,800	$44,800
Net cattle sales	$344,438	$343,710
Direct costs excluding bulls	$31,992	$31,934
Bull replacement	$18,548	$18,592
Gross margin for herd	$293,898	$293,184
Gross margin after imputed interest	*$249,098*	*$248,384*

Mayer *et al*. (2012) did not produce equations to predict the mortality rate of steers and the actual mortality rate response of steers at different ages to a fall in BCS due to drought is unknown. However, Henderson *et al.* (2013) surveyed the mortality rate in steers across a number of regions of northern Australia and found that rates of steer mortality were likely to be as high, if not higher, than that identified in females of similar age and were also likely to increase with age. One of the key insights gained from Henderson *et al*. (2013) is that rates of steer mortality in northern Australia are higher than normally anticipated by property managers. It has also been shown that any increased rate of steer mortality has a much greater impact on herd profitability than a similar rate of increase in mortality in female cattle (Chudleigh *et al*. 2016).

3.3 The effect of herd structure on drought risk and profitability

Increasing the proportion of breeders in the herd will increase drought risk due to the greater nutritional demands related to reproduction, and the added complexity and expense of management interventions for heavily pregnant cows or cows with small calves. The proportion of breeders in the herd will also affect profitability due to changes in the quantity and value of sale beef. If the age of turnoff for steers is increased from weaners to bullocks (slaughter steers) the number of breeders mated falls from 791 to 543 at the same grazing pressure applied (i.e. if AE are kept constant; Table 93). This means that if the beef enterprise were structured to produce weaner steers there are likely to be more than 600 wet cows going into a drought due to a failed wet season. Conversely, a herd structured to target 3-4 year old slaughter steers would likely have more than 400, but less than 450, wet cows at risk. The herd structured to produce weaner steers would, on average, have 51% of the total herd as females mated and kept while the herd structured to produce slaughter steers would have 30% of the total herd as females mated and kept.

As indicated in Table 93, for the baseline herd and production system, there is little difference between the profitability of targeting 1-2 year old (the optimum in terms of profitability) or 2-3 old steers, so there may be some benefit in terms of reducing drought risk in choosing the 2-3 year age of turnoff over the 1-2 year old age of turnoff. Targeting the production of weaner steers appears likely to both reduce profit and increase drought risk while targeting 3-4 year old steers may reduce drought risk but also reduce profit.

Table 93 – Change in herd structure and gross margin with age of turnoff for steers

Parameter	Age of steer turnoff			
	Weaner steers	1-2 year old steers	2-3 year old steers	3-4 year old steers
Total adult equivalents	1,500	1,500	1,500	1,500
Total cattle carried	1,288	1,440	1,535	1,488
Weaner heifers retained	306	276	249	210
Total breeders mated	791	715	644	543
Total breeders mated and kept	658	595	535	452
Total calves weaned	611	552	497	419
Weaners/total cows mated (%)	77.23%	77.23%	77.23%	77.23%
Overall breeder deaths	4.36%	4.36%	4.36%	4.36%
Female sales/total sales (%)	45.86%	46.87%	47.89%	48.91%
Total cows and heifers sold	259	234	211	178
Maximum cow culling age	9	9	9	9
Heifer joining age	2	2	2	2
2 year old heifer sales (%)	47.75%	47.75%	47.75%	47.75%
Total steers and bullocks sold	306	265	229	186
Maximum bullock turnoff age	0	1	2	3
Average female price	$748.11	$748.11	$748.11	$748.11
Average steer or bullock price	$318.44	$639.98	$799.48	$1,043.32
Capital value of herd	$816,362	$825,857	$895,990	$910,427
Imputed interest on herd value	$40,818	$41,293	$44,800	$45,521
Net cattle sales	$290,967	$344,748	$340,701	$326,495
Direct costs excluding bulls	$36,159	$33,841	$31,934	$28,911
Bull replacement cost	$22,856	$20,659	$18,592	$15,685
Gross margin for herd	$231,952	$290,248	$290,174	$281,898
GM after imputed interest	*$191,134*	*$248,955*	*$245,375*	*$236,377*

The treatments applied in the baseline herd model allow for drought feeding of female cattle with a frequency of 1 year in 7 so the herd gross margins shown in Table 93 are affected to some extent by the expected frequency of drought feeding and the changing proportion of females in the herd. Some allowance has therefore already been made for the impact of having a higher proportion of females in the herd going into a drought when comparing the profitability of these different herd structures.

3.4 Assessing key strategies which may be applied in response to drought

3.4.1.1 Reducing grazing pressure by culling dry females

The identification of dry females is an obvious first target in a destocking strategy when it is apparent early in the New Year that the wet season may be short and normal numbers of cattle may need to be reduced. The group of females in the breeding herd that were pregnancy tested in calf (PTIC) the previous year but have subsequently lost their calf prior to branding or weaning (hereafter 'PTIC empties') can be identified. Note that in the baseline herd model, 100% of females that were pregnancy tested and determined to be non-pregnant (empty) the previous year would have already been culled, so the group of PTIC empties would be expected to be relatively small. Table 94 shows the expected herd structure of the baseline herd with a 9-year old cow cull age and identifies the PTIC empty breeders. About 38 cows are likely to fall into this category in the baseline herd and would be easily identifiable as dry breeders at branding time. Although these breeding females have a high probability of being pregnant again after losing their calf, they are likely to be in reasonable body condition and are an obvious candidate for immediate sale at the branding muster. Although this action may reduce weaner numbers in 15-18 months' time, the sale of PTIC empties will allow an early reduction in grazing pressure and may also remove sub fertile breeders from the herd. If drafting off and culling PTIC empty females at the branding muster is not already practiced then it may be an easy way to reduce grazing pressure early in the year.

Table 94 - Herd structure showing pregnancy tested in calf (PTIC) empties (females that have lost a calf prior to branding or weaning)

Cow age of culling is 9 years old; PTIC empties shaded grey

Herd structure parameter	**Joining age group**								
	1-2	**2-3**	**3-4**	**4-5**	**5-6**	**6-7**	**7-8**	**8-9**	**9-10**
Opening breeders	241	234	128	96	80	67	56	47	37
Number mated	0	169	128	96	80	67	56	47	0
Conception (%)	0	80	78	87	87	87	87	84	84
Conception losses (%)	0	10	7	6	6	6	6	5	5
Sale of empties (%)	0	100	100	100	100	100	100	100	100
Number able to mate	0	169	128	96	80	67	56	47	0
Number pregnant	0	135	100	84	70	58	49	39	0
Number empty	0	34	28	13	10	9	7	7	0
Number PTIC empties	0	14	7	5	4	4	3	2	0
Number remaining pregnant	0	122	93	79	66	55	46	37	0
Number empties sold	0	34	28	13	10	9	7	7	0
Total sold	0	34	28	13	10	9	7	7	0
Number retained	0	135	100	84	70	58	49	39	0
Calves weaned	0	122	93	79	66	55	46	37	0
Sales (%)	0	20	22	13	13	13	13	16	0
Calves weaned/cows retained (%)	0	90	93	94	94	94	94	95	0

3.4.1.2 Reducing liveweight loss of breeders by early weaning

Early weaning is known to be the most effective strategy to reduce liveweight loss of breeders during the dry season and droughts, and hence reduce breeder mortality rates and improve reproductive efficiency (Dixon 1998; Tyler *et al.* 2012). As weaning a breeder is expected to improve their liveweight by ca. 10 kg/month, the management decision to wean a breeder in February rather than May (for the baseline, case-study herd) results in a breeder 30+ kg heavier in May than an unweaned breeder.

Early weaning at branding in February (rather than the usual weaning in mid-May) for the baseline herd would lead to approximately 500 weaners with an average weight of about 110-115 kg needing to be fed supplements. The lighter weaners, less than 100 kg liveweight, will need to be separated and fed a diet that has more than 20% crude protein and they may need to be fed for some weeks. For example, a target weight gain of 250 g/d may require feeding 1.5 kg/head.day of calf pellets for at least 30 days to shift the light weaners from 92 to 100 kg liveweight (Tyler *et al.* 2012). The heavier weaners, greater than 100 kg liveweight, will also need supplements of protein meal, hay and optionally grain, if pasture quality is too poor for the growth rate required.

The program Splitsal (Holmes *et al.* 2017) indicated that if the mob of weaners produced by the baseline herd had a standard deviation of 15 kg liveweight either side of the average, ca. 20% would be less than 100 kg and these would have an average weight of about 92 kg. The remaining 80% of weaners would be heavier than 100 kg and have an average weight of about 117 kg (Table 95).

Table 95 - Splitsal analysis of expected weaning weight distribution in February for the baseline, case-study herd

Parameter	Value
Average liveweight of total group (kg)	110
Standard deviation of weights (kg)	15
Liveweight range in total group for 95% of group, assuming a normal distribution (kg)	83-142
Cut-off weight for lighter group (kg)	100
% of total group above cut-off weight	80
Average weight of heavier group (kg)	117
Average weight of lighter group (kg)	92

The Cowtrade program (Holmes *et al.* 2017) and spreadsheets can be used to determine the additional cost of supplementing the early weaners through until the usual weaning date in mid-May and this can be compared to the benefits of anticipated reduction in mortality rate and the improvement in reproduction efficiency expected in the breeders that had their calves weaned early.

3.4.1.3 Reducing grazing pressure by culling from within cow, heifer and steer groups of the remaining herd vs. drought feeding

The sale of a few PTIC empties and early weaning will not do much to reduce grazing pressure if the season continues to deteriorate. Given the previous two strategies have been implemented, by the middle of March, the baseline herd is expected to have:

- ca. 500 early weaners in the yards being fed,
- ca. 500 mated cows that have been weaned but whose pregnancy status is unknown,
- ca. 230 x 2-3 year old heifers of which 90 have already been culled but not yet sold and the remainder mated,
- ca. 240 yearling heifers who will be mated at the end of the year, and
- ca. 240 yearling steers who have another 12 months to go before their usual sale date.

As per normal management for the baseline herd, the sale, feed-on steers have already been sold in February so the next candidates must be the cull heifers due to go in May. Removing them early in February or March will free up only a small amount of capacity, possibly less than 3 months grazing which will be utilised by the retained heifers of the same age group.

At this point the choices become more complex as selling down the numbers of each class of cattle that remain (cows, heifers, steers) will have substantial ramifications for the future earning capacity of the property.

3.4.1.3.1 Considering the sale of PTIC cows and later re-purchase of cows and calves

A substantial component of the remaining herd are breeder cows that can soon be pregnancy tested and their status revealed. The expected conception rates indicate that a number of PTE (pregnancy tested empty) cows will be identified and can be sold to reduce grazing pressure but this action would probably be considered part of the normal seasonal reduction in stock numbers. One option is to consider the sale of PTIC cows at pregnancy testing with the expectation of repurchasing cows and calves prior to the normal weaning period in the following year. This action effectively maintains the expected output of the breeding herd over time and could substantially reduce the grazing pressure applied to the property.

There are significant risks in this action but one approach to assessing the potential impact of the decision is to compare the costs of keeping the PTIC cows with the expected costs of replacing them at a later date. The following tables demonstrate the process, and highlight the key data, required to assess the decision to sell PTIC cows.

Estimating the current sale value of the PTIC cows is necessary to identify the opportunity costs of retaining the cows. Table 96 shows the calculation of the current on-farm value of the cows.

Table 96 – Estimating the current sale value of PTIC cows

Parameter	**Value**
Cow weight in the paddock (kg)	450
weight loss to get to sale yards or works	5%
Cow weight at saleyards or works (kg)	428
Sale price at yards or works ($ /kg live)	$2.00
Gross sale price ($/head)	$855
Commission & insurance % on sales	3.50%
Commission & insurance ($/head)	$29.93
Transaction levy, yard dues etc.	$15.00
Transport cost ($/head)	$10.53
Cow value net of selling expenses	$799.55
Selling cost ($/kg)	$0.13
Net value in the paddock ($/kg)	*$1.78*

Table 97 demonstrates the process required to identify the number and value of PTIC cows and the expected period of time until they are expected to be replaced with cows and calves. For this exercise, the benefits to the business of holding and feeding, or selling and replacing, 100 PTIC cows was examined. However, the case study property would be likely to have ca. four times this many PTIC at the start of a drought.

Table 97 – Identification of the number and value of PTIC cows in the herd and the expected period of time until they are expected to be replaced

Parameter	**Value**
Number of PTIC cows	100
Date that PTIC cows could be sold	1 May 2018
Date that cows and calves could be replaced	1 May 2019
Days to replacement	365
Current liveweight of PTIC cows (kg)	450
Expected sale price now ($/kg liveweight)	$1.78
Current sale value ($/head) on farm	*$799.55*
Current sale value ($/mob) on farm	*$79,955*

Table 98 shows the calculation of the expected feeding costs if the cows are retained, the opportunity cost of not selling the cows (interest forgone) and the approximate cost (value) of the 90 cows and calves available at the end of the period. Allowance is made for the percentage of cows (10%) likely to lose their calves and the percentage of cows likely to die (5%). The expected cost of replacing 90 cows and 90 calves at the end of the period is also identified.

Table 98 –Expected feeding and opportunity costs for retained cows, the value of cows and calves at the end of the feeding period and the cost of replacing them

Parameter	**Per head**	**Per mob**
Treatment costs of holding PTIC cows		
Number of PTIC cows to be fed		100
Number of days to be fed		182
Supplement intake at 1% of 450 kg liveweight (4.5 kg/head.day); (kg/head, as-fed)	819	82,000
Cost of supplement (/t landed)		$300
Total supplement cost ($)		$24,570
Wages and fuel for 1 feeding out		$50
Number of times fed (supplement is fed out twice per week)		52
Total feeding out cost		$2,600
Total supplement and feeding out cost ($)	$271.70	$27,170
Health costs if held and not sold ($/head)	$5.00	
Other supplement costs if held and not sold ($/head)	$25.00	
Management costs if held and not sold ($/head)	$0.00	
Total treatment costs ($)	*$301.70*	*$30,170*
Opportunity cost of interest foregone in holding PTIC cows (5% interest rate)		
Interest cost - cattle ($)	$39.98	$3,998
Interest cost - treatment costs ($)	$7.54	$754.3
Opportunity cost of interest ($)	*$47.52*	*$4,752*
Total cost of retaining cows and calves		
Weaning rate from retained PTIC breeders		90.00%
Number of cow and calf units held at the end of the period		90
Mortality rate for retained cows		5.00%
PTIC empty cows at the end of the period		5
Adjustment for value of PTIC empty cows		-$3,998
Value or cost of cow and calf units at the end of the period	*$1,231.99*	*$110,879*
Expected cost of replacing cows and calves		
Number of cow and calf units to be purchased		90
Total travel costs (total costs of finding stock)		$300
Travel costs ($/head)	$3.33	
Transport costs to property (90 head, 200 km at $2.00/km, 24 per deck)	$16.67	$1,500
Induction cost $/unit	$10.00	$900
Expected purchase cost of cow and calf unit ($)	$1,250.00	$112,500
Total landed cost of cow and calf unit ($)	*$1,280.00*	*$115,200*
Gain (or loss) on holding and feeding		***-$4,321***

The values in the table suggest that the beef business is better off not selling the cows now and replacing them in 12 months' time with cows and calves if they can be purchased for about $1,250 per unit. Table 99 reveals the sensitivity of the exercise to variation in the current sale price and the expected replacement cost. A positive number indicates that it was better to hold the PTIC cows and feed them.

Table 99 – Sensitivity analysis for gain from holding and feeding PTIC cows ($) in relation to replacement cost for cow and calf unit and sale price for PTIC cows

Expected price of replacement cow and calf unit ($)	**Expected sale price of PTIC cow at the yards or works ($/kg liveweight)**				
	$1.80	**$1.90**	**$2.00**	**$2.10**	**$2.20**
	$ per head on farm				
	$717.04	**$758.29**	**$799.55**	**$840.80**	**$882.05**
$950	-$14,015	-$18,347	-$22,679	-$27,010	-$31,342
$1,050	-$5,015	-$9,347	-$13,679	-$18,010	-$22,342
$1,150	$3,985	-$347	-$4,679	-$9,010	-$13,342
$1,250	$12,985	$8,653	$4,321	-$10	-$4,342
$1,350	$21,985	$17,653	$13,321	$8,990	$4,658
$1,450	$30,985	$26,653	$22,321	$17,990	$13,658
$1,550	$39,985	$35,653	$31,321	$26,990	$22,658

This exercise looks at holding and feeding or selling and replacing 100 PTIC cows and this property is likely to have four times this many on hand at the start of the drought. Making the wrong choice could be disastrous for this property. Other factors such as the expected availability of cows and calves at the end of the period and their ongoing performance compared to the PTIC cows already on the property will also be factors that can influence this decision. Classes of PTIC cows currently on the property, and likely to experience increased rates of mortality, are candidates for sale.

3.4.1.3.2 Assessing destocking vs. a drought feeding strategy for breeders with 'Cowtrade'

The Cowtrade and Bullocks programs that are part of the Breedcow and Dynama suite of programs (Holmes *et al.* 2017) can be used to consider wider choices that may include the options of comparing feeding PTIC cows with selling other classes of stock. These analyses will also be specific to the seasonal and financial circumstances prevailing at the time.

In the previous example we considered the PTIC cows in isolation as we decided the choice under consideration was to feed them or sell them and purchase them back at a later time. However, there are other classes of cattle left on the property and selling some of them may provide a better outcome than either selling or retaining the PTIC cows.

In general, if selling stock to reduce grazing pressure or to relieve financial pressure, the objective should be to achieve the grazing or financial objective with least damage to future income. Each class of stock remaining on the property will contribute to the future income of the property in different ways and it is necessary to assess this impact of the sale of each alternative class of stock if an informed choice is to be made.

If the objective is to reduce grazing pressure, then selling first those groups with the lowest gross margin/AE after interest is recommended as this strategy will get rid of the most AE at the least impact of future prospects. If the objective is to reduce financial pressure, then selling first those groups with the lowest percent return on livestock and expenses capital is recommended as this will free up the most cash and do less damage to future prospects. Both measures (gross margin/AE and % return on livestock and expenses capital) are produced by the Cowtrade and Bullocks programs.

The Cowtrade program should first be used to test the decision to feed or sell the PTIC cows and then this result can be compared to selling other classes of livestock. During this process a number of key assumptions have to be made:

- The value of the breeder unit in the paddock (net of selling expenses) now. This may be a cow and calf unit that will need to be fed for a considerable period if it is retained in the herd until weaning time.
- The value of the breeder unit at the end of the period? The end of the period could be a) at the expected time of the drought breaking (end of feeding period), b) the weaner being sold off the mother, or c) the time that the cow and calf unit will be replaced.
- The cost to retain the breeder unit over the required period.

Table 100 shows an example analysis of drought feeding options for the baseline herd. The scenario was that the producer is running out of feed for a group of PTIC cows and can either sell them now (1st May) for $800/head net or hold them and feed them. If they are sold, the decision would be to replace the breeder units with cow and calf units in about April-May the following year. The calves would be likely to be close to weaning age at this time. The expected landed replacement cost is $1,228 ($810 + $418). The cost and length of the feeding exercise would be unknown so it was tested at $150, $250 and $350/cow. Weaning costs were expected to be about the same in each scenario. The figure calculated for the gross margin per AE after interest was considered the most appropriate indicator of the success of the feeding venture as it is an accurate method of comparing the impact of selling different classes of cattle going into a drought. In this case we need the most efficient way to reduce grazing pressure (AE's on the property) and selling the class with the lowest future return per AE will remove the most AE's at the least cost to long term profit. It can be seen at a feeding cost of $350/head for the breeders, the best option would be to sell the cows and buy back in a year later. At feeding costs of $247/head, or lower, the best option would be to hold the breeders and feed them. The breakeven level for the feeding exercise was ca. $247/cow for feed inputs.

Table 100 – Example Cowtrade analysis of a drought feeding option for the baseline, case-study herd

Interest rate for 'gross margin after interest' calculation was 5%; Break-even level of feeding at $247/cow shown and shaded grey

Parameter	**Drought feeding option**			
	$247/cow	**$150/cow**	**$250/cow**	**$350/cow**
Starting date for analysis	01/05/2018	01/05/2018	01/05/2018	01/05/2018
Calving date	15/11/2018	15/11/2018	15/11/2018	15/11/2018
Sale date for adults and progeny	01/5/2019	01/5/2019	01/5/2019	01/5/2019
Weight of breeders at start (kg)	450	450	450	450
Weight of breeders at sale (kg)	450	450	450	450
Weight of progeny at 5 months (kg)	150	150	150	150
Weight of progeny at sale 9kg)	200	200	200	200
Age of progeny at sale (days)	167	167	167	167
Starting value of group (net/head)	$800	$800	$800	$800
Sale value of breeders (net/head)	$800	$800	$800	$800
Sale value of progeny (net/head)	$418	$418	$418	$418
Weaning rate from breeders (%)	90	90	90	90
Death rate on breeders (%)	5	5	5	5
Death rate on progeny after 5 months (%)	3	3	3	3
Husbandry cost on breeders ($/head)	$247	$150	$250	$350
Husbandry cost on progeny ($/head)	$25	$25	$25	$25
Period of rating for breeder (days)	365	365	365	365
Period of rating progeny to 5 months (days)	348	348	348	348
Period of rating for progeny after 5 months (days)	17	17	17	17
Adult equivalent (AE) rating of breeder	0.99	0.99	0.99	0.99
AE rating of progeny to 5 months	0.31	0.31	0.31	0.31
AE rating of progeny post 5 months	0.02	0.02	0.02	0.02
AE rating for breeder and progeny	1.32	1.32	1.32	1.32
Total gross margin per unit (breeder & progeny)	$55.41	$152.41	$52.41	-$47.59
Gross margin/AE.year	$42.00	$115.53	$39.73	-$36.07
Interest on breeders	$39.00	$39.00	$39.00	$39.00
Interest on progeny	$9.12	$9.12	$9.12	$9.12
Interest on husbandry costs	$6.74	$4.31	$6.81	$9.31
Total interest/unit on stock and expenses capital	$54.86	$52.44	$54.94	$57.44
Average capital base/AE (12 month equivalent)	$831.65	$794.89	$832.79	$870.69
Total gross margin/unit after interest	$0.55	$99.98	-$2.52	-$105.02
Gross margin/AE.year after interest	***$0.42***	***$75.78***	***-$1.91***	***-$79.60***
Return on livestock and expenses capital	*5.05%*	*14.53%*	*4.77%*	*-4.14%*

3.4.1.3.3 Assessing destocking vs. drought feeding options by combining 'Cowtrade' and 'Bullocks'

In the previous section a strategy was considered in Cowtrade that looked at either selling PTIC females or keeping them and feeding them when a drought was beginning to take effect. As there are usually are a number of classes of dry stock that could also be sold as an alternative to breeding females to reduce grazing pressure going into a drought, the Bullocks program can be used to evaluate these options.

The Bullocks program can be used to test the same options for non-breeding cattle as the Cowtrade program does for breeder groups. Although the primary focus of the Bullocks program is on selecting the most profitable turnover cattle, it may also be used to evaluate forced sales options. Furthermore, the gross margins calculated in the Bullocks program for non-breeders may be compared with the gross margin for breeders as calculated in the Cowtrade program if they are compared on a per AE after interest, or capital invested, basis. The Bullocks program, as for the Cowtrade program, requires data for purchase and sale dates, weights, prices (landed and net, respectively), expected mortalities, variable costs, interest rate and purchase and sale price increments for the sensitivity tables.

The scenario outlined in the previous section was extended by identifying that the manager also has an option of selling some steers that would normally be sold in 12 months' time. This would allow the cows to spread out over the property, reducing grazing pressure and saving on feeding costs. This option was considered by firstly adjusting the feeding costs in the Cowtrade drought feeding example and identifying the 'gross margin after interest' for the change. In this case, it was estimated that selling the steers and freeing up some pasture could reduce the cow feeding cost to $75/PTIC cow if the drought continued on to the end of the year. In this case, expenses of $25 per head for the husbandry expenses usually incurred are also included with the drought feeding cost to give a total treatment cost per cow of $100.

Table 101 shows the modified output from the Cowtrade analysis for this extended scenario. The gross margin/AE after interest is the number that should be considered when looking at the option of keeping the steers or keeping the cows. In this case, keeping the cows, selling the steers, and incurring a drought feeding cost of $75/cow retained produced a gross margin/AE after interest of $114.63.

Once the Cowtrade analysis was adjusted to look at the alternative of spreading the cows out on to the steer country, the Bullocks program was used to identify the value of holding the steers and selling the breeders. Table 102 shows the expected sale weight (381 kg) of the steers if they are sold now compared to keeping them for another 10 months. A dressing percentage of 100% was used as the steers will be sold as 'feed-on' steers if they are kept. The selling price is the expected liveweight selling price for this class of steers. In this example, keeping the steers produced a gross margin/AE after interest of $126.31 cf. $114.63 for the strategy of keeping the PTIC cows and selling the steers. Hence in this example, selling steers and reducing the feeding costs of cows would reduce the profitability of the business by about $12 for each steer AE sold.

This comparison indicates it is probably better to keep the steers (as they will also generate more profit over the next 12 months) and either sell some cows (and possibly buy them back after the drought) or embark on an intensive drought feeding or agistment program, depending upon the estimate of drought feeding costs. There are many unknowns in this form of analysis. It is very difficult to successfully predict the cost of a drought feeding program or the length of a drought. Allocating expected values based on experience, the seasonal timing of the decision, and current market circumstances will often highlight the core differences between options and what it will take to make them work.

Table 101 - Example Cowtrade analysis showing the expected gross margin if steers are sold as an alternative to fully drought feeding breeders

Interest rate for 'gross margin after interest' calculation was 5%

Parameter	**Drought feeding at $75/cow**
Starting date for analysis	01/05/2018
Calving date (max 150 days earlier than start)	15/11/2018
Sale date for adults	01/05/2019
Sale date for progeny	01/052019
Weight of breeders at start (kg)	450
Weight of breeders at sale (kg)	450
Weight of progeny at 5 months (kg)	150
Weight of progeny at sale (kg)	200
Age of progeny at sale (days)	167
Starting value of group (net/head)	$800.00
Sale value of breeders (net/head)	$800.00
Sale value of progeny (net/head)	$418.00
Weaning rate from breeders (%)	90
Death rate on breeders (%)	5
Death rate on progeny after 5 months (%)	3
Husbandry cost on breeders ($/head)	$100
Husbandry cost on progeny ($/head)	$25
Period of rating for breeder (days)	365
Period of rating progeny to 5 months (days)	348
Period of rating for progeny after 5 months (days)	17
Adult equivalent (AE) rating of breeder	0.99
AE rating of progeny to 5 months	0.31
AE rating of progeny post 5 months	0.02
AE rating for breeder and progeny	1.32
Total gross margin per unit (breeder & progeny)	$202.41
Gross margin/AE.year	$153.42
Interest on breeders	$39.00
Interest on progeny	$9.12
Interest on husbandry costs	$3.06
Total interest/unit on stock & expenses capital	$51.19
Average capital base/AE (12 month equivalent)	$775.94
Total gross margin/unit after interest	$151.23
Gross margin/AE.year after interest	*$114.63*

Table 102 – Example drought sale analysis for steers using Bullocks

Parameter	**Value**
Start date	01/05/2018
End date	16/02/2019
Days on forage	291
Paddock purchase weight (kg)	381
Traded purchase weight (kg)	362
Paddock sale weight (kg)	495
Traded sale weight (kg)	470
Purchase price $/kg live, landed	$1.96
Sale price $/kg dressed weight net	$1.87
Dressing % @ sale	100%
Adult Equivalent (AE) standard weight (kg)	455
Mortality	4%
Variable cost/head	$6.20
Interest rate (per annum)	5.00%
Gross margin/beast purchased	$128.02
Gross margin/AE.year	$166.81
Gross margin/AE.year after interest	*$126.31*

3.4.1.3.4 Calculating the cost of drought feeding

There have been a number of detailed guides produced to inform beef producers about management of stock going into a drought and supplementary feeding stock as they progress through a drought (see https://futurebeef.com.au/knowledge-centre/drought/). As each situation has different costs and returns, no detailed examples have been added here. Spreadsheets for calculating the relative cost of feeds are available at https://publications.qld.gov.au/dataset/agbiz-tools-animals-and-grazing-beef. These tools can be used to calculate the approximate cost of drought feeding based on appropriate strategy where cattle are segregated according to their feed requirements, and provided feed which addresses the most limiting nutrient (Tyler *et al.* 2008). Once the costs of feeding stock have been calculated, they can be incorporated in such programs as Cowtrade and Bullocks to assess whether it is worth feeding or selling.

3.4.1.4 Agistment

The direct cost of agistment, if it is available, is relatively straight forward to calculate. Table 103 presents an example the cost of agistment for cows until the end of February after which time the cows were expected to be returned home with 90% calves at foot. This cost was compared to the cost of keeping the cows at home and feeding them a drought supplement.

The indirect costs of agistment are more difficult to calculate. No allowance has been made in Table 103 for any additional losses above and beyond those expected if the cows were kept at home and it is difficult incorporate the risk of agistment running out halfway through the agistment period forcing the cows home or into the sale yards at an unknown price.

It is also difficult to incorporate potential damage done to land condition on the home property if the cows are kept at home and fed drought supplements. For instance, protein supplements usually cause an increase in appetite and potentially a rapid decline in the remaining paddock feed.

The effect of the agistment strategy, on future cash flow after the drought has ended, is explored in the Drought Recovery section and compared to strategies where stock have been sold.

Table 103 - Cow agistment cost

Factor	**Cost/head**
Freight to agistment (24 head/deck for 500 km at $2.00/km)	$41.67
Agistment cost ($4.00/week.head over 43.43 weeks from 01/05/18-01/03/19)	$173.71
Mustering and travelling	$15.00
Veterinary costs	$5.00
Freight home (20 head/deck for 500 km at $2.00/km)	$50.00
Total costs per head	*$285.38*

3.5 Decision making in the drought recovery phase

The choices available during the drought recovery phase depend partly upon the decisions previously made during the drought response phase. If the decision was made to sell young females the choices will be different to those available after a decision to sell breeding age females or extra steers. Each alternative will result in a different herd structure on the property at the end of the drought and different options available for recovery.

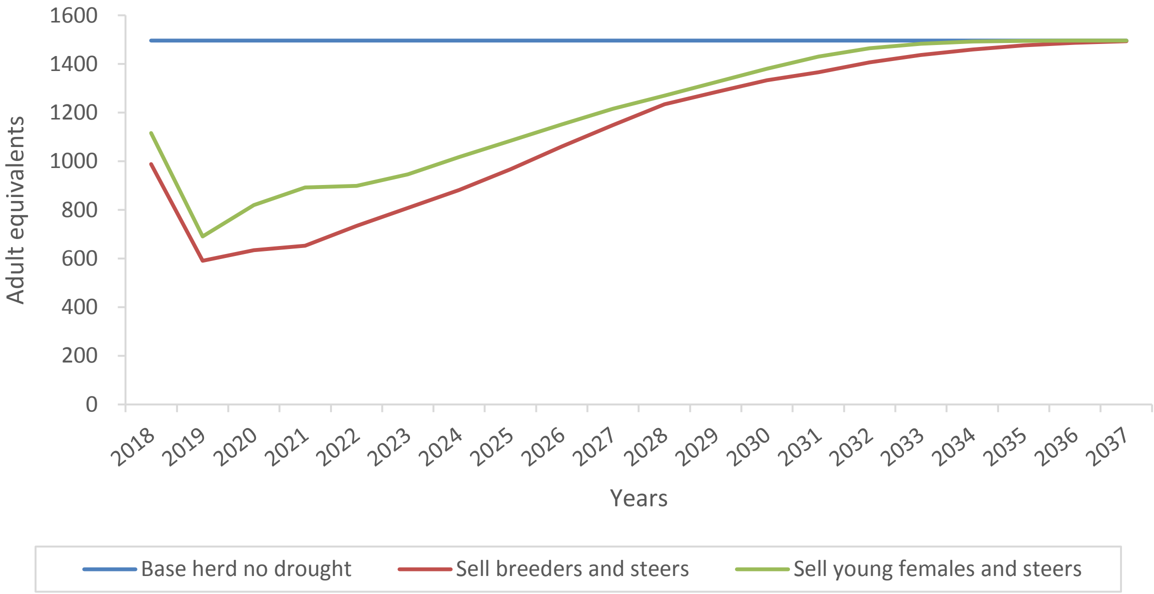
Table 104 shows an example for the sale of alternative groups of cattle in response to a significant but short term drought. The first column shows the expected number in each class at the start of the period. This is followed by columns that show the expected level of sales in an average year, the sales if the steers and the mature breeders are targeted and the sales if the young females and the steers are targeted.

Table 104 - Expected sale pattern and herd structure for the baseline herd with different response to drought

Class of cattle	Number of cattle			
	Start of year	Normal sales	Steers and mature breeders sold	Young females and steers sold
Heifer weaners	249	0	0	249
Heifers 1 year	242	0	0	242
Heifers 2 years	235	120	120	235
Cows 3 years	109	24	109	24
Cows 4 years	82	11	82	11
Cows 5 years	68	9	68	9
Cows 6 years	57	7	57	7
Cows 7 years	48	6	48	6
Cows 8 years	40	6	40	6
Cows 9 years	32	5	32	5
Cows 10 years	26	5	26	5
Cows 11 years	20	3	20	3
Cows 12 years	16	3	16	3
Cows 13 years	12	12	12	12
Steer weaners	249	0	249	249
Steers 1 year old	239	0	239	239
Steers 2 years	229	229	229	229
Herd bulls	21	3	15	7
Total cattle	*1974*	*443*	*1362*	*1541*
Total adults	*1476*	*443*	*1113*	*1043*

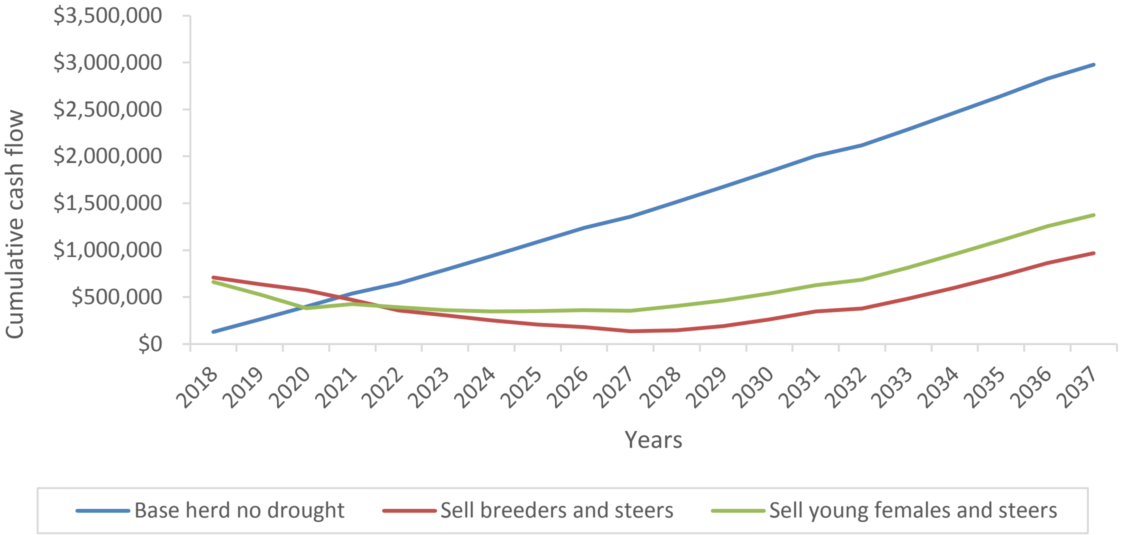
The two sales strategies made to rapidly reduce numbers (above) end up with a similar reduction in grazing pressure (Figure 13). It is noticeable that it takes a considerable period of time before the property returns to its long term carrying capacity if the normal culling and selling procedures are resumed once the drought breaks and no additional cattle are purchased.

Figure 13 - Change in adult equivalents over time with sale strategies



Although the reductions in numbers are broadly similar, the choice made of how many to sell and when will impact the capacity of the property to service commitments as they arise. The choice to sell down the mature breeder herd may provide slightly more cash in the short term but the ongoing retention of females to rebuild the breeder herd causes deficits for longer than the alternative strategy to dramatically reduce the young female herd (Figure 14).

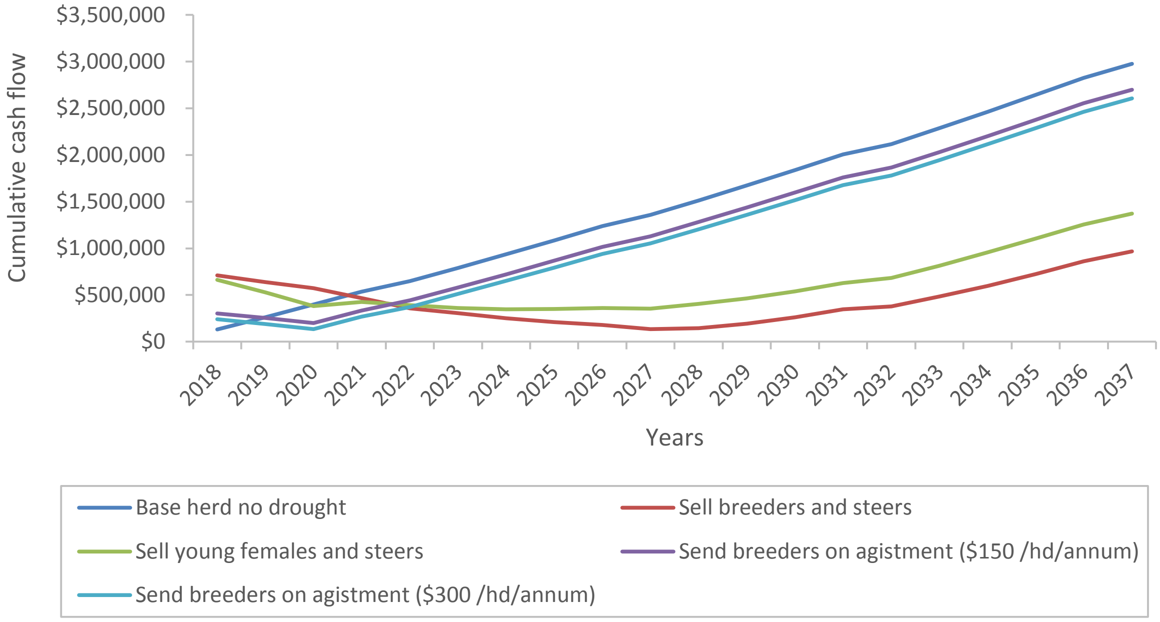
Figure 14 - Cumulative cash flow over time



It is also apparent that letting the herd slowly rebuild from retained progeny is likely to seriously impact the ongoing viability of the property. It appears a decision to rebuild numbers by retaining progeny will cause the property to forgo between $1.5 million and $2 million in cash flow over the following 20 years, with losses increasing the longer the slow build up in numbers is allowed to continue. It is necessary to identify strategies that will efficiently fill the gap between the actual grazing pressure applied and the total carrying capacity available each year as the herd rebuilds.

One option is to send the breeder herd on agistment for the period of the drought (let's say 12 months) and then return them once the season has broken. Figure 15 shows the comparable cumulative cash flow if the retained breeders 3 years plus were sent on agistment for 12 months at total costs of $150 per head or at $300 per head inclusive of transport and management expenses. The steers were still also sold as per the 'sell mature breeders and steers' scenario allowing the same reduction in grazing pressure on the home property to be made. Deficits were increased by more than $400,000 in the short term compared to the sale option but cash flow and profit more rapidly returned to their long term trend.

Figure 15 – Comparative cash flows for alternative herd rebuilding strategies including agistment



Successfully finding suitable agistment that allows the breeder herd to perform at a similar level to the home property may prove problematic but incurring the short term cost of expensive agistment may be a more viable option than dramatically selling down the herd and trying to eventually rebuild numbers over time. Long term agistment is a different scenario with different costs and returns.

If no agistment can be found and the sell down occurs, strategies that efficiently fill the gap between potential income and realised income while the herd is rebuilding will need to be identified. The available choices also depend upon the timing of the seasonal break and how widespread it is in nature. An early break with follow up rain prior to Christmas will allow a different recovery to a late break with little chance of effective follow up summer rainfall.

The baseline property will have up to 900 AE/annum spare grazing capacity if a substantial sell down of numbers occurs. The available options for filling this gap will probably include:

- the purchase of cows (and calves) to rebuild the herd faster
- taking cattle on agistment
- the purchase of groups of steers, heifers or cows and calves as turnover stock. That is, they are purchased specifically as a trading option to be sold once they reach a target weight or condition

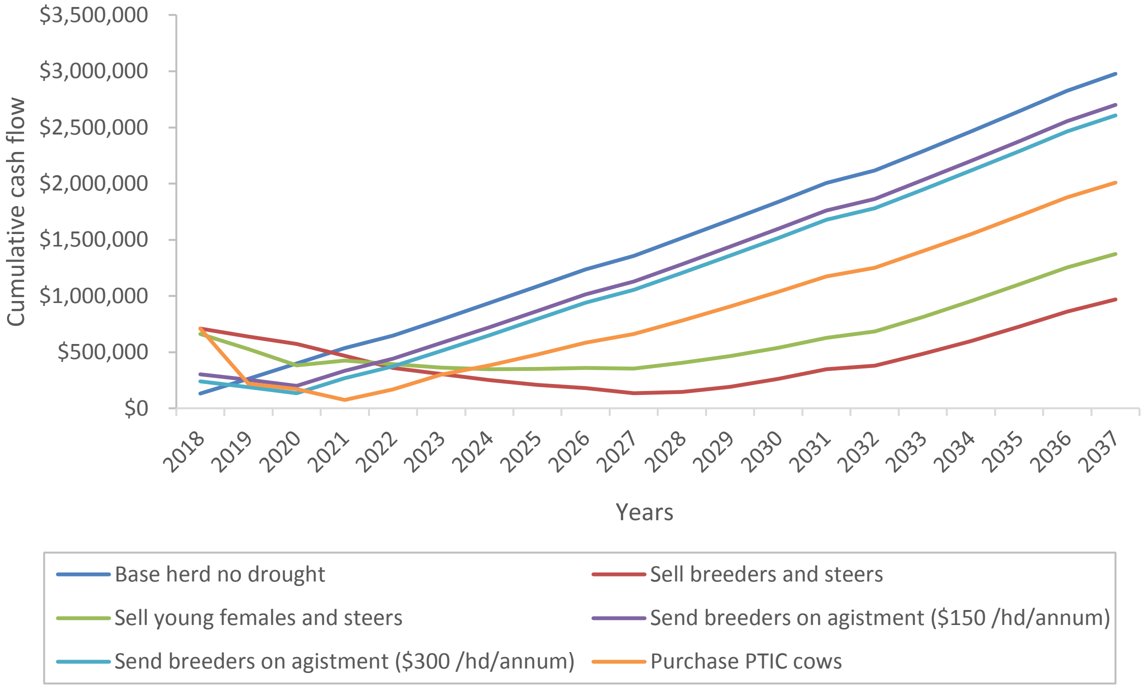
- re-purchasing the components of the herd that were sold to rebuild numbers to the long term herd structure
- a combination of all of the above.

Each drought will provide different opportunities related to the availability of stock and the length of the drought but in each case the same framework can be applied to consider potential outcomes associated with each choice. It is necessary to consider all options for their impact on the profit and cash flow of the property both in the short term and over time. This section will concentrate on cash flow aspects.

3.5.1 The purchase of cows to rebuild the herd

The purchase of PTIC cows in May of the year after the drought breaks will be used as an example of the framework applied to assess the relative efficiency of rebuilding the profit of the property through breeder purchases. In this example, the drought causes the sales in early 2018 with the PTIC cows purchased in May the following year. The purchased cows will contribute to calves produced at the end of 2019 so that the normal complement of calves will be produced at the end of 2019. Figure 16 indicates that purchasing PTIC cows to rapidly restore the breeder herd will substantially increase and extend cash flow deficits in the short term but potentially provide a better outcome than just allowing the herd to return to normal numbers through foregoing sales. Even so, most producers would be wary of a strategy taking 7 years to regain the same bank balance as that of a much lower risk strategy (rebuilding the herd).

Figure 16 - Comparative cash flows including the impact of purchasing PTIC cows



3.5.2 Taking stock on agistment

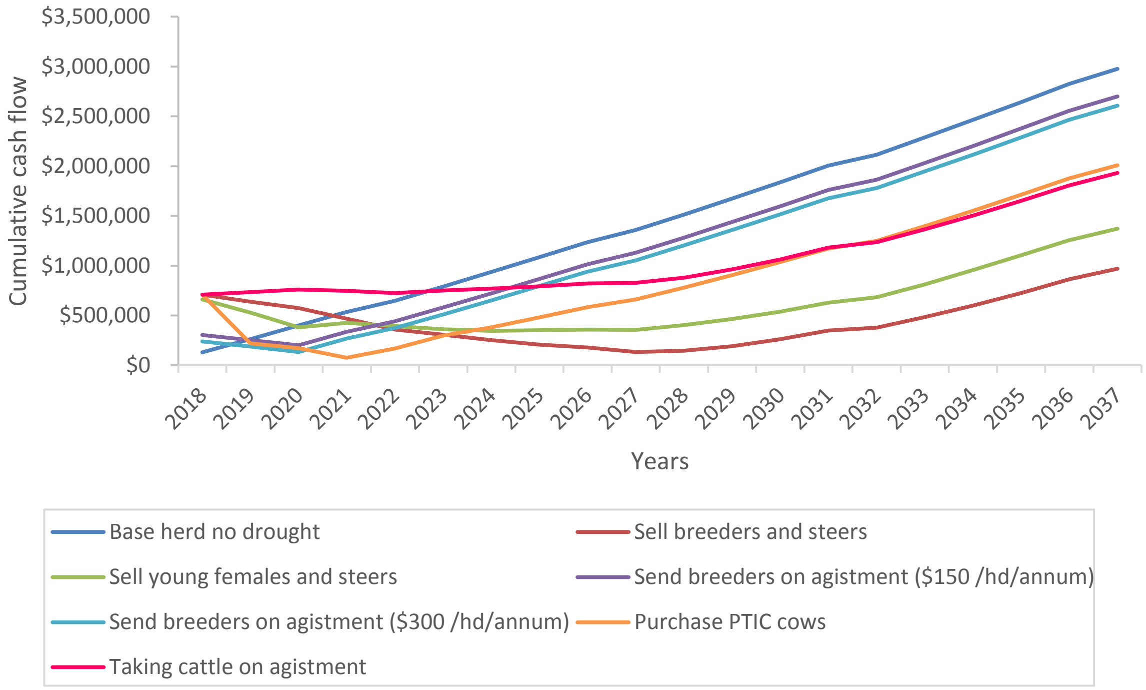
For this example we will assume that the difference in AE count between the baseline herd and the herd that sells down mature breeders and steers is available for agistment from 2019 onwards. Table 105 shows the additional income available from long term agistment taken while the breeder herd is rebuilt if $2 per AE per week is received. Agistment income will continue to be received until 2036 in this scenario, although only minor amounts will be received after 2032.

Table 105 - Potential extra income from agisting the spare carrying capacity of the property while the herd rebuilds

Parameter	**Year**									
	2019	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**
Room for agistment (AE)	907	863	844	763	689	615	530	437	347	262
Agistment income	$94,298	$89,721	$87,755	$79,300	$71,665	$63,964	$55,122	$45,429	$36,136	$27,293

Figure 17 indicates the cumulative cash flow if the spare grazing capacity can be filled by stock on agistment at $2 per AE per week. Whether this is possible once the drought is broken is unknown but higher or lower rates of income from agistment are easily tested in the model. Taking cattle on agistment provides substantial protection of cash balances in the early years while the herd is rebuilding and appears to be more profitable than just purchasing PTIC cows. It also appears to be the lowest risk option available in the 5-8 years after a significant short term drought.

Figure 17 - Comparative cash flows including the impact of agisting while numbers are rebuilt



3.5.3 Trading cattle

There are numerous scenarios for the trading of cattle as part of recovering from drought and it is recommended that a number of alternatives are assessed using current prices for each class, and expected weight gains, to confirm which alternative may be lower risk and more profitable at the time the decision is being made. The Bullocks program can be used to assess the purchase of dry stock and the Cowtrade program can be applied to assess the purchase of cows and calves or PTIC cows as a trading option. In each case the decision criteria is to select the class of cattle likely to provide the highest gross margin per AE after interest. It should also be noted that where cattle are purchased to be traded the choice of which class of stock to purchase should be reassessed at least once each year.

An example for the annual trading of steers is presented here to show the process of assessment, not to identify a recommended course of action. In this scenario yearling steers were purchased in February after the drought and the exercise was repeated every 12 months until the remaining breeder herd was rebuilt. The steers were purchased at the long term selling prices for this class of steers applied in the baseline herd model although this will vary every 12 months in reality. The number purchased was decided by the AE rating for the steers and the spare grazing capacity available as the breeding herd returned to normal size. The steers were sold at the long term price applied to the class of steers one year older in the baseline herd model. The understanding was that, on average, these will be the average prices over time and represent the average margin between the purchase and sale price. The annual weight gain of the steers was set at about 10% lower than that expected in the baseline herd growth path for steers due to some of the purchased steers running on breeder country in this exercise. Table 106 shows data extracted from the Bullocks program. The indication was that the each steer purchased and held for twelve months was equivalent to 0.86 AE.

Table 106 - Bullocks program extract for steer trading

Start date	01-Feb-2019			
End date	31-Jan-2020			
Days on forage	364			
	Paddock weight (kg)	Traded weight (kg)		
Purchase weight	314	314	Average daily gain (kg)	0.44
Sale weight (live)	474	450		
Purchase price $/kg live, landed	$1.96		Purchase price/head (landed)	$615.44
Sale price $/kg dressed weight net	$1.87		Sale price/head (net)	$886.38
Adult Equivalent (AE) standard weight (kg)	455		Average weight for AE calculation	394
Mortality	2.00%		Adult Equivalents per head	0.86
Variable cost/head	$36.20			
Interest rate (per annum)	0.00%			

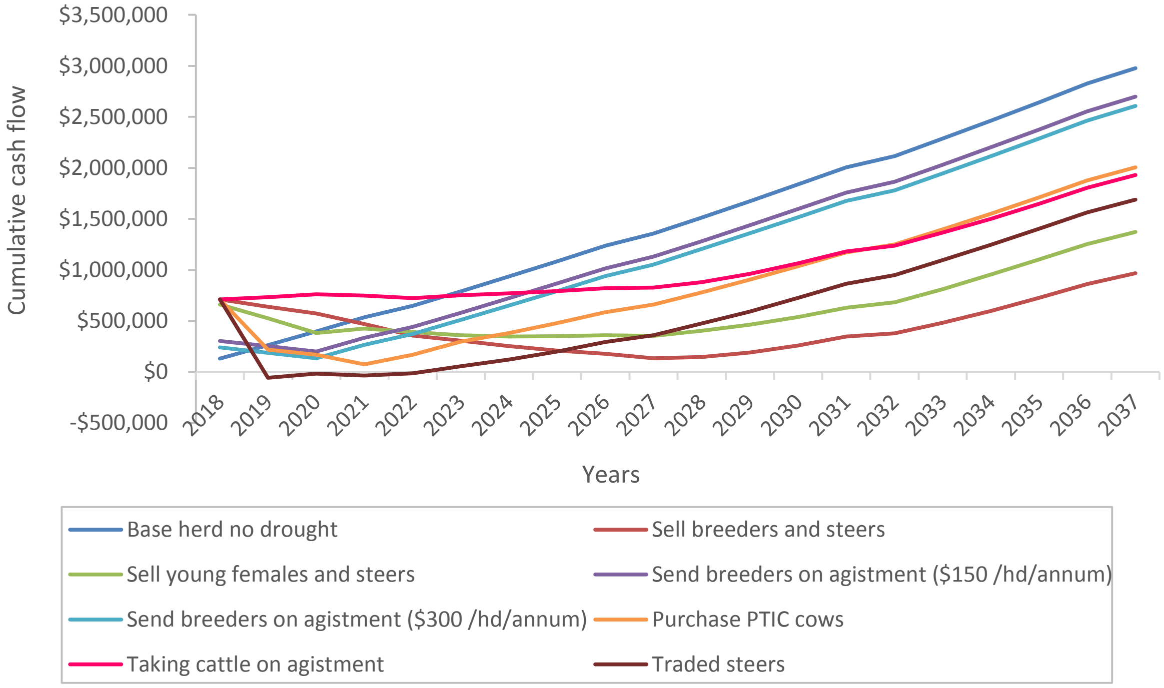
The gross margin per AE calculated in the Bullocks program could not be multiplied by the spare grazing capacity to identify the impact of the trading exercise as the steers were purchased one year and then sold the next, thereby impacting the cash flow and interest costs of the property. Table 107 shows the gross margin calculation for the steer trading activity for the first 9 years after the drought finished.

Table 107 - Steer trading gross margin

Parameter	**Year**								
	2019	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**
Number purchased	1054	1003	981	887	801	715	616	508	404
Purchase weight (kg)	314	314	314	314	314	314	314	314	314
Purchase price	$1.96	$1.96	$1.96	$1.96	$1.96	$1.96	$1.96	$1.96	$1.96
Total purchase cost	$648,868	$617,377	$603,848	$545,667	$493,128	$440,142	$379,295	$312,602	$248,654
Treatment costs	$38,166	$36,314	$35,518	$32,096	$29,006	$25,889	$22,310	$18,387	$14,626
Number sold	1002	953	932	842	761	679	585	483	384
Sale weight (kg)	450	450	450	450	450	450	450	450	450
Sale price	$1.87	$1.87	$1.87	$1.87	$1.87	$1.87	$1.87	$1.87	$1.87
Total sale value	$843,408	$802,475	$784,890	$709,266	$640,975	$572,103	$493,014	$406,325	$323,204
Selling costs	$69,561	$66,185	$64,735	$58,498	$52,865	$47,185	$40,662	$33,512	$26,657
Gross margin	*$86,813*	*$82,600*	*$80,789*	*$73,005*	*$65,976*	*$58,887*	*$50,746*	*$41,823*	*$33,268*

Figure 18 indicates that, in this example, the substantial additional interest and other expenses incurred in trading steers is likely to reduce the cumulative cash flow below that of the options of purchasing PTIC cows or taking stock on agistment. The capacity of the property to fund the steer purchases may also be a relevant factor to consider. The steer trading model would also be more risky than any of the other options considered so far.

Figure 18 - Comparative cash flows including the impact of trading steers while numbers are rebuilt

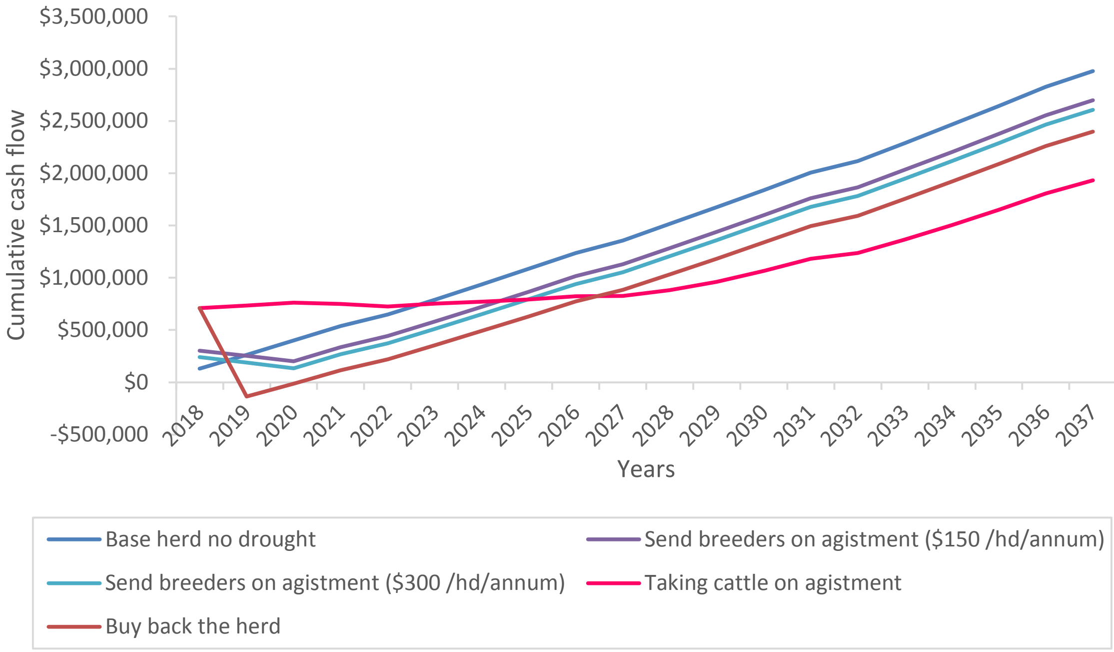


3.5.4 Buying back the herd

'Buying back the herd' is an option aimed at getting the herd back into full production as soon as possible. The stock purchased when the drought breaks depends entirely upon the stock sold in response to the drought but in this example the breeder herd was sold down and sufficient PTIC cows and other stock were purchased to return the property to full capacity in the shortest period of time possible. Prices paid were equivalent to 20% above the long term sale price plus $30/head transport and handling costs.

The option to 'buy back the herd' was modelled by adding the purchase of weaner steers and heifers plus yearling steers to the PTIC cow purchase model. More than 1000 cattle (including PTIC cows) were purchased at a cost of about $800,000. The herd then sold the expected pre-drought numbers from Year 3 onwards. It can be seen that buying back the herd caused a substantial cash flow deficit and it is likely to be 10 years before bank balances return to the level of taking stock on agistment as you wait for the herd to rebuild (Figure 19).

Figure 19 - Comparative cash flows including the impact of buying back the herd while numbers are rebuilt



The analysis of options is becoming complicated but different outcomes are becoming identifiable. Although the outcomes rely heavily on the parameters chosen, there is sufficient difference between each of the options for more informed decisions to be made.

This exercise would need to be compiled at each point in time that drought recovery decisions have to be considered as it is obvious that a small change in the parameters applied will change the relative ranking of the options. It is also clear that just looking at the short term ramifications of these choices does not reveal the full picture. However, beef production is very dynamic and variable and hence predicting outcomes at a time in the medium term future is very challenging.

It is obvious that once a couple of likely prospects for recovery options are identified some detailed consideration should be given to the relative riskiness of the alternatives. This is particularly so with exercises that incorporate agistment. Due diligence seems to be a key ingredient of successfully concluding an agistment agreement.

4 Summary of findings

A summary of the key findings from this analysis are given below. Note that ‘annualised marginal NPV’ results are referred to as ‘the change in profit per annum’ here.

4.1 Preparing for drought by improving profit and business resilience

4.1.1 Improving steer growth rates

1. Optimising steer growth path performance with investment in leucaena-grass pastures, planted in strips into existing buffel grass pastures, substantially improved the profit of the beef business and was the most profitable of all strategies assessed when the breeder herd was phosphorus (P) -adequate ($40,336-$46,135 extra profit per annum). Purchase of additional breeders to match weaner numbers to the supply of leucaena, rather than waiting for natural increase in breeder numbers, resulted in the greatest improvement in profit. However, implementing a leucaena-grass system substantially increased peak deficit levels (-$145,722 or -$190,539, with natural breeder increase or purchase of additional breeders, respectively) and financial risk, with a payback period of 7 years.
2. Improving steer growth path performance with investment in a shrubby legume such as desmanthus, planted in strips into existing buffel grass pastures, substantially improved the profit of the beef business ($26,779 extra profit per annum). As for leucaena, peak deficit levels were substantially increased (-$103,212) and a considerable payback period was required (8 years).
3. Investing in a strategy of growing forage oats to sell feed-on steers at a younger age than if grazed only on buffel grass substantially reduced the economic and financial performance of the beef business resulting in $34,521 less profit/annum than the baseline scenario with no forage oats. The use of forage oats also substantially increased financial risk with the strategy not generating sufficient returns to repay the additional borrowings required to implement the system within the 30 years of the analysis. In this example it was assumed that conditions would be suitable for planting a forage oats crop in 67% of years.
4. Implementing a strategy of custom feedlotting, feed-on steers to slaughter weight substantially reduced the economic and financial performance of the beef business resulting in $48,841 less profit/annum than the baseline scenario. The large negative gross margin per head of ca -$244 indicated that grain prices would have to decrease substantially and/or the price margin ($/kg) between cattle entering and exiting the feedlot improve substantially, relative to current prices, for this strategy to be profitable. The results of this analysis will equally apply to the use of custom feedlotting as a drought response strategy.
5. Using hormonal growth promotants (HGP’s) on a long term basis will change the weight for age for steers, the range of accessible markets and the structure of the total herd. Implementing a strategy of HGP use from weaning until sale of feed-on steers at the same age as for the baseline herd (27 months) resulted in positive returns but only if the same sale price was received as for the feed-on steers in the baseline herd despite the HGP-treated steers exceeding the target feed-on weight: $10,794 extra profit per annum. When these same HGP-treated steers received a price discount of 10c/kg liveweight, as a result of exceeding the target weight for feed-on steers at 27 months, the HGP strategy reduced profit: $806 less profit/annum. Alternatively, if the HGP-treated steers were sold at a younger age than steers in

the baseline herd, in order to meet the target weight for feed-on steers and avoid price discounts, the profit of the beef business was also reduced ($5,494 less profit/annum). This was predominantly due to the herd structure changes associated with selling younger steers which, in effect, caused proportionally more (less valuable) cow beef to be sold out of the herd as the sale age of the steers reduced. These results demonstrate the importance of getting the target market and herd structure right when applying HGPs to improve steer growth rates.

4.1.2 Improving breeder reproduction performance

1. Improving breeder reproductive performance by investment in genetically superior bulls to improve the average weaning rate by 6% reduced economic and financial performance of the beef business resulting in $3,265 less profit/annum. Peak deficit levels were increased (-$135,215) and the strategy did not generate sufficient returns to break-even within the 30 years of the analysis. The poor economic performance was due to the extended period of time before the improved genes predominated in the herd as well as the pre-existing reproduction efficiency in the baseline herd (77% weaning rate).
2. To achieve a 50% reduction in calf loss in heifers and first lactation cows, no more than $5/head.annum should be spent if a return on funds invested is to be achieved. At $5/head investment, additional profit generated was only ca. $474/annum over the 30 years of the analysis. For this enterprise, supporting 1,500 AE, expenditure of up to $20,000 as an upfront capital expenditure with no additional ongoing expenditure would result in an extra $1,019 profit/annum if calf/foetal loss could be reduced by 50% in heifers and first lactation cows. Increasing capital expenditure above $30,000, to achieve the same improvement in reproductive performance reduced returns. These results demonstrate the diminishing returns available from investing to improve reproduction efficiency in a herd that has the median level of performance of 10.2% foetal/calf loss in heifers and 7.3% in first lactation cows.
3. A beef property with a high prevalence of pestivirus and a 2% reduction in average conception rate was only slighter better off with a long term vaccination program that treated all breeding females ($1,025 extra profit/annum), with 15 years required before the investment in annual vaccination was repaid. If the same high prevalence herd could recover the 2% reduction in average conception rate by vaccinating only the heifers, then the benefits of the vaccination program would more than double ($3,683 extra profit/annum). If the beef herd was assumed to be naive to pestivirus, the marginal returns from implementing a full vaccination program were -$2,436 annualised NPV/annum.
4. Analysis of investments in inorganic supplements to improve the performance of low P status breeder herds showed that where a biological response to supplements can be identified, wet season P supplementation alone appears to be more efficient than either supplementing with N+P during the dry season or supplementing with N+P during the dry season combined with P supplements during the wet season. However, for herds considered ‘deficient’ and ‘acutely deficient’ in P, supplementation with P in any season substantially increased profitability (range $9,025-$48,216 extra profit/annum). The maximum response ($48,216 extra profit/annum) resulted from supplementing an acutely P deficient herd with P in the wet season only.
5. Supplementing first calf heifers with an M8U (molasses with 8% urea by weight) supplement to improve their re-conception rates from 78 to 80% reduced the returns of the business by $9,684/annum. This demonstrates that although maintaining body weight is critical to the

performance of young breeders, the extra costs associated with achieving extra weaners through supplementing first calf heifers will not be repaid.

4.1.3 Marketing options

1. Targeting the certified organic beef market with steers and cull heifers was only marginally more profitable than the baseline production system, resulting in an extra profit of $2,436/annum. Over the longer term (i.e. after the initial 30 years examined in this analysis) the 25% price premium for organic cattle would not be adequate to offset the 20% reduction in grazing pressure which was assumed to remove the need for supplementation or drought feeding.
2. Targeting the European Union (EU) beef market and selling steers at the same age as for the baseline herd, with 67% going to slaughter and the remainder to the feed-on market, resulted in an extra profit of $5,949/annum. If EU steers were sold at a younger age than the baseline herd and in two cohorts as feed-on steers, the annualised NPV was a similar amount: $5,338/annum. However, these results were very dependent on the price premium received for EU cattle (15 c/kg LW). If the price premium was reduced by half, the sale of EU steers as two cohorts of feed-on steers resulted in -$3,845 annualised NPV.
3. Converting to a purebred Wagyu herd substantially improved the profitability of the beef enterprise if the price premium of 100% for Wagyu cattle was maintained from Year 7 of the transition until Year 30 years of the analysis: $32,943 extra profit/annum. However, when price premiums were reduced from Year 20 of the analysis (to $0 by Year 25) the investment in Wagyu cattle was only marginally profitable: $3,218 extra profit/annum. When price premiums were reduced from Year 10 of the analysis (to $0 by Year 15) the investment in Wagyu cattle was not profitable: $42,071 less profit/annum than the baseline herd.

4.2 Assessing the potential impact of drought on the herd as well as the effect of herd structure on drought risk and profitability

1. As breeders age they have a greater expected mortality if they suffer liveweight loss during a drought. Having breeder BCS in better than a forward store condition (better than score 5 on a 9 point scale) going into a drought could substantially reduce the mortality rate of mature and aged cows who are considered likely to lose more than 10% of their starting liveweight. Reducing the age of cow culling from 12-13 years to 9-10 years of age, and consequently reducing the percentage of 2 year old heifers sold as culls, only marginally reduced the profit (by less than $1,000/annum). This reduction is more than likely to be offset by the breeding herd having a substantially reduced number of mature cows, and no aged cows, going into a drought and consequent reduced mortality rates.
2. Targeting production of 1-2 year old feed-on steers resulted in the optimum profitability for the baseline herd. Changing the age of steer turnoff to older or younger than 1-2 years of age reduced profit but also changed drought risk due to changing the number of wet cows in the herd. Over the longer term, a strategy of targeting 2-3 year old steers appears to be worth consideration to reduce drought risk. This increased age of steer turnoff only marginally reduced profit (by 1.4% for herd gross margin) whilst reducing drought risk due to decreasing the number of wet cows in the herd (35% of the herd vs. 40% in the baseline herd). Re-structuring the herd to turn off 3-4 year old steers reduced drought risk further (30% of the herd now wet cows) but also reduced profit more substantially (5% decrease in herd gross margin).

When the herd was restructured to turn off weaner steers drought risk increased due to 51% of the total herd being breeders mated and kept whilst profit also decreased substantially (by 23% for herd gross margin).

4.3 Assessing key strategies which may be applied in response to drought

1. Drought response strategies are tactical, short-term decisions which are highly dependent on the individual circumstances prevailing at the time. As it is not possible or practical to create scenarios to reflect every possible combination of assumptions, expected ‘answers’ cannot be given – the strategies need to be assessed using the relevant input figures at the time of the decision. Hence, examples were developed to demonstrate a) the key strategies which may be considered in response to drought, and b) how to assess strategies using tools available in the Breedcow and Dynama suite of programs. These strategies are summarised below.
2. Drafting off and culling PTIC empties (females that were pregnancy tested in calf the previous year but subsequently lost a calf prior to branding) at the branding muster is an easy way to reduce grazing pressure early in the year in response to poor seasonal conditions and outlook. In a well-managed herd that has a lower rate of foetal/calf loss, the number available for sale are not likely to be a substantial portion of the herd or grazing pressure but sale of these females may also remove sub fertile cows.
3. Early weaning at branding in February (rather than usual weaning in mid-May) will reduce liveweight loss of breeders during poor seasonal conditions and hence reduce breeder mortality rates and improve reproductive efficiency. The weaners will need to be segregated on weight (>/< 100 kg) and fed supplements suitable for each group. The Splitsal program can be used to indicate the expected weight distribution of weaners in February, allowing feeding costs to be calculated. The Cowtrade program can then be used to compare these costs to the anticipated benefits of a reduction in breeder mortality rate and improved reproductive efficiency.
4. Selling PTIC cows (females pregnancy tested in calf) at pregnancy testing in early May and then re-purchasing cows and calves 12 months later is another strategy that can be considered using the Cowtrade program. This strategy is aimed at maintaining the number of weaners available to the property over time and can be compared to the expected feeding costs if the cows are retained to produce weaners as normal. A table can be produced to indicate the sensitivity of the exercise to variation in the sale price for PTIC cows, the cost of feeding, and the replacement costs of cows and calves. The break-even level for the drought feeding strategy can be determined using the Cowtrade program.
5. The sale of other classes of dry stock as an alternative to selling breeding females can be evaluated by combining the Bullocks and Cowtrade programs. The Bullocks program can be used to test the same options for non-breeding cattle as the Cowtrade program does for breeder groups. In many cases a drought response can include ‘either or’ options where different classes of cattle can be sold to achieve the same level of reduction in grazing pressure. The criteria for deciding which class of cattle needs to be sold first is usually the ‘gross margin per AE after interest’ calculated over the selected period of time with the class achieving the lowest gross margin sold first. The class of cattle chosen for sale could change over time due to changing market opportunities and feeding costs.

6. The direct costs of agistment can be determined using spreadsheets and compared to the costs of alternative management responses.

4.4 Assessing key strategies which may be applied in the drought recovery phase

1. The choices available during the drought recovery phase depend partly upon the decisions previously made during the drought response phase. Each alternative strategy implemented during a drought will result in a different herd structure on the property at the end of the drought and different options available for recovery. As it is not possible or practical to create scenarios to reflect every possible combination of assumptions, expected ‘answers’ cannot be given – the strategies need to be assessed using the relevant input figures at the time of the decision. Hence, examples were developed to demonstrate a) the key strategies which may be considered in the drought recovery phase, and b) how to assess strategies these using tools available in the Breedcow and Dynama suite of programs. Drought recovery strategies should be targeted at returning business cash flow and profit to their long term trend as quickly as possible. The results of the examples developed are summarised below.
2. Where a substantial herd reduction has been carried out, allowing herd numbers to rebuild slowly from retained progeny, and taking no other action, is likely to seriously impact the ongoing viability of the business.
3. If breeders had been sent on agistment for the period of a short term drought (12 months) cash flow deficits would be increased in the short term compared to the sale of breeders but cash flow and profit could be more rapidly returned to the long term trend.
4. Purchasing PTIC (pregnancy tested in calf) cows to rapidly restore the breeder herd at the conclusion of the drought would increase and extend cash flow deficits in the short term but potentially provide a better outcome than just allowing the herd to return to normal numbers through foregoing sales.
5. If the spare grazing capacity created by selling cattle at the start of the drought can be filled by stock on agistment once the drought breaks this strategy improves the cash balances in the early years while the herd is rebuilding and hence appears to be more profitable than purchasing PTIC cows.
6. Cattle trading can be initially considered as part of a drought recovery strategy by using the Bullocks program to assess the purchase of dry stock and the Cowtrade program to assess the purchase of cows and calves or PTIC cows. The resulting gross margins need to be incorporated into a cash flow budget for the property over the medium term future to identify the impact of interest costs associated with funding stock purchases. It appears the short term trading of large numbers of stock when recovering from drought may be a risky venture that needs close consideration if costs are to be contained.
7. Another recovery option is ‘buying back the herd’. This is a risky option that takes an extended period of time to recover the additional costs incurred.
8. The best drought recovery option will only be identified after a number of strategies are compared for both their short term and medium term impact on the cash flow and profit outlook for the property.
9. The analysis makes it clear that drought recovery and drought response actions are closely linked and that the impact of response actions on the choices available for recovery action at

the end of the drought need to be fully considered. Even so, deciding prior to drought upon the recovery action that is considered most likely to return the property to a positive cash flow, and profitable operation the quickest, will often determine the response actions which should be considered first. However, this may not be the best management mindset to take into a drought. Flexibility is the key when responding to drought and setting a drought response (and recovery) plan prior to drought may prevent the consideration of more viable alternatives that are revealed as the drought progresses. It is necessary to apply the right planning framework and to reassess the strategy as change occurs.

5 General discussion

This study represents the first known attempt to assess the economic implications of a comprehensive range of management decisions that can be applied to prepare for, respond to, or recover from drought. In this analysis 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 businesses in the Fitzroy NRM region of central Queensland. The results of these analyses can be used to support informed decision making by producers.

The information provided here should be used, firstly, as a guide to an appropriate method to assess alternative strategies aimed at improving the profitability and drought resilience of a beef enterprise in central Queensland 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 key to improving the performance of individual beef enterprises 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 (Johnson 2018). 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 manager or enterprise. Producers or their advisors can use the tools and models developed in this study to conduct their own analyses specific their circumstances.

Many alternative beef production systems 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. The key insight is that the value of any change in management to build drought 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 that exhibit drought resilience are predominately those that spend considerable time and resources preparing for drought. 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 assessing options when responding to drought.

5.1 Preparing for drought

The results of the economic analysis summarised in Table 1 indicate the difference in returns between the baseline, case-study property and the same property after implementing the specified management strategy. They are a guide to possible strategies that may build profit and resilience prior to drought. It is important to note that a negative NPV does not necessarily indicate that a business implementing such a strategy is unprofitable, just that the strategy causes the business to be less profitable than baseline scenario.

The analysis indicates that a number of the alternative management strategies or technologies that could be applied to beef businesses in the Fitzroy region are unlikely to substantially improve resilience or add to profit. This is due to the representative, regional case-study model already being an efficient beef production system with existing production targets well considered by beef producers for their impact on risk and profit. For example, the available data for reproduction efficiency for the Fitzroy identifies a relatively high level of performance compared to other regions in northern Australia

(McGowan *et al.* 2014). This reduces the economic benefit of marginal improvements in strategies like the genetic improvement of fertility and reducing pre-weaning calf loss. Higher cost strategies aimed at improving reproduction efficiency, such as providing energy rations to first calf heifers prior to calving, appear unlikely to ever be economic due to the changes in herd structure that occur when one component of an already efficient system is targeted in such a manner.

There are available strategies that target growth rates of the steer component of the herd that will improve efficiency and resilience as long as they are initially selected for their likely impact on profit at the level of the property. It is clear that the incorporation of perennial legumes, especially leucaena, into the diet of steers provides a substantial step forward in profitability and therefore resilience. Even so, the long payback periods for perennial legume-grass pastures suggest that investments will have to be targeted closely with a piecemeal development process applied to reduce the riskiness of the investment. The financial risk and long payback period is likely to be one factor explaining the low exploitation of this resource in Queensland despite the large potential area suited to leucaena and other perennial legume plantings (Peck *et al.* 2011; Beutel *et al.* 2018). Johnson *et al*. (2002) identified the perceived risk associated with achieving higher levels of productivity as a major impediment to producers adopting new practices. Perceived risks included financial failure and increased stress from managing a more intensive system. The difficulty and risks associated with legume establishment, as well as the additional management expertise required to productively utilise the resource, have been identified as constraints to perennial legume establishment in Queensland and elsewhere (Shelton *et al.* 2005; Peck *et al.* 2011; Bowen *et al.* 2015*a*).

In contrast to the investment in perennial legumes, other strategies targeting steer nutrition reduced both the profitability and resilience of the beef production system. One strategy often used in the Fitzroy is to send steers to a feedlot to be custom fed and then slaughtered, either as a strategy to increase output or in preparation for drought. This action substantially and consistently reduces the profitability of the beef production system. Likewise, targeting the use of annual forages such as forage oats or forage sorghum have been shown in this analysis and others (Bowen *et al.* 2015*b*, 2016; Bowen and Chudleigh 2017) to be both high risk and low profit ventures.

When considering a strategy of HGP use from weaning until sale producers need to ensure they will meet the specifications for the market they are targeting and need to consider effects on the overall herd structure if the age of turn-off changes. A relatively small change in price can make this strategy either profitable or unprofitable.

The one strategy that considered disease management in the breeder herd indicated that potentially high impact, episodic events, such as an outbreak of pestivirus in a naive breeder herd, are difficult to assess for their impact on profit and risk making a recommendation of change to the current strategy (of no treatment) difficult to justify. Diseases that have an ongoing, low level of impact also provide difficulties when recommending a change in management given the often high cost of treatment and the difficulty of isolating and measuring the impact of treatment. The survey data of Barbi *et al.* (2016) indicates that producers are capable of assessing these risks within the context of the circumstances of their property if they are provided with adequate information about the risks of the disease and its aetiology. A decision not to prevent a disease can be shown to be equally as rational as taking action to prevent disease, depending upon the circumstances of the beef production system under threat.

Phosphorus deficiency has been shown to be widespread across northern Australia and is considered to be a major constraint to the performance of beef cattle (Jackson *et al.* 2012). In this analysis we looked at the breeder herd in isolation and found that the value of providing inorganic supplements to reduce the impact of varying levels of P deficiency depended very much on the marginal benefits of providing an efficient supplementation program. Rigorous analysis of the existing level of P deficiency and its impact, the appropriate method of overcoming the deficiency and the value of fixing the deficiency need to be undertaken prior to implementation of any supplementation program. Breeder herds that are performing at the median level indicated in regional surveys (McGowan *et al.* 2014; Adequate P status) are unlikely to show an economic response to nutritional supplements whereas breeder herds running on country with an acute level of P deficiency are likely to show a strong economic response to appropriate levels of P supplementation. Breeder herds that run exclusively on Marginal P country appear likely to only show a measureable economic response to P supplements delivered in the wet season. However, breeder herds run on Deficient P and Acute P country are expected to show a measureable economic response to P supplementation delivered either in the wet season only, in the dry season only and in combination with N supplements, or in both the wet season and dry season. For all herds with a measureable P deficiency, response to supplementation is likely to be more profitable if delivered in the wet season only.

The results of our study suggest that, other than P supplementation when appropriate, strategies focused on improving the performance of the breeder component of the herd in isolation are unlikely to improve to business profit and resilience. This lack of capacity to identify changes that improve breeder herd efficiency highlights the critical importance of implementing low cost strategies to get body condition and herd structure right as key factors in being drought prepared. The section of this report that identifies the impact of entering a period of falling body condition and weight loss with higher or lower body condition scores demonstrates the importance of the day-to-day management of the breeder herd and its nutrition in preparing for drought. Selecting the appropriate age for female culling and steer sale can also reduce drought risk

Strategies that target different markets such as the EU market for steers, organic production and Wagyu beef may offer short term opportunities to improve profitability but also appear to increase drought risk due to the focus on a more narrow production system. Production systems that reduce flexibility over the longer term have been shown to be inherently more risky and therefore likely to expose the property to greater variation in returns.

Ash *et al.* (2015) reported results of whole-farm-scale dynamic simulation modelling to assess a range of technology interventions that may improve productivity and profitability of northern Australian beef enterprises. Our results are in accord with their finding that incorporating perennial legumes in pasture systems was the most profitable of all individual technologies for their Queensland case study properties. However, while Ash *et al.* (2015) reported increases in enterprise profit from strategies to improve reproductive efficiency of breeders through genetic gain, our study showed such a strategy to decrease enterprise profit. The difference in the results of the two studies is largely due to the economic methods used by Ash *et al.* (2015) which did not consider the implementation phase required for each of the scenarios but assumed the that the strategies were fully implemented from the start of their 25-year scenario runs. The poor economic performance of the improved breeder genetics strategy in our study was partly a result of the extended period of time before the improved genes predominated in the herd, in addition to the pre-existing high level of reproduction efficiency.

The importance of incorporating the implementation phase in any analysis of change in the management of beef enterprises in northern Australia have been conclusively demonstrated in the studies of Chudleigh *et al*. (2016, 2017) and Bowen and Chudleigh (2017). These analyses, as well as our current study, have highlighted the importance of appropriately modelling the steps in moving from an existing herd structure and target market to a different target market and consequently a different herd structure when implementing alternative management strategies. 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 strategies to improve the economic performance of breeding herds run under extensive grazing conditions in northern Australia. These analyses indicated that capital constraints and financial risk play a large role in the level of adoption, and the rate at which a management strategy is likely to be adopted and implemented. Applying a method that appropriately highlights the financial risks associated with the implementation of a management strategy, as well as the potential economic benefits, is necessary to assist understanding of the nature of the alternative investments. This assertion was also made by Foran *et al.* (1990) who concluded that the ‘whole enterprise’ approach is essential for both comparing management options and for setting priorities for research and development in the northern beef industry.

In this study we did not examine land management strategies to improve land condition. One assessment based on remotely sensed ground cover time series (1996-2012) suggests ca. 48% of the Fitzroy NRM grazing land is in A condition (Beutel *et al.* 2014; scale A-D, Quirk and McIvor 2003; DAF 2011). A more recent 2017 assessment of land condition based on a different model suggests this value is around 40%, although qualitative expert assessments suggest the newer model may not fully account for the negative effects of invasive Indian couch on land condition rating (T. Beutel, pers. comm.). However, there is little field research to indicate rates of degradation and recovery across land types and regions in northern Australia. There is a particular paucity of data for effects of utilisation rate on the productivity of buffel grass pastures (or any sown tropical grasses under comparable rangeland conditions) and, hence, on land condition rating. Grazing management guidelines recommended by Scanlan *et al.* (2014) and Hunt *et al.* (2014*b*) are yet to be tested experimentally. Recent field experiments with two native pasture systems in central and north Queensland, respectively, failed to improve land initially in C condition with wet season spelling strategies, over a 3 or 5-year period (Jones *et al.* 2016). Additionally, there are practical difficulties in implementing land recovery strategies such as pasture spelling on commercial properties as cattle from rested paddocks are necessarily spread across the remainder of the property, increasing the short-term stocking rate on non-rested paddock over the growing season when pastures are most vulnerable to heavy grazing pressure. Some land condition aspects have been previously examined, for effects on profitability of beef businesses in the Fitzroy NRM region, in a scoping study examining a range of outcomes (Bowen and Chudleigh 2017; Bowen and Chudleigh 2018*a*). These publications identified a positive financial and economic incentive to apply high stocking rates, even under conditions of declining land condition rating.

5.2 Responding to drought

The capacity of the representative property to respond to drought is initially defined by the way the breeder herd is already segregated on age and managed. In this analysis the case study breeder herd had been culled on pregnancy status with all empties removed during the previous season. This reduced the opportunity for the manager to take decisive action, in rapidly reducing grazing pressure, if the following season was below average and hence complicated the decision making process when forced sales were being considered. These difficulties are part and parcel of having an efficient production system in place prior to drought but are less challenging than those faced by the producer that does not pregnancy test and has in place a breeder herd structure that exposes them to increased drought risk.

The analysis showed that an efficient system has no easy decisions when it comes to substantially reducing grazing pressure. The initial tweaks to herd numbers that can be made when responding to drought do not make large reductions in numbers or grazing pressure and the remaining choices involve the sale of classes of cattle that will substantially impact the future earning capacity of the property. At this time, detailed analysis of the options available needs to be made as each set of circumstances will be different and a successful action taken at the start of the last drought may not meet with success this time around. The finding from this study was that assessing the sale of alternative classes of cattle should be done on the basis of the impact of either future profit or future cash flow, depending upon the immediate needs of the property, and that all classes of cattle should be incorporated in the assessment.

5.3 Recovering from drought

Drought recovery strategies should be targeted at returning business cash flow and profit to their long term trend as quickly as possible. However, it is known that rapid rebuilding of herd numbers following a drought can exacerbate land degradation (McKeon *et al.* 2004). Hence, appropriate monitoring of the pasture resource needs to be conducted to ensure it is capable of supporting the livestock numbers during each phase of the herd rebuilding period.

The analysis makes it clear that drought recovery and drought response actions are closely linked and that the impact of response actions on the choices available for recovery action at the end of the drought need to be fully considered. Even so, deciding prior to drought upon the recovery action that is considered most likely to return the property to a positive cash flow, and profitable operation the quickest, will often determine the response actions which should be considered first. However, this may not be the best management mindset to take into a drought. Flexibility is the key when responding to drought and setting a drought response (and recovery) plan prior to drought may prevent the consideration of more viable alternatives that are revealed as the drought progresses. It is necessary to apply the right planning framework and to reassess the strategy as change occurs.

Graziers in western Queensland have recommended two key actions required to better manage droughts:

1) developing a strategic drought plan prior to a drought, and
2) participating in an ‘after action review’ process following a drought in which drought plans are reviewed and improved in readiness for subsequent droughts (Counsell and Houston 2017).

The tools, herd models and framework developed in this study can be used by producers and their advisors to support such planning and review activities. The best recovery option will only be identified after a number of strategies are compared for both their short term and medium term impact on the cash flow and profit outlook for the property.

5.4 The constraints that apply to scenario analysis when using nonspecific data

There are significant constraints when applying the broad understandings gained from modelling the performance of typical production systems to the circumstances of the individual property, herd or flock. It has been shown that the relative and absolute value of alternative investment strategies varies substantially between beef enterprises in northern Australia (Chudleigh *et al.* 2016). Opportunities for improving enterprise performance are specific to the unique resources, management system and management skill of each enterprise, not necessarily to regions, production systems or land types. This means that an investment that improves the performance of property A may or may not improve the performance of property B even though they are both found in the same region and have similar production characteristics. Scenario analysis based on data that is not specific to any property will often not be representative of the achievable outcomes for any property in particular. This is because each property has a different set of constraints and opportunities and there is no common starting point. The usefulness of any particular change in management or investment to an individual manager, therefore, completely depends upon the relative value of a change within their enterprise. That is, the marginal return on the investment needs to be assessed within the constraints of each particular property considering change.

It should be clearly recognised that:

- The key to economic and financial success is the ability of management to apply an appropriate framework to assess the trade-offs, responses, costs and benefits likely from the implementation of any opportunity for their property under their own specific circumstances.
- The ultimate decision criteria to judge a potential change is the extra return on extra capital invested (marginal return) that is likely to result, weighed up in the context of the extra risk (both enterprise risk and financial risk) associated with the change.
- Applying an appropriate framework to decision making and understanding the reasoning behind the process will point roughly which direction to go, not the ‘answer’.

While considering the results of an analysis based on the circumstances of another property or an ‘example’ property is rarely an accurate indicator of the likely outcome for each separate manager or enterprise, it is a way of understanding the key factors in the decision. The scenarios modelled here are aimed at providing a broad understanding of the range of opportunities available for improvement, the potential response functions in a production system and an appropriate framework to support decision making.

6 Conclusions

This study represents the first known attempt to assess the economic implications of a comprehensive range of management decisions that can be applied to prepare for, respond to, or recover from drought. In this analysis 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 businesses in the Fitzroy region of Queensland. The scenarios modelled here are aimed at providing a broad understanding of the range of opportunities available for improvement, the potential response functions in a production system and an appropriate framework to support decision making. The property-level, regionally-specific herd and business models that we have developed can be used by consultants, advisors and producers to assess both strategic and tactical strategies for their own alternative scenarios.

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8 Glossary of terms and abbreviations

AE	Adult equivalent. An AE is defined in terms of the daily forage dry matter intake of a standard animal which was defined by McLean and Blakeley (2014) as a 2.25 year old, 450 kg *Bos taurus* steer at maintenance, walking 7 km/day. The spreadsheet calculator QuikIntake (McLennan and Poppi 2016) was used to calculate daily cattle dry matter intakes for the specified average dry matter digestibility of each forage type.
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.
BCR	Body condition ratio. A BCR is the ratio of liveweight to the expected liveweight for age of animals at average condition ('N').
BCS	Body condition score. A visual assessment of cow BCS (scale 0-9) is used to rate her body fat reserves or 'condition'.
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.
BVDV	Bovine viral diarrhoea virus. Also known as 'pestivirus'.
Constant (real) dollar terms	All variables are expressed in terms of the price level of a single given year.
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 rate of a future value by discounting.
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. DMD is the intake of DM minus the amount in the corresponding faeces, expressed as a proportion of the intake (or as a percentage).
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.
EU	European Union. One of the market options for Australian beef producers.
Feed-on steers	Steers marketed to the feedlot (450 kg at the feedlot or 474 kg paddock liveweight).
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.
Finished steers	Steers marketed to an abattoir to achieve 310 kg carcass weight (605 kg paddock liveweight).
Forage utilisation	The percentage of annual forage (including high quality sown forage or perennial pasture) biomass growth that is consumed by grazing livestock.
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 on 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.
HGP	Hormonal growth promotant. HGP implants are used to increase growth rates in cattle.
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 marginal capital – referred to as the IRR in this report.
Land condition	The capacity of the land to produce useful forage, arbitrarily assessed as one of four broad categories: A, B, C or D, with A being the best condition rating. Three components are assessed: 1) soil and 2) pasture condition, and 3) extent of woodland thickening/tree basal area or other weed encroachment.
N	Nitrogen
'N'	'N' indicates the expected bodyweight for age of animals in average condition. This parameter is calculated using an exponential model describing weight from birth to maturity, given adequate nutrition.
n/a	Not applicable or not able to be calculated
NPV	Net present value. Refers to the net returns (income minus costs) over the life of an investment (in this case, provision of high quality forages), expressed in present day terms. A discounted cash-flow allows future cash-flows (costs and income) to be discounted back to a NPV so that investments over varying time periods can be compared. The investment with the highest NPV is preferred. NPV was calculated at a 5% rate of return which was taken as the real opportunity cost of funds to the producer. NPV can be expressed as the total business returns or as the marginal return. NPV is the extra return received as a result of the investment. Annualised NPV converts the NPV to an amortised annual value and can be viewed as approximately equivalent to the change in profit per year.
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.
Opportunity cost	The benefit foregone by using a scarce resource for one purpose instead of its next best alternative use.
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.
PCAS	Pasturefed Cattle Assurance System. One of the market options for Australian beef producers.

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.
PI	Persistently infected animal. PI refers to cattle born after exposure to the pestivirus (bovine viral diarrhoea virus) disease *in utero* during the first trimester of gestation.
PTE	Pregnancy tested empty (not in calf)
PTIC	Pregnancy tested in calf
Rate of return on assets	An estimate of how profitable a business is relative to its total assets. It is the net income of a business divided by total assets.
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).
SRW	Standard reference weight. The SRW is the liveweight that would be achieved by an animal of specified breed and sex when skeletal development is complete and conditions score is in the middle of the range. This is an important parameter in the prediction of the energy, fat and protein content of empty body gain in immature animals.
Year of peak deficit	The year in which the peak deficit is expected to occur.

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