Central West Mitchell Grasslands livestock production systems

Preparing for, responding to, and recovering from drought

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

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Summary

This report details the analysis of the economic implications of management decisions that can be applied to: (1) prepare for, (ii) respond to, or (iii) recover from drought in the Central West Mitchell Grasslands of Queensland. Accompanying reports in this series present results for other regions across Queensland's grazing lands. It is intended that the results of these analyses will support the implementation of resilient grazing, herd and business practices necessary in managing seasonal variability. The property-level, regionally specific herd, flock and business models which we have developed can be used by consultants, advisors and producers to assess both strategic and tactical management decisions for their own properties.

To allow assessment of alternative management strategies on the profitability and drought resilience of livestock production systems in the Central West Mitchell Grasslands region, we developed a model of a representative beef cattle property. An alternative base enterprise running only wool sheep was also modelled, for comparison at steady-state, for the same property. The biological and economic parameters underpinning the representative beef and sheep enterprises were based on local knowledge and experience together with the median herd data from relevant industry surveys and research.

The investigation of four alternative grazing management strategies applied over a 30-year period was conducted for a beef enterprise by integrating output from the GRASP daily pasture growth model with the beef cattle herd modelling software, Breedcow and Dynama, to develop discounted cash flow budgets for each alternative grazing management strategy. The economic and financial effect of implementing each strategy was assessed by comparison to a base grazing management system for the representative beef property. Property level productivity and profitability was assessed over the 30-year investment period and incorporated the change in profit and risk generated by alternative grazing management strategies, the changes in herd structure and capital, and included the implementation phase.

The investigation of tactical management options which may be considered in response to drought tend to need consideration of both short term and long-term implications and were examined using beef cattle herd models in conjunction with spreadsheets designed to assess these tactical decisions.

Representative (base) property

A hypothetical (base) property was established to be representative of the Longreach region. The base property was 16,200 ha of primarily native pastures growing on six land types common to the region. The property would typically be capable of running either wool sheep or beef cattle. The land condition of the base property was set to be in B condition (69% perennial grasses). The initial stocking of ca.1,071 adult equivalents (AE) or 9,639 dry sheep equivalents (DSE) was determined by running the GRASP model several times to establish the number of livestock that could be grazed in order to maintain pasture condition (ca. 70% perennial grasses) over the 36 years of simulation (i.e. the average pasture condition over 36 years was the same as the initial pasture condition). Expected biological and economic values were applied within the herd or flock budgeting software to identify the relative profitability of wool sheep and beef enterprises in a steady-state analysis.

The understanding gained from this steady-state analysis was that, at the long-term prices and production parameters assumed, the expected profitability of the beef and the sheep enterprise types was likely to be roughly equivalent at the same standard of management. The rate of return on total capital for the sheep and the beef enterprise were 1.39 vs. -0.02%, respectively. An important

assumption for the sheep enterprise analysis was that wild dogs had minimal impact on the sheep production system, i.e. that the property was already protected from wild dogs with suitable fencing. Due to a lack of data and complexity, no attempt was made to model a combined sheep and beef production system. Therefore, no comment can be provided on a suitable mix of each enterprise type for any property, or whether a mixed production system would be more or less profitable or resilient to drought than one focussing on sheep and excluding beef or vice versa.

The impact of climate variability on drought preparation, response and recovery strategies

The impact of climate variability on a range of drought-related grazing management strategies within a beef enterprise was modelled by integrating output from the GRASP daily pasture growth model with beef cattle herd models using the Breedcow and Dynama software. Four alternative grazing management strategies were simulated over a 36-year period (1982-2017) in the GRASP pasture growth model using historic climate records for Longreach in central west Queensland. Simulated annual stocking rates and steer liveweight gain predictions from GRASP were integrated with published functions for mortality and conception rates in beef breeding cattle in northern Australia. This information was used to develop dynamic Breedcow and Dynama cattle herd models and discounted cash flow budgets representing the modelled property near Longreach over the last 30 years of the period (1988-2017). The first grazing management strategy, Set stocking rate strategy, was used to determine the set (fixed) stocking rate that did not cause pasture condition to decline over time. This baseline stocking rate was established through several runs of the GRASP model to maintain pasture condition (i.e. 69% perennial grasses) over the 36 years of simulation (i.e. the average pasture condition after 36 years was the same as the initial pasture condition). This stocking rate was applied as a starting point for other strategies as well as a reference point for comparing the alternative grazing strategies. All subsequent strategies started in the first year of simulation (Year 1) with the same stocking rate but differed in de-stocking and re-stocking responsiveness to annual changes in total standing dry matter (TSDM) of pasture on 1 May. Sub-scenarios within each of the following three grazing management strategies (Retain core herd, Drought responsive and Fully flexible) were compared to a base scenario of Retain herd structure (a sub-scenario of the Retain core herd strategy). In all scenarios, three levels of supplementary feeding could be triggered based on a) predicted cattle liveweight gain (LWG; stage 1 - non-protein nitrogen (NPN) and stage 2 - NPN and whole cottonseed), or b) critical TSDM level (stage 3 - drought feeding of hay).

a) Set stocking rate strategy

A set (fixed) stocking approach was simulated over 36 years (1982-2017) using a stocking rate which ensured that the average pasture condition (% perennial grasses) and land condition rating (scale A-D) over that period approximated the initial condition (ca. 70% perennial grasses and B condition), i.e. taken to indicate no change in pasture condition. As the total number of cattle was held constant, there was no opportunity to take advantage of the better years. While this management strategy is unlikely to be applied in the real world, it was established as a reference point for the other scenarios where cattle numbers fluctuated over the 36 years of the analysis.

The 30-year economic analysis found that the base property implementing this grazing strategy over the period 1987-2017 produced a poor internal rate of return (IRR) of -0.09%. Hay feeding expenses, high mortality rates, low weaning rates and poor cattle growth rates in the initial years of the sequence (1987-1989) caused a starting cash flow deficit of ca. -$1M and the cumulative cash flow generated by the property failed to become positive over the 30-year period. The poor result for this Set stocking rate strategy indicates that applying a very conservative stance to setting stocking rates, in combination with an unwillingness to adjust numbers quickly in response to seasonal conditions, is likely to result in reduced profitability and low levels of business resilience.

While the Set stocking rate strategy was specifically designed with the objective of maintaining pasture condition over 36 years (defined as the average percentage perennial grasses over 36 years being the same as the initial value of 69%), the GRASP model output for the 36 years, 1982 to 2017 chosen in this study, did indicate a significant ($P < 0.001$) positive trend in the annual value of percentage of perennial grasses with the property-level percentage of perennial grasses increasing to 86% (final 5-year average). This positive trend reflects (i) the sequence of years chosen in the study, (ii) the high degree of rainfall variability, and (iii) the impacts of stocking rates on the resultant year-to-year fluctuation in percentage of perennial pasture within this environment. A different sequence of years may produce a different response in the annual value of percentage of perennial pasture species.

b) Retain core herd strategy

The approach in this strategy was to keep a core cattle herd during a drought, in order to rebuild the herd more quickly once the drought breaks. The core herd was kept regardless of possible animal production, land condition and financial implications. This management approach was based on the perception of some managers that unfavourable cattle prices during and after drought result in increased risk and possibly reduced profit from de-stocking and then re-stocking decisions at those times. Such managers expect that when it becomes apparent that drought is widespread and persistent, prices will slump due to rapidly increasing numbers of cattle being sold that are generally in poorer condition. These managers expect that when the drought breaks the demand for, and price of, cattle will spike. This perception of a very likely and large disparity in prices for re-stocking compared with de-stocking leads many to hold on to a core herd. They expect that holding on to a core herd will allow a quicker recovery once the drought breaks, allowing them to recommence production without having to potentially buy large numbers back in at high prices. This Retain core herd concept was modelled by allowing annual changes in cattle numbers to match forage TSDM available on the 1 May with the following limitations:

a) annual changes in cattle numbers were limited to 10% increases and 20% decreases, and
b) over the 36 years, changes in animal numbers were limited to a 100% increase and a 25% decrease from the initial stocking rate.

A critical aspect of this strategy was that cattle numbers were only rebuilt through natural herd increases in response to increasing TSDM in good seasons. Two sub-scenarios were examined:

a) 'Retain herd structure', where a mix of cattle, including breeders were sold in response to poor seasonal conditions, and
b) b) 'Retain core breeders', where steers were sold first before reducing the breeding herd to achieve reduced grazing pressure.

The GRASP model output for annual percentage of perennial grasses over 36 years showed no trend in percentage of perennial grasses for two land types ($P > 0.05$; Open downs and Boree wooded downs; 64% of property area), a negative trend for two land types ($P < 0.05$; Wooded downs and Open alluvia; 26% of property area) and a positive trend for the two remaining land types ($P < 0.05$;

Soft gidgee – cleared, and Soft gidgee - wooded; 10% of the property area). The property-level percentage of perennial grasses declined from 69% in Year 1 to 49% (final 5-year average).

The results of the 30-year economic analysis showed similar, poor, property-level investment returns for both sub-scenarios with IRR -0.28 and -0.26%, for the Retain herd structure and Retain core breeders sub-scenarios, respectively. As for the Set stocking rate scenario, the low rainfall years, resulting in poor herd performance and hay feeding in the early years of sequence (1987-1989), resulted in a negative cash flow of ca. -$1M for both sub-scenarios at the start of the modelled period. The greater number of AE carried by the property later in the sequence of years allowed the cumulative cash flow to become positive for a period of ca. 9 years before hay feeding was again triggered in 2015-2016. The marginal returns for changing from a Retain herd structure to a Retain core breeders strategy (ca. $5,000 extra profit over 30 years) indicate that, over the modelled sequence of years, there was no difference between the two sub-scenarios in terms of economic performance.

c) Drought responsive stocking

The Drought responsive strategy was modelled by allowing annual changes in cattle numbers to match forage TSDM available on the 1 May with the following limitations:

a) annual changes in cattle numbers were limited to 30% increases and 60% decreases, and

b) over the 36 years changes in animal numbers were limited to a 100% increase and 75% decrease from the initial stocking rate.

The retention of 25% of the initial cattle numbers, regardless of seasonal conditions, was adopted based on producer survey data indicating that the majority of properties retained 25% of their pre-drought stock numbers rather than completely de-stocking. In the herd model, de-stocking was achieved through additional female sales as the previous analysis for the Retain core herd strategy showed no economic difference between selling down steers or females first when reducing numbers. A number of sub-scenarios were compared which examined alternative recovery and herd re-building strategies as TSDM increased after drought: a) natural increase, b) purchase of pregnancy-tested in-calf (PTIC) cows, c) purchasing a mix of cattle to rebuild the complete herd structure more quickly, d) trading steers, and e) taking stock on agistment.

The GRASP model output for annual percentage of perennial grasses over 36 years resulted in a positive trend for four land types representing the greatest proportion of the property (*P* </= 0.05; Open downs, Soft gidgee – cleared, Soft gidgee - wooded, Boree wooded downs; 75% of property area), no trend for the Wooded downs land type (*P* > 0.05; 21% of property area) and a negative trend for the Open alluvia land type (*P* < 0.05; 5% of property area). The property-level percentage of perennial grasses was maintained over 36 years: 68% (final 5-year average) cf. 69% in Year 1.

The 30-year economic analysis indicated that responding more fully to drought than for the Retain core herd strategy, with a larger herd reduction, but then allowing the herd to rebuild over time through natural increase, was unlikely to produce a more profitable outcome (-1.57% cf. ca. -0.27% property-level IRR for Drought responsive with natural increase and Retain core herd, respectively). Not incurring the hay feeding expenses or mortalities associated with the Retain core herd strategy resulted in a less negative starting cash flow for the Drought responsive property: ca. -$90K cf. -$1M. However, cumulative cash flow showed a steady decline over the 30 years of the analysis (to ca. -$2.7M) due to the inability to fully utilise the additional pasture grown as the herd rebuilt through natural increase.

Purchasing a mix of cattle to rebuild the herd was not much different in resulting property-level IRR to purchasing PTIC cows only (1.70 cf.1.45%) and, if sensible decisions were made at the time of purchase, not much different to the purchase of steers for trading (0.50%). It appears more important to select, at the time of purchase, cattle with the best potential return for the property over the short to medium term, rather than selecting cattle that will return the herd to a certain size or shape in the shortest time. These purchases are made within the context of returning the herd structure to its optimum over the medium term, so some view of the long-term, optimum herd structure has to be retained. The analysis also identified that the optimal class of stock to be purchased could be different at each point in time according to relative prices at the time. It is obvious that a small change in the parameters applied could change the relative ranking of the purchase options and that having a fixed goal of recovering via a predetermined pathway could prevent more profitable options from being considered.

In this scenario, the number of stock that could be taken on agistment was limited by the stocking rate parameters set in the GRASP program (limited to 30% increase in property cattle numbers per annum). Taking this limited number of stock on agistment did not improve the long-term profitability of the property as much as purchasing replacement stock at reasonable prices (IRR 0.19%). However, taking on limited agistment stock reduced risk in the short to medium term and risk-averse managers would be likely to favour this strategy.

The options analysed did not include sending the herd away on agistment instead of selling down the herd. Agisting the herd is likely to be a very good idea if the drought is relatively short, the agistment reliable and reasonably priced. However, it is also easy to identify the risks associated with such agistment. Agistment often runs out just as prices crash and sometimes not all of the cattle are re-discoverable when being mustered. Agisting components of the herd is a strategy that can be considered early in drought and analyses compiled for other regions suggest it is worthy of close consideration if the criteria of reasonable cost and reliability can be met.

d) Fully flexible stocking

The Fully flexible strategy was modelled by allowing annual changes in cattle numbers to match forage TSDM available on the 1 May with no limitations to changes in animal numbers. This scenario was the opposite of the herd management approach applied in the Set stocking rate scenario and was an extreme management strategy, unlikely to be applied in the real world. Up to double the maximum number of AE were allowed at times on the property under this strategy compared to the Retain core herd and the Drought responsive strategies, i.e., modelled maximums of 6,416 vs. 2,266 and 2,359 AE, respectively. A number of sub-scenarios were compared which examined alternative recovery and herd re-building strategies as TSDM increased after drought: a) natural increase, b) purchasing a mix of cattle to rebuild the complete herd structure, c) trading steers, and d) taking stock on agistment.

The GRASP model output for annual percentage of perennial grasses over 36 years resulted in a negative trend for all land types under the Fully flexible stocking strategy ($P < 0.001$). This result was linked to how the model was defined, which allowed only one change to livestock numbers per year (1 May) hence resulting in instances where large numbers were carried on the property during failed or poor wet seasons. The property-level percentage of perennial grasses declined from 69% in Year 1 to 24% (final 5-year average).

The 30-year economic analysis indicated that the purchase of stock of any type to completely fill the spare grazing capacity indicated by GRASP substantially increased the riskiness of the property due to the large cash flow deficits associated with purchasing such large numbers of livestock. It is likely that few, if any, managers would be prepared take on this level of risk. Conversely, fully utilising the spare grazing capacity with agistment stock potentially provides a substantially more positive cash flow compared to the other sub-scenarios. Whether the Fully flexible with agistment income strategy is possible to be fully implemented in the real world would be a topic for discussion. Property-level IRR for the Fully flexible sub-scenarios ranged from 0.70% for the Drought responsive with repurchasing the herd to -4.44% for Fully flexible with natural increase.

A summary of the effect of grazing management strategy on property-level investment returns expressed as IRR, and property-level pasture condition expressed as the average percentage of perennial grasses over the final 5 years of the analysis, is presented in Table 1. The profitability and resilience of the representative beef property when implementing alternative grazing management strategies, compared to a base scenario of Retain herd structure, is given in Table 2. Moving from a Retain herd structure scenario to an alternative grazing management scenario improved profitability for all strategies except 1) those where natural increase in cattle numbers was allowed to occur after herd reductions, and 2) the Fully flexible stocking rate strategy with trading steers. As previously highlighted, there was minimal difference between a Retain herd structure and Retain core breeders strategy.

Table 1 – Property-level investment returns expressed as internal rate of return (IRR) over 30 years, and average percentage perennial grasses (%P) in the pasture over the last 5 years, for grazing management scenarios implemented for a beef enterprise in the Central West Mitchell grasslands

Grazing management scenario	**IRR**[A]	**Average %P (final 5 years)**[B]
Set stocking rate	-0.09%	86
Retain core herd		49
Retain herd structure	-0.28%	-
Retain core breeders	-0.26%	-
Drought responsive		68
Natural increase	-1.57%	-
Purchase PTIC cows	1.45%	-
Repurchasing the herd	1.70%	-
Trading steers	0.50%	-
Agistment income	0.19%	-
Fully flexible		24
Natural increase	-4.44%	-
Repurchasing the herd	0.70%	-
Trading steers	-2.60%	-
Agistment income	-0.11%	-

[A]**IRR (internal rate of return) is the rate of return on the capital invested**. It is the discount rate at which the present value of income from the project equals the present value of total expenditure (capital and annual costs) on the project, i.e. the break-even discount rate. It is a discounted measure of project worth. The IRR represents the return to the investment in the land, plant and livestock over the 30-year period. Closing asset values were not adjusted for any potential (or hoped for) real increase in value.

[B]The property-level, Year 1 value for percentage perennial grass (%P) was 69%.

Table 2 – Value of implementing grazing management strategies to improve profitability and drought resilience of a representative beef property in the Central West Mitchell grasslands, compared to the base situation of Retain herd structure

The analysis was conducted for a 30-year investment period

Grazing management scenario	**Annualised NPV**[A]	**Peak deficit (with interest)**[B]	**Years to peak deficit**	**Payback period (years)**[C]
Retain core breeders	$300	-$144,100	4	18
Drought responsive				
Natural increase	-$41,800	-$3,206,100	27	n/a
Purchase PTIC cows	$94,800	n/a	n/a	n/a
Repurchasing the herd	$108,400	n/a	n/a	n/a
Trading steers	$39,400	-$133,300	22	n/a
Agistment income	$50,600	n/a	n/a	n/a
Fully flexible				
Natural increase	-$67,500	-$4,018,700	27	n/a
Repurchasing the herd	$15,000	-$3,817,500	13	n/a
Trading steers	-$142,100	-$7,504,400	23	n/a
Agistment income	$90,300	$0	n/a	n/a

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

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

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

Limitations of the modelling approach

The results of this analysis must be considered in light of the limitations of the modelling approach. These include the following:

- The inability of any bio-economic model to adequately represent a complex management, environmental and economic system.
- The relatively simple grazing rules applied in each of the strategies, particularly the ability to alter stock numbers only once per year, which is inadequate to represent the frequent and complex decision-making opportunities taken by grazing managers.
- The one-way modelling approach which did not allow the herd models to provide feedback to GRASP for changes in grazing pressure and pasture condition, or individual animal LWG, likely to result from:
    - different allocations of animals to paddocks as a result of changing herd structures in scenarios over time;

- the animal numbers predicted by the herd model being different to those predicted in GRASP (e.g. due to effects on predicted mortality rates, conception and weaning rates of breeders preventing target animal numbers being achieved);
- feeding supplements which result in increased pasture intake (e.g. feeding NPN supplements to cattle grazing dry season pasture); and
- feeding supplements which will substitute for pasture (e.g. high energy or protein supplements and hay).

- The steer LWG predictions rely on user-defined parameters.
- Breeder liveweight change (and hence effects on mortality and fertility parameters) are based on steer liveweight change predictions.
- A lack of scientific data to inform assumed rates of pasture decline and improvement for the individual pasture communities and regions within the GRASP modelling framework.
- The assumption that the current economic prospects will persist.
- The restriction of evaluations to only one historical climate sequence of 36 years (1982-2017).

The analysis relies heavily on modelled output from GRASP, the conversion of steer LWG data from GRASP into breeding herd performance estimates and finally the construction of an integrated bio-economic model to estimate the likely outcomes from changes in management strategy. Whilst every effort has been made to ensure that the results generated are broadly indicative of what might happen on Mitchell grasslands in central western Queensland, it must be realised that the analysis provides, at best, a broad approximation of the true nature of the economic benefits likely to occur.

Assessing key strategies that may be applied in response to drought in beef production systems

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 representative breeder herd had been culled on pregnancy status with all empties removed during the previous season. This reduces the opportunity for the manager to take decisive action, in rapidly reducing grazing pressure if the following season were to be below average, and hence complicates the decision making process when forced sales are 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.

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 herd management and stocking rate decisions made prior to the drought. Likewise, the actions taken in response to drought conditions will often determine the medium term outcomes once the drought breaks. Flexibility is the key when analysing response and recovery steps as viable alternatives are often only revealed as the drought progresses. Therefore, a key element is the ability of a management team to assess and re-assess options as a drought progresses and apply logical decision making during a time of high stress and physical workload.

The consideration of alternative responses should initially be undertaken by looking at impacts on components of the herd in isolation together with the extra costs and benefits associated with the option. It is not possible or practical to create scenarios to reflect every possible assumption or management decision. Hence, examples were developed to demonstrate a) the key drought response strategies, and b) the analysis tools available in the Breedcow and Dynama suite of programs. The key finding from these analyses was that assessing the sale of alternative classes of cattle should be done on the basis of the impact on both future profit and future cash flow and that all classes of cattle should be incorporated in the assessment.

Conclusions

The Central West Mitchell Grasslands region has high levels of climate variability and a history of suffering extended and extensive droughts. Our analysis identified that prescriptive livestock management strategies, like setting a conservative stocking rate and sticking doggedly to it, are likely to be less profitable than being as responsive as possible to the feed supply available in the paddock. More flexible management strategies where livestock numbers are changed regularly in response to pasture availability are likely to be more profitable, however, also incur more risk. In simplistic terms, the most useful management strategy for this region appears to be setting the herd or flock numbers based on safe pasture utilisation rate principles but selling early and often when drought occurs and then re-stocking as soon as safely possible once good seasonal conditions return. As long as safe pasture utilisation rate principles are applied this drought responsive strategy should maintain pasture and land condition over time.

Our results indicate that the current market prices, and those expected during the start of the recovery phase, for each class of cattle (e.g. steers vs. breeders) at the time the decision is being made to de-stock should determine which class to sell first. During the drought recovery phase, using agistment income to utilise available pasture when building up herd numbers is a lower risk strategy compared to the alternatives but appears likely to be less profitable over the longer term than purchasing livestock to rebuild the breeding herd or trading cattle. The relative profitability of alternative options can be assessed each time the decision is being made by looking firstly at the immediate impact on cash flow and profit of the available choices using the more simple spreadsheet tools and then considering the medium term impact on herd structure, profit and cash flow using the more complex herd models and budgets of the Breedcow and Dynama suite of programs. The property-level, regionally-specific herd and business models developed in this project are available to be used by consultants, advisors and producers to assess both strategic and tactical decisions for their own businesses.

The integrated pasture and beef herd modelling approach developed in this study represents an advance in integrating output from the GRASP pasture growth model with the Breedcow and Dynama beef cattle herd model that determines whole-of-business productivity and profitability. Importantly, published functions were applied to describe breeder conception and mortality rates applicable to northern Australia beef cattle herds. This modelling approach allowed the impact of climate variability on a range of grazing management scenarios to be modelled in the current study. However, while providing useful insights, this modelling approach must be viewed in light of its limitations which are related to the difficulties in adequately representing a complex management, environmental and economic system. Allowing the GRASP model to adjust stocking rates dynamically and more than once a year, and using a two-way linked modelling approach may improve simulation of complex grazing livestock production systems.

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1 General introduction

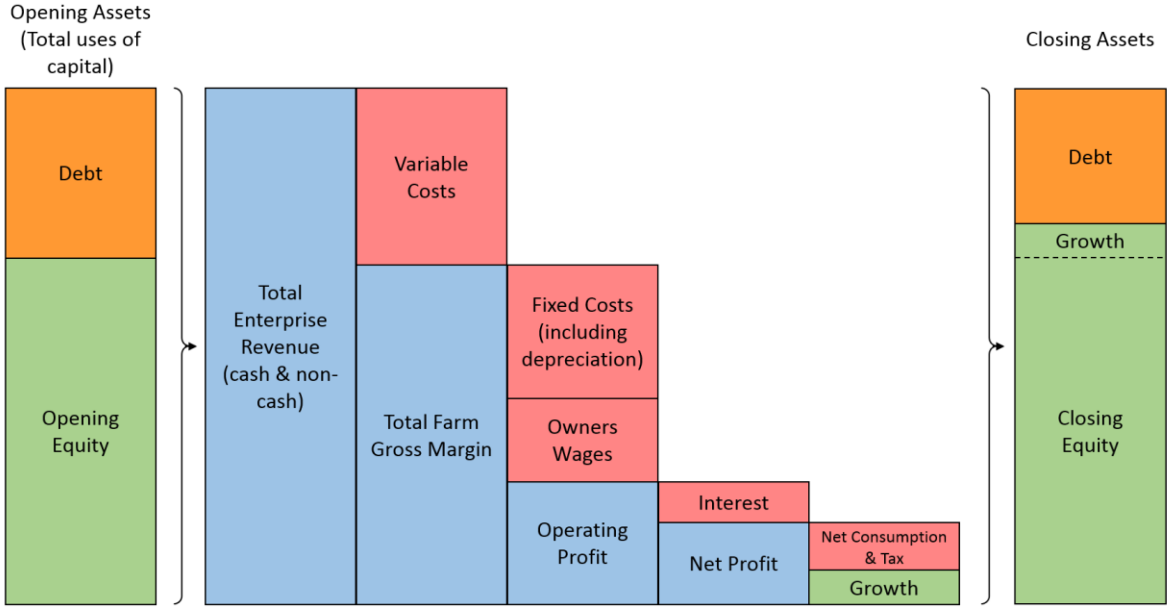
More than 80% of Queensland's total area of 173 million ha is used for grazing livestock on lands extending from humid tropical areas to arid western rangelands (QLUMP 2017). Most extensive grazing enterprises occur on native pastures with introduced (sown) pastures constituting less than 10% of the 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 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 production, and to build drought/climate resilience, beef and sheep properties need to be profitable and to build equity (Figure 1). Building resilience usually means investments have to be made and alternative management strategies considered well before encountering extended dry spells or drought. To make profitable management decisions graziers need to be able to appropriately assess the impact of different strategies on profitability, the associated risks, and the period of time before benefits can be expected. The effects of such alternative management strategies are best assessed using property-level, regionally-relevant herd models that determine whole-of-property 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 to assess the relative value of the alternatives available over both the short and medium term. Recovery from drought is also a challenging period when decision making should include suitable blend of the strategic – returning to the most profitable herd structure, and tactical - how to survive while the production system is being rebuilt. Simple spreadsheets applying a farm management economics framework can be used to quickly gather relevant information and highlight possible outcomes of decision making during and after drought. These tools can complement traditional decision-making processes.

Figure 1 – The link between profit and growth in equity



Although we have identified that regularly achieving a profit is a key ingredient of a drought resilient beef or sheep production system we do not see what is commonly termed the 'profit motive' as necessarily driving the goals of the vast majority of livestock producers. The factors that motivate producers are much more complex and diverse. However, to be a livestock producer in northern Australia you need to be efficient, i.e. you need to regularly produce a profit. Therefore profit is necessarily the focus of this report.

The objective of this project, 'Delivering integrated production and economic knowledge and skills to improve drought management outcomes for grazing enterprises', was to improve the knowledge and skills of advisors and graziers in assessing the economic implications of management decisions which can be applied to (i) prepare for, (ii) respond to, or (iii) recover from drought. We have applied scenario analysis to examine a range of management strategies and technologies that may contribute to building both more profitable and more drought resilient grazing properties for a number of disparate regions across Queensland. In doing this we have developed property-level, regionally-specific herd 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 in the Central West Mitchell Grasslands of Queensland to (i) prepare for, (ii) respond to, and (iii) recover from drought.

2 General methods – approach to economic evaluation

2.1 Summary of approach

The implications of alternative management strategies on the capacity of a livestock enterprise to (i) prepare for, (ii) respond to, and (ii) recover from drought were investigated for a representative extensive grazing property in the Central West Mitchell Grasslands of Queensland using scenario analysis. The levels of production associated with this representative 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 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 representative property and for each scenario.

The approach was implemented according to the following steps:

1. A hypothetical, representative property was defined for the Longreach region and a base management strategy was initially modelled for a beef herd using expected values for rates of growth, mortality and conception using the Breedcow and Dynama (Version 6.02; Holmes *et al.* 2017) suite of programs. The property was also modelled for a sheep flock using a modified version of the Breedcow and Dynama suite of programs, for sheep: Breedewe and Sheepdyn (W. Holmes, pers. comm). The initial stocking of ca. 1,071 adult equivalents (AE) or 9,639 dry sheep equivalents (DSE) was determined by running the GRASP model several times to establish the number of livestock that could be grazed in order to maintain average pasture condition (ca. 70% perennial grasses) over the 36-year simulation period chosen for the study (1982 – 2017). This modelled, steady-state, base cattle herd and sheep flock provided a reference point for,
    a) comparison of the expected performance of sheep and beef production systems, and
    b) comparison of alternative grazing management strategies using an integrated pasture and beef herd modelling approach.
2. In the integrated pasture and beef herd modelling approach, the impact of year-to-year climate variability on a range of drought-related grazing management scenarios was modelled by integrating output from the GRASP daily pasture-growth model (McKeon *et al.* 2000; Rickert *et al.* 2000), with beef cattle herd models (Breedcow and Dynama, Version 6.02; Holmes *et al.* 2017) over a climate sequence of 36 years (1982-2017). The base management strategy and alternative strategies were modelled as described below.
    a) Firstly, the GRASP pasture growth model was applied to identify the impact of the strategy on:
        i. the number of adult equivalents (AE) able to be carried on the representative property in each calendar year given the available pasture, impacts of grazing on pasture and the grazing management constraints imposed, and
        ii. the predicted annual liveweight gain (LWG) of a 200 kg steer, and

iii. the percentage of perennial pasture species over time in each paddock on the property,

b) Secondly, the GRASP-derived estimates of steer LWG and stocking rate were converted to estimates of annual rates of mortality, conception, growth and stocking, and sale weights, for the various stock classes within a mixed herd of beef cattle principally using the functions described by Mayer *et al*. (2012) and an AE calculation based on the metabolic weight of the class of animal expected to run in the paddock (liveweight to the power of 0.75).

c) Lastly, the GRASP output and the herd parameter values derived from the Mayer *et al*. (2012) functions were integrated with the Breedcow and Dynama herd budgeting software to allow consideration of alternative herd management strategies over the 30-year climate sequence (1988-2017). A spreadsheet-based herd model with four calving periods (I. Braithwaite pers. comm.) was constructed separately, but using the same Mayer *et al.* (2012) functions and data input, specifically to check for errors in the Dynamaplus model linked to GRASP data.

The standard methods of farm management economics (Makeham and Malcolm 1993) were applied to consider the difference between alternative management strategies for the same property. Key components of this framework were as described below.

- A marginal, whole-farm perspective was used rather than a discrete, whole-farm perspective.
- Investments were analysed over their expected life and the same investment period was applied to all comparable, alternative investments.
- The full profit or cash implications of any capital investments were captured.
- Cash (financial feasibility) and profit (economic efficiency) components were clearly distinguished.
- The time value of capital invested was incorporated.
- Livestock reconciliation or trading schedules appropriately incorporated livestock trading profits and losses.
- Nominal (or real) dollar values were consistently applied and not interchanged.
- The relative riskiness of the alternative strategy was identified, where possible. As it is usual for the comparison to be between an investment in a relatively low-input, low-output operation and other more intensive operations, an assessment of the risks can be critical.

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 and the optimal herd structure resulting from 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 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 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. Additional detail and description of the Breedcow and Dynama suite of programs is provided by Holmes *et al*. (2017).

In summary, for each management scenario, the regionally-relevant herd was applied in the Breedcow and Dynama suite of programs to determine and compare the expected and alternative productivity and profitability over a 30-year investment period. Change was implemented by altering the herd performance and inputs of the base scenario 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.

Partial discounted cash flow (DCF) techniques were applied using an extended, 30-year version of the Investan program linked to the Dynamaplus program to look at the returns (net present value (NPV) and internal rate of return (IRR) 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 the current relationship between costs and prices would be maintained for the period of the analysis. Livestock sale prices averaged over the recent past (i.e. July 2008-November 2015) were taken to represent the constant value of livestock prices with the price basis of livestock classes set at levels typical of the recent past.

The 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 property. The calculation of operating profit included an allowance for the labour and management supplied by the owner, even though it is often unpaid or underpaid. For a true estimate of farm profit, this allowance needs to be valued appropriately and included. 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.

Any annual figures usually 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 changed land condition and hence allocated stocking rates occurring at the end of the 30-year investment period as there is no evidence that land value is linked to land condition in practice.

The examination of short-term, tactical strategies that can be applied by managers of a beef production system in the response phase of drought were also analysed using a farm management economics framework (Malcolm 2000). These analyses were conducted with reference to the Breedcow base 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 software and 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 this report. A summary of the role of each component of the Breedcow and Dynama suite of programs is provided in Appendix 1. Breedcow and Dynama software. Additionally, more detailed explanation of the methods and terminology used investment analysis is provided in Appendix 2. Discounting and investment analysis.

2.2 Criteria used to compare the strategies

The economic criterion were NPV at the required rate of return (5%; taken as the real opportunity cost of funds to the producer) and IRR. A present value model is a mathematical relationship that depicts the value of discounted future cash flows in the current period. It therefore provides a measure of the net impact of the investment in current value terms and takes into account the timing of benefits and costs over the life of the investment. NPV is the sum of the discounted values of the future income and costs associated with the change in the herd or pasture management strategy and was calculated as the incremental net returns (operating profit as adjusted) over the life of the investment, expressed in present day terms. In an IRR model, NPV is equal to zero and the discount rate is unknown and must be discovered. IRR was calculated as the discount rate at which the present value of income from a project equals the present value of total expenditure (capital and annual costs) on the project (i.e. the break-even discount rate). An amortised (annualised) NPV was calculated at the discount rate over the investment period to assist in communicating the difference between the representative, base property and the property after the management strategy was implemented. This measure is not the same as the average annual difference in operating profit between the two strategies. The average annual change in operating profit is likely to be greater than the value of the amortised NPV for any given investment as the NPV represents the operating profit discounted back to a present value whereas the average annual change in operating profit is undiscounted. The annualised NPV can be considered as an approximation of potential average annual change in profit over 30 years, resulting from the management strategy.

The financial criteria were peak deficit, the number of years to the peak deficit, and the payback period in years. The beef property started with no debt but 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 net cash flow to become positive. The net cash flow was compounded at the discount rate.

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

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.

3 The Central West Mitchell Grasslands region and the representative, beef and sheep enterprises

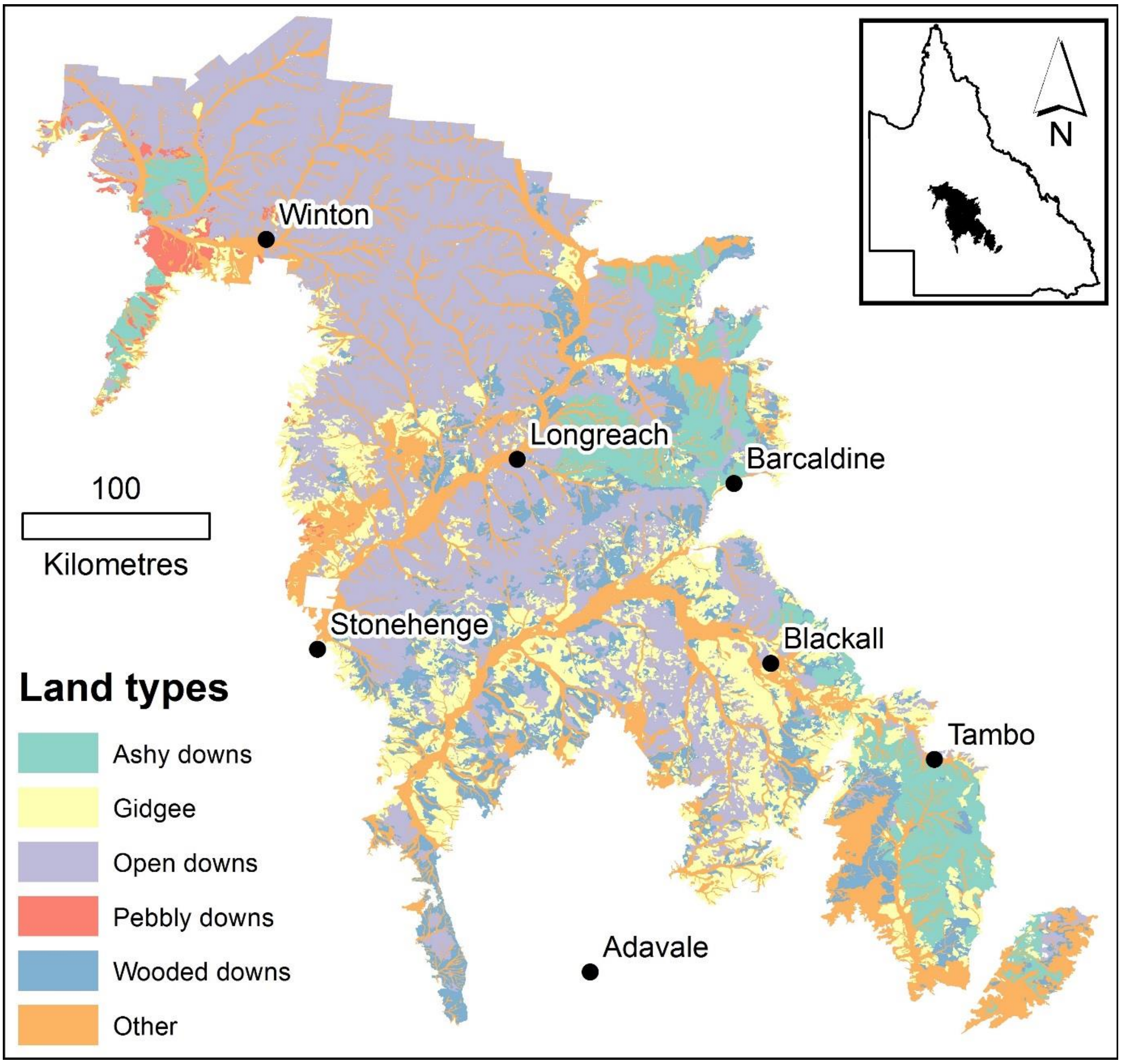
3.1 Introduction

3.1.1 The land resource

The Central West Mitchell Grasslands encompasses ca. 10 million ha of grazing land (DNRM 2010; DNRM 2017) used for both sheep and cattle production. This region (Figure 2) is part of the larger Mitchel Grass Downs bioregion (hereafter, Mitchell Grasslands) which extends across central Queensland and into the Northern Territory with a total area of ca. 45 million ha (Orr and Phelps 2013). The Mitchell Grasslands consist of largely treeless, undulating clay-soil downs. Other land types comprise ca. 30% of the Mitchell Grasslands bioregion (Bray *et al.* 2014) and include timbered gidgee, boree and mulga woodlands, flooded country and spinifex sand plains. The dominant vegetation type in the bioregion is perennial native Mitchell grasses (*Astrebla* spp.). Mitchell grasses are characterised by their resilience under heavy grazing and variable rainfall and their ability to recover well in good rainfall years due their deep root system and tough tussock crowns (Partridge 1996; Orr and Phelps 2013). A range of other perennial and annual native grasses and forbs are found in the bioregion, including the introduced perennial grass, buffel (*Cenchrus ciliaris*).

Figure 2 – Map of the Central West Mitchell Grasslands region of Queensland showing the distribution of major land types on land used for grazing

Land used for purposes other than grazing is marked white. The Central West Mitchell Grasslands region includes the Mitchell Grasslands bioregion sub-IBRAs MGD07 and MGD08 but with the northern boundary set as the ABS Outback South statistical division boundary. Note that Wooded downs land type includes Boree wooded downs on this map



3.1.2 Rainfall and drought

The Central West Mitchell Grasslands region is characterised by a semi-arid to arid environment with long dry seasons, extreme temperatures and high evaporation rates, and high rainfall variability. The amount and distribution of rainfall are primary determinants of pasture growth and quality with the expected pasture growing season and highest quality of forage typically lasting for 8-10 weeks during summer (Bray *et al.* 2014). Examples of seasonal distribution of rainfall are shown for six locations across the region (BOM 2019; Table 3). Annual rainfall in the region ranges from 485 mm at Tambo to 313 mm at Jundah. The variability of annual rainfall in the Central West Mitchell Grasslands region ranges from 'high' in the west to 'moderate to high' in the 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 managers of grazing enterprises. Drought regularly has a severe impact on profitability and provides the context for many production and investment decisions made by managers of grazing properties. While there is no universal definition of drought, one that is common in agriculture is the 'drought percentile method' (BOM 2019). 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 2019). 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 4) for Longreach. Using this definition, there have been 38 droughts at Longreach since 1900, the longest lasting 23 months.

Table 3 - Median seasonal distribution of rainfall (mm) for the 30-year 'climate normal' period 1961-1990; (BOM 2018a)

Town	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Winton[A]	48.5	54.5	31.5	7.7	6.5	0.2	0.0	0.0	0.0	5.6	9.0	46.0	363.2
Longreach	40.3	35.3	52.8	11.1	12.7	3.8	5.7	3.5	0.9	8.4	14.4	40.0	436.7
Barcaldine	66.1	55.7	40.4	28.0	13.8	7.2	9.6	6.1	3.0	20.8	26.7	49.8	424.8
Blackall	53.9	46.4	39.9	24.5	22.8	8.3	7.4	8.5	8.1	21.9	26.4	54.0	477.6
Jundah	29.5	35.4	32.5	10.1	6.6	3.2	7.5	4.0	2.5	8.3	6.6	20.7	313.1
Tambo	51.8	58.5	47.7	20.5	20.9	9.6	9.0	15.9	7.4	23.5	33.9	47.2	485.2

[A]Data for closest weather station at Bladensburg 13.8 km from Winton.

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

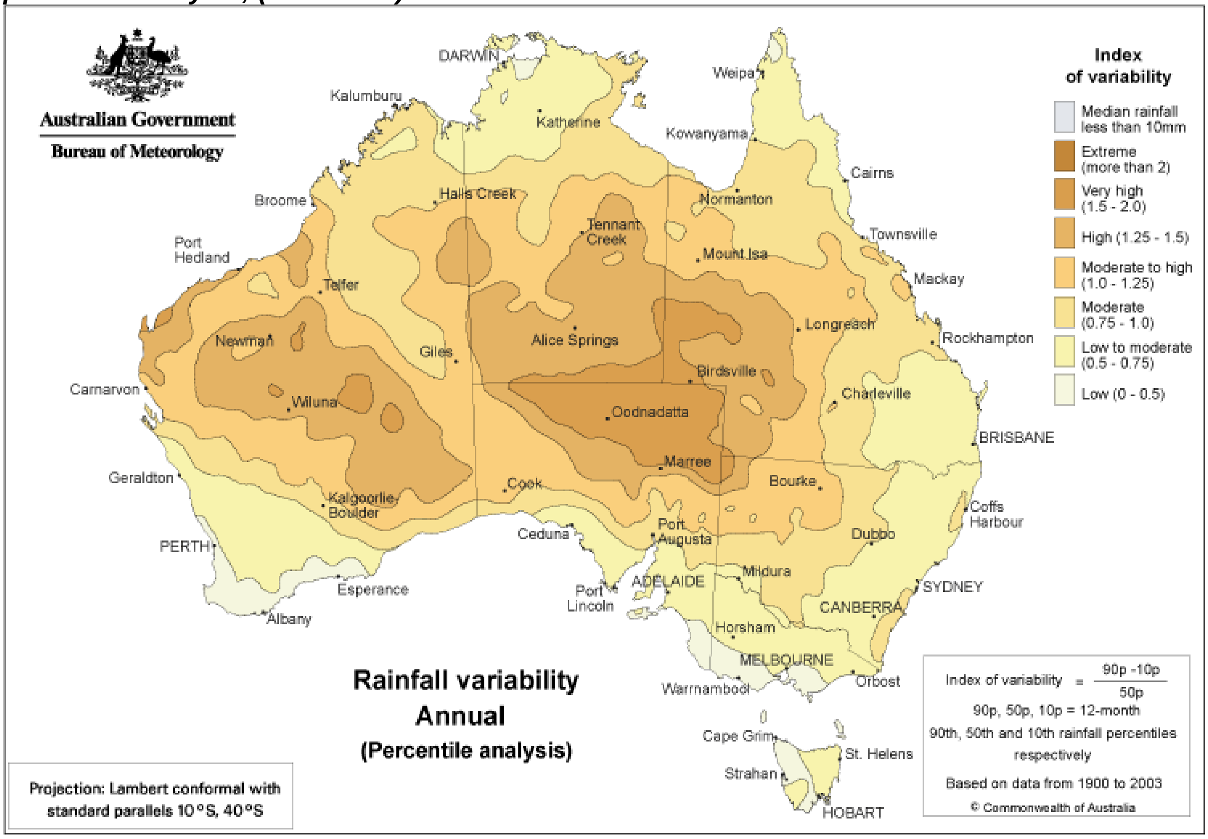


Table 4 - Historical droughts (1900 – 2019) at Longreach ranked by depth and duration and with subsequent recovery rainfall [A]

Rank	Drought period	Drought length (months)	Drought depth (percentile)	Subsequent recovery rainfall (mm)
1	Feb 2014 - Dec 2015	23	1.7	323
2	May 1902 - Feb 1903	10	0	125
3	Feb 1915 - Dec 1915	11	0	175
4	May 1969 - Nov 1969	7	0.9	34
5	Mar 1926 - Aug 1926	6	1.7	51
6	Dec 1934 - Sep 1935	10	0.9	180
7	Nov 1982 - Apr 1983	6	0	139
8	Oct 2002 - Jan 2003	4	0	27
9	Feb 1988 - Jul 1988	6	1.7	153
10	Dec 1900 - Mar 1901	4	0	96
11	Sep 1927 - Nov 1927	3	1.7	21
12	Feb 1920 - Apr 1920	3	0.9	123
13	Oct 1905 - Jan 1906	4	1.7	125
14	Jul 1985 - Sep 1985	3	4.3	37
15	Aug 1967 - Nov 1967	4	5.1	28
16	Feb 1945 - May 1945	4	5.1	47
17	Jan 1947	1	0.8	34
18	May 1933 - Jun 1933	2	5.1	31
19	May 1993 - Jul 1993	3	5.1	49
20	Dec 2017 - Jan 2018	2	4.2	23
21	Sep 2017 - Oct 2017	2	6	19
22	Feb 1923 - Mar 1923	2	5.1	43
23	Jan 1967	1	5.1	5
24	May 1978 - Jun 1978	2	6.8	22
25	Jul 1970 - Aug 1970	2	7.7	0
26	Aug 1946 - Oct 1946	3	7.7	3
27	Dec 1965	1	5.9	56
28	Jan 1952	1	5.9	0
29	Mar 1952 - Apr 1952	2	6.8	32
30	Jan 1944	1	6.8	23
31	Jun 1952 - Aug 1952	3	8.5	13
32	Apr 1992	1	7.7	0
33	Oct 2018 - Nov 2018	2	8.5	23
34	Nov 1948	1	8.5	17
35	Sep 1993	1	8.5	14
36	Apr 1930	1	8.5	0
37	Dec 1952	1	9.3	8
38	Feb 1939	1	9.4	25

[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 2019).

3.1.3 Central West Mitchell Grasslands region beef and sheep production systems

Extensive grazing, primarily on native pastures, is the principal land use across the Central West Mitchell Grasslands. The Central West Mitchell Grasslands falls within the Desert Channels Natural Resource Management (NRM) region for statistical reporting which is a total of 44,150,071 ha and supports 557 meat cattle businesses and 173 sheep businesses (ABS 2018*a*). The Desert Channels NRM region has a total meat cattle herd size of ca. 1,306,593, representing 6% of Australia’s and 12% of Queensland’s meat cattle numbers and producing $671,517,668 or 6% of Australia’s and 12% of Queensland’s gross value of cattle in 2016-17 (ABS 2018*a*,*b*). The meat and wool sheep flock in the region totals 691,539, representing 0.96% of Australia's and 33% of Queensland's total sheep flock and producing $28,048,150 or 0.4% of Australia's and 33% of Queensland's gross value of sheep (ABS 2018*a*,*b*).

While historically Merino sheep production systems were dominant in the Central West Mitchell Grasslands region cattle numbers increased during the 1990s so that by 2010 very few wool sheep remained north of Longreach (Bray *et al.* 2014). Economic factors as well as increases in wild dog numbers have contributed to the decline in sheep production in the region.

In previous decades the Mitchell Grasslands bioregion has been documented as being in better land condition than many other bioregions in Australia's grazing lands due to the resilient nature of the Mitchell grass pastures (Partridge 1996; Commonwealth of Australia 2008). Further, areas of poor land condition were historically due to invasion by woody weeds (primarily in the north of the region), increasing white speargrass (*Aristida leptopoda*; in the south-west) and feathertop (*Aristida latifolia*; in the central west).

However, more recent reports suggest application of higher stocking rates and pasture utilisation rates in the Mitchell Grasslands bioregion than used traditionally (Commonwealth of Australia 2008; Bray *et al.* 2014). This has been highlighted as posing a potential risk to land condition over time (Bray *et al.* 2014). It has been suggested that this trend towards increased pasture utilisation is linked to financial pressures of graziers, as well as increased total grazing pressure from macropods and feral animals such as goats, and increasing density and area of native and weedy woody vegetation which decreases pasture growth (Commonwealth of Australia 2008; Bray *et al.* 2014).

3.2 Methods

3.2.1 Representative property

The representative property, herd and flock characteristics were informed by recent industry surveys and research relevant to the region (McIvor 2010; Bray *et al.* 2014; McGowan *et al.* 2014). The property closely followed the assumptions described in Scanlan and McIvor (2010) and Scanlan *et al.* (2011) for Mitchell grasslands of western Queensland which were derived from regional consultation with beef producers, researchers and extension officers via workshops and out-of-session reviews. The representative, hypothetical property was a total area of ca. 16,200 ha of primarily native pastures growing on six land types characteristic of the Longreach region. The property was considered to be currently in B land condition on average (scale A-D; Quirk and McIvor 2003; DAF 2011), supporting ca. 1,071 adult equivalents (AE) or 9,639 dry sheep equivalents (DSE); (using an AE:DSE conversion of 1: 9; MLA 2001, 2017). The initial stocking was determined by running the GRASP model several times to establish the number of livestock that could be grazed in order to maintain the same average pasture condition (ca. 70% perennial grasses, B land condition) over the 36 years of simulation (1982-2017), (i.e. the average pasture condition after 36 years was same as the initial pasture condition). This land condition rating was considered as broadly representative of the grazing lands in the target region in 2018-2019.

The modelled property was divided into 10 main paddocks. Each paddock was allocated an area, a main land type, a land condition rating and a carrying capacity. Table 5 indicates the basic paddock data applied in the construction of the property model.

Table 5 - Paddocks, land types and land condition rating

Paddock	Area (ha)	Main land type	Starting land condition rating	Total AE /paddock	ha/ AE
1	810	Boree wooded downs	B	35.63	22.7
2	810	Open alluvia	B	30.54	26.5
3	2,835	Open downs	B	187.07	15.2
4	2,835	Open downs	B	187.07	15.2
5	2025	Open downs	B	133.62	15.2
6	1,820	Open downs	B	120.09	15.2
7a	1,134	Soft gidgee, cleared of timber[A]	B	149.65	7.6
7b	486	Soft gidgee[B]	B	-	-
8	1,215	Wooded downs	B	80.17	15.2
9	1,215	Wooded downs	B	80.17	15.2
10	1,015	Wooded downs	B	66.98	15.2
Total	*16,200*			*1,071*	*15.13*

[A]Tree basal area (TBA) of 1 m^2/ha; sown to buffel grass.

[B]TBA of 5 m^2/ha; not considered to make a significant contribution to carrying capacity in its present state.

The property was modelled as either running a beef enterprise or a sheep enterprise, not a combination of both. A typical property in this region is likely to have sheep and wool production in its history and to have moved towards beef production partly or wholly of recent decades. A typical property in this region would also likely to have more than one land type within one paddock. Assessing the optimum combination of each enterprise and accommodating for mixed land types within the modelled property was outside the scope of this project.

3.2.1.1 Operating expenses and asset value

Additional information required to complete the analysis included 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 property. Table 6 indicates the expected fixed cash costs for the property. Non-cash fixed costs include part or all of the operators allowance, which will be identified later.

Table 6 – Annual fixed cash costs for the base property

Item	Cost
Administration	$10,000
Electricity and gas - farm	$5,000
Farm rates	$15,000
Fuel and oil	$10,000
Insurance - farm	$7,500
Motor vehicle expenses	$10,000
Plant repairs	$20,000
Wages	$15,000
Weed control	$10,000
Total	*$102,000*

Table 7 shows the plant inventory for the base property. The replacement cost is an estimate of how much it would cost to replace the item if it were to be replaced now. The salvage value is estimated on the basis of the item being valued now but with the item in a condition equivalent to what it will be in when it is replaced. The items were either salvaged or replaced in the DCF analysis at the intervals and capital values indicated in Table 7.

Table 7 - Plant inventory

Item	Market value	Years to replacement	Replacement cost	Subsequent Replacement interval (years)	Salvage value
4wd ute	$25,000	4	$40,000	4	$10,000
0ld ute	$5,000	10	$10,000	10	$2,000
Box trailer	$2,500	20	$5,000	20	$0
Tractor with bucket	$40,000	15	$60,000	15	$15,000
4wd motor bike	$4,000	10	$5,000	10	$0
Buggy	$11,000	5	$15,000	5	$1,000
Motor bikes x 4	$20,000	5	$30,000	5	$1,000
Grain trailer	$5,000	20	$10,000	20	$1,000
Grader	$30,000	20	$50,000	20	$10,000
Workshop and saddlery	$50,000	20	$50,000	20	$0
Total	*$192,500*		*$275,000*		

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 $4,400,000. This resulted in an opening value of the total land, plant and improvements for the property investment of $4,592,500.

3.2.1.2 Beef production activity

The base beef 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.

3.2.1.2.1 Steer and heifer growth assumptions

The pattern of growth over time for steers and heifers underpinned the markets available for both steers and surplus heifers as well as the likely mating age and reproduction performance of the heifers as they enter the breeding herd. Some evidence exists that, where the same nutrition is available, male calves grow about 8% faster than female calves pre-weaning and steers grow about 5% faster than heifers post-weaning (Fordyce *et al.* 1993). To simplify the analyses, all 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.

Table 8 indicates the expected post-weaning seasonal performance for steers. Steers were assumed to gain weight at about 0.40 kg/head.day on grass pastures to achieve 148 kg/head.annum post weaning and heifers to gain ca. 0.38 kg/head.day to achieve 140 kg/head.annum post weaning.

Table 8 - Expected post weaning steer growth rates for the base scenario

Month	Days	Daily liveweight gain (kg/d)	Total liveweight gain (kg)
Jan	31	0.9	27.9
Feb	28	0.9	25.2
Mar	31	0.8	24.8
Apr	30	0.7	21.0
May	31	0.6	18.6
Jun	30	0.5	15.0
Jul	31	0.2	6.2
Aug	31	0	0.0
Sep	30	0	0.0
Oct	31	0	0.0
Nov	30	0	0.0
Dec	31	0.3	9.3
Average/Annual	*365*	*0.41*	*148.0*

Table 9 shows the expected month-by-month growth pattern for steers and heifers. Expected liveweight at birth, weaning and birthdays are highlighted (yellow, green and orange, respectively). The steer (and heifer) growth model underpinned the herd performance for the modelled base enterprise.

Table 9 - Expected growth of steers and heifers for the base scenario

Age (months)	Month	Steer daily gain (kg/day)	Steer liveweight (kg)	Heifer daily gain (kg /day)	Heifer liveweight (kg)
0	Dec		35		35
1	Jan	0.90	62	0.86	61
2	Feb	0.90	90	0.86	87
3	Mar	0.90	117	0.86	113
4	Apr	0.90	145	0.86	139
5	May	0.90	172	0.86	165
6	Jun	0.90	200	0.86	191
7	Jul	0.2	206	0.19	197
8	Aug	0	206	0.00	197
9	Sep	0	206	0.00	197
10	Oct	0	206	0.00	197
11	Nov	0	206	0.00	197
12	Dec	0.3	215	0.29	206
13	Jan	0.9	242	0.86	232
14	Feb	0.9	270	0.86	258
15	Mar	0.8	294	0.76	281
16	Apr	0.7	316	0.67	302
17	May	0.6	334	0.57	319
18	Jun	0.5	349	0.48	333
19	Jul	0.2	355	0.19	339
20	Aug	0	355	0.00	339
21	Sep	0	355	0.00	339
22	Oct	0	355	0.00	339
23	Nov	0	355	0.00	339
24	Dec	0.3	364	0.29	348
25	Jan	0.9	392	0.86	374
26	Feb	0.9	419	0.86	400
27	Mar	0.8	444	0.76	423
28	Apr	0.7	465	0.67	444
29	May	0.6	483	0.57	461
30	Jun	0.5	499	0.48	475
31	Jul	0.2	505	0.19	481
32	Aug	0	505	0.00	481
33	Sep	0	505	0.00	481
34	Oct	0	505	0.00	481
35	Nov	0	505	0.00	481
36	Dec	0.3	514	0.29	490
37	Jan	0.9	541		
38	Feb	0.9	569		
39	Mar	0.8	593		
40	Apr	0.7	615		
41	May	0.6	633		
42	Jun	0.5	648		
43	Jul	0.2	654		
44	Aug	0	654		
45	Sep	0	654		
46	Oct	0	654		
47	Nov	0	654		
48	Dec	0.3	663		

3.2.1.2.2 Prices

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 related to the selected selling centre. While these are not the closest selling centres to the base property these centres have the best available price data for the relevant classes of stock. Prices at local selling centres are considered to generally reflect Dinmore or Roma prices with a freight adjustment, hence resulting in similar values of stock to those used in our analysis.

Figure 4 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.

Figure 4 - Steer prices over time from 2009 to 2016

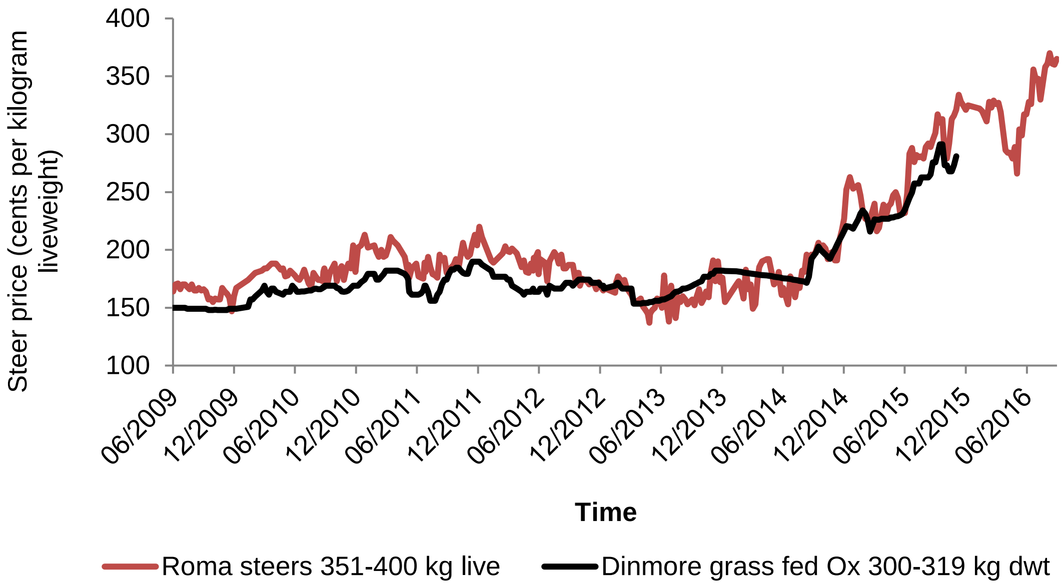


Table 10 shows average price data (July 2008 – November 2015) for a range of slaughter stock at Dinmore abattoirs.

Table 10 - 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 11 indicates the price variation for sale weights for steers and heifers at the Roma store sale between 2008 and 2015.

Table 11 - Price ranges at Roma sale yards (July 2008- November 2015) expressed as cents per kg 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 in our analysis to reflect the expected average values for prices. Not all of the recent price spike was included in the average as its long-term effect on prices is unknown. Table 12 shows the price data and selling costs for each class of stock retained in the herd models.

Table 12 - 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	333	5	316	$1.69	4.00	$17.00	$45.50
Heifers 2 years	475	5	451	$1.61	0.00	$5.00	$95.00
Cows 3 years plus	450	5	428	$1.61	0.00	$5.00	$87.69
Steers 1 year	349	5	332	$1.93[A]	4.00	$17.00	$45.50
Steers 2 years	499	5	474	$1.89	4.00	$17.00	$56.88
Steers 3 years	648	5	616	$1.87	0.00	$5.00	$126.67
Cull bulls	700	5	665	$1.65	0.00	$5.00	$142.50

[A]Value halfway between the 281-350 kg and the 351-400 kg mean price.

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. ($1.95 /km /deck and 700 km to Roma; $1.90 /km /deck and 1200 km to Dinmore)

3.2.1.2.3 Husbandry costs and treatments

Table 13 shows the 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.

Table 13 - Treatments applied and cost per head

Treatment	Weaners	Females 1-2 years	Females 2-3 years	Females 3+ years	Bulls
Weaner feed	$10.50				
NLIS tag	$3.00				
Dry season supplement	$12.00	$23.00	$23.00	$23.00	$21.00
Vibrio vaccine bulls					$10.00
Three day vaccine bulls					$35.00
Pregnancy testing		$5.00	$5.00	$5.00	

3.2.1.2.4 Other herd performance parameters

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 'Northern Downs' are summarised in Table 14. This data set was seen as being closest to the expected median performance of a beef breeding herd located in the Central West Mitchell Grasslands region near Longreach.

Table 14 - Median reproduction performance for 'Northern Downs' data (McGowan et al. 2014)

Reproduction performance indicator	Heifers	First lactation cows	2nd lactation cows	Mature	Aged	Overall
P4M*		45%	62%	67%	71%	66%
Annual pregnancy**	87%	75%		82%	83%	80%
Foetal / calf loss	14.9%	4.7%		7.20%	9.30%	10.0%
Contributed a weaner^	77%	68%		71%	70%	72%
Pregnant missing#		6.7%		7.0%	6.50%	6.6%

*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 15 shows the level of reproductive performance of each class of females required to achieve an average weaning rate of 73.5% for all cows mated in the Breedcowplus model. The values retained produced a weaning rate equivalent to the CashCow project contributed a weaner figure of 72% 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. The expected mortality rates in the base herd were influenced by the CashCow project data for missing pregnant females but were based on the mortality rates estimated by local case study participants.

Table 15 - 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	87	75	80	80	80	80	81
Expected calf loss from conception to weaning (%)	n/a	0	14.9	4.7	7.2	7.2	7.2	7.2	9.3
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	85.1	95.3	92.8	92.8	92.8	92.8	90.7
Female death rate (%)	2	2	5	4	4	4	4	4	5
Male death rate (%)	2	2	4	4	n/a	n/a	n/a	n/a	n/a

n/a: not applicable.

PTE, pregnancy tested 'empty'.

Table 16 shows the expected median birth date for calves and the weaning month for the base herd based on a 3-month mating period beginning in the middle of the previous January. Bulls were removed from the breeding herd with one main muster undertaken in June to wean calves and identify cull breeding cows.

Table 16 - Expected mating period for breeders

Parameter	Value
Bulls in	18/01/year
Days mated	91
Months mated	2.99
Bulls out	18/04/year
Days gestation	287
First calf	31/10/year
Last calf	30/01/year

3.2.1.3 Sheep and wool production activity

The base sheep and wool activity was a self-replacing activity that relied on the production of weaner sheep by a breeding merino flock. Weaner wethers entered a growing system that varied in size with the period of time wethers were retained prior to sale. Maiden ewes were used to maintain the breeding flock or were culled and sold. Flock ewes were culled on reproductive performance and age. Flock rams were retained in the breeding herd for an average of 4 years.

In the steady-state sheep model it was assumed that there would be no impact from wild dogs on the level of flock performance. This requires the property to be appropriately fenced or part of an effective cluster although it is estimated that at present only 10-15% of the district would be appropriately fenced. The property employed no permanent labour other than the owner/manager.

3.2.1.3.1 Flock management and husbandry assumptions

The following flock management and husbandry assumptions were used in the analysis:

- Ewes: 50 kg average liveweight; 6.5 years casting age; 4% mortality increasing to 10% in older age groups; 70% weaning

- Maiden ewes: 18 months first mating; lamb at 24 months; 5% mortality; 50% weaning rate
- Rams: run at 1.75%; 10% mortality; $650 purchase price of replacements; culls sold for $50
- 3.5 year wether casting age.
- DSE ratings:
    - 0.8 DSE/head for young ewes and weathers 0.5-1.5 years
    - 1.0 DSE/head for ewes and wethers 1.5 years and above
    - 0.5 DSE/head extra weighting for ewes carrying a lamb
    - 1.5 DSE/head for rams
    - Stock sold during the year were rated at half the annual DSE rating for their age/class.
- Control mating was practiced; wether and ewe weaners were run together but other classes were held in separate groups. The wether flock was not separated on age but maiden ewes were separated from older ewes.
- Rams entered the ewe flock in early October; 8 week joining period; ewes were expected to conceive in November.
- Pregnancy testing was conducted mid to late January (half-way through 2nd trimester) to determine wet/dry ewes. A second pregnancy test was conducted in March.
- Lambing occurred in autumn (April, with the tail in May)
- Lamb mark end of May
- Wean June/July
- Sales in autumn
- Crutching early September
- Shearing early December
- Mulesing is not conducted
- Lice control – back liner treatment applied at shearing time
- Vaccinate with 5-in-1
- Blowfly control – tactical treatment when necessary
- Urea-based, non-protein nitrogen (NPN) supplement was fed to breeding ewes for 10 weeks during the dry season (September to November period)
- Maiden ewes were fed supplements for 15 weeks at 1 kg/week
- Weaner supplementation:
    - Target 100g/d weight gain; supplemented from July to mid-January (26 weeks) with whole cottonseed or a protein grain (e.g. lupins or faba beans)
- Wool quality was assumed to be 20 microns with the long-term price taken to be $12/kg clean. This is equivalent to a $7.50/kg greasy wool price net of selling and freight expenses (at a 62.5% yield). Note that the Breedewe program incorporates both selling and freight expenses in this step and does not separate them

- 192 kg average wool bale weight.

Table 17 shows the treatments applied to the various classes of sheep and their cost.

Table 17 - Sheep enterprise direct costs

Cost	$/Lamb	$/Weaner	$/Wether	$/Ewe	$/Ram
Shearing	n/a	$6.50	$6.50	$6.50	$8.00
Crutching	n/a	$1.50	$1.50	$1.50	$2.00
Contractors (marking etc.)	$2.00	$0.00	$0.00	$0.60	$0.00
Drench, dip, vaccine etc.	$1.40	$1.00	$1.00	$1.00	$1.00
Fodder, licks, and supplements	$0.00	$13.50	$0.00	$2.60	$5.00
Other labour	$1.50	$1.50	$1.50	$1.50	$1.50
Total direct costs	*$12,386*	*$48,062*	*$34,012*	*$32,404*	*$1,167*

n/a, not applicable.

3.2.1.3.2 Assumed sheep and wool prices

The sheep and wool prices assumed in this analysis are given in Table 18, Table 19 and Table 20. The wool basis factor converted Micron Price Guide (MPG) to 'whole clip greasy price net of selling and freight costs'. The wool basis factor can vary from 40-50% depending on wool characteristics.

Table 18 - Sheep prices ($/head)

Sheep age at sale	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5
Ewe sale price	$50	$75	$75	$75	$75	$60	$40	$30	$30	$30	$30
Wether sale price	$50	$80	$80	$80	$80	$80	$80	$80	$40	$40	$40

Table 19 - Wool price basis

Parameter	Value
Clean wool price per kg - Micron Price Guide (MPG), ($/kg)	$12.00
Basis Factor	62.5%[A]
Price applied to calculate gross margin	$7.50

[A]This is a not a yield calculation as the % has to allow for selling and freight costs.

Table 20 - Wool price factors for each age and class of sheep

Parameter	Value										
Age at start of year of shearing	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5
Ewe wool price % of average	123.1	112.8	100.5	97.4	97.4	92.3	92.3	90.3	87.2	87.2	87.2
Wether wool price % of average	123.1	112.8	102.6	102.6	102.6	97.4	97.4	94.4	92.3	92.3	92.3
Ram wool price % of average	100.0										

3.2.1.3.3 Flock performance parameters

Table 21 shows the assumed lamb weaning rates, ewe and weather death rates applied in the flock model.

Table 21 - Lambing and death rate assumptions

Initial sheep age **Final sheep age**	**0.5** **1.5**	**1.5** **2.5**	**2.5** **3.5**	**3.5** **4.5**	**4.5** **5.5**	**5.5** **6.5**	**6.5** **7.5**	**7.5** **8.5**	**8.5** **9.5**	**9.5** **10.5**	**10.5** **11.5**
Weaning (%)	n/a	50.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0
Ewe deaths (%)	5.0	4.0	4.0	4.0	4.0	4.0	6.0	10.0	10.0	10.0	10.0
Wether deaths (%)	5.0	3.0	3.0	3.0	3.0	3.0	3.0	5.0	5.0	10.0	10.0

3.3 Results and discussion

3.3.1 Base beef production system

The growth path, sale weight, sale age, costs, price, reproduction efficiency, and female culling strategy values were entered in the Breedcowplus model and then optimised to identify the highest herd gross margin after interest. Surplus yearling heifers were culled and all breeding females were culled on a pregnancy diagnosis or age. Females that were pregnancy tested in calf and then failed to produce a weaner were retained.

Expected breeder deaths were 22/annum or 4.42% of female breeding stock maintained for the year. The application of the data for reproduction efficiency and mortality rates to the herd model produced an expected average weaning rate of 73.52% (i.e. weaners from all cows mated). The optimised base property produced about 406 weaners from 555 females mated and sold 372 head/ annum. Cull female sales made up 47.5% of total sales.

Table 22 indicates the herd gross margin after interest for each steer sale age after the cow culling age was optimised. Selling steers between 24 and 36 months of age at an average paddock weight of 499 kg, combined with 32% of the yearling heifers being culled prior to mating, produced the highest expected herd gross margin.

Table 22 - Steer age of turnoff and herd optimisation

Parameter	Age of steer turnoff			
	Weaners	**12-23 months**	**24-35 months (Base herd)**	**36-48 months**
Total adult equivalents (AE)	1,071	1,071	1,071	1,071
Total cattle carried	1,055	1,173	1,199	1,161
Weaner heifers retained	268	238	203	169
Total breeders mated	730	646	552	459
Total breeders mated and kept	590	523	446	371
Total calves weaned	536	475	406	338
Weaners/total cows mated	73.52%	73.52%	73.52%	73.52%
Overall breeder deaths	4.42%	4.42%	4.42%	4.42%
Female sales/total sales %	46.51%	47.01%	47.52%	48.53%
Total cows and heifers sold	233	207	176	147
Maximum cow culling age	13	13	13	13
Heifer joining age	2	2	2	2
One year old heifer sales %	31.83%	31.83%	31.83%	31.83%
Two year old heifer sales %	13.00%	13.00%	13.00%	13.00%
Total steers and bullocks sold	268	233	195	156
Maximum bullock turnoff age	0	1	2	3
Average female price	$546.65	$546.65	$546.65	$546.65
Average steer/bullock price	$312.65	$551.80	$786.24	$1,019.50
Capital value of herd	$578,659	$587,063	$610,544	$636,026
Imputed interest on herd value	$28,933	$29,353	$30,527	$31,801
Net cattle sales	$211,302	$241,445	$249,468	$238,996
Direct costs excluding bulls	$36,369	$33,773	$28,816	$24,000
Bull replacement	$16,505	$14,626	$12,479	$10,394
Herd gross margin	$158,427	$193,047	$208,173	$204,602
Herd gross margin less interest	*$129,494*	*$163,694*	*$177,646*	*$172,800*

The selected sale prices, sale weights, selling costs, treatment costs and bull replacement strategy were applied to produce the summary of the optimised herd gross margin shown in Table 23.

Table 23 - Herd gross margin for the representative, base enterprise

Parameter	$/herd	$/AE
Net cattle sales	$249,468	$232.93
Husbandry costs	$28,816	$26.91
Net bull replacement	$12,479	$11.65
Gross margin	$208,173	$194.37
Gross margin less interest	*$177,646*	*$165.87*

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

The opening value of the land and fixed improvements for the example breeding property was taken as $4,400,000. The opening value of the total value of land, plant and improvements for the beef enterprise investment was $4,592,500. The opening value of the cattle inventory was $819,116. Table 24 indicates the expected average annual performance parameters for the beef property calculated as a steady-state in Dynamaplus, and specifically designed to maintain pasture condition as defined by the average percentage perennial grass composition over 36 years being the same as the initial value (69%).

Table 24 - Expected value of annual outcomes for the beef property

Parameter	Value
Adult equivalents (AE)	1,071
Cash flow for debt service	$23,198
Return on total capital	-$1,152
Rate of return on total capital	-0.02%

3.3.2 Base sheep and wool production system

Table 25 shows the optimised flock performance for the base sheep and wool production system. Surplus weaner ewes were culled with all flock ewes culled on a pregnancy diagnosis or age. The average price/head for ewes and wethers sold was $44.79 and $80.00, respectively.

Table 25 – Steady state flock performance

Parameter	Value
Flock size (DSE)	9,639
Age at first mating (1.5 or 2.5 years)	1.5
Ewe casting age	6.5
Total ewes joined	3,811
Total lambs weaned	2,528
Lambs weaned/ewes joined (%)	66.32
Ewe weaners retained	739
Surplus ewe weaners sold (42%)	525
Mature ewes sold	572
Total mature ewes shorn	3,811
Total ewe weaners shorn	739
Weaner wethers sold	0
Mature wethers sold	1,130
Total wethers shorn	4,759

Table 26 shows the female flock structure and Table 27 the wether flock structure for the base flock. The estimated ram requirements are shown in Table 28. Classes of sheep in the flock are presented in Table 29 and wool production and value in Table 30 and Table 31. The total wool bales produced per annum were 199 at 192 kg/bale. The flock gross margin is presented in Table 32.

Table 26 – Female flock structure for the base flock

Ewe age at start year Ewe age at end year	1.5 2.5	2.5 3.5	3.5 4.5	4.5 5.5	5.5 6.5	6.5 7.5
Ewes available at start year	702	674	647	621	596	572
Optional sales % at start year	0%	0%	0%	0%	0%	0%
Number sold	0	0	0	0	0	572
% of start year number sold before joining	0%	0%	0%	0%	0%	0%
Number joined	702	674	647	621	596	572
% of joined ewes sold before lambing	0%	0%	0%	0%	0%	0%
Number lambing	702	674	647	621	596	572
Lambs weaned from ewes joined and kept	351	472	453	435	417	401
% of start year number sold before shearing	0%	0%	0%	0%	0%	0%
Number shorn	702	674	647	621	596	572

Table 27 - Wether flock structure for the base flock

Wether age at start year Wether age at end year	0.5 1.5	1.5 2.5	2.5 3.5	3.5 4.5
Wethers available at start year	1,264	1,201	1,165	1,130
Optional sales % of number at start year	0.0%	0.0%	0.0%	0.0%
Number sold	0	0	0	1130
% of start year number sold pre shearing	0%	0%	0%	0%
Number shorn	1,264	1,201	1,165	1,130

Table 28 - Ram requirements for the base flock

Parameter	Value
Rams/ewes to be used (%)	1.75
Rams required per year	67
% of rams replaced annually (25%; $650/head)	17
Rams sold per year ($50/head)	10
Ram deaths or destruction (10%)	7
Net ram replacement costs/year	$10,339
Net ram cost/lamb weaned	$4.09

Table 29 - Classes of sheep in the flock

Class	Number carried	Number sold	DSE/head carried	DSE/head sold	DSE Total	Deaths number	Deaths %
Extra for ewes weaning a lamb	n/a	n/a	0.50	n/a	1,264	n/a	n/a
Ewes and wethers 0.5 years	2,003	525	0.80	0.40	1,812	100	5%
Ewes 1.5 years plus	3,329	572	1.00	0.50	3,525	130	4%
Wethers 1.5 years and older	2.365	1,130	1.00	0.50	2,930	71	3%
Rams	73	11	1.50	0.75	108	7	10%
Total number and DSE	*7,674*				*9,639*	*307*	*4%*

n/a, not applicable.

Table 30 - Wool production

Sheep age (years)	0.5	1.5	2.5	3.5	4.5	5.5	6.5
Wool/ewe (kg)	2.50	3.50	4.50	4.50	4.50	4.50	4.00
Wool/wether (kg)	2.50	3.75	5.00	5.50	6.00	6.00	6.00
Wool/ram (kg/year)	8.00						
Ewes shorn	739	702	674	647	621	596	572
Wethers shorn	1264	1201	1165	1130	0	0	0
Rams shorn	67						
Value of ewe wool	$16,264	$19,828	$21,804	$20,291	$19,479	$17,716	$15,118
Value of wether wool	$27,825	$36,346	$42,734	$45,597	$0	$0	$0
Value of ram's wool	$3,818						

Table 31 – Wool value by class

Class	kg total	kg/head horn	$ total	$/head shorn
Wool from weaners	5,006	2.50	$44,089	$22.02
Wool from ewes	16,164	4.24	$114,237	$29.97
Wool from wethers	16,539	4.73	$124,677	$35.67
Wool from rams	534	8.00	$3,818	$57.24
Total wool produced	38,243	4.08	$286,820	$30.59

Table 32 - Flock gross margin for the base, case-study enterprise

Parameter	$/flock	$/sheep	$/DSE
Net wool sales	$286,820	$37.38	$29.76
Net sheep sales excluding rams	$139,520	$18.18	$14.47
Less net ram purchases + husbandry costs	$12,534	$11,506	$1.50
Less other direct costs	$126,864	$16.53	$13.16
Gross margin	*$287,970*	*$37.53*	*$29.88*

The opening value of the land and fixed improvements for the example property was taken as $4,400,000. This makes the opening value of the total value of land, plant and improvements for the sheep enterprise investment, $4,592,500. Opening value of sheep is $667,270. Table 33 indicates the expected average annual performance parameters for the sheep property calculated in Sheepdyn. Note that the average number of DSE calculated in Sheepdyn is slightly greater than the target in Breedewe (9,639 DSE) due to rounding differences between the two models. Similar to the beef production activity, the base sheep and wool production activity resulted in a rate of return on total capital of < 5%, at what was considered equivalent grazing pressure (1.68 ha/DSE) for the base property of 16,200 ha. However, this result was based on the assumption that the property was already protected from wild dogs with appropriate fencing infrastructure. The costs of implementing cluster fencing, or similar, were not included in this analysis.

Table 33 - Expected value of annual outcomes for the sheep and wool property

Parameter	Value
Dry sheep equivalents	9,686
Cash flow for debt service	$98,014
Return on total capital	$72,414
Rate of return on total capital	1.39%

4 The impact of climate variability on drought preparation, response and recovery strategies

4.1 Integrating GRASP data with a beef herd model

4.1.1 Introduction

The impact of climate variability on a range of drought-related grazing management scenarios was modelled by integrating output from the GRASP pasture-growth model (McKeon *et al.* 2000; Rickert *et al.* 2000), over a climate sequence of 36 years (1982-2017), with beef cattle herd models (Breedcow and Dynama, Version 6.02; Holmes *et al.* 2017), and the Braithwaite four period calving model (I. Braithwaite pers. comm.), to determine whole-of-business productivity and profitability. The objective was to assess the grazing management strategies for their effect on pasture condition and on business profitability and resilience.

The impact of drought related grazing management scenarios for a sheep flock were not modelled with GRASP due to the limited capacity of GRASP to model wool production systems. There was also an expectation that the relative value of the strategies would probably be similar for beef and sheep production systems given that the response for both would be directly related to the same amount of variation in pasture production over time.

4.1.1.1 Description of the GRASP model

GRASP is a dynamic, point-based biophysical pasture-animal growth model developed for northern Australia and rangeland pastures (McKeon *et al.* 2000; Rickert *et al.* 2000). The model simulates soil moisture, pasture growth and animal production from daily inputs of rainfall, temperature, humidity, pan evaporation and solar radiation. GRASP has been widely used to evaluate the effects of various grazing management practices for many regions across northern Australia including estimation of long-term, safe carrying capacity (e.g. McKeon *et al.* 2009) and to predict effects of different stocking rates on soil, pasture and animal production parameters (e.g. Ash *et al.* 2000; McKeon *et al.* 2000).

The GRASP model has been recently modified to enable the negative effects of grazing strategies on pasture condition to be more accurately modelled (Scanlan *et al.* 2011; Scanlan *et al.* 2013). In summary, within GRASP, the percentage of perennial grasses in the pasture (on a DM basis) is a non-linear function of pasture 'state' with state 0 having 90% perennial grass and state 11 having 1% perennial grasses. Change in pasture 'condition' or 'state' is driven by annual, user-defined rates of pasture degradation or improvement which are linked to a specified ‘safe’ utilisation level for that pasture type (e.g. Scanlan *et al.* 2013, 2014).

The GRASP model simulates annual cattle LWG per head for a 200 kg steer as a function of utilisation of annual forage growth and the length of the growing season (proportion of days in which the growth index is above a threshold of 0.05 (Whish *et al.* 2013). The coefficients in this equation were adjusted to achieve what were considered reasonable LWG outcomes for the region based on measured LWG data and expert opinion (G. Whish pers. comm.). The consumption of pasture dry matter by cattle is estimated by first determining a 'potential intake' calculated from a user-defined potential cattle daily LWG assigned to each of the four seasons (Littleboy and McKeon 1997). This 'potential intake' is then reduced by an 'intake restriction' factor which accounts for 1) diet quality based on the proportion of accumulated growth which has already been consumed, and 2) low levels of total standing dry matter (TSDM) of pasture, the value of which is also user-defined.

The GRASP model has been previously coupled with the dynamic beef herd model Enterprise (MacLeod and Ash 2001) and used to examine property-level implications of different grazing strategies for breeding-finishing cattle businesses (e.g. Scanlan *et al.* 2013). However, the limitations of this approach were identified by Mayer (2013) and Mayer *et al*. (2012) who demonstrated that the models used in Enterprise to predict the reproduction and mortality rates of breeding cows were unsatisfactory. These authors proposed superior models for prediction of conception and mortality rates of breeders under northern Australian conditions which were based on an extensive data set from across northern Australia. The approach taken here, of integrating output from the GRASP model with the Breedcow and Dynama herd modelling suite and incorporating the functions developed by Mayer *et al.* (2012), was intended to reduce the identified limitations and provide improved predictions of the effect of grazing management strategies on business profitability and resilience.

4.1.1.2 Description of the Breedcow and Dynama software

The Breedcow and Dynama software (Version 6.02; Holmes *et al.* 2017) is a herd budgeting program designed to evaluate the profitability and financial risk of alternative management strategies for extensive beef enterprises, at the property level. Property-level, regionally-relevant herd models are used to determine business productivity and profitability of defined investment periods of 10+ years. The spreadsheets contain livestock schedules linked to cash flow and investment budgets to allow a marginal analysis comparing a base scenario with alternative management scenarios. This approach accounts for the implementation phase of an alternative management strategy, the additional capital required, the economic life of the investment and the effect on herd structure. The first version of the Breedcow and Dynama software was released to the public in 1990 and the software has been applied by users across northern Australia since this time (e.g. Holmes 1990; Stockwell *et al.* 1991). The Breedcow and Dynama software is described in more detail in Appendix 1. Breedcow and Dynama software. The principles of investment analysis applied in the software are explained in Appendix 2. Discounting and investment analysis.

4.1.1.3 Description of the Braithwaite four period calving model

The four-period calving herd model originally developed by I. Braithwaite allows the consideration of impacts associated with uncontrolled mating and herd segregation on foetal aging, specifically the impact on inter-calving interval and differing growth rates associated with the season of calving. These aspects cannot be assessed in the Breedcow and Dynama software format.

4.1.2 Methods

To facilitate error checking and model development, two separate herd modelling frameworks were developed to combine GRASP output with dynamic cash flow budgets and investment models. Both applied the functions developed by Mayer *et al.* (2012) but their insertion into two different herd modelling frameworks allowed for error checking. Both of these models were extended to allow combination with GRASP output to model a 30-year climate sequence. The growth of steers and heifers in up to 5 years immediately prior to the 30-year period of economic analysis were accounted for in the weights of steers and heifers sold or mated in the initial years.

4.1.2.1 Converting GRASP outputs to estimates of herd productivity

The outputs of the GRASP model include estimates of 1) the annual growth of a 200 kg steer and 2) the expected stocking rate per square kilometre for these steers given the grazing management parameters applied in GRASP. The use of GRASP animal productivity estimates in a cattle herd model required relationships to be developed between steer growth and stocking rate output and female conception rates, mortality rates, individual heifer and steer growth and stocking rates over time plus sale weights for cull animals and steers. The following sections describe the method applied to derive these estimates. For each paddock of the representative, base property the annual stocking rates and cattle growth rates (LWG gain/head.year) simulated by GRASP were used as data input to the herd models.

Cattle mortality and conception rates were estimated by applying the prediction equations developed by Mayer *et al.* (2012) for breeding cattle in northern Australia. These equations were developed from historical data from across northern Australia and were considered the most accurate and appropriate for our purposes. Use of the Mayer *et al*. (2012) equations allowed identification of the appropriate starting herd structure and sales targets for the GRASP modelling. The first step in any economic analysis for beef cattle herds is to determine the optimal culling and sales strategy. Any improvements in profitability due to changed management strategies can then be said to be more economically optimal.

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 450 kg which was considered as representative for contemporary *Bos indicus* and *B. indicus* crossbred cattle in the Central West Mitchell Grasslands region (Table 34).

Table 34 – Equivalence of breeder body condition score (BCS) to body condition ratio (BCR) and calculated liveweight based on a breeder standard reference weight (SRW) of 450 kg liveweight; calculated using equations from Mayer et al. (2012)

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

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

4.1.2.1.1 Female conception rates

Mayer *et al.* (2012) describe the relationship between body condition ratio (BCR) and expected conception rate for various female age groups for mature females as:

$$CR(\%) = a/(1 + e^{(-b(BCR-))})$$

where *a*, *b* and *c* are parameter values related to the class and breed of mature female.

In our study, conception rates per 21 day cycle were converted to pregnancy rates for a mating period by reworking the relationship described by Mayer *et al.* (2012):

$$CR = 1 - (1 - PR)^{1/n} \text{ (Where n is the number of cycles).}$$

This equation was reconstructed to calculate the expected pregnancy rate for a number of 21 day breeding cycles; giving:

$$PR = 1 - (CR - 1)^n.$$

For example, a breeding period of 12 weeks = 84 days = 4 cycles = *n*.

Table 35 shows the modelled relationship between liveweight change, conception rate and pregnancy rate over a 3-month mating period for mature lactating *B. indicus* females. The standard reference weight (SRW) was taken to be 450 kg. The predicted pregnancy rate over 3 cycles was taken to be equivalent to the pregnancy rate achieved over a 3- month mating period.

Table 35 – Modelled output for conception rate and pregnancy rate over a 3-month mating period for mature, lactating Bos indicus females; calculated using equations of Mayer et al. (2012)

All terms defined in the text and in the Glossary of terms and abbreviations; predictions for a cow of 450 kg body weight highlighted grey

Liveweight (kg)	Body condition Ratio	Body weight change	Conception rate	Pregnancy rate
225	0.500	-225	2.12	0.082
236	0.525	-213.75	2.49	0.096
248	0.550	-202.5	2.92	0.112
259	0.575	-191.25	3.41	0.130
270	0.600	-180	3.99	0.150
281	0.625	-168.75	4.65	0.173
293	0.650	-157.5	5.41	0.199
304	0.675	-146.25	6.28	0.228
315	0.700	-135	7.26	0.260
326	0.725	-123.75	8.38	0.295
338	0.750	-112.5	9.63	0.333
349	0.775	-101.25	11.03	0.373
360	0.800	-90	12.57	0.416
371	0.825	-78.75	14.26	0.460
383	0.850	-67.5	16.09	0.504
394	0.875	-56.25	18.05	0.549
405	0.900	-45	20.12	0.593
416	0.925	-33.75	22.29	0.635
428	0.950	-22.5	24.53	0.676
439	0.975	-11.25	26.82	0.713
450	1.000	0	29.11	0.747
461	1.025	11.25	31.38	0.778
473	1.050	22.5	33.60	0.806
484	1.075	33.75	35.74	0.829
495	1.100	45	37.77	0.850
506	1.125	56.25	39.69	0.868
518	1.150	67.5	41.47	0.883
529	1.175	78.75	43.10	0.895
540	1.200	90	44.59	0.906
551	1.225	101.25	45.93	0.915
563	1.250	112.5	47.14	0.922
574	1.275	123.75	48.21	0.928
585	1.300	135	49.15	0.933
596	1.325	146.25	49.98	0.937
607	1.350	157.5	50.70	0.941
619	1.375	168.75	51.33	0.944
630	1.400	180	51.87	0.946
641	1.425	191.25	52.34	0.948
652	1.450	202.5	52.75	0.950
664	1.475	213.75	53.10	0.952
675	1.500	225	53.39	0.953

Steer growth rates estimated by GRASP for the 12 months prior to the mating period were used to identify the change in the liveweight of a breeder and therefore estimate the expected pregnancy rate. For example, if the steers on a particular class of country gained 100 kg per head for the year to 1 May, the mature lactating Bos indicus breeders would be expected to achieve a 90% pregnancy rate over the three month mating period. It should be noted that steer weight gain was estimated by GRASP for a 12-month period from 1 May each year and this data was applied to estimate pregnancy rates for a period that started in January and finished in April of the same year.

The estimate of conception rates in heifers was based on the modelled weight of the heifer in mid-March of the year of first mating and was calculated using Equation 7 developed by Mayer *et al.* (2012):

$$CR(\%) = a/(1 + e^{\left(-b\left(\frac{weight}{SRW}-c\right)\right)})$$

where *a* = 37.0 for *B.indicus* and European, 43.6 for British, or 49.0 for Africander breeds of cattle; SRW = 520 for European breeds, 465 for recent tropical composites, and 425 otherwise; b = 22.4 and *c* = 0.614. Heifer weights were adjusted to be 5% lower than the modelled steer weight gain or loss for the same period. The SRW applied in the calculation of 2-year old heifer conception rates was 425 kg liveweight with 37 applied as the value of *a*.

Conception rates were modified for each period based on the estimate provided by the combined GRASP output and Mayer *et al.* (2012) functions after reference to the median conception rates identified for the Northern Downs region in the CashCow project (McGowan *et al.* 2014; Table 36). That is, the median conception rate over the 30-year period for the modelled base herd that applied the 36-year, safe stocking rates was adjusted to be equivalent to the median conception rate calculated by the CashCow project. Alternative management strategies resulted in higher or lower modelled conception rates according to the differences in predicted annual steer growth. That is, if an alternative management strategy achieved relatively higher steer growth rate in a period, the conception rate for the breeder herd would also be relatively higher than the base herd.

The foetal/calf loss estimates for the breeding herd were fixed in each period and for each age group of females. Estimates were derived from the median foetal/calf loss made by the CashCow project for the Northern Downs region (McGowan *et al.* 2014). Pregnancy rates were converted to weaning rates for all classes of females by deducting the standard figure for foetal/calf loss identified as the median for the region and class by the CashCow project (McGowan *et al*. 2014).

Table 36 - Calf loss parameters for representative, base herd

Cattle age year start	**Weaners**	**1**	**2**	**3**	**4**	**8**
Cattle age year end	**1**	**2**	**3**	**4**	**5 to 8**	**9+**
Expected conception (%)	n/a	0	87	75	80	81
Expected calf loss from conception to weaning (%)	n/a	0	14.9	4.7	7.2	9.3

4.1.2.1.2 Female mortality rates

Mortality rates were estimated using Equation 2 of Mayer *et al.* (2012) was:

$$mortality\ \% = 100/(1 + e^{-logit})$$

where:

logit = -21.3 + 40.7 x BCR -24.2 x BCR^2 +1.05 X Age -0:0255 x Weight change -0.893 x Age x BCR.

This model includes a complex interaction between BCR and age. Mayer *et al.* (2012) report that the model “appears biologically meaningful, and agrees with researchers’ expectations”.

GRASP output that provides monthly data was used to estimate the weight loss or gain expected for the period up to December each year in the modelled sequence. The figure for the last six months of the calendar year immediately preceding the target year was applied in Equation 2 of Mayer *et al.* (2012) as the estimate of weight change in calculating an expected BCR for the animal.

This estimate of the opening BCR was combined with the weight gain or loss for the last six months of the current year to estimate the rate of mortality in the current year. Table 37 shows a section of a 'lookup table' that calculates the annual rates of mortality for 7 year-old females. For example, cows in this age group that started the year with a BCR of 1 and lost no weight would incur a mortality rate of 2.41% in the model.

Table 37 – Example of a 'lookup Table' used to estimate breeder mortality using body condition ratio (BCR) and weight change, for 7 year old cows

All terms defined in the text and in the Glossary of terms and abbreviations; mortality estimates for cows starting the year with a BCR of 1 as well as for cows with 0 kg weight change but with a range of BCR, are highlighted

Change in weight (kg)	**Body condition ratio (BCR) start of year**								
	0.90	**0.93**	**0.95**	**0.98**	**1.00**	**1.03**	**1.05**	**1.08**	**1.10**
-100	50.05	44.01	37.43	30.63	24.03	18.02	12.91	8.84	5.80
-90	43.71	37.85	31.67	25.50	19.69	14.56	10.30	6.99	4.55
-80	37.57	32.06	26.43	20.96	15.96	11.66	8.17	5.50	3.56
-70	31.80	26.78	21.77	17.05	12.83	9.28	6.45	4.32	2.78
-60	26.54	22.08	17.74	13.74	10.24	7.34	5.07	3.38	2.17
-50	21.88	18.01	14.32	10.98	8.12	5.79	3.98	2.64	1.69
-40	17.83	14.54	11.47	8.73	6.41	4.54	3.11	2.06	1.31
-30	14.39	11.65	9.12	6.90	5.04	3.56	2.43	1.60	1.02
-20	11.53	9.27	7.22	5.43	3.95	2.78	1.89	1.25	0.79
-10	9.17	7.34	5.68	4.26	3.09	2.17	1.47	0.97	0.62
0	7.26	5.78	4.46	3.33	2.41	1.69	1.14	0.75	0.48
10	5.72	4.54	3.49	2.60	1.88	1.31	0.89	0.58	0.37
20	4.49	3.55	2.73	2.03	1.46	1.02	0.69	0.45	0.29
30	3.51	2.78	2.13	1.58	1.14	0.79	0.54	0.35	0.22
40	2.74	2.17	1.66	1.23	0.88	0.62	0.42	0.27	0.17
50	2.14	1.69	1.29	0.95	0.69	0.48	0.32	0.21	0.13
60	1.67	1.31	1.00	0.74	0.53	0.37	0.25	0.16	0.10
70	1.30	1.02	0.78	0.58	0.41	0.29	0.19	0.13	0.08
80	1.01	0.79	0.60	0.45	0.32	0.22	0.15	0.10	0.06
90	0.78	0.61	0.47	0.35	0.25	0.17	0.12	0.08	0.05
100	0.61	0.48	0.36	0.27	0.19	0.13	0.09	0.06	0.04

Lookup tables were compiled for female age groups from weaning up to 12-13 years of age. The form of Equation 2 from Mayer *et al.* (2012) causes calculated rates of mortality to peak and then fall as BCR falls below 1. The peak mortality rate and subsequent decline occurs at different levels of BCR in different age groups. The authors of these equations identified that it was best to retain mortality rates at the maximum for values of BCR below the tipping point of the equation in each age group (D. Mayer, pers. comm.).

In the Dynamaplus model the actual number of deaths for the each class of stock in each period was calculated as the opening number for the class, plus purchases, less spays, less sales, multiplied by the rate of mortality. In the Braithwaite four period calving model the actual number of deaths was calculated as the opening number in each class multiplied by the mortality rate. Steer rates of mortality were taken to be the same as those calculated for the same age group of females. Rates of mortality for herd bulls were equivalent to the annual rate of mortality experienced by mature breeding cows in the same year.

4.1.2.1.3 Steer and heifer growth rates

Annual steer growth rates predicted by GRASP were accumulated from each calving date to represent the growth path of steers and heifers. Heifer growth rates were adjusted to be 5% lower on an annual basis when steer growth rates were both positive and negative as per data of Fordyce *et al.* (1993). This reduced the impact of weight loss years on the growth path of heifers, but is not considered to be critical in this analysis due to the small number of years that incurred an annual weight loss in the model.

Calf growth rates pre-weaning were adjusted to reflect the potential impact of the range of steer growth rates estimated by GRASP on the average weight of weaners. The level of adjustment of weaning weights can be varied by the modeller. Table 38 indicates the level of adjustment made to weaning weight in the current analysis. For example, if the annual steer LWG calculated in GRASP for the period was 100 kg, then the average weaner weight of male weaners would be ca. 200 kg. For the same year weaner heifers would average 190 kg (5% lower than the steer value). Weaning weights of 200 and 190 kg for steers and heifers, respectively, were the expected values applied for weaner weights in the base herd model.

Table 38 - GRASP annual weight gain and weaning weight adjustment

Values applied in the base herd model are highlighted

GRASP annual weight gain (kg)	6th month weight impact	steer weaner weight (kg)	heifer weaner weight (kg)
-200	-30.00%	140	133
-175	-27.50%	145	138
-150	-25.00%	150	142
-125	-22.50%	155	147
-100	-20.00%	160	152
-75	-17.50%	165	157
-50	-15.00%	170	161
-25	-12.50%	175	166
0	-10.00%	180	171
25	-7.50%	185	175
50	-5.00%	190	180
75	-2.50%	195	185
100	0.00%	199.70	189.715
125	5.00%	210	199
150	10.00%	220	209
175	15.00%	230	218
200	20.00%	240	228

The annual steer LWG calculated by GRASP were converted to monthly LWG (or loss) estimates based on the share of annual growth predicted to be achieved by the growth path analysis. Table 39 shows how the annual LWG or loss predicted by GRASP was allocated to each month of each year post weaning. Where steers and heifers lost liveweight over a 12-month period, the weight loss was apportioned using the same relationships identified in Table 39. Therefore, the months predicted to have the best LWG consequently suffer weight loss at the same proportional rate. As there were only a small number of years with negative steer growth in our analyses the impact of this assumption on the economic analysis was minimal.

Table 39 - Allocation of monthly liveweight gain for steers and heifers

Month	Days	% annual liveweight gain
Jan	31	19%
Feb	28	17%
Mar	31	17%
Apr	30	14%
May	31	13%
Jun	30	10%
Jul	31	4%
Aug	31	0%
Sep	30	0%
Oct	31	0%
Nov	30	0%
Dec	31	6%
Total	*365*	*100%*

4.1.2.1.4 Modelling herd management

Steers and heifers were allocated to different paddocks for each year they were held post weaning. Where it was necessary to allocate steers or heifers to paddocks with different land types the GRASP output for the relevant paddock and land type was applied to calculate the component of the growth path for the period of time the livestock grazed the paddock.

The Breedcow and Dynama software

The Dynamaplus model cannot separate breeding females into lactating and non-lactating classes so all non-pregnant females were culled in this model at pregnancy testing. This allowed all mature breeders to be treated as lactating females in the model and have their expected conception rates calculated using one Mayer *et al*. (2012) function. This management strategy of culling all non-pregnant females after the mating period can only be applied where pregnancy rates are sound. Beef herds that require large numbers of empty females to be retained in the herd to maintain breeder numbers (as happens across large areas of northern Australia) would need to be modelled in the Braithwaite model where different Mayer *et al.* (2012) functions can be applied to females in each class with a different lactation status at mating.

The Dynamaplus modelling framework allows mating of yearling heifers but first mating for this analysis was restricted to 2 year-old heifers due to the inability to separate 2 year-old first calf heifers and non-pregnant 2 year-olds in the Dynamaplus model. This age group of females has substantially different chances of conceiving as 2 year-olds, largely related to their lactation status during the mating period. Furthermore, there is no Mayer *et al*. (2012) function for calculating pregnancy rates in lactating 2 year-old females. Heifers did not conceive in if their bodyweight was less than 270 kg in May (assumption based on results of Schatz 2010).

For the Dynamaplus model, the proportion and number of cattle in each class was set by reference to the stocking rate identified for that year by GRASP and the optimum starting herd structure. Adjustment to female and steer sales was made in each year of the Dynamaplus herd schedule where the management strategy being modelled required herd numbers to be either built up or sold down to achieve stocking rate (grazing pressure) targets. Periods of high conception rates due to excellent seasonal conditions had limited impact on the number of weaners produced due to the automatic sale of surplus females whether they were pregnant or not to achieve the targeted, optimal herd structure. Years with poor seasonal conditions that reduced conception rates and increased mortality rates led to a retention of additional female stock to regain the targeted herd structure and grazing pressure of the management scenario.

The Braithwaite four calving period model

The Braithwaite four calving period model separates breeding females on pregnancy status at the beginning of each period. This allowed breeding herds to have their reproduction efficiency modelled using a function that reflected the expected lactation status of the female at mating. Periods of high conception rates that were related to above average seasonal conditions were modelled by either retaining all pregnant females to build up herd numbers or selling some to maintain a target stocking rate at the property level. Periods of low conception rates were responded to by either retaining pregnancy tested empty (PTE) cows or purchasing additional stock depending upon the strategy being modelled.

Cows that were pregnancy tested in calf and then subsequently lost that calf prior to weaning could be separated in the four calving period model but were kept in the mating group and achieved the same re-conception rates, on average, as the remainder of the mating group. This is even though they were unlikely to be lactating during the mating period.

As identified previously, Mayer *et al.* (2012) did not develop functions for the conception rates at the second mating for heifers that conceive as yearlings and are lactating at their second mating. The yearling mating problem was also avoided in the four calving period model by first mating as 2 year olds. As assumed for the Breedcow and Dynama model, heifers did not conceive if their bodyweight was less than 270 kg in May (assumption based on results of Schatz 2010).

4.1.2.1.5 Steer and heifer sale and purchases

All cull heifers and steers were sold in June to match the decision criteria set for reassessing the annual paddock stocking rate in the GRASP model. GRASP was configured to reset the property grazing pressure at the start of May each year and the assumption was that normal sale activities plus any stock that are removed (or added) to balance the grazing pressure modelled in GRASP would occur by the middle of June. This was on the basis that about a month would be required for the management team to move cattle onto or off the property after the pasture assessment.

The weight gain for purchased dry cattle was the same as the May to May annual weight gain calculated using GRASP output for the same class of home-bred stock for the same period of time. Although unlikely to gain much weight over the 4 months after purchase, steers and heifers were purchased to balance the grazing pressure modelled in GRASP in June of each year at the same opening weight and value as the home bred stock. Purchase and associated transport costs were added to the purchase price. Sale values and selling costs for purchased stock were the same as those achieved for home-bred sale stock of the same class and age.

4.1.2.1.6 Cull cow sale weights

Cull cow sale weights were calculated by adding or subtracting the GRASP annual steer growth rate to a predefined cull cow reference weight to achieve a median of 450 kg in the paddock in the 36-year, safe stocking rate herd model. Scenarios that achieved higher or lower steer LWG than the 36-year, safe stocking rate model, achieved relatively higher or lower cull cow weights and a different median sale weight. The sale strategy required that cows were culled and sold at weaning (in June) generally after just weaning a calf. This practice was expected to impact cull cow sale weights at the point of sale but the combination of GRASP annual steer weight gains or losses plus a fixed component to estimate the cull cow sale weight allowed the differences between the management practices and seasonal conditions being modelled to be reflected in cull cow income.

4.1.2.1.7 Calculating and adjusting the total grazing pressure applied

For each scenario cattle numbers were adjusted by comparing the total number of AE produced by the herd model to those calculated for the same period for the total property by the GRASP model. The GRASP AE formula, calculated using metabolic liveweight, was adjusted to incorporate actual modelled LWG of steers (rather than using a fixed steer LWG as in GRASP). These AE derived from GRASP were used as an index to match the total AE in Dynamaplus. The outputs provided by the GRASP model were converted to a Dynamaplus total AE number for the property for each May to May period using the following method:

- Firstly, the stocking rate figure (head per square kilometre) calculated by GRASP for each paddock area/land type/land condition combination was used to calculate the number of head in each paddock in each year.
- Secondly, the annual LWG figure for the same period for the same paddock was used, in combination with the LWG of a 200 kg steer predicted by GRASP, to account for estimated pasture intake in calculating the AE rating for the animal in the paddock for that period. The form of the function was:

$$\frac{POWER((starting\ weight+(starting\ weight+weight\ gain))/2{,}0.75)}{POWER(455{,}0.75)}$$

  where the starting weight was the paddock weight for the relevant class of livestock to allow for intake associated with different classes of stock in GRASP.

- The AE rating for the period was combined with the number of head grazing the paddock to identify the total number of AE in each paddock and on the total property in each year of the simulation.

Within the Dynamaplus program an AE was taken as a non-pregnant, non-lactating beast of average weight 455 kg (1,000 lbs) carried for 12 months. Animals of average weight over the 12 months of more or less than 455 kg were rated in proportion to their average liveweight over the period. Thus a beast growing from 450 to 600 kg (average 525 kg) would be rated at 1.15 AE for twelve months (525 divided by 455 equals 1.15). In the calculation of total AE in the Dynamaplus herd model an additional allowance of 0.35 AE was made for each breeder that rears a calf. This allowance covers the extra nutritional requirements of pregnancy, lactation, and incidental forage consumption by the calf until age 5 months. This rating is placed on the calves themselves, effectively from conception to age five months, while their mothers are rated entirely on weight. Five months is an arbitrary age beyond which the calves are rated purely on weight. This age may bear no relationship to the age at which they are actually weaned.

The grazing pressure applied in each year in each Dynamaplus herd model was estimated by converting the livestock shown in each class in each period of the livestock schedule, and their expected change in liveweight and numbers, to a number of AE for the year. A pro rata allowance was made for the period of the year for stock were held prior to being sold during the year. Cattle carried for periods less than 12 months in Dynamaplus, e.g. sale cattle carried 3 months into the budget year, were rated on the period of time carried as a fraction of 12 months. A beast carried for

3 months and growing from 400 to 440 kg would be rated at 0.23 AE (average weight 420 divided by 455 multiplied by 3 and divided by 12 equals 0.23).

4.1.2.2 Grazing management scenarios

4.1.2.2.1 Scenario 1 – Set stocking rate strategy

For each of the 10 paddocks, a set stocking approach was simulated over 36 years (1982-2017) using a stocking rate which ensured that the average pasture condition (% perennial grasses) and land condition rating (scale A-D) over that period approximated the initial condition (ca. 70% perennial grasses and B condition), i.e. taken to indicate no change in pasture condition. The pasture utilisation rates used to achieve this outcome are shown in Table 40. Note that as the total number of cattle were held constant (0.1% change allowed from starting number in Year 1), pasture growth, the total available pasture biomass (TSDM) on 1 May, pasture consumption, and the percentage of perennial grasses in the biomass, fluctuated from year to year according to rainfall. This Set stocking rate management strategy was a reference point for the other three grazing management strategies where stocking rate fluctuated over the 30 years of the analysis.

Table 40 – Pasture utilisation rates of both annual pasture biomass growth and total standing dry matter (TSDM) at 1 May, defined in the GRASP pasture growth model for primary land types in the Central West Mitchell Grasslands

Primary land type	Utilisation % of annual pasture biomass growth (dry matter basis)	Utilisation % of TSDM (dry matter basis) at 1 May used to set stock numbers
Boree wooded downs	22	30
Open alluvia	18	20
Open downs	22	30
Soft gidgee – pulled	30	35
Soft gidgee – wooded	18	20
Wooded downs	20	25

4.1.2.2.2 Scenario 2 – Retain core herd strategy

The objective of Scenario 2 - Retain core herd was to maintain a core herd on the property during drought so as to rebuild the herd more quickly once the drought breaks. During drought periods, small reductions (10%) in cattle numbers were allowed from year to year, as TSDM declined and then cattle numbers were rebuilt through natural herd increases as TSDM increased after rain. Annual changes in cattle numbers occurred to match forage TSDM available on the 1 May using the safe utilisation rates defined in Table 40 with the limitations:

a. annual changes in cattle numbers were limited to 10% increases and 20% decreases, and

b. over the 36 years changes in animal numbers were limited to a 100% increase and a 25% decrease from the initial stocking rate.

The core herd numbers were retained regardless of the requirement and length of supplementary feeding which was required according the rules outlined in Section 4.1.2.4.1. The annual steer LWG predicted by GRASP for any period during which hay feeding occurred was applied to calculate the weaning rate and mortality rates for the period, even though the cows were being fed.

This management approach was based on the perception of some managers that unfavourable cattle prices during and after drought result in poor profitability from de-stocking and then re-stocking decisions at those times. Such managers expect that when it becomes apparent that drought is widespread and persistent, prices will slump due to rapidly increasing numbers of cattle being sold that are generally in poorer condition. These managers expect that when the drought breaks the demand for, and price of, cattle will spike. This perception of a very likely and large disparity in prices for restocking compared with destocking leads many to hold onto a core herd. They expect that holding onto a core herd will allow a quicker recovery once the drought breaks, allowing them to recommence production without having to potentially buy large numbers back in at high prices.

In this section, the Retain core breeders scenario (2b) was compared to a scenario (2a – Retain herd structure) which involved retaining the herd structure rather than the core breeders, during drought. In scenarios 2a and 2b the same underlying GRASP AE were applied when setting herd numbers in Dynamaplus but different herd management strategies were used in relation to selling down the herd in drought. Both Scenario 2a and 2b started from same opening herd structure, capital invested and overheads, allowing the direct comparison of the economic outputs of the Dynamaplus model.

- For Scenario 2a – Retain herd structure, the model started with the optimal herd structure identified for the base, steady-state herd with total numbers that matched the available carrying capacity in the first year of the modelled sequence. During a drought a mix of cattle were sold to maintain the same 'business as usual' breeder herd structure, only with lower numbers of females in each class. Steers were sold at their normal target age.
- For Scenario 2b – Retain core breeders, the model also started with the optimal herd structure identified for the base, steady-state herd with total numbers that matched the available carrying capacity in the first year of the modelled sequence. During a drought steers were sold before reducing the breeding herd size to achieve the desired grazing pressure.

4.1.2.2.3 Scenario 3 – Drought responsive stocking

For Scenario 3 - Drought responsive stocking, the approach was intended to mimic a drought responsive manager making annual changes in cattle numbers to match forage TSDM available on the 1 May using the safe utilisation rates (defined in Table 40) with the limitations:

a) annual changes in cattle numbers were limited to 30% increases and 60% decreases, and

b) over the 36 years changes in animal numbers were limited to a 100% increase and a 75% decrease from the initial stocking rate.

An AgForce producer survey indicated that the majority of properties retained 25% of their pre-drought stock numbers (AgForce 2015) and hence this proportion was used as the 'floor' for stock numbers in this scenario, rather than fully destocking. The intention of this scenario was to reflect what many producers and pasture scientists believe is the optimal way to manage grazing pressure in a highly variable climate. Previous modelling has demonstrated that a flexible approach to cattle numbers preserved land condition, but large swings in stock numbers exposed the business to price risk (e.g. Whish *et al.* 2013).

The Dynamaplus model was set to reduce herd numbers through additional sales of females to meet the AE targets identified by GRASP modelling and there was no minimum number of breeders kept. As analysis for Scenario 2 showed no real economic difference between selling down steers or females first when reducing numbers (see Section 4.1.3), an automated approach of reducing of the female herd first was applied (i.e. steers sales were not brought forward but were sold at the usual time). The supplementation and hay feeding strategy applied was according to the rules identified in Section 4.1.2.4.1.

A number of sub-scenarios were considered:

- Scenario 3a – Drought responsive with natural increase. In this scenario, the herd was rebuilt after drought only through retention of breeders and heifers. The model culled minimal cows after mating to rebuild the herd as quickly as possible. As herd reduction at the start of the period prevents the available grazing capacity over time being fully utilised if the herd was rebuilt only through natural increase, four other sub-scenarios were examined as alternative ways to utilise the forage during the herd rebuilding period and to assist the profitability of the property.
- Scenario 3b – Drought responsive with pregnancy tested in-calf (PTIC) cow purchase. Following herd reduction and the end of the drought, the herd was rebuilt more rapidly through the annual purchase of sufficient PTIC cows to match the spare AE in the Dynamaplus model with those estimated as available by GRASP. These cows produced 90% calves in the year purchased. Replacement cows were valued at $750/head (based on average gross sale price of cull cows of $691 plus transport and induction costs).
- Scenario 3c – Drought responsive with repurchasing the herd. Following herd reduction and the end of the drought, the supply of TSDM was matched each year by purchasing steers and heifers as well as PTIC cows to achieve the optimal herd structure previously identified. Prices paid for purchased stock were equivalent to the long-term sale price for the class of stock being purchased plus approximately $30-$50/head transport and handling costs, depending upon the class of stock purchased.
- Scenario 3d - Drought responsive with trading steers. The spare carrying capacity following drought, as indicated by GRASP, was matched by purchased steers as the breeding herd returned to normal size. Yearling steers were purchased at the average 18 month-old steer liveweight in June of each year expected for the base herd, and at the expected sale price for the same class of yearling steers in the base herd. The purchased steers were sold 12 months later at the selling price, selling costs and estimated weight of the same cohort of steers in the base herd.
- Scenario 3e – Drought responsive with agistment income. In this scenario, sufficient cattle were taken on agistment following drought to match any spare carrying capacity as indicated by GRASP. Agistment income was set at $2/AE/week.

4.1.2.2.4 Scenario 4 - Fully flexible stocking

The approach in Scenario 4 – Full flexible stocking, was to match animal numbers annually to the TSDM on 1 May, according the long-term, safe pasture utilisation rates, and with no limitations to changes in animal numbers. This scenario was the opposite in herd management to the Set stocking rate scenario considered first in this analysis, although it still applied the limit of a long-term, safe utilisation rate (Table 40) when numbers were calculated on the 1 May each year.

This strategy aimed to de-stock cattle in response to declining feed during drought, and to re-stock once feed had grown, taking advantage of the available forage. Destocking was achieved through sales and there was no minimum number of breeders kept. As analysis for Scenario 2 showed no real economic difference between selling down steers or females first when reducing numbers (see Section 4.1.3), an automated approach of reducing of the female herd first was applied (i.e. steers sales were not brought forward but were sold at the usual time). The supplementation and hay feeing strategy applied was according to the rules identified in Section 4.1.2.4.1. In the Breedcow and Dynama modelling, the model was set to reduce herd numbers through sales to meet the AE targets identified by GRASP modelling.

Four sub-scenarios were examined:

- Scenario 4a – Fully flexible with natural increase. In this scenario, the herd was rebuilt after drought only through retention of breeders and heifers. The model culled minimal cows after mating to rebuild the herd as quickly as possible. As herd reduction at the start of the period prevents the available grazing capacity over time being fully utilised if the herd was rebuilt only through natural increase, three other sub-scenarios were examined as alternative ways to utilise the forage during the herd rebuilding period and to assist the profitability of the property.
- Scenario 4b – Fully flexible stocking with repurchasing the herd. Following herd reduction and the end of the drought, the supply of TSDM was matched each year by purchasing steers and heifers as well as PTIC cows to achieve the total AE on the property identified by GRASP. Prices paid for purchased stock were equivalent to the long-term sale price for the class of stock purchased with approximately \$30-\$50/head transport and handling costs added depending upon the class of stock purchased.
- Scenario 4c – Fully flexible with trading steers. The spare carrying capacity following drought, as indicated by GRASP, was matched by purchased steers. Yearling steers were purchased at the average 18-month old steer liveweight in June of each year for the base herd, and at the expected sale price for the same class of yearling steers in the base herd. They were sold 12 months later at the selling price, selling costs and estimated weight of the same cohort of steers in the base herd.
- Scenario 4d – Fully flexible with agistment income. In this scenario any spare carrying capacity following drought, as indicated by GRASP, was matched by taking cattle on agistment while the breeder herd is rebuilt. Agistment income of \$2/AE.week was received.

For each sub-scenario the same alternative rebuilding strategies were applied as previously but in a more fully flexible manner.

4.1.2.3 GRASP modelling structure and assumptions

For the scenarios detailed above, all simulations in GRASP were conducted over 36 years (1982-2017) with a 400-day lead-in time to stabilise the model. The Longreach daily climate files were used to simulate pasture and animal production in the paddocks and land types identified in Table 5. All paddocks started the simulation period in B land condition (ca. 70% perennial grasses) and any changes in pasture (% perennial grasses) and land condition were an output of the modelling. In each year of simulations, the starting animal class and weight was set to match the initial animal class defined for each paddock according to the optimisation of the steady-state herd model in Breedcowplus (Table 41).

Each year in the simulation period, the pasture utilisation rate of TSDM at the end of the growing season (1 May) specified for each land type (see Table 40) determined the number of AE for the following 12-month period. Each strategy varied in the degree to which the numbers of AE were able to be altered to match available forage supply. The Set stocking rate strategy was simulated over 36 years (1982-2017) using a stocking rate which ensured that the average pasture condition (% perennial grasses) and land condition rating (scale A-D) over that period approximated the initial condition (ca. 70% perennial grasses and B condition), i.e. taken to indicate no change in pasture condition. This 'set stocking rate' was used as the initial stocking rate for all four grazing management strategies, i.e. all strategies started with the same stocking rate in Year 1 of the simulations. The difference between the scenarios related to:

a) the allowed annual changes in cattle numbers to match pasture TSDM available on the 1 May each year, and

b) the allowed percentage change in cattle numbers from the initial (Year 1) stocking rate over the entire 36-year simulation period.

Stocking rate flexibility and pasture condition subroutines were used. The GRASP model parameters were primarily those of Scanlan and McIvor (2010) with modifications including:

- Use of the Barkly Mitchell grass degradation and recovery parameters recommended by Walsh and Cowley (2016) of 0.6 for the increase in pasture state at zero utilisation and 0.5 for the annual rate of deterioration in state at 100% utilisation; and
- Adjustment of predicted cattle annual LWG for all land types (other than Open alluvia) to provide reasonable agreement with expected LWG.

There was no feedback to GRASP for changes in grazing pressure or individual animal LWG resulting from:

- different allocations of animals to paddocks as a result of changing herd structures in scenarios over time,
- changes in animal numbers over time due to scenario-specific management rules applied in Breedcow,
- feeding supplements which result in increased pasture intake (e.g. feeding NPN supplements to cattle grazing dry season pasture) as well as changes to animal performance (4.1.2.4.1),
- feeding supplements which substitute for pasture biomass in the diet of cattle (e.g. high energy/protein supplements and hay) and also change animal performance (4.1.2.4.1.

Table 41 - Allocation of the steady-state cattle herd to paddocks in GRASP

Paddock	Primary land type	Area (ha)	Total AE /paddock	Livestock class	Starting liveweight of class at 1 May (kg)
1	Boree wooded downs	810	35.63	heifers 18-30 months	330
2	Open alluvia	810	30.54	heifers 18-30 months	330
3	Open downs	2,835	187.07	breeders	390
4	Open downs	2,835	187.07	breeders	390
5	Open downs	2,025	133.62	breeders	390
6	Open downs	1,820	120.09	breeders	390
7a	Soft gidgee, cleared of timber[A]	1,134	149.65	steers 6-18 months	200
7b	Soft gidgee[B]	486		steers 6-18 months	200
8	Wooded downs	1,215	80.17	steers >18 months	350
9	Wooded downs	1,215	80.17	heifers 6-18 months	190
10	Wooded downs	1,015	66.98	heifers 18-30 months	330
Total		*16,200*	*1,071.00*		

[A]Tree basal area (TBA) of 1; sown to buffel grass.

[B]TBA of 5; not considered to make a significant contribution to carrying capacity in its present state.

4.1.2.4 Breedcow and Dynama modelling assumptions

GRASP steer annual LWG data was inputted to the Breedcow and Dynama model as described in Section 4.1.2.1. Data from the last 30 years of each 36-year GRASP modelling run were inputted to Dynama, i.e. from 1987-2017. However, the steers sold in the first year of the 30-year economic analysis took their weaner weight and weight gains from data for the years immediately prior to the start of the 30-year run. The number of years prior to the sale year accessed to calculate steer sale weight varied with the sale age chosen for steers which was held constant at 30 months of age for each scenario in this analysis. Additionally, the livestock mortality rates in the first year of analysis reflected the performance in the first year (1987) and the previous year (1986).

Table 42 indicates the apportionment of AE for the expected structure of the starting base cattle herd. About 60% of the grazing pressure was applied by the breeders 3 years plus in age, calves to 5 months of age and herd bulls; about 20% by the replacement and first mated heifers with the final 20% applied by steers post weaning up until sale. The herd structure (proportions in each class) shown in Table 42 was applied as the opening herd structure in Year 1 of each modelled management strategy.

Table 42 - Classes of stock in the base beef cattle herd and their proportions

Class of cattle	Number kept for entire year	Number Sold	Proportion of total grazing pressure
Weaners 5 months	406	0	<1%
Heifers 1 year but less than 2	135	63	9%
Heifers 2 years but less than 3	115	17	11%
Cows 3 years plus	330	96	59%
Steers 1 year but less than 2	199	0	12%
Steers 2 years but less than 3	0	195	9%
Bulls all ages	14	1	<1%
Total number	*1,199*	*372*	*100%*

Table 43 shows the allocation of the various classes of stock to the paddocks on the property. The breeders accessed paddocks 3, 4, 5 and 6. The steers grazed paddocks 7a, 7b and 8 while paddocks 1, 2, 9 and 10 were used by the yearling and replacement heifer age groups. The paddock allocations were maintained in each modelled scenario.

Table 43 - Allocation of the cattle herd to paddocks

Paddock	Area (ha)	Total AE /paddock	Ha /AE	Class of cattle
1	810	35.63	22.7	heifers
2	810	30.54	26.5	heifers
3	2,835	187.07	15.2	breeders
4	2,835	187.07	15.2	breeders
5	2,025	133.62	15.2	breeders
6	1,820	120.09	15.2	breeders
7a	1,134	149.65	7.6	steers
7b	486	-	-	steers
8	1,215	80.17	15.2	steers
9	1,215	80.17	15.2	heifers
10	1,015	66.98	15.2	heifers
Overall	*16,200*	*1,071.00*	*15.1*	

The self-replacing *B. indicus* crossbred breeding herd grazed the Open downs land types. Replacement heifers were separated from the breeding herd until they were first mated at about 2 years of age and grazed a mixture of Wooded downs, Boree and open alluvia land types. Steers mostly grazed Soft Gidyea and wooded downs land types until sold at 30 months of age.

4.1.2.4.1 Supplement and drought feeding rules applied

In each year, supplementary feeding rules that responded to the variation in GRASP output were applied in all modelled scenarios. Decisions about when and how long to feed supplements, which type of supplement to feed and to which classes of animals were determined with reference to published literature (e.g., Winks 1984; Dixon 1998) and input from M. Sullivan and R. Dixon who have extensive knowledge of supplementation responses across northern Australia. Three stages of feeding were applied depending on severity of nutritional deficits for cattle:

1) Stage 1 – supplementary NPN

- This type of supplementary feeding was expected to be necessary in ca. 3 years in 10 but the actual frequency of feeding was informed by the GRASP model output.
- This feeding rule was invoked if the estimated annual steer LWG/head predicted by GRASP fell below a threshold of 100 kg/head but was above 50 kg/head.
- Breeders, yearling heifers and female weaners were fed for 120 days (i.e. 4 months; September-December).
- The supplement was a loose lick consisting of 30% urea, 8% ammonium sulphate (GranAm) and 62% salt, cost $636/t landed (excluding GST), and was fed at 156 g/head.day for breeders, 94 g/head.day for yearling heifers and 78 g/head.day for weaners.
- The assumed benefit to the breeder from feeding supplement was 6 kg liveweight/month for each of the 4 months of feeding, i.e. 24 kg liveweight total benefit in that year of feeding. This benefit was applied to the annual steer LWG output from GRASP in that year to determine corresponding benefits in conception rates according to functions outlined Section 4.1.2.1.1.

2) Stage 2 – supplementary NPN and whole cottonseed

- This type of supplementary feeding was expected to be necessary in ca. 2 years in 10 but the actual frequency of feeding was informed by the GRASP model output.
- This feeding rule was invoked if the estimated annual steer LWG/head predicted by GRASP fell below a threshold of 50 kg/head but was above 0 kg/head.
- Breeders, yearling heifers, weaner heifers and weaner steers received:
    - NPN loose lick for 90 days (e.g. June-August) at same intakes rates and cost as above for Stage 1.
    - Then, whole cottonseed and NPN loose lick for 120 days (e.g. September-December). Whole cottonseed cost $550/t landed and was fed at 1,300 g/head.day for breeders, 800 g/head.day for yearling heifers and 600 g/head.day for weaners. Loose lick was consumed at half the rates described above for Stage 1 when fed without whole cottonseed.
- Yearling steers received NPN loose lick for 210 days (June – December) at 94 g/head.day.
- The assumed benefit to the breeder from feeding supplement was 6 kg liveweight/month for each of the 3 months of NPN loose lick feeding and then 8 kg/month liveweight benefit for each of the 4 months of whole cottonseed feeding, i.e. 50 kg liveweight total benefit in that year of feeding. This benefit was applied to the annual steer LWG output from GRASP in that year to determine corresponding benefits in conception rates according to functions outlined Section 4.1.2.1.1.

3) Stage 3 – drought feeding hay

- This feeding rule was invoked in every month for which the GRASP predicted TSDM of pasture to fall below 300 kg DM/ha. This critical biomass was derived with reference to the long-term Toorak grazing trial data (Orr and Phelps 2013) and Phelps (2006).

- All livestock, except yearling steers, on the property were fed hay at a rate of 1.6% of liveweight (dry matter basis) and a cost of $400/t landed.
- The assumed benefit from feeding hay was a halving of mortality rates otherwise predicted for that year.
- It was possible for drought feeding of hay to occur in years that Stage 1 or 2 supplement feeding was undertaken, as the rules are not mutually exclusive.

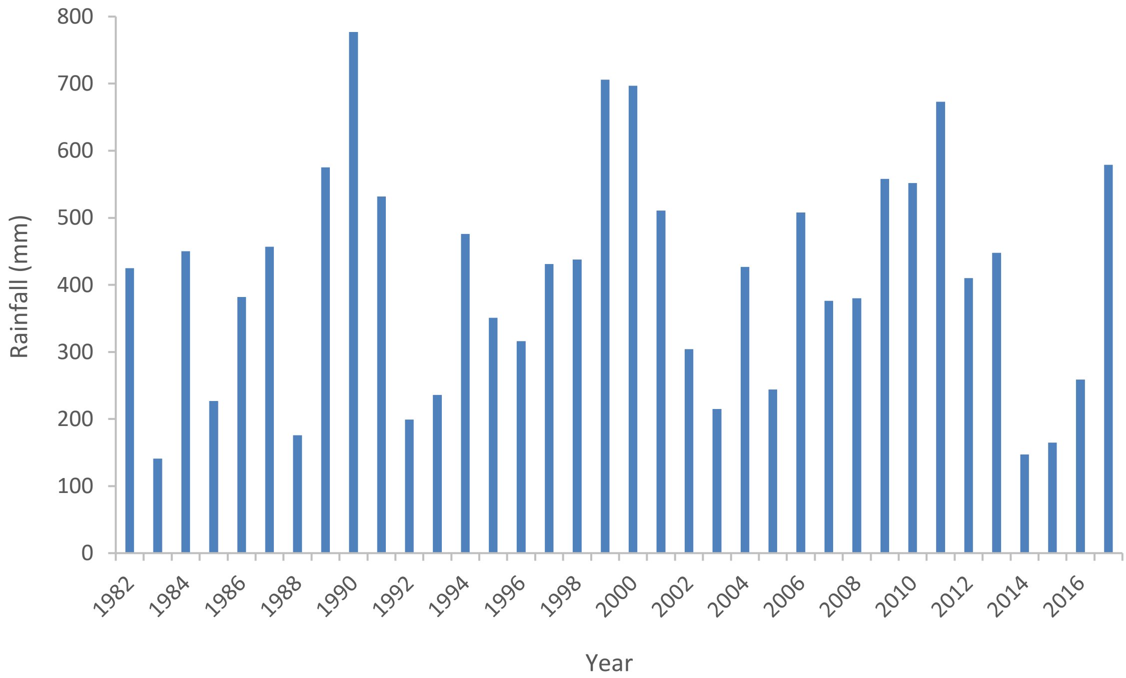
4.1.3 Results and discussion

4.1.3.1 Effect of grazing management strategies on herd productivity and profitability

Herd productivity and profitability results are only presented for the Breedcow and Dynama herd model as the Braithwaite four period calving model resulted in similar output and hence confirmed the lack of any error in the application of the equations of Mayer *et al.* (2012) to integrate GRASP output with the Dynamaplus model.

Median annual rainfall for the representative property near Longreach, averaged over the 36-year GRASP pasture modelling period from 1982-2017, was similar to the median rainfall at Longreach for the 30-year climate normal period (1961-1990): 426 cf. 437 mm (Figure 5 and Table 3). The annual rainfall over the 36 years ranged from 141 mm in 1983 (Year 2) to 777 mm in 1990 (Year 9). It is evident from the rainfall distribution over the 30-year herd modelling period (1988-2017) that there were four significant periods of potential de-stocking followed by re-stocking during this time, dependent on the modelling assumptions for each grazing management strategy.

Figure 5 – Annual rainfall for the representative property near Longreach over the 36-year period 1982-2017



The options analysed did not include sending the herd away on agistment instead of selling down the herd. Agisting the herd is likely to be a very good idea if the drought is relatively short, and the agistment reliable and reasonably priced. It is also easy to identify the risks associated with the agistment. It often runs out just as prices crash and sometimes not all of the cattle are discoverable when being mustered. Agisting components of the herd is a strategy that can be considered early in drought and analyses compiled for other regions suggest it is worthy of close consideration if the criteria of reasonable cost and reliability can be met. In this analysis, however, we have focussed on the sale of livestock as the strategy to adjust grazing pressure.

4.1.3.1.1 Scenario 1 – Set stocking rate strategy

Figure 6 indicates the 12-month total pasture growth per hectare (dry matter basis) and TSDM on 1 May, estimated by GRASP for the years 1987 to 2017 for the Open downs land type in B land condition near Longreach under the Set stocking rate strategy. The annual pasture growth ranged from 47-4,642 kg DM/ha while TSDM at 1 May ranged from 125-6,120 kg DM/ha over the same period (Table 44).

Figure 6 - GRASP estimate of 12-month total pasture growth per hectare (kg DM/ha) and total standing dry matter (TSDM; kg DM/ha) on 1 May for Paddock 3 with Open downs land type near Longreach over the 31-year period 1987-2017 under the Set stocking rate strategy

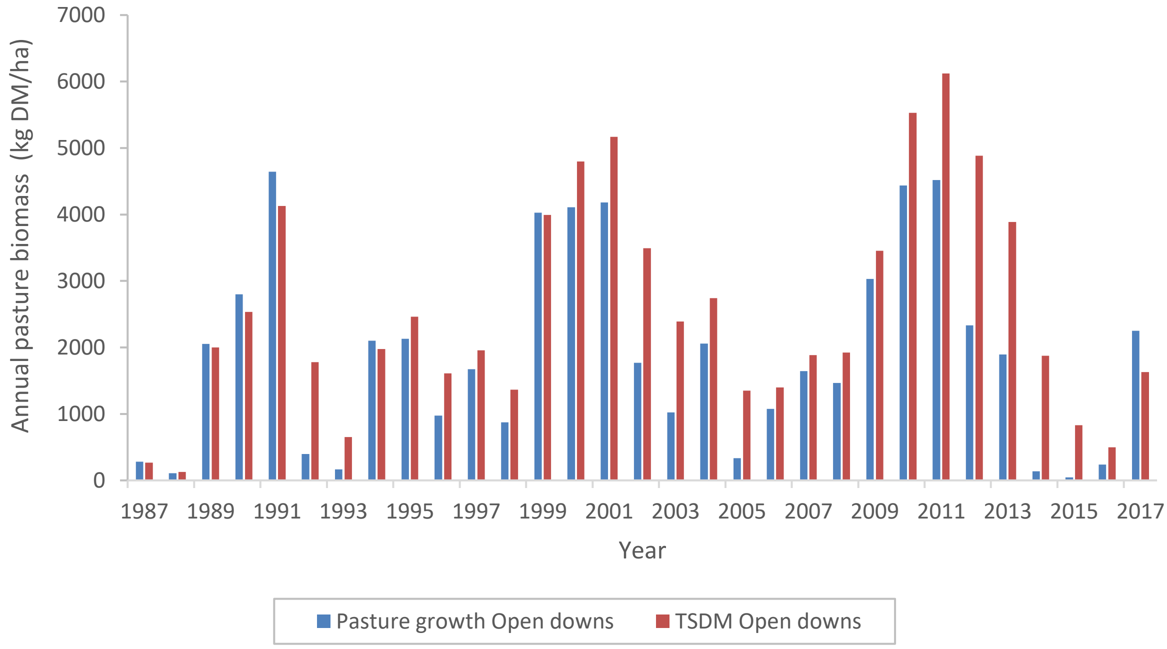


Table 44 - Annual statistics for 12-month total pasture growth per hectare (kg DM/ha) and total standing dry matter (TSDM; kg/ha) on 1 May for Paddock 3 with Open downs land type near Longreach over the 31-year period 1987-2017 under the Set stocking rate strategy

Factor	Average	Median	Minimum	Maximum
Pasture growth	1,896	1,768	47	4,642
TSDM	2,539	1,975	125	6,120

Figure 7 shows the total AE calculated by GRASP for the property for each year of the Set stocking rate simulation. The method applied to calculate the AE in GRASP combines the weight gain per head, the number of steers, and the 'intake weight' for each paddock applied in the GRASP simulation (Section 4.1.1.1). As the total number of cattle was held constant over the 30 years for this scenario, the variation in total AE per annum on the property reflected those years when steers were modelled to grow faster or slower than the average assumed in the steady-state herd model (Section 3.2.1.2).

Figure 7 - Annual property adult equivalents (AE) predicted by GRASP for the Set stocking rate strategy over 31 years (1987-2017)

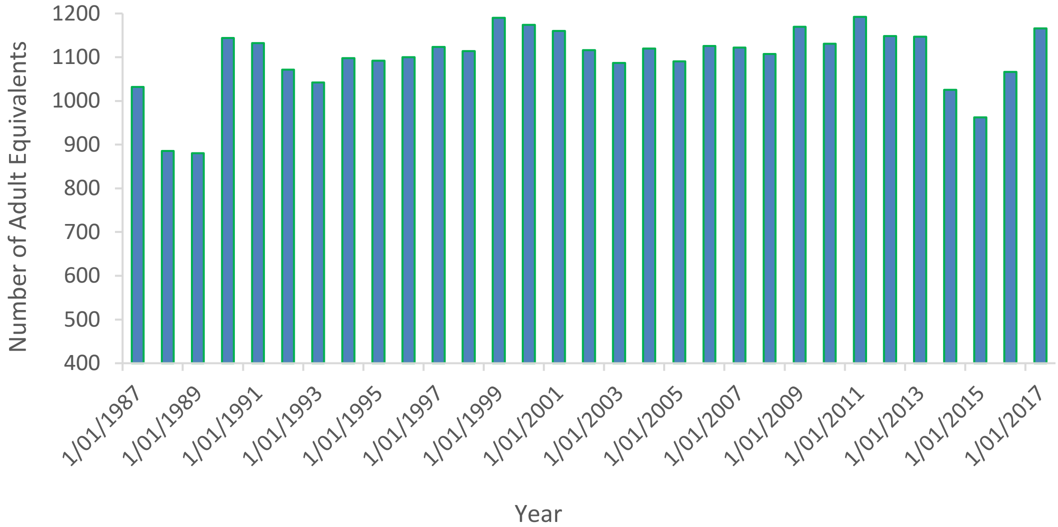


Table 45 shows that the grazing strategy applied in the Set stocking rate scenario varied the total AE calculated by GRASP by about 18% below, and less than 11% above, the target grazing pressure (1071 AE; Table 43), mainly due to the variation in predicted steer weight gain.

Table 45 - Annual statistics for GRASP adult equivalent (AE) outcomes for the Set stocking rate strategy over 31 years (1987-2017)

Factor	Average	Median	Minimum	Maximum
Total property AE	1,097	1,116	880	1,192

Figure 8 compares the AE calculated with GRASP output and those calculated for each year by the Dynamaplus herd model when the opening herd structure was applied in the first year and then allowed to respond to the annual variation in herd performance predicted by the combination of Mayer *et al.* (2012) functions and GRASP output. The Dynamaplus AE at the beginning of the 30-year period are greatly affected by two years of negative steer weight gains in Years 1 and 2. The Set stocking rate herd in GRASP required ca. 8 years to rebuild herd numbers to the target in GRASP with natural increase in herd numbers.

The discrepancies between the number of AE predicted on the property by GRASP and the number of AE calculated as being on the property in Dynamaplus are related to years with low weaning rates, low weight gains and high mortality rates causing stock numbers and weight gains to be lower than expected in the steady-state herd model (Section 3.2.1.2). After the decrease in livestock numbers due to poor herd productivity the herd could only rebuild numbers slowly through natural increase to return to the target set stocking rate for the strategy.

The Dynamaplus model adjusts numbers to meet herd size targets by holding empty cows in years with poor conception or selling additional females when conception rates are higher. AE totals can fall over consecutive years in Dynamaplus when the impact of a year or years with a low weaning rate and or high mortality rate flows through the steer and heifer numbers. The impacts of this are demonstrated clearly in the late 1980s and early 1990s where no additional livestock are purchased to make up the deficit in numbers caused by the drought conditions encountered early in the modelling period. Note that there is no feedback to GRASP for the reduced herd and AE numbers predicted from Dynamaplus and hence the pasture yields and pasture condition reflect the GRASP AE rather than those predicted in the Dynamaplus herd model.

Figure 8 - Comparison of Dynamaplus adult equivalents (AE) and GRASP AE for the Set stocking rate scenario

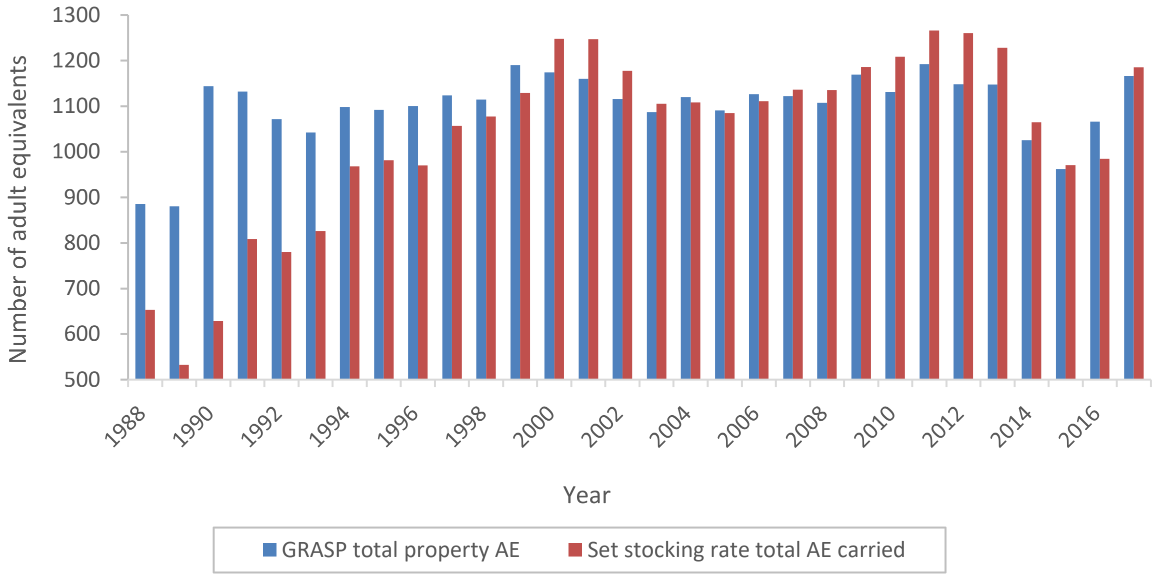


Figure 9 and Table 46 indicate the range of values for number of mortalities per annum calculated in the Dynamaplus model for the Set stocking rate strategy. The peak in 1988 is due to a weight loss in the final 6 months of 1987 followed by a weight loss in the final 6 months of 1988. Mortalities are calculated in the Dynamaplus model by adjusting the opening numbers for sales, purchases and spays and then applying mortalities. The average mortality is lower than the expected value applied the steady-state herd model in Section 3.2.1.2 (35 deaths/annum). The same rule for calculating mortality rates were applied in all scenarios so they are comparable in a relative sense, although they appear likely to be lower, on average, than that predicted by industry and as applied in the steady-state herd model.

Figure 9 - Total annual herd mortalities predicted by the Dynamaplus model for the Set stocking rate scenario

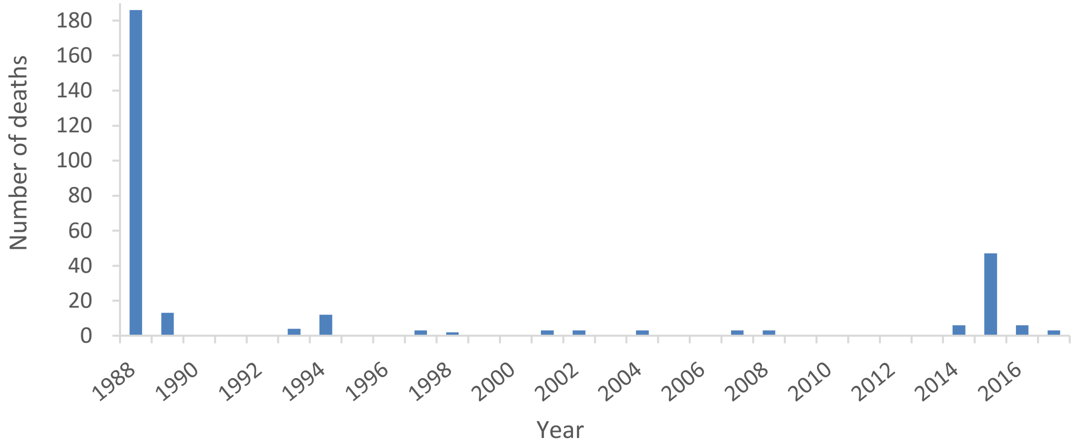


Table 46 – Annual statistics for the number of mortalities predicted by the Dynamaplus model for the Set stocking rate strategy

Factor	Average	Median	Minimum	Maximum
Number of mortalities/annum	10	1	0	186

Figure 10 shows the annual variation in the weaning rate for the Set stocking rate strategy, expressed as weaners produced per 100 cows mated.

Figure 10 - Annual weaners produced per 100 cows mated for the Set stocking rate strategy

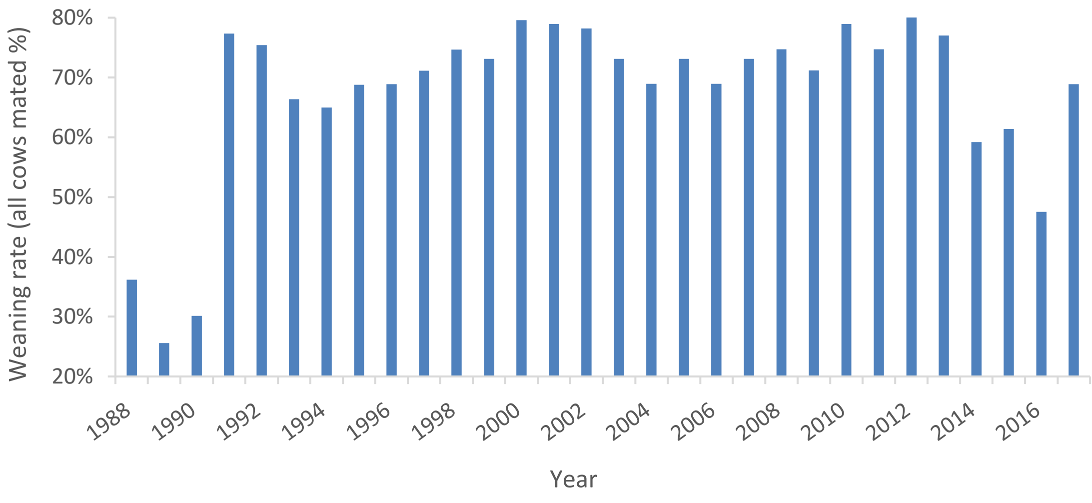


Figure 11 and Table 47 indicate the range of values for the number of weaners produced per annum by the Set stocking herd modelled using GRASP data and Mayer *et al.* (2012) functions. The average value for the steady-state herd model was 404 weaners/annum while the average and median number of weaners for the integrated model were 382 and 408 weaners/annum, respectively.

Figure 11 - Number of weaners produced per annum by the Set stocking rate herd modelled using GRASP data and Mayer et al. (2012) functions

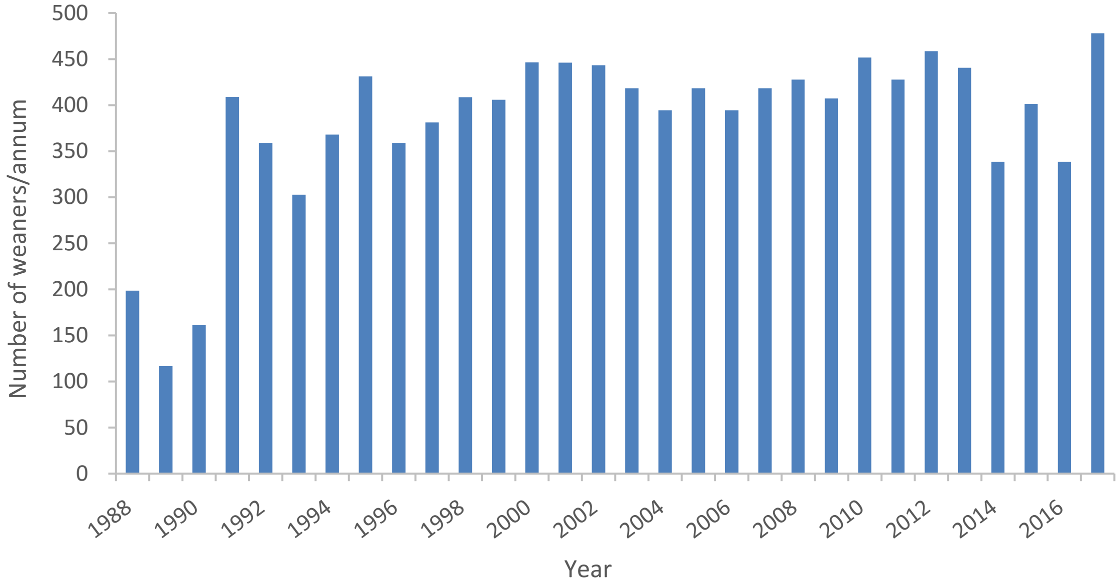


Table 47 – Annual statistics for the number of weaners produced per annum predicted by the Dynamaplus model for the Set stocking rate strategy

Factor	Average	Median	Minimum	Maximum
Number of weaners/annum	382	408	117	478

Figure 12 shows the annual steer growth rates predicted by GRASP from birth to 36 months of age. The growth path applied in Breedcow for the steady-state, base herd is also shown. Steers weaned in 2015 and 2016 did not yet have sufficient data to be able to model their growth to 36 months of age. The steer growth path with the lowest trajectory was for the steers sold in 1988. Their growth was impacted by drought years that occurred just prior to the start of the modelled sequence.

Figure 12 – GRASP-predicted steer growth rates for the Set stocking rate herd to 36 months of age and the expected steer growth rates used for the modelling of the steady-state base herd in Breedcow over 1988-2016

Each GRASP-predicted steer growth path relates to steers weaned in the year specified in the legend

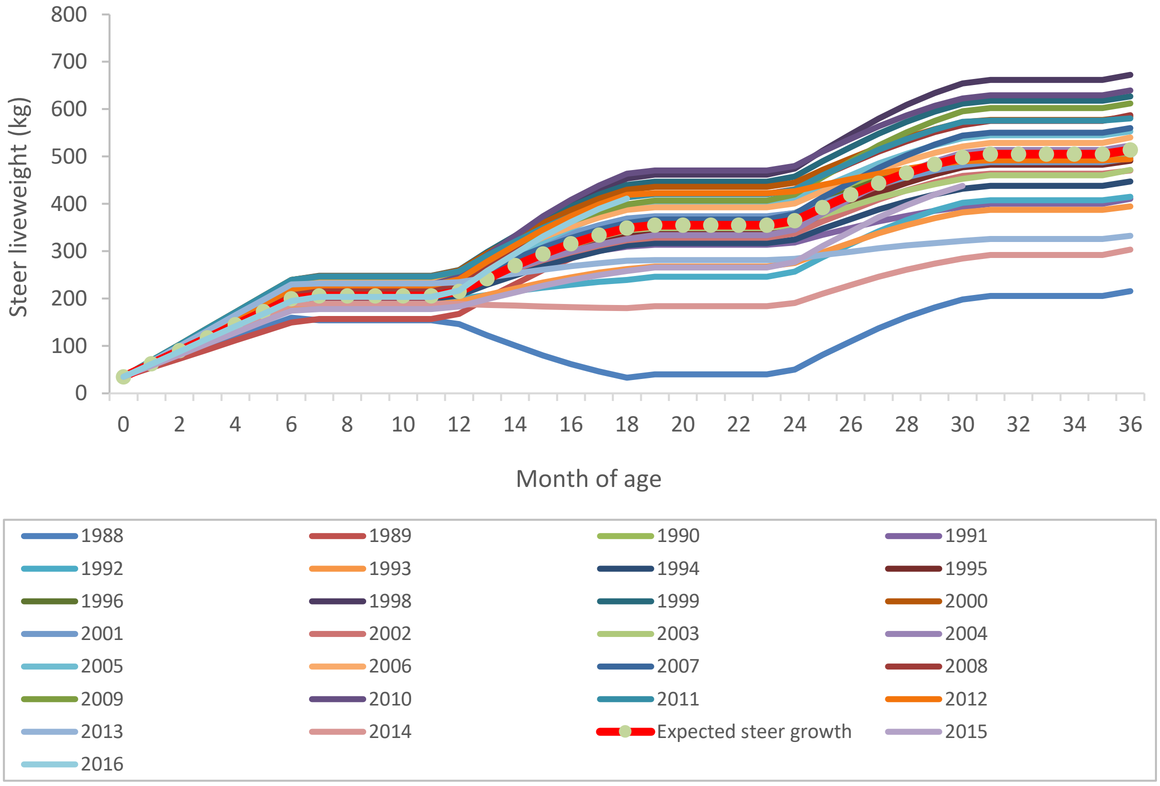


Figure 13 shows the annual sale weights applied in the integrated Dynamaplus herd model. The modelled sale weights for steers and heifers were derived by summing the GRASP-predicted paddock weight gains over time. The LWG of steers, heifers and cows grazed in different paddocks reflected the relative differences in steer LWG predicted by GRASP for each paddock when modelled in Dynamaplus. The overall median mature cull cow sale weight was 450 kg in the paddock. The average and median predicted steer sale weights in the paddock were 469 and 491 kg, respectively, and thus lower than the expected value of the steer sale weight of 499 kg applied in the steady-state, base herd model. Average heifer weights were 321 and 445 kg for the 1 to 2 year old and the 2 to 3 year old heifers, respectively, while median sale weights were 336 and 455 kg respectively. The expected sale weights in the steady-state, base herd model were 333 and 475 kg respectively.

Figure 13 - Mature cow, heifer and steer sale weights predicted for the Set stocking rate herd

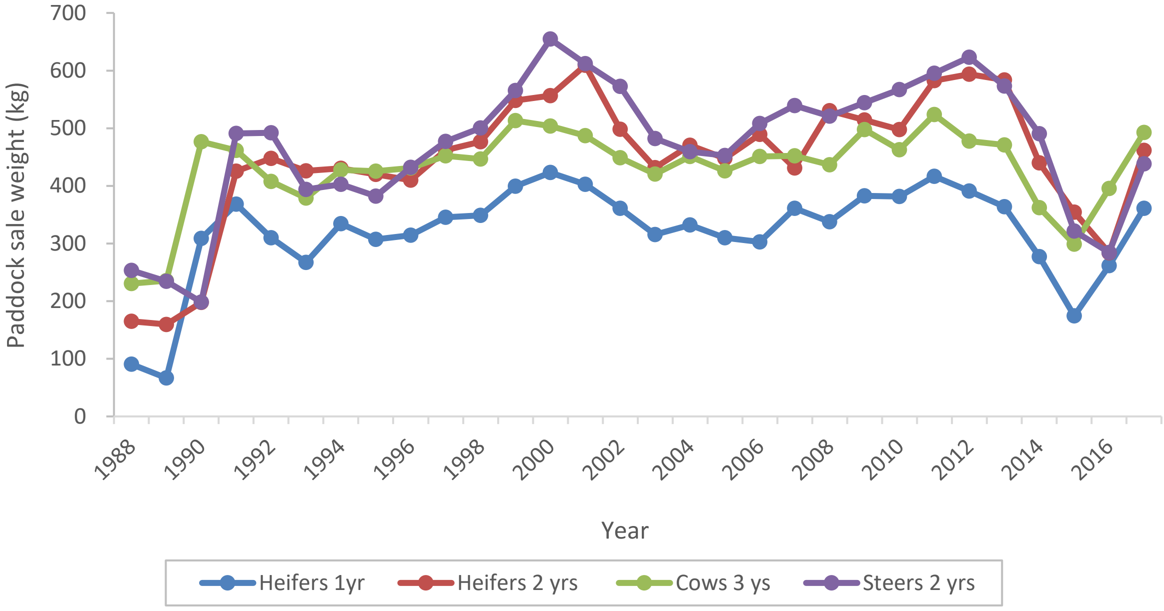


Figure 14 and Figure 15 indicate the predicted frequency and amount of supplement and drought feeding costs for the Set stocking rate strategy.

Figure 14 - Annual supplement feeding costs (Stages 1 and 2) for the Set stocking rate strategy

Stage 1 feeding with supplementary NPN was triggered if annual steer LWG/ha predicted by GRASP was < 100 kg but > 50 kg. Stage 2 feeding with supplementary NPN and whole cottonseed was triggered if annual steer LWG/head predicted by GRASP was < 50 kg but > 0 kg

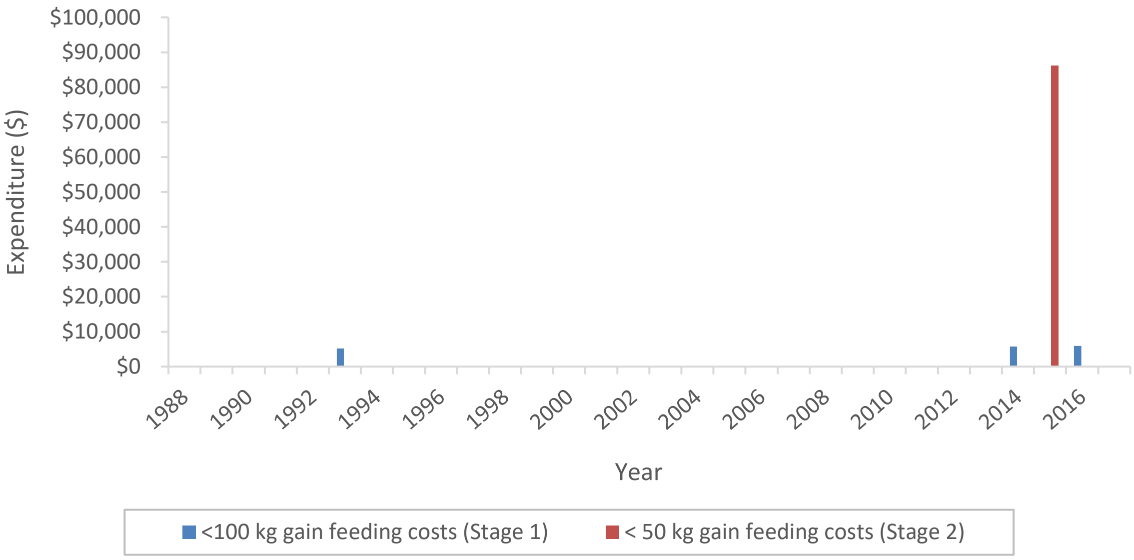


Figure 15 – Annual drought feeding hay costs (Stage 3 feeding) for the Set stocking rate strategy

Stage 3 feeding with hay was triggered for months when GRASP-predicted total standing dry matter (TSDM) of pasture was < 300 kg DM/ha.

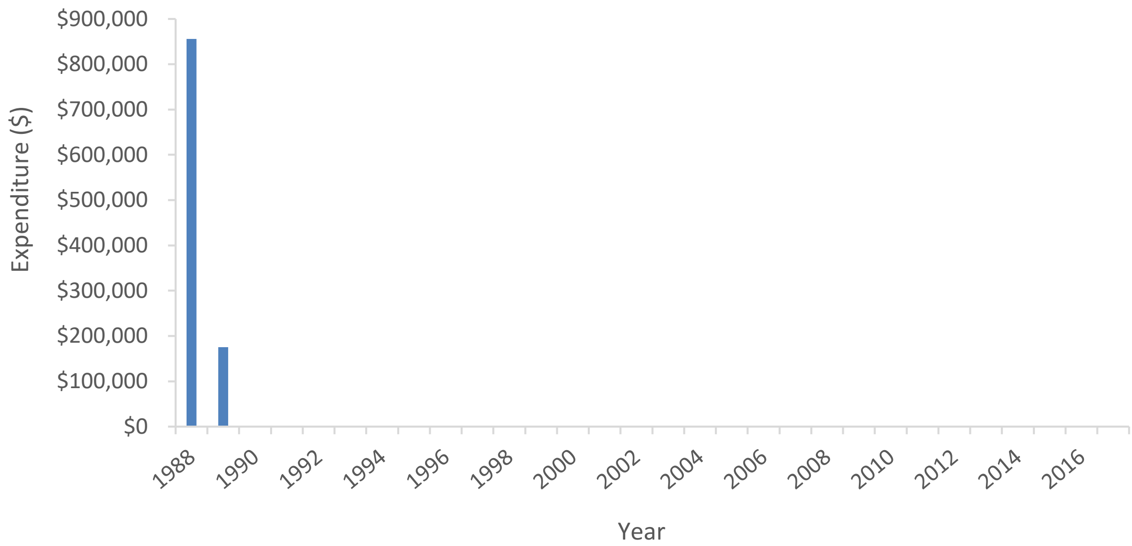


Figure 16 shows the cumulative cash flow generated by the Set stocking rate strategy. The hay feeding expense, high mortality rates, low weaning rates and low growth rates of 1987, 1988 and 1989 prevented the modelled cash flow from ever showing a positive balance. In this region, applying a very conservative stance when it comes to setting a stocking rate, together with an inability to reduce numbers quickly (and hence feeding hay in drought years), produced a very risky outcome.

Figure 16 - Cumulative cash flow over 30 years for the Set stocking rate strategy

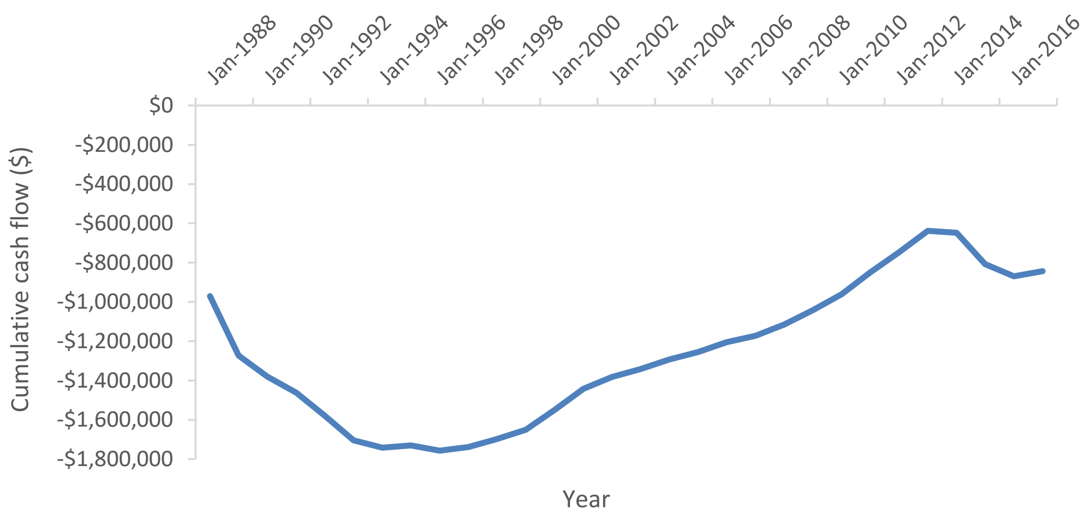


Table 48 indicates the investment returns generated by the Set stocking rate strategy over 30 years. This return can be compared to the steady-state, base beef property. The negative IRR of -0.09% is consistent with the rate of return on total capital of -0.02% determined for the steady-state base beef cattle herd (Section 3.3.1).

Table 48 – Property level investment return, expressed as the internal rate of return (IRR) over 30 years for the Set stocking rate strategy

Grazing management scenario	IRR
Set stocking	-0.09%

4.1.3.1.2 Scenario 2 – Retain core herd strategy

Figure 17 shows the total AE calculated by GRASP for the property for each year of the Retain core herd strategy. The underlying estimate of AE in each year produced by GRASP was the same for each sub-scenario (Scenario 2a - Retain herd structure and Scenario 2b - Retain core breeders) as the same grazing pressure was applied in each case. The herd structures and numbers in the Dynamaplus livestock schedule were sometimes different for Scenario 2a and 2b, depending upon the actions of the manager to reduce numbers.

Figure 17 - Annual property adult equivalents (AE) predicted by GRASP for the Retain core herd strategy over 31 years (1987-2017)

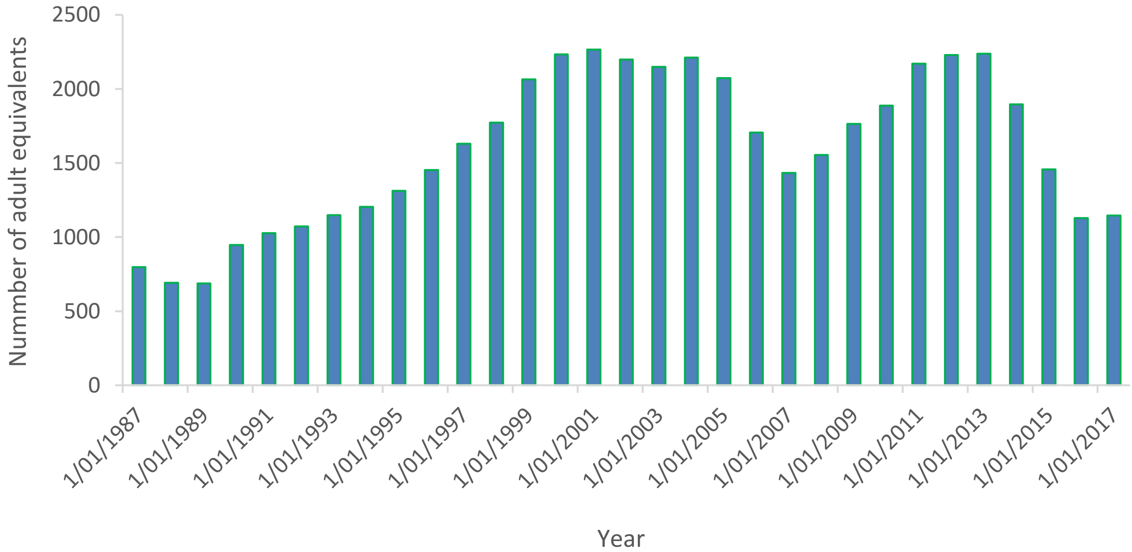


Table 49 indicates that under the Retain core herd strategy the total annual AE in GRASP varied by about 57% below and about 42% more than the average for that strategy. The average GRASP-predicted AE for the Retain core herd strategy was greater than for the Set stocking strategy (1,598 cf. 1,097).

Table 49 - Annual statistics for GRASP adult equivalent (AE) outcomes for the Retain core herd strategy over 31 years (1987-2017)

Factor	Average	Median	Minimum	Maximum
Total property AE	1,598	1,630	688	2,266

Scenario 2a – Retain herd structure

In this scenario, a proportion of the breeder herd were sold down when additional sales had to be made to reduce the stocking rate on the property; steer sales were not bought forward. Additional breeder sales occurred in 1988, 2003 and 2005. Number targets were not set for steer cohorts in the Retain herd structure model, only the percentage sold, so no younger steers were sold when the herd was reduced. This means the strategy maintained steer numbers until they were sold at their normal age and took additional sales from the female portion when the herd size was being reduced. This is different to a strategy that reduces all components of the herd equally, including a portion of the younger steers, when a herd reduction is undertaken.

Figure 18 compares the AE calculated using GRASP output and those calculated each year by the Dynamaplus herd model when the opening herd structure was applied in the first year and then allowed to respond to the annual variation in herd performance predicted by the combination of Mayer *et al.* (2012) functions and GRASP output. Herd targets were reset when necessary so that the AE calculated in Dynamaplus had a reasonable match with the AE calculated with the GRASP output. No additional stock were purchased other than the extra herd bulls required occasionally to meet increased breeder numbers. The combination of lower weaner numbers and higher mortalities due to drought combined to create the lag in grazing pressure observed in some years. The herd started from a low base in 1988 and could not retain sufficient replacement stock to build up numbers quickly enough to eliminate the lag. Part of this is due to the sell down of females early in the period to reset the herd grazing pressure.

Figure 18 - Comparison of Dynamaplus adult equivalents (AE) and GRASP AE for the Retain herd structure scenario

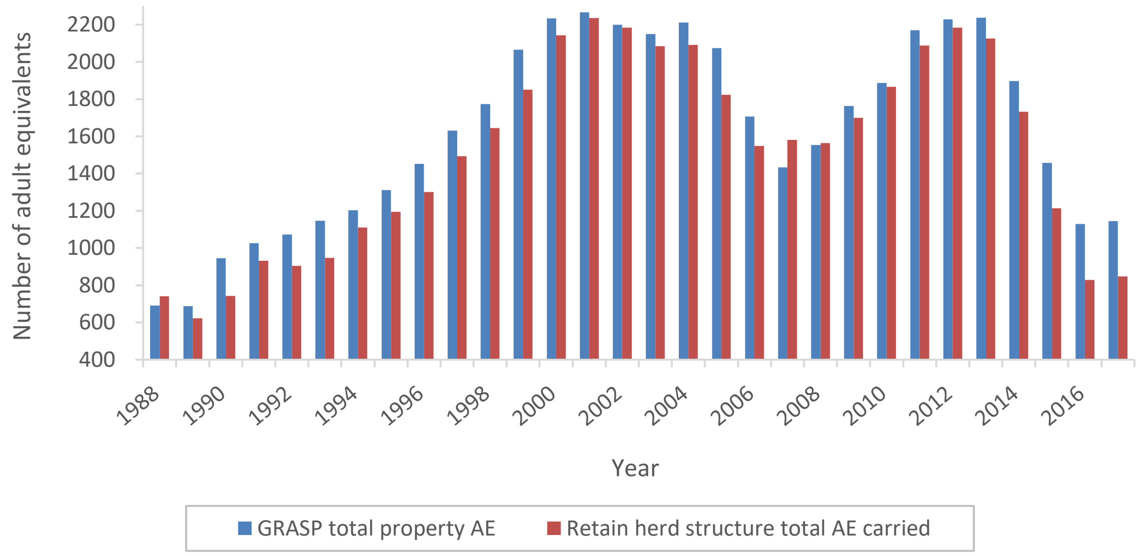


Figure 19 shows the total number of mortalities per annum calculated in the Dynamaplus model for the Retain herd structure scenario (Scenario 2a). The very high mortalities in 2015 occurred despite the feeding of hay as a drought management strategy. The annual mortality statistics for the Steady-state, Set stocking rate herd and the Retain herd structure scenarios are presented in Table 50. The average number of mortalities/annum was greater than for the Set stocking rate strategy (22 cf. 10) but less than that assumed for the steady-state herd (35).

Figure 19 - Total annual herd mortalities predicted by the Dynamaplus model for the Retain herd structure scenario

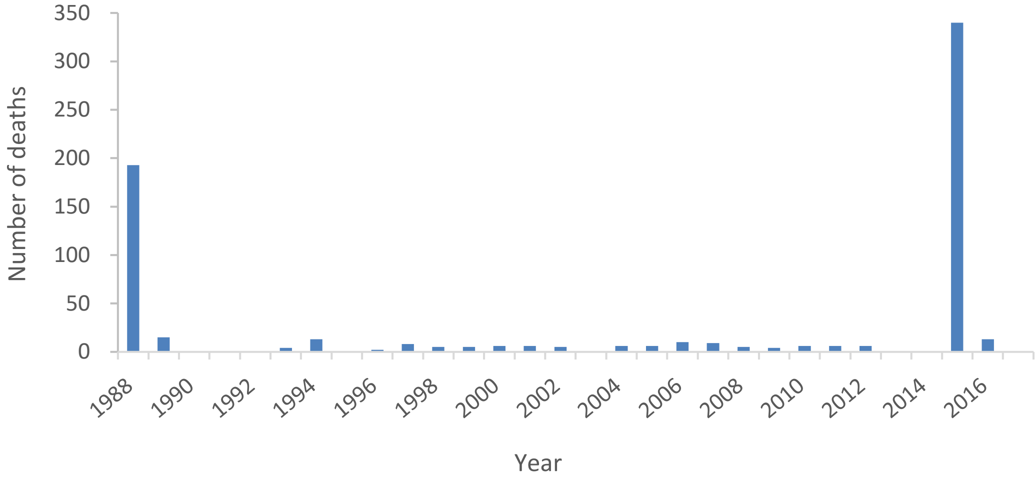


Table 50 – Annual statistics for the number of mortalities predicted by the Dynamaplus model for the Retain herd structure scenario and, for comparison, the Set stocking rate scenario and the steady-state herd

Grazing management scenario	Average	Median	Minimum	Maximum
Steady-state herd	35	35	35	35
Set stocking rate	10	1	0	186
Retain core herd				
Retain herd structure	22	6	0	340

Figure 20 and Table 51 indicate the range of values for the number of weaners produced per annum by the Retain herd structure scenario with Table 51 also providing comparison with the previous scenarios. On average, the Retain herd structure scenario produced more weaners than the Set stocking rate strategy and the steady-state herd.

Figure 20 - Number of weaners produced per annum by the Retain herd structure scenario

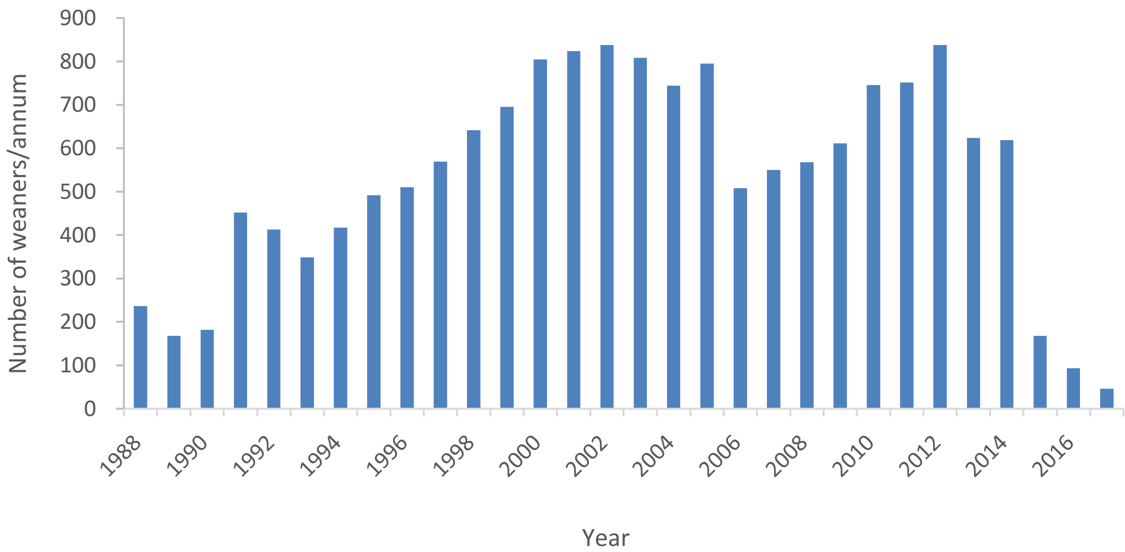


Table 51 – Annual statistics for the number of weaners produced per annum for the Retain herd structure scenario and, for comparison, the Set stocking rate scenario and the steady-state herd

Grazing management scenario	Average	Median	Minimum	Maximum
Steady-state herd	404	404	404	404
Set stocking rate	382	408	117	478
Retain core herd				
Retain herd structure	521	559	46	933

Table 52 indicates the range of values for the paddock sale weight of steers while Figure 21 compares the number of stock sold by the Retain herd structure scenario and the Set stocking strategy. Although more steers were produced by the Retain herd structure scenario, they were lighter on average than for the Set stocking rate strategy and the steady-state herd.

Table 52 - Statistics for the paddock sale weights of steers (kg) for the Retain herd structure scenario and, for comparison, the Set stocking rate scenario and the steady-state herd

Grazing management scenario	Average	Median	Minimum	Maximum
Steady-state herd	499	499	499	499
Set stocking rate	469	491	198	654
Retain core herd				
Retain herd structure	448	462	207	650

Figure 21 - Total number of sales for the Retain herd structure scenario and the Set stocking rate strategy

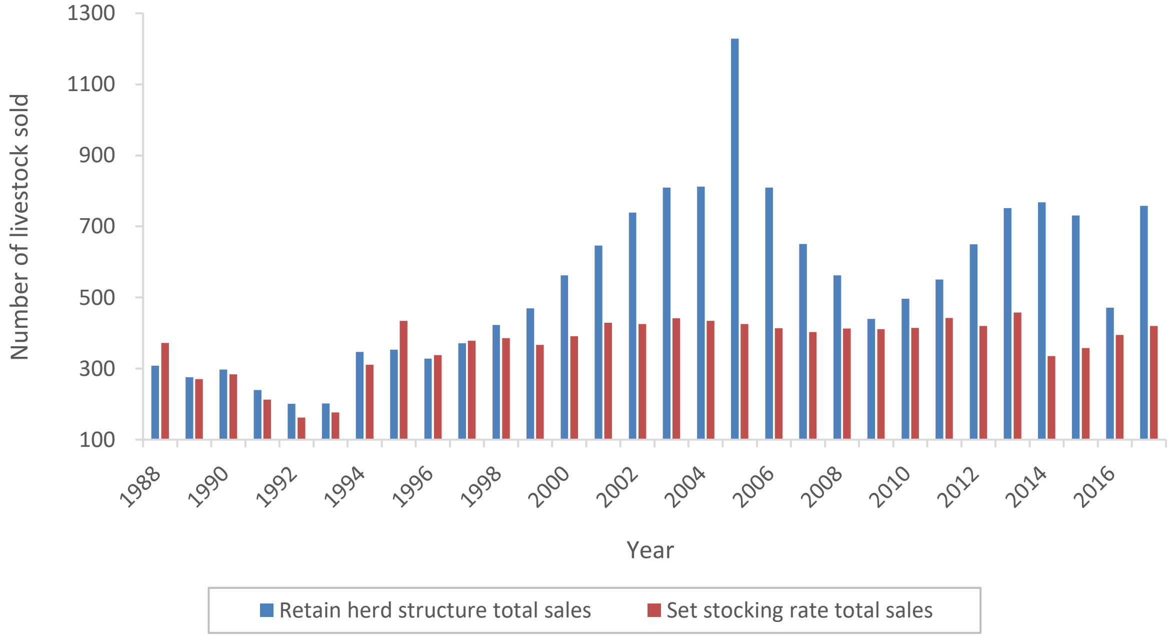


Figure 22 and Figure 23 indicate the predicted frequency and amount of supplement and drought feeding costs for the Retain herd structure scenario.

Figure 22 – Annual supplement feeding costs (Stages 1 and 2) for the Retain herd structure scenario

Stage 1 feeding with supplementary NPN was triggered if annual steer LWG/ha predicted by GRASP was < 100 kg but > 50 kg. Stage 2 feeding with supplementary NPN and whole cottonseed was triggered if annual steer LWG/head predicted by GRASP was < 50 kg but > 0 kg

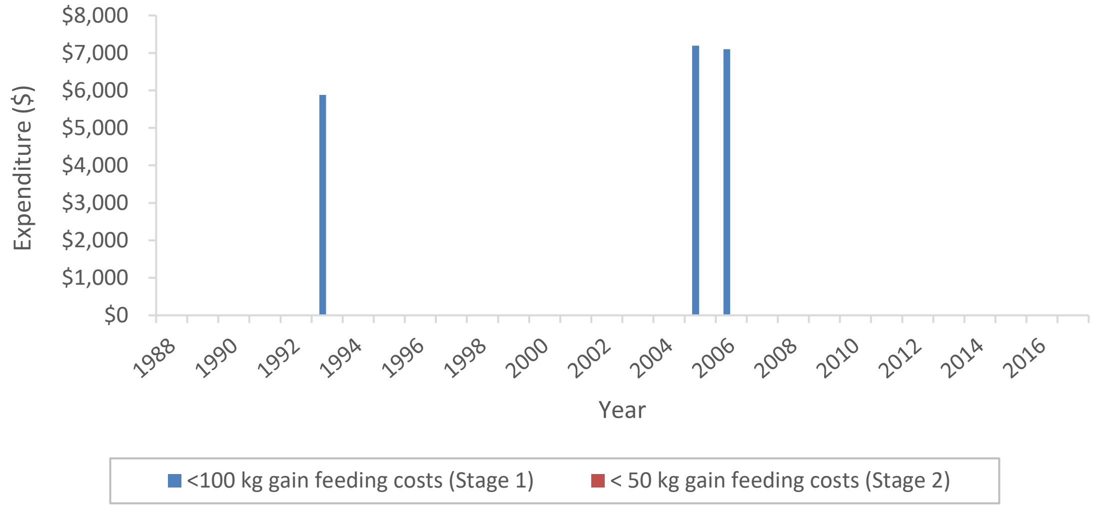


Figure 23 – Annual drought feeding hay costs (Stage 3 feeding) for the Retain herd structure scenario

Stage 3 feeding with hay was triggered for months when GRASP-predicted total standing dry matter (TSDM) of pasture was < 300 kg DM/ha

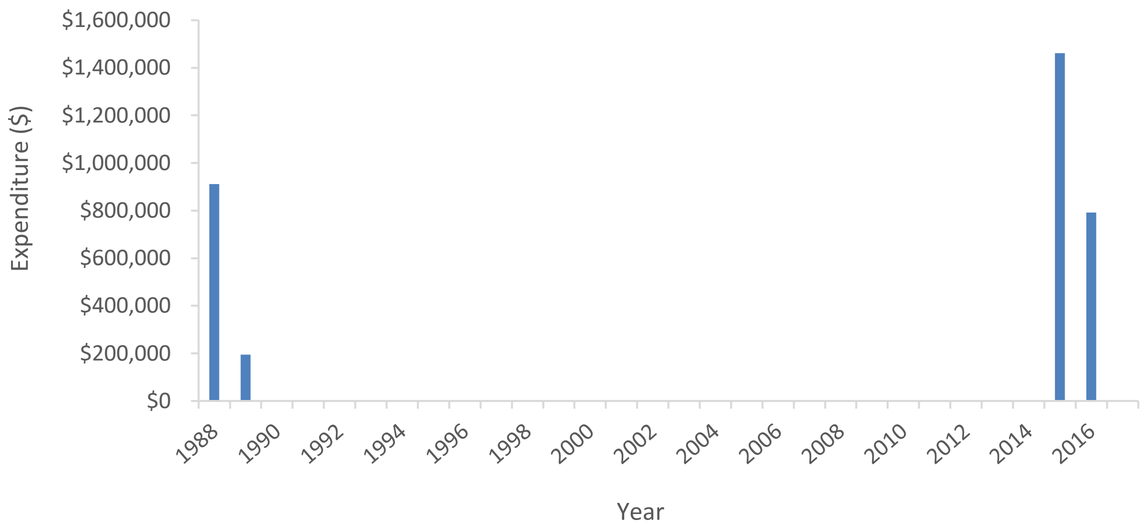


Figure 24 shows the cumulative cash flow generated by the Retain herd structure scenario and the Set stocking rate strategy. The negative cash flow of ca. $1M at the start of the period for both scenarios was due to the hay feeding at the start of the sequence of years and comparatively lower level of sales during the early years of the modelled sequence when herd numbers were being retained to build up the stock numbers after drought. The greater number of AE carried by the property later in the sequence of years for the Retain herd structure scenario compared to the Set stocking rate strategy allowed the cumulative cash flow to become positive for a period of years before hay feeding was again triggered in 2015 and 2016.

Figure 24 - Cumulative cash flow over 30 years for the Retain herd structure scenario and the Set stocking rate strategy

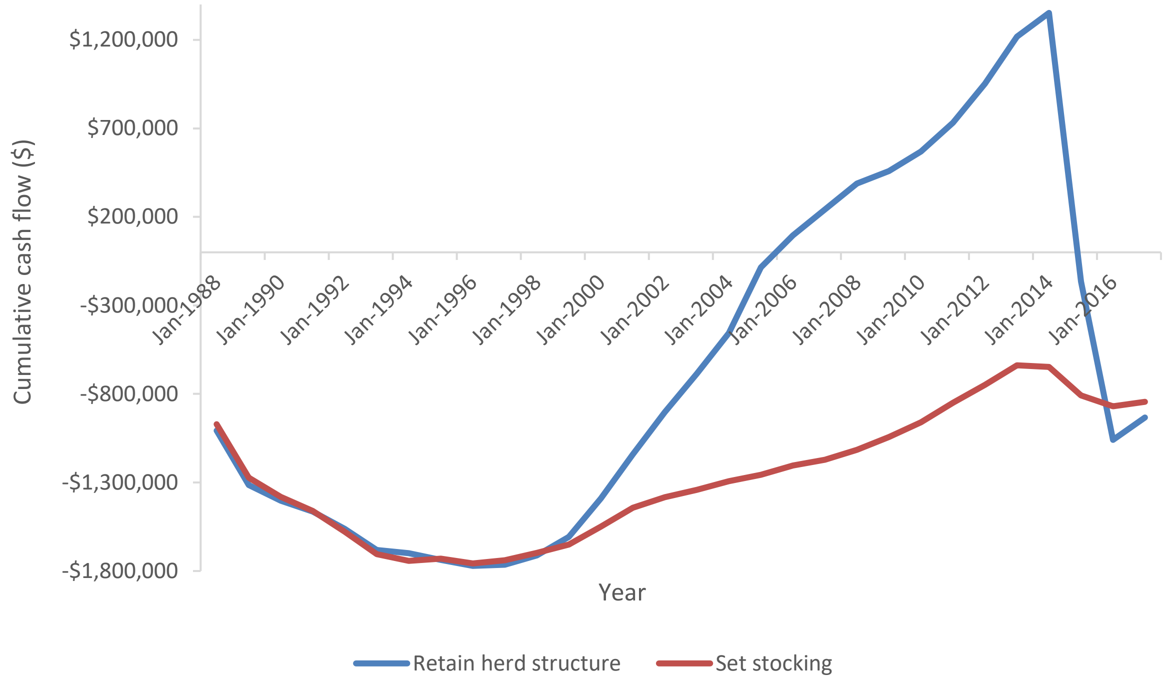


Table 53 indicates the investment returns generated by the Set stocking rate strategy and the Retain herd structure scenario over 30 years. Compared to the Set stocking rate strategy, the Retain herd structure scenario showed no better economic performance over the 30-year period. The negative financial consequence of feeding hay to large numbers of cattle is apparent.

Table 53 – Property level investment returns expressed as the internal rate of return (IRR) over 30 years for the Retain herd structure scenario and, for comparison, the Set stocking rate strategy

Grazing management scenario	IRR
Set stocking rate	-0.09%
Retain core herd	
Retain herd structure	-0.28%

Scenario 2b – Retain core breeders

In this scenario steer numbers were reduced first when additional sales had to be made to reduce grazing pressure/stock numbers on the property. This happened in 1988, 2006, 2007, 2008, 2010 and 2012. The core breeding herd was retained as much as possible in this scenario contrast to the Retain herd structure scenario where breeders were sold first.

Figure 25 compares the AE calculated in Dynamaplus for the Retain core breeders and the Retain herd structure scenarios. The different scenarios were adjusted in different years to maintain (almost) equivalent grazing pressure on the property. The capacity of the Retain core breeders strategy to rebuild numbers more quickly is indicated by the additional AE on the property during the herd rebuilding sequence of years from 1993 to 2000. Breeders were sold first in the Retain herd structure scenario and hence AE numbers could not be rebuilt at the same rate as for the Retain core breeders sub scenario in the absence livestock purchases.

Figure 25 - Comparison of Dynamaplus adult equivalents (AE) for the Retain core breeders and the Retain herd structure scenarios

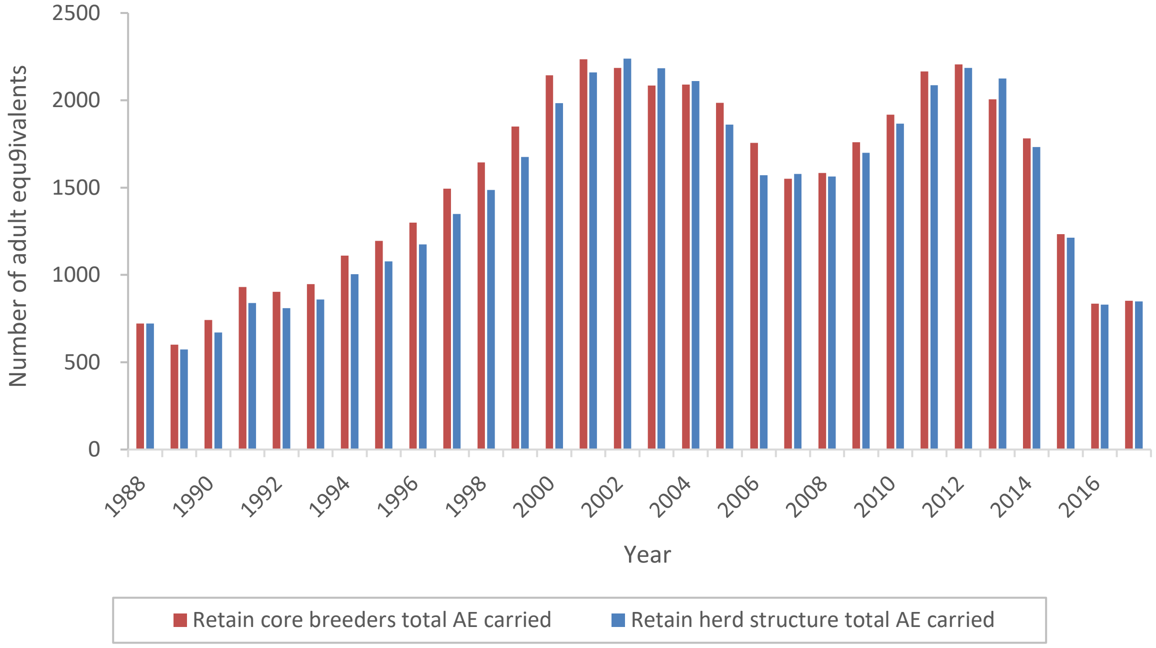


Figure 26 compares the total mortality per annum calculated in the Dynamaplus model for the Retain core breeders and Retain herd structure scenarios. The rate of mortality was very similar, with little difference in the number of stock lost in any year.

Figure 26 - Total annual herd mortalities for the Retain core breeders and Retain herd structure scenarios

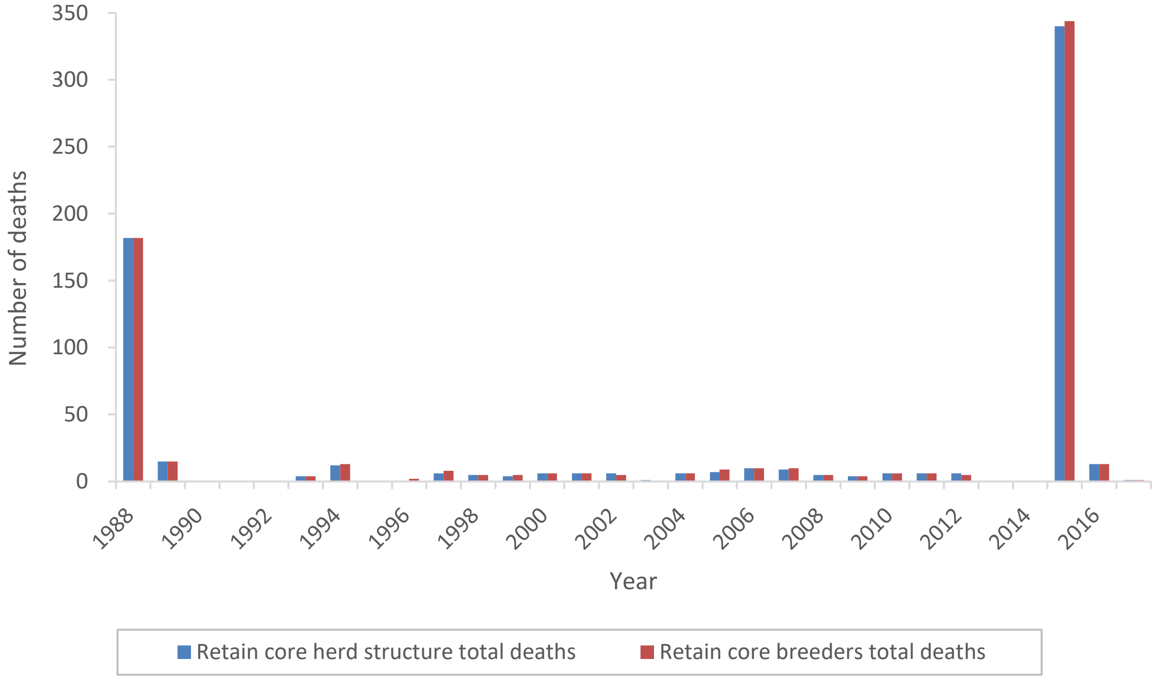


Figure 27 shows the number of weaners produced per annum by the Retain core breeder and the Retain herd structure scenarios modelled using GRASP data and Mayer *et al.* (2012) functions in the Dynamaplus model. Table 54 provides a comparison, of the range of values for the number of weaners produced per annum, for the Retain core breeders scenario and previous scenarios. The strategy of retaining the breeders and selling the steers first (Retain core breeders scenario) in a response to drought phase marginally increased the number of weaners produced in most years compared to the Retain core herd structure scenario, and substantially so from 2006 to 2010. The Retain core breeders scenario produced about 50 more weaners/annum, on average, than the Retain herd structure scenario. Both Retain core herd scenarios produced much greater numbers of weaners/annum than the Set stocking rate strategy or the steady-state herd.

Figure 27 - Number of weaners produced per annum by the Retain core breeders and the Retain herd structure scenarios

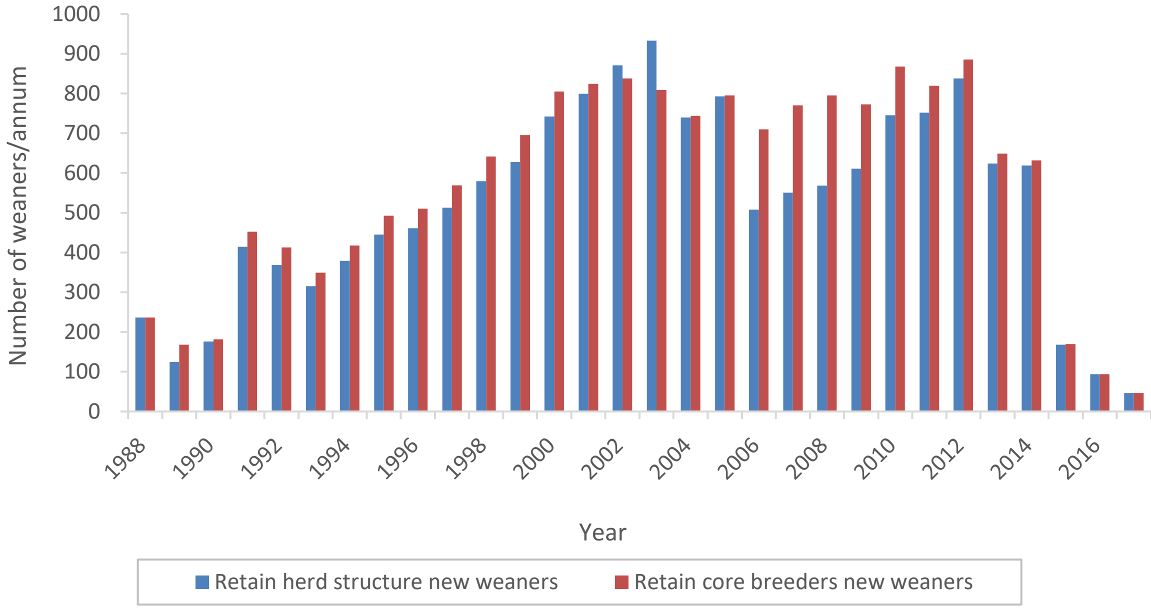


Table 54 – Annual statistics for the number of weaners produced for the Retain core breeders scenario and, for comparison, the previous grazing scenarios

Grazing management scenario	Average	Median	Minimum	Maximum
Steady-state herd	404	404	404	404
Set stocking rate	382	408	117	478
Retain core herd				
Retain herd structure	521	559	46	933
Retain core breeders	572	645	46	885

Table 55 indicates the range of values for the paddock sale weight of steers. The scenarios 2a and 2b were identical due to the underlying GRASP data being identical.

Table 55 - Statistics for the paddock sale weights of steers (kg) for Retain core breeders scenario and, for comparison, the previous grazing scenarios

	Average	Median	Minimum	Maximum
Steady-state herd	499	499	499	499
Set stocking rate	469	491	198	654
Retain core herd				
Retain herd structure	448	462	207	650
Retain core breeders	448	462	207	650

Figure 28 and Figure 29 indicate the expected frequency of supplement and hay feeding costs for the Retain core breeders and the Retain herd structure scenarios. The larger number of breeders retained and fed as part of the Retain core breeders scenario increased the supplement feeding costs (Stages 1 and 2). The hay feeding expense (Stage 3) was similar due to hay being fed to all classes of stock on the property at a percentage of their bodyweight. At equivalent AE on the property, the total amount of hay fed was therefore similar.

Figure 28 – Annual supplement feeding costs (Stages 1 and 2) for the Retain core breeders and the Retain herd structure scenarios

Stage 1 feeding with supplementary NPN was triggered if annual steer LWG/ha predicted by GRASP was < 100 kg but > 50 kg. Stage 2 feeding with supplementary NPN and whole cottonseed was triggered if annual steer LWG/head predicted by GRASP was < 50 kg but > 0 kg

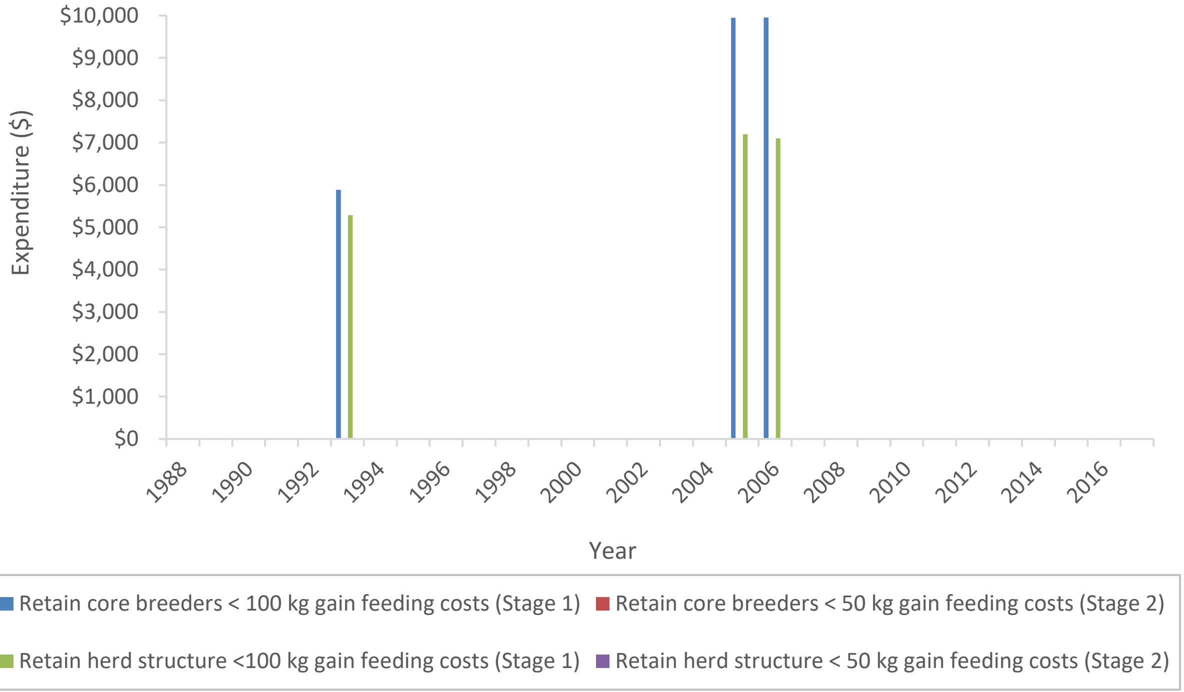


Figure 29 – Annual drought feeding costs (Stage 3 feeding) for the Retain core breeders and Retain herd structure scenarios

Stage 3 feeding with hay was triggered for months when GRASP-predicted total standing dry matter (TSDM) of pasture was < 300 kg DM/ha.

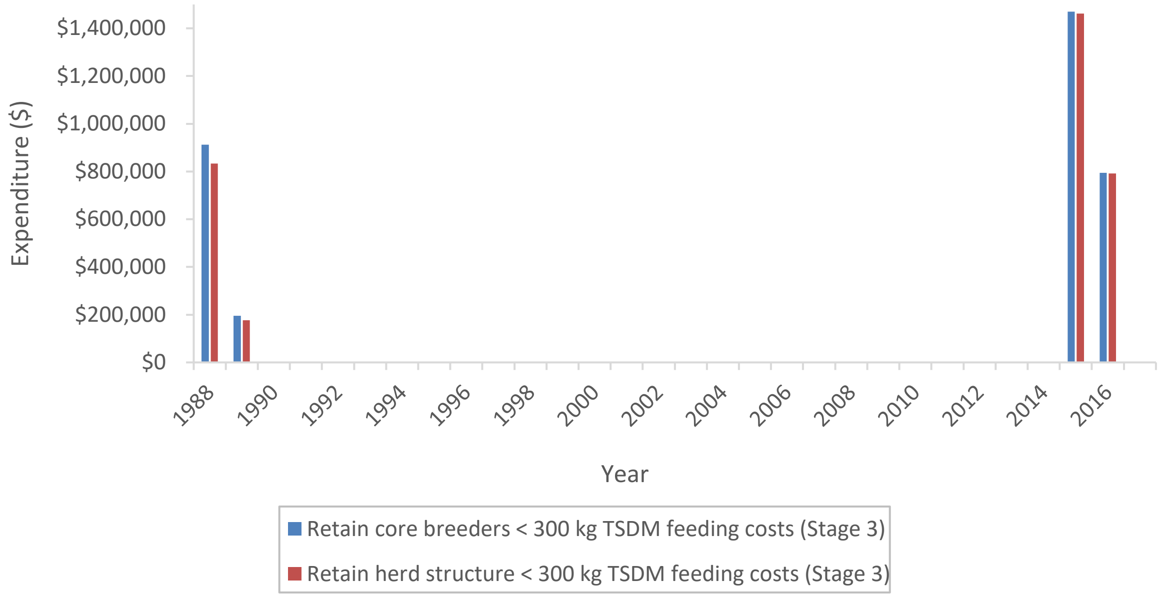


Figure 30 shows the number of stock sold for the Retain core breeders and Retain herd structure scenarios. On average, the Retain core breeders strategy sold 51 more cattle per annum.

Figure 30 - Total number of cattle sales for the Retain core breeders and Retain herd structure scenarios

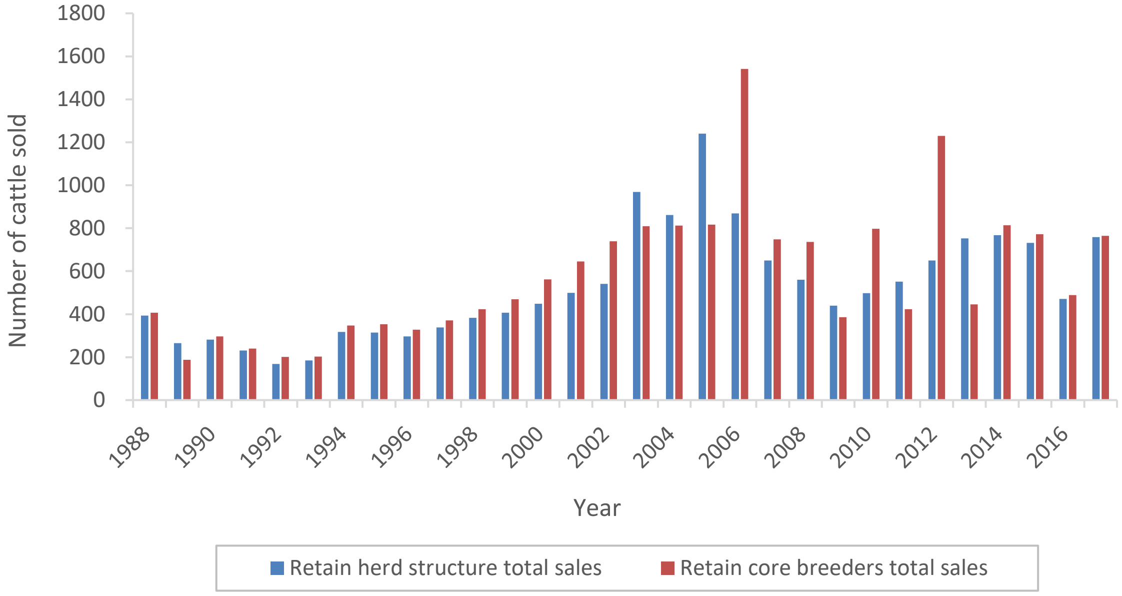


Figure 31 shows the cumulative cash flow generated by the Retain core breeders and Retain herd structure scenarios. Even though there were differences in the total sales and the number of weaners produced, when costs were taken into account, there were no real differences in annual or cumulative cash flow.

Figure 31 - Cumulative cash flow over 30 years for the Retain core breeders and the Retain herd structure scenarios

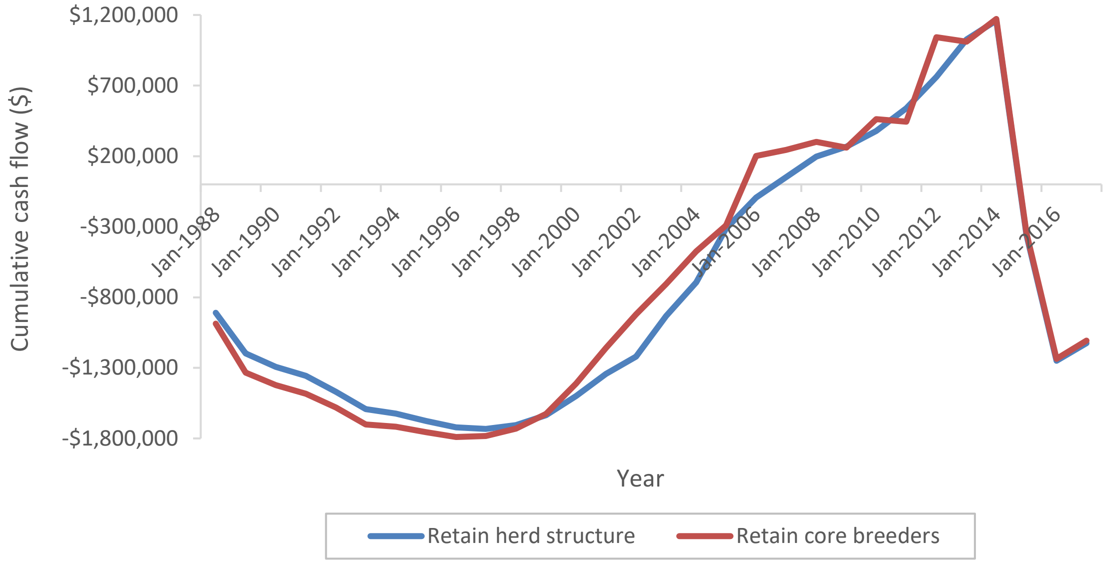


Table 56 indicates the investment returns generated by each grazing management scenario investigated thus far. The Retain herd structure and Retain core breeders scenarios produced very similar, negative, property-level investment returns which were no better than the Set stocking rate strategy.

Table 56 – Property level investment return expressed as internal rate of return (IRR) over 30 years for three grazing management scenarios including the Retain core breeders scenario

Grazing management scenario	IRR
Set stocking rate	-0.09%
Retain core herd	
Retain herd structure	-0.28%
Retain core breeders	-0.26%

Table 57 indicates the marginal return gained by moving from the Retain herd structure to the Retain core breeders strategy. The low level of margin return indicates that, under the assumptions and prices applied, it doesn't make any difference whether you sell down the steers first or a cross-section of the breeder herd in response to drought. The marginal returns for changing from a Retain herd structure to a Retain core breeders strategy indicates that, over the modelled sequence of years, there was no difference between the two scenarios in terms of economic performance. The results of this analysis indicate that, in reality, the market prices available for each class of cattle at the time the decision is being made to sell numbers down (together with their expected value at the end of the drought) will largely determine the choice of which class to sell first. This decision could be assessed using more simple models than that used in this analysis (i.e., Cowtrade and Bullocks within the Breedcow and Dynama suite).

Table 57 - Marginal returns expressed as net present value (NPV) for the change from Retain herd structure to Retain core breeders strategy, over a 30-year investment period

Factor	Value
Interest rate for NPV	5.00%
NPV	$5,000
Annualised NPV	$300
Peak deficit (with interest)	-$144,100
Years to peak deficit	4
Payback year	n/a
Payback period (years)	18

4.1.3.1.3 Scenario 3 – Drought responsive stocking

Figure 32 shows the total AE calculated by GRASP for the property for each year of the Drought responsive stocking strategy as well as for the Retain core herd strategy for comparison. The sudden decline in AE for the Drought responsive scenario in the late 1980s is in response to low pasture production (Figure 6). All strategies started with the same opening herd numbers and herd capital. However, additional sales of cattle in the first year for the Drought responsive stocking strategy resulted in the 200 fewer AE for that year than the Retain core herd strategy.

Figure 32 - Annual property adult equivalents (AE) predicted by GRASP for the Drought responsive scenario and the Retain core herd strategy over 31 years (1987-2017)

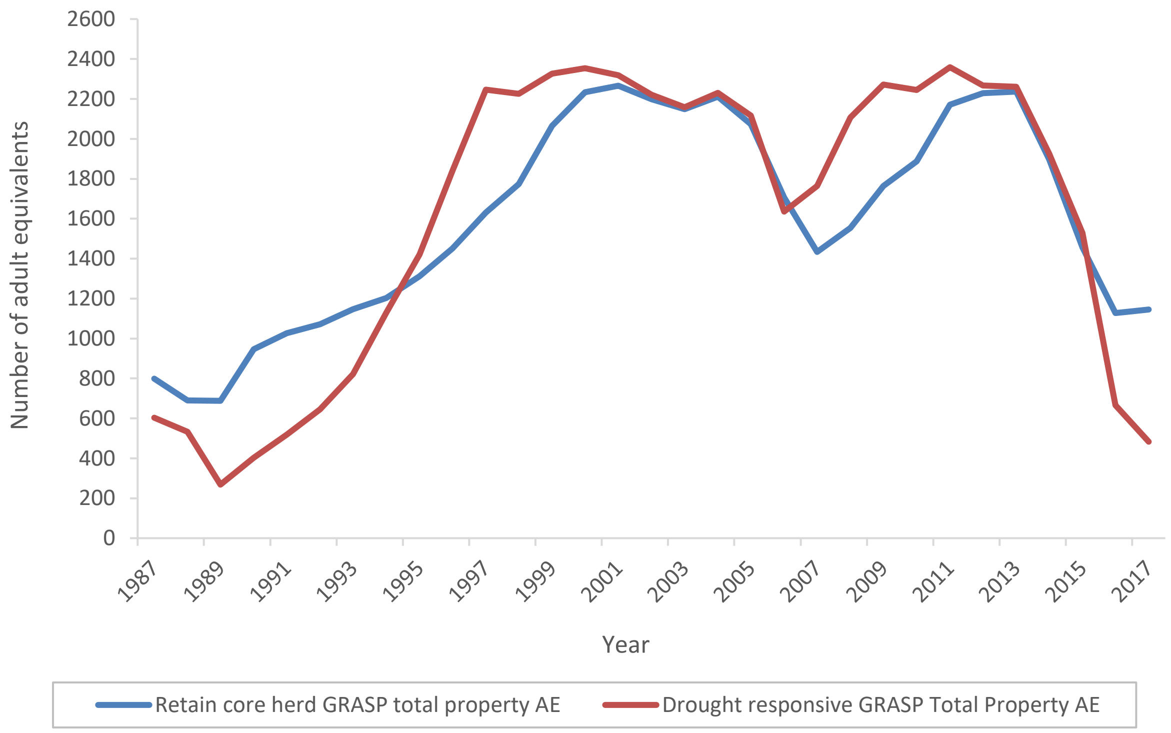


Table 58 indicates that, compared with the Retain core herd strategy, the grazing strategy applied in the Drought responsive scenario has about the same average number of AE, a much lower minimum and a slightly higher maximum and median.

Table 58 - Annual statistics for GRASP adult equivalent (AE) outcomes for the Drought responsive and the Retain core herd strategies over 31 years (1987-2017)

Grazing management scenario	Average	Median	Minimum	Maximum
Retain core herd	1,598	1,630	688	2,266
Drought responsive	1,609	1,926	268	2,359

Scenario 3a – Drought responsive with natural increase

In this scenario, the herd was rebuilt after drought only through retention of breeders and heifers, similarly to the Retain cord herd strategy and its two scenarios. Figure 33 compares the total, annual AE for the Drought responsive strategy calculated in GRASP with those calculated in Dynamaplus for the natural increase scenario. The Dynamaplus herd was a close match to the total GRASP AE determined for the first year. The Dynamaplus model was set to reduce herd numbers to meet the AE identified in the Drought responsive GRASP modelling. The herd was allowed to rebuild through natural increase via the retention of additional breeders and heifers. The model culled minimal cows after mating to rebuild the herd as quickly as possible. Allowing numbers to rebuild naturally from the 1989 herd level did not fully utilise the available pasture resources for most of the investment period of 30 years.

Figure 33 - Comparison of the Dynamaplus adult equivalents (AE) and GRASP AE for the Drought responsive with natural increase scenario

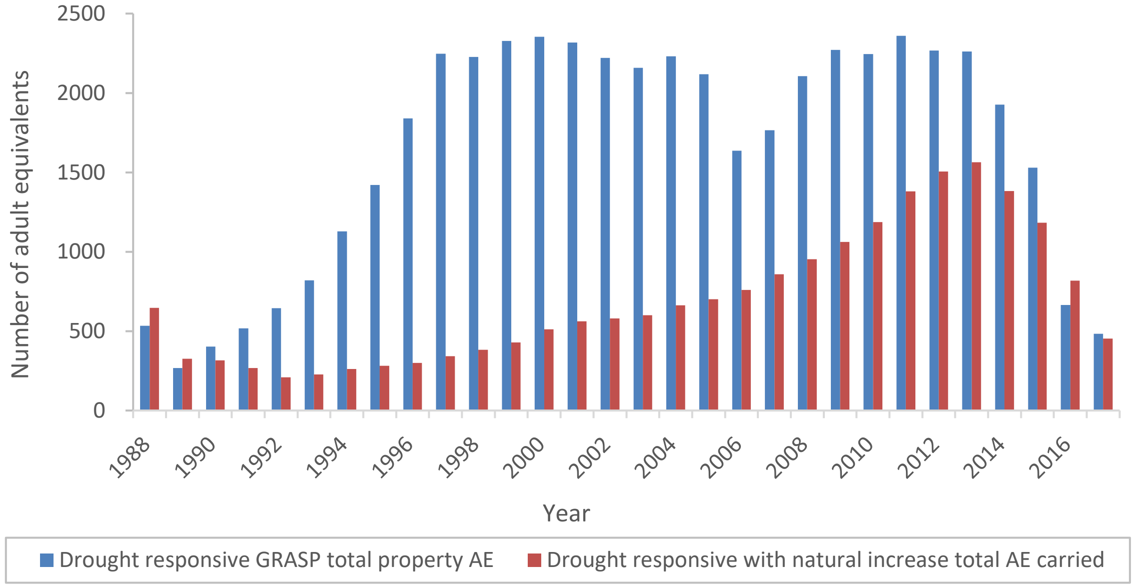


Figure 34 shows the total mortalities per annum calculated in the Dynamaplus model for the Drought responsive with natural increase scenario and the Retain herd structure scenario, for comparison. Dynamaplus calculates deaths after sales and this causes the Drought responsive scenario with natural increase to incur a much lower rate of loss than for other herd management strategies. Additionally, there are few cattle on the property in the early years due to the herd rebuilding strategy applied.

Figure 34 - Total annual herd mortalities predicted by the Dynamaplus model for the Drought responsive with natural increase scenario and the Retain herd structure scenario

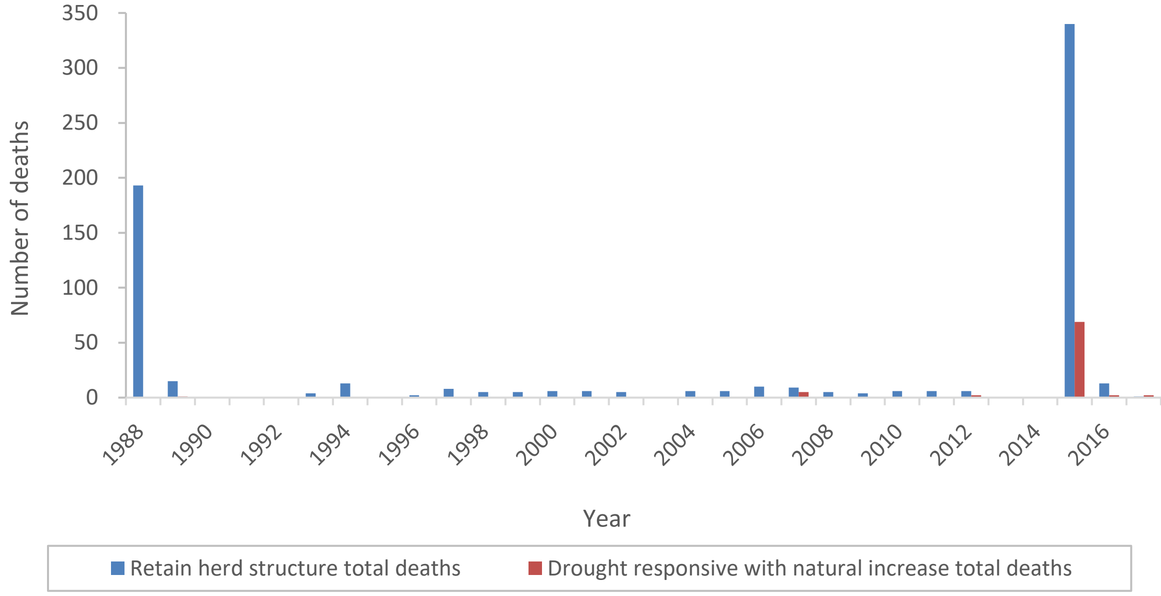


Figure 35 shows the number of weaners produced per annum by the Drought responsive herd and the Retain herd structure herd, for comparison. Even though additional heifers and cows were retained to build breeder numbers after the major herd reduction associated with 1988 and 1989, progress was slow without the purchase of additional breeding stock.

Figure 35 - Number of weaners produced per annum by the Drought responsive with natural increase scenario and the Retain herd structure scenario

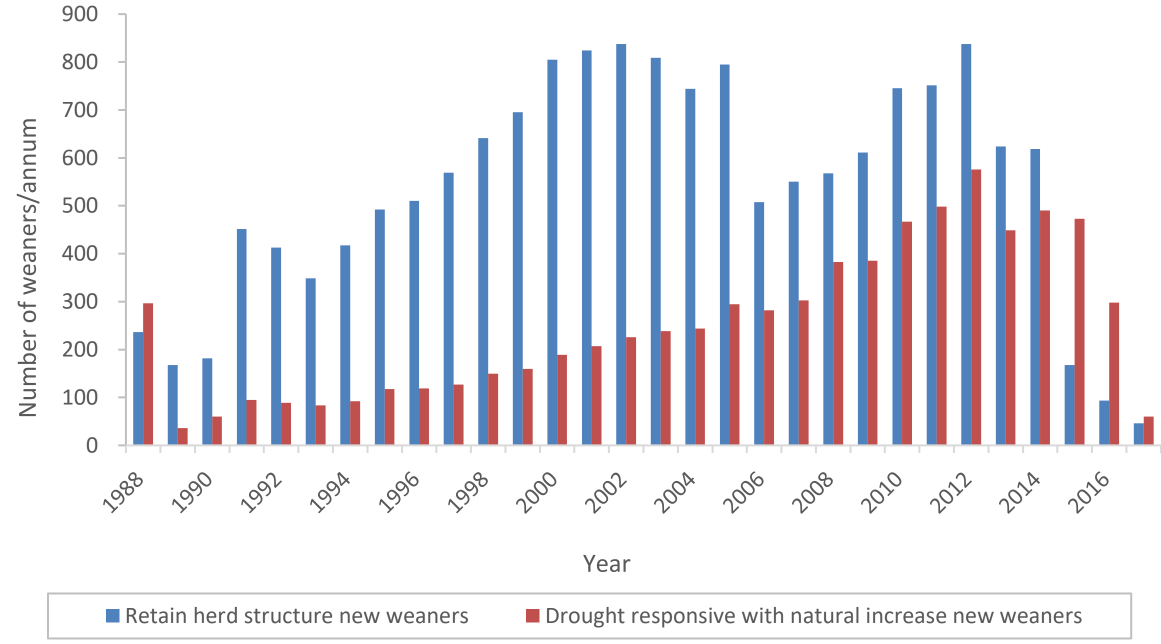


Table 59 indicates the statistics for the number of weaners produced per annum for the scenarios modelled so far. It is evident that the policy to sell down and not re-purchase breeding females severely limits the capacity of the property to generate weaners.

Table 59 – Annual statistics for the number of weaners produced per annum for the Drought responsive with natural increase scenario and, for comparison, all other grazing scenarios

Grazing management scenario	Average	Median	Minimum	Maximum
Steady-state herd	404	404	404	404
Set stocking rate	382	408	117	478
Retain core herd				
Retain herd structure	521	559	46	933
Retain core breeders	572	645	46	885
Drought responsive				
Drought responsive with natural increase	250	232	36	576

Table 60 indicates the statistics for sale weight of steers. Compared to the previous grazing management scenarios modelled, the Drought responsive with natural increase scenario produced better sale weights for steers on average but the number sold was low.

Table 60 - Statistics for the paddock sale weights of steers (kg) for the Drought responsive with natural increase scenario and, for comparison, all other grazing scenarios

Scenario	Average	Median	Minimum	Maximum
Steady-state herd	499	499	499	499
Set stocking rate	469	491	198	654
Retain core herd				
Retain herd structure	448	462	207	650
Retain core breeders	448	462	207	650
Drought responsive				
Drought responsive with natural increase	477	474	214	648

Figure 36 and Figure 37 indicate the predicted frequency and amount of supplement and drought feeding costs for the Drought responsive with natural increase scenario and the Retain herd structure scenario for comparison. Supplement and hay feeding costs were substantially lower than for the Retain herd structure scenario as there were far fewer cattle on the property.

Figure 36 – Annual supplement feeding costs (Stages 1 and 2) for the Drought responsive with natural increase and the Retain herd structure scenarios

Stage 1 feeding with supplementary NPN was triggered if annual steer LWG/ha predicted by GRASP was < 100 kg but > 50 kg. Stage 2 feeding with supplementary NPN and whole cottonseed was triggered if annual steer LWG/head predicted by GRASP was < 50 kg but > 0 kg

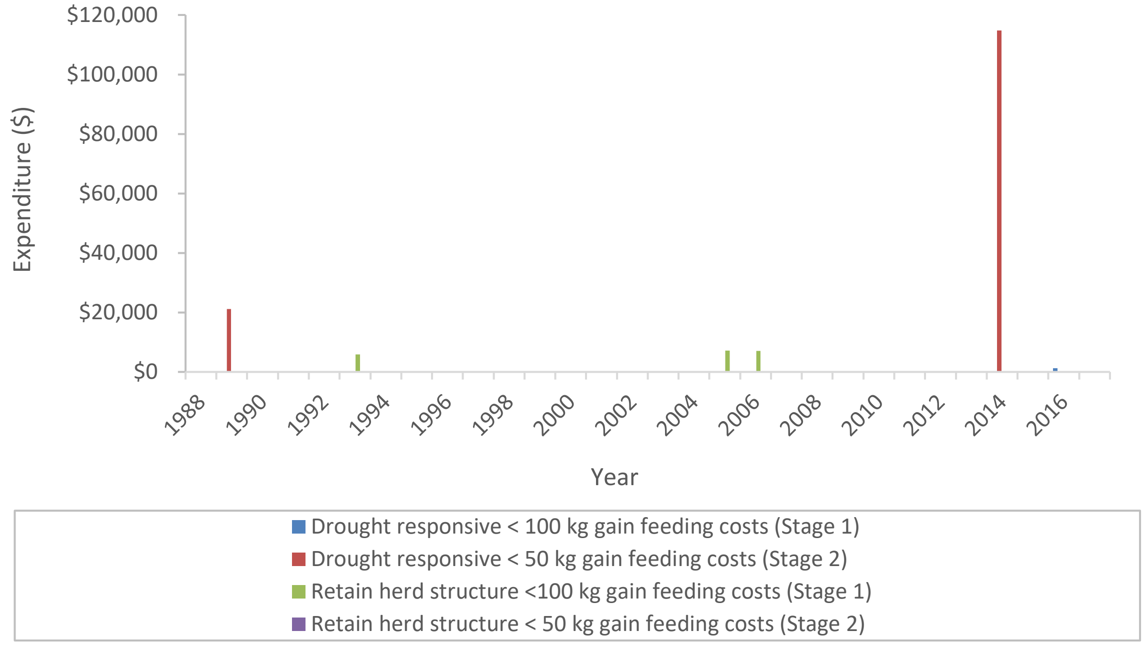


Figure 37 - Annual drought feeding hay costs (Stage 3 feeding) for the Drought responsive with natural increase and the Retain herd structure scenarios

Stage 3 feeding with hay was triggered for months when GRASP-predicted total standing dry matter (TSDM) of pasture was < 300 kg DM/ha

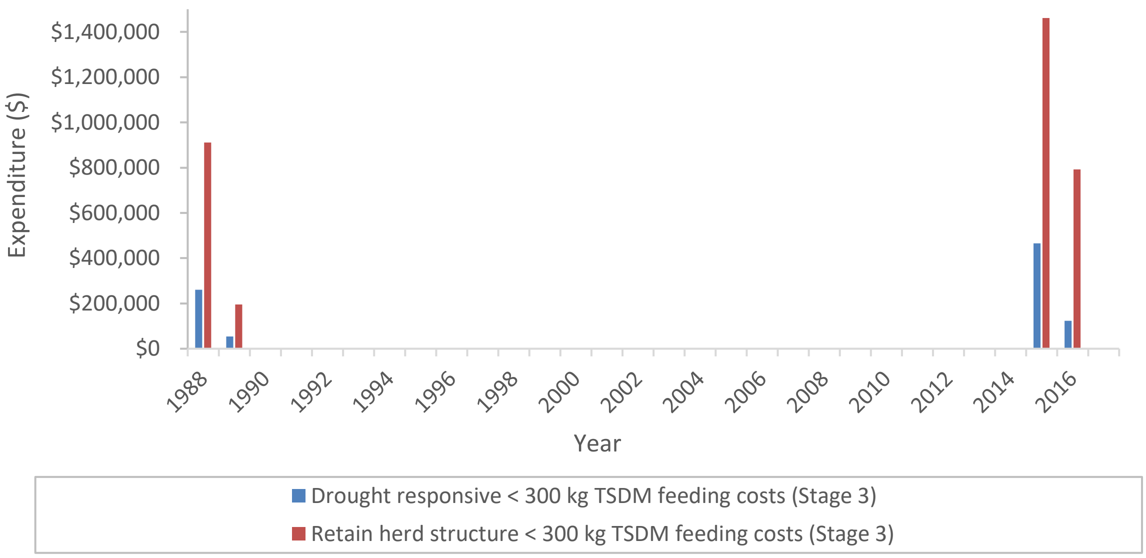


Figure 38 compares the number of stock sold by the Drought responsive with natural increase and the Retain herd structure scenarios.

Figure 38 - Total number of sales for the Drought responsive with natural increase and the Retain herd structure scenarios

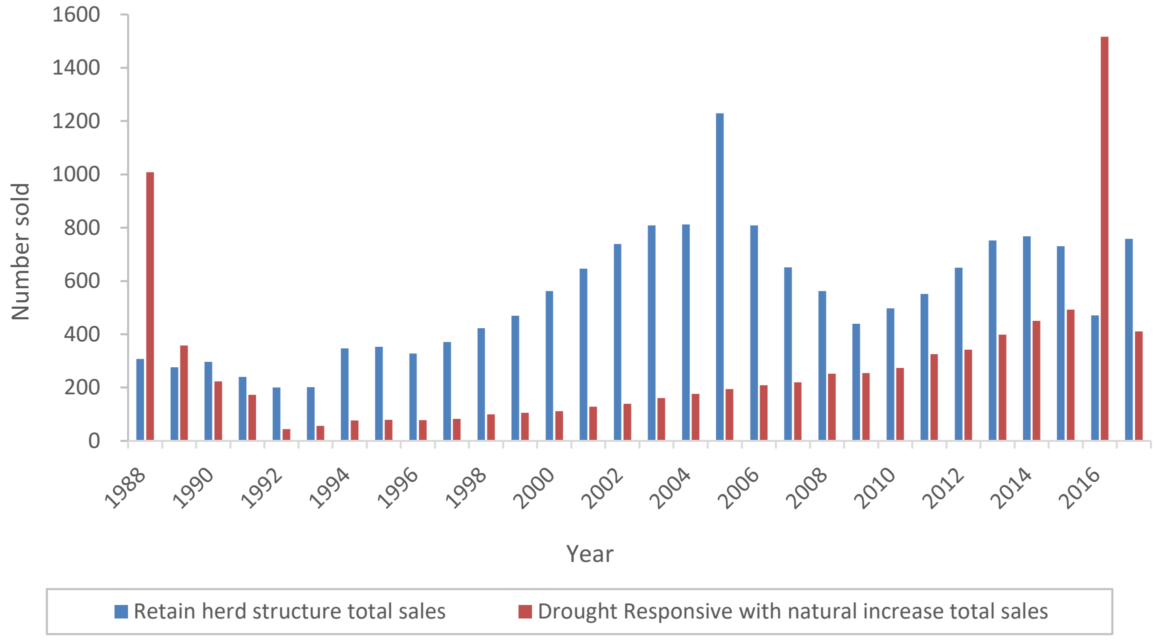


Figure 39 shows the cumulative cash flow generated by the Drought responsive with natural increase and the Retain herd structure scenarios. The additional sales and reduced hay feeding costs in the first year of the Drought responsive with natural increase scenario improves the initial cash flow performance of this scenario when compared to previous scenarios. However, reduced cattle sales over the remaining years of the analysis results in relatively poorer cumulative cash flow figures.

Figure 39 - Cumulative cash flow over 30 years for the Drought responsive with natural increase and the Retain herd structure scenarios

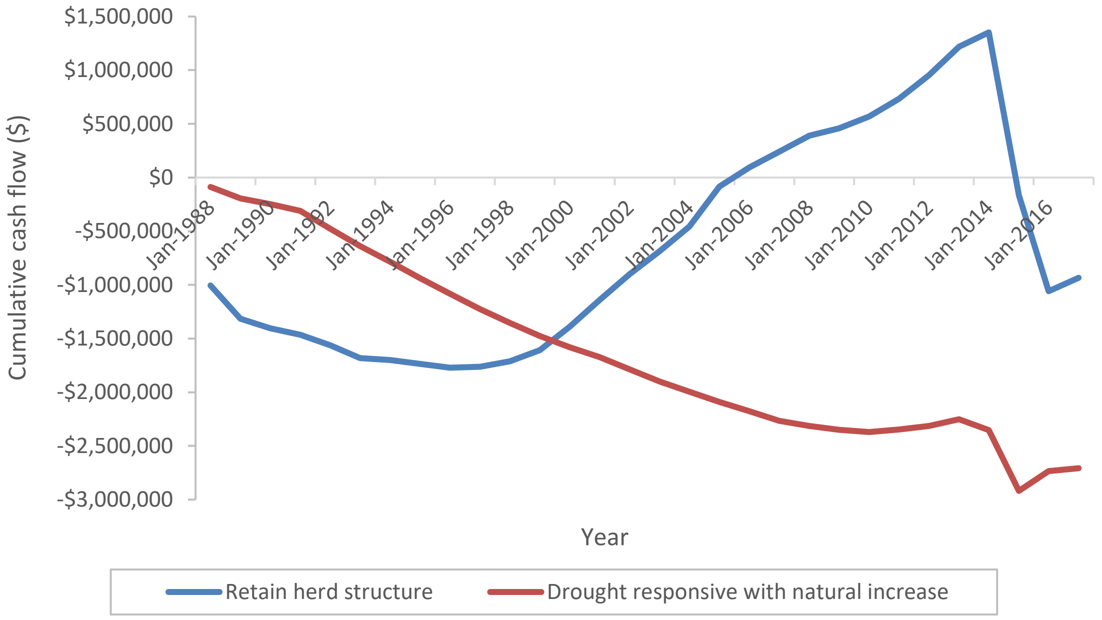


Table 61 indicates the investment returns generated by each grazing management scenario investigated thus far. The Drought responsive with natural increase scenario resulted in a negative IRR. Compared to the previous, less flexible scenarios, the Drought responsive with natural increase scenario incurred less hay feeding expenses and fewer mortalities. However, allowing the herd to rebuild over time through natural increase, after a significant drought-related de-stocking event, has major negative consequences for profitability.

Table 61 – Property level investment return expressed as internal rate of return (IRR) over 30 years for the Drought responsive with natural increase scenario and, for comparison, all other grazing scenarios

Grazing management scenario	IRR
Set stocking rate	-0.09%
Retain core herd	
Retain herd structure	-0.28%
Retain core breeders	-0.26%
Drought responsive	
Natural increase	-1.57%

Table 62 indicates the marginal return gained by moving from the Retain herd structure scenario to the Drought responsive with natural increase scenario. The very large negative return indicates that such a change would substantially reduce the profitability of the enterprise.

Table 62 - Marginal returns expressed as net present value (NPV) over a 30-year investment period for the change from Retain herd structure scenario to Drought responsive with natural increase scenario

Factor	Value
Interest rate for NPV	5.00%
NPV	-$642,700
Annualised NPV	-$41,800
Peak deficit (with interest)	-$3,206,100
Years to peak deficit	27
Payback year	n/a
Payback period (years)	n/a

Figure 33 (previously) indicated a large gap during the herd rebuilding phase between the available carrying capacity of the property and that achieved using a Drought responsive with natural increase herd management strategy (i.e. with no stock purchases or agistment). Table 63 indicates the annual difference in the GRASP-predicted AE (the carrying capacity) and the AE able to be achieved by the herd through natural increase alone (Dynama output). The property was under-stocked for 27 out of the 30 years of the economic analysis.

Table 63 – GRASP-predicted adult equivalents (AE) and the AE achieved by the Drought responsive with natural increase herd in Dynama over 30 years

Year	GRASP-predicted AE	Dynama Drought responsive with natural increase AE	Difference (AE)
1988	533	646	-113
1989	268	327	-59
1990	403	315	88
1991	518	268	250
1992	645	209	435
1993	821	227	593
1994	1129	262	867
1995	1421	282	1,140
1996	1841	299	1,542
1997	2247	343	1,904
1998	2226	382	1,844
1999	2327	428	1,899
2000	2353	512	1,841
2001	2318	562	1,756
2002	2221	580	1,641
2003	2158	599	1,559
2004	2230	664	1,567
2005	2117	702	1,416
2006	1636	760	876
2007	1764	858	907
2008	2106	953	1,154
2009	2272	1063	1,209
2010	2244	1188	1,057
2011	2359	1380	979
2012	2268	1505	762
2013	2260	1563	697
2014	1926	1381	545
2015	1529	1182	346
2016	665	818	-152
2017	483	454	29

Under the Drought responsive with natural increase scenario, the property had up to 1,900 AE/annum spare grazing capacity after the significant sell down occurred in 1988 and 1989. This was due to the herd being unable to rebuild quickly by natural increase from the low residual numbers available in 1990. The options for filling this gap in property carrying capacity include:

- the purchase of PTIC cows to rebuild the herd faster;
- re-purchasing the components of the herd that were sold to rebuild numbers to the long-term herd structure more quickly;
- the purchase of steers as turnover stock. That is, steers are purchased specifically as a trading option to be sold once they reach a target weight;
- taking cattle on agistment.

In the next sections we will consider these options for their impact on the profit and cash flow of the property over the modelled period. Although managers could select different combinations of each alternative, they were treated here as mutually exclusive simply to isolate any differences in their potential impact.

Scenario 3b – Drought responsive with PTIC cow purchase

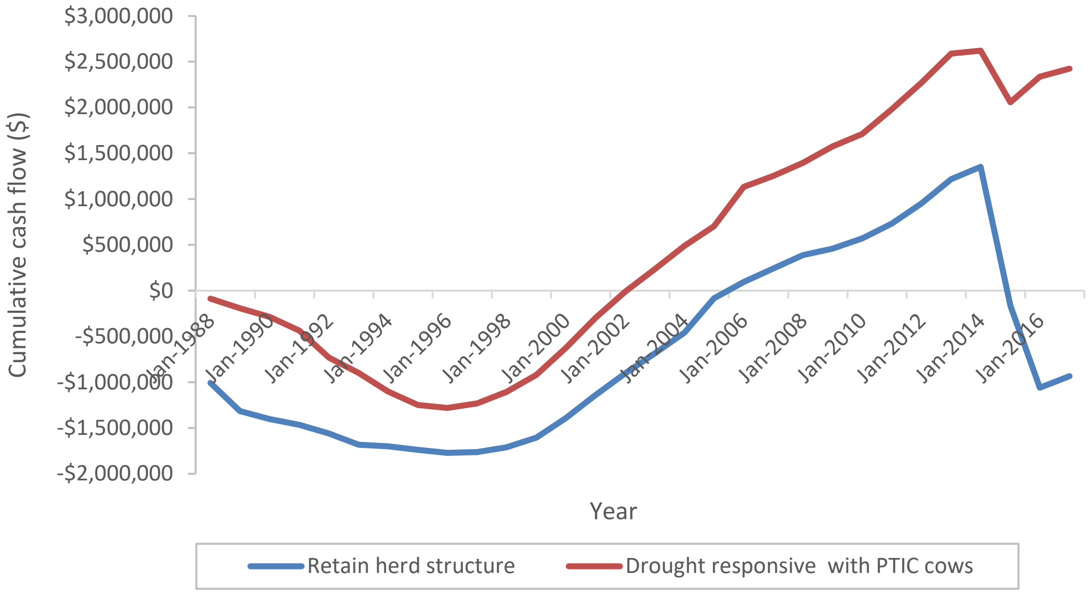
In this scenario the purchase of sufficient PTIC cows, to match the AE in the Dynamaplus model with the spare capacity estimated by GRASP, was modelled. These cows produced 90% calves in the year purchased (100% PTIC less 10% calf loss to weaning). Replacement cows were valued at $750/head landed (based on an average gross sale price of cull cows of $691 plus transport and induction costs). Table 64 shows the number of PTIC cows purchased between 1990 and 2008 in the Drought responsive with PTIC cow purchase scenario. Both replacement herd bulls and PTIC cows were included in the totals for each year.

Table 64 - Stock purchases (PTIC cows and replacement herd bulls) for the Drought responsive with PTIC cow purchase scenario over 1990 to 2008

Year	Total purchases	Total purchases ($)
1990	115	$50,000
1991	231	$105,000
1992	346	$155,000
1993	97	$47,500
1994	328	$152,500
1995	263	$137,500
2008	233	$115,000

Figure 40 indicates that responding to drought with additional sales, and then recovering numbers by purchasing PTIC cows to match the available pasture, reduced the expenditure on hay in the early drought years compared to the Retain herd structure scenario. Cash flow deficits were more severe with PTIC cow purchase than just allowing natural increase (data not shown) but a quick de-stocking response, and then rebuilding the herd through PTIC purchases, appears to result in a better outcome than retaining the herd and feeding hay.

Figure 40 - Cumulative cash flow over 30 years for the Drought responsive with PTIC cow purchase scenario and the Retain herd structure scenario



Building up numbers through the purchase of PTIC females to take advantage of the better years underpins the relative improvement in economic and financial performance of the Drought responsive with PTIC cow purchase scenario. However, there was no available information to support the purchase price selected for PTIC females in this analysis and there is some evidence that such females may not produce 90% weaners when transferred between properties. This, together with the cash flow deficit, indicate that this strategy is a risky, but potentially useable, scenario.

Table 65 indicates the investment returns generated by each grazing management scenario investigated thus far. The Drought responsive with PTIC cow purchase resulted in a positive IRR.

Table 65 – Property level investment return expressed as internal rate of return (IRR) over 30 years for the Drought responsive with purchase PTIC cows scenario and, for comparison, all other grazing scenarios

Grazing management scenario	**IRR**
Set stocking rate	-0.09%
Retain core herd	
Retain herd structure	-0.28%
Retain core breeders	-0.26%
Drought responsive	
Natural increase	-1.57%
Purchase PTIC cows	1.45%

Table 66 indicates the marginal return gained by moving from the Retain herd structure to the Drought responsive with PTIC cow purchase scenario. The property was about $95,000/annum better off with the Drought responsive strategy that purchased PTIC cows compared to the strategy to retain the herd structure and feed hay.

Table 66 - Marginal returns expressed as net present value (NPV) over a 30-year investment period for the change from Retain herd structure to the Drought responsive with PTIC cow purchase scenario

Factor	Value
Interest rate for NPV	5.00%
NPV	$1,457,400
Annualised NPV	$94,800
Peak deficit (with interest)	n/a
Years to peak deficit	n/a
Payback year	n/a
Payback period (years)	n/a

Scenario 3c – Drought responsive with repurchasing the herd

'Buying back the herd' is a strategy aimed at getting the whole herd back into full production as soon as possible. In this example, the stock purchased were a mix of sufficient PTIC cows and other stock to consume the spare feed supply indicated by the Drought responsive GRASP AE. Prices paid for purchase stock were equivalent to the long-term sale price for the class of stock being purchased plus approximately $30 to $50/head transport and handling costs, depending upon the class of stock purchased. The option to 'buy back the herd' was modelled by adding the purchase of steers and heifers to the PTIC cow purchase model and removing the purchase of some PTIC cows to balance the supply and demand of AE in each year.

As for other scenarios that required purchase of livestock, the herd rebuilding scenario caused a large cash flow deficit and produced an almost identical cash flow performance to the purchase of PTIC females only (Figure 41). The insight provided by this very rudimentary analysis is that as long as suitable stock are purchased at the right price, the goal should be to respond appropriately to the pasture available in the paddock rather than overly worry about rebuilding any particular component of the herd.

__Figure 41 - Cumulative cash flow over 30 years for three grazing management scenarios including the drought responsive with repurchasing the herd scenario__

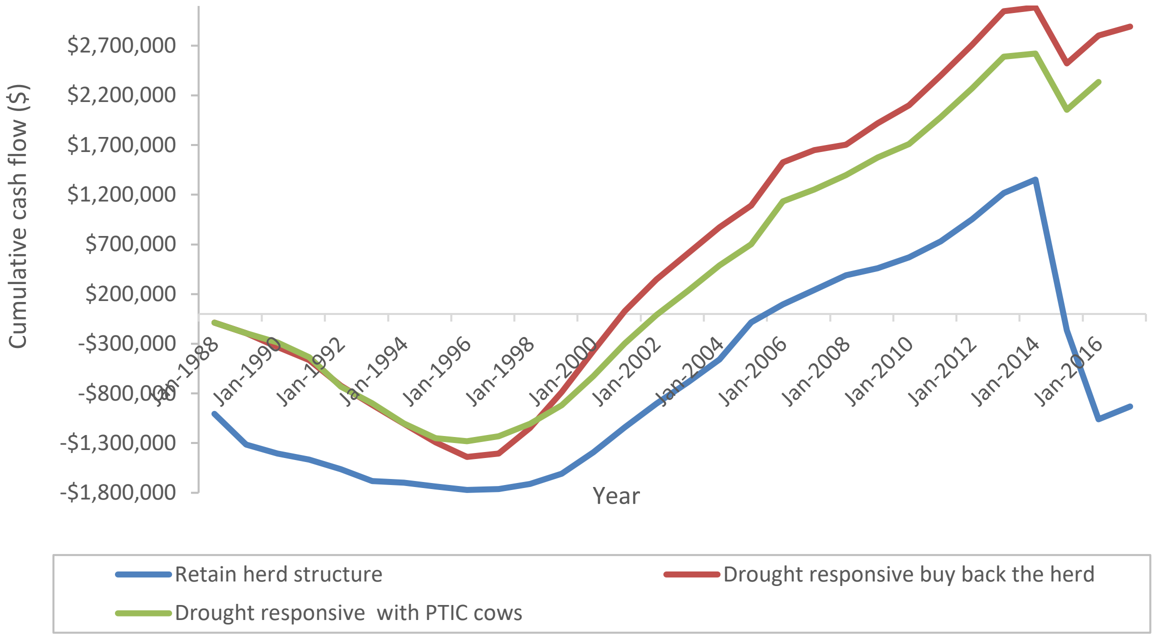


Table 67 indicates the investment returns generated by each grazing management scenario investigated thus far. Similar to the Drought responsive with PTIC cow purchase scenario the Drought responsive with repurchasing the herd scenario resulted in a positive IRR.

__Table 67 – Property level investment return expressed as internal rate of return (IRR) over 30 years for the Drought responsive with repurchasing the herd scenario and, for comparison, all other grazing scenarios__

Grazing management scenario	**IRR**
Set stocking rate	-0.09%
Retain core herd	
Retain herd structure	-0.28%
Retain core breeders	-0.26%
Drought responsive	
Natural increase	-1.57%
Purchase PTIC cows	1.45%
Repurchasing the herd	1.70%

Table 68 indicates the marginal return gained by moving from the Retain herd structure strategy to the Drought responsive with repurchasing the herd scenario. A review of the assumptions made for the prices paid for replacement stock suggests that purchasing a mix of cattle to rebuild the herd is not much different in impact to purchasing just PTIC cows. It appears more important to select, at the time of purchase, cattle with the best potential return for the property over the short to medium term, not cattle that will return the herd to a certain size or shape in the shortest time period. The analysis identifies that a different class of stock could be purchased at each point in time that stock purchases associated with drought recovery have to be considered. It is obvious that a small change in the parameters applied could change the relative ranking of the options and that having a fixed goal of recovering via a predetermined pathway could prevent more profitable options being considered.

Table 68 - Marginal returns expressed as net present value (NPV) over a 30-year investment period for the change from Retain herd structure to Drought responsive with repurchasing the herd scenario

Factor	Value
Interest rate for NPV	5.00%
NPV	$1,666,200
Annualised NPV	$108,400
Peak deficit (with interest)	n/a
Years to peak deficit	n/a
Payback year	n/a
Payback period (years)	n/a

Scenario 3d – Drought responsive with trading steers

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 at the time the decision is being made using current and expected prices for each class, and expected weight gains, to confirm which alternative may be lower risk and more profitable. The Bullocks program can assess the purchase of dry stock and the Cowtrade program can assess the purchase of cows and calves, or PTIC cows, as a trading option. In each case, the decision criteria should be to select the class of cattle likely to provide the highest gross margin/AE after interest over the relevant time period. Where cattle are purchased to be traded, the choice of which class of stock to purchase should be reassessed at each time purchases are being contemplated.

An example for the annual trading of steers was presented here to show a process for assessing the potential benefits and risks, not to identify a recommended course of action. Yearling steers were purchased in June of each year to match the spare AE calculated for that year. They were purchased at the 18 month-old steer weight and price in June of each year. Transport and induction costs were added to the purchase price of the steers. They were sold at the selling price, selling costs and estimated weight of the same cohort of home-bred steers 12 months later.

The number of steers purchased was decided by the AE rating for the steers (which could vary according the GRASP-derived estimate of opening weight and weight gain for each period) and the spare grazing capacity available as the breeding herd returned to normal size. Table 69 shows the data used to calculate the costs and benefits of steer trading. Steers were not purchased in all years and purchases and sales were offset by one year in the Dynamaplus model.

Table 69 – Data used in the steer trading analysis for the Drought responsive with trading steers scenario

Steer sales occurred one year after purchase; AE = adult equivalent

Year	Available AE	Number of steers purchased	Opening weight	Closing weight	Total $ purchases	Total $ sales net of selling costs
1988	-113	0	212	244	$0	
1989	-59	0	184	243	$0	$0
1990	88	136	204	385	$55,716	$0
1991	250	344	248	413	$170,192	$85,672
1992	435	678	233	352	$315,531	$233,560
1993	593	1,052	209	305	$441,185	$388,025
1994	867	1,392	210	356	$587,721	$518,314
1995	1,140	1,821	223	347	$812,361	$807,836
1996	1,542	1,782	334	453	$1,182,655	$1,029,862
1997	1,904	2,125	336	479	$1,417,736	$1,330,890
1998	1,844	1,814	394	531	$1,414,357	$1,682,706
1999	1,899	1,809	375	580	$1,345,508	$1,597,212
2000	1,841	1,474	470	666	$1,370,164	$1,742,304
2001	1,756	1,471	460	627	$1,337,392	$1,631,284
2002	1,641	1,465	442	577	$1,281,044	$1,528,996
2003	1,559	1,657	374	482	$1,228,733	$1,402,618
2004	1,567	1,821	329	454	$1,188,668	$1,321,346
2005	1,416	1,627	349	443	$1,126,044	$1,364,650
2006	876	1,070	301	444	$640,383	$1,188,493
2007	907	923	381	513	$697,508	$783,520
2008	1,154	1,169	386	512	$894,561	$784,340
2009	1,209	1,218	367	536	$887,065	$991,402
2010	1,057	973	421	568	$809,795	$1,082,866
2011	979	901	403	586	$718,935	$918,646
2012	762	649	459	609	$588,501	$877,330
2013	697	651	420	555	$540,589	$656,818
2014	545	0	414	453	$0	$599,856
2015	346	0	228	224	$0	$0
2016	-152	0	160	263	$0	$0
2017	29	0	289	387	$0	$0

Figure 42 indicates that, in this example, the significant additional interest and other expenses incurred in trading yearling steers was likely to initially reduce the cumulative cash flow below that of the other options for rebuilding profit after the drought. The capacity of the property to fund the steer purchases may also be a relevant factor to consider. The steer trading model would be more risky than other options. No assessment of the price risk associated with trading cattle in this environment was included.

Figure 42 - Cumulative cash flow over 30 years for four grazing management scenario including the Drought responsive with trading steers scenario

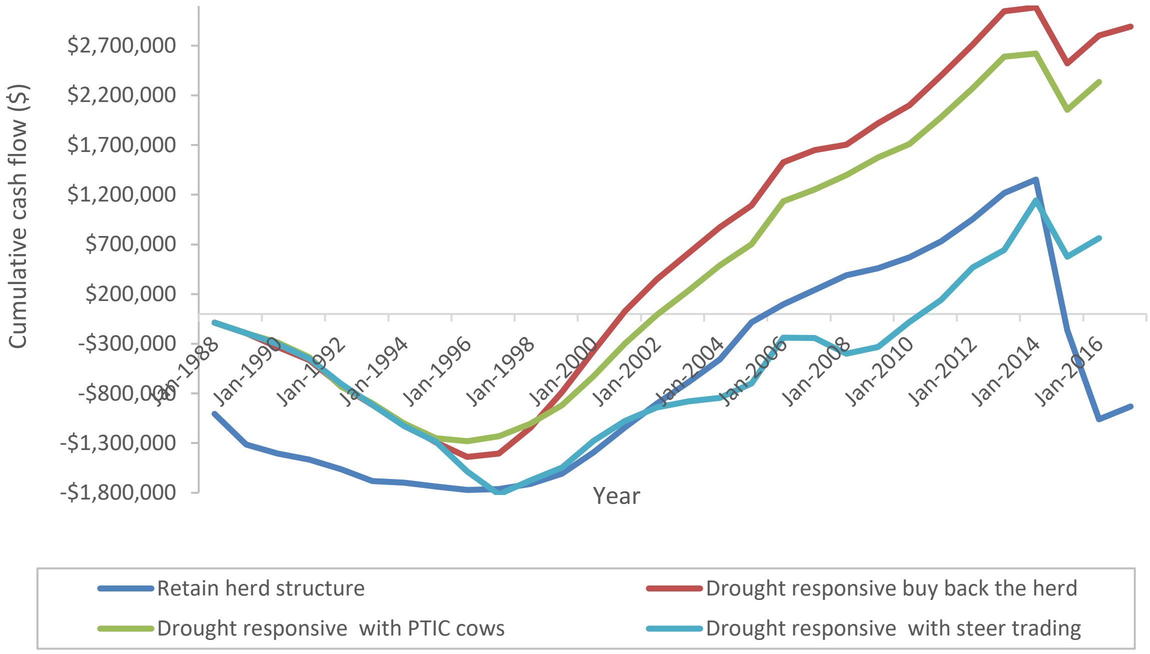


Table 70 indicates the investment returns generated by each grazing management scenario investigated thus far. Similar to the other Drought responsive scenarios which used some means to fill the spare grazing capacity after drought, the Drought responsive with trading steers scenario resulted in a positive IRR.

Table 70 – Property level investment return expressed as internal rate of return (IRR) over 30 years for the Drought responsive with trading steers scenario and, for comparison, all other grazing scenarios

Grazing management scenario	**IRR**
Set stocking rate	-0.09%
Retain core herd	
Retain herd structure	-0.28%
Retain core breeders	-0.26%
Drought responsive	
Natural increase	-1.57%
Purchase PTIC cows	1.45%
Repurchasing the herd	1.70%
Trading steers	0.50%

Table 71 indicates the marginal return gained by moving from the Retain herd structure scenario to the Drought responsive scenario with trading steers. The marginal returns indicate a benefit over the Retain herd structure scenario but net benefits were negative compared to the Drought responsive with PTIC cow purchase or with repurchasing the herd scenarios. Unless the manager could consistently achieve a better price margin on the steer trade, than the average over time in the market data, the strategy would be considered high risk and likely to be less profitable than purchasing PTIC cows or a mix of cattle during the drought recovery phase.

Table 71 - Marginal returns expressed as net present value (NPV) over a 30-year investment period for the change from Retain herd structure to Drought responsive with trading steers scenario

Factor	Value
Interest rate for NPV	5.00%
NPV	$605,200
Annualised NPV	$39,400
Peak deficit (with interest)	-$133,300
Years to peak deficit	22
Payback year	n/a
Payback period (years)	n/a

Scenario 3e – Drought responsive with agistment income

In this scenario, sufficient cattle were taken on agistment following drought to match any spare carrying capacity as indicated by GRASP. The difference in AE count between the Drought responsive herd and the GRASP output was allocated to agistment from 1990 onwards. Table 72 shows the additional income available from long-term agistment taken while the breeder herd was rebuilt if an average of $2/AE.week was received for 50 weeks of the year. Agistment income continued to be received until 2015 in this scenario.

Table 72 - Potential extra income from agisting the spare carrying capacity (adult equivalents; AE) of the property while the herd rebuilt following drought, for the Drought responsive with agistment income scenario (compared to Drought responsive with natural increase)

Year	GRASP AE	Dynama Drought responsive with natural increase AE	Difference in AE	Agistment income
1988	533	646	-113	nil
1989	268	327	-59	nil
1990	403	315	88	$8,795
1991	518	268	250	$24,995
1992	645	209	435	$43,530
1993	821	227	593	$59,321
1994	1,129	262	867	$86,675
1995	1,421	282	1,140	$113,975
1996	1,841	299	1,542	$154,179
1997	2,247	343	1,904	$190,376
1998	2,226	382	1,844	$184,367
1999	2,327	428	1,899	$189,876
2000	2,353	512	1,841	$184,097
2001	2,318	562	1,756	$175,632
2002	2,221	580	1,641	$164,074
2003	2,158	599	1,559	$155,906
2004	2,230	664	1,567	$156,679
2005	2,117	702	1,416	$141,552
2006	1,636	760	876	$87,580
2007	1,764	858	907	$90,666
2008	2,106	953	1,154	$115,369
2009	2,272	1,063	1,209	$120,914
2010	2,244	1,188	1,057	$105,692
2011	2,359	1,380	979	$97,924
2012	2,268	1,505	762	$76,231
2013	2,260	1,563	697	$69,723
2014	1,926	1,381	545	$54,480
2015	1,529	1,182	346	$34,626
2016	665	818	-152	nil
2017	483	454	29	nil

Figure 43 indicates the cumulative cash flow that would occur if the spare grazing capacity, after de-stocking episodes, was filled by stock on agistment at $2/AE.week. Whether this is possible is unknown but higher or lower rates of income from agistment are easily tested in the model. Taking cattle on agistment provided significant protection of cash balances in the early years of the 1990s while the herd was rebuilding after the destocking phase during the 1980s. The strategy appears to be less risky, but also less profitable, than purchasing PTIC cows, repurchasing the herd or trading steers. Unfortunately, just as herd numbers were rebuilt in the agistment scenario, another drought hit (ca. 2015) and hay was fed to the rebuilt herd causing a substantial decline in cumulative cash flow.

Figure 43 - Cumulative cash flows over 30 years for the Drought responsive with agistment income and four other grazing management scenarios for comparison

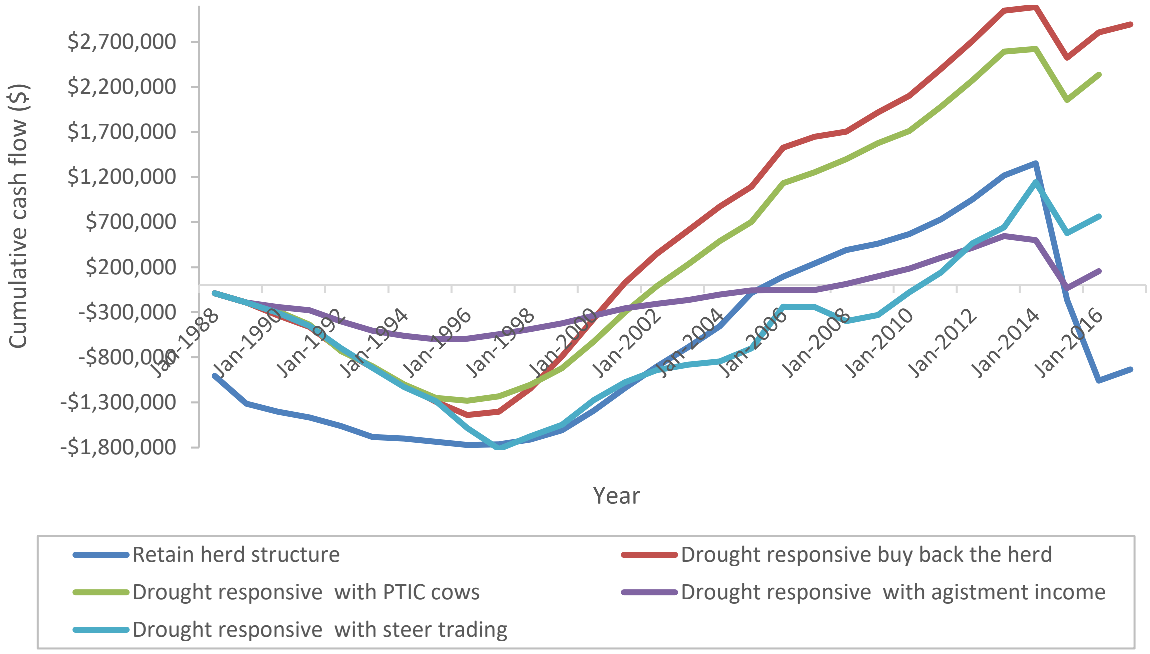


Table 73 indicates the investment returns generated by each grazing management scenario investigated thus far. Similar to the other Drought responsive scenarios which used some means to fill the spare grazing capacity after drought, the Drought responsive with agistment income scenario resulted in a positive IRR.

Table 73 – Property level investment return expressed as internal rate of return (IRR) over 30 years for the Drought responsive with agistment income scenario and, for comparison, all other grazing scenarios

Grazing management scenario	**IRR**
Set stocking rate	-0.09%
Retain core herd	
Retain herd structure	-0.28%
Retain core breeders	-0.26%
Drought responsive	
Natural increase	-1.57%
Purchase PTIC cows	1.45%
Repurchasing the herd	1.70%
Trading steers	0.50%
Agistment income	0.19%

Table 74 indicates the marginal return gained by moving from the Retain herd structure scenario to the Drought responsive strategy with agistment income scenario. The Drought responsive with agistment income scenario produced better returns than the Retain herd structure scenario but was less profitable than the Drought responsive with either PTIC breeder purchases or repurchasing the herd scenarios.

Table 74 - Marginal returns expressed as net present value (NPV) over a 30-year investment period for the change from Retain herd structure to Drought responsive with agistment income scenario

Factor	Value
Interest rate for NPV	5.00%
NPV	$778,100
Annualised NPV	$50,600
Peak deficit (with interest)	n/a
Years to peak deficit	n/a
Payback year	n/a
Payback period (years)	n/a

4.1.3.1.4 Scenario 4 - Fully flexible stocking

Figure 44 shows the total AE calculated by GRASP for the property for each year of the Fully flexible stocking scenario as well as for the Drought responsive scenario for comparison. The much more dramatic changes in allowed property AE for the Fully flexible stocking strategy, as compared to the Drought responsive strategy, are evident, particularly for the increases in AE allowed in response to years of good pasture biomass yield.

Figure 44 - Annual property adult equivalents (AE) predicted by GRASP for the Fully flexible and the Drought responsive scenarios over 31 years (1987-2017)

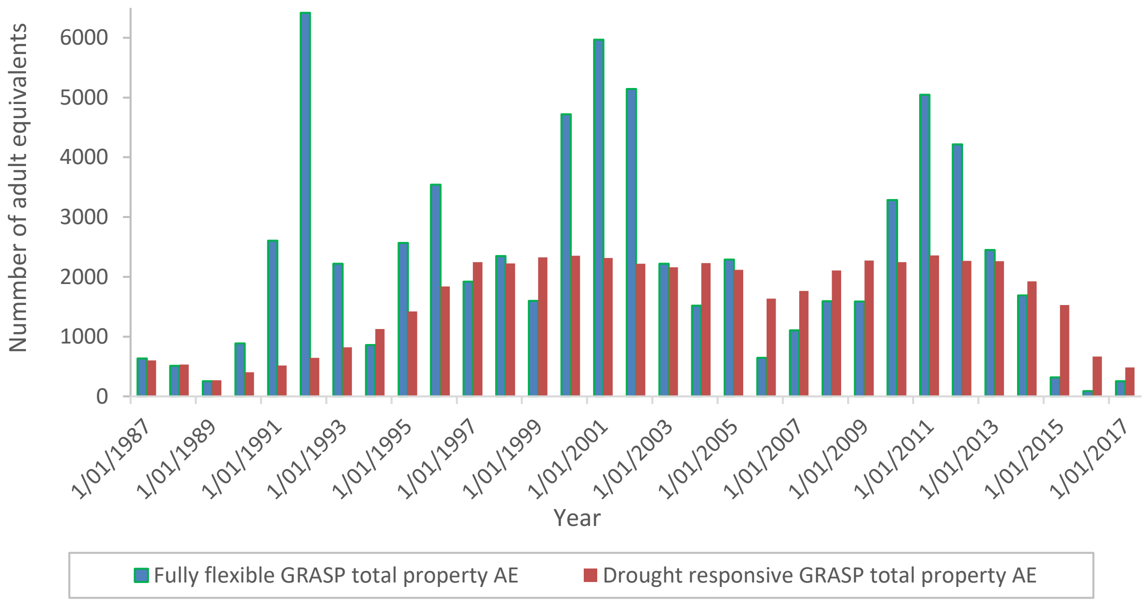


Table 75 indicates that, compared with the Retain core herd and Drought responsive strategies, the grazing strategy applied in the Fully flexible scenario has a higher average number of AE, a much lower minimum and a much higher maximum. The median AE carried in the Fully flexible scenario is about the same as for the Drought responsive scenario.

Table 75 - Annual statistics for GRASP adult equivalent (AE) outcomes for the Fully Flexible, Drought responsive and Retain core herd strategies over 31 years (1987-2017)

Scenario	Average	Median	Minimum	Maximum
Retain core breeders	1,598	1,630	688	2,266
Drought responsive	1,609	1,926	268	2,359
Fully flexible	2,274	1,918	90	6,416

Scenario 4a – Fully flexible with natural increase

In this scenario the herd was rebuilt after drought only through natural retention of breeders and heifers, similarly to the Retain core herd strategy and its two scenarios and to the Drought responsive with natural increase scenario. Figure 45 compares the total, annual AE for the Fully flexible strategy calculated in GRASP with those calculated in Dynamaplus for the natural increase scenario. The Dynamaplus model was set to reduce herd numbers to meet the AE identified in the Fully flexible GRASP modelling in the 1988 and 1989 droughts. The herd then rebuilt through natural increase and the retention of additional breeders and heifers. The model culled minimal cows after mating to rebuild the herd as quickly as possible. Allowing numbers to rebuild from the 1989 herd level did not fully utilise the available pasture resources during the investment period of 30 years.

Figure 45 - Comparison of the Dynamaplus adult equivalents (AE) and GRASP AE for the Fully flexible with natural increase scenario

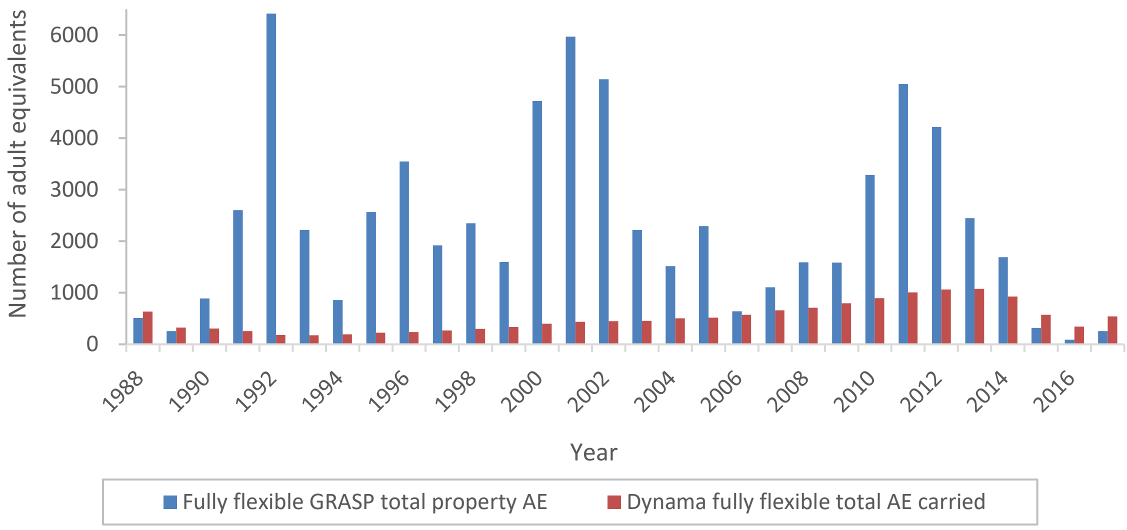


Figure 46 shows the number of weaners produced per annum by the Fully flexible herd. Even though many heifers and cows were retained to build breeder numbers, progress was slow after the major herd reduction associated with 1988 and 1989 without purchase of additional breeding stock.

Figure 46 - Number of weaners produced per annum by the Fully flexible with natural increase scenario

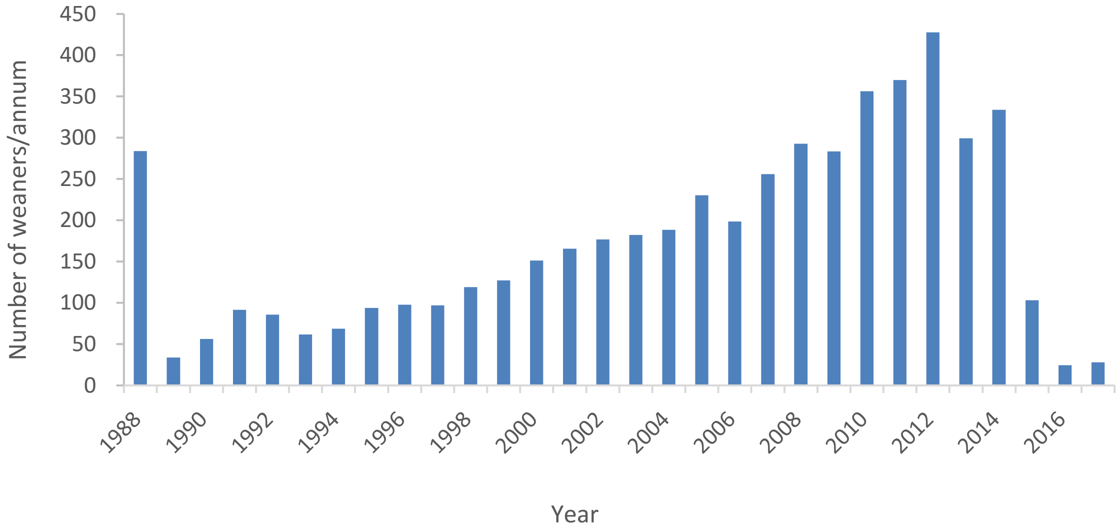


Table 76 indicates the statistics for the number of weaners produced per annum for the scenarios modelled so far. It is evident that a policy to sell down dramatically and then not re-purchase breeding females severely limits the capacity of the property to generate weaners.

Table 76 – Annual statistics for the number of weaners produced for the Fully flexible with natural increase scenario and, for comparison, the other grazing scenarios relying solely on natural increase to rebuild herd numbers

Scenario	Average	Median	Minimum	Maximum
Steady-state herd	404	404	404	404
Set stocking rate	382	408	117	478
Retain core herd				
Retain herd structure	521	559	46	933
Retain core breeders	572	645	46	885
Drought responsive with natural increase	250	232	36	576
Fully flexible with natural increase	176	158	25	428

Table 77 indicates the statistics for the paddock sale weight of steers. It is important to note that the steer weights are an output of GRASP and are based on the target GRASP stocking rate (AE numbers) for that strategy, with no feedback to GRASP when the herd model is unable to achieve the target stocking rate, as for the natural increase scenarios. Compared to the previous grazing management scenarios modelled, the Fully flexible with natural increase scenario produced lower sale weights for steers which is an artefact of the lack of feedback from the herd model to GRASP when total property AE were lower than the target. The number of steers sold for this scenario was also low. The negative value for minimum steer sale weight is an artefact of the GRASP model when steer death would occur in practice as the GRASP model simply accumulates predicted weight losses until the pre-determined sale date.

Table 77 - Statistics for the paddock sale weights of steers (kg) for the Fully flexible with natural increase scenario and, for comparison, the other grazing scenarios relying solely on natural increase to rebuild herd numbers

Scenario	Average	Median	Minimum	Maximum
Steady-state herd	499	499	499	499
Set stocking rate	469	491	198	654
Retain core herd				
Retain herd structure	448	462	207	650
Retain core breeders	448	462	207	650
Drought responsive with natural increase	477	474	214	648
Fully flexible with natural increase	416	426	-38[A]	623

[A]Modelled outcome for steer sales in 2016.

Figure 47 shows the cumulative cash flow generated by the Fully flexible with natural increase scenario.

Figure 47 - Cumulative cash flow over 30 years for the Fully flexible with natural increase scenario

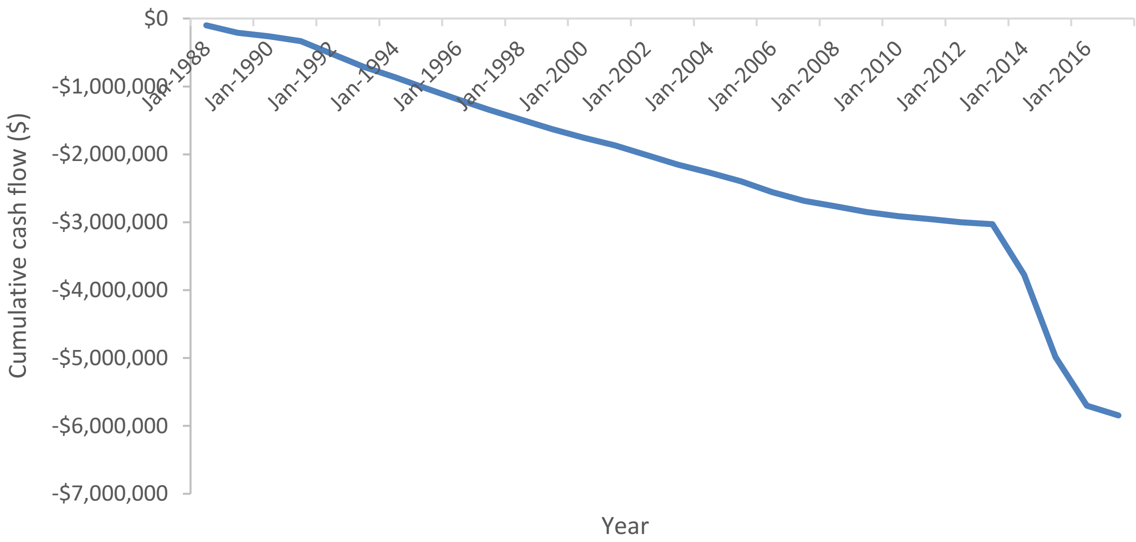


Table 78 indicates the property-level investment returns generated by each grazing management scenario assessed so far. As for the all strategies rebuilding herd numbers after drought through only natural increase, the Fully flexible with natural increase scenario resulted in poor profitability and negative IRR.

Table 78 – Property level investment return expressed as internal rate of return (IRR) over 30 years for the Fully flexible with natural increase scenario and, for comparison, all other grazing scenarios

Grazing management scenario	IRR
Set stocking rate	-0.09%
Retain core herd	
Retain herd structure	-0.28%
Retain core breeders	-0.26%
Drought responsive	
Natural increase	-1.57%
Purchase PTIC cows	1.45%
Repurchasing the herd	1.70%
Trading steers	0.50%
Agistment income	0.19%
Fully flexible	
Natural increase	-4.44%

Table 79 indicates the marginal return gained by moving from the Retain herd structure scenario to the Fully flexible with natural increase scenario. The very large negative return indicates that such a change would substantially reduce the profitability of the enterprise.

Table 79 - Marginal returns expressed as net present value (NPV) over a 30-year investment period for the change from Retain herd structure to Fully flexible with natural increase scenario

Factor	Value
Interest rate for NPV	5.00%
NPV	-$1,037,400
Annualised NPV	-$67,500
Peak deficit (with interest)	-$4,018,700
Years to peak deficit	27
Payback year	n/a
Payback period (years)	n/a

Table 80 indicates the annual difference in the GRASP-predicted AE (the carrying capacity) and the AE able to be achieved by the herd through natural increase alone (Dynama output). The property was under-stocked for 25 out of the 30 years of the economic analysis.

Table 80 – GRASP-predicted adult equivalents (AE) and the AE achieved by the Fully flexible with natural increase herd in Dynama over 30 years

Year	GRASP-predicted AE	Dynama Fully flexible with natural increase AE	Difference (AE)
1988	510	632	-122
1989	255	323	-67
1990	888	309	579
1991	2605	258	2,347
1992	6416	182	6,234
1993	2220	176	2,043
1994	856	196	660
1995	2566	222	2,345
1996	3544	236	3,308
1997	1918	269	1,649
1998	2348	301	2,048
1999	1600	334	1,266
2000	4718	398	4,320
2001	5968	437	5,531
2002	5141	445	4,696
2003	2219	456	1,762
2004	1516	505	1,011
2005	2290	519	1,771
2006	642	573	69
2007	1107	657	450
2008	1593	709	884
2009	1587	797	791
2010	3287	895	2,392
2011	5047	1006	4,042
2012	4216	1063	3,153
2013	2447	1074	1,372
2014	1689	930	760
2015	320	571	-251
2016	90	343	-253
2017	253	539	-286

Under the Fully flexible with natural increase strategy the property had up to 6,234 AE/annum spare grazing capacity after the significant sell down occurred in 1988 and 1989. Some options for filling this gap in property carrying capacity include:

- re-purchasing the components of the herd that were sold to rebuild numbers to the long-term herd structure;
- the purchase of steers as turnover stock. That is, they are purchased specifically as a trading option to be sold once they reach a target weight;
- taking cattle on agistment.

Scenario 4b - Fully flexible with repurchasing the herd

'Buying back the herd' is a strategy aimed at getting the whole herd back into full production as soon as possible. In this example, the stock purchased were a mix of sufficient PTIC cows and other stock to consume the spare feed supply indicated by the Fully flexible GRASP AE output. Prices paid for purchase stock were equivalent to the long-term sale price for the class of stock being purchased plus approximately $30 to $50/head transport and handling costs, depending upon the class of stock purchased. It can be seen that the strategy of Fully flexible with repurchasing the herd caused a large cash flow deficit while the herd was being rebuilt (Figure 48).

Figure 48 - Comparative cash flow over 30 years for five grazing management strategies including the Fully flexible with repurchasing the herd strategy

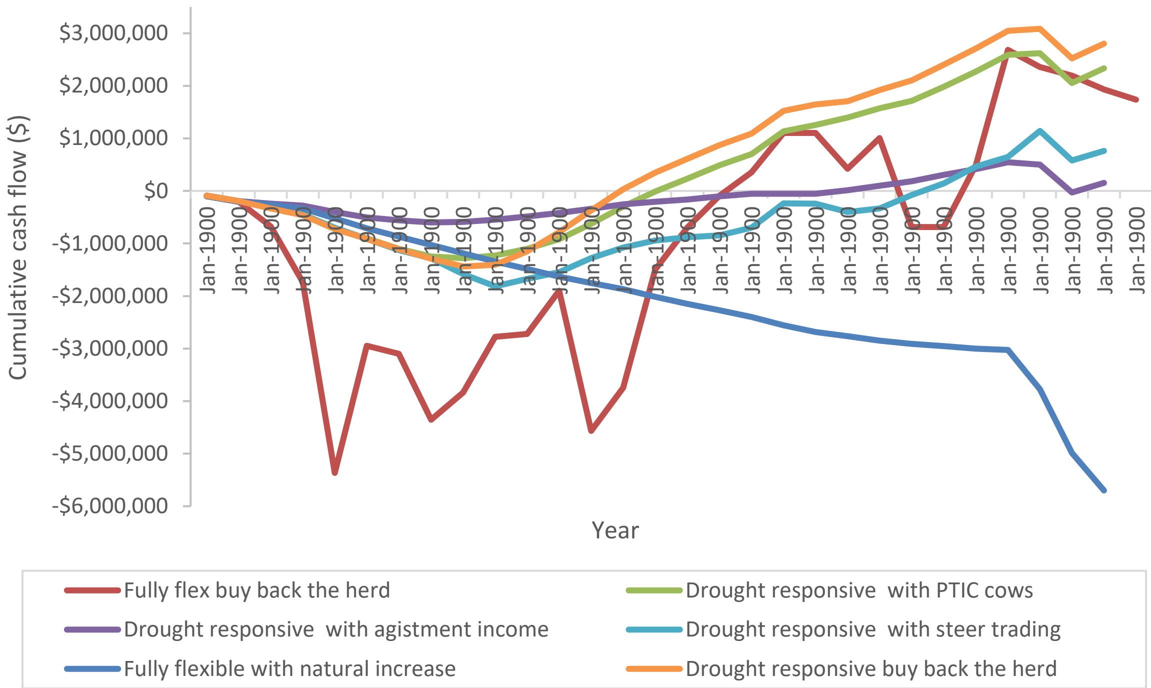


Table 81 indicates the property-level investment returns generated by each grazing management scenario assessed so far. As for the Drought responsive with either PTIC cow purchase or repurchasing the herd scenarios, the Fully flexible with repurchasing the herd scenario resulted in a positive IRR, although <1.0% .

Table 81 – Property level investment return expressed as internal rate of return (IRR) over 30 years for the Fully flexible with natural increase scenario and, for comparison, all other grazing scenarios

Grazing management scenario	IRR
Set stocking rate	-0.09%
Retain core herd	
Retain herd structure	-0.28%
Retain core breeders	-0.26%
Drought responsive	
Natural increase	-1.57%
Purchase PTIC cows	1.45%
Repurchasing the herd	1.70%
Trading steers	0.50%
Agistment income	0.19%
Fully flexible	
Natural increase	-4.44%
Repurchasing the herd	0.70%

Table 82 indicates the marginal return gained by moving from the Retain herd structure scenario to the Fully flexible with repurchasing the herd scenario. Although the NPV was positive, the peak deficit should be sufficient in size to scare most managers away from this strategy.

Table 82 - Marginal returns expressed as net present value (NPV) over a 30-year investment period for the change from Retain herd structure to Fully flexible with repurchasing the herd scenario

Factor	Value
Interest rate for NPV	5.00%
NPV	$230,800
Annualised NPV	$15,000
Peak deficit (with interest)	-$3,817,500
Years to peak deficit	13
Payback year	n/a
Payback period (years)	n/a

Scenario 4c – Fully flexible with trading steers

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 at the time the decision is being made using current and expected prices for each class, and expected weight gains, to confirm which alternative may be lower risk and more profitable. The Bullocks program can assess the purchase of dry stock and the Cowtrade program can 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/AE after interest over the relevant time period. Where cattle are purchased to be traded, the choice of which class of stock to purchase should be reassessed at each time purchases are being contemplated.

An example for the annual trading of steers is presented to show a process for assessing the potential benefits and risks, not to identify a recommended course of action. Yearling steers were purchased in June of each year to match the spare AE and weight gains calculated by GRASP for that year. They were purchased at the average 18 month-old steer weight in June of each year and at the expected price for the same class of yearling steers. Transport and induction costs were added to the purchase price of the steers. They were sold at the selling price, selling costs and estimated weight of the same cohort of steers 12 months later.

The number of steers purchased was decided by the AE rating for the steers (which could vary according the GRASP-derived estimated of opening weight and weight gain for each period) and the spare grazing capacity available as the breeding herd returned to normal size. Table 83 shows the data used to calculate the costs and benefits of steer trading. Steers were not purchased in all years and purchases and sales were offset by one year in the Dynamaplus model. It is evident that in some years steers were traded at a loss.

Table 83 – Data used in the steer trading analysis for the Fully flexible with trading steers scenario

Steer sales occurred 1 year after purchase; AE = adult equivalent

Year	Available AE	Number of steers purchased	Opening weight (kg)	Closing weight (kg)	Total $ purchases	Total $ sales net of selling costs
1988	-122	0	339	405	$0	0
1989	-67	0	228	377	$384,587	$0
1990	579	843	228	397	$1,729,416	$517,382
1991	2,347	2,383	366	530	$5,399,666	$1,976,003
1992	6,234	6,958	392	424	$1,655,211	$4,576,138
1993	2,043	3,387	245	304	$452,289	$1,567,486
1994	660	938	241	399	$1,789,174	$579,666
1995	2,345	2,981	302	414	$2,564,301	$1,912,245
1996	3,308	4,053	319	424	$1,233,728	$2,670,110
1997	1,649	1,942	320	453	$1,592,503	$1,366,396
1998	2,048	2,243	358	473	$899,345	$1,656,399
1999	1,266	1,321	343	529	$3,209,497	$1,092,180
2000	4,320	3,707	438	623	$4,217,085	$3,626,417
2001	5,531	4,939	432	587	$3,765,370	$4,550,183
2002	4,696	4,655	409	509	$1,406,132	$3,706,133
2003	1,762	2,092	339	428	$760,872	$1,387,879
2004	1,011	1,302	294	413	$1,467,197	$832,490
2005	1,771	2,292	322	381	$49,609	$1,343,481
2006	69	101	246	377	$350,443	$58,427
2007	450	488	362	478	$698,231	$363,006
2008	884	951	370	475	$579,504	$704,118
2009	791	893	327	479	$1,834,927	$666,849
2010	2,392	2,457	377	509	$3,015,860	$1,955,304
2011	4,042	4,040	376	534	$2,508,068	$3,375,696
2012	3,153	3,126	405	513	$1,078,649	$2,505,847
2013	1,372	1,501	362	470	$714,050	$1,099,931
2014	760	997	361	332	$0	$506,470
2015	-251	0	202	150	$0	$0
2016	-253	0	38	-38	$0	$0
2017	-286	0	-3	126	$0	$0

Figure 49 indicates that, in this example, the significant additional interest and other transaction expenses incurred in trading yearling steers is likely to initially reduce the cumulative cash flow below that of the other options. The capacity of the property to fund the steer purchases may also be a relevant factor to consider. The steer trading model would be more risky than the other options. No assessment of the price risk associated with trading cattle in this environment was included.

Figure 49 - Comparative cash flow over 30 years for five grazing management scenario including the Fully flexible with trading steers scenario

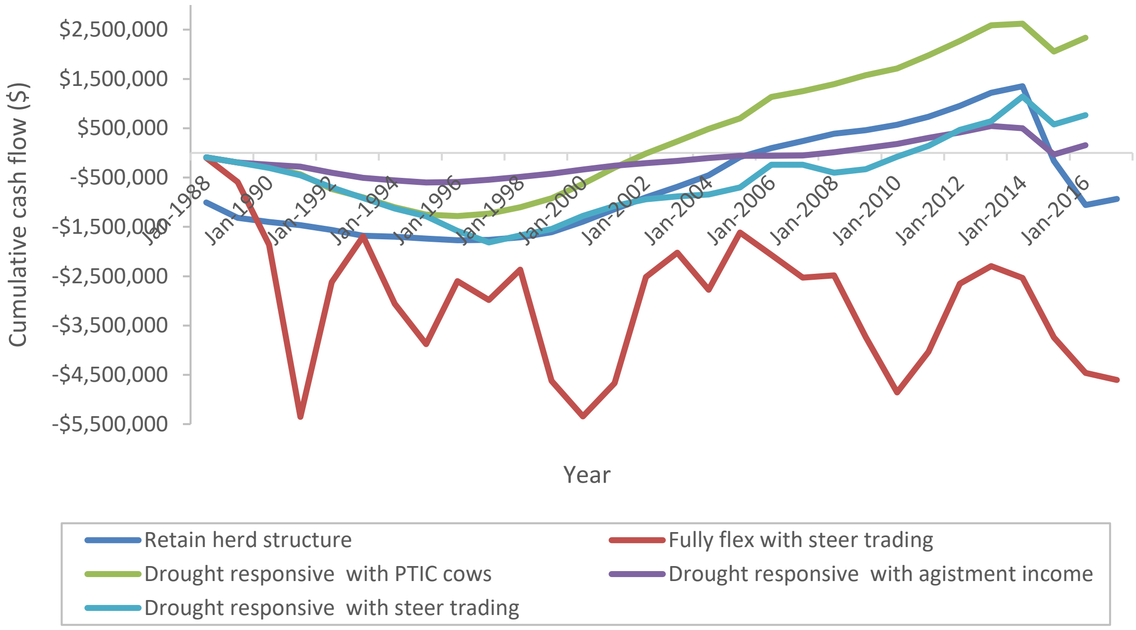


Table 84 indicates the property-level investment returns generated by each grazing management scenario assessed so far. The Fully flexible with trading steers scenario resulted in a negative IRR, primarily due to the large numbers of steers being traded at a loss in some years to match the extreme variation in TSDM between years.

Table 84 – Property level investment return expressed as internal rate of return (IRR) over 30 years for the Fully flexible with trading steers scenario and, for comparison, all other grazing scenarios

Grazing management scenario	IRR
Set stocking rate	-0.09%
Retain core herd	
Retain herd structure	-0.28%
Retain core breeders	-0.26%
Drought responsive	
Natural increase	-1.57%
Purchase PTIC cows	1.45%
Repurchasing the herd	1.70%
Trading steers	0.50%
Agistment income	0.19%
Fully flexible	
Natural increase	-4.44%
Repurchasing the herd	0.70%
Trading steers	-2.60%

Table 85 indicates the marginal return gained by moving from the Retain herd structure scenario to the Fully flexible with trading steers scenario. It is evident that trading large numbers of steers with a small, and sometimes negative, margin exposes the property to significant risk.

Table 85 – Marginal returns expressed as net present value (NPV) over a 30-year investment period for the change from Retain herd structure to Fully flexible with trading steers

Factor	Value
Interest rate for NPV	5.00%
NPV	-$2,184,900
Annualised NPV	-$142,100
Peak deficit (with interest)	-$7,504,400
Years to peak deficit	23
Payback year	n/a
Payback period (years)	n/a

Scenario 4d – Fully flexible with agistment income

In this scenario, sufficient cattle were taken on agistment following drought to match any spare carrying capacity as indicated by GRASP. The difference in AE count between the Fully flexible herd and the GRASP output was allocated to agistment from 1990 onwards. Table 86 shows the additional income available from long-term agistment taken while the breeder herd was rebuilt if $2/AE.week was received for 50 weeks of the year. Agistment income was received until 2014 in this scenario.

Table 86 - Potential extra income from agisting the spare carrying capacity (adult equivalents; AE) of the property while the herd rebuilt following drought for the Fully flexible with agistment income scenario (compared to Fully flexible with natural increase)

Year	GRASP AE	Dynama Fully flexible with natural increase AE	Difference in AE	Agistment income
1988	510	632	-122	nil
1989	255	323	-67	nil
1990	888	309	579	$57,901
1991	2,605	258	2,347	$234,701
1992	6,416	182	6,234	$623,388
1993	2,220	176	2,043	$204,344
1994	856	196	660	$66,032
1995	2,566	222	2,345	$234,459
1996	3,544	236	3,308	$330,796
1997	1,918	269	1,649	$164,855
1998	2,348	301	2,048	$204,791
1999	1,600	334	1,266	$126,566
2000	4,718	398	4,320	$431,999
2001	5,968	437	5,531	$553,063
2002	5,141	445	4,696	$469,566
2003	2,219	456	1,762	$176,221
2004	1,516	505	1,011	$101,107
2005	2,290	519	1,771	$177,074
2006	642	573	69	$6,904
2007	1,107	657	450	$45,015
2008	1,593	709	884	$88,385
2009	1,587	797	791	$79,065
2010	3,287	895	2,392	$239,175
2011	5,047	1,006	4,042	$404,178
2012	4,216	1,063	3,153	$315,259
2013	2,447	1,074	1,372	$137,234
2014	1,689	930	760	$75,956
2015	320	571	-251	nil
2016	90	343	-253	nil
2017	253	539	-286	nil

Figure 50 indicates the cumulative cash flow if the spare grazing capacity was filled by stock on agistment at $2/AE.week. Whether this is possible is unknown but higher or lower rates of income from agistment are easily tested in the model. Taking cattle on agistment provided significant protection of cash balances in the early years of the 1990s while the herd was rebuilding after the destocking phase during the 1980s. However, it is evident that feeding hay to the herd at the end of the 30-year period does some serious damage to the cash flow. The strategy appears to be less risky, but also less profitable, than repurchasing the herd. The low profitability exposes the property to significant losses once hay feeding begins in 2014. However, having $2M in the bank in 2014, and taking no real risk to that point, would make most managers think this was a successful strategy!

Obviously, timing the herd reduction prior to the need to feed hay would be critical to success of this strategy. This was not possible in this modelling exercise due to the constraint of only one reduction/year in livestock numbers, on 1 May.

Figure 50 - Cumulative cash flow over 30 years for the Fully flexible with agistment income strategy and four other grazing management strategies for comparison

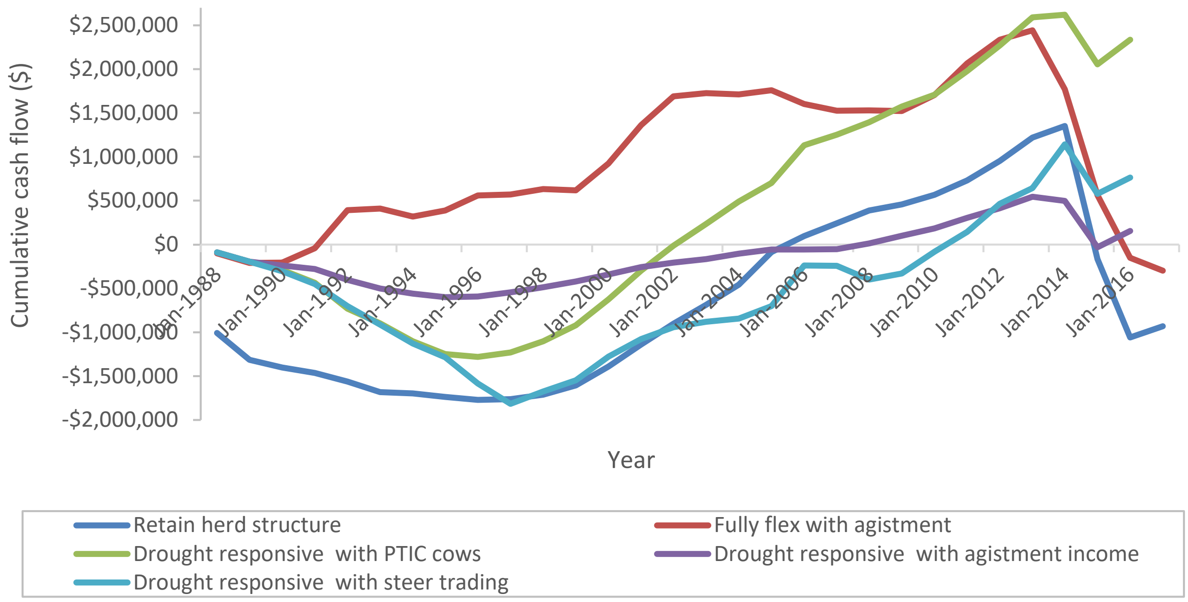


Table 87 indicates the property-level investment returns generated by each grazing management scenario assessed so far. The Fully flexible with agistment income scenario resulted in a negative IRR, primarily due to the large hay feeding expense on the final years of the analysis due to the constraint of only one reduction/year in livestock numbers, on 1 May.

Table 87 – Property level investment return expressed as internal rate of return (IRR) over 30 years for the Fully flexible with trading steers scenario and, for comparison, all other grazing scenarios

Grazing management scenario	IRR
Set stocking rate	-0.09%
Retain core herd	
Retain herd structure	-0.28%
Retain core breeders	-0.26%
Drought responsive	
Natural increase	-1.57%
Purchase PTIC cows	1.45%
Repurchasing the herd	1.70%
Trading steers	0.50%
Agistment income	0.19%
Fully flexible	
Natural increase	-4.44%
Repurchasing the herd	0.70%
Trading steers	-2.60%
Agistment income	-0.11%

Table 88 indicated a positive marginal return was gained by moving from the Retain herd structure strategy to the Fully flexible with agistment income strategy.

Table 88 - Marginal returns expressed as net present value (NPV) over a 30-year investment period for the change from Retain herd structure to Fully flexible with agistment income scenario

Factor	Value
Interest rate for NPV	5.00%
NPV	$1,387,400
Annualised NPV	$90,300
Peak deficit (with interest)	0
Years to peak deficit	n/a
Payback year	n/a
Payback period (years)	n/a

4.1.3.2 Effect of grazing management strategies on pasture and land condition

The long-term percentage of perennial grass species (on a DM basis) in the pasture is used as a key indicator of the pasture and land condition (A land condition >77%, B = 41-77%, C = 7.5-40%, D <7.5; from Scanlan *et al.* 2014, Walsh and Cowley 2016). In this study we determined the annual percentage of perennial grasses over 36 years. Figure 51 to Figure 56 show the annual percentage of perennial pasture species (DM basis) on the six land types for each of the four grazing management strategies over 36 years of GRASP simulation. The different grazing management strategies resulted in fluctuations in the annual percentage of perennial grasses over time, reflecting the year-to-year rainfall variability as well as the level of pasture utilisation applied by the management strategy.

Linear regressions were fitted to each of the trend lines in Figure 51 to Figure 56 to determine if the slopes were significantly different from zero ($P < 0.05$). The results of a grouped regression analysis comparing the four grazing managements strategies within each land type over 36 years are presented in Table 89 and indicate that:

- The trend in annual percentage of perennial grasses in the Set stocking rate strategy was positive ($P < 0.001$) for all land types.
- The Retain core herd strategy produced more varied results across land types with no trend in percentage of perennial grasses for two land types ($P > 0.05$; 64% of property area), a negative trend for two land types ($P < 0.05$; 26% of property area) and a positive trend for two remaining land types ($P < 0.05$; 10% of property area).
- The Drought responsive strategy resulted in a positive trend in the modelled percentage of perennial grasses for four land types representing the greatest proportion of the property (P =/< 0.05; 75% of property area), no trend for the Wooded downs land type ($P > 0.05$; 21% of property area) and a negative trend for the Open alluvia land type ($P < 0.05$; 5% of property area).
- The Fully flexible strategy resulted in a decrease in the percentage of perennial grasses for all land types ($P < 0.001$).

However, there was considerable variation around the fitted regressions for some treatment x land-type combinations. The analysis indicated that regressions explained > 70% of the variation across all land types (range across the six land types of r^2=69.8 to 90.0). For all land types and all stocking rate strategies, there was a decrease in annual percentage perennial grass in the pasture over the first 6 years of the analysis (1982-1988) after which there was a steep increase for the following 3 years to 1991. Both changes reflected the rainfall patterns. However, there was only a small difference between treatments in absolute value of percentage perennial grass after the first 9 years of analysis (to 1991). This outcome is consistent with the results of long-term grazing trials on native pasture communities in Queensland (Silcock *et al.* 2005; Orr *et al.* 2010; Orr and Phelps 2013; O'Reagain *et al.* 2014; Hall *et al.* 2017), which indicate that it may take decades for the long-term effects of high levels of pasture utilisation to impact the percentage of perennial grasses within a pasture.

In the GRASP simulations reported here, greater differences between the percentage of perennial grasses (%P) in the pasture between treatments were observed after Year 10. Table 90 indicates the 36-year average of percentage perennial grasses, the final 5-year average of percentage perennial grasses, and the change in percentage perennial grasses and land condition rating from starting values (ca. 69% and B, respectively). These results indicate that:

- The annual percentage of perennial grasses increased over time for all land types under the Set stocking rate strategy (>20% increase; property-level, final-5-years average %P 86%) while the 36-year property average (70%) was the same as the initial level of 69%.
- The Retain core herd strategy resulted in substantial decreases in the percentage perennials (21-40% decrease; property-level, final-5-years average %P 49%) for all land types except Soft gidgee cleared and pulled.
- The Drought responsive stocking strategy resulted in very little change in percentage perennials (property-level, final-5-years average %P 68%) except for the Open alluvia (23% decrease) and Soft gidgee - cleared (17% increase).
- The Fully flexible stocking strategy decreased the annual percentage of perennial grasses over time for all land types (≥65% decrease for all except Soft gidgee - cleared which showed a 35% decrease). The property-level, final-5-years average %P was 24%.

In conclusion, while the average percentage of perennial grass over 36 years was maintained at the initial level of ca. 70% for the Set stocking rate strategy, both the analysis of 36-year trend lines, and the change from Year 1 to the average of Years 32-36, for percentage perennials indicated that the Set stocking rate strategy improved the annual percentage of perennial grass in the pasture. In contrast, the Fully flexible stocking strategy substantially decreased annual percentage of perennial grass over 36 years. The Drought responsive stocking strategy either maintained or improved the percentage of perennial grass other than for the sensitive Open alluvia land type. The Retain core herd strategy gave mixed results across land types and methods of analysis but either maintained or decreased the percentage of perennial grass across the majority of the property area.

The modelled increase in annual percentage perennials over 36 years under the Set stocking strategy reflects, (i) the year-to-year sequence of years from 1982 to 2017, and (ii) the boundaries put on the model in terms of (a) fixed livestock numbers and (b) maintaining overall perennial grasses at ca. 70%. While this was important to set a baseline on which to compare other grazing management strategies, the inability to increase cattle numbers to use the pasture available contributed to low pasture utilisation and therefore increased % perennial grass.

These results should be interpreted in light of the limitations of the modelling approach which include, (i) the inability to change animal numbers more than once per year, which does not reflect commercial management or best-practice recommendations, (ii) the lack of feedback to GRASP for any animal productivity parameters (e.g. the actual herd and AE numbers predicted from Dynamaplus due to changed conception rates, weaning rates and mortalities, or for changed pasture intake due to supplementation), and (iii) the rigidity of decision making in a modelling framework not reflecting the fluidity of decision-making in the real world.

Figure 51 – Change in the percentage of perennial grasses in the annual pasture biomass growth over 1982-2017 for the Open downs land type (Paddocks 3-6; 59% of total property area) under four alternative grazing management strategies of Set stocking rate, Retain core herd, Drought responsive and Fully flexible stocking

A linear regression for each grazing management strategy is presented with the equation provided below the corresponding strategy in the legend

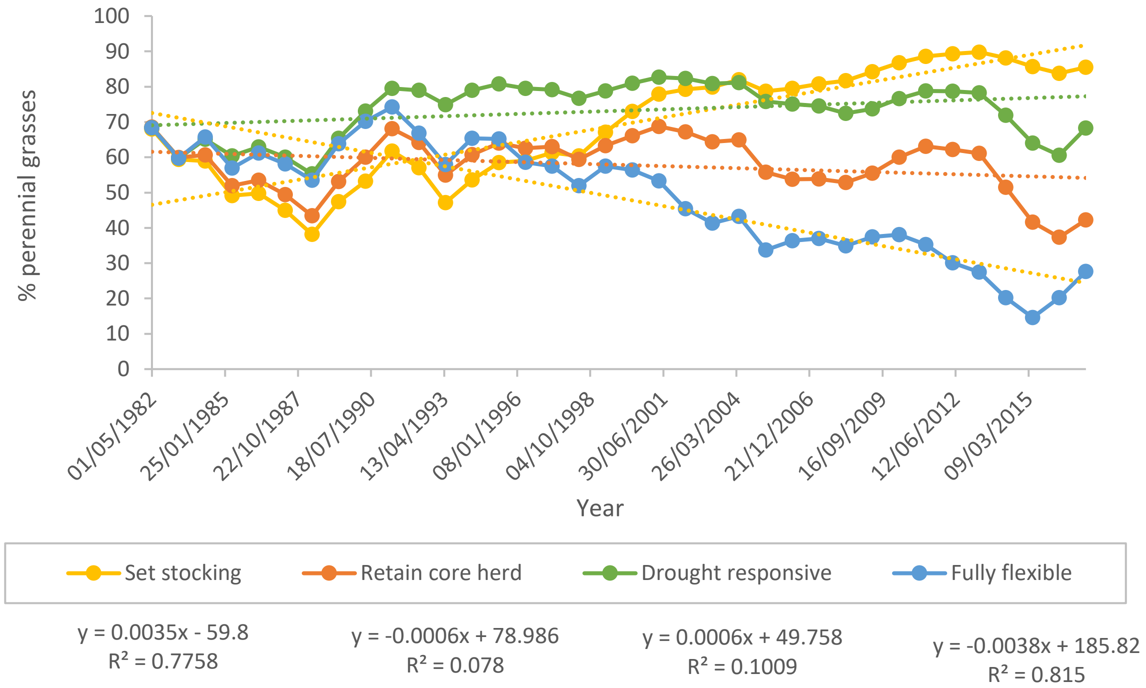


Figure 52 – Change in the percentage of perennial grasses in the annual pasture biomass growth over 1982-2017 for the Wooded downs land type (Paddocks 8-10; 21% of total property area) under four alternative grazing management strategies of Set stocking rate, Retain core herd, Drought responsive and Fully flexible stocking

A linear regression for each grazing management strategy is presented with the equation provided below the corresponding strategy name in the legend

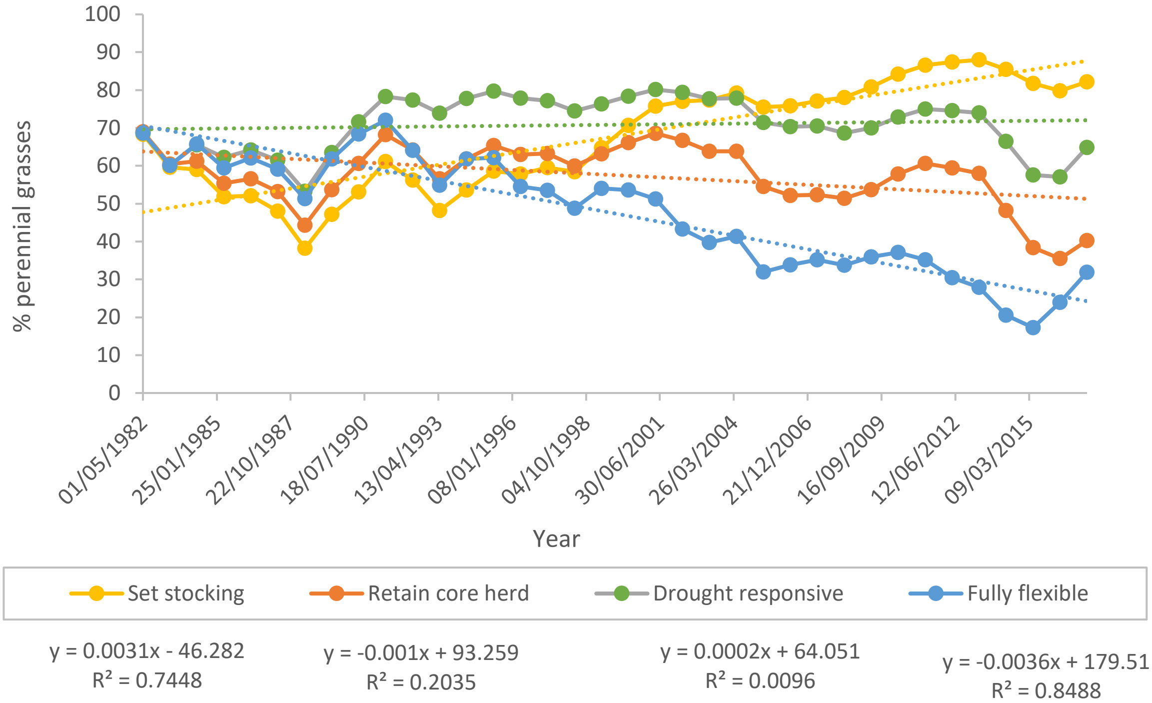


Figure 53 – Change in the percentage of perennial grasses in the annual pasture biomass growth over 1982-2017 for the Soft gidgee land type cleared of timber (Paddock 7a; 7% of total property area) under four alternative grazing management strategies of Set stocking rate, Retain core herd, Drought responsive and Fully flexible stocking

A linear regression for each grazing management strategy is presented with the equation provided below the corresponding strategy name in the legend

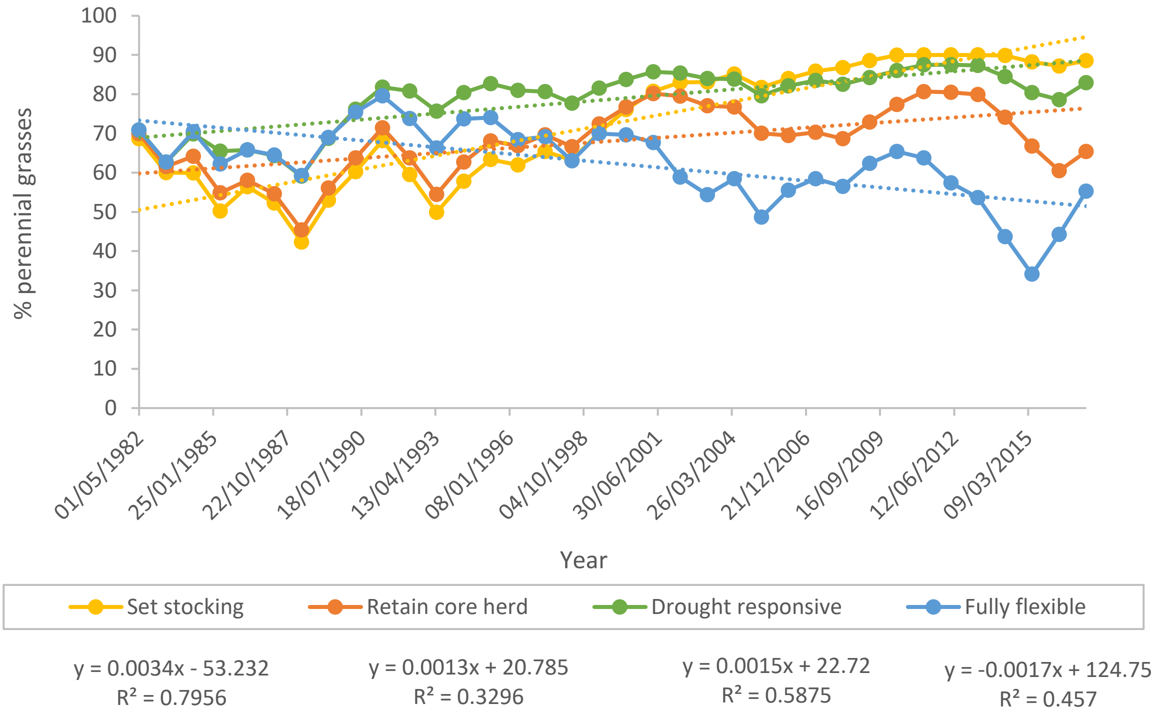


Figure 54 – Change in the percentage of perennial grasses in the annual pasture biomass growth over 1982-2017 for the Soft gidgee land type, wooded (Paddock 7b; 7% of total property area) under four alternative grazing management strategies of Set stocking rate, Retain core herd, Drought responsive and Fully flexible stocking

A linear regression for each grazing management strategy is presented with the equation provided below the corresponding strategy name in the legend

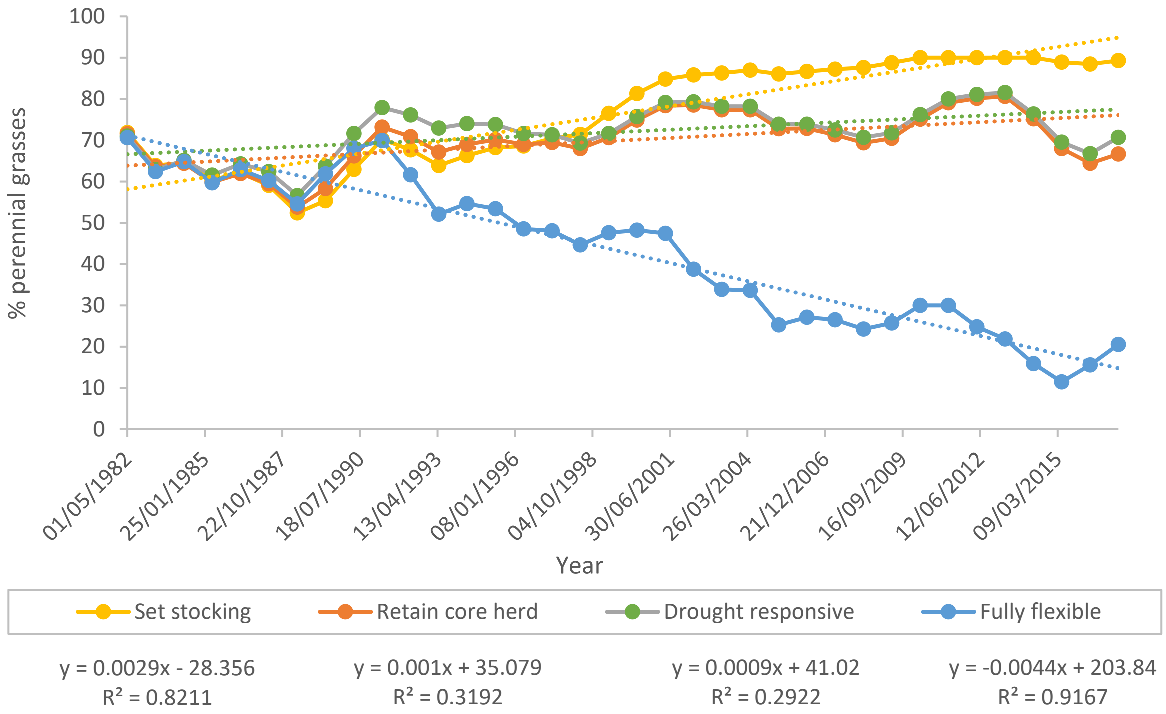


Figure 55 – Change in the percentage of perennial grasses in the annual pasture biomass growth over 1982-2017 for the Boree wooded downs land type (Paddock 1); 5% of total property area) under four alternative grazing management strategies of Set stocking rate, Retain core herd, Drought responsive and Fully flexible stocking

A linear regression for each grazing management strategy is presented with the equation provided below the corresponding strategy name in the legend

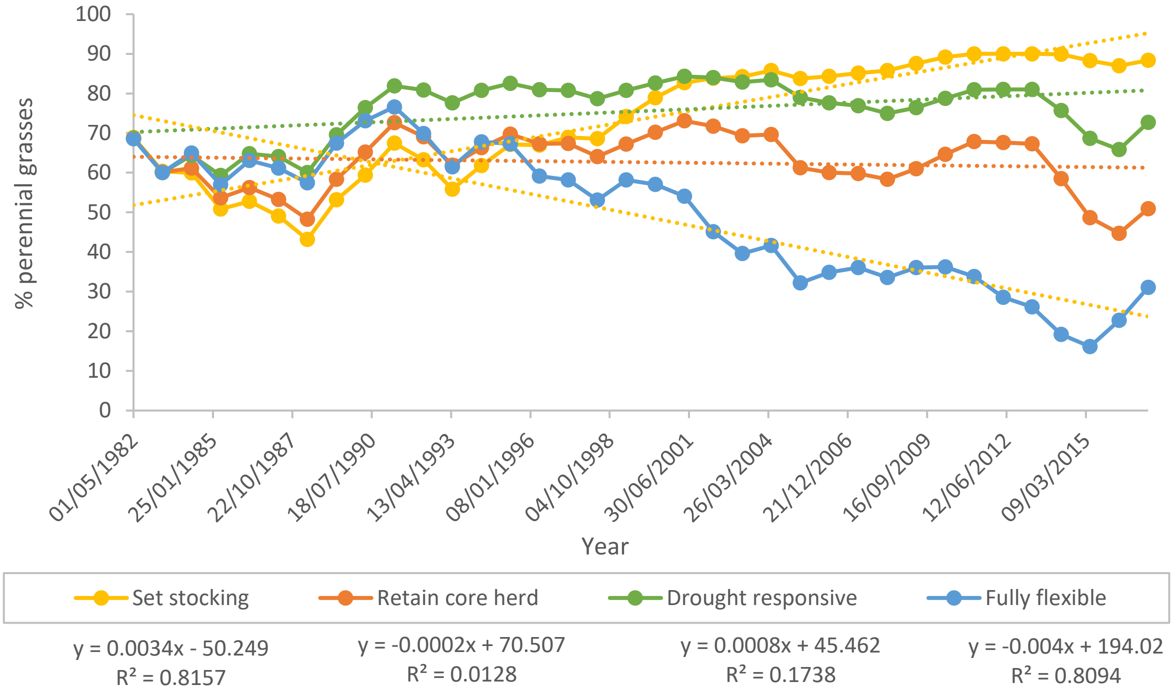


Figure 56 – Change in the percentage of perennial grasses in the annual pasture biomass growth over 1982-2017 for the Open alluvia land type (Paddock 2); 5% of total property area) under four alternative grazing management strategies of Set stocking rate, Retain core herd, Drought responsive and Fully flexible stocking

A linear regression for each grazing management strategy is presented with the equation provided below the corresponding strategy name in the legend

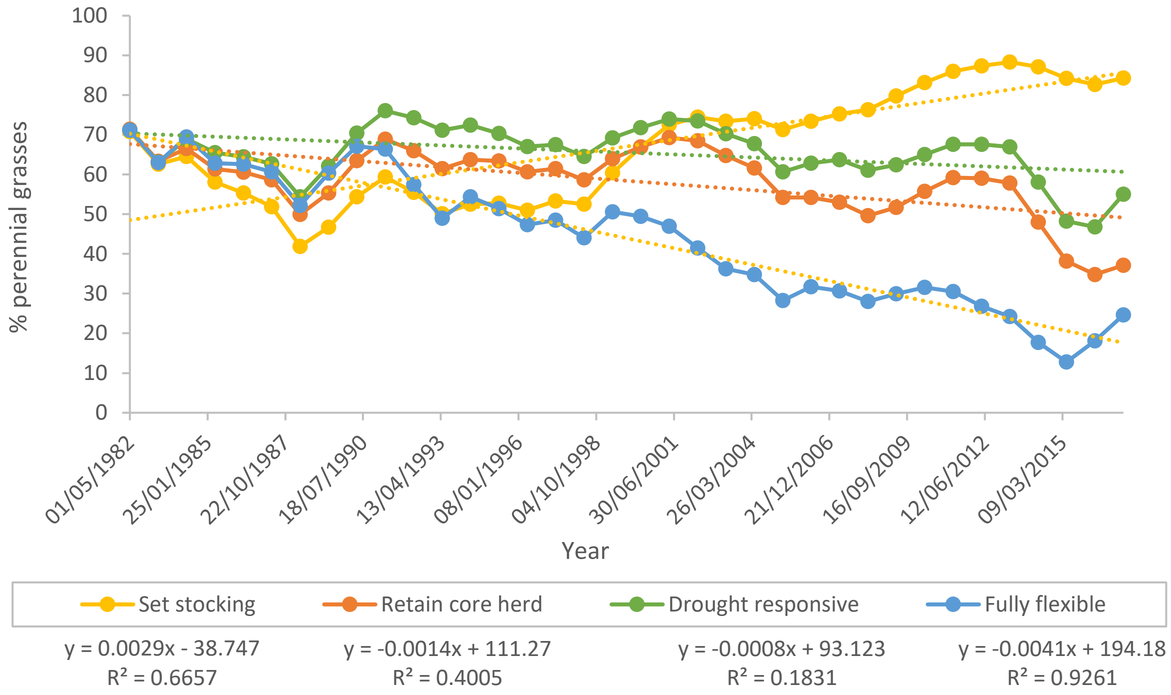


Table 89 – Slope and significance of the regression for trend in annual percentage perennial grass (%P) in the pasture biomass over 36 years of implementing one of four grazing management strategies

Grazing management strategy	**Land type and area as a % of total property**					
	Open downs (59%)	**Wooded downs (21%)**	**Soft gidgee, cleared (7%)**	**Soft gidgee, wooded (3%)**	**Boree wooded downs (5%)**	**Open alluvia (5%)**
Set stocking rate	0.0035 (*P*<0.001)	0.0031 (*P*<0.001)	0.0035 (*P*<0.001	0.0029 (*P*<0.001)	0.0034 (P<0.001)	0.0029 (P<0.001)
Retain core herd	-0.0006 (*P*=0.078)	-0.0010 (*P*=0.002)	0.0013 (*P*<0.001)	0.0010 (*P*<0.001)	-0.0002 (P=0.489)	-0.0015 (P<0.001)
Drought responsive	0.0006 (*P*=0.051)	0.0002 (*P*=0.458)	0.0015 (*P*<0.001)	0.0009 (*P*<0.001)	0.0008 (P=0.009)	-0.0008 (P=0.010)
Fully flexible	-0.0038 (*P*<0.001)	-0.0036 (*P*<0.001)	-0.0017 (P<0.001)	-0.0044 (*P*<0.001)	-0.0040 (P<0.001)	-0.0041 (P<0.001)
r^2	77.6	77.4	69.8	90.0	80.7	81.0

Table 90 – Change in percentage perennial grass (%P) in the pasture biomass over 36 years of implementing one of four grazing management strategies (Set stocking rate, Retain core herd, Drought responsive stocking, or Fully flexible stocking)

The percentage of perennial grass species (on a DM basis) in the pasture is used as a key indicator of the pasture and land condition: A land condition >77%, B = 41-77%, C = 7.5-40%, D <7.5 (from Scanlan et al. 2014, Walsh and Cowley 2016)

Grazing management strategy	**Land type**					
	Open downs	**Wooded downs**	**Soft gidgee, cleared**	**Soft gidgee, wooded**	**Boree wooded downs**	**Open alluvia**
Area as a % of the total property area (16,200 ha)	59	21	7	3	5	5
Set stocking rate						
36-year average %P	69	68	73	76	74	67
Land condition category based on 36-year average %P	B	B	B	B	B	B
Final-5-years average %P	86.6	83.5	88.8	89.3	88.7	85.3
% change in %P from Year 1 (ca. 69%)	27.2	22.2	29.4	24.3	28.8	20.5
Land condition category based on final 5 years %P	A	A	A	A	A	A
Retain core herd						
36-year average %P	58	57	68	70	63	47
Land condition category based on 36-year average %P	B	B	B	B	B	B
Final-5-years average %P	46.8	44.1	69.3	71.0	54.0	43.2
% change in %P from Year 1 (ca. 69%)	-31.8	-36.1	-0.8	-0.8	-21.4	-39.5
Land condition category based on final 5 years %P	B	B	B	B	B	B
Drought responsive						
36-year average %P	73	70	79	72	66	55
Land condition category based on 36-year average %P	B	B	A	B	B	B
Final-5-years average of %P	68.6	64.0	82.8	73.0	72.8	55.0
% change in %P from Year 1 (ca. 69%)	0.3	-6.8	16.8	2.8	6.1	-22.7
Land condition category based on final 5 years %P	B	B	A	B	B	B
Fully flexible						
36-year average %P	48	47	62	43	49	44
Land condition category based on 36-year average %P	B	B	B	B	B	B
Final-5-years average of %P	22.0	24.3	46.2	17.1	23.1	19.5
% change in %P from Year 1 (ca. 69%)	-67.8	-64.6	-34.8	-75.8	-66.4	-72.5
Land condition category based on final 5 years %P	C	C	B	C	C	C

5 Assessing key strategies that may be applied in response to drought in beef production systems

5.1 Introduction

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 influences 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; Bowen and Chudleigh 2018*a*). Knowledge and tools to assess the relative short and longer-term profitability of various strategies that can be applied prior to, during, and after a drought would assist managers to evaluate various destocking options for relative profitability and risk and potentially 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 it is more efficient to provide 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 representative, base beef cattle herd. Additional examples for both response and recovery strategies are available in the accompanying reports completed for other regions as part of this project (e.g. Bowen and Chudleigh 2018*b*; Bowen *et al.* 2019).

5.2 Methods

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

5.3 Results and discussion

5.3.1 Reducing grazing pressure by culling dry females and pregnancy tested 'empty' (PTE) cows

In a circumstance where it is apparent early in the New Year that normal numbers of cattle may need to be reduced, there will be a group of females in the breeding herd that were PTIC the previous year but have subsequently lost, or will lose, their calf. Table 91 shows the expected average herd structure and identifies the PTIC empty breeders (females that have a positive pregnancy test but then lose the calf prior to branding or weaning). About 40 cows will fall into this category in the base herd and will be identifiable as dry breeders at weaning time.

Although these PTIC empty 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. Although this action may reduce weaner numbers in 15-18 months' time, their sale 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 is not already practiced, then it may be an easy way to reduce grazing pressure early in the year and can coincide with any early weaning activities being undertaken. The only way these cows can be identified is to keep an accurate record of individual breeder reproduction performance.

A substantial component of the herd are mothers of weaners that can soon be pregnancy tested and their status revealed. The usually lower than normal conception rates that occur over a dry summer make it likely that a number of PTE cows will be identified and a higher than normal culling rate can be applied at weaning to reduce grazing pressure. The PTE group of cows at weaning represent a significant opportunity to reduce cow numbers early in a drought.

Table 91 - Herd status showing pregnancy tested in calf (PTIC) empty cows (females that have had a positive pregnancy test but then lost a calf prior to branding or weaning)

Cow age of culling is 13 years old; PTIC empties shaded grey

	Joining age group											
Herd structure parameter	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Opening breeders	199	133	110	79	61	47	36	27	21	16	13	10
Number mated	0	133	110	79	61	47	36	27	21	16	13	10
Conception (%)	0	87	75	80	80	80	80	81	81	81	81	81
Conception losses (%)	0	15	5	7	7	7	7	9	9	9	9	9
Sale of empties (%)	0	100	100	100	100	100	100	100	100	100	100	100
Number able to mate	0	133	110	79	61	47	36	27	21	16	13	10
Number pregnant	0	115	82	63	49	37	29	22	17	13	10	8
Number empty	0	17	27	16	12	9	7	5	4	3	2	2
Number PTIC empties	0	17	4	5	3	3	2	2	2	1	1	1
Number remaining pregnant	0	98	78	59	45	35	27	20	16	12	9	7
Number empties sold	0	17	27	16	12	9	7	5	4	3	2	2
Total sold	0	17	27	16	12	9	7	5	4	3	2	2
Number retained	0	115	82	63	49	37	29	22	17	13	10	8
Calves weaned	0	98	78	59	45	35	27	20	16	12	9	7

5.3.2 Reducing liveweight loss of breeders by early weaning

Early weaning is the most effective strategy to reduce live weight 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 individual liveweight by ca. 10 kg/month, the management decision to wean a breeder 3 months early results in a breeder 30+ kg heavier mid-year cf. an unweaned breeder.

Early weaning in about March would lead to approximately 400 weaners with an average weight of about 115 kg needing supplementary feeding. 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 application of the program Splitsal (Holmes *et al.* 2017) to the expected weaner weights at an early weaning indicated that if the mob of weaners had a standard deviation of 15 kg liveweight, ca. 15% would be less than 100 kg and have an average weight of about 93 kg. The remaining 85% would be heavier than 100 kg and have an average weight of about 119 kg (Table 92). The Cowtrade program (Holmes *et al.* 2017) and spreadsheets can be used to determine the additional cost of supplementing the early weaners and this can be compared to the expected reduction in mortality rate and the improvement in reproduction efficiency in the breeders that had their calves weaned early. It is considered likely that early weaning would generally be the more economic option but this depends entirely upon the expected severity of the following season.

Table 92 - Splitsal analysis of expected weaning weight distribution in February

Parameter	Value
Average live weight of total group (kg)	115
Standard deviation of weights (kg)	15
Live weight range in total group for 95% of group, assuming a normal distribution (kg)	86-144
Cut-off weight for lighter group (kg)	100
% of total group above cut-off weight	85
Average weight of heavier group (kg)	119
Average weight of lighter group (kg)	93

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

5.3.3.1 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 with feed that 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.

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

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 after a failed season.

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 next section follows a format that highlights the key data required to assess the decision to sell or retain PTIC cows.

Estimating the current sale value is necessary to identify the opportunity costs of retaining the cows. Table 93 shows the calculation of the current on farm value of the cows. This value is required to estimate the relative merit of the alternative strategies.

Table 93 - Calculation of on property value of sale cattle

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 94 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.

Table 94 – Identification of the number and value of pregnancy tested in calf (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 95 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 was 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 was also identified.

Table 95 – Expected feeding and opportunity costs for retained pregnancy tested in calf (PTIC) 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 retained in the table suggest that the beef property was not worse off selling the cows now and replacing them in twelve months' time with cows and calves if they could be purchased for about $1,250 per unit. Table 96 reveals the sensitivity of the exercise to variation in the current sale price and the expected replacement cost. A positive value indicates it was better to hold the PTIC cows and feed them.

Table 96 - Sensitivity analysis for gain from holding and feeding pregnancy tested in calf (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 ($/kg liveweight)	Expected sale price of PTIC cow at the yards or works ($/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 the potential candidates for sale.

5.3.3.3 Considering culling from within cow, heifer and steer groups

Early weaning and the sale of a few PTIC empties will not do much to reduce grazing pressure if the season continues to deteriorate. Early in the drought, the herd is likely to have:

- ca. 400 early weaners sitting around the yards being fed,
- ca. 450 cows who have been weaned but whose pregnancy status is unknown,
- ca. 130, 2-3 year old heifers that have been mated,
- up to 200 heifers that will be selected from with the bulk to be mated at the end of the year, and
- ca. 400 steers that have another 6 or 18 months to go before their usual sale date.

There are two age groups of heifers that can be managed separately in a circumstance where it is apparent that the season may be short and normal numbers of cattle may need to be reduced. The heifers that are about 12+ months of age are a saleable item but are required over time to maintain the breeding herd. There are about 200 of these heifers and selling the lead may produce a cash flow and reduce grazing pressure. Culling and selling the tail will produce less cash but is likely to have a smaller impact on the future requirements of the breeding herd. The second cohort of heifers that are about 24 months of age are likely to be with the bulls and they can be sorted as early as April, with all heifers that are not pregnant (or not detectible) at that time viewed as candidates for sale. In a dry year, the conception rate in these heifers could be lower than normal with potentially a significant portion of these heifers available for sale.

One way of considering the choices, is to use the Cowtrade and Bullocks programs that are part of the Breedcow and Dynama suite of programs (Holmes *et al.* 2017). The Cowtrade program is used to calculate the prospective profitability of breeder groups (i.e. some of them will have or already have calves) while the Bullocks programs is used to calculate the prospective profitability for groups of steers and empty cows or heifers. The Cowtrade and Bullocks programs can also assist with decisions where sales are forced by drought or a variety of other circumstances.

When buying cattle to fatten or grow out, it is logical that the most profitable options (the options that provide the greatest future benefits) are the ones to choose. The profitability criterion for choosing between fattening or growing opportunities is nearly always the predicted gross margin per AE after interest. If finance is tight to the degree that the available pasture cannot be completely stocked, then the gross margin expressed as a percent of herd and expenses capital is a more satisfactory criterion. However, if selling stock to reduce grazing pressure or to relieve financial pressure, the object should be to achieve the grazing or financial objective with least damage to future income. That is, if the issue is grazing pressure, it is best to sell first those groups with the lowest gross margin per AE after interest. If the issue is financial, it is best to sell first those groups with the lowest percent return on livestock and expenses capital.

5.3.3.4 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. Such analyses will also be specific to the seasonal and financial circumstances prevailing at the time.

In a previous example, we considered the sale and repurchase of 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 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. This method uses the current value and future value of each class of stock together with costs associated with selling or holding to calculate a gross margin. The total gross margin for each class is divided by the number of AE to identify the class with, in effect, the lowest present value.

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 was used to test the decision to feed or sell the PTIC cows and then this result was compared to selling other classes of livestock. During this process, a number of key assumptions had 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 97 shows an example analysis of drought feeding options for the base herd. The scenario has the producer running out of feed for a group of PTIC cows and they can either be sold now (1st May) for $800/head net or held and fed. If they were sold, the decision was 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 was 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.

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 97 – Example Cowtrade analysis of a drought feeding option for the representative, base herd

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

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
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%*

5.3.3.5 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 other classes of dry stock that could be sold as an alternative to breeding females to reduce grazing pressure, the Bullocks program can be used to evaluate these options.

The Bullocks program can 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 is also 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 current and future sale (valuation) 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 be spread out over the property, reduce total grazing pressure and save 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. 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 98 shows the modified output from the Cowtrade analysis for this extended scenario. 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.

After adjusting the Cowtrade analysis 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 99 shows the expected sale weight (381 kg) of the steers if they were 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 live weight 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 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 the options and what it will take to make them work.

Table 98 - 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%' AE = adult equivalent

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
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 99 – Example drought sale analysis for steers using Bullocks

AE = adult equivalent

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%
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*

5.3.4 Agistment

The direct cost of agistment, if it is available, is relatively straight forward to calculate. Table 100 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 100 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.

Table 100 - 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*

6 General discussion

This study represents a detailed attempt to assess the economic implications of management decisions that can be applied to (i) prepare for, (ii) respond to, or (iii) recover from drought in the Central West Mitchell Grasslands of Queensland. In this analysis we have combined scenario analysis and bio-economic modelling to examine a range of management strategies and technologies that may contribute to building both more profitable and more drought resilient grazing businesses. The results of these analyses can be used to support informed decision making by property managers.

The information provided here should be used, firstly, as a guide to an appropriate method to assess alternative strategies aimed at improving the profitability and drought resilience of grazing properties in the Central West Mitchell Grasslands 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 or sheep properties is the ability of management to recognise relevant opportunities and then being able to assess the trade-offs, responses, costs and benefits likely from the implementation of any opportunity on their property (Broad *et al.* 2016; 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 an individual property. Managers and their advisors can use the tools and models developed in this study to conduct their own analyses specific to their circumstances.

A number of alternative beef and sheep production strategies are available, and it is shown in this study for beef businesses, 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 and sheep production systems which exhibit drought resilience are predominately those where managers spend considerable time and resources preparing for drought and frequently monitor their pastures, livestock, financial position, markets, options and wellbeing. We propose that having the right production system in place prior to drought is a key factor in surviving drought, as is maintaining a clear framework for assessing options when responding to drought.

6.1 The impact of climate variability on drought preparation, response and recovery strategies

The major challenges facing beef and sheep property managers in the Central West Mitchell Grasslands are the high levels of climate variability and the history of extended and extensive droughts. In addition, the Queensland beef and sheep industries will continue to be challenged 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' (e.g. McCosker *et al.* 2010; McLean *et al.* 2014). The results of the steady-state analysis of a base beef or sheep enterprise, on the representative, base property of 16,200 ha, confirmed the low profitability of rangeland grazing businesses at long-term prices with a rate of return on total capital for the sheep and beef enterprise of 1.39 and -0.02%, respectively.

In this analysis, the beef and sheep enterprises were stocked at what was considered an equivalent grazing pressure of 15.13 ha/AE and 1.68 ha/DSE, respectively, which was selected to match the 36-year, safe carrying capacity of country considered to be in B land condition (i.e. supporting 75% of the carrying capacity in A condition). An assessment of land condition at 1,056 sites in the Longreach region over 2005-2007 indicated that across all land types ca. 5% of sites were in A condition, 50% in B condition and 45% in C or D condition (Beutel and Silcock 2008; scale A-D, Quirk and McIvor 2003; DAF 2011). This data substantiates the selection of a B land condition rating as representative of the base property in our study. While a property in A land condition and able to support a higher stocking rate would be expected to have a greater potential profitability than the identical property in B land condition, it is evident that a considerable proportion of properties in the region may have land in C or D condition and hence result in even lower levels of potential profitability than that determined in this study.

In this study we did not examine grazing management strategies to improve land condition. There is little field research to indicate rates of degradation and recovery across land types and regions in northern Australia. Grazing management guidelines recommended by Scanlan *et al.* (2014) and Hunt *et al.* (2014) 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.

There is indication that land managers are applying higher stocking and pasture utilisation rates in the Mitchell Grasslands bioregion than used traditionally (Commonwealth of Australia 2008; Bray *et al.* 2014) and that this may be resulting in declining land condition over time. Evidence from other rangeland regions in Queensland suggests that financial pressures are likely contributors to high stocking rates (Rolfe *et al.* 2016; Bowen and Chudleigh 2017; Bowen *et al.* 2018) and that there is an economic advantage over the medium term (e.g. 30 years) from increasing pasture utilisation rates, even with declining land condition and animal performance (Burrows *et al.* 2010; Star *et al.* 2013; Bowen and Chudleigh 2018*a*). This demonstrates the tension between achieving profitable grazing businesses and maintaining land condition over time.

Hence the first priority, in terms of management strategies for the Central West Mitchell Grasslands, was to assess the impact of climate variability in the region on alternative grazing management strategies. The objective was to identify grazing management strategies which could be more profitable and maintain pasture condition over time and under climate variability typical of the region. Our analysis identified that prescriptive livestock management strategies, like setting a conservative stocking rate and sticking doggedly to it, are likely to be less profitable than being more responsive to the feed supply available in the paddock (Table 1 and Table 87).

The Retain core herd scenarios examined in this analysis (4.1.2.2.2) were intended to reflect the approach of some managers in keeping a core cattle herd during drought to rebuild the herd more quickly once drought breaks. The results of the 30-year economic analysis showed poor investment returns for the two scenarios: -0.28 and -0.26% IRR for Retain herd structure and Retain core breeders, respectively. Our results indicate that the market prices available for each class of cattle (e.g. steers vs. breeders) at the time the decision is being made to de-stock should determine which class to sell first as there was little economic difference between the options. The analysis also indicated that although additional weaners and sale cattle were produced over time by retaining breeders in a de-stocking situation, the additional costs of supporting those additional breeders offset the additional benefits.

Our study indicated that more flexible management strategies where livestock numbers are changed from year to year in response to pasture availability are likely to be more profitable, however, also incur more risk. In simplistic terms, the most useful management strategy for this region is to set herd or flock numbers according to safe utilisation rate principles rate but sell early and often as pasture availability declines and then re-stock as soon as safely possible once good seasonal conditions return. As long as safe pasture utilisation rates are used, this Drought responsive strategy (4.1.2.2.3) should maintain pasture condition over time. The Fully flexible stocking strategy (4.1.2.2.4), which had no limits to annual changes in cattle numbers to match pasture available on 1 May, resulted in decreased pasture condition over time in this study. However, a limitation of the model was that cattle numbers could only be altered once per year. More frequent and timely removal of livestock as conditions deteriorate (recommended as best management practice) could allow the Fully flexible strategy to maintain pasture condition and demonstrate improved profitability. However, the additional risk encountered with this strategy due to the large numbers of cattle being traded, and the potential for pasture degradation, are likely to dissuade most from following a fully flexible approach over the longer term.

During the drought recovery phase, using agistment income to utilise available pasture when building up herd numbers was a low risk strategy compared to the alternatives but appeared likely to be less profitable than purchasing livestock to rebuild the breeding herd or trading cattle (Table 1). However, the relative profitability of alternative purchasing options should be assessed at the time the decision is being made. The property-level, regionally specific herd and business models developed in this project that can be used by consultants, advisors and producers to assess both strategic and tactical decisions for their own businesses.

These analyses indicate that capital constraints and financial risk are likely to 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-of-property' approach is essential for both comparing management options and for setting priorities for research and development in the northern beef industry.

6.2 Assessing key strategies that may be applied in response to drought in beef production systems

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 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 affect 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 on 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.

6.3 Limitations of the integrated GRASP modelling approach

The results of the analysis assessing the impact of climate variability on the effects of grazing management strategies must be considered in light of the limitations of the modelling approach. These include the following:

- The inability of a bio-economic model to adequately represent a complex management, environmental and economic system.
- The relatively simple grazing rules applied in each of the strategies, particularly the ability to alter stock numbers only once per year, which is inadequate to represent the frequent and complex decision-making opportunities taken by grazing managers.
- The inability to provide feedback to GRASP for changes in grazing pressure and pasture condition, or individual animal LWG, likely to result from:
    - different allocations of animals to paddocks as a result of changing herd structures in scenarios over time;
    - the animal numbers predicted by the herd model being different to those predicted in GRASP (e.g. due to effects on predicted mortality rates, conception and weaning rates of breeders preventing target animal numbers being achieved);
    - feeding supplements which result in increased pasture intake (e.g. feeding NPN supplements to cattle grazing dry season pasture); and
    - feeding supplements which will substitute for pasture (e.g. high energy or protein supplements and hay).
- The steer LWG predictions rely on user-defined parameters.
- Breeder liveweight change (and hence effects on mortality and fertility parameters) are based on steer liveweight change predictions.
- A lack of scientific data to inform assumed rates of pasture decline and improvement for the individual pasture communities and regions within the GRASP modelling framework.
- The assumption that the current economic prospects will persist.
- The restriction of evaluations to only one historical climate sequence of 36 years (1982-2017).

The analysis relies heavily on modelled output from GRASP, the conversion of steer LWG data from GRASP into breeding herd performance estimates and finally the construction of an integrated bio-economic model to estimate the likely outcomes from changes in management strategy. Whilst every effort has been made to ensure that the results generated are broadly indicative of what might happen on Mitchell grasslands in central western Queensland, it must be realised that the analysis provides at best a broad approximation of the true nature of the economic benefits likely to occur. Similar observations have been made by others attempting to integrate GRASP output with cattle herd models (e.g. Donaghy *et al.* 2007). Nevertheless, the overall pattern of resource use, management strategy and underlying production trade-offs identified in our analysis are consistent with the regional grazing management practices observed by the authors.

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

There are significant limitations when applying the broad understandings gained from modelling the performance of typical production systems to the circumstances of the individual property, herd or flock. As demonstrated by Chudleigh *et al.* (2016, 2017) opportunities for improvement are specific to properties and management systems, 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 livestock producer, therefore, completely depends upon the relative value of that 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 to result 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 range of production systems, and an appropriate framework to support decision making.

7 Conclusions

The Central West Mitchell Grasslands region has high levels of climate variability and a history of suffering extended and extensive droughts. Our analysis identified that prescriptive livestock management strategies, like setting a conservative stocking rate and sticking doggedly to it, are likely to be less profitable than being as responsive as possible to the feed supply available in the paddock. More flexible management strategies where livestock numbers are changed regularly in response to pasture availability are likely to be more profitable, however, also incur more risk. In simplistic terms, the most useful management strategy for this region appears to be setting the herd or flock numbers according to safe utilisation rate principles but then selling early and often in response to declining pasture availability and re-stocking as soon as safely possible once good seasonal conditions return. As long as safe pasture utilisation rates are used this drought responsive strategy should maintain pasture and land condition over time.

Our results indicate that the current market prices, and those expected during the start of the recovery phase, for each class of cattle (e.g. steers vs. breeders) at the time the decision is being made to de-stock should determine which class to sell first. During the drought recovery phase, using agistment income to utilise available pasture when building up herd numbers is a lower risk strategy compared to the alternatives but appears likely to be less profitable over the longer term than purchasing livestock to rebuild the breeding herd or trading cattle. The relative profitability of alternative purchasing options can be assessed each time the decision is being made by looking firstly at the immediate impact on cash flow and profit of the available choices using the more simple spreadsheet tools and secondly considering the medium term impact on herd structure, profit and cash flow using the more complex herd models and budgets of the Breedcow and Dynama suite of programs.

The integrated pasture and beef herd modelling approach developed in this study represents a conscious effort to advance the integration of output from the GRASP daily pasture growth model with beef cattle herd models that determine whole-of-business productivity and profitability, namely the Breedcow and Dynama software and the Ian Braithwaite, four period calving, spreadsheet model. Importantly, these models apply published functions describing breeder conception and mortality rates applicable to northern Australia beef cattle herds. This modelling approach allowed the impact of climate variability on a range of drought-related management scenarios to be modelled in the current study. These new models could be applied to investigate a range of pasture and grazing management strategies on business productivity and profitability, across any regions of northern Australia which have been calibrated for GRASP pasture model output. However, while providing useful insights, this modelling approach must be viewed in light of its limitations, which are related to the difficulties in adequately representing a complex management, environmental and economic system. Allowing the GRASP model to adjust stocking rates dynamically and more than once a year, and using a two-way linked modelling approach may improve simulation of complex grazing livestock production systems.

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9 Glossary of terms and abbreviations

AE	Adult equivalent. In the GRASP calculation of total grazing pressure applied an AE was considered to be a 450 kg non-lactating beast at maintenance, calculated as the average cattle liveweight for the period to the power of 0.75 (i.e. metabolic weight AE). In our analysis the GRASP formula was adjusted to incorporate actual modelled liveweight gain of steers rather than using a fixed steer liveweight gain. In the Dynamaplus program an AE was taken as a non-pregnant, non-lactating beast of average weight 455 kg (1,000 lbs) carried for 12 months (i.e. a linear AE, not adjusted for metabolic weight). An additional allowance of 0.35 AE was made for each breeder that reared a calf. This rating was placed on the calves themselves, effectively from conception to age 5 months, while their mothers were rated entirely on weight.
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.
Breedcow and Dynama software	A herd budgeting program designed to evaluate the profitability and financial risk of alternative management strategies for extensive beef businesses, at the property level. This software can be downloaded free from https://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 this report.
Constant (real) dollar terms	All variables are expressed in terms of the price level of a single given year.
Cumulative cash flow	Cumulative cash flow is the predicted final bank balance of the property at the end of the investment period due to the implementation of the strategy.
Current (nominal) dollar terms	All variables are expressed in terms of the year in which the costs or income occur. The impact of expected inflation is explicitly reflected in the cash flow projections.
DAF	Department of Agriculture and Fisheries, Queensland Government
DCF	Discounted cash flow. This technique is a way of allowing that when money is invested in one use, the chance of spending that money in another use is gone. Discounting means deducting from a project's

	expected earnings the amount which the investment funds could earn in its most profitable alternative use. Discounting the value of money to be received or spent in the future is a way of adjusting the future net rewards from the investment back to what they would be worth in the hand today.
Depreciation (as applied in estimating operating profit)	A form of overhead cost that allows for the use (fall in value) of assets that have a life of more than one production period. It is an allowance that is deducted from gross revenue each year so that all of the costs of producing an output in that year are set against all of the revenues produced in that year. Depreciation of assets is estimated by valuing them at either current market value or expected replacement value, identifying their salvage value in constant dollar terms and then dividing by the number of years until replacement. The formula used in this analysis is: (replacement cost – salvage value)/number of years until replacement.
Discounting	The process of adjusting expected future costs and benefits to values at a common point in time (typically the present) to account for the time preference of money. With discounting, a stream of funds occurring at different time periods in the future is reduced to a single figure by summing their present value equivalents to arrive at a 'Net Present Value' (NPV). Note that discounting is not carried out to account for inflation. Discounting would still be applicable in periods of nil inflation.
Discount rate	The interest rate used to determine the present 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).
DSE	Dry sheep equivalent. This standard unit represents a 2-year old, 50 kg Merino sheep (wether, or non-lactating, non-pregnant ewe) at maintenance. In the Breedewe and Sheepdyn programs a linear DSE was calculated, i.e. not adjusted for metabolic weight.
Economic analysis	Economic analysis usually focusses on profit as the true measure of economic performance or how efficiently resources are applied. The calculation of profit includes non-cash items like opportunity costs, unpaid labour, depreciation and change in the value of livestock or crop inventory. NPV and amortised NPV are both measures of profit.
Equity capital	The value of the owner's capital. This is equal to total capital minus total liabilities.
Financial analysis	Financial analysis focusses on cash flow and the determination of whether all business and family cash costs can be met. Financial analysis can also include analysis of debt servicing capacity.
Fixed (or overhead) costs	Defined as costs which are not affected by the scale of the activities in the farm business. They must be met in the operation of the farm. Examples include: wages and employee on-costs, repairs, insurance,

	shire rates and land taxes, depreciation of plant and improvements, consultant's fees and the operators allowance for labour and management. Some fixed costs (such as depreciation or operator's allowance) are not cash costs. It is usual to count the smaller amounts of interest on a typical overdraft or short term working capital as an operating expense (fixed cost) and deducted in the calculation of operating profit. The returns to lenders of fixed capital (interest, rent, lease payments) are deducted in the calculation of net profit.
GRASP	A dynamic, point-based biophysical pasture-animal growth model developed for northern Australia and rangeland pastures. The model simulates soil moisture, pasture growth and animal production from daily inputs of rainfall, temperature, humidity, pan-evaporation and solar radiation.
Gross margin	The gross income received from an activity less the variable costs incurred. Gross margins are only the first step in determining the effect of a management decision on farm or business profitability. To determine the value of a potential strategy to the whole farm or business, a more complete economic analysis is required in the form of a marginal analysis that considers the effect of alternative strategies at the property or business level.
IRR	Internal rate of return. This is the discount rate at which the present value of income from a project equals the present value of total expenditure (capital and annual costs) on the project, i.e. the break-even discount rate. This indicates the maximum interest that a project can pay for the resources used if the project is to recover its investment expenses and still just break even. *IRR can be expressed as either* ***the return on the total investment*** *or* ***the return on the extra capital***
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.
Marginal return	Extra or added return. Principle of marginality emphasises the importance of evaluating the changes for extra effects, not the average level of performance.
'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
Net Profit	This is the reward to the farmers own capital. Net Profit equals Operating profit less the returns to outside capital. The returns to lenders of fixed capital (interest, rent, leases) are deducted from Operating Profit in the calculation of Net Profit. It is available to the owner of the business to pay

	taxes or to provide living expenses (consumption) or it can be used to reduce debt. Net profit minus income tax minus personal consumption (above operators allowance if it has already been deducted from operating profit) = change in equity
NPN	Non-protein nitrogen. Nitrogen not derived from protein (e.g. urea, biuret and ammonia) but which can be converted into proteins by microbes in the rumen of ruminant animals.
NPV	Net present value. Refers to the net returns (income minus costs) over the life of an investment, expressed in present day terms. A discounted cash-flow allows future cash-flows (costs and income) to be discounted back to a NPV so that investments over varying time periods can be compared. The investment with the highest NPV is usually preferred. NPV was calculated at a 5% rate of return which was taken as the real opportunity cost of funds to the producer. NPV can be expressed as the total business returns or as the marginal returns. Marginal NPV is the extra return received as a result of the investment. Annualised NPV converts the NPV to an amortised, annual value. *The **annualised NPV** can be considered as an approximation of the **average annual change in profit over 30 years**, resulting from the management strategy.*
NRM region	Natural Resource Management region. NRM regions across Australia are based on catchments or bioregions. The boundaries of NRM regions are managed by the Australian Government and used for statistical reporting and allocation and reporting of environmental investment programs.
Operators allowance	An allowance for the owners labour and management; it can be estimated by reference to what professional farm managers/overseers are paid. Although it is often not paid in the farm accounts, it is an input required to generate the operating profit and must be deducted if a true estimate of operating profit and the return to the total capital in the business/property is to be calculated. It is generally not equal to the irregular wages paid to or drawings made by the owners. If some wages have been paid to the owners in the farm accounts and they are already included in the calculation of fixed costs, then the only difference between the wages paid and the true opportunity cost of their labour and management will need to be allowed for when calculating operating profit.
Opportunity cost	The benefit foregone by using a scarce resource for one purpose instead of its next best alternative use.
Pasture condition	Pasture condition is one of three components of land condition. In the pasture growth model GRASP percent perennial grass is used as an indicator of pasture condition and varies between a maximum of 90% and a minimum of 1%. Changes to simulated percent perennial grass are a function of utilisation of pasture growth and are calculated once a year.

Pasture utilisation	The proportion of pasture consumed by grazing livestock. The utilisation can be expressed as a proportion of annual pasture biomass growth or of total standing dry matter (TSDM). In the pasture growth model GRASP changes in pasture condition are a function of the utilisation of simulated annual pasture growth. In this study, the utilisation of simulated total standing dry matter (TSDM) at May 1 was used to set stocking rates.
Payback period	The number of years it takes for the cumulative present value to become positive. Other things being equal, the shorter the payback period, the more appealing the investment.
Peak deficit	This is an estimate of the peak deficit in cash flow caused by the implementation of the management strategy. It assumes interest is paid on the deficit and is compounded for each additional year that the deficit continues into the investment period. It is a rough estimate of the impact of the investment on the overdraft if funds for the development are not borrowed but sourced from the cash flow of the business.
PTE	Pregnancy tested empty (not in calf)
PTIC	Pregnancy tested in calf
Rate of return on total capital	An estimate of how profitable a business is relative to its total capital. It is the operating profit expressed as a percentage of the average of the total capital employed for the period under review (usually a year).
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.
TSDM	Total standing dry matter. This refers to the pasture presentation yield (on a dry matter basis) measured at a point in time in the paddock and is the net result of pasture growth, death, detachment, consumption and trampling. In this study, a specified proportion of GRASP-simulated TSDM at 1 May was used to set stocking rates.
Variable costs	These costs change according to the size of an activity. The essential characteristic of a variable cost is that it changes proportionately to changes in business size (or to change in components of the business).
Year of peak deficit	The year in which the peak deficit is expected to occur.

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11 Appendix 1. Breedcow and Dynama software

11.1 Brief description of the Breedcow and Dynama software

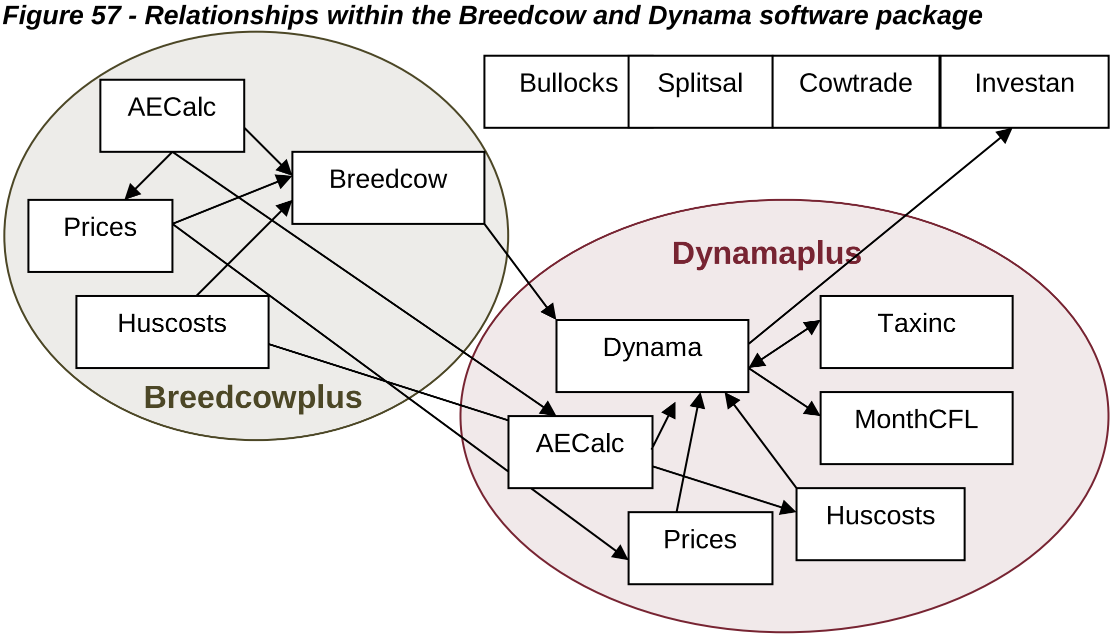
The Breedcow and Dynama package of software programs is used to assess choices for the management of beef cattle herds run under extensive conditions. **It is not an accounting package or a paddock records package and does not record individual animals**. It presents budgeting processes, adapted to the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

Breedcow and Dynama programs are based on four budgeting processes:

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

In short, Breedcowplus is a steady-state herd model that generates its own structure around a starting number of weaner heifers retained and Dynamaplus program is a 10-year herd budgeting program that usually starts with the current herd numbers and structure. The term 'herd budgeting' is used to emphasise the central role of herd dynamics in cattle enterprise budgeting. Figure 57 indicates the relationships between the individual components of the Breedcow and Dynama software package. A menu system within Dynamaplus enables data from Breedcowplus to be imported. The flow of data is indicated by the arrows shown in Figure 57.

Figure 57 - Relationships within the Breedcow and Dynama software package



11.2 Summary of the components of the Breedcow and Dynama software

The package currently comprises six separate programs: Breedcowplus, Dynamaplus, Investan, Cowtrade, Bullocks and Splitsal.

11.2.1 Breedcowplus

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

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

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

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

11.2.2 Dynamaplus

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

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

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

11.2.3 Investan

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

11.2.4 Cowtrade, Bullocks and Splitsal

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

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

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

12 Appendix 2. Discounting and investment analysis

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

12.1 The need to discount

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

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

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

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

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

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

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

12.2 Profitability measures

Three profitability criteria can be calculated. They are:

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

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

The three decision criteria are interrelated. For example, Table 101 presents an example of the range of values expected for each profitability criteria at a discount rate of eight%.

Table 101 - Relationship between profitability measures at a discount rate of 8%

Factor	**Relative value**		
NPV	Negative	Zero	Positive
IRR	< 8%	8%	>8%
B/C ratio	Less than 1	1	Greater than 1

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

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

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

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

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

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

12.3 ‘With’ and ‘without’ scenarios

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

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

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

12.4 Compounding and discounting

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

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

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

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

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

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

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

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

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

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

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