Productivity and profitability of a range of alternative steer growth paths resulting from manipulating the pasture feed base in central Queensland – a modelling approach

M.K. Bowen and F. Chudleigh

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This publication has been compiled by:
Maree Bowen, Principal Research Scientist, Animal Science, Department of Agriculture and Fisheries, Queensland (DAF)
Fred Chudleigh, Principal Economist, Strategic Policy and Planning, DAF.

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Executive summary

The work reported here represents the first known attempt to assess the most profitable way of incorporating high quality forages into the whole-of-life steer growth path on forage systems in central Queensland using property-level, regionally-relevant herd models to determine whole-of-business productivity. Twenty-two growth paths (liveweight change over time) for steers from weaning to marketing were developed for steers grazing buffel grass (*Cenchrus ciliaris*) with and without access to leucaena-grass pastures (*Leucaena leucocephala* spp. *glabrata* + perennial, tropical grass (C_4) species) or forage oats (*Avena sativa*) for varying intervals throughout their growth path. The economic and financial effect of each of these growth paths was assessed by comparison to a production system without the high quality forage intervention as a baseline (i.e. buffel grass scenario that produced finished, slaughter steers). The relative profitability of marketing steers at feedlot entry (feed-on) weight (474 kg) instead of slaughter weights (605 kg) was assessed. The growth paths were applied within two discrete beef enterprises, one a steer turnover enterprise and, the second, a breeding and finishing beef enterprise, over a 30-year investment period. Integrated herd models and discounted cash flow budgets were developed for each scenario. The effect of implementing each growth path was modelled by starting each farm investment at the same point and changing from the base scenario to the alternative.

For both enterprises, grazing steers on leucaena-grass pastures from weaning until they achieved feedlot entry weight was substantially more profitable than any other growth path. Compared to the base scenario, this optimal growth path improved profitability by 121 and 37% for the steer turnover and the breeding and finishing enterprises, respectively. The purchase of additional breeders for the latter enterprise was required to optimise utilisation of the leucaena-grass pastures immediately. Incorporating leucaena-grass pastures at any steer age improved the profitability of the steer turnover enterprise ($7,368-$106,508 extra profit/annum), and similarly for the breeding and finishing enterprise ($1,754-$31,383 extra profit/annum) except for two scenarios where leucaena-grass pastures were provided to older steers targeted at the feed-on market ($4,816 and $23,886 less profit/annum). However, incorporation of leucaena-grass in to steer growth paths also resulted in increased peak deficit levels and financial risk to the business compared to buffel grass-only production systems with payback periods for the most profitable growth path of 8 and 14 years, for the steer turnover and the breeding and finishing enterprise, respectively. All growth paths that incorporated forage oats resulted in lower economic and financial performance than comparable growth paths that incorporated leucaena. Furthermore, incorporating oats into a buffel grass-only growth path always reduced the enterprise profitability. There were no meaningful relationships, across scenarios within an enterprise, between change in profit and the number of extra weaners produced or the amount of extra beef produced per hectare.

In conjunction with the investigation of the most efficient use of high quality forages, a scoping study was conducted to investigate the effects of grazing pressure and land condition on productivity and profitability of the baseline buffel grass pastures. The objective was to provide some insights into the stocking rate decisions of land managers. This was considered important due to the considerable effort currently being applied to encourage a reduction in grazing pressure from beef cattle across Queensland’s pastoral lands as well as the widespread evidence that some land managers are stocking perennial pastures at significantly higher rates than recommended guidelines. Property level, regionally relevant herd models were used to determine whole-of-business productivity and profitability over a 30-year investment period for a steer turnover enterprise. Growth paths for steers from weaning to marketing were developed for 16 scenarios encompassing a range of pasture

utilisation rates (30, 35 and 50% of annual biomass growth), land condition (A, B and C) and market targets (feedlot entry (474 kg) or slaughter (605 kg)). The economic and financial effect of each of these scenarios was assessed by comparison, where pastures started in A condition, to a baseline buffel grass production system in A condition with 30% pasture utilisation and producing slaughter steers. For scenarios where pastures started in B condition they were compared to a buffel grass production system in B condition with 30% pasture utilisation to produce slaughter steers.

Our analyses demonstrated a large economic advantage from increasing grazing pressure above 30% for buffel grass pastures, even under assumptions of declining land condition and animal performance. For instance, producing slaughter steers under a 50% pasture utilisation regime with a continuous decline in land condition from A to C (and hence productivity) over years 10 to 30, was 25% more profitable than a 30% pasture utilisation strategy, which is recommended as closer to a long-term, safe utilisation rate. The sensitivity of profit to pasture utilisation rate was demonstrated by the substantial increase in profitability (15% improvement in net present value) from utilising an extra 5% of the annual biomass growth (35% rather than 30%) of A condition buffel grass pastures to produce slaughter steers. This analysis of effects of grazing pressure should be considered a scoping study due to the paucity of data for effects of utilisation rate on the productivity of buffel grass pastures (or any sown tropical grasses under rangeland conditions) and hence on land condition rating. Our approach was to consider a range of pasture utilisation rates and corresponding rates of land condition decline for buffel grass pastures starting in A condition. Due to the limitations of available data, a normative model was used with transitions which may or may not appropriately reflect the dynamics of pasture growth under declining land condition. Despite these limitations, this study has provided insights into the drivers of high stocking rates commonly applied on commercial beef cattle properties in northern Australia.

In this report we outline the effect of the change in cattle growth path on overall herd structure and whole-farm profitability to provide valuable insights which can be used to guide business investment decisions in high quality forages. Additionally, examination of effects of grazing pressure and land condition on the productivity and profitability of buffel grass pastures has provided preliminary insights into the trade-off between stocking rate decisions and medium-term financial returns. Further research is required to better understand compensatory growth effects in northern cattle production systems and also effects of utilisation rates of buffel grass, and other sown grass and legume species, on plant biomass production, land condition decline, cattle diet quality and cattle production. This would allow improvement of existing modelling capabilities which, in turn, will better inform whole-farm economic analysis.

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1 Introduction

The beef cattle industry makes an important contribution to the Australian economy. In 2014-2015 it accounted for ca. 21% ($11.5 billion) of the total gross value of farm production and ca. 23% of the total value of farm exports income (ABARES 2017). The Fitzroy Natural Resource Management (NRM) Region of Central Queensland is an important beef producing area of Australia, producing ca. 11% of Australia's gross value of cattle in 2014-2015 from ca. 12.4 million ha of pastures (ABS 2014, 2016). The Fitzroy NRM region falls largely within the Brigalow Belt bioregion with ca. 39% of the land area having arable soils capable of supporting sown forages suitable for beef cattle finishing (slaughter) or backgrounding (preparing for feedlot entry), (Bowen *et al.* 2015*a*).

Although the Brigalow Belt bioregion has been regarded as a highly productive agricultural area due to its inherent soil fertility and moderate rainfall environment, pasture and beef cattle productivity have appreciably declined since pasture establishment due to a 'run-down' or decline in available nitrogen in the soil with increasing age of the pasture stand since tree clearing (Peck *et al.* 2011, 2015, 2017). Furthermore, this decline in productivity of the largely buffel grass (*Cenchrus ciliaris*) pastures has been exacerbated in some cases by sustained heavy grazing pressure, causing a decline in land condition (Beutel *et al.* 2014), as well as by invasion by the less productive pasture species, Indian couch (*Bothriochloa pertusa*; Spiegel 2016) and the increasing but poorly understood phenomenon of pasture dieback (Buck 2017).

Establishment of adapted legumes into the existing grass-only pastures has been identified as the best long-term option to increase both the productivity and returns from run-down, sown grass pastures due to their ability to biologically fix atmospheric nitrogen (Peck *et al.* 2015, 2017). Of the commercially available perennial legumes suited to central Queensland, leucaena (*Leucaena leucocephala* spp. *glabrata*) has been identified as the most productive and profitable, increasing beef production per ha by ca. 2.5 times and doubling gross margin per ha, compared to perennial grass pastures (Bowen *et al.* 2016). The area planted to leucaena in the Fitzroy NRM region is currently estimated to be ca. 106,225 ha (Corbet *et al.* 2016). Assessments of suitable soil and climatic conditions indicate that there is considerable scope to expand plantings within this region as well as across Queensland (T. Beutel, pers. comm.) with Peck *et al.* (2011) estimating that leucaena has been sown to only 2.5% of the area to which it is adapted in Queensland. Leucaena and other legume options remain an under-exploited resource in Queensland due to a number of constraints, primarily the difficulty, cost and risk of establishment as well as the additional management expertise required to productively utilise the resource (Shelton *et al.* 2005; Peck *et al.* 2011; Bowen *et al.* 2015*a*).

While perennial legumes, especially leucaena, have been identified as the most profitable high quality forage option for beef cattle production in central Queensland, annual forage cropping is common despite the marginal contribution to business profit when alternatives are considered (Bowen *et al.* 2015*a*, 2015*b*). Studies of commercial beef production systems in central Queensland showed oats (*Avena sativa*) to be the most profitable, of the commonly applied annual forage crop options in central Queensland, in terms of gross margin per hectare (Bowen *et al.* 2015*b*, 2016).

Beef producers will generally only have a limited area of suitable soil on any particular property for sowing to high quality forages. Additionally, application of increased capital and skills are required to effectively establish and utilise high value forages. Hence, for implementation of any high quality forage system to be profitable, producers need to be well informed as to the best time and place to target an increase in inputs. In particular, producers need to make choices about how best to allocate high quality forages amongst different age groups of cattle in their herd. This involves considering the resultant effect of the high quality nutritional intervention on the cattle growth path, age and time to reach target market weight, and enterprise profitability. Producers need to address questions such as: 'when should cattle commence grazing on high quality forage, for how long, and for what target market?' The effect of such alternative management strategies is best assessed using property-level, regionally-relevant herd models that determine whole-of-business productivity and profitability (Chudleigh *et al.* 2017*a*).

The Queensland beef industry 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' (McCosker *et al.* 2010; McLean *et al.* 2014; Hall 2016). There is widespread evidence that land managers are stocking perennial pastures at significantly higher rates than guidelines provided by research and government agencies (Shaw *et al.* 2007; Beutel *et al.* 2014; Bowen *et al.* 2015*b*, 2016) and some indication that these decisions have financial and economic attributes (Shaw *et al.* 2007; Beutel *et al.* 2014; Bowen *et al.* 2015*b*, 2016; Rolfe *et al.* 2016). The consequences for Great Barrier Reef water quality, of high levels of pasture utilisation and degraded pastures, are well documented (Thorburn *et al.* 2013) and much effort is currently applied in the Fitzroy River catchment to maintaining ground cover via encouraging a reduction in grazing pressure applied by beef enterprise managers (The State of Queensland 2013). A better understanding of the trade-off between stocking rate decisions and economic sustainability for land managers is imperative to better inform policy makers.

The objective of this study was to conduct a scientific and economic analysis of alternative steer growth paths on perennial, buffel grass pasture in central Queensland, with or without access to leucaena-grass pastures or forage oats provided at various points in their growth path from weaning to marketing. These two high quality forage interventions were considered as the most profitable examples of sown perennial legume-grass pastures and annual forage crops, respectively. The effects of grazing pressure and land condition on productivity and profitability of baseline perennial grass pasture systems were also investigated.

2 Methods

2.1 Summary of approach

Growth paths (liveweight change over time) for steers from weaning to marketing were developed from interrogation of existing data sets, and the expert opinion of experienced Department of Agriculture and Fisheries, Queensland (DAF) staff, for a representative land type and location within the target region of central Queensland. Growth paths were developed for steers grazing buffel grass (*Cenchrus ciliaris*) with and without access to leucaena-grass pastures (*Leucaena leucocephala* spp. *glabrata* + perennial, tropical grass (C_4) species) or forage oats (*Avena sativa*) for varying periods of time throughout their growth path from weaning to marketing. The economic and financial effect of each of these growth path scenarios was then assessed by comparison to a production system without the high quality forage intervention as a baseline (i.e. buffel grass scenario that produces finished, slaughter steers). The growth paths were applied within two discrete beef enterprises, one a steer turnover enterprise and the second a breeding and finishing beef enterprise, both examined over an investment period of 3 decades. The Breedcow and Dynama herd budgeting software (Version 6.02; Holmes *et al.* 2017) and spreadsheet-based investment analysis tools (as described by

Gittinger (1982), Makeham and Malcolm (1993) and Campbell and Brown (2003)) were used to develop integrated herd models and discounted cash flow budgets for each alternative scenario. The effect of implementing each alternative growth path was modelled by starting each farm investment at the same point and following the steps of changing from the base scenario to the alternative. The marginal returns associated with any additional capital or resources invested within farm operations were then used to indicate the relative and absolute value of the investment in terms of the key economic measures: net present value (NPV) and internal rate of return (IRR). The analyses apply a discounting process to account for the varying timing of income and costs across the different scenarios.

2.2 Model parameters

A summary of the hypothetical beef enterprises used to model the growth path scenarios, including key input factors and assumptions, is given here. A more detailed description of the herd structure and dynamics as well as management activities, treatments and cost assumptions required as inputs is given in Appendix 1. All Breedcow and Dynama herd models developed in this analysis, plus the associated spreadsheets applied in the economic modelling process, can be downloaded with the Breedcow and Dynama software from: https://www.daf.qld.gov.au/animal-industries/beef/breedcow-and-dynama-software.

2.2.1 Enterprise location and land type used for growing and finishing steers

The modelled enterprises were situated centrally in the Fitzroy NRM region in central Queensland, near Rolleston, with the predominant land type used for growing and finishing cattle considered to be Brigalow softwood scrub (Whish 2011). This land type constitutes the largest land type area within the Fitzroy NRM area (1.5 million ha, 9.7% of the entire area; T. Beutel pers. comm.). The majority of this land type has been cleared and developed to sown pasture with buffel the predominant species. A significant proportion of this land type is suitable for alternative sown pastures and forages including leucaena-grass pastures and oats forage (Bowen *et al.* 2015*a*). The properties were considered to have been cleared of timber and sown to buffel grass pasture during the 1970-80s, as is typical for the region (Thornton and Elledge 2013; DNRM 2017).

2.2.2 Forage and animal production

2.2.2.1 Production from buffel grass pasture

The buffel grass pasture provided either with or without access to leucaena-grass or forage oats in the steer growth path scenarios was considered to be A land condition (scale A-D; Quirk and McIvor 2003; DAF 2011), reflecting optimal capacity of the land to produce useful forage. The buffel pasture was assigned a pasture utilisation of 30% of the annual pasture biomass growth, which is suggested as a safe level of pasture utilisation for this land type for long-term sustainability (Whish 2011) based on research for native pasture communities (Silcock *et al.* 2005; Orr *et al.* 2010; Orr and Phelps 2013; O'Reagain *et al.* 2014; Hall *et al.* 2017), and in the absence of any data for buffel grass utilisation rates in central Queensland Brigalow land types. Additional scenarios were also modelled for cattle production from buffel pastures in A land condition but with 35% and 50% pasture utilisation. In addition, to reflect the situation in which long-term heavy grazing pressure has occurred, scenarios were modelled assuming buffel pasture declined to B and C land condition under a 50% pasture utilisation regime. Finally, production from pasture considered to be in B land condition but now under a reduced grazing pressure regime, resulting in 30% pasture utilisation, was examined.

The GRASP pasture growth model (McKeon *et al.* 2000; Rickert *et al.* 2000) was used to simulate median pasture (assumed to be primarily buffel grass) biomass production for the location using 100 years of historical rainfall and climate data to June 2016. For buffel grass pastures assumed to have 2 m^2/ha tree basal area which is considered typical for the region (P. Jones pers. comm.) the median, long-term annual pasture biomass production was estimated as 5,100, 3,800 and 2,300 kg dry matter (DM)/ha for pastures in A, B and C land condition, respectively.

Seasonal steer growth rates for buffel grass pastures in either A, B or C land condition were assigned with reference to available measured data for diet dry matter digestibility (DMD), seasonal rainfall data and liveweight gain (QDPI 2003; Bowen *et al.* 2010; Bowen *et al.* 2015*a*); (Table 1). The greatest annual growth rates (180 kg/head.annum) were for steers grazing buffel grass pastures in A land condition and utilising 30 or 35% of the annual biomass growth with an average annual diet DMD of 57%. The lowest annual growth rates (148 kg/head.annum) were for steers grazing buffel grass pastures in C land condition under a 50% utilisation regime and average annual diet DMD 52%. There was limited available data for buffel grass pastures to inform these assumptions but the basic premise was that diet digestibility and hence liveweight gain would decrease with increased pasture utilisation due to reduced ability for selection (Stobbs 1975). Furthermore, it was assumed that for buffel grass pastures in B and C land condition, the encroachment of other species (such as Indian couch and annual species) as well as declining pasture vigour would result in reduced average annual diet digestibility and hence cattle liveweight gain. It is recognised that the reverse situation (i.e. greater cattle liveweight gain on degraded pastures) can occur under some seasonal circumstances (R. Silcock pers. comm.) but this analysis was intended to represent the median, long-term situation.

For pasture in A land condition with 50% utilisation, four alternative sub-scenarios were considered: a) no decline in pasture biomass production or quality, and hence cattle production, over the 30 years of analysis; b) linear decline in productivity parameters from A to B condition from years 20 to 30, c) linear decline in productivity from A to B condition parameters over years 10 to 20 and then maintenance of B condition for the final 10 years of the analysis, and d) linear decline in productivity from A to B condition over years 10 to 20 and then linear decline from B to C condition over years 20 to 30.

The carrying capacity of each pasture was calculated by multiplying the median annual pasture biomass production by the specified utilisation level and then dividing by the annual pasture consumption of a standard animal unit or 'adult equivalent' (AE). An adult equivalent was defined here in terms of the forage dry matter intake at the specified diet DMD, of a standard animal which was defined by McLean and Blakeley (2014) as a 2.25 year old, 450 kg *Bos taurus* steer at maintenance, walking 7 km/day. The spreadsheet calculator, QuikIntake (McLennan and Poppi 2016), which is based on the Australian Feeding Standards (NRDR 2007) with some modifications for tropical feeding systems (McLennan 2014), was used to calculate daily cattle dry matter intakes for the specified pasture DMDs in Table 1. The resultant carrying capacities were highest for pastures in A land condition and 50% pasture utilisation: 0.75 AE/ha, and lowest for pastures in C land condition with 50% utilisation: 0.31 AE/ha.

Table 1 – Assumed pasture and steer growth parameters for buffel grass pastures in either A, B or C land condition and with varying levels of utilisation of annual pasture biomass growth

Definitions of parameters are given in the text

Biological parameter	**A condition Utilisation (%)**		**B condition Utilisation (%)**		**C condition Utilisation (%)**
	30 and 35	**50**	**30**	**50**	**50**
Median, annual pasture biomass production (kg DM/ha)	5,100		3,800		2,300
Average, annual diet dry matter digestibility of grazing cattle (%)	57	55	54	53	52
Steer liveweight gain on buffel grass pasture					
Average, annual gain (kg/head)	180	173	168	165	148
Average, annual daily gain (kg/head over 365 days)	0.49	0.47	0.46	0.45	0.41
Summer daily gain (kg/head over 90 days)[A]	0.80	0.79	0.79	0.78	0.77
Autumn daily gain (kg/head over 92 days)	0.73	0.71	0.69	0.68	0.66
Winter daily gain (kg/head over 92 days)	0.35	0.33	0.31	0.30	0.15
Spring daily gain (kg/head day over 91 days)	0.10	0.07	0.05	0.05	0.05
Carrying capacity (AE/ha)[B]	0.47 and 0.55[C]	0.75	0.33	0.53	0.31

[A] The seasonal periods were considered to be summer: December, January and February; autumn: March, April and May; winter: June, July and August; and spring: September, October and November.

[B] AE (adult equivalent). Defined in terms of the forage intake of a 2.25 year old, 450 kg *Bos taurus* steer at maintenance, consuming a diet of the specified dry matter digestibility and walking 7 km/day.

[C] Carrying capacity figures at 30 and 35% pasture utilisation, respectively.

2.2.2.2 Production from leucaena-grass pasture

Where leucaena growth path scenarios were modelled, the leucaena was considered to be sown in 8 m, double rows with perennial grasses sown in the inter-rows (2.5 kg/ha leucaena seed and 4 kg/ha tropical grass species); (Bowen *et al.* 2015*b*). The leucaena was assumed to receive phosphorus (P) fertiliser, in the form of superphosphate, and mechanical cutting every 10 years (on average) to maintain productivity of the leucaena over time, with the productive life of leucaena assumed to be at least 30 years (Radrizzani *et al.* 2010; Bowen *et al.* 2015*a*; Radrizzani *et al.* 2016). Perennial grass biomass production in the leucaena-grass pasture was assumed to be the same as that for the grass-only pastures in A condition and with 30% utilisation (5,100 kg DM/ha.year), which is in line with comparative measured data on commercial properties in the central Queensland region (Bowen *et al.* 2015*b*). Edible leucaena biomass production was assumed to be 1,800 kg DM/ha.year with 85% of this utilised (consumed) by the grazing cattle (adapted from Dalzell *et al.* 2006; Elledge and Thornton 2012; Bowen *et al*. 2016; and data obtained from DAF producer demonstration sites (S. Buck pers. comm.)). At these yields and utilisation levels, the resultant average proportion of leucaena forage in the diet of grazing steers would be about 0.50, which was the measured proportion for cattle on commercial properties in central Queensland (Bowen *et al.* 2016).

Seasonal steer growth rates when grazing leucaena-grass pastures were assigned with reference to comparative measured data on commercial properties in central Queensland (Bowen *et al.* 2015*b*) and from data obtained from DAF producer demonstration sites (S. Buck pers. comm.). Daily growth rates were assumed to be: 1.1 kg/head over the summer period (December to February), 0.8 kg/head during early-mid autumn (March and April), and 0.5 kg/head during late autumn, winter and spring (May to November). The resultant annual liveweight gain was 255 kg/head (0.7 kg/head.day over 365 days). The carrying capacity of leucaena-grass pasture (1.1 AE/ha) was calculated as the sum of the utilisable components of grass and leucaena biomass, divided by the annual forage DM intake (calculated using QuikIntake; McLennan and Poppi 2016) of an AE (standard animal as defined above), assuming the average diet DMD was 63% (Bowen *et al.* 2015*b*). Although commonly quoted industry figures of ca. 0.67 AE/ha (Bowen *et al*. 2015*a*) are much less than our calculated carrying capacity, our carrying capacity method results in a stocking rate of growing animals which is in the range of the industry figure, i.e. 450 kg steers gaining 0.7 kg/day (cf. 0 kg/day) would be run at 0.74 animals/ha.

2.2.2.3 Production from forage oats

For scenarios where steers grazed forage oats, the oats was assumed to provide grazing for 83 days from 20 July, providing an average diet DMD of 65% and resulting in an average steer growth rate over this period of 1.1 kg/day (Bowen *et al.* 2015*a*, 2015*b*). The APSIM modelling framework (The Agricultural Production Systems Simulator; McCown *et al.* 1996; Keating *et al.* 2003) was used to simulate median annual forage biomass production for the location using 117 years of climate data and assuming 100 kg N/ha as a base N level (Cox 2009): 5432 kg DM/ha. It was assumed that 30% of the annual oats biomass was utilised (from data collected from commercial properties; Bowen *et al.* 2015*b*). The carrying capacity of oats forage (2.73 AE/ha) was calculated by dividing the utilisable biomass component by the annual forage DM intake of an AE (standard animal as defined above).

In growth path scenarios where steers grazed a leucaena-grass or a buffel grass pasture after grazing an oats crop, their growth rate was reduced (relative to steers not fed oats) over the following 140 days to allow for a reverse compensatory growth effect, i.e. higher growth rate of cattle not receiving oats. The assumed reduction in growth rate, of 0.25 relative to cattle that had not grazed oats, was informed by compensatory growth rate data for steers fed supplements in pens and then grazed on tropical grass pastures in central Queensland (Tomkins *et al.* 2006).

Our analysis did not include the impact of seasonal variability (missed oats planting opportunities) although APSIM modelling showed that, on average, only 69% of the last 117 years were suitable for planting oats at the target location (i.e. at this location one would expect suitable conditions to plant oats in 7 out of every 10 years). The median oats biomass production was determined for years in which an oats crop was planted and did not include zero values for years in which there were no production.

2.2.3 Beef production enterprises and herd parameters

2.2.3.1 Enterprise A – steer turnover enterprise

Enterprise A was a 1,000 ha steer turnover property carrying 470 AE and considered to be uniformly a Brigalow softwood scrub land type supporting buffel grass pasture. Steers were purchased as weaners (200 kg in May) and entered a growing system that provided access at various points in the growth path to sale to one, or a combination over time, of buffel grass, leucaena-grass or oats forage systems. The base scenario for Enterprise A was production of finished steers for slaughter (605 kg liveweight) from buffel pastures in A condition with 30% pasture utilisation. Minimal plant and equipment was required to operate the enterprise and contractors were used for all leucaena-grass and forage oats plantings.

2.2.3.2 Enterprise B – breeding and finishing enterprise

Enterprise B was a breeding and finishing enterprise with a total area of 8,700 ha and carrying capacity of ca. 1,470 AE. The property was considered to have a mixture of land types with the higher quality Brigalow softwood scrub land type used for growing and fattening steers and lesser quality land types, predominantly open Eucalypt woodlands, used for the breeder herd.

The property and herd characteristics were informed by a beef industry survey undertaken by Barbi *et al.* (2016) in the Fitzroy NRM region as well as by commercial property data documented in Bowen *et al.* (2015*b*). The beef enterprise was defined as a self-replacing breeding and growing activity that relied on production of weaners by a *B. indicus* crossbred breeding herd. Weaner steers entered a growing system that provided access at various points in the growth path to sale to one, or a combination over time, of buffel grass, leucaena-grass or oats forage systems. Heifers were used to maintain the breeding herd or were culled and sold. Breeding cows were culled on reproductive performance and age with reproduction efficiency parameters as measured in commercial herds in the CashCow project (McGowan *et al.* 2014). Heifers were first mated at 2 years of age. Cows were culled that did not show as pregnant after mating or after they had produced a calf at 12-13 years old. This age at culling was selected as the age at which economic performance is optimised (Chudleigh *et al.* 2017*b*). Mortality rates for each age cohort and class of cattle were based on McGowan *et al.* (2014) and Henderson *et al.* (2012) and are detailed in Appendix 1. Herd bulls were retained in the breeding herd for an average of 5 years. The assumed average calving date (15th November) and weaning date (17th May) were informed by Barbi *et al.* (2016) and Bowen *et al.* (2010, 2015*a*). Assumed average calf birth weight (35 kg), and daily gain to weaning (0.9 kg/day) were according to representative data from the Beef Cooperative Research Centre research in Queensland (unpublished data, M. Sullivan pers. comm.). These parameters result in an average weaner steer liveweight of 200 kg at 6 months of age. As for Enterprise A, the base scenario was production of finished steers for slaughter (605 kg liveweight) from buffel pastures in A condition with 30% pasture utilisation. Additionally, surplus heifers and cull cows were sold to abattoirs.

As the baseline property undertook no farming activities and grew no annual forage, the growing of oats required the purchase of additional plant and equipment suitable for the area to be grown. Growing leucaena did not require purchase of additional plant and equipment as contractors were used to prepare the paddock and plant the forage.

2.2.3.3 Paddock C - established leucaena

In addition, an example 100 ha paddock (Paddock C), already fully developed to leucaena-grass pasture, was modelled to look separately at the leucaena component of steer growth paths involving access to leucaena-grass pasture. This removed the effect of the growth path implementation phase and the non-leucaena components of each growth path, and hence allowed comparison of the efficiency of the individual leucaena components of each growth path to be identified. The objective of the analysis for ‘Paddock C’ was to complement the whole-farm, integrated herd modelling analyses conducted for Enterprise A and B above to 1) test the usefulness of the gross margin methodology for comparing forage and cattle growth path scenarios, and 2) consider whether the most efficient growth path also represented the most efficient use of a limited area of developed leucaena-grass pasture.

2.3 Growth path scenarios

2.3.1 Cattle growth path scenarios for steers grazing buffel grass with or without access to leucaena-grass, or to leucaena-grass in combination with forage oats

Growth paths were developed for steers grazing buffel grass with and without access to leucaena-grass pastures, or leucaena-grass pastures in combination with forage oats, for varying periods of time throughout their growth path from weaning to sale. Steers were mostly marketed as either a) 'feed-on' steers (450 kg at feedlot), or b) 'finished' steers to achieve 310 kg carcass weight at the abattoir. These two key markets were selected as representative of the most common sale targets off buffel grass in the central Queensland region (Bowen *et al.* 2015*a*). Feed-on steers were required to reach 474 kg liveweight in the paddock prior to sale due to an assumed loss of 5% liveweight during transit from the paddock to the feedlot. Finished steers were required to reach 605 kg in the paddock prior to sale due to loss of 5% liveweight prior to slaughter and assuming a dressing percentage at the abattoir of 54% of the slaughter liveweight (Wythes *et al.* 1983; McKiernan *et al.* 2007). Some growth paths finished at sale weights that coincided with the end of an oats crop. The periods during which steers were grazed on various forages after weaning were broadly identified as being either the 'dry season', considered to be from March to November, or the 'wet season', considered to be from December to February. The dry and wet seasons were nominated as being either the first, second or third after weaning.

In total, 22 growth path scenarios were modelled. Scenarios were for pastures in A land condition and with 30% buffel pasture utilisation, unless otherwise indicated. The baseline scenario was considered to be Scenario 2, producing finished steers from buffel grass pastures in A land condition and with 30% utilisation:

1. **Scenario 1**: buffel grass pasture (B) from weaning to produce feed-on steers (FO), (B_FO), (100% of post-weaning growth period on buffel)
2. **Scenario 2**: buffel grass pasture from weaning to produce finished steers (F), (**baseline scenario**), (B_F), (100% of post-weaning growth period on buffel)
3. **Scenario 3**: leucaena-grass pasture (L) from weaning in the first dry season (DS1) to produce feed-on steers, (DS1L_FO), (100% of post-weaning growth period on leucaena-grass)
4. **Scenario 4**: leucaena-grass pasture from weaning in the first dry season to produce finished steers (DS1L_F), (100% of post-weaning growth period on leucaena-grass)
5. **Scenario 5**: buffel grass pasture from weaning then leucaena-grass from the start of wet season one (WS1) to produce feed-on steers (B-WS1L_FO), (60% of post-weaning growth period on leucaena-grass)
6. **Scenario 6**: buffel grass pasture from weaning then leucaena-grass from start of wet season one to produce finished steers (B-WS1L_F), (70% of post-weaning growth period on leucaena-grass)

7. **Scenario 7**: buffel grass pasture from weaning then leucaena-grass from start of dry season two (DS2) to produce feed-on steers (B-DS2L_FO), (48% of post-weaning growth period on leucaena-grass)
8. **Scenario 8**: buffel grass pasture from weaning then leucaena-grass from start of dry season two to produce finished steers (B-DS2L_F), (58% of post-weaning growth period on leucaena-grass)
9. **Scenario 9**: buffel grass pasture from weaning then leucaena-grass from start of wet season two (WS2) to produce feed-on steers (B-WS2L_FO), (6% of post-weaning growth period on leucaena-grass)
10. **Scenario 10**: buffel grass pasture from weaning then leucaena-grass from start of wet season two to produce finished steers (B-WS2L_F), (26% of post-weaning growth period on leucaena-grass)
11. **Scenario 11**: buffel grass pasture from weaning then leucaena-grass from start of dry season three (DS3) to produce finished steers (B-DS3L_F), (20% of post-weaning growth period on leucaena-grass)
12. **Scenario 12**: buffel grass pasture from weaning then oats (O) in dry season one followed by leucaena-grass to produce feed-on steers (B-O-L_FO), (61% of post-weaning growth period on leucaena-grass, 22% on oats)
13. **Scenario 13**: buffel grass pasture from weaning then oats (O) in dry season one followed by leucaena to produce finished steers (B-O-L_F), (76% of post-weaning growth period on leucaena-grass, 14% on oats)
14. **Scenario 14**: buffel grass pasture from weaning then oats in dry season one followed by leucaena and then oats in dry season two to produce finished steers (B-O-L-O_F), (55% of post-weaning growth period on leucaena-grass, 32% on oats)
15. **Scenario 15**: buffel grass pasture in A land condition and 35% utilisation from weaning to produce feed-on steers (B35_FO), (100% of post-weaning growth period on buffel)
16. **Scenario 16**: buffel grass pasture in A land condition and 35% utilisation from weaning to produce finished steers (B35_F), (100% of post weaning growth period on buffel)
17. **Scenario 17**: buffel grass pasture in A land condition and 50% utilisation from weaning to produce feed-on steers (B50_FO), (100% of post weaning growth period on buffel)
    - **17a:** no decline in pasture quantity or quality (and hence beef production) over 30 years (considered as an upper threshold)
    - **17b:** pasture quality and quantity declined linearly from A to B condition from year 20 to 30
    - **17c:** pasture quality and quantity declined linearly from A to B condition from year 10 to 20 and then remained in B condition from year 20 to 30
    - **17d:** pasture quality and quantity declined linearly from A to B condition from year 10 to 20 and then declined linearly from B to C condition from year 20 to 30
18. **Scenario 18**: buffel grass pasture in A land condition and 50% utilisation from weaning to produce finished steers (B50_F), (100% of post-weaning growth period on buffel)

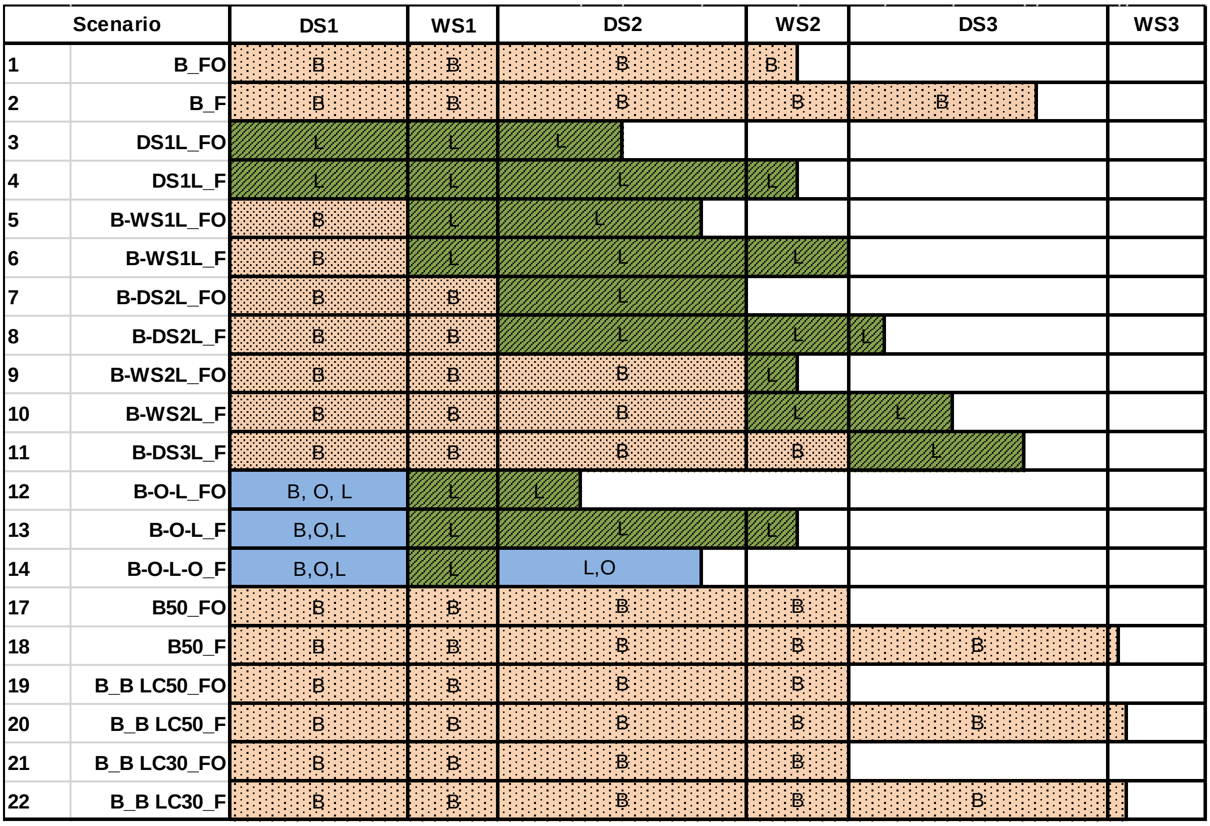
- **18a:** no decline in pasture quantity or quality (and hence beef production) over 30 years (considered as an upper threshold)
- **18b:** pasture quality and quantity declined linearly from A to B condition from year 20 to 30
- **18c:** pasture quality and quantity declined linearly from A to B condition from year 10 to 20 and then remained in B condition from year 20 to 30
- **18d:** pasture quality and quantity declined linearly from A to B condition from year 10 to 20 and then declined linearly from B to C condition from year 20 to 30

19. **Scenario 19**: buffel grass pasture in B land condition and 50% utilisation from weaning to produce feed-on steers (B_B LC50_FO; considered as an upper threshold), (100% of post-weaning growth period on buffel)
20. **Scenario 20**: buffel grass pasture in B land condition and 50% utilisation from weaning to produce finished steers (B_B LC50_F; considered as an upper threshold), (100% of post-weaning growth period on buffel)
21. **Scenario 21**: buffel grass pasture in B land condition and 30% utilisation from weaning to produce feed-on steers (B_B LC30_FO), (100% of post-weaning growth period on buffel)
22. **Scenario 22**: buffel grass pasture in B land condition and 30% utilisation from weaning to produce finished steers (B_B LC30_F), (100% of post-weaning growth period on buffel).

The change in liveweight of steers over time in each growth path was determined by applying the assigned daily growth rates for each forage type and seasonal period, until steers reached either feed-on or finishing weights as per the scenario definition. A schematic representation of the growth paths is given in (Figure 1). Scenarios 15-16 are not displayed as the growth paths from steers grazing buffel grass pasture in A land condition with 35% pasture utilisation are assumed to be identical to that under a 30% pasture utilisation regime, and hence equivalent to Scenarios 1 and 2 for feed-on and finished steers, respectively.

Figure 1 – Schematic representation of steer growth paths according to forage provided (buffel (B), leucaena-grass (L) or leucaena-grass in combination with oats (O)) during the dry seasons (DS) and wet seasons (WS) between weaning and sale as either 'feed-on' (FO) or 'finished' (F) steers

Definitions of scenarios are given in the text. Brown shading indicates grazing on buffel grass pastures, green shading indicates grazing on leucaena-grass pastures and blue shading indicates grazing periods which included forage oats



2.3.2 Cattle growth path scenarios for steers grazing buffel grass with access to forage oats

Growth paths were developed for steers grazing buffel grass with and without access to forage oats at various points in time throughout their growth path from weaning to sale. Steers were mostly marketed either at the end of the grazing period on the oats crop or returned to buffel grass pastures until they reached the target finished weight of 605 kg in the paddock to achieve 310 kg carcass weight at the abattoir, as for leucaena-grass scenarios. Some growth paths finished at sale weights that coincided with the end of an oats crop. Steers were grazed on forage oats in either the first, second or third dry season after weaning (DS1, DS2 and DS3, respectively) or in both first and second dry seasons.

In total, 7 growth path scenarios examining forage oats provided in combination with buffel grass pastures were modelled:

23. **Scenario 23**: buffel grass pasture from weaning and then oats (O) in the first dry season to produce yearlings (DS1O), (57% of post-weaning growth period on oats)
24. **Scenario 24**: buffel grass pasture from weaning, oats in the first dry season and then buffel grass to produce feed-on steers (DS1O-B-FO), (18% of post-weaning growth period on oats)

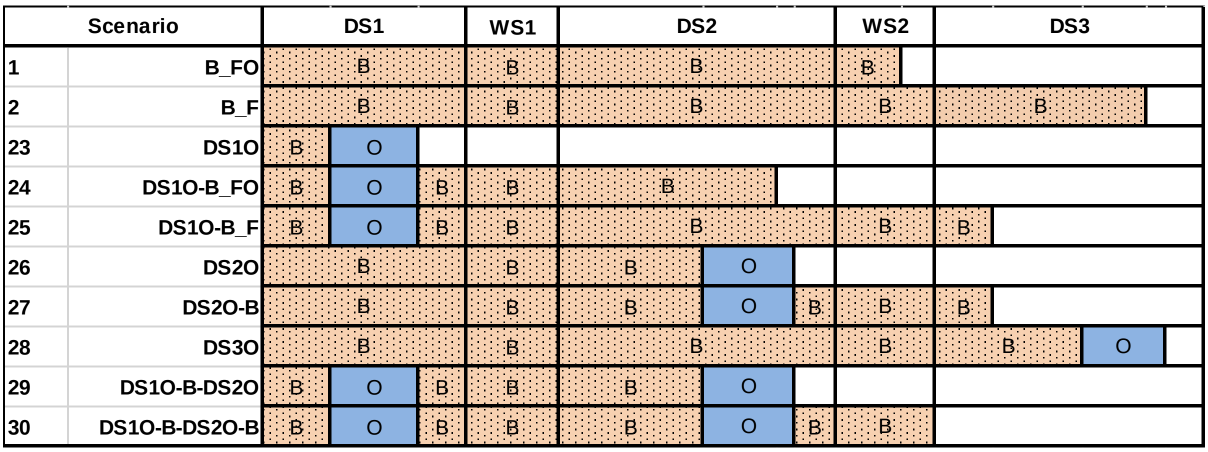
25. **Scenario 25**: buffel grass pasture from weaning, oats in the first dry season and then buffel grass to produce finished steers (DS1O-B_F), (12% of post-weaning growth period on oats)
26. **Scenario 26**: buffel grass pasture from weaning and then oats in the second dry season to produce feed-on steers (DS2O), (16% of post-weaning growth period on oats)
27. **Scenario 27:** buffel grass pasture from weaning, oats in the second dry season and then buffel grass to produce finished steers (DS2O-B), (12% of post-weaning growth period on oats)
28. **Scenario 28**: buffel grass pasture from weaning and then oats in the third dry season to produce finished steers (DS3O), (9% post-weaning growth period on oats)
29. **Scenario 29**: buffel grass pasture from weaning, oats in the first dry season, then buffel followed by oats in the second dry season to produce a combination of feed-on and finished steers (DS1O-B-DS2O), (32% of post-weaning growth period on oats)
30. **Scenario 30**: buffel grass pasture from weaning, oats in the first and second dry seasons, followed by buffel to produce finished steers (DS1O-B-DS2O-B), (26% of post-weaning growth period on oats).

The buffel grass pastures in Scenarios 23 to 30 were assumed to be in A land condition with 30% pasture utilisation. As for Scenarios 1 to 22, the change in liveweight of steers over time in each growth path was determined by applying the daily growth rates for each forage type and seasonal period, as defined above, until steers either completed grazing on the oats crop or reached 'feed-on' or 'finishing' weights, as per the scenario definition.

A schematic representation of the growth paths is given in (Figure 2). Scenarios 1 and 2 for steers grazing buffel grass pastures without access to oats are also presented for comparison with the growth paths incorporating oats forage.

Figure 2 – Schematic representation of steer growth paths according to forage provided (buffel (B) or oats (O)) during the dry seasons (DS) and wet seasons (WS) between weaning and sale at either the end of grazing on the oats crop or as 'feed-on' (FO) or 'finished' (F) steers

Definitions of scenarios are given in the text. Brown shading indicates grazing on buffel grass pastures and blue shading indicates grazing on forage oats



2.3.3 Calculation of grazing area required for each forage type

The stocking rate (and hence number of ha required) for each grazing period on either buffel grass pasture, leucaena-grass pasture or oats forage was determined by calculating available pasture biomass for consumption per hectare (based on the specified forage utilisation rate for that scenario) and then dividing by the calculated steer intake of pasture dry matter over that period. For leucaena-grass pastures, the respective annual biomass production and utilisation levels of the buffel grass and edible leucaena components were summed to determine total biomass available. It was assumed that cattle consumed 50% of their diet DM as leucaena biomass, as per data from Bowen *et al.* (2016). The pasture biomass available for consumption during a defined growth path was adjusted proportionally for days greater or less than the full annual period except for oats grazing where the land area allocated to oats production was only available for grazing once every 12 months.

As described previously for calculation of representative carrying capacity figures (AE/ha), the average DM intake by steers of each forage type within each growth path was estimated using the QuikIntake Excel spreadsheet calculator (McLennan and Poppi 2016) modified from the Australian ruminant feeding standards (NRDR 2007) to better predict intake for *B. indicus* content cattle and tropical diets (McLennan 2014). In the prediction of average DM intake, the average DMD of buffel, leucaena or oats forage for the relevant period was assigned based on data from Bowen *et al.* (2015*b*). The average liveweight of the cattle (i.e. liveweight at the mid-way point) and the assumed average daily gain over the relevant period were used as key inputs. The cattle were assumed to be 50% *B. indicus*, to have a standard reference weight (SRW) of 660 kg, to walk 7 km/day (as per McLean and Blakely 2014) and the terrain to be 'level 2' (gentle slope).

Enterprise A had a size limit of 1,000 ha and the area allocated to each forage type in each growth path was based on the balance between the demand for forage and the supply of forage within the phases of the growth path. This was achieved by varying the number of steers entering the growth path as weaners to match forage supply by each component of the growth path and demand by the steers, within the 1,000 ha limit.

Enterprise B had 1,327 ha of the property initially allocated to the finishing of steers from weaning on buffel grass. The breeder herd was allocated to the remainder of the property and supplied weaner steers to the steer finishing system. The area required to meet the needs for each steer growth path was initially based on the supply of weaners steers in the baseline scenario. In the vast majority of scenarios, implementing the alternative growth paths reduced the area of the property required to operate the steer component of the beef enterprise, allowing proportionally more breeders to be carried and hence more weaner steers to be produced. An iterative process of balancing the supply of weaner steers, with the area of the property required to meet the needs of the growth path and the needs of the breeder herd, identified the optimal size of the breeding component that was able to supply the weaner numbers to meet the needs of the growth path. In all scenarios the performance of the breeding herd was the same with no allowance for the potential impact on components of the breeder herd most likely having access to better pasture nutrition within the property as the area of the property allocated to carrying breeders, increased. The herd size and structure were optimised within the limits applied by the property size and the respective areas and quality of forage type.

The forage area allocated to each growth path in each scenario was sufficient to meet the needs of the steers for the entire period they were on the growth path. The allocation included allowance for steer age groups that overlapped while they were on the growth path.

2.4 Economic and financial analysis of the scenarios

2.4.1 Modelling process

The economic and financial analyses consisted of the comparison of the baseline scenario (Scenario 2: B_F) management system continued into the future, with each alternative system starting at the same point and also continued into the future. Change was implemented by altering the herd performance and inputs of the baseline scenario so that a new scenario was constructed from the baseline 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. For example, all of the steer turnover enterprise spreadsheets started with the opening stock required for the baseline scenario and steers were sold and purchased as required to implement individual growth path scenarios. All scenarios were compared to the baseline scenario of turning off finished steers as this was identified as the current optimum buffel growth path for the central Queensland region by Chudleigh *et al*. (2017*b*).

Discounted cash flow (DCF) techniques were applied to look at the marginal returns associated with any additional capital or resources invested within farm operations. The DCF analysis was compiled in real (constant value) terms, with all variables expressed in terms of the price level of the present year. It was also assumed that future inflation would affect all costs and benefits even-handedly.

The economic criterion were NPV at the required rate of return (5%; taken as the real opportunity cost of funds to the producer) and the IRR. NPV was calculated as the net returns (income minus costs) over the life of the investment, expressed in present day terms. IRR was calculated as the discount rate at which the present value of income from a project equals the present value of total expenditure (capital and annual costs) on the project (i.e. the break-even discount rate). The NPV was amortised at a 5% discount rate over the life of the investment to identify the annual average improvement in profit generated by the implementation of the alternative growth path. Profit was calculated net of an operator's allowance.

Financial measures of peak deficit, the number of years to the peak deficit, and the payback period in years were also calculated. The beef enterprise started with no debt but accumulated debt and paid interest as required by the implementation of each growth path. An inventory of plant and equipment developed for each scenario provided estimates of the replacement interval, replacement cost and residual value for purchased or owned equipment.

A 3 decade analysis period was used for all scenarios to match the likely economic life of an investment in leucaena (Radrizzani *et al.* (2010, 2016) and the requirement to compare all investments over equal lives when the NPV decision rule is applied (Campbell and Brown 2003).

2.4.2 Enterprise A - steer turnover enterprise

Excel spreadsheets were developed using the methodology described by Gittinger (1982) and Robinson and Barry (1996), and applied in Makeham and Malcolm (1993) and Campbell and Brown (2003). The spreadsheets contained livestock schedules linked to cash flow and investment budgets, for the base scenario and each alternative scenario, for a period of 3 decades. This allowed a marginal analysis of a property running steers on buffel to slaughter weight (Scenario 2: B_F) with the same property converted to running steers on various forages to achieve the desired growth paths.

2.4.3 Enterprise B - breeding and finishing enterprise

The Breedcow and Dynama herd budgeting software (Version 6.02; Holmes *et al.* 2017) were used to build a representative, integrated beef breeding and finishing enterprise based on the baseline scenario (Scenario 2 : B_F). An assessment was then made of the economic and financial impact of the property moving from the baseline scenario to each alternative growth path scenario. In general:

- The steady state herd model, Breedcowplus, was applied to model the starting point for the baseline scenario, the steps required to implement change, and the end point or target of each scenario. The outputs of this step were herd structure and herd value.
- The 10-year herd budgeting program, Dynamaplus, was used to model the baseline scenario on an annual basis based on the parameters developed in Breedcowplus. Two decadal Dynamaplus models were developed to match the structure of the Investan program.
- Dynamaplus was then used to model from the baseline scenario starting point through the implementation phase to the end point of each of the growth path scenarios, also over 2 decades.
- The investment analysis program, Investan, was used to compare the baseline scenario investment with each of the alternative growth path scenarios to identify the extra costs and extra benefits of the scenario; i.e. the marginal returns on the investment, expressed as NPV and IRR.
- As the Investan program only models over 2 decades, the analysis was extended to 30 years by calculating the 'present value' of the difference between the alternative scenarios over the second decade, or once they both achieved a steady state, and adding this to the closing non-cash assets value of the Investan file.
- The indicators of peak deficit, the year of the peak deficit, and the number of years taken to payback the original investment were also estimated in the Investan model where they were calculable within the first two decades.

For growth path scenarios where an increase in breeder numbers were required to meet the requirements of the growth path for steers, two alternatives where examined: a) building up breeder numbers naturally over time (i.e. no additional purchases), and b) purchase of additional breeders to meet the requirements of the steer growth path. Economic and financial results of purchasing additional breeders are only presented for Scenario 3 (DS1L_FO).

Scenarios 15-22 were not modelled as part of the breeder enterprise analysis as there is no data to allow assumptions to be made about the potential impact of changing pasture utilisation on breeder herd performance.

2.4.4 Paddock C – established leucaena

The gross margin framework developed by Bowen *et al*. (2015*b*) was applied to look at the leucaena component of steer growth paths involving access to leucaena-grass pasture and to determine the 'extra' value added by that component of the growth path. For each scenario, a gross margin analysis was applied by valuing the steers into and out of the leucaena grazing phase with appropriate variable costs applied. The cost per hectare of accessing the leucaena grass forage was derived by amortising leucaena development and maintenance costs over a 30-year period at a discount rate of 5% and was applied equally to all scenarios. The leucaena was taken to be fully established. This removed the impact of the growth path implementation phase and the non leucaena components of each growth path and hence allowed comparison of the efficiency of the individual leucaena components of each growth path to be identified. In this analysis, Scenario 2 (the baseline scenario of buffel grazing from weaning to finishing; B_F) was included for comparison.

3 Results

3.1 Effect of steer growth paths on age of turn-off (sale)

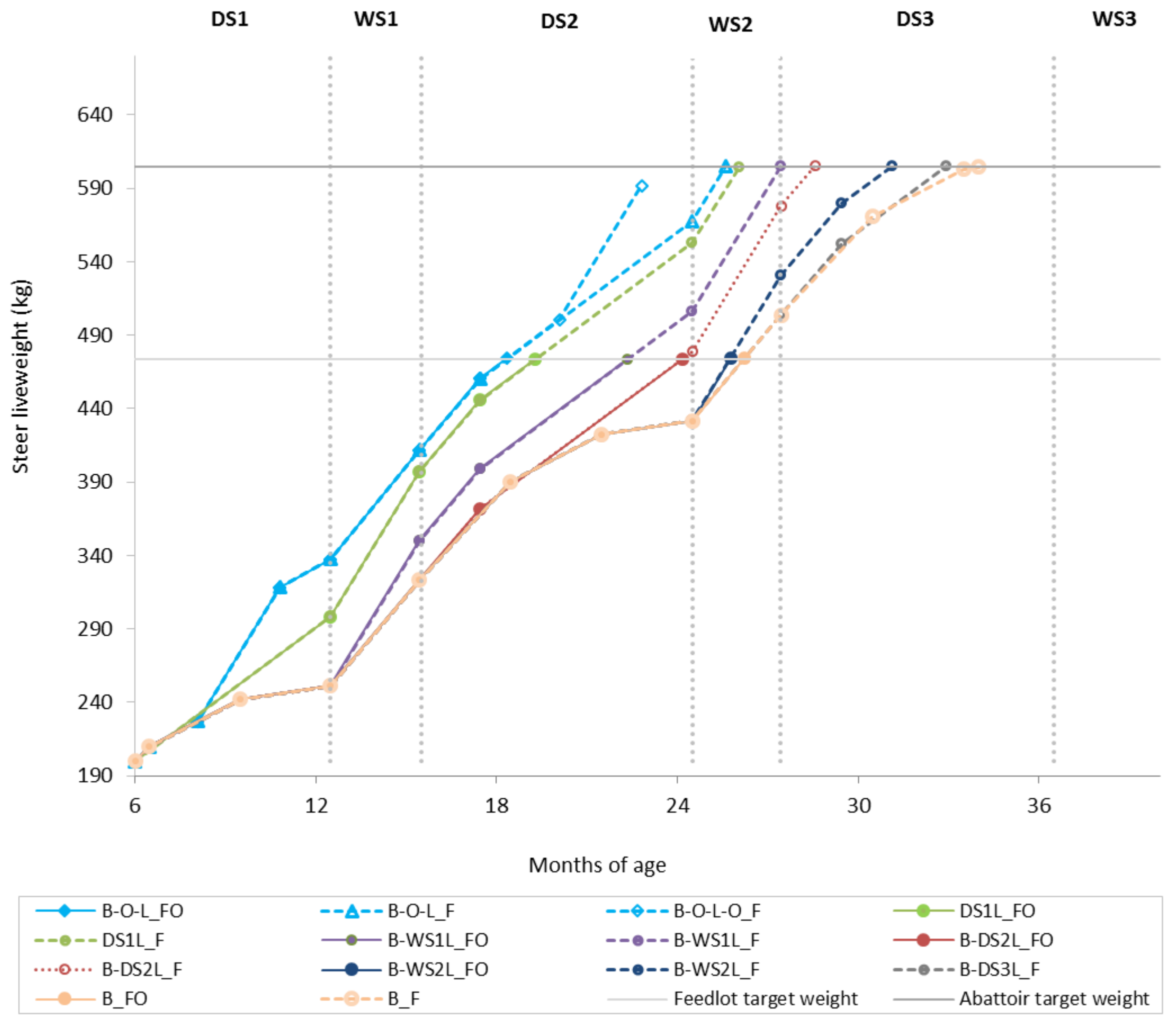
3.1.1 Steer growth paths resulting from access to buffel grass pastures with or without leucaena-grass pastures, or leucaena-grass in combination with forage oats

The steer growth paths developed for Scenarios 1-14, where cattle were given access to leucaena-grass pastures at some stage in their growth path between weaning and attaining either feedlot or abattoir target weights, are shown in Figure 3.

The effect on age of steer turn-off of providing leucaena, or leucaena in combination with forage oats, in the steer growth path, can be summarised as follows:

- Steers grazing buffel grass pastures in A land condition and with 30% pasture utilisation until marketing reached feedlot target entry weight (474 kg paddock weight) at 26.2 months of age and abattoir target weight (605 paddock weight) at 34.0 months of age in their third dry season after weaning.
- The earlier in the growth path that steers commenced grazing leucaena-grass pastures, the younger the turn-off age, with steers grazing leucaena-grass pastures from weaning (DS1L_FO and DS1L_F) reaching feedlot and abattoir target entry weights at 19.3 and 26.0 months of age, respectively. This age of turn-off is 7 and 8 months earlier for feed-on and finished steers, respectively, than if grazed solely on buffel grass pastures.
- Steers not given access to leucaena-grass pastures until the start of their third dry season post-weaning (B-DS3L_F) reached the abattoir target weight at 32.9 months of age (after 167 days on leucaena-grass), only ca. 1 month earlier than if they had remained on buffel grass.
- Providing oats forage to weaners in their first dry season followed by leucaena-grass pastures (B-O-L_FO and B-O-L_F), allowed steers to reach feedlot and abattoir target weights at a younger age than steers not fed oats: 18.3 and 25.6 months of age, respectively. This age of turn-off is 1 month or ca. 13 days earlier for feed-on or finished steers, respectively, than for steers exclusively fed leucaena from weaning.
- Providing oats forage twice in the growth path, in the first and second dry seasons after weaning, with access to leucaena-grass pasture in between (B-O-L-O_F), allowed steers to reach abattoir entry weights at the youngest age of all scenarios: 22.8 months, 11.2 months younger than if sold off buffel grass.

Figure 3 – Liveweight change over time for steers fed 14 different forage scenarios including combinations of buffel (B), leucaena-grass (L) or oats (O), over dry (DS) and wet (WS) seasons between weaning and sale at either 'feed-on' (FO) or 'finished' (F) target weight
Definitions of scenarios are given below



Definitions of scenarios shown in Figure 3:

- B-O-L_FO (Scenario 12): buffel grass pasture from weaning then oats (O) in dry season one followed by leucaena-grass to produce feed-on steers
- B-O-L_F (Scenario 13): buffel grass pasture from weaning then oats (O) in dry season one followed by leucaena to produce finished steers
- B-O-L-O_F (Scenario 14): buffel grass pasture from weaning then oats in dry season one followed by leucaena and then oats in dry season two to produce finished steers
- DS1L_FO (Scenario 3): leucaena-grass pasture (L) from weaning in the first dry season (DS1) to produce feed-on steers
- DS1L_F (Scenario 4): leucaena-grass pasture from weaning in the first dry season to produce finished steers
- B-WS1L_FO (Scenario 5): buffel grass pasture from weaning then leucaena-grass from the start of wet season one (WS1) to produce feed-on steers

- B-WS1L_F (Scenario 6): buffel grass pasture from weaning then leucaena-grass from start of wet season one to produce finished steers
- B-DS2L_FO (Scenario 7): buffel grass pasture from weaning then leucaena-grass from start of dry season two (DS2) to produce feed-on steers
- B-DS2L_F (Scenario 8): buffel grass pasture from weaning then leucaena-grass from start of dry season two to produce finished steers
- B-WS2L_FO (Scenario 9): buffel grass pasture from weaning then leucaena-grass from start of wet season two (WS2) to produce feed-on steers
- B-WS2L_F (Scenario 10): buffel grass pasture from weaning then leucaena-grass from start of wet season two to produce finished steers
- B-DS3L_F (Scenario 11): buffel grass pasture from weaning then leucaena-grass from start of dry season three (DS3) to produce finished steers
- B_FO (Scenario 1): buffel grass pasture (B) from weaning to produce feed-on steers (FO)
- B_F (Scenario 2): buffel grass pasture from weaning to produce finished steers (F), (baseline scenario).

3.1.2 Steer growth paths resulting from buffel grass pastures with or without access to forage oats

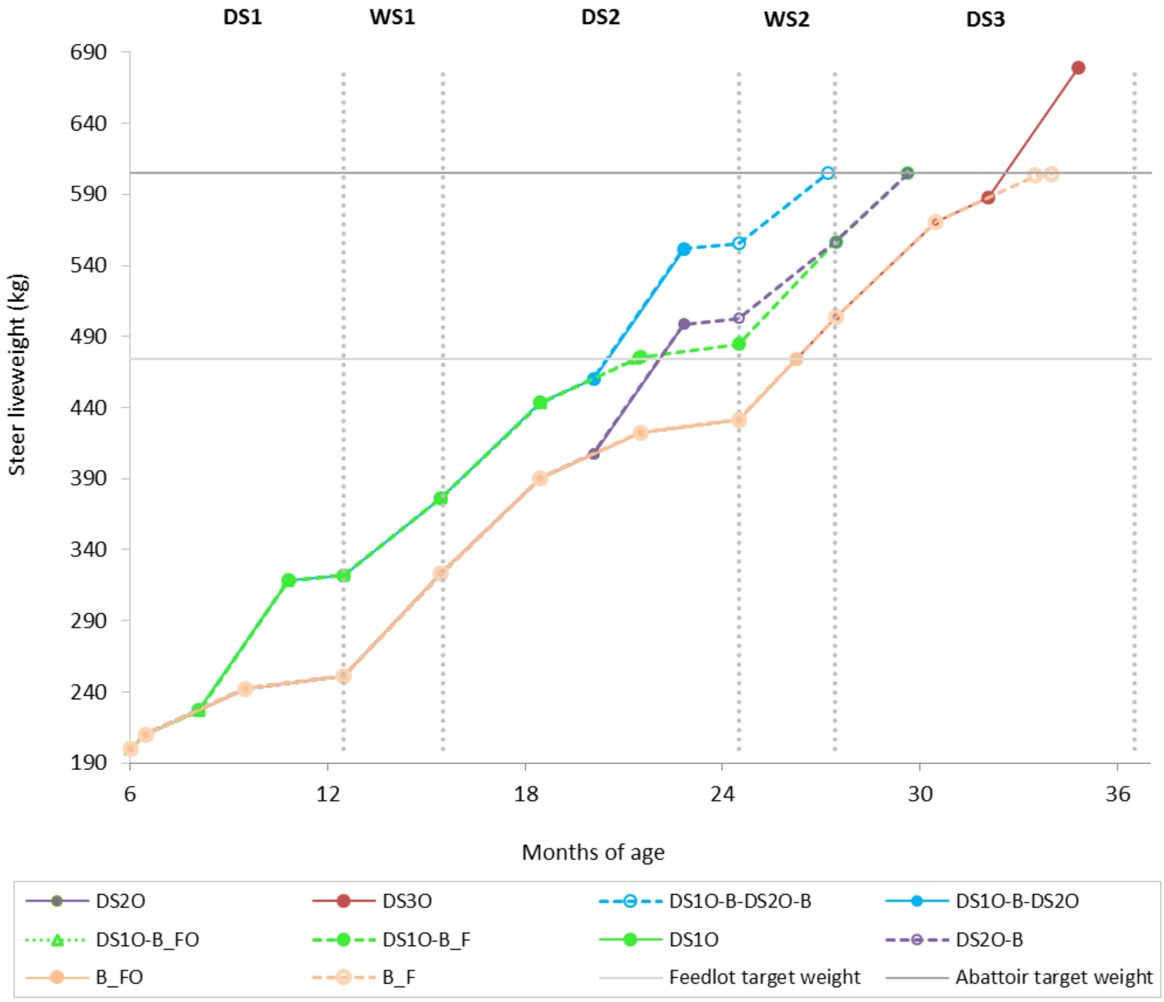
The steer growth paths developed for scenarios where cattle received access to forage oats at various points in their growth path (Scenarios 23-30) are shown in Figure 4. Growth paths for steers grazing buffel grass pastures without access to oats (Scenarios 1 and 2 (B_FO and B_F)) are also presented for comparison.

The effect of providing forage oats in the steer growth path, on the age of turn-off, can be summarised as follows:

- Steers grazed on forage oats during their first dry season after weaning (DS1O) were 318 kg and 10.8 months of age when marketed at the end of the oats crop.
- If steers were returned to buffel grass pastures after grazing oats in dry season one (DS1O-B_FO and DS1O-B_F), they reached feedlot and abattoir target weights at 21.4 and 29.6 months of age, respectively, 4.8 and 4.4 months earlier than steers grazing buffel pastures throughout the entire growth path (B_FO and B_F).
- Steers grazing oats forage in their second dry season after weaning (DS2O) reached 499 kg by 22.8 months of age. If these steers were returned to buffel grass pastures after grazing oats (DS2O-B), they reached the abattoir target weight at the same age (29.6 months) as for steers grazed on forage oats in DS1 and then returned to buffel to finish (DS1O-B_F).
- Providing oats only in the third dry season after weaning (DS3O) to steers already 588 kg average liveweight at commencement of grazing, resulted in a final, finished liveweight of 679 kg at 34.8 months of age.
- Providing oats forage twice in the growth path, in the first and second dry seasons after weaning, (DS1O-B-DS2O), resulted in a sale liveweight of 552 kg at 22.8 months. If these steers were instead returned to buffel grass pastures after grazing oats in dry season two, (DS1O-B-DS2O-B), they reached abattoir target entry weight at 27.2 months of age,

2.4 months earlier than cattle only grazing an oats crop once in their growth path (DS1O-B or DS2O-B) and 6.8 months earlier than cattle grazing buffel pastures throughout their entire growth path (B_F).

Figure 4 – Liveweight change over time for steers fed buffel grass pastures (B) during wet (WS) and dry (DS) seasons and with or without access to oats forage (O) in DS1, 2 or 3, or both DS1 and 2, between weaning and sale at either 'feed-on' (FO) or 'finished' (F) target weight
Definitions of scenarios are given in the below



Definitions of scenarios shown in Figure 4:

- DS1O **(**Scenario 23): buffel grass pasture from weaning and then oats (O) in the first dry season to produce yearlings
- DS1O-B-FO (Scenario 24): buffel grass pasture from weaning, oats in the first dry season and then buffel grass to produce feed-on steers
- DS1O-B_F (Scenario 25): buffel grass pasture from weaning, oats in the first dry season and then buffel grass to produce finished steers
- DS2O (Scenario 26): buffel grass pasture from weaning and then oats in the second dry season to produce feed-on steers

- DS2O-B (Scenario 27): buffel grass pasture from weaning, oats in the second dry season and then buffel grass to produce finished steers
- DS3O (Scenario 28): buffel grass pasture from weaning and then oats in the third dry season to produce finished steers
- DS1O-B-DS2O (Scenario 29): buffel grass pasture from weaning, oats in the first dry season, then buffel followed by oats in the second dry season to produce predominantly finished steers
- DS1O-B-DS2O-B (Scenario 30): buffel grass pasture from weaning, oats in the first and second dry seasons, followed by buffel to produce finished steers
- B_FO (Scenario 1): buffel grass pasture (B) from weaning to produce feed-on steers (FO).
- B_F (Scenario 2): buffel grass pasture from weaning to produce finished steers (F), (baseline scenario).

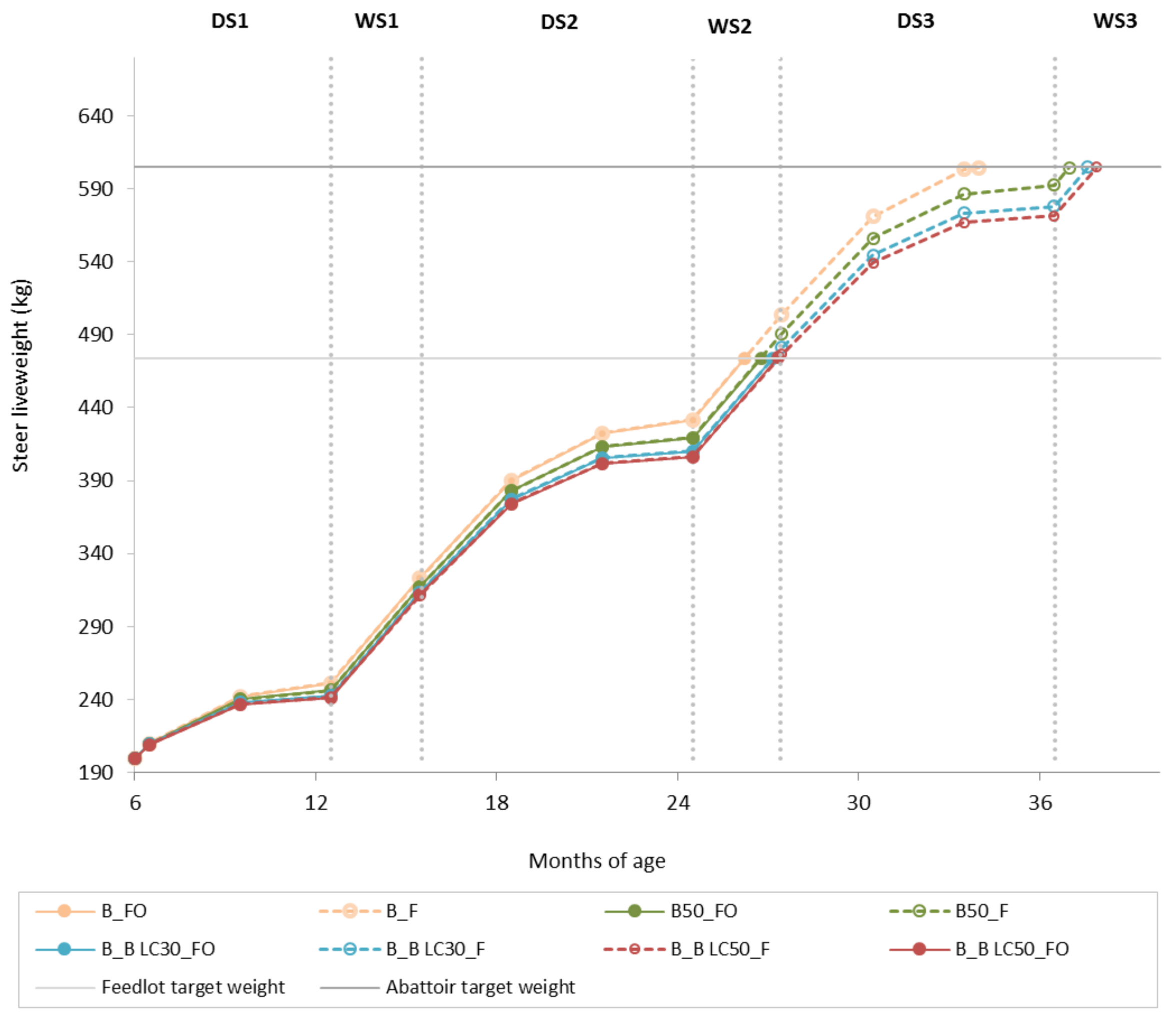
3.1.3 Steer growth paths resulting from alternative pasture utilisation levels and land condition of buffel grass pastures

The steer growth paths developed for scenarios where different levels of buffel grass pasture utilisation and land condition were examined (Scenarios 17-22) are shown in Figure 5. Growth paths for steers grazing baseline buffel grass pastures considered to be in A land condition and with 30% pasture utilisation (Scenarios 1 and 2 (B_FO and B_F)) are also presented for comparison.

The effect of pasture utilisation level and land condition, on age of steer turn-off from buffel grass pastures, can be summarised as follows:

- When buffel pasture utilisation rates of land in A condition were increased from 30 or 35 to 50% of the annual biomass growth (B50_FO and B50_F), steers took an additional 16 days or 3 months to reach feedlot or abattoir target entry weights, respectively, when land was assumed to remain in A condition (Scenario 17a).
- Steers grazing buffel grass pastures in B land condition under a 50% pasture utilisation regime until marketing (B_B LC50_FO and B_B LC50_F) took an additional 34 days or 4 months grazing, respectively, to reach feedlot or abattoir target entry weights, compared to grazing on A condition pasture under a 30 or 35% utilisation regime.
- When the buffel grass pastures in B land condition were utilised at a rate of 30% of the annual biomass growth, steers took an additional 28 days or 3.6 months grazing, respectively, to reach feed or abattoir target entry weights, compared to grazing on A condition pasture under a 30 or 35% utilisation regime.
- All scenarios of increasing buffel pasture utilisation rates above 35% or decreasing land condition from A to B, required cattle to remain on buffel pasture until their third wet season after weaning until reaching abattoir target weight (rather than finishing during their third dry season).

Figure 5 – Liveweight change over time for steers grazing buffel grass pasture (B) in either A or B (_B LC) land condition and at 30, 35 or 50% pasture utilisation, over dry (DS) and wet (WS) seasons between weaning and sale at either 'feed-on' (FO) or 'finished' (F) target weight
Definitions of scenarios are given below. Growth paths for steers grazing land in A condition and utilising 35% of pasture biomass (B35_FO and B35_F) were identical to those for steers utilising 30% of the pasture (B_FO and B_F) and hence are not presented separately.



Definitions of scenarios shown in Figure 5:

- B_FO (Scenario 1): buffel grass pasture (B) from weaning to produce feed-on steers (FO)
- B_F (Scenario 2): buffel grass pasture from weaning to produce finished steers (F), (baseline scenario)
- B50_FO (Scenario 17a): buffel grass pasture in A land condition and 50% utilisation from weaning to produce feed-on steers
- B50_F (Scenario 18a): buffel grass pasture in A land condition and 50% utilisation from weaning to produce finished steers
- B_B LC30_FO (Scenario 21): buffel grass pasture in B land condition and 30% utilisation from weaning to produce feed-on steers

- B_B LC30_F (Scenario 22): buffel grass pasture in B land condition and 30% utilisation from weaning to produce finished steers
- B_B LC50_FO (Scenario 19): buffel grass pasture in B land condition and 50% utilisation from weaning to produce feed-on steers
- B_B LC50_F (Scenario 20): buffel grass pasture in B land condition and 50% utilisation from weaning to produce finished steers.

3.2 Effect of land condition and pasture utilisation rates on carrying capacity

The effects of changes in land condition and pasture utilisation rates on the carrying capacity of buffel grass pastures are demonstrated in Table 2. In summary, the key effects were:

- Increasing pasture utilisation rates from 30 to 35%, with no change in land condition from A status, increased the number of steers that could be run per 1,000 ha until attaining target weight by 17% for both feed-on and finished steers.
- Increasing pasture utilisation rates from 30 to 50%, with no change in land condition from A status, increased the number of steers that could be run per 1,000 ha until attaining target weight by 54 and 43%, for feed-on and finished steers, respectively.
- If it is assumed that land condition had declined to B condition under a long-term 50% pasture utilisation strategy, the number of animals able to be run per 1,000 ha until attaining target weight was very similar to that under a 30% utilisation strategy for land in A condition: 5% greater and 2% less, for feed-on and finished steers, respectively.
- If pasture utilisation on land in B condition was decreased from 50 to 30%, this reduced the carrying capacity over the entire grazing period by 38% for both feed-on and finished steers.

Table 2 – Number of steers able to be carried per 1,000 ha of buffel grass pasture from weaning (200 kg liveweight) to sale weight (474 or 605 kg paddock liveweight for 'feed-on' (FO) and 'finished' (F) target markets, respectively), for pastures in A and B land condition and with 30, 35 or 50% utilisation

Definitions of parameters are given in the text

Scenario	**Steers/1,000 ha**	**Days to achieve target weight**	**Average liveweight gain over total period (kg/d)**
'Feed-on' target market			
Scenario 1: B_FO A land condition, 30% utilisation	249	615	0.45
Scenario 15: B35_FO A land condition, 35% utilisation	291	615	0.45
Scenario 17a: B50_FO A land condition, 50% utilisation	384	631	0.43
Scenario 19: B_B LC50_FO B land condition, 50% utilisation	261	649	0.42
Scenario 21: B_B LC50_FO B land condition, 30% utilisation	163	643	0.43
'Finished' target market			
Scenario 2: B_F A land condition, 30% utilisation	161	851	0.48
Scenario 16: B35_F A land condition, 35% utilisation	188	851	0.48
Scenario 18a: B50_F A land condition, 50% utilisation	230	942	0.43
Scenario 20: B_B LC50_F B land condition, 50% utilisation	157	970	0.42
Scenario 22: B_B LC50_F B land condition, 30% utilisation	97	961	0.42

3.3 Modelled enterprise production outputs

Table 3 through Table 8 detail modelled production outputs for each enterprise and scenario. The values shown are for the average output or value achieved once the growth path or grazing system has been fully implemented.

3.3.1 Enterprise A – steer turnover enterprise

The modelled areas of forage required to implement the growth path scenarios on the 1,000 ha steer turnover enterprise are shown in Table 3. Allocation of forage area on the enterprise ranged from 100% of the area as buffel grass pasture (for the buffel-only production systems) to 100% of the area as leucaena-grass (steers grazed on leucaena-grass from weaning to turn-off). The largest area of oats was required for the production system producing yearling steers from oats (Scenario 23: DS10): 623 ha (62% of the total area).

The growth path scenario resulting in the greatest annual beef production per ha for the steer turnover enterprise was Scenario 23 (DS10) where weaner steers were grazed on oats and sold as yearlings at the end of the oats grazing period: 345 kg/ha.annum (Table 4). Scenario 23 also resulted in the greatest number of steers per 1,000 ha (1,345), the least number of days grazing to achieve target weight (146) and the greatest average daily liveweight gain (0.81 kg/d). The second greatest beef production was achieved from Scenario 3 (DS1L_FO) which involved grazing weaner steers on leucaena-grass until they attained feed-on weight: 183 kg/ha.annum. The least beef output was produced from scenarios which involved grazing weaner steers on buffel grass until attaining finishing weights with the baseline scenario (Scenario 2: B_F) producing: 26 kg/ha.annum (7.5 and 14.2% of the output from Scenarios 23 and 3, respectively). The beef production was lower again when steers were finished on B land condition pastures, with the lowest output achieved when these pastures were utilised at 30% (Scenario 22: B_B LC30_F): 14 kg/ha.annum).

3.3.2 Enterprise B – breeding and finishing enterprise

The modelled herd structure for the breeding and finishing enterprise (Enterprise B), using the Breedcowplus steady-state herd model, resulted in a maximum number of cattle carried for the full year for Scenario 4: DS1L_F (1759 head of cattle) which applied the growth path of grazing weaner steers on leucaena-grass until they attained finished weight (Table 5). The application of the steer growth path scenario of producing yearling steers from oats (Scenario 23: DS1O) resulted in the greatest number of cows and heifers mated (828), calves weaned (641) and cattle sold (583) per annum. The growth path scenarios resulting in the greatest numbers of steers entering the growth path each year for Enterprise B were Scenarios 23 (DS1O) and 3 (DS1L_F): 321 and 307, respectively (Table 7)

The allocation of total forage area for the steer component of Enterprise B ranged from a maximum of 1363 ha (Scenario 28: DS3O_F) where steers were finished on oats in their third dry season after weaning, to a minimum of 239 ha (Scenario 23: DS1O) where weaners were grazed on oats until attaining yearling weight (Table 6). The greatest area of leucaena-grass was required for Scenario 4 (DS1L_F) where steers were grazed on leucaena from weaning to finishing: 603 ha. The greatest area of forage oats was required for the production system producing finished steers by providing oats in dry season 1, then leucaena-grass, then oats in dry season 2 (Scenario 14: B-O-L-O_F): 333 ha total for dry seasons 1 and 2.

The growth path scenario resulting in the greatest annual beef production per ha for the whole herd was Scenario 4 (DS1L_F) where weaner steers were grazed on leucaena until sale as finished steers: 31 kg/ha.annum, an increase of 30% over the baseline scenario which produced 24 kg/ha.annum (Table 7). The next greatest beef production was achieved from Scenarios 3 (DS1L_FO), 6 (B-WS1L_F), 13 (B-O-L_F) and 14 (B-O-L-O_F) which all resulted in a whole herd beef production of ca. 30 kg/ha.annum, a 25% increase over the baseline herd. The least whole herd beef output was produced from Scenario 23 (DS1O) in which yearling steers were produced from forage oats: 22 kg/ha.annum, a decrease of 8.3% compared to the baseline scenario.

3.3.3 Paddock C – established leucaena

Table 8 summarises the production outputs for each growth path scenario applied to Paddock C (100 ha) containing established leucaena. In this analysis, Scenario 2 (the baseline scenario of buffel grazing from weaning to finishing; B_F) was included for comparison. Scenario 9 (B-WS2L_FO) is an extreme example as cattle are only held for one month in leucaena-grass paddock until sale.

Although this scenario was considered less likely to be applied by beef producers it was included to test the capacity of the modelling process to handle a very wide range of scenarios. Scenario 9 resulted in the greatest number of steers entering the growth path (648), the shortest grazing period (39 days) and the greatest beef production (1,144 kg/ha.annum, an increase of 44-fold over the baseline scenario). The scenario of grazing steers on leucaena-grass from weaning until attaining finishing weights (Scenario 4: DS1L_F) resulted in the least number of steers able to enter the growth path (47), the longest grazing period until sale (609 days) and the lowest beef production (105 kg/ha.annum, which was still 4-fold greater than for the baseline scenario).

Table 3 – Enterprise A: modelled areas of forage required to implement the growth path scenarios on the steer turnover enterprise. Definitions of parameters are given in the text

Scenario	**Allocated area of forage (ha)**			
	Buffel	**Oats – dry season 1**	**Leucaena**	**Oats – dry season 2**
Scenario 1 Feed-on steers from weaning on buffel (B_FO)	1,000			
Scenario 2 Finished steers from weaning on buffel (B_F)	1,000			
Scenario 3 Feed-on steers leucaena from weaning (DS1L_FO)			1,000	
Scenario 4 Finished steers leucaena from weaning (DS1L_F)			1,000	
Scenario 5 Feed-on steers leucaena from WS1 (B-WS1L_FO)	474		526	
Scenario 6 Finished steers leucaena from WS1 (B-WS1L-F)	354		646	
Scenario 7 Feed-on steers leucaena from DS2 (B-DS2L_FO)	617		383	
Scenario 8 Finished steers leucaena from DS2 (B-DS2L_F)	497		503	
Scenario 9 Feed-on steers leucaena from WS2 (B-WS2L_FO)	958		42	
Scenario 10 Finished steers leucaena from WS2 (B-WS2L_F)	809		191	
Scenario 11 Finished steers leucaena from DS3 (B-DS3L_F)	859		141	
Scenario 12 Feed-on steers oats DS1 then leucaena (B-O-L_FO)	185	306	509	
Scenario 13 Finished steers oats DS1 then leucaena (B-O-L_F)	107	247	646	
Scenario 14 Finished steers oats then leucaena then oats (B-O-L-O_F)	120	188	395	297
Scenario 15 Feed-on steers from weaning on buffel 35% utilisation (B35_FO)	1,000			
Scenario 16 Finished steers from weaning on buffel 35% utilisation (B35_F)	1,000			
Scenario 17 Feed-on steers from weaning on buffel 50% utilisation (B50_FO)	1,000			
Scenario 18 Finished steers from weaning on buffel 50% utilisation (B50_F)	1,000			
Scenario 19 Feed-on steers on B condition buffel 50% utilisation (B_B LC50_FO)	1,000			
Scenario 20 Finished steers on B condition buffel 50% utilisation (B_B LC50_F)	1,000			
Scenario 21 Feed-on steers on B condition buffel 30% utilisation (B_B LC30_FO)	1,000			
Scenario 22 Finished steers on B condition buffel 30% utilisation (B_B LC30_F)	1,000			
Scenario 23 Yearling steers oats DS1 (DS1O)	377	623		
Scenario 24 Oats DS1 then grass feed-on steers (DS1O-B_FO)	848	152		
Scenario 25 Buffel grass then oats finished steers (DS1O-B_F)	913			87
Scenario 26 Buffel grass then oats DS2 then grass feed-on steers (DS2O)	793			207
Scenario 27 Buffel grass then oats DS2 buffel finished steers (DS2O-B)	870			130
Scenario 28 Buffel grass then oats DS3 (DS3O)	877			123*
Scenario 29 Buffel grass oats DS1 buffel oats DS2 (DS1O-B-DS2O)	664	133		202
Scenario 30 Buffel grass oats DS1 buffel oats DS2 buffel (DS1O-B-DS2O-B)	753	98		149

* Oats fed in DS3 (Dry Season 3)

Table 4 – Enterprise A: modelled production outputs for each growth path scenario applied to the steer turnover enterprise

Definitions of parameters are given in the text

Scenario	Steers/1,000 ha	Days to achieve target weight	Average liveweight gain over total period (kg/d)	Beef production (kg/ha.annum)
Scenario 1 Feed-on steers from weaning on buffel (B_FO)	249	615	0.45	37
Scenario 2 Finished steers from weaning on buffel (B_F)	161	851	0.48	26
Scenario 3 Feed-on steers leucaena-grass from weaning (DS1L_FO)	809	404	0.68	183
Scenario 4 Finished steers leucaena-grass from weaning (DS1L_F)	475	609	0.67	107
Scenario 5 Feed-on steers leucaena-grass from WS1 (B-WS1L_FO)	542	497	0.55	100
Scenario 6 Finished steers leucaena-grass from WS1 (B-WS1L-F)	405	562	0.55	99
Scenario 7 Feed-on steers leucaena-grass from DS2 (B-DS2L_FO)	417	552	0.50	69
Scenario 8 Finished steers leucaena-grass from DS2 (B-DS2L_F)	335	686	0.59	67
Scenario 9 Feed-on steers leucaena-grass from WS2 (B-WS2L_FO)	275	601	0.46	42
Scenario 10 Finished steers leucaena-grass from WS2 (B-WS2L_F)	232	764	0.53	42
Scenario 11 Finished steers leucaena-grass from DS3 (B-DS3L_F)	199	819	0.50	33
Scenario 12 Feed-on steers oats DS1 then leucaena-grass (B-O-L_FO)	660	375	0.73	161
Scenario 13 Finished steers oats DS1 then leucaena-grass (B-O-L_F)	411	596	0.68	94
Scenario 14 Finished steers oats then leucaena-grass then oats (B-O-L-O_F)	405	511	0.77	105
Scenario 15 Feed-on steers from weaning on buffel 35% utilisation (B35_FO)	291	615	0.45	43
Scenario 16 Finished steers from weaning on buffel 35% utilisation (B35_F)	188	851	0.48	30
Scenario 17a Feed-on steers from weaning on buffel 50% utilisation (B50_FO)	384	631	0.43	56
Scenario 18a Finished steers from weaning on buffel 50% utilisation (B50_F)	230	942	0.43	33
Scenario 19 Feed-on steers on B condition buffel 50% utilisation (B_B LC50_FO)	261	649	0.42	37
Scenario 20 Finished steers on B condition buffel 50% utilisation (B_B LC50_F)	157	970	0.42	22
Scenario 21 Feed-on steers on B condition buffel 30% utilisation (B_B LC30_FO)	163	643	0.43	23
Scenario 22 Finished steers on B condition buffel 30% utilisation (B_B LC30_F)	97	961	0.42	14
Scenario 23 Yearling steers oats DS1 (DS1O)	1,345	146	0.81	345
Scenario 24 Oats DS1 then grass feed-on steers (DS1O-B_FO)	328	467	0.59	64
Scenario 25 Buffel grass then oats finished steers (DS1O-B_F)	188	718	0.56	36
Scenario 26 Buffel grass then oats DS2 then grass feed-on steers (DS2O)	315	511	0.59	62
Scenario 27 Buffel grass then oats DS2 buffel finished steers (DS2O-B)	197	718	0.56	38
Scenario 28 Buffel grass then oats DS3 (DS3O)	156	876	0.55	29
Scenario 29 Buffel grass oats DS1 buffel oats DS2 (DS1O-B-DS2O)	288	511	0.69	67
Scenario 30 Buffel grass oats DS1 buffel oats DS2 buffel (DS1O-B-DS2O-B)	212	644	0.63	45

Table 5 – Enterprise B: modelled herd structure for each growth path scenario applied to the breeding and finishing enterprise

Definitions of parameters are given in the text. Scenarios modelled as a Breedcowplus steady-state herd

Scenario	Total cattle carried per annum	Cattle sold per annum	Total cows and heifers mated per annum	Calves weaned per annum
Scenario 1 Feed-on steers from weaning on buffel (B_FO)	1,531	433	643	498
Scenario 2 Finished steers from weaning on buffel (B_F)	1,350	382	567	439
Scenario 3 Feed-on steers leucaena from weaning (DS1L_FO)	1,597	546	794	615
Scenario 4 Finished steers leucaena from weaning (DS1L_F)	1,759	497	738	571
Scenario 5 Feed-on steers leucaena from WS1 (B-WS1L_FO)	1,516	519	754	584
Scenario 6 Finished steers leucaena from WS1 (B-WS1L-F)	1,710	483	718	556
Scenario 7 Feed-on steers leucaena from DS2 (B-DS2L_FO)	1,452	497	722	559
Scenario 8 Finished steers leucaena from DS2 (B-DS2L_F)	1,645	465	690	534
Scenario 9 Feed-on steers leucaena from WS2 (B-WS2L_FO)	1,567	443	658	509
Scenario 10 Finished steers leucaena from WS2 (B-WS2L_F)	1,497	423	628	486
Scenario 11 Finished steers leucaena from DS3 (B-DS3L_F)	1,429	404	599	464
Scenario 12 Feed-on steers oats DS1 then leucaena (B-O-L_FO)	1,559	534	775	600
Scenario 13 Finished steers oats DS1 then leucaena (B-O-L_F)	1,715	485	720	557
Scenario 14 Finished steers oats then leucaena then oats (B-O-L-O_F)	1,443	494	718	556
Scenario 23 Yearling steers oats DS1 (DS1O)	1,346	583	828	641
Scenario 24 Oats DS1 then grass feed-on steers (DS1O-B_FO)	1,381	473	687	532
Scenario 25 Buffel grass then oats finished steers (DS1O-B_F)	1,398	395	587	454
Scenario 26 Buffel grass then oats DS2 feed-on steers (DS2O)	1,369	469	681	527
Scenario 27 Buffel grass then oats DS2 buffel finished steers (DS2O-B)	1,424	403	598	497
Scenario 28 Buffel grass then oats DS3 (DS3O)	1,307	369	548	425
Scenario 29 Buffel grass oats DS1 buffel oats DS2 (DS1O-B-DS2O)	1,339	458	665	553
Scenario 30 Buffel grass oats DS1 buffel oats DS2 buffel (DS1O-B-DS2O-B)	1,457	412	612	474

Table 6 – Enterprise B: modelled areas of forage required to implement the steer growth paths for the breeding and finishing enterprise

Definitions of parameters are given in the text

Scenario	**Allocated area of forage (ha)**				
	Buffel	**Oats – dry season 1**	**Leucaena**	**Oats – dry season 2**	**Total**
Scenario 1 Feed-on steers from weaning on buffel (B_FO)	989				989
Scenario 2 Finished steers from weaning on buffel (B_F)	1,327				1,327
Scenario 3 Feed-on steers leucaena from weaning (DS1L_FO)			378		378
Scenario 4 Finished steers leucaena from weaning (DS1L_F)			603		603
Scenario 5 Feed-on steers leucaena from WS1 (B-WS1L_FO)	256		283		539
Scenario 6 Finished steers leucaena from WS1 (B-WS1L-F)	243		444		687
Scenario 7 Feed-on steers leucaena from DS2 (B-DS2L_FO)	413		256		670
Scenario 8 Finished steers leucaena from DS2 (B-DS2L_F)	396		400		796
Scenario 9 Feed-on steers leucaena from WS2 (B-WS2L_FO)	889		39		928
Scenario 10 Finished steers leucaena from WS2 (B-WS2L_F)	847		201		1,047
Scenario 11 Finished steers leucaena from DS3 (B-DS3L_F)	1,000		165		1,165
Scenario 12 Feed-on steers oats DS1 then leucaena (B-O-L_FO)	84	139	231		454
Scenario 13 Finished steers oats DS1 then leucaena (B-O-L_F)	78	129	472		679
Scenario 14 Finished steers oats then leucaena then oats (B-O-L-O_F)	82	129	272	204	687
Scenario 23 Yearling steers oats DS1 (DS1O)	90	149			239
Scenario 24 Oats DS1 then grass feed-on steers (DS1O-B_FO)	688	123			812
Scenario 25 Buffel grass then oats finished steers (DS1O-B_F)	1,103	105			1209
Scenario 26 Buffel grass then oats DS2 feed-on steers (DS2O)	665	173			838
Scenario 27 Buffel grass then oats DS2 buffel finished steers (DS2O-B)	1,019	152			1,171
Scenario 28 Buffel grass then oats DS3 (DS3O)	1,253	110			1,363
Scenario 29 Buffel grass oats DS1 buffel oats DS2 (DS1O-B-DS2O)	595	120		181	896
Scenario 30 Buffel grass oats DS1 buffel oats DS2 buffel (DS1O-B-DS2O-B)	844	110		167	1,120

* Oats fed in DS3 (Dry Season 3)

Table 7 – Enterprise B: modelled production outputs for the steer component of the breeding and finishing enterprise

Definitions of parameters are given in the text

Scenario	Number of weaner steers entering the growth path	Days to achieve target weight	Average liveweight gain over total period (kg/d)	Whole herd beef production (kg/ha.annum)
Scenario 1 Feed-on steers from weaning on buffel (B_FO)	249	615	0.45	24
Scenario 2 Finished steers from weaning on buffel (B_F)	219	851	0.48	23
Scenario 3 Feed-on steers leucaena from weaning (DS1L_FO)	307	404	0.68	30
Scenario 4 Finished steers leucaena from weaning (DS1L_F)	286	609	0.67	31
Scenario 5 Feed-on steers leucaena from WS1 (B-WS1L_FO)	292	497	0.55	28
Scenario 6 Finished steers leucaena from WS1 (B-WS1L_F)	278	562	0.55	30
Scenario 7 Feed-on steers leucaena from DS2 (B-DS2L_FO)	279	552	0.50	27
Scenario 8 Finished steers leucaena from DS2 (B-DS2L_F)	267	686	0.59	29
Scenario 9 Feed-on steers leucaena from WS2 (B-WS2L_FO)	255	601	0.46	24
Scenario 10 Finished steers leucaena from WS2 (B-WS2L_F)	243	764	0.53	26
Scenario 11 Finished steers leucaena from DS3 (B-DS3L_F)	232	819	0.50	25
Scenario 12 Feed-on steers oats DS1 then leucaena (B-O-L_FO)	300	375	0.73	29
Scenario 13 Finished steers oats DS1 then leucaena (B-O-L_F)	279	596	0.68	30
Scenario 14 Finished steers oats then leucaena then oats (B-O-L-O_F)	278	511	0.77	30
Scenario 23 Yearling steers oats DS1 (DS1O)	321	146	0.81	22
Scenario 24 Oats DS1 then grass feed-on steers (DS1O-B_FO)	266	467	0.59	26
Scenario 25 Buffel grass then oats finished steers (DS1O-B_F)	227	718	0.56	24
Scenario 26 Buffel grass then oats DS2 feed-on steers (DS2O)	264	511	0.59	26
Scenario 27 Buffel grass then oats DS2 buffel finished steers (DS2O-B)	231	718	0.56	25
Scenario 28 Buffel grass then oats DS3 (DS3O)	212	876	0.55	24
Scenario 29 Buffel grass oats DS1 buffel oats DS2 (DS1O-B-DS2O)	258	511	0.69	27
Scenario 30 Buffel grass oats DS1 buffel oats DS2 buffel (DS1O-B-DS2O-B)	237	644	0.63	26

Table 8 – Paddock C: modelled production outputs for the leucaena component of selected growth paths applied to the 100 ha paddock of established leucaena

Definitions of parameters are given in the text

Scenario	Number of steers entering the growth path	Days to achieve target weight	Average liveweight gain over total period (kg/d)	Beef production (kg/ha.annum)
Scenario 2 Finished steers from weaning on buffel (B_F)	16	851	0.48	26
Scenario 3 Feed-on Steers leucaena from weaning (DS1L_FO)	81	404	0.68	184
Scenario 4 Finished Steers leucaena from weaning (DS1L_F)	47	609	0.67	105
Scenario 5 Feed-on steers leucaena from WS1 (B-WS1L_FO)	103	300	0.74	249
Scenario 6 Finished steers leucaena from WS1 (B-WS1L-F)	63	455	0.78	164
Scenario 7 Feed-on steers leucaena from DS2 (B-DS2L_FO)	109	265	0.57	191
Scenario 8 Finished steers leucaena from DS2 (B-DS2L_F)	67	399	0.71	155
Scenario 9 Feed-on steers leucaena from WS2 (B-WS2L_FO)	648	39	1.10	1,144
Scenario 10 Finished steers leucaena from WS2 (B-WS2L_F)	121	202	0.86	311
Scenario 11 Finished steers leucaena from DS3 (B-DS3L_F)	141	167	0.61	221

3.4 Modelled economic and financial performance

Table 9 through Table 14 indicate a wide range in the potential economic and financial performance for the modelled growth paths. Where n/a is shown the value could not be calculated or was not applicable.

3.4.1 Enterprise A – steer turnover enterprise

The most profitable growth path scenario for the steer turnover enterprise was that where steers were grazed on leucaena from weaning until achieving feed-on weight (Scenario 3: DS1L_FO): an additional $106,508 annualised marginal return on investment over 30 years compared to the baseline scenario of finishing steers on buffel grass pasture (Scenario 2: B_F), (Table 9). Taking weaner steers through to finishing weights on leucaena (Scenario 4: DS1L_F) was the 2nd most profitable growth path scenario (an additional $74,076 per annum) whilst feeding leucaena to steers from the start of their first wet season following weaning to finishing or feed-on weights (B-WS1L_F and B-WS1L_FO, respectively) were the 3rd and 4th most profitable growth paths, respectively. Growth paths incorporating leucaena-grass, without oats, required 4-12 years to pay back the total extra costs (including opportunity costs) incurred to implement the growth path. The most profitable scenario, DS1L-FO, required an 8-year payback period.

Growth paths that incorporated oats forage in addition to leucaena-grass, resulted in lower profitability than similar growth paths that only incorporated leucaena, i.e. B-O-L_FO < DS1L_FO and B-O-L-F < DS1L_F. The growth path providing oats forage twice, in dry season 1 and 2 with leucaena-grass in between, and resulting in the youngest age of turnoff at finished weights (B-O-L-O_F), was only marginally more profitable than the baseline scenario: $2,015 extra profit per annum.

The incorporation of forage oats into a buffel-based growth path (without leucaena) always reduced the profitability of the steer turnover enterprise compared to the baseline scenario of finishing steers from weaning on buffel grass pasture (Scenario 2: B_F), (Table 9). The most profitable of the oats with buffel grass scenarios was that where weaner steers were fed oats in dry season 1 and then returned to buffel grass to produce feed-on steers (Scenario 24: DS1O-B_BO): -$471 annualised marginal return. The other 7 oats and buffel grass scenarios did not achieve peak deficit within the 30-year investment period meaning that the investment would not have the capacity to repay the additional costs required to incorporate oats into the growth paths.

Whilst the top four growth paths in terms of economic performance for the steer turnover enterprise all incorporated leucaena, the 5th was the scenario incorporating an increase in buffel grass pasture utilisation from 30 to 50% with a target market of feed-on steers and assuming no decline in land condition over the 30 years of analysis (Scenario 17a: B50_FO): an additional $47,759 per annum (Table 10). This higher utilisation rate was still profitable under assumptions of declining land condition (to B) during the 30 year period: +$44,082 (Scenario 17b) and +$34,034 (Scenario 17c) representing declining land condition to B over the years 20-30 and years 10-20, respectively. Producing finished steers (instead of feed-on steers) from buffel grass pastures utilised at 50% also resulted in a substantially greater profitability than the baseline scenario of 30% utilisation of buffel grass pasture. Furthermore, utilising buffel grass pastures in B condition at 50% was more profitable than utilising the same pastures at 30%: ($30,814-39,467 extra profit/annum). Unlike scenarios incorporating high quality forage (leucaena or oats) into the growth path which all increased the indebtedness of the business substantially (as indicated by peak deficit) those scenarios involving increased utilisation rates of buffel grass did not. The relative small peak deficits calculated for some of the scenarios incorporating increased pasture utilisation rates reflects the requirement for purchase of additional steers. Although targeting feed-on steers on a buffel pasture with utilisation of 30% appeared unlikely to significantly improve profitability compared to the baseline herd producing finished steers, once pasture utilisation increased past 30%, it was noticeably more profitable to move to the production of feed-on steers.

As demonstrated in Tables 11 and 12 there was no relationship across the alternative growth path scenarios between change in profit and the amount of extra beef produced, with the scenario producing greatest % increase in beef production also resulting in the greatest decrease in annual profit (DS1O), compared to the baseline scenario (B_F).

3.4.2 Enterprise B – breeding and finishing enterprise

The most profitable growth path scenario for the breeding and finishing enterprise was that where steers were grazed on leucaena-grass from weaning until achieving feed-on weight (Scenario 3: DS1L_FO with purchased breeders): an extra $31,383 per annum return on investment over 30 years compared to the baseline scenario of finishing steers on buffel grass pasture (Scenario 2: B_F), (Table 13). If breeder numbers were allowed to increase naturally over time rather than maximising utilisation of the leucaena immediately, then the most profitable growth path scenario was finishing steers on leucaena-grass from wet season 1 (Scenario 6: B-WS1L_F): ($17,625 extra profit per annum). For all growth path scenarios where the age of turn-off of steers was reduced (compared to the baseline of producing finished steers from buffel grass pastures) and breeder numbers were allowed to naturally increase, the foregone income related to retaining breeders, plus the delay in matching steer weaner numbers to the increased supply of nutrition, significantly reduced the NPV (data for purchase of additional breeders only presented for Scenario 3). The purchase of additional breeders also increased peak deficit for most growth path scenarios and often reduced the period of time required to pay back the total funds invested (Scenario 3 results presented as an example). Growth paths incorporating leucaena-grass, without oats, required 19 years to pay back the additional costs (including opportunity costs) incurred to implement the growth path if additional breeders were not purchased to fully utilise the additional forage supply more quickly. The scenario, DS1L-FO, required a 19-year payback period with natural breeder number increase but 14-year payback period if additional breeders were purchased.

Growth paths that incorporated oats forage in addition to leucaena-grass, resulted in lower profitability than similar growth paths that only incorporated leucaena, i.e. B-O-L_FO < DS1L_FO and B-O-L-F < DS1L_F. Furthermore, all three of the growth paths incorporating oats forage in addition to leucaena (B-O-L_FO, B-O-L_F and B-O-L-O_F) resulted in substantially lower return than the baseline scenario of finishing steers on buffel grass pasture (B_F). The growth path providing oats forage twice, in dry season 1 and 2 with leucaena-grass in between, and resulting in the youngest age of turnoff at finished weights (B-O-L-O_F), produced an annualised marginal return of -$28,236 when compared to the baseline scenario (B_F).

The incorporation of forage oats into a buffel-based growth path (without leucaena) always reduced the profitability of the breeding and finishing enterprise compared to the baseline scenario of finishing steers from weaning on buffel grass pasture (Scenario 2: B_F), (Table 13). The most profitable of the oats with buffel grass scenarios was where weaner steers were fed oats in dry season 1 and then returned to buffel grass to produce finished steers (Scenario 25: DS1O-B_F): -$17,308 annualised marginal return. None of the eight oats with buffel grass scenarios achieved peak deficit within the first 20 years of the 30-year investment period meaning that the investment would not have the capacity to repay the additional costs required to incorporate oats into the growth paths.

As is evident from Table 14 there were no meaningful relationships across the alternative growth path scenarios between change in annual profit and the amount of extra weaners or beef produced, although there was some evidence of a weak relationship between % change in annual profit and % change in total beef production (r^2=0.32). Although the scenario producing greatest % increase in beef production was amongst the most profitable for this enterprise (Scenario 3: DS1L_F), many of the other scenarios which produced large increases in weaner and beef production (e.g. B-O-L-O_F) resulted in a decrease in annual profit compared to the baseline scenario (B_F).

3.4.3 Paddock C – established leucaena

Table 15 indicates the calculated paddock gross margin for utilising established leucaena with steers of different starting ages. There was poor correlation of the results from this component analysis with those from the whole-farm, integrated herd modelling analyses, indicating that gross margin analysis of growth path components provides little insight into the relative impact on profit or financial risk of changing a growth path. However, the leucaena component of the same growth path scenario that was found to be most profitable for Enterprise A and B, Scenario 3: DS1L_FO was also found to be in the top two most profitable growth paths in this analysis. This indicates the underlying efficiency of this growth path compared to other ways of utilising a paddock of leucaena.

Table 9 – Enterprise A: modelled economic and financial indicators for the steer turnover enterprise for scenarios with leucaena-grass and or oats forage as part of the growth path

Definitions of parameters are given in the text

Scenario	Annualised marginal return on investment (extra profit/annum for analysis period)	Peak deficit (with interest)	Year of peak deficit	Payback period (years)	Marginal IRR (%)
Scenario 1 Feed-on steers from weaning on buffel (B_FO)	$2,803	n/a	n/a	n/a	1.57
Scenario 2 Finished steers from weaning on buffel (B_F)	Base scenario				
Scenario 3 Feed-on steers leucaena from weaning (DS1L_FO)	$106,508	-$893,492	3	8	18.68
Scenario 4 Finished Steers leucaena from weaning (DS1L_F)	$74,076	-$1,048,630	4	11	13.08
Scenario 5 Feed-on steers leucaena from WS1 (B-WS1L_FO)	$56,676	-$488,273	3	7	19.82
Scenario 6 Finished steers leucaena from WS1 (B-WS1L-F)	$64,578	-$719,117	4	10	14.90
Scenario 7 Feed-on steers leucaena from DS2 (B-DS2L_FO)	$29,210	-$337,287	3	9	13.72
Scenario 8 Finished steers leucaena from DS2 (B-DS2L_F)	$43,927	-$541,820	4	11	14.08
Scenario 9 Feed-on steers leucaena from WS2 (B-WS2L_FO)	$7,863	-$71,411	3	4	70.10
Scenario 10 Finished steers leucaena from WS2 (B-WS2L_F)	$18,361	-$211,333	4	10	14.64
Scenario 11 Finished steers leucaena from DS3 (B-DS3L_F)	$7,368	-$144,167	4	12	11.10
Scenario 12 Feed-on steers oats DS1 then leucaena (B-O-L_FO)	$42,412	-$696,685	3	12	13.30
Scenario 13 Finished steers oats DS1 then leucaena (B-O-L_F)	$16,419	-$911,233	4	17	7.31
Scenario 14 Finished steers oats then leucaena then oats (B-O-L-O_F)	$2,015	-$788,473	4	20	5.34
Scenario 23 Yearling steers oats DS1 (DS1O)	-$51,073	n/a^^	n/a	n/a	n/a
Scenario 24 Oats DS1 then grass feed-on steers (DS1O-B_FO)	-$471	-$117,478	1	6	4.52
Scenario 25 Buffel grass then oats finished steers (DS1O-B_F)	-$32,220	n/a^^	n/a	n/a	n/a
Scenario 26 Buffel grass then oats DS2 then grass feed-on steers (DS2O)	-$9,224	n/a^^	n/a	n/a	-7.43
Scenario 27 Buffel grass then oats DS2 buffel finished steers (DS2O-B)	-$8,541	n/a^^	n/a	n/a	0.24
Scenario 28 Buffel grass then oats DS3 (DS3O)	-$8,731	n/a^^	n/a	n/a	-3.59
Scenario 29 Buffel grass oats DS1 buffel oats DS2 (DS1O-B-DS2O)	-$38,377	n/a^^	n/a	n/a	-8.54
Scenario 30 Buffel grass oats DS1 buffel oats DS2 buffel (DS1O-B-DS2O-B)	-$49,194	n/a^^	n/a	n/a	-6.70

n/a: the value could not be calculated or was not applicable.

^^ in all cases peak deficit was not achieved within the 30-year investment period. The investment does not have the capacity to repay the additional costs (including opportunity costs).

Table 10 – Enterprise A: modelled economic and financial indicators for the steer turnover enterprise for scenarios examining alternative pasture utilisation levels and land condition of buffel grass pasture

Definitions of parameters are given in the text

Scenario	Annualised marginal return on investment (extra profit/annum for analysis period)	Peak deficit (with interest)	Year of peak deficit	Payback period (years)	Marginal IRR
Scenario 1 Feed-on steers from weaning on buffel (B_FO)	$2,803	n/a	n/a	n/a	1.57
Scenario 2 Finished steers from weaning on buffel (B_F)	Base scenario				
Scenario 15 Feed-on steers from weaning on buffel 35% utilisation (B35_FO)*	$16,770	n/a	n/a	n/a	n/a
Scenario 16 Finished steers from weaning on buffel 35% utilisation (B35_F)*	$13,170	n/a	n/a	n/a	n/a
Scenario 17a Feed-on steers from weaning on buffel 50% utilisation (B50_FO)**	$47,759	n/a	n/a	n/a	n/a
Scenario 17b – decline in land condition from year 20[#]	$44,082	n/a	n/a	n/a	n/a
Scenario 17c – decline in land condition from year 10[##]	$34,034	n/a	n/a	n/a	n/a
Scenario 17d - continuous decline in land condition[###]	$30,663	n/a	n/a	n/a	n/a
Scenario 18a Finished steers from weaning on buffel 50% utilisation (B50_F)**	$34,145	-$59,780	2	4	54.17
Scenario 18b – decline in land condition from year 20[#]	$29,635	-$59,780	2	4	54.17
Scenario 18c - decline in land condition from year 10[##]	$24,952	-$59,780	2	4	53.71
Scenario 18d - continuous decline in land condition[###]	$21,772	-$59,780	n/a	n/a	n/a
Scenario 19 Feed-on steers on B condition buffel 50% utilisation (B_B LC50_FO)***	$39,467	n/a	n/a	n/a	83.19
Scenario 20 Finished steers on B condition buffel 50% utilisation (B_B LC50_F)***	$30,814	-$19,469	2	3	39.20
Scenario 21 Feed-on steers on B condition buffel 30% utilisation (B_B LC30_F)***	$6,848	n/a	n/a	n/a	81.00
Scenario 22 Finished steers on B condition buffel 30% utilisation (B_B LC30_F)	Base for B condition				

n/a: the value could not be calculated or was not applicable.

*compared to base scenario of finished steers at 30% pasture utilisation.

**no decline in land condition over 30 years.

[#]decline in land condition from year 20 - reduces to B condition by year 30.

[##]decline in land condition from year 10 - reduces to B condition by year 20.

###continuous decline in land condition from year 10 – reduces to 'B" condition by year 20 and to C condition by year 30.

***compared to base – B condition buffel finished steers at 30% utilisation.

Table 11 – Enterprise A: modelled change in production and economic indicators, relative to the baseline scenario, for scenarios with leucaena-grass and or oats forage as part of the growth path when applied within the steer turnover enterprise.

Definitions of parameters are given in the text

Scenario	% improvement in the NPV compared to baseline*	% change in beef production (kg/ha.annum) compared to baseline
Scenario 1 Feed-on steers from weaning on buffel (B_FO)	-3	43
Scenario 2 Finished steers from weaning on buffel (B_F)	Base scenario	
Scenario 3 Feed-on steers leucaena from weaning (DS1L_FO)	121	609
Scenario 4 Finished Steers leucaena from weaning (DS1L_F)	85	313
Scenario 5 Feed-on steers leucaena from WS1 (B-WS1L_FO)	65	286
Scenario 6 Finished steers leucaena from WS1 (B-WS1L-F)	74	282
Scenario 7 Feed-on steers leucaena from DS2 (B-DS2L_FO)	33	168
Scenario 8 Finished steers leucaena from DS2 (B-DS2L_F)	50	159
Scenario 9 Feed-on steers leucaena from WS2 (B-WS2L_FO)	9	62
Scenario 10 Finished steers leucaena from WS2 (B-WS2L_F)	21	61
Scenario 11 Finished steers leucaena from DS3 (B-DS3L_F)	8	29
Scenario 12 Feed-on steers oats DS1 then leucaena (B-O-L_FO)	48	523
Scenario 13 Finished steers oats DS1 then leucaena (B-O-L_F)	19	265
Scenario 14 Finished steers oats then leucaena then oats (B-O-L-O_F)	2	306
Scenario 23 Yearling steers oats DS1 (DS1O)	-58	1237
Scenario 24 oats DS1 then grass feed-on steers (DS1O-B_FO)	-1	149
Scenario 25 Buffel grass then oats finished steers (DS1O-B_F)	-37	39
Scenario 26 Buffel grass then oats DS2 then grass feed-on steers (DS2O)	-11	139
Scenario 27 Buffel grass then oats DS2 buffel finished steers (DS2O-B)	-10	45
Scenario 28 Buffel grass then oats DS3 (DS3O)	-10	12
Scenario 29 Buffel grass oats DS1 buffel oats DS2 (DS1O-B-DS2O)	-44	158
Scenario 30 Buffel grass oats DS1 buffel oats DS2 buffel (DS1O-B-DS2O-B)	-56	75

*The NPV (net present value) of the alternative investments are used in this calculation, rather than the marginal returns presented in Tables 9 and 10, as it is not possible for marginal returns to be used in such a calculation.

Table 12 – Enterprise A: modelled change in production and economic indicators, relative to the baseline scenario, for scenarios examining alternative pasture utilisation levels and land condition of buffel grass pasture when applied within the steer turnover enterprise.

Definitions of parameters are given in the text

Scenario	**% improvement in NPV compared to baseline***	**% change in beef production (kg/ha.annum) compared to baseline**
Scenario 1 Feed-on steers from weaning on buffel (B_FO)	-3	43
Scenario 2 Finished steers from weaning on buffel (B_F)	Base scenario	
Scenario 15 Feed-on steers from weaning on buffel 35% utilisation (B35_FO)	19	68
Scenario 16 Finished steers from weaning on buffel 35% utilisation (B35_F)	15	17
Scenario 17a Feed-on steers from weaning on buffel 50% utilisation (B50_FO)	55	115
Scenario 17b – decline in land condition from year 20	50	n/a
Scenario 17c – decline in land condition from year 10	39	n/a
Scenario 17d – continuous decline in land condition from year 10	35	n/a
Scenario 18 Finished steers from weaning on buffel 50% utilisation (B50_F)	39	29
Scenario 18b – decline in land condition from year 20	34	n/a
Scenario 18c – decline in land condition from year 10	28	n/a
Scenario 18d – continuous decline in land condition from year 10	25	n/a
Scenario 19 Feed-on steers on B condition buffel 50% utilisation (B_B LC50_FO)	44	167
Scenario 20 Finished steers on B condition buffel 50% utilisation (B_B LC50_F)	35	60
Scenario 21 Feed-on steers on B condition buffel 30% utilisation (B_B LC30_F)	8	68
Scenario 22 Finished steers on B condition buffel 30% utilisation (B_B LC30_F)	Base for B condition	

n/a: the value could not be calculated or was not applicable.

*The NPV (net present value) of the alternative investments are used in this calculation, rather than the marginal returns presented in Tables 9 and 10, as it is not possible for marginal returns to be used in such a calculation.

Table 13 – Enterprise B: modelled economic and financial indicators for the breeding and finishing enterprise for scenarios with leucaena-grass or oats forage as part of the growth path of steers

Definitions of parameters are given in the text

Scenario	Annualised marginal return on investment (extra profit/annum for analysis period)	Peak deficit (with interest)	Year of peak deficit^^	Payback period (years)^^	Marginal IRR (%)
Scenario 1 Feed-on steers from weaning on buffel (B_FO)	-$21,368	-$742,224	19	n/a	n/a
Scenario 2 Finished steers from weaning on buffel (B_F)	Base scenario				
Scenario 3 Feed-on steers leucaena from weaning (DS1L_FO)	$14,794	-$560,947	10	19	8.14
Scenario 3 with purchased breeders	$31,383	-$516,081	4	14	11.69
Scenario 4 Finished steers leucaena from weaning (DS1L_F)	$16,190	-$826,018	10	19	7.28
Scenario 5 Feed-on steers leucaena from WS1 (B-WS1L_FO)	$4,797	-$514,947	10	19	6.27
Scenario 6 Finished steers leucaena from WS1 (B-WS1L-F)	$17,625	-$671,548	10	19	7.92
Scenario 7 Feed-on steers leucaena from DS2 (B-DS2L_FO)	-$4,816	-$544,955	14	n/a	3.49
Scenario 8 Finished steers leucaena from DS2 (B-DS2L_F)	$2,812	-$722,764	10	n/a	5.52
Scenario 9 Feed-on steers leucaena from WS2 (B-WS2L_FO)	-$23,886	-$846,859	n/a	n/a	n/a
Scenario 10 Finished steers leucaena from WS2 (B-WS2L_F)	$3,234	-$304,947	10	19	6.35
Scenario 11 Finished steers leucaena from DS3 (B-DS3L_F)	$1,754	-$212,908	10	n/a	6.02
Scenario 12 Feed-on steers oats DS1 then leucaena (B-O-L_FO)	-$18,217	-$1,074,191	19	n/a	1.42
Scenario 13 Finished steers oats DS1 then leucaena (B-O-L_F)	-$30,943	-$1,633,459	n/a	n/a	0.52
Scenario 14 Finished steers oats then leucaena then oats (B-O-L-O_F)	-$28,236	-$1,397,290	n/a	n/a	-0.50
Scenario 23 Yearling steers oats DS1 (DS1O)	-$43,317	-$1,474,978	n/a	n/a	n/a
Scenario 24 Oats DS1 then grass feed-on steers (DS1O-B_FO)	-$24,667	-$848,509	n/a	n/a	n/a
Scenario 25 Buffel grass then oats finished steers (DS1O-B_F)	-$17,308	-$646,393	n/a	n/a	n/a
Scenario 26 Buffel grass then oats DS2 feed-on steers (DS2O)	-$24,491	-$820,216	n/a	n/a	n/a
Scenario 27 Buffel grass then oats DS2 buffel finished steers (DS2O-B)	-$29,872	-$987,733	n/a	n/a	n/a
Scenario 28 Buffel grass then oats DS3 (DS3O)	-$27,881	-$921,924	n/a	n/a	n/a
Scenario 29 Buffel grass oats DS1 buffel oats DS2 (DS1O-B-DS2O)	-$41,316	-$1,366,161	n/a	n/a	n/a
Scenario 30 Buffel grass oats DS1 buffel oats DS2 buffel (DS1O-B-DS2O-B)	-$74,711	-$2,470,384	n/a	n/a	n/a

^^n/a in these columns indicates that for these scenarios peak deficit was not achieved within the initial 20 years of the investment period and/or the investment does not have the capacity to repay the additional costs (including opportunity costs) within the first 20 years.

Table 14 – Enterprise B: modelled change in production and economic indicators, relative to the baseline scenario, for each alternative steer growth path scenario applied within the breeding and finishing enterprise

Definitions of parameters are given in the text. Scenarios modelled as a Breedcowplus steady-state herd

Scenario	% improvement in average annual profit compared to baseline*	% change in numbers of weaners produced compared to baseline	% change in total beef production (kg/ha.annum) compared to baseline
Scenario 1 Feed-on steers from weaning on buffel (B_FO)	-25	14	-0.47
Scenario 2 Finished steers from weaning on buffel (B_F)		Base scenario	
Scenario 3 Feed-on steers leucaena from weaning (DS1L_FO)	17	40	26
Scenario 3 with purchased breeders	37	40	26
Scenario 4 Finished steers leucaena from weaning (DS1L_F)	19	30	30
Scenario 5 Feed-on steers leucaena from WS1 (B-WS1L_FO)	6	33	19
Scenario 6 Finished steers leucaena from WS1 (B-WS1L_F)	21	27	27
Scenario 7 Feed-on steers leucaena from DS2 (B-DS2L_FO)	-6	27	14
Scenario 8 Finished steers leucaena from DS2 (B-DS2L_F)	3	22	22
Scenario 9 Feed-on steers leucaena from WS2 (B-WS2L_FO)	-28	16	2
Scenario 10 Finished steers leucaena from WS2 (B-WS2L_F)	4	11	11
Scenario 11 Finished steers leucaena from DS3 (B-DS3L_F)	2	6	6
Scenario 12 Feed-on steers oats DS1 then leucaena (B-O-L_FO)	-21	37	23
Scenario 13 Finished steers oats DS1 then leucaena (B-O-L_F)	-36	27	27
Scenario 14 Finished steers oats then leucaena then oats (B-O-L-O_F)	-33	27	28
Scenario 23 Yearling steers oats DS1 (DS1O)	-51	46	-7
Scenario 24 Oats DS1 then grass feed-on steers (DS1O-B_FO)	-29	21	9
Scenario 25 Buffel grass then oats finished steers (DS1O-B_F)	-20	3	4
Scenario 26 Buffel grass then oats DS2 feed-on steers (DS2O)	-29	20	11
Scenario 27 Buffel grass then oats DS2 buffel finished steers (DS2O-B)	-35	13	5
Scenario 28 Buffel grass then oats DS3 (DS3O)	-33	-3	3
Scenario 29 Buffel grass oats DS1 buffel oats DS2 (DS1O-B-DS2O)	-48	26	14
Scenario 30 Buffel grass oats DS1 buffel oats DS2 buffel (DS1O-B-DS2O-B)	-87	8	8

*The average annual returns are used in this calculation, rather than the marginal returns presented in Table 13, as it is not possible for marginal returns to be used in such a calculation.

Table 15 – Paddock C: modelled economic values for the leucaena component selected steer growth paths applied to the 100 ha paddock of established leucaena

Definitions of parameters are given in the text

Scenario	Gross margin	Improvement over base
Scenario 2 Finished steers from weaning on buffel (B_F)	$8,584	Base
Scenario 3 Feed-on Steers leucaena from weaning (DS1L_FO)	$23,286	171%
Scenario 4 Finished Steers leucaena from weaning (DS1L_F)	$20,887	143%
Scenario 5 Feed-on steers leucaena from WS1 (B-WS1L_FO)	$19,096	122%
Scenario 6 Finished steers leucaena from WS1 (B-WS1L-F)	$23,604	175%
Scenario 7 Feed-on steers leucaena from DS2 (B-DS2L_FO)	$3,943	-54%
Scenario 8 Finished steers leucaena from DS2 (B-DS2L_F)	$15,093	76%
Scenario 9 Feed-on steers leucaena from WS2 (B-WS2L_FO)	-$86,927	-1113%
Scenario 10 Finished steers leucaena from WS2 (B-WS2L_F)	$9,436	10%
Scenario 11 Finished steers leucaena from DS3 (B-DS3L_F)	-$7,081	-182%

4 Discussion

The work reported here represents the first known attempt to assess the most profitable way of incorporating high quality forages into the whole-of-life steer growth path on forage systems in central Queensland. In this analysis we have assessed the effect of the change in growth path on overall herd structure and whole-farm profitability to provide valuable insights which can be used to guide investment decisions for both industry and the public sector. Additionally, examination of effects of grazing pressure and land condition on productivity and profitability of the perennial buffel grass pasture has provided valuable insights into the trade-off between stocking rate decisions and financial returns.

4.1 Economic implications of utilising leucaena and/or forage oats in the growth path of steers to reduce age of turn-off

Both the steer turnover enterprise analysis and the breeding and finishing analysis showed that placing steers onto leucaena-grass pastures at weaning and keeping them there until they achieve a feed-on weight (DS1L_FO) was substantially more profitable than any other growth path (once the breeder numbers were optimised). Furthermore, incorporating leucaena-grass pastures at any steer age improved the profitability of the steer turnover enterprise ($7,368-$106,508 extra profit/annum), and similarly for the breeding and finishing enterprise ($1,754-$31,383 extra profit/annum) except for two scenarios where leucaena-grass pastures were provided to older steers targeted at the feed-on market ($4,816 and $23,886 less profit/annum). These results are in agreement with those from gross margin analysis conducted for commercial properties, and whole-farm case study analyses, where leucaena-grass systems were identified as the most profitable forage option for beef cattle production in central Queensland (Bowen *et al*. 2015*a*, 2015*b*). Unlike the previous work, however, our current analyses have identified the most profitable way to utilise leucaena within the steer growth path, considering the effect on herd structure and whole-of-business profitability. The gross margin analysis of components of the leucaena-grass growth paths (Paddock C) showed that even where a limited area of established leucaena-grass was available, one of the most efficient options still appeared to be stocking the leucaena-grass with weaner steers and leaving them there until they reached feedlot entry (feed-on) weight.

Despite the evident profitability of implementing a leucaena-grass system, the increased peak deficit levels and financial risk to the business from doing so is a limitation to implementation, with payback periods of 8-14 years required after implementing the most profitable leucaena-grass growth path (DS1L_FO). The added financial risk and long payback period after implementing leucaena-grass systems is likely to be one factor influencing the under-exploitation of this resource in Queensland despite the large potential area suited to leucaena plantings (Peck *et al.* 2011; T. Beutel, pers. comm.). Further constraints to leucaena implementation include the difficulty and risk of establishment as well as the additional management expertise required to productively utilise the resource (Shelton *et al.* 2005; Peck *et al.* 2011; Bowen *et al.* 2015*a*). Furthermore, full productivity of existing leucaena-grass forage systems has not always been realised due to the failure of some producers to recognise and address fertiliser requirements (Radrizzani *et al.* 2010, 2016), particularly P and sulphur, or to inoculate cattle with the *in vitro Synergistes jonesii* rumen fluid inoculum to prevent mimosine and dihydroxypyridine toxicity and consequent reduction in cattle growth rates (Dalzell *et al.* 2012; Bowen *et al.* 2015*b*). In addition, research is required to better elucidate dose/response relationships for P fertiliser, in particular, and thus enhance economic efficiency (Peck *et al.* 2015).

Any growth path that incorporated forage oats, in either a turnover or breeding and finishing enterprise, resulted in a lower economic and financial performance than a similar growth path that incorporated leucaena. Furthermore, incorporation of oats into a buffel grass growth path always reduced the profitability of a steer turnover or a breeder and finishing enterprise. These findings do not indicate that beef enterprises that incorporate forage oats are unprofitable, only that they are likely to be less profitable than the alternative buffel grass-only beef enterprise. In our analysis we did not account for the years likely to be unsuitable for planting oats (30% of years) which would further reduce the profitability of the oats growth path scenarios. The poor relative profitability of utilising oats forage was seen despite oats enabling a younger age of turn-off and despite filling the apparent 'feed gap' resulting from poor quality of available forage over the winter dry season. These results are also in agreement with our previous gross margin and whole-farm analyses conducted for commercial properties in central Queensland (Bowen *et al*. 2015*a*, 2015*b*). Our results are in contrast, however, with results of enterprise-scale bio-economic modelling, which indicated potentially large economic benefits from utilising small areas of irrigated annual forages, including oats, as part of beef production systems in central Queensland and northern Australia in general (Bell *et al.* 2014; Hunt *et al.* 2014). As for beef enterprises incorporating leucaena-grass into the production system, planting oats increased the peak deficit and financial risk of the business substantially compared to utilising buffel grass pastures for growing and finishing steers.

The relative ranking in profitability of producing feed-on vs. finished steers from the same growth path, was not consistent across different growth paths or between the steer turnover and the breeding and finishing enterprises. A number of factors contributed to the relative profitability of the alternative market targets, including the time taken to change the growth path and build up breeder and/or steer numbers, the efficiency of younger steers in converting forage to weight gain per hectare, and the premium paid for feed-on steer beef compared to finished steer beef.

For the breeding and finishing enterprise, building up breeder numbers naturally over time to meet the steer needs of a growth path had slightly higher financial risk and was substantially less profitable over the life of the investment than purchasing additional breeders. The purchase of additional breeders increased the peak deficit in some cases but often reduced the period of time required to pay back the total costs of the implementation of the growth path. Producers seeking to rapidly adopt the most profitable growth path would need to carefully plan the implementation phase to reduce the riskiness of the investment. Industry observations indicate that producers developing leucaena paddocks often adopt a piecemeal approach to reduce both establishment risk and financial risk.

Our analysis clearly showed that there was no meaningful relationship between change in profit and change in productivity of the enterprise, in terms of the number of extra weaners produced or the additional beef produced per hectare. These results are in agreement with those reported by Bowen *et al.* (2016) for gross margin results obtained for commercial beef producers utilising a range of forage types in central Queensland. They are also in line with results of Chudleigh *et al.* (2016) for investments to improve the productivity of the breeder herd in northern Australia.

4.2 Economic implications of grazing pressure and land condition on buffel grass pastures

Long term grazing trials in Queensland's rangelands on native pasture communities have identified guidelines for long-term safe (sustainable) carrying capacity (e.g. Johnston *et al.* 1996*a*,*b*; Silcock *et al.* 2005; Orr *et al.* 2010; Orr and Phelps 2013; Hunt *et al.* 2014; O'Reagain *et al.* 2014; Hall *et al.* 2017). However, there is widespread evidence that producers are stocking perennial pastures at significantly higher rates than the guidelines provided by research and government agencies (Shaw *et al.* 2007; Beutel *et al.* 2014; Bowen *et al.* 2015*b*, 2016*a*). Previous reports have provided some evidence that decisions by land managers to apply higher stocking rates than recommended have financial and economic drivers (Bowen *et al.* 2015*b*, 2016*a*; Rolfe *et al.* 2016).

Our analysis indicates a large economic advantage gained from increasing grazing pressure and provides some insight into the actions of many beef enterprise managers. The sensitivity of profit to pasture utilisation rate, is demonstrated by the substantial increase in annualised marginal return by moving from 30 to 35% utilisation of A condition buffel grass pastures on a steer turnover enterprise ($13,170-16,770 extra profit/annum over 30 years, a 15-19% improvement across steer finishing scenarios (FO vs F)). All scenarios involving utilising A condition buffel grass pasture at 50% were substantially more profitable, under the assumptions made here, than for pastures utilised at 30%, even where land condition was assumed to decline to B condition during the 30-year period ($24,952-47,759 extra profit/annum over 30 years, a 28% to 55% improvement) or to C condition by the end of the 30 year period ($21,772-30,663 extra profit/annum over 30 years, a 25% to 35% improvement).

Figure 6 and Figure 7 show the difference in annual surplus and the total surplus generated when a decision is made to stock the baseline steer turnover property at a 50% utilisation rate and target the production of feed on steers (B50_FO). The example presented here is the worst case scenario, i.e. the decline of pasture in A condition to C condition by year 30 under the 50% utilisation regime (Scenario 17d). It can be seen that the business will generate a greater annual net profit for the first 2 decades at least and that the business is likely to have at least $500,000 additional funds available in the 30th year, even if the surplus does not earn interest.

Figure 6 – The net cash flow over 30 years for a steer turnover enterprise for a) production of finished steers from buffel grass pastures under a 30% utilisation regime, or b) conversion to production of feed-on steers from buffel grass pastures under a 50% pasture utilisation regime and declining land condition from A to C

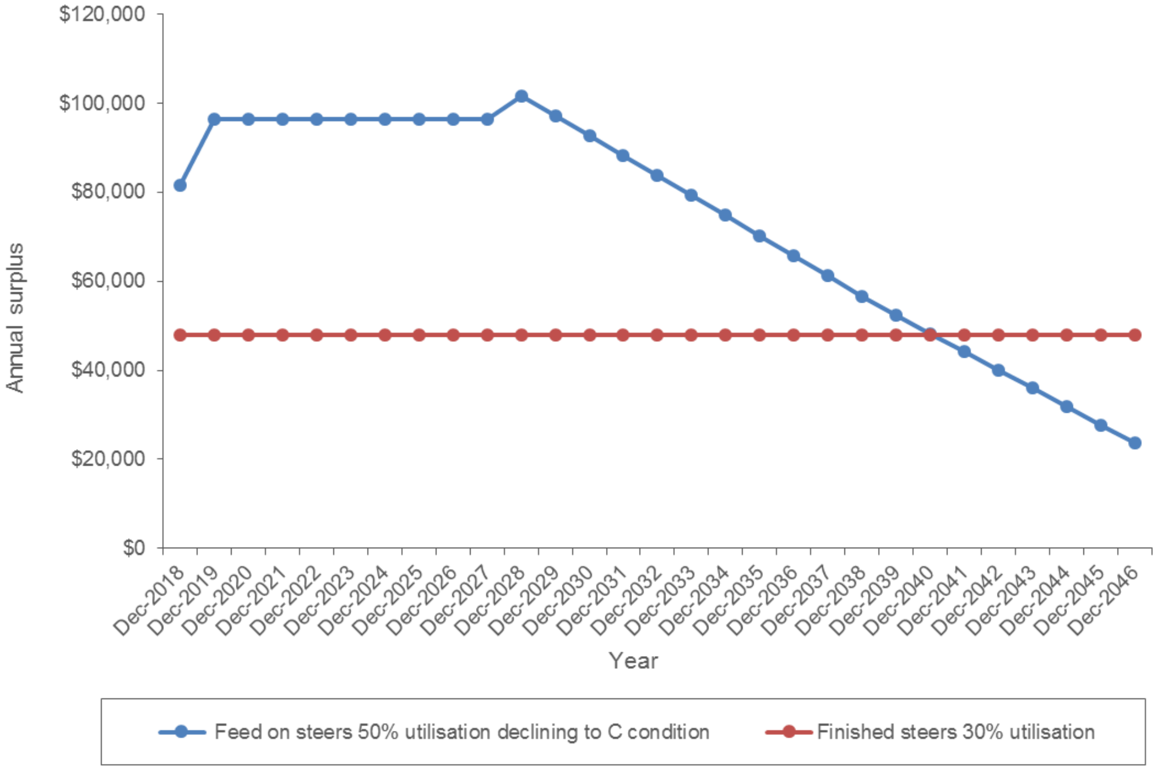
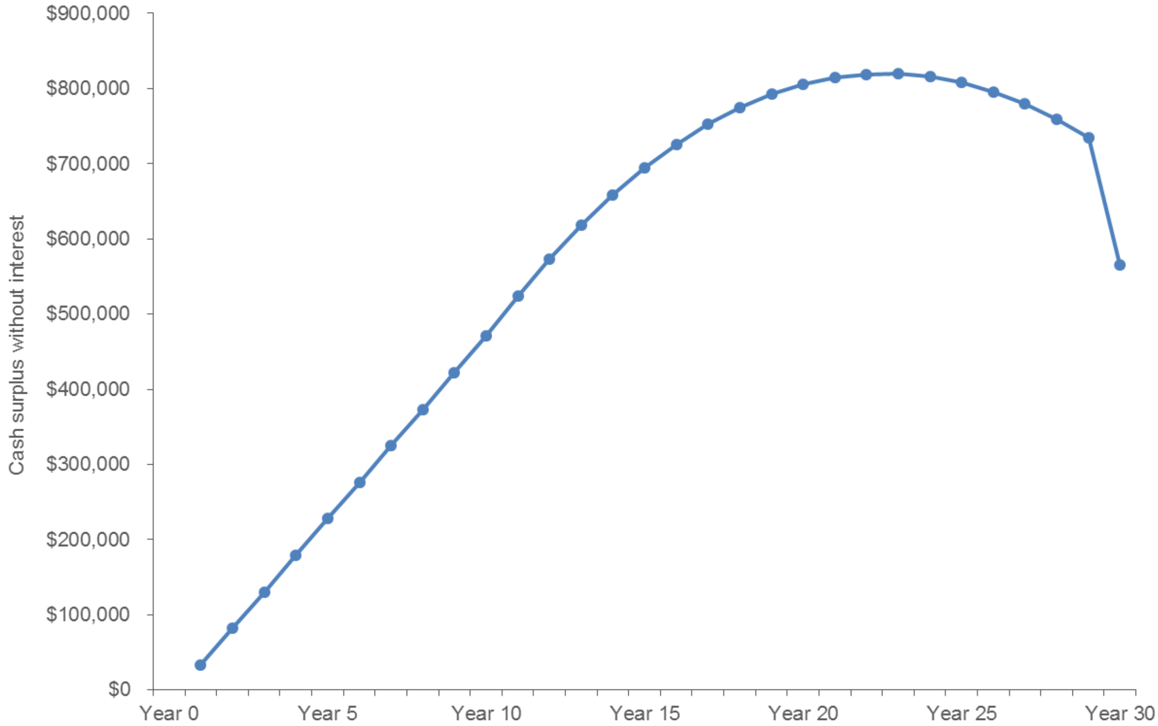


Figure 7 – Accumulated cash difference (without interest added) over 30 years between two scenarios: a) conversion to production of feed-on steers from buffel grass pastures under a

50% pasture utilisation regime and declining land condition from A to C and b) production of finished steers from buffel grass pastures under a 30% utilisation regime



Bio-economic modelling undertaken by Star *et al.* (2013) for the Fitzroy catchment produced results consistent with our conclusions with profit optimised at higher rates of pasture utilisation (60%) on a Brigalow land type in A condition, supporting buffel grass pasture. Research reported by Burrows *et al.* (2010) for a native, *Heteropogon contortus*-dominated, pasture type in central Queensland also found that financial returns were greatest at the highest pasture utilisation rate (61%), despite indications that land condition was declining. However, in studies where market penalties were applied or market incentives forgone, or where decisions were made to provide expensive feed to cattle in dry years, then higher stocking rates resulted in lower overall returns than moderate or low stocking rates (MacLeod and MacIntyre 1997; MacLeod *et al.* 2004; O'Reagain *et al.* 2011). Other than our study, few have attempted to identify the full costs (including the opportunity costs) of implementing changed grazing management strategies and none have involved marginal economic analysis at the property level that incorporated the impact of the implementation phase.

Due to lack of data on the impacts of drought on buffel pastures grazed at higher utilisation rates we did not attempt to differentiate between growth paths for possible interactions of pasture utilisation rate with drought years and consequences for pasture health and land condition decline. The incorporation of any potential effects of episodic events with unknown frequency and impact is unlikely to change the relative values of the results but could reduce the absolute value of parameters for all growth paths. Further, as there is no evidence that the level of management skill applied varies with the level of grazing pressure applied, we assumed that the level of management skill applied in each grazing strategy was the same and that the response to episodic events such as drought would therefore also be the same, have the same relative impact on returns, and not change the ranking of the scenarios..

Compounding the apparent economic incentive to apply high grazing pressure, tropical grass pasture systems have shown resilience to heavy grazing pressure. 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) suggest it may take decades to seriously impact land condition at high levels of pasture utilisation. Therefore, there is little immediate feedback to beef enterprise managers to suggest that their action of increasing utilisation rates above those recommended is doing anything other than increase their business viability. As shown by Rolfe *et al.* (2016) beef enterprise managers who are already in financial difficulty or have lower levels of equity are very unlikely to forego fully utilising their pasture resources. Furthermore, this analysis indicates that even financially sound beef enterprises with pastures in good starting condition can build a financial buffer against changed circumstances, and increase wealth, by increasing pasture utilisation.

An additional complication in estimating effects of pasture utilisation in the Brigalow lands of central Queensland is that there has been little grazing research, comparative to that for native pasture systems, to determine pasture utilisation (grazing pressure) effects on buffel grass or other sown grass or grass-legume pastures. In the absence of such data, the precautionary principle has been followed in recommendations of a safe utilisation of annual biomass growth of buffel grass pastures of 30%, similar to that recommended for native pasture systems (Whish 2011). However, general observation, and limited data from south west Queensland (Johnston 1996, 1997), indicates that buffel grass pastures are likely to be more resilient than many native pastures when grazed heavily and hence it is possible that higher utilisation rates, >30%, may be having little impact on pasture productivity and land condition. Although, it is possible that more heavily utilised buffel grass pastures may be prone to invasion by Indian couch and susceptible to the buffel dieback phenomenon (Buck 2017).

The consequences for Great Barrier Reef water quality, of high levels of pasture utilisation and subsequent degraded pastures are well documented (Thorburn *et al.* 2013) and much effort is applied in the Fitzroy catchment to maintaining ground cover via encouraging a reduction in grazing pressure applied by beef enterprise managers (The State of Queensland 2013). The Queensland beef industry 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' (McCosker *et al.* 2010; McLean *et al.* 2014; Hall 2016). Hence, a better understanding of the trade-off between stocking rate decisions and economic sustainability for Queensland grazing enterprises is imperative to better inform policy makers.

As well as the apparent resilience of native pastures in Queensland's rangelands, they appear slow to recover once grazing pressure is reduced. Research with two native pasture systems in Queensland showed that wet season spelling strategies did not produce significant differences in land condition over a 5-year period (Jones *et al.* 2016). There is no available data on recovery of degraded buffel grass pastures. However, it follows that if tropical grass pastures are slow to recover under a reduced grazing pressure regime, the economic consequences of implementing such a regime would not be guaranteed to be positive. Any recovery is likely to depend on how severely rainfall infiltration and soil surface friability has diminished during the fall in land condition rating (R. Silcock pers. comm.).

Our analysis for the steer turnover property identified the advantage of stocking a B condition buffel grass pasture at 50% utilisation and producing feed-on steers when compared to stocking the same B condition pasture at a 30% utilisation rate to produce finished steers. The higher utilisation rate and younger age of turnoff generated about $40,000 per annum additional profit which increased farm profit from $10,000 per annum to $50,000 per annum. This increase in economic (and financial) performance could be the difference between business survival and business failure in the short to medium term and this consideration is likely to greatly outweigh the possible damage being done over the longer term to the land resource and/or water quality - in the mind of the current beef enterprise manager.

One strategy that can be used to rapidly improve productivity, from a buffel grass pasture in B or C condition, is conversion (if suitable) to a leucaena-grass pasture. Research in the Fitzroy NRM region has shown that leucaena-grass systems result in nutrient and sediment loads in runoff water which are similar to those for A condition buffel grass pasture (Thornton and Elledge 2013). All of the growth path scenarios in this study that introduced leucaena maintained a buffel grass utilisation of 30% after its introduction. Those scenarios where leucaena-grass was incorporated from weaning or wet season 1, were also markedly more profitable than both the baseline and high utilisation (>30%) buffel grass scenarios. It can be inferred that improved economic performance as well as reef water quality outcomes are possible through planting leucaena on overgrazed, degraded buffel grass pastures. Large areas of B or C condition buffel grass pasture would have to be renovated and sown to suitable legume pastures across the landscape to make a significant difference to reef water quality and this is unlikely to happen in the foreseeable future due to:

- the institutional constraints - leucaena is still treated as a weed by some,
- the financial constraints – overly rapid development of leucaena grass pastures could lead to the demise of the beef business,
- the leucaena constraints - leucaena is not suitable for many degraded buffel pastures due to landscape and soil quality constraints, and
- the knowledge constraints - some alternative legumes are available where leucaena is not suitable but little is yet known of their biological or economic performance.

Constraints on the availability of capital applied by the typical size of beef enterprises in the Fitzroy region also indicate that choices will be made by beef enterprise managers concerning which paddock to develop first to leucaena. This could give rise to some interesting outcomes. For example, a beef producer may have two identical buffel paddocks except that one is in B condition with a 30% utilisation rate and one is in A condition with a 30% utilisation rate. Analysis indicates that there is little difference in long term returns from developing either paddock to leucaena (data not shown). Where a choice between paddocks has to be made, the best returns for the beef business would be made by planting the B condition paddock to leucaena and increasing the utilisation rate of the A condition paddock significantly above 30%. The application of economic logic suggests that once the A condition paddock has reduced to B or C condition, there should be sufficient capital available to plant it to leucaena, thereby renovating it and immediately returning it to a highly productive, A condition pasture. There appears to be an opportunity to encourage a reduction in high utilisation rates of buffel pastures, and to potentially improve outcomes for the reef, by promoting legume adoption by beef producers. However, targeted research, development and extension activities that focus on reducing the riskiness of leucaena and alternative pasture legumes is required.

4.3 Steer growth paths and meat quality

Research has shown that most issues around low meat quality of Brahman crossbred cattle (up to 75% *B. indicus*) in northern Australia would disappear if a finished carcass was achieved at 2-2.5 years of age (Tomkins *et al*. 2006; Schutt *et al*. 2009; Poppi and McLennan 2010). A number of strategies are available to reduce the age of turn-off and improve meat quality for steers in central Queensland. Feeding energy-based production supplements or rations is one nutritional intervention to achieve reduced age of turnoff but has produced variable economic and financial outcomes. Analysis such as that by McLennan (2014) showed that the use of energy–based production supplements to increase cattle growth rates was unlikely to be profitable on a regular basis. Furthermore, Chudleigh *et al.* (2017b) identified that regularly finishing steers in a feedlot on a contract basis in the Fitzroy region was likely to significantly reduce the profitability of the beef business.

Incorporating high quality forages into the growth path is an alternative nutritional intervention that can reduce age of turn-off. Whilst providing forage oats was shown to be unprofitable compared to a buffel grass-only grazing system, our analysis shows that feeding leucaena from weaning until the steer is ready for sale will significantly reduce the age of turnoff and improve profitability. Steers reached feedlot and abattoir target entry weights at 19.3 and 26.0 months of age, respectively when grazed on leucaena-grass pastures from weaning. This age of turn-off is 7 and 8 months earlier for feed-on and finished steers, respectively, than if grazed solely on buffel pastures. Feeding strategies incorporating leucaena later in the growth path can also reduce age of turn-off and allow premium markets to be accessed. The relative economic advantage of providing high quality forages earlier in the growth path, compared to providing high quality forage later in the growth path, will be influenced by the extent to which compensatory growth of later-fed cattle occurs and erodes the production and profitability advantages of feeding early. We did not attempt to adjust growth rates of cattle according to whether leucaena was provided early or late in the growth path due to insufficient data to inform such assumptions. In addition, we did not attempt to account for potential effects of growth path, and thus age, on final body composition and carcass attributes (e.g. far cover and marbling) of the finished, 605 kg steer.

4.4 The impact of price on the relative performance of steer growth paths

The price basis for each class of livestock was derived from Roma store sale data and Dinmore abattoir prices achieved between July 2008 and November 2015 (Appendix 1). These prices were taken to be representative of long term averages but there has been a considerable and sustained increase in the price paid for beef since the middle of 2014. As long as the price basis (relationship) between the different classes of steers does not change, the rising prices will make all options more profitable and the ranking of the options will remain. However, there is some evidence that the demand for younger classes of steers (weaner and lighter steers) have improved in price more than the finished classes of steers over recent times.

Figure 8 and Figure 9 show the difference in saleyard price between major classes of steers recorded by Meat and Livestock Australia since 2012 (MLA 2017). There has been a noticeable shift in the price basis between younger/lighter steers and older/heavier steers with not so much change between medium steers and heavy steers. The main drivers of this appear to be the combination of the overall shortness of supply of cattle and steers, property managers restocking with younger steers after drought and the impact of the live export market on young steer prices in northern Australia. Much of this change in the price basis for steers has not been captured in the analysis and could have substantial implications for the outcomes if continued into the future. Based on current steer prices there is a very strong case for targeting the production of lightweight steers off leucaena (possibly lighter than the feed-on scenarios examined in this analysis). Beef enterprise managers thinking of targeting heavier steers off leucaena at current prices would need to incorporate the steer price basis, relevant to their options, into their calculations at the time the decision is being made.

Figure 8 – The difference in Queensland saleyard price ($/kg liveweight) of medium (400-500 kg) relative to heavy weight (500-600 kg) steers between 05/07/2012 and 22/06/2017

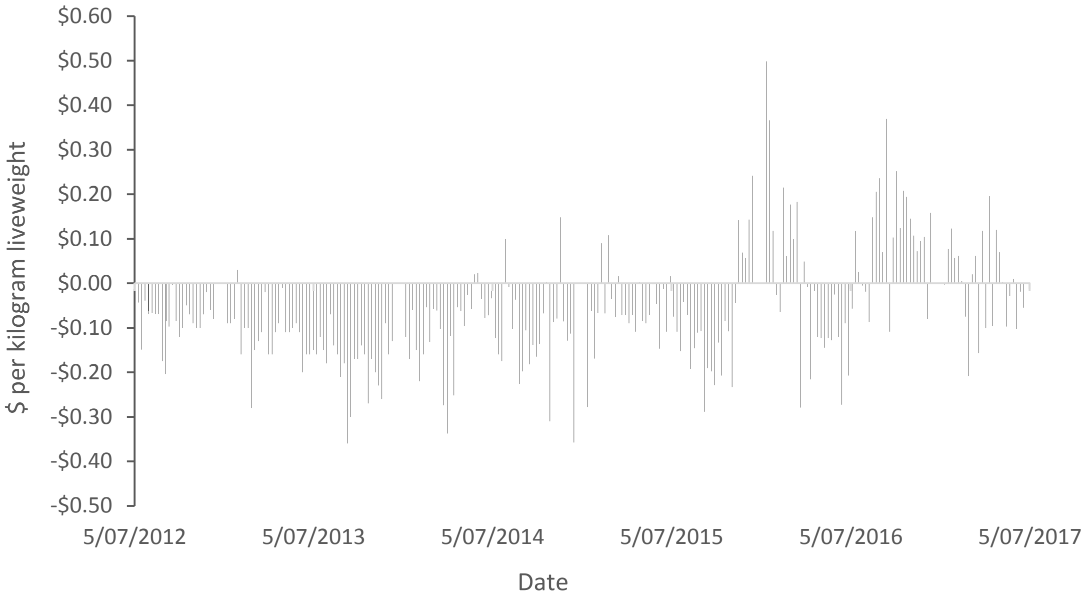
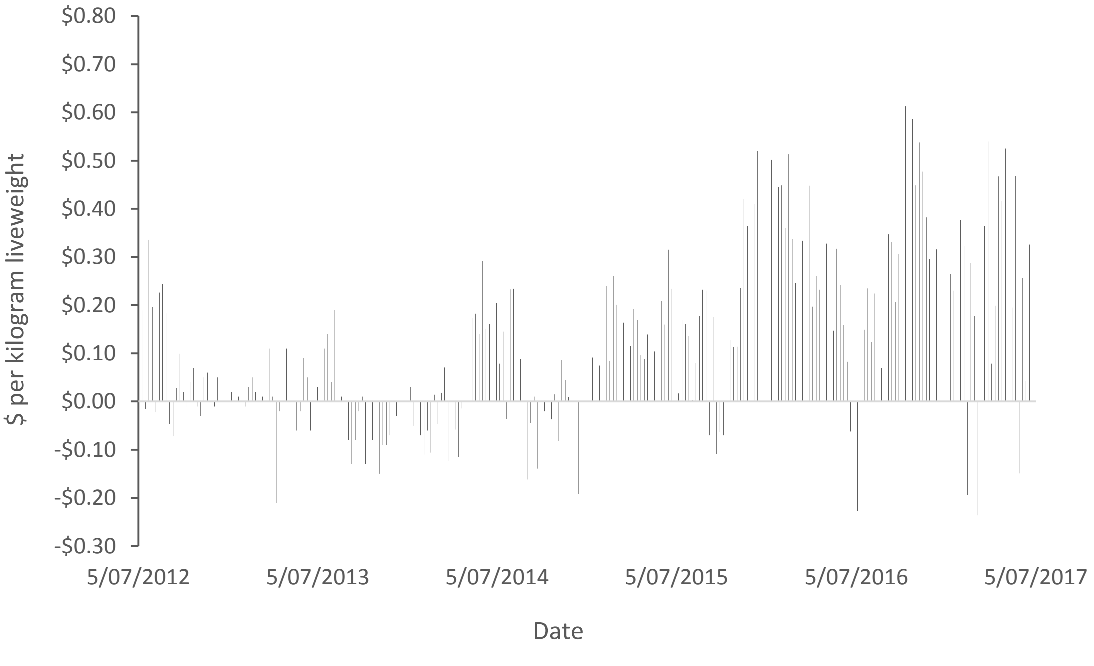


Figure 9 – The difference in Queensland saleyard price ($/kg liveweight) of trade (330-400 kg) relative to heavy weight (500-600 kg) steers between 05/07/2012 and 22/06/2017



Feed-on and finishing market targets were modelled here. Other sale targets, such as EU (European Union) or MSA (Meat Standards Australia), are also commonly applied but this analysis is limited to looking at the two with the most available market and production data and we are not suggesting that targeting alternative markets (e.g. EU, MSA) will not improve profitability. Interested parties can use the base models developed in our analysis to consider other scenarios or they can build their own models.

4.5 Appropriateness of the selected methodology in providing insights into the relative profitability of steer growth paths

The growth path modelling exercise has identified an economic optimum. This was unexpected as such studies usually identify a number of combinations of alternatives likely to be equally profitable. For example, Pannell (2006) identified that often there is a large set of alternatives within the neighbourhood of any economically “optimal” management system that are only slightly less attractive than the optimum. He found, quite rightly, that in many cases even large deviations from optimal decisions make little difference to the payoff.

The unexpectedly clear economic optimum across a wide range of alternative forage management systems identified in this analysis appears to partly depend upon the accurate estimation of how efficiently forage resources are used by different classes of steers. That is, the impact of one of the constraints identified by Pannell (2006), that “the value of information used to refine management decisions is often low”, has been reduced. The technique developed by McLennan (2014) and McLennan and Poppi (2016) to appropriately identify the amount and quality of forage required to achieve the target weight gains in alternative subtropical and tropical grazing systems is critical to the accurate determination of the efficiency of each forage system when utilised by different classes and ages of steers.

The accurate identification of the relative efficiency of steers, combined with the detailed construction of relevant price, cost and asset structures for representative livestock enterprises, eliminates much of the “averaging” that can occur in farm modelling exercises. The Breedcow and Dynama software package is also a well proven method of accurately estimating the change in herd structure arising from a change in the market or age of sale targeted.

Unfortunately just identifying the economic optimum is insufficient. The analysis indicates that capital constraints and financial risk will play a large role in the level of adoption and the rate at which an optimum growth path is likely to be adopted. The modelled steer trading enterprise would show a fairly rapid and significant fall in equity if the optimum growth path from this analysis were to be implemented at the maximum rate (i.e., planting the entire area to leucaena in the first period). The integrated breeding operation incurs less financial risk due to the structure and relative size of the business investment but is also unlikely to rapidly implement the optimum growth path due to the requirement to purchase a significant number of additional breeders to maximise economic returns. Chasing the economic optimum without consideration of financial and production risks could easily lead to the failure of the steer turnover enterprise. Applying a method that appropriately highlights the financial risks associated with the implementation of a growth path as well as the potential economic benefits is necessary to assist understanding of the nature of the alternative investments.

The importance of incorporating the implementation phase in any analysis of change in the management of a beef enterprise in northern Australia has again been conclusively identified in this analysis. Chudleigh *et al*. (2016, 2017*b*) identified the critical importance of correctly incorporating any change in the timing and/or amount of benefits and costs when implementing strategies to improve the economic performance of breeding herds run under extensive grazing conditions in northern Australia. This current analysis also highlights the importance of appropriately modelling the steps in moving from an existing herd structure and target market to a different target market and consequently a different herd structure when implementing alternative growth paths for steers. Noticeable features of modelling the implementation phase of the alternative growth paths in this analysis were the occasionally large amounts of livestock capital released prior to the planting of leucaena and the always positive impact on economic performance of purchasing sufficient breeders to more quickly balance the supply of forage with the number of steers available to graze it. These were critical aspects of the economic and financial performance of a number of scenarios.

The “marginal analysis” applied here as partial discounted net cash flow budgets over the life of the investment are critical to the insights provided by the analysis. Such partial budgeting estimates the extra return on extra capital invested in developing the existing operation. This marginal approach that considers the impact of alternative growth paths at the level of the property or beef business reveals the weakness of methods such as gross margin analysis undertaken at the paddock level. For example, forage oats is often considered to fill a winter “feed gap” and to be capable of finishing steers to slaughter weights when they are unable to do so during the summer growing season. It is often seen as a high quality forage capable of producing a positive gross margin in many central Queensland winters. The weakness of this type of “feed gap” thinking that relies on a gross margin analysis is immediately identified when a marginal analysis that incorporates all of the costs, including opportunity costs, is undertaken. The incorporation of forage oats into any growth path reduced the profitability of the alternative beef enterprise. Therefore, even though feed supplies may be low in winter and steers can be finished on oats, it is generally not economic to do so. The existence of a seasonal feed gap is no indication that it needs to be “filled”.

In summary, for the majority of cases in the Fitzroy NRM region of central Queensland where the property is a going concern and the aim is to increase profitability, the appropriate method to assess alternative investments is marginal analysis using partial budgeting.

The key factors that underpinned the economic advantage created by grazing steers on alternative growth paths in our analysis were:

- the accurate estimation of the efficiency of feed utilisation by QuikIntake,
- the difference in price for the steer beef produced compared to finished steers, and
- the maintenance of a high proportion of steer beef produced as a proportion of total herd output by an integrated breeding and finishing operation when the steer growth path is changed.

The analysis of components of a growth path using gross margin analysis did not effectively identify relative value when assessing both the profitability and riskiness of alternative growth paths.

4.6 Limitations of the biological assumptions and modelling approach

4.6.1 Approach to predicting forage and animal growth

In our study the biological parameters required as inputs for the analysis were exogenously derived from empirical data and expert opinion and by utilising outputs from plant and animal process sub-models where these were known to produce reliable results. Although our approach is reliant on these base assumptions and is not a dynamic, simulation modelling approach we believe it is the most appropriate approach presently available to represent the relevant plant and animal production responses in central Queensland grazing lands. A whole-farm-scale dynamic simulation model has been developed for the northern beef industry to simulate livestock production at the enterprise level, including reproduction, growth and mortality based on energy and protein supply from native tropical pastures (Northern Australia Beef Systems Analyser (NABSA); Ash *et al.* 2015). However, evidence exists to show that the underlying sub-models for simulating sown pasture and animal production are unreliable for prediction of performance from the tropical forage systems modelled here, particularly leucaena-grass pastures, and this will be discussed in more detail below.

In our study, the GRASP pasture growth model (McKeon *et al.* 2000; Rickert *et al.* 2000) and the APSIM cropping simulation model (McCown *et al.* 1996; Keating *et al.* 2003) were used to predict median forage output for buffel, and oats forage, respectively, due to satisfactory agreement of predicted and observed data for perennial grass pastures and oats forage biomass growth in previous studies (e.g., Bowen *et al.* 2015*b*). However, as the growth models for these forage species were developed from a limited pool of data sets, the reliability of the output should be treated with caution. In particular, while modifications have been made to the GRASP native pasture model to allow simulation of buffel grass growth, and ongoing improvements made as data becomes available, sown pastures such as buffel grass were never parameterised as part of the original model development and there has been no validation work conducted (G. Stone, G. Whish pers. comm.). Furthermore, measurements on commercial properties have shown that the APSIM model was not able to adequately predict the effects of grazing (consumption and trampling) on oats biomass growth (Bowen *et al.* 2015*b*). As no biophysical models currently exist which can predict leucaena edible biomass growth or growth of grass pasture within leucaena rows, these values were necessarily derived in this study from available empirical data and expert opinion.

In this study we worked backwards, from an assumed seasonal liveweight gain, to arrive at a seasonal pasture intake by using the QuikIntake spreadsheet calculator (McLennan and Poppi 2016) based on the Australian ruminant feeding standards (NRDR 2007) with modifications for tropical forage systems (McLennan 2014). This approach was taken due to the generally poor accuracy of prediction of grazing cattle performance in the tropics, primarily due to difficulties in predicting intake of forage (McLennan and Poppi 2005; Dove *et al.* 2010; McLennan 2014; Bowen *et al.* 2015*b*). The determination of the diet quality selected by cattle from a standing forage biomass, as in the temperate version of the GrazFeed decision support tool (CSIRO 2014) and as used in NABSA, adds an additional component of error for tropical pastures due to their heterogeneity in terms of both species composition and plant morphology (Stobbs 1975) with output, to our knowledge, not validated for tropical pasture systems. The QuikIntake spreadsheet calculator, whilst incorporating some modifications to reduce over-prediction of intake for *B. indicus* cattle and tropical diets, still results in some over-prediction of intake (McLennan 2014). This is a source of error in our studies resulting in less than the intended utilisation of pastures across all scenarios. However, as additional grazing pressure from kangaroos and wallabies has been ignored in this analysis, the over-prediction of cattle intake provides some buffer to allow for macropod consumption.

4.6.2 Effects of compensatory growth

Compensatory growth is the greater than expected weight gain in animals following an extended period of slow growth or weight loss due to restricted nutrition. This is a well-recognised phenomenon in northern Australia rangeland beef systems (McLennan 1997). The age at which restriction of growth occurs, and the severity and duration of the restriction, have been identified as the major factors contributing to compensatory growth (Ryan 1990). The ‘higher than expected’ rates of growth are likely to be caused primarily by an above-average feed intake (Thornton *et al*. 1979; Graham and

Searle 1979). There is also evidence of an increase in the gross efficiency of conversion of feed to body gain due to a greater proportion of the liveweight gain being stored as protein and water (Oddy and Sainz 2002) as well as a reduced maintenance requirement carried over for some time after the period of under-nutrition (NRDR 2007). However, sound equations or principles upon which to predict the extent and period of compensatory growth have remained elusive with reports showing it can vary from 1-100% (Winks 1984). Currently, the Australian ruminant feeding standards and the decision support tools based on them, GrazFeed and QuikIntake, do not attempt to predict effects of compensatory growth for cattle except those that have been severely restricted and are at a lower weight than the maximum they have reached previously in their lives. This is a major potential source of error for prediction of weight gain of cattle in northern Queensland production systems where the majority of cattle grown on tropical perennial pastures would be subjected to some degree of 'nutritional restriction' during their lifetime, even if not severe, where they would have received inadequate nutrition to grow to their genetic potential.

In our study the assumed seasonal growth rates for steers grazing on buffel grass pastures or leucaena-grass, were based on available measured data sets for the pastures and region of interest and hence automatically incorporate an allowance for effects of compensatory gain after winter periods of reduced nutrition. However, we did not attempt to adjust growth rates of cattle associated with varying degrees of compensatory gain arising from leucaena-grass pastures provided either early or late in the growth path, due to insufficient data to inform such assumptions.

In scenarios where steers grazed leucaena-grass or buffel grass pasture after grazing an oats crop over winter, their assumed growth rates were reduced (relative to steers not fed oats) over the following 140 days to allow for a reverse compensatory growth effect, i.e., higher growth rate of cattle not receiving oats. The assumed reduction in growth rate, of 0.25 relative to cattle not grazed on oats, was informed by compensatory growth rate data for steers grazing tropical grass pastures in central Queensland after receiving varying levels of supplementation (Tomkins *et al.* 2006).

To capture the maximum benefit from feeding any high quality forage (or supplement), the general recommendation to beef producers has been to maintain the high quality nutritional intervention through to the point of sale. This prevents erosion of liveweight benefits over subsequent summer seasons due to compensatory gain by non-fed cattle. In our study for central Queensland Brigalow country, regardless of whether steers which had grazed oats were sold at the end of the oats phase or after subsequent grazing on leucaena-grass or buffel grass pastures, the provision of the oats crop reduced the profitability of the enterprise relative to growth paths not including oats.

Finally, it should be recognised that compensatory growth is an apparent effect associated with the vagaries of using liveweight as a measure of growth. The real effects of any treatment on important economic characteristics such as carcass growth may be greater than those reflected by liveweight changes due to variability in body hydration, gut size and gut fill effects, etc. There is an on-going and urgent need to research these factors which are so important in the final analysis of economic outcomes.

4.6.3 Relative efficiency of growth of younger vs. older cattle

As cattle age, relatively more fat and less protein is deposited (NRDR 2007). Due to the association of water with lean tissue deposition, energy used exclusively for protein synthesis results in 5-6 times greater empty body weight gain than when it is used exclusively for fat deposition (NRDR 2007). Thus, it is generally expected that young cattle with their higher protein deposition and composition would be more efficient in conversion of units of energy to growth, or liveweight gain, than older animals. The implications of this are that for a given diet, younger cattle will demonstrate a higher growth rate than older cattle. However, in this study we did not adjust seasonal liveweight gain for age of cattle due to the absence of good local data to inform this adjustment, the poor ability of current models to predict liveweight gain of grazing cattle in central Queensland (Bowen *et al.* 2015*b*) and the likely over-riding and confounding effect of compensatory gain.

4.6.4 Effects of increasing pasture utilisation rate on forage and animal production

We could find no data reporting effects of utilisation rate on buffel grass or any improved tropical grasses under extensive conditions. Furthermore, historical grazing trials on native pasture systems did not provide good comparative data on cattle performance due to difficulties in experimental design caused by the primary goal of achieving desired pasture treatment effects (Orr *et al.* 2010; Orr and Phelps 2013; O'Reagain *et al.* 2014; Hall *et al.* 2017). Hence, in this study, we worked on the basic premise that diet digestibility would decrease with increased pasture utilisation, resulting in a corresponding decrease in liveweight gain. The basic premise was that diet digestibility and hence liveweight gain would decrease with increased pasture utilisation due to reduced ability for selection (Stobbs 1975). Furthermore, it was assumed that for buffel grass pastures in B and C land condition, the encroachment of other species (such as Indian couch and annual species) as well as declining pasture vigour would result in reduced average annual diet digestibility and hence cattle liveweight gain. It is recognised that the reverse situation (i.e. greater cattle liveweight gain on degraded pastures) can occur under some seasonal circumstances (R. Silcock pers. comm.) but this analysis was intended to represent the median, long-term situation.

Given the lack of existing data, we assessed four alternative outcomes in terms of land condition decline under heavy grazing pressure (50% utilisation) on buffel grass pasture starting in A condition: a) no decline in pasture biomass production or quality, and hence in cattle production, over 30 years, b) linear decline in productivity parameters from A to B condition from years 20 to 30, c) linear decline in productivity from A to B condition parameters over years 10 to 20 and then maintenance of B condition for the final 10 years of the analysis, and d) linear decline in productivity from A to B condition parameters over years 10-20 and then linear decline from B to C condition from year 20 to 30.

Given the importance of understanding declining land condition, sediment run-off to the reef, and corresponding trade-offs with animal production and economic outcomes for producers, research to better elucidate these responses should be given high priority.

4.7 Limitations of the economic and financial analysis

There are constraints to the more general applicability of the economic and financial analysis. It has been shown that the relative and absolute value of alternative investment strategies varies significantly between beef enterprises in northern Australia (Chudleigh *et al*. 2016). Opportunities for improving enterprise performance are specific to the unique resources, management system and management skill of each enterprise. 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.

The key to improving the performance of individual beef enterprises is the ability of management to recognise relevant opportunities and then being able to assess the trade-offs, responses, costs and benefits likely from the implementation of any opportunity on their property. Considering the results of an analysis based on the circumstances of another property or an “example” property is a way of understanding the key factors in the decision but rarely an accurate indicator of the likely outcome for each separate manager or enterprise.

The information provided here should be used, firstly, as a guide to an appropriate method to assess alternative investments aimed at identifying efficient growth paths for a beef enterprise in the Brigalow lands of the Fitzroy NRM region and, secondly, the potential level of response to change revealed by relevant research. Other methods based on the use of production indicators, such as an increase in the amount of beef produced or an increase in the number of weaners produced, to assess the value of alternative growth paths are shown in this analysis to be entirely misleading.

It is also important to note that the scenario modelling for the integrated breeding and finishing operation is constrained by 1,470 AE – not by areas of particular land types. One of the minor problems with this approach is that changing the herd structure in the real world will obviously change the balance of land types accessed by the breeding herd. The land owner / manager is usually relied on to rebalance the performance of the components of the herd impacted but in this case the blanket assumption applied is that the performance of the component of the breeder herd impacted will not alter sufficiently to change the results. For example, although the breeder herd producing feed-on steers could have the performance of the heifers improved compared to the breeder herd producing finished steers – thereby improving the relative economic performance of the feed-on steer operation, this effect cannot be incorporated in the analysis due to a lack of specific information.

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.

5 Summary of findings

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

1. Providing a high quality forage for any period during the growth path of steers reduced the age of turn-off to below 26.2 and 34.0 months, for feed-on and finished steers, respectively, relative to counterparts grazed on buffel grass-only pastures.
2. The earlier in the growth path that steers commenced grazing leucaena-grass pastures, the younger the turn-off age, with steers grazing leucaena-grass pastures from weaning (DS1L_FO and DS1L_F) reaching feedlot and abattoir target entry weights at 19.3 and 26.0 months of age, respectively. This age of turn-off is 7 and 8 months earlier for feed-on and finished steers, respectively, than for steers grazed solely on buffel grass pastures.
3. Providing oats forage twice in the growth path, in the first and second dry seasons after weaning, with access to leucaena-grass pasture in between (B-O-L-O_F), allowed steers to reach abattoir entry weights at the youngest age of all scenarios: 22.8 months, 11.2 months younger than if grazed on buffel grass alone.
4. Analysis for the steer turnover enterprise and the breeding and finishing enterprise identified the same economically optimum growth path which was grazing steers on leucaena-grass pastures from weaning until they reached feed-on (feedlot entry) weight (DS1L_FO).

5. To achieve the economically optimum growth path (DS1L_FO) for the breeding and finishing enterprise, purchase of additional breeders was necessary to match weaner numbers to the supply of additional nutrition provided by the leucaena-grass forage.
6. If the preferred option is to allow breeder numbers to increase naturally, then the most profitable growth path scenario with this constraint was B-WS1L_F where steers are grazed on leucaena-grass from their first wet season after weaning until they reach finishing weights. This growth path becomes the most profitable under the constraint of natural breeder number increase as there is a lesser requirement for increased breeder numbers in this scenario allowing the full utilisation of the leucaena-grass pasture, earlier in time.
7. For both enterprises, the economic optimum was achieved by fully utilising the optimum growth path as soon as possible. For growth path scenarios where the age of turn-off of steers was reduced (compared to the baseline of producing finished steers from buffel grass pastures) and breeder numbers were allowed to naturally increase, the foregone income related to retaining breeders, plus the delay in matching steer weaner numbers to the increased supply of nutrition, significantly reduced the NPV (i.e. profitability).
8. Incorporating leucaena-grass pastures at any steer age improved the profitability of the steer turnover enterprise ($7,368-$106,508 extra profit/annum), and similarly for the breeding and finishing enterprise ($1,754-$31,383 extra profit/annum) except for two scenarios where leucaena-grass pastures were provided to older steers targeted at the feed-on market ($4,816 and $23,886 less profit/annum).
9. Implementing a leucaena-grass system substantially increased peak deficit levels and financial risk, with payback periods of 8-14 years required for even the most profitable leucaena-grass growth path (DS1L_FO), for the steer turnover and the breeding and finishing enterprise, respectively.
10. Any growth path that incorporated forage oats, in either a turnover or breeding and finishing enterprise, resulted in a lower economic and financial performance than that of corresponding growth paths that incorporated leucaena.
11. Incorporation of oats into a buffel grass growth path always reduced the profitability of a steer turnover or a breeding and finishing enterprise.
12. Implementing forage oats into either beef enterprise substantially increased peak deficit levels and financial risk with the majority of oats-buffel grass growth paths not generating sufficient returns to repay the additional borrowings during the first 20 years of the investment period.
13. For the breeding and finishing enterprise, building up breeder numbers naturally over time to meet the steer needs of a growth path often had lower financial risk but was substantially less profitable over the life of the investment than purchasing additional breeders in the short term. The purchase of additional breeders increased the peak deficit in some cases but often reduced the period of time required to pay back the total funds invested.
14. There was no meaningful relationship between the change in profit and change in productivity resulting from changes to the growth paths, in terms of number of extra weaners produced or the additional beef produced per hectare.
15. There was a large economic advantage from increasing grazing pressure on buffel grass pastures for a steer turnover enterprise.

16. Whilst the top four growth paths in terms of economic performance for the steer turnover enterprise all incorporated leucaena, the 5th was the scenario incorporating an increase in utilisation of the buffel grass pasture from 30 to 50% with a target market of feed-on steers and assuming no decline in land condition over the 30 years of analysis (B50_FO). Producing finished steers (instead of feed-on steers) from buffel grass pastures utilised at 50% also resulted in a substantially greater profitability than the baseline scenario of 30% utilisation of buffel grass pasture.
17. A 50% pasture utilisation rate, with declining land condition from A to B or from A to C during the 30 year period of analysis, was substantially more profitable than for 30% utilisation, for a steer turnover enterprise.
18. Utilising buffel grass pastures in B condition at 50% was more profitable than utilising the same pastures at 30%.
19. Unlike scenarios incorporating high quality forage (leucaena or oats) into the growth path which all increased the peak deficit of the business substantially, those scenarios involving increased utilisation rates of buffel grass did not in the medium term.
20. There was poor correlation of the results from the leucaena component analysis (Paddock C) with results from the whole-farm, integrated herd modelling analysis (Enterprise A and B). This indicates that gross margin analysis of growth path components provides little insight into the relative impact on profit or riskiness of changing a growth path.

6 Conclusions

This study represents the first known attempt to assess the most profitable way of incorporating high quality forages into the whole-of-life growth paths of steers in central Queensland, using regionally relevant herd models at the property level to determine whole-of-business productivity and profitability. In this analysis we have assessed the effect of the change in growth path on overall herd structure and farm profitability to provide valuable insights which can be used to guide business investment decisions. Additionally, an examination of the effects of grazing pressure and land condition on productivity and profitability of the perennial grass pasture systems has provided valuable insights into the interaction between stocking rate and financial returns. Further research is required to better understand compensatory growth effects in northern cattle production systems and also effects of utilisation rates of buffel and other sown grass and legume species. This would allow improvement of existing modelling capabilities which, in turn, will better inform whole-farm economic analysis.

7 Recommendations and future research directions

7.1 Key recommendations and research directions

1. A grazing trial designed as a whole-of-life growth path study with steers (from weaning to marketing) should be carried out with the aim of testing and validating the optimal growth paths identified in this desk-top analysis. Such a study should incorporate detailed measurements of forage and animal responses to allow continual improvement of existing modelling capabilities and to better inform whole-farm economic analyses.
2. There is an ongoing and urgent need for research to better understand compensatory growth and its effects in the context of northern cattle production systems in Australia. A major difficulty in

accurately assessing the effects of forage and other nutritional interventions on both cattle production and economic returns is the effect of compensatory growth on cattle performance throughout the growth path to slaughter. The majority of cattle grown on tropical, perennial pastures in northern Australia are subject to some degree of 'nutritional restriction' during their lifetime, where they receive inadequate nutrition to grow to their genetic potential. Our inability to accurately predict the resultant intervals of compensatory growth is a major potential source of error for prediction of cattle liveweight gain as well as changes in important economic characteristics such as carcass composition. It is recommended that research to better elucidate compensatory gain effects be encompassed within any future work to examine whole-of-life cattle growth paths.

3. Investigation is required to understand the effects of utilisation rate of buffel grass, and other sown pasture grass and legume species, on plant biomass production, plant quality (DMD and crude protein), land condition decline and corresponding cattle production. Given the importance of understanding declining land condition, sediment run-off to the reef, and corresponding trade-offs with animal production and economic outcomes for producers, research to better elucidate these responses is imperative.

7.2 Associated research needs

1. Further research to improve the underlying biophysical plant growth models is required before they can be used with confidence in central Queensland and northern Australia more broadly. This would require appropriate data collection to parameterise and validate growth models for a range of appropriate sown (introduced) pasture grass and legume species in common commercial use. In particular:
    - A growth model for leucaena, and grass growth in leucaena inter-rows, is currently not available at all and this is a major gap considering the economic importance of leucaena to the northern beef industry.
    - While modifications have been made to the GRASP native pasture model to allow simulation of buffel grass growth, and ongoing improvements made as data becomes available, sown pastures such as buffel grass were never parameterised as part of the original model development. This is also a major gap considering the importance of buffel grass pastures in terms of area and economic contribution to the northern beef industry.
    - If the APSIM model is to be used with confidence to predict biomass growth of grazed forage crops, additional modifications and validations are required. Whilst biomass predictions for un-grazed oats crops have been shown to be satisfactory, the model markedly under-predicted forage sorghum and lablab biomass for sites in central Queensland (Bowen *et al.* 2015*b*). Furthermore, improvements are required to better account for the effects of grazing (consumption and trampling) on biomass growth for all forage models in APSIM as the models substantially under-predicted the effects of grazing in reducing biomass production for commercial sites in central Queensland (Bowen *et al.* 2015*b*).
2. Further investigation is required to understand why the Australian feeding standards, and the GrazFeed model based on these, currently under-predicts liveweight gain for cattle grazing forages grown in northern Australia. Modifications are required before these equations can be

used with any reliability to predict animal performance from either diet quality inputs from faecal near-infrared reflectance spectroscopy (NIRS) or from simulated pasture biomass growth.

3. Given the low P status of many soils across central Queensland and northern Australia more broadly, as well as increasing economic importance of legume-grass pastures, a detailed study is required to quantify responses to P fertiliser for perennial legume-grass pastures, and especially leucaena-grass pastures. Any such study should include measurement of forage and grazing cattle responses.

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9 Glossary of terms and abbreviations

AE	Adult equivalent. An AE is defined in terms of the daily forage dry matter intake of a standard animal which was defined by McLean and Blakeley (2014) as a 2.25 year old, 450 kg *Bos taurus* steer at maintenance, walking 7 km/day. The spreadsheet calculator QuikIntake (McLennan and Poppi 2016) was used to calculate daily cattle DM intakes for the specified average DMD of each forage type. Hence the average, annual intake of an AE consuming the key forages of interest were: baseline buffel grass pasture (57% DMD): 8.9 kg DM/day, leucaena-grass pasture (63% DMD): 7.6 kg DM/d, oats forage (65% DMD): 7.2 kg DM/d.
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.
Constant (real) dollar terms	All variables are expressed in terms of the price level of a single given year.
Current (nominal) dollar terms	All variables are expressed in terms of the year in which the costs or income occur. The impact of expected inflation is explicitly reflected in the cash flow projections.
DAF	Department of Agriculture and Fisheries, Queensland Government
DCF	Discounted cash flow. This technique is a way of allowing that when money is invested in one use, the chance of spending that money in another use is gone. Discounting means deducting from a project's expected earnings the amount which the investment funds could earn in its most profitable alternative use. Discounting the value of money to be received or spent in the future is a way of adjusting the future net rewards from the investment back to what they would be worth in the hand today.
Depreciation (as applied in estimating operating profit)	A form of overhead cost that allows for the use (fall in value) of assets that have a life of more than one production period. It is an allowance that is deducted from gross revenue each year so that all of the costs of producing an output in that year are set against all of the revenues produced in that year. Depreciation of assets is estimated by valuing them at either current market value or expected replacement value, identifying their salvage value in constant dollar terms and then dividing by the number of years until replacement. The formula used in this analysis is: (replacement cost – salvage value)/number of years until replacement.
Discounting	The process of adjusting expected future costs and benefits to values at a common point in time (typically the present) to account for the time preference of money. With discounting, a stream of funds occurring at different time periods in the future is reduced to a single figure by summing their present value equivalents to arrive at a 'Net Present Value' (NPV). Note that discounting is not carried out to account for inflation. Discounting would still be applicable in periods of nil inflation.

Discount rate	The interest rate used to determine the present rate of a future value by discounting.
DM	Dry matter. DM is determined by oven drying feed or faecal material in an oven until constant weight is reached (i.e. all moisture is removed).
DMD	Dry matter digestibility. DMD is the intake of DM minus the amount in the corresponding faeces, expressed as a proportion of the intake (or as a percentage).
Economic analysis	Economic analysis usually focusses on profit as the true measure of economic performance or how efficiently resources are applied. The calculation of profit includes non-cash items like opportunity costs, unpaid labour, depreciation and change in the value of livestock or crop inventory. NPV and amortised NPV are both measures of profit.
Feed-on steers	Steers marketed to the feedlot (450 kg at the feedlot or 474 kg paddock liveweight).
Financial analysis	Financial analysis focusses on cash flow and the determination of whether all business and family cash costs can be met. Financial analysis can also include analysis of debt servicing capacity.
Finished steers	Steers marketed to an abattoir to achieve 310 kg carcass weight (605 kg paddock liveweight).
Forage utilisation	The percentage of annual forage (including high quality sown forage or perennial pasture) biomass growth that is consumed by grazing livestock.
Gross margin	The gross income received from an activity less the variable costs incurred.
IRR	Internal rate of return. This is the discount rate at which the present value of income from a project equals the present value of total expenditure (capital and annual costs) on the project, i.e. the break-even discount rate. This indicates the maximum interest that a project can pay for the resources used if the project is to recover its investment expenses and still just break even. IRR can be expressed as either the return on the total investment or the return on the marginal capital – referred to as the Marginal IRR in this report.
Land condition	The capacity of the land to produce useful forage, arbitrarily assessed as one of four broad categories: A, B, C or D, with A being the best condition rating. Three components are assessed: 1) soil and 2) pasture condition, and 3) extent of woodland thickening/tree basal area or other weed encroachment.
Marginal return	Extra or added return. The principle of marginality emphasises the importance of evaluating the changes for extra effects, not the average level of performance.
NPV	Net present value. Refers to the net returns (income minus costs) over the life of an investment (in this case, provision of high quality forages),

	expressed in present day terms. A discounted cash-flow allows future cash-flows (costs and income) to be discounted back to a NPV so that investments over varying time periods can be compared. The investment with the highest NPV is preferred. NPV was calculated at a 5% rate of return which was taken as the real opportunity cost of funds to the producer.
NRM region	Natural Resource Management region. NRM regions across Australia are based on catchments or bioregions. The boundaries of NRM regions are managed by the Australian Government and used for statistical reporting and allocation and reporting of environmental investment programs.
Opportunity cost	The benefit foregone by using a scarce resource for one purpose instead of its next best alternative use.
P	Phosphorus
Payback period	The number of years it takes for the cumulative present value to become positive. Other things being equal, the shorter the payback period, the more appealing the investment.
Peak deficit	This is an estimate of the peak deficit in cash flow caused by the implementation of the development scenario. 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.
SRW	Standard reference weight. The SRW is the liveweight that would be achieved by an animal of specified breed and sex when skeletal development is complete and conditions score is in the middle of the range. This is an important parameter in the prediction of the energy, fat and protein content of empty body gain in immature animals.
Year of peak deficit	The year in which the peak deficit is expected to occur.

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11 Appendix 1: Modelled enterprise details

11.1 The beef enterprises

The breeding and finishing enterprise had a total area of 8700 ha and carried about 1470 AE. The steer turnover enterprise had a total area of 1000 ha and carried about 470 AE.

The case study beef enterprises were located centrally in the Fitzroy NRM region with a number of selling centres and abattoirs available for sale stock. Detailed price data over time is available for the Roma stock selling centre (ca. 350 km) and Dinmore abattoirs (ca. 650 km). As both centres are considered relevant indicators of market prices for beef producers in the region, these two selling centres were used to calculate net sale values. Transport costs to other selling centres may be lower but net sale values are expected to be similar.

11.2 Beef production activity

The baseline activity on the breeding and finishing enterprise was a self-replacing breeding and growing activity that relied on the production of weaners by a breeding herd. Weaner steers entered a growing system that varied in size with the period of time steers were retained prior to sale. Heifers were used to maintain the breeding herd or were culled and sold. Breeding cows were culled on reproductive performance and age. Herd bulls were retained in the breeding herd for an average of 5 years. The target was to sell finished steers, surplus heifers and cull cows to the abattoirs.

The baseline activity on the steer turnover enterprise was a production system that purchased steers as weaners in May and then grew them through to slaughter weight steers.

11.3 Steer and heifer growth model

The pattern of growth over time for steers and heifer underpins the markets available for both steers and surplus heifers and the likely mating age and reproduction performance of the heifers as they enter the breeding herd. Table 16 shows the expected “average” birthdate and weaning date plus the pre-weaning performance of the steers and heifers on the breeding and finishing property.

Table 16 - Birthdate, weaning and pre weaning performance

Factor	Value	Units
Average calving date	15/11/2016	
Average weaning date	17/05/2017	
Age at weaning	6.0	months
Days to weaning	183	days
Birth weight	35	kg
Male calf average daily gain birth to weaning	0.9	kg/day
Reduction in growth rate of heifers compared to steers	5	%
Heifer average daily gain birth to weaning	0.86	kg/day

Some evidence exists that, where the same nutrition is available, male calves grow about 8% faster than female calves pre-weaning and steers grow about 5% faster than heifers post-weaning (Fordyce *et al.* 1993). To simplify the analyses, all pre-weaning growth rates for female calves were set at 5% lower than male calves, the same as the post-weaning growth rate difference between steers and heifers. This only applied to the base herd model as the relationship between steer and heifer growth rates changed with the implementation of the alternative steer growth paths.

Table 17 indicates the expected post weaning seasonal performance for steers. Steers were assumed to gain weight at about 0.49 kg/head.day on buffel grass pastures to achieve 180 kg/head.annum post weaning and heifers to gain ca. 0.47 kg/head.day to achieve 171 kg/head.annum post weaning. The steer growth rates were applied to both the breeding and finishing, and the steer turnover properties.

Table 17 - Expected post weaning steer growth rates: Baseline scenario in A land condition with 30 and 35% pasture utilisation (average annual diet DMD 57%)

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

Table 18 shows the expected month by month growth pattern for steers on buffel grass. Expected liveweight at birth, weaning and birthdays are highlighted (orange, green and orange, respectively). The baseline sale weight target for steers is highlighted in red. The steer (and heifer) growth model underpinned the herd performance for the modelled baseline properties.

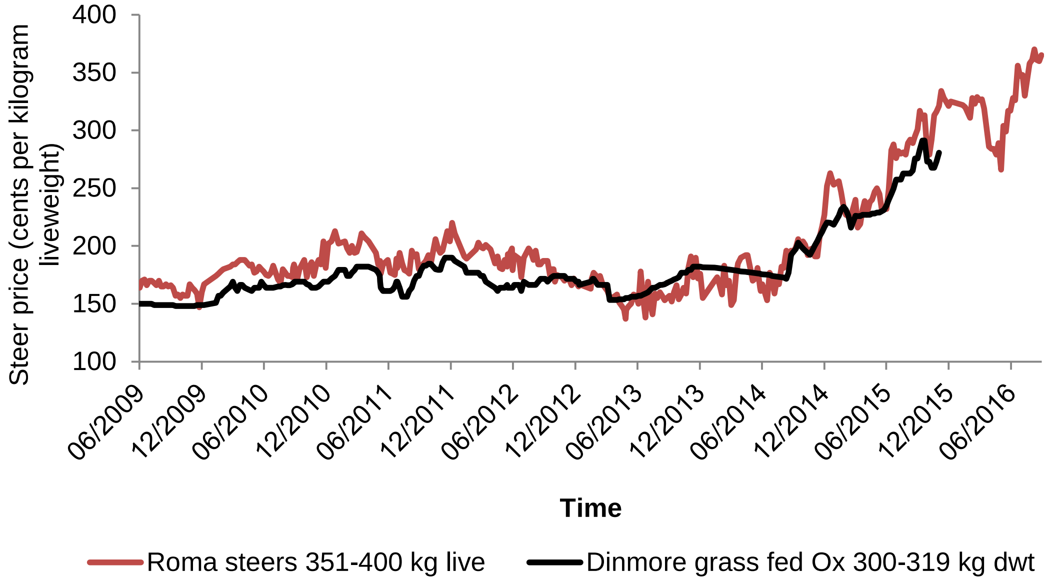
Table 18 - Expected growth of steers: Baseline scenario in A land condition with 30 and 35% pasture utilisation (average, annual diet DMD 57%)

Date	Daily gain (kg/d)	LW (kg)	Age (months)
15/11/2016	0	35	0.0
16/12/2016	0.9	63	1.0
15/01/2017	0.9	90	2.0
13/02/2017	0.9	116	3.0
16/03/2017	0.9	144	4.0
15/04/2017	0.9	171	5.0
17/05/2017	0.9	200	6.0
31/05/2017	0.73	210	6.5
30/06/2017	0.35	220	7.5
31/07/2017	0.35	231	8.5
31/08/2017	0.35	242	9.5
30/09/2017	0.1	245	10.5
31/10/2017	0.1	248	11.5
15/11/2017	0.1	250	12.0
30/11/2017	0.1	251	12.5
31/12/2017	0.8	276	13.5
30/01/2018	0.8	300	14.5
28/02/2018	0.8	323	15.5
31/03/2018	0.73	346	16.5
30/04/2018	0.73	368	17.5
31/05/2018	0.73	390	18.5
30/06/2018	0.35	401	19.5
31/07/2018	0.35	412	20.5
31/08/2018	0.35	423	21.5
30/09/2018	0.1	426	22.5
31/10/2018	0.1	429	23.5
15/11/2018	0.1	430	24.0
30/11/2018	0.1	432	24.5
31/12/2018	0.8	456	25.5
31/01/2019	0.8	481	26.5
28/02/2019	0.8	504	27.4
31/03/2019	0.73	526	28.5
30/04/2019	0.73	548	29.5
31/05/2019	0.73	571	30.5
30/06/2019	0.35	581	31.5
31/07/2019	0.35	592	32.5
31/08/2019	0.35	603	33.5
15/09/2019	0.1	605	34.0

11.4 Prices

Figure 10 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 10 - Steer prices over time from 2009 to 2016



Roma store sale data were used to estimate the values of store stock classes and Dinmore prices were used to estimate slaughter prices. Selling costs relate to the selected selling centre. Table 19 shows average price data (July 2008 – November 2015) for a range of slaughter stock at Dinmore abattoirs.

Table 19 - Price ranges for Dinmore abattoir (July 2008 – November 2015)

	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 20 indicates the price variation for sale weights for steers and heifers at the Roma store sale between 2008 and 2015.

Table 20 - Price ranges at Roma sale yards (July 2008- November 2015) expressed as cents per kilograms liveweight

Parameter	Steers					Heifers
Live weight range (kg)	<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 initially applied to reflect the expected real average for prices into the future. Not all of the recent price spike was included in the average as its long term effect on prices is unknown. The impact of the change in market prices and price basis between classes of sale stock between November 2015 and June 2017 was applied to selected results and likely impacts discussed. Table 21 shows the price data and selling costs for each class of stock retained in the herd models.

Table 21 - 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)
Heifer weaners 5-11 months	190	5	181	$1.76	4.00	$17.00	$18.05
Heifers 1 year	320	5	304	$1.69	4.00	$17.00	$22.56
Heifers 2 years	520	5	494	$1.61	0.00	$5.00	$53.70
Cows 3 years plus	520	5	494	$1.61	0.00	$5.00	$53.70
Steer weaners 5-11 months	190	5	181	$2.04	4.00	$17.00	$18.05
Steers 1 year	349	5	332	$1.96	4.00	$17.00	$24.07
Steers 2 years	605	5	575	$1.87	0.00	$5.00	$65.00
Cull bulls	750	5	713	$1.65	0.00	$5.00	$77.19

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. Table 22 shows the expected transport costs per head for each potential class of sale cattle.

Table 22 - Transport cost calculations for January steer sales

	Weaners	**Heifers 12-24 months**	**Heifers 24-36 months**	**Cows**	**Steers 24-36 months**	**Bulls**
Transport cost $/deck/km	$1.90	$1.90	$1.90	$1.90	$1.90	$1.90
Distance (km)	350	350	650	650	650	650
Number of head per deck	40	32	23	23	20	16
Freight cost/head	$17.50	$21.88	$53.70	$53.70	$65.00	$77.19

11.5 Husbandry costs and treatments

Table 23 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 23 - Treatments applied and cost per head

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

Steers entering the turnover property were treated for ticks ($2.00/head) and given a 5-in-1 injection. Steers purchased for growth paths that include a period of time on leucaena were dosed with leucaena inoculum at a cost of $2.80 per head.

11.6 Other herd performance parameters

Data to describe the reproduction efficiency of the breeder herd was based on the data collected by the Cash Cow project (McGowan *et al.* 2014). The median reproductive performance values for the Cash Cow project country type termed 'Central Forest' are summarised in Table 24. This data set was seen as being closest to the expected median performance of a beef breeding herd in the Fitzroy catchment.

Table 24 - Median reproduction performance for 'Central Forest' data (McGowan et al. 2014)

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

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

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

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

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

Table 25 shows the level of reproductive performance of each class of females required to achieve an average weaning rate of 77% for all cows mated in the Breedcowplus model. The values retained produced a weaning rate equivalent to Cash Cow's weaner figure of 77% while maintaining a strong relationship to the annual pregnancy (conception), calf loss and missing data provided by the Cash Cow project. Heifers were first mated at 2 years of age.

Table 25 - Calving rate and death rate assumptions

Cattle age start year	Weaners	1	2	3	4	5	6	7	8	9	10	11	12
Cattle age end year	1	2	3	4	5	6	7	8	9	10	11	12	13
To display weaning % calculations, place cursor on column of interest, or block of columns, and press F12 key (Sections A and E only).													
Expected conception rate for age group (%)	na	0.0%	80.0%	78.0%	87.0%	87.0%	87.0%	87.0%	84.0%	84.0%	84.0%	84.0%	84.0%
Expected calf loss from conception to weaning (%)^	na	0.0%	10.0%	7.0%	6.0%	6.0%	6.0%	6.0%	5.0%	5.0%	5.0%	5.0%	5.0%
Proportion of empties (PTE) sold (%)	na	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Proportion of pregnants sold (%)	na	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Calves weaned/cows retained	na	0.0%	90.0%	93.0%	94.0%	94.0%	94.0%	94.0%	95.0%	95.0%	95.0%	95.0%	95.0%
Female death rate	3.0%	3.0%	8.0%	6.0%	6.0%	6.0%	6.0%	6.0%	5.5%	5.5%	5.5%	5.5%	5.5%
Spayed or unmated female death rate ..	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
Male death rate	4.0%	4.0%	4.0%	4.0%	4.0%	*No entries allowed for bullocks past 5 yrs of age*							

The culling strategy for the baseline herd removed cows that did not show as pregnant after mating or after they had produced a calf at 12-13 years old.

The mortality rates are based on the Cash Cow project data for missing pregnant females and also reflect the mortality data analysed by Henderson *et al.* (2012) for the northern beef industry. Although data from Henderson *et al.* (2012) was not collected from the Fitzroy catchment, the mortality rates applied in the Breedcowplus herd model are a seen as a balance between the Cash Cow estimates of missing pregnant females and the values identified by Henderson *et al*. (2012) for steers and breeding females and contribute to achieving the median reproduction performance identified by the Cash Cow project.

11.7 Herd structure for the base herd

Table 26 shows the female management strategies including last mating cows at 12-13 years old, culling further heifers pre-mating and then culling breeding females on a pregnancy diagnosis. Females that were pregnancy tested in calf and then fail to produce a weaner were retained.

Table 26 - Female herd structure for the growth path base herd

SECTION E: FEMALE HERD STRUCTURE

Weaner heifers to be retained	219	*(Enter 219.36 to give required AEs)*			
Age at first joining (max 3 yrs)	2	If 1, % joined =	100.00%		*Note 3: "Spays" include cows set aside pre-mating*
Cow culling age (integer, max 13)	13				*(e.g. paddocked separately for fattening).*
Required herd size (AE)	1470				*Default rule is to sell the year after spaying.*
Surplus weaner heifers sold or spayed ...	0	Weaner % spayed =	0.00%	*Number =* 0	

Cow age start year	1	2	3	4	5	6	7	8	9	10	11	12
Cow age end year	2	3	4	5	6	7	8	9	10	11	12	13
Cows/heifers available start year	213	206	100	73	60	49	40	33	26	21	16	13
Sales unmated, % start yr cows	0.00%	34.24%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cows spayed or left unmated, % of start year	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sales after mating, % of number mated	0.00%	20.00%	22.00%	13.00%	13.00%	13.00%	13.00%	16.00%	16.00%	16.00%	16.00%	16.00%
Unspayed cows sold	0	98	22	10	8	6	5	5	4	3	3	2
Spayed or unmated cows from previous years	0	0	0	0	0	0	0	0	0	0	0	0
Cows spayed or unmated at start of year	0	0	0	0	0	0	0	0	0	0	0	0
Sales of spayed or unmated cows; % carryover no	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Spayed or unmated cows sold	0	0	0	0	0	0	0	0	0	0	0	0
To display weaning % calculations, place cursor on column of interest, or block of columns, and press F12 key (Sections A and E only).												
Cows mated in each age group	0	136	100	73	60	49	40	33	26	21	16	13
Mated cows retained in each group	0	109	78	64	52	43	35	28	22	17	14	11
Calves weaned from each group	0	98	72	60	49	40	33	26	21	16	13	10

Total female sales	176	Weaner heifer cull	0.00%	Average female price	$736.64	Female sales #	176
		Female/total sales	46.60%	Average price breeders	$736.64	Breeder sales #	176
Cows and heifers spayed or unmated	0	Turnoff/total herd	28.26%	Average price spayed or unmated	$0.00	Spay or unmated sales #	0
Total cows and heifers mated	567	Weaners/all cows mated	77.43%				
Calves weaned	439	Weaners/cows surviving	99.43%	Breeder deaths	30	Spay or unmated deaths #	0
Females mated and retained	471	Weaners/cows mated & kept	93.11%	Breeder deaths %	6.36%	Spay or unmated deaths %	0.00%

The value of the land and fixed improvements for the example breeding property was taken to be $5,872,500. This makes the opening value of the total value of land, plant and improvements for the beef enterprise investment, $6,075,740. The value of land and fixed improvements for the steer turnover enterprise was set at $2,470,000.

11.8 Leucaena development costs

The detailed development costs for leucaena are shown in Table 27. It was assumed that leucaena that is successfully established and managed has an effective grazing life of at least 30 years (Radrizzani *et al*. 2010, 2016). Contract rates for planting leucaena were used as the pasture was planted no more than once every 30 years. The paddock was converted from perennial grass to leucaena by using a chisel plough and a tyne cultivator, twice each, to establish an appropriate seed bed.

Leucaena was established by destocking the area of buffel pasture allocated to leucaena during the winter of the first year of the analysis. Leucaena was then planted during the late summer of the second year and grazing commenced (generally) after May of the third year. The commencement of grazing varied with the growth path applied. All analyses were compiled on a calendar year basis.

Table 27 - Leucaena development costs at contract rates

	Rate of application	Cost / unit	Number of applications	% of area treated	Cost per hectare
Pre planting costs					
Chisel plough	1	$61.44	2.00	100	$122.88
Tyne cultivator	1	$36.91	2.00	100	$73.82
Linkage spray rig	1	$8.35	2.00	100	$16.70
Roundup CT	2 L/ha	$4.50	2.00	100	$18.00
Amicide 625	0.5 L/ha	$6.83	2.00	100	$6.83
Planting costs					
Leucaena planter	1	$21.23	1.00	100	$21.23
Leucaena seed	2 kg/ha	$30.00	1.00	100	$60.00
Leucaena inoculant	1	$0.24	1.00	100	$0.24
MAP (Starterphos)	50 kg/ha	$0.88	1.00	100	$44.00
Beetle bait	1	$7.00	1.00	100	$7.00
Linkage spray rig	1	$8.35	1.00	100	$8.35
Spinnaker	0.14 kg/ha	$255.00	1.00	50	$17.85
Roundup CT	1.5 L/ha	$4.50	1.00	50	$3.38
Post planting costs					
Linkage spray rig	1	$8.35	1.00	80	$6.68
Fusilade	1.5 L/ha	$69.27	1.00	80	$83.13
Grass planter	1	$11.68	1.00	80	$9.34
Grass seed	4 kg/ha	$17.00	1.00	80	$54.40
Total					**$554**

Leucaena has a relatively high requirement for soil P and it was assumed that a soil test revealed an adequate state for establishment but some additional P was required to maintain the productivity of the leucaena over time. The expected maintenance and fertiliser costs are shown in Table 28 and were incurred at the end of each decade.

Table 28 - Leucaena maintenance costs – expected every decade

	Rate of application	Cost/unit	Number of applications	% of forage area treated	Cost per hectare
Superphosphate	150 kg/ha	$0.58	1	100	$87.00
Leucaena maintenance (chopping)	1	$81.51	1	100	$81.51
Leucaena fertiliser spreading	1	$8.00	1	100	$8.00
Decadal maintenance costs					**$176.50**

11.9 Oats planting costs

Table 29 presents the oats planting costs applied for Enterprise A where contract rates were used while Table 30 presents oats planting costs used for Enterprise B where it was assumed that producers' own plant and equipment was used.

Table 29 – Oats planting costs with contract rates

Item	Rate of application	Cost / unit	Number of applications	Cost per hectare
Chisel plough	1	$61.44	1	$61.44
Tyne cultivator	1	$36.91	1	$36.91
Linkage spray rig	1	$8.35	2	$16.70
Amicide 625	0.75 L/ha	$6.83	2	$10.25
Glyphosate 450 CT	1.50 L/ha	$4.64	2	$13.91
No till seeder	1	$33.72	1	$33.72
Oats seed	40 kg/ha	$1.00	1	$40.00
Linkage spray rig	1	$8.35	1	$8.35
MCPA LVE	1 L/ha	$10.75	1	$10.75
			Total	**$232.00**

Table 30 – Oats planting costs with owned machinery

Item	Rate of application	Cost / unit	Number of applications	Cost per hectare
Chisel plough	1	$34.41	1	$34.41
Tyne cultivator	1	$17.74	1	$17.74
Linkage spray rig	1	$3.66	2	$7.33
Amicide 625	0.75 L/ha	$6.83	2	$10.25
Glyphosate 450 CT	1.50 L/ha	$4.64	2	$13.91
No till seeder	1	$13.66	1	$13.66
Oats seed	40 kg/ha	$1.00	1	$40.00
Linkage spray rig	1	$3.66	1	$3.66
MCPA LVE	1 L/ha	$10.75	1	$10.75
			Total	**$151.70**

11.10 References

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