Department of **Employment, Economic Development and Innovation**

Using high quality forages to meet beef markets

in the Fitzroy River catchment

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1 Introduction

Beef production is the major land use in the Fitzroy River catchment, occurring on around 13 million hectares or approximately 89% of the catchment. Livestock slaughterings account for 73% of the total value of agricultural production (ACLUMP 2008; OESR 2000). Three of the four major land types in the region – Brigalow, Alluvial and Downs – have soils capable of growing high quality forages suitable for backgrounding and finishing cattle. Forages capable of producing the higher growth rates required for backgrounding and finishing include summer and winter annual forage crops and perennial legume–grass pasture systems such as butterfly pea–grass and leucaena–grass pastures.

Targeted use of high quality forages has potential to improve the profitability of beef enterprises in the Fitzroy River catchment of Queensland. This occurs through increased enterprise turnover and productivity and providing a viable alternative to grain finishing for the production of quality beef. However, in order to achieve a profitable outcome, best practice forage agronomy and management must go together with knowledge of expected cattle performance, expertise in cattle husbandry, feed planning and marketing and an understanding of the financial implications for the business.

This guide brings together information on:

- the selection, agronomy and management of suitable forages
- indicative forage yields at key sites across the Fitzroy River catchment
- expected content of principal nutrients in the forages and their relationship to cattle performance
- indicative cattle growth rates from a range of high-output forages
- approaches to incorporating high-output forages into feed plans to produce the target growth rates and liveweights required to meet market specifications
- non-nutritional factors that can affect liveweight gain
- example economic analyses at key sites across the catchment to provide objective comparisons of various forage options
- spreadsheets to allow calculation of the economic performance of key forage systems using the user's own input variables.

References

ACLUMP (Australian Catchment Land Use Mapping Program) 2008, Land use summary. Fitzroy NRM Region – Qld. 21 November, 2008. Commonwealth of Australia, Bureau of Rural Sciences and Australian Bureau of Statistics, Canberra.

OESR (Office of Economic and Statistical Research) 2009, Queensland Regional Profiles. Fitzroy Statistical Division. Profile generated on 14 January 2010. The State of Queensland, Queensland Treasury, Brisbane.

David Sasse

Butterfly pea

2 Why use high quality forages?

Beef production from both native and sown grass pastures is subject to highly seasonal and variable rainfall. This means that the feed available to cattle can vary widely in quality and quantity, both through the year and between years, making it difficult for beef producers to consistently meet carcass weight and fat specifications. In addition, market specifications for high-value beef continue to tighten and trend towards a preference for younger cattle. For these reasons, production systems that enable cattle to be finished more quickly are important to increase a beef producer's ability to meet market specifications for high-value beef and to increase turnover of cattle. Both of these aspects contribute to increased profitability of beef businesses.

In the Fitzroy River catchment of Queensland, opportunities exist to finish cattle in a feedlot or in a 'grain-assist' situation with access to pasture. These options are widely used and offer rapid weight gain and potential marketing advantages. However both systems involve high input costs and may not be economically viable, particularly in years when feed grain prices are high and/or the premium for finished cattle is low.

The use of summer and winter annual forage crops, as well as perennial legume–grass pasture systems, has the potential to significantly increase cattle growth rates and provide an alternative to grain feeding.

Benefits

Annual forage crops and perennial legume–grass pastures, such as butterfly pea–grass and leucaena–grass systems, have the following advantages over native and sown grass-only pastures. They can:

- provide higher quality feed (i.e. more digestible and higher protein content)
- allow higher stocking rates due to higher forage yields
- provide grazing, or fill a feed gap, when the quality of grass-only pastures is low, for example in autumn, winter or spring.

Legume–grass pasture systems have additional advantages through their ability to:

- contribute to soil nitrogen levels and halt declining soil fertility in grass pasture systems
- reduce nitrogen fertiliser requirements in subsequent crop rotations when used as short- or long-term leys (burgundy bean and butterfly pea are particularly suited for this purpose)
- enable higher productivity and longer persistence of grasses that have high nitrogen requirements, such as green or Gatton panic, Rhodes and buffel grass.

Other benefits of using high quality annual and perennial forage systems include:

- having more options and flexibility in choosing target markets and timing of turn-off
- reducing grazing pressure on the remainder of the property, allowing pastures to be spelled
- providing high quality feed for special classes of cattle such as cull cows and weaners or to allow earlier mating of replacement heifers
- conserving excess forage as hay or silage in good years.

Constraints

Constraints to using high quality forage systems also need to be considered, and include:

- availability of suitable arable land
- the need to purchase, or arrange access to, equipment such as tractors, ploughs, sprayers and planters
- expertise in land preparation, planting and weed control
- costs of crop or pasture establishment failures
- variable seasonal conditions
- difficulties in integrating more intensive forage systems into the business and existing property operations
- uncertainty about the short- and long-term profitability of the activity.

3 The land resource

Land types

The fertility and water holding capacity of soils determines the suitability of the land for forage cropping or planting to high quality legume–grass pastures. Most properties have a number of land types. Broadly speaking, the dominant vegetation and soil type identifies the land type. The major land types suitable for high quality pasture and forage crop production in the Fitzroy River catchment are shown in figure 1. Table 1 summarises the broad suitability and limitations of the major land types for pasture and forage crop production.

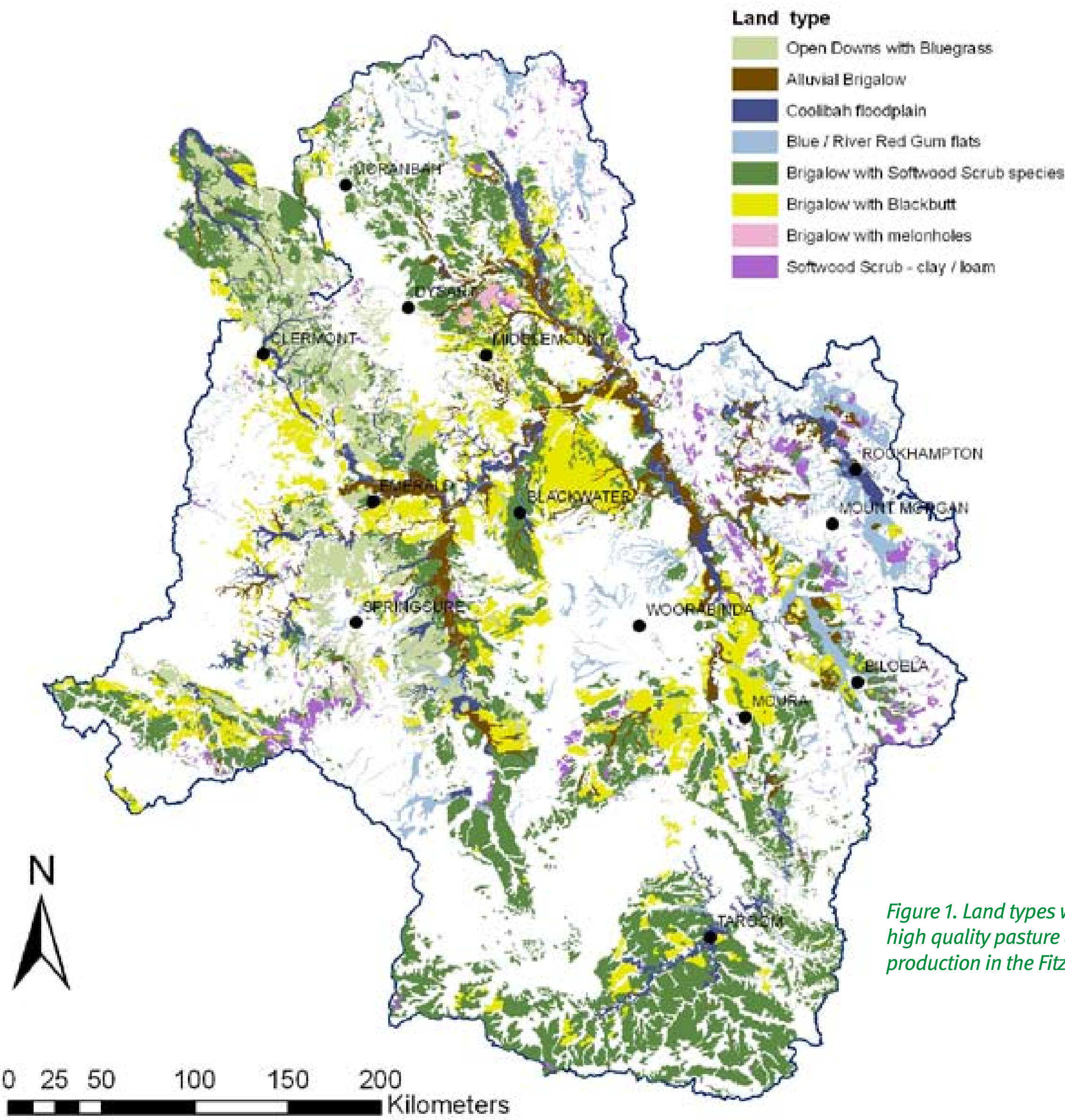

Figure 1. Land types with suitability for high quality pasture and forage crop production in the Fitzroy River catchment

Table 1. Description of major land types in the Fitzroy River catchment with suitability for high quality sown pasture and forage crop production

Land type	Land use and management recommendations	Land use limitations	Suitable sown forages
Brigalow with softwood scrub species *Soil – dark brown and grey-brown cracking clay (vertosol or dermosol)* • **soil fertility**: moderate total N, moderate P • **water availability**: moderate to high	• suitable for sown pastures • suitable for cropping on soils deeper than 60 cm and on slopes less than 4%	• tree regrowth • salinity can affect rooting depth • moderate erosion hazard when cultivated	***Grasses*** Buffel grass, Gatton, green and bambatsi panic, creeping bluegrass, purple pigeon grass, angelton bluegrass (floren) ***Perennial legumes*** Leucaena, butterfly pea, burgundy bean, siratro, caatinga stylo, desmanthus ***Annual forage crops*** Forage sorghum, lablab, oats
Alluvial brigalow *Soil – strongly self-mulching black (occasionally grey) cracking clay (black or grey vertosol and dermosol)* • **soil fertility**: moderate to high total N, moderate P • **water availability**: high	• pasture establishment difficult due to coarse self-mulching surface • maintain good ground cover to discourage weed invasion • monitor for overgrazing when mixed with other, less fertile, land types	• moderate to poor drainage • occasional flooding • salinity • weed invasion • tree regrowth	***Grasses*** Bambatsi panic, angelton bluegrass (floren), purple pigeon grass, buffel grass, Rhodes grass, creeping bluegrass ***Perennial legumes*** Caatinga stylo, leucaena, butterfly pea, desmanthus ***Annual forage crops*** Forage sorghum, lablab, oats
Brigalow with melonholes *Soil – gilgaied, brown or grey cracking clay (brown or grey vertosol)* • **soil fertility**: low to moderate total N, low to moderate P • **water availability**: low to moderate	• depending on melonhole severity, may not be suited to cultivation	• melonholes • tree regrowth	***Grasses*** Bambatsi panic, angleton bluegrass (floren), purple pigeon grass, buffel grass, Rhodes grass ***Perennial legumes*** Butterfly pea, caatinga stylo, desmanthus, leucaena (in paddocks with minor melonholes) ***Annual forage crops*** Forage sorghum, lablab, oats; in paddocks with minor melonholes
Brigalow with blackbutt (Dawson gum) *Soil – hard-setting, red to brown, texture-contrast with sodic B horizon (brown sodosol)* • **soil fertility**: low to moderate total N, moderate P • **water availability**: low to moderate	• suitable for sown pastures as the light surface texture responds to small rainfall events • maintain surface cover to reduce sheet erosion, nutrient loss and pasture rundown	• sodic subsoil • poorly drained • hardsetting surface • tree regrowth	***Grasses*** Buffel grass, Gatton and green panic, Rhodes grass, sabi grass, digit/finger grasses ***Perennial legumes*** Shrubby stylo (seca) or Caribbean stylo (verano or amiga) in high rainfall areas ***Annual forage crops*** Forage sorghum, lablab, oats; dependant on seasonal conditions
Softwood scrub *Soil – brown clay (vertosol, chromosol) or deep red clay (ferrosol)* • **soil fertility**: moderate total N, moderate P • **water availability**: moderate (red clays) to high (brown clays)	• suitable for sown pastures	• tree regrowth • surface sealing soils after continual cultivation	***Grasses*** Buffel grass, Gatton and green panic, angleton bluegrass (floren), sabi grass, creeping bluegrass, Rhodes grass (various cultivars) ***Perennial legumes*** Butterfly pea, leucaena, caatinga stylo, burgundy bean, siratro ***Annual forage crops*** Forage sorghum, lablab, oats
Blue gum/ river red gum flats *Soil – deep, black cracking clay (vertosol) or deep alluvial loam soil (dermosol)* • **soil fertility**: moderate to high total N, moderate to high P • **water availability**: moderate to high	• suitable for sown pastures • only plant Caribbean and shrubby stylos on areas where the soil surface is sandy • disturbance encourages germination of woody plants • monitor for overgrazing when mixed with other, less fertile, land types	• flooding and waterlogging on clay soils • restricted access in wet conditions • weed invasion where regular flooding occurs • erosive flooding in some areas • pasture establishment problems on cracking clays and some alluvial loams	***Grasses*** Gatton, green and bambatsi panic, buffel grass, creeping bluegrass, Rhodes grass, angleton bluegrass (floren; on clay soils) ***Perennial legumes*** Caatinga stylo, butterfly pea, burgundy bean, siratro, leucaena (on deeper, well drained areas) ***Annual forage crops*** Forage sorghum, lablab, oats; on deeper, more fertile soils

Land type	Land use and management recommendations	Land use limitations	Suitable sown forages
Coolibah floodplains *Soil – black cracking clay (vertosol)* • **soil fertility**: moderate total N, moderate P • **water availability**: moderate to high	• suitable for sown pastures although establishment can be difficult • suitable for cropping in areas not subject to severe flooding • soil disturbance encourages germination of woody species • monitor for overgrazing when mixed with other, less fertile, land types	• flooding and waterlogging • salinity and surface cracking • restricted access in wet conditions • weed invasion in frequently flooded areas • erosive flooding in some areas • establishment problems with improved pastures due to crusting/ cracking or coarse/ self-mulching surface	***Grasses*** Bambatsi panic, angleton bluegrass (floren), purple pigeon grass, Rhodes grass, creeping bluegrass ***Perennial legumes*** Caatinga stylo, desmanthus, butterfly pea, leucaena ***Annual forage crops*** Forage sorghum, lablab, oats
Open downs *Soil – black or brown cracking clay (black or brown vertosol)* • **soil fertility**: low to moderate total N, low to moderate P • **water availability**: moderate to high	• suitable for cropping on soils deeper than 60 cm and on slopes less than 4% • some potential for pasture improvement • to minimise saline seepages, do not clear teatree • maintain surface cover to minimise erosion	• soil erosion hazard when cultivated • rooting depth in some shallow soils • some rockiness • low fertility • establishment problems with some small-seeded plants and pastures • high water tables in teatree drainage lines	***Grasses*** Bambatsi panic, angleton bluegrass (floren), purple pigeon grass, Rhodes grass ***Perennial legumes*** Leucaena (on deeper soils >90 cm), butterfly pea, caatinga stylo ***Annual forage crops*** Forage sorghum, lablab, oats; on deeper soils

N: nitrogen, P: phosphorus.

Adapted from *Land types of Queensland CD version 1.2, 2008.*

Climate

The amount and distribution of rainfall is the primary determinant of pasture and forage growth. Temperature can also be a constraint for some crop and pasture species. The Fitzroy River catchment is characterised by a sub-tropical, semi-arid climate with high rainfall variability. Annual rainfall decreases with distance from the east coast. The ratio of summer to winter rainfall decreases from north to south in the catchment with an average ratio of 70:30. Mean maximum and mean minimum temperatures decrease from north to south with mean daily maxima over 33 °C in January. Frosts occur regularly throughout the region but become more frequent and severe towards the south. For example, Brigalow Research Station near Theodore averages 12.3 frosts (days with ground temperature </= –1 °C) annually whereas Taroom averages 18.2 frosts annually.

Examples of long-term mean and seasonal distribution of rainfall and temperature are shown for three sites across the Fitzroy River catchment, representing the South Queensland Brigalow region (Taroom–Wandoan area), the Central Queensland Brigalow region (Bauhinia–Theodore area) and the Central Queensland Open Downs region (Capella area) (tables 2–4). These three sites have been used as case study sites throughout this guide.

Table 2. Long-term[A] mean and seasonal distribution of rainfall and temperature at Taroom

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Rainfall (mm)	97.9	88.5	62.8	35.1	40.5	36.6	33.8	27.6	31.1	55.3	74.1	88.5	671.1
Maximum temp (°C)	33.7	32.8	31.7	28.8	24.5	21.5	21.0	23.0	26.7	29.9	31.8	33.5	28.2
Minimum temp (°C)	20.6	20.4	18.1	14.1	9.7	6.3	5.1	6.5	10.3	14.6	17.5	19.6	13.6
Mean number of days with minimum temperature ≤ 2 °C[B]	0	0	0	0	0.7	4.6	9.5	5.3	0.7	0	0	0	20.8

[A] Weather station site: Taroom Post Office. Rainfall records for period 1870–2010; temperature records for period 1952–2010.
[B] A guide for frost potential

Table 3. Long-term[A] mean and seasonal distribution of rainfall and temperature for Banana and the Brigalow Research Station

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Rainfall (mm)	95.2	96.3	68.1	34.2	35.9	38.0	30.5	22.0	28.8	53.7	68.1	92.2	663.8
Maximum temp (°C)	33.7	32.4	31.7	29.0	25.3	22.1	21.8	23.8	27.2	30.1	31.7	33.2	28.5
Minimum temp (°C)	21.0	20.7	18.7	15.1	11.5	8.0	6.4	7.5	10.9	14.8	17.7	19.8	14.3
Mean number of days with minimum temperature ≤ 2 °C[B]	0	0	0	0	0.1	2.3	5.4	2.5	0.1	0	0	0	10.4

[A] Weather station site for rainfall: Banana Post Office; Records for period 1871–2010. Weather station site for temperature: Brigalow Research Station; Records for period 1968–2010.
[B] A guide for frost potential

Table 4. Long-term[A] mean and seasonal distribution of rainfall and temperature for Capella and Clermont

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Rainfall (mm)	96.5	96.6	61.2	31.5	29.8	29.7	23.3	17.1	18.4	39.9	56.2	83.0	583.9
Maximum temp (°C)	34.3	33.0	32.0	29.5	26.1	23.1	23.1	25.3	28.8	32.0	34.0	34.9	29.7
Minimum temp (°C)	21.6	21.1	19.4	15.7	11.5	8.1	6.7	8.2	12.1	16.3	19.0	20.8	15.0
Mean number of days with minimum temperature ≤ 2 °C[B]	0	0	0	0	0.1	2.2	5	1.6	0	0	0	0	8.9

[A] Weather station site for rainfall: Capella Post Office; Records for period 1898–2010. Weather station site for temperature: Clermont Sirius St; Records for period 1910–2010.
[B] A guide for frost potential

References and further information

The State of Queensland, Department of Primary Industries and Fisheries (DPI&F) 2008 *Land types of Queensland*. CD-ROM Version 1.2. The State of Queensland, Department of Primary Industries and Fisheries, Brisbane.

Bureau of Meteorology website: www.bom.gov.au/

4 Planning for profitable beef production from forages

Cattle selection and target markets

Breeds and cattle selection

There can be large variation both between and within groups of cattle in their ability to gain weight. Selection of a uniform group of cattle with high growth rate potential is an important step in successful forage finishing.

Beef producers should assess the suitability of the cattle breed for the target market or finishing weight. Early-maturing British breeds (e.g. Angus) and *Bos indicus* x British breed crossbreds finish at lighter weights than European breeds (e.g. Limousin or Charolais) when grazing the same forage. Early-maturing *Bos indicus* crossbreds reach premium market fatness at a similar weight to British breeds. Early-maturing breeds can be in danger of becoming too fat for heavier export carcass specifications if they have been grown on high quality feed from weaning. However, late-maturing breeds such as the large European breeds need to grow to a high liveweight before they lay down enough fat for premium markets.

Beef CRC research has shown that cattle that experience a severe growth restriction in early life will have a reduced potential for growth during backgrounding and finishing. The earlier in life that the severe restriction occurs, the greater the effect. This is an important consideration when buying in weaners to grow out as part of a backgrounding or finishing operation.

Markets

To achieve price premiums, cattle must meet the requirements of the target market. The major criteria for describing carcasses are generally carcass weight, fat thickness at the P8 rump site and age measured by dentition or the more accurate ossification (skeletal maturity) method. Other criteria include sex, bruising, butt shape and fat and meat colour. Specifications for the various beef markets vary both over time and between processors and retail outlets. As specifications are not static, it is important to regularly check grid specifications with potential buyers and meat processors. Table 5 summarises the general specifications for major grass-finished cattle markets in Queensland.

Assessing the likely cattle growth pathways in conjunction with market options can help identify profitable market targets. Figure 2 shows the major beef slaughter markets and typical growth pathways to meet these markets.

More accurate techniques for assessing the saleable meat content of carcasses (retail beef yield) and the eating quality of individual cuts (using MSA grading) are now available and some processors are beginning to introduce payments based on these traits. Beef CRC research has highlighted the main factors influencing these two traits that may receive greater emphasis and financial incentives in the future.

Factors resulting in higher retail beef yield:

- more muscular cattle
- cattle with European breed content
- preventing cattle becoming overfat.

Factors that increase eating quality:

- high overall growth rates and thus younger age at slaughter
- using genetic selection within breeds to increase marbling scores
- implementing management schemes to ensure that animals grade under the MSA grading scheme.

Table 5. General beef market or grading specifications for grassfed product

Market or grading system	Store specifications	Live specifications – finished	Carcass specifications –finished
JAP OX – Grassfed	No special requirements	Liveweight: 540–810 kg Fat score: 4 Age: 42 months maximum Muscle score: A–C	HSCW: 280–420 kg Fat depth: 7–22 mm Dentition: 0–8 Butt shape: A–C Fat colour: 0–4 Meat colour: 1A–4
KOREA – Grassfed	No special requirements	Liveweight: 480–620 kg Fat score: 3–4 Age: 36 months maximum Muscle score: A–C	HSCW: 250–320 kg Fat depth: 12–22 mm Dentition: 0–6 Butt shape: A–C Fat colour: 0–9 Meat colour: 1A–6
EUROPEAN UNION	HGP-free	Liveweight: 460–810 kg Fat score: 2+ – 4- Age: 30 months maximum Muscle score: A–C	HSCW: 240–420 kg Fat depth: 7–22 mm Dentition: 0–2 Butt shape: A–C Fat colour: 0–4 Meat colour: 1B–4
DOMESTIC	No special requirements	Liveweight: 350–620 kg Fat score: 2–3 Age: 18 months Muscle score: A–C	HSCW: 180–320 kg Fat depth: 5–22 mm Dentition: 0–2 Butt shape: A–C Fat colour: 0–3 Meat colour: 1B–2
MSA GRADING	Cattle should meet specified handling, nutritional and growth requirements	Liveweight: 350–650 kg Fat score: 2–3 Age: 30 months maximum Muscle score: A–C	HSCW: 180–340 kg Fat depth: 5–22 mm Dentition: 0–4 Butt shape: A–C Fat colour: 0–3 Meat colour: 1B–3 pH: 5.3–5.7

Definitions:

- Butt shape: A (very heavy muscling) to E (light muscling); 5 point scale.
- Dentition: number of permanent incisors.
- Fat colour: visually assessed colour of the intermuscular fat lateral to the rib eye muscle; 0 (white) to 9 (yellow); 10 point scale.
- Fat depth: mm of fat on hot standard carcass at the P8 rump site.
- Fat score, assessed at the P8 rump site: 1 (0–2 mm) to 6 (>32 mm); 6 point scale.
- HGP: hormonal growth promotant.
- HSCW: hot standard carcass weight.
- Liveweight range was calculated from HSCW by assuming a dressing percentage of 52%.
- Meat colour: visually assessed colour of the bloomed loin muscle at the carcass quartering point using AusMeat language; 1A (light) to 7 (dark); 9 point scale.
- Muscle score: A (very heavy) to E (very light); 5 point scale.

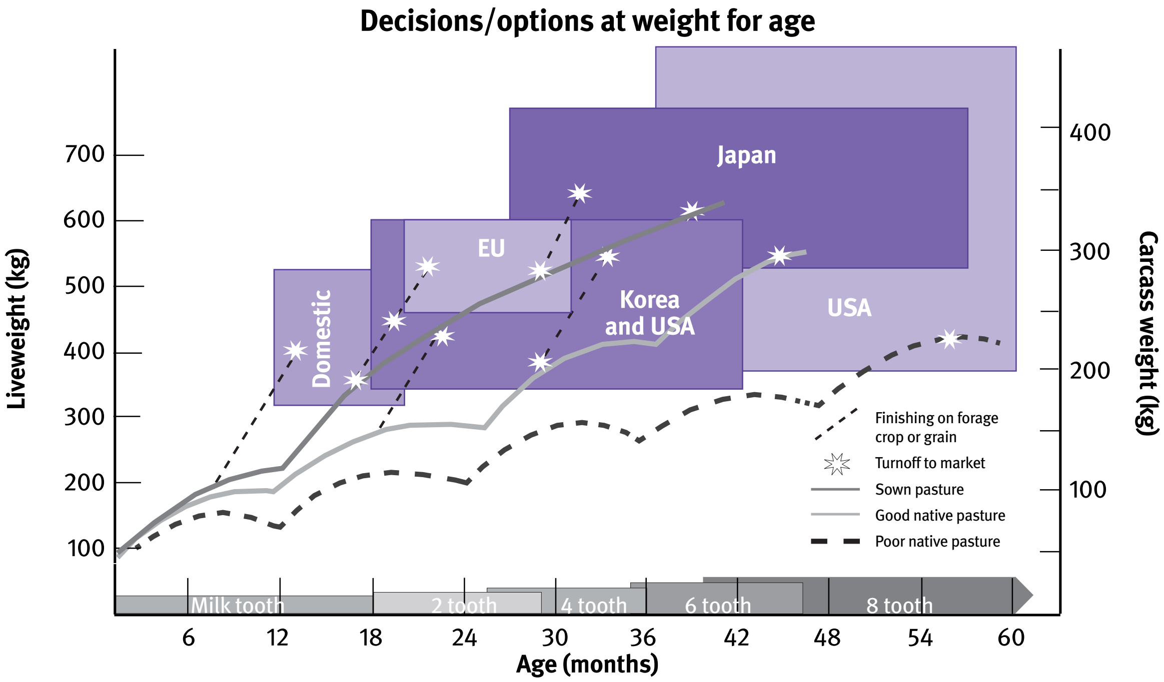

Figure 2. Major beef slaughter markets and typical growth pathways to meet these markets. *From Tyler (2004)*

Female cattle

Crop or high quality forage finishing can be beneficial for heifers and cull cows as well as steers. The potential increase in profit from selling prime females can be greater than for steers due to the greater potential improvement in their market suitability. In addition, females can be slaughtered at lighter weights than males because they reach the desired fat levels earlier and this can increase the turnover of cattle. However, producers should be aware that heifers may not grow as quickly as steers. It is important to assess the profitability of the venture for individual situations. The economic spreadsheet calculator provided with this guide can be used for this purpose.

Backgrounding

High quality forages are often used for backgrounding cattle prior to feedlot entry. As for finishing operations, backgrounding can be risky, so it is important to calculate the gross margin to check that the outcome is likely to be positive. Sensitivity analyses between sale and purchase price and between liveweight gain and cattle price can help assess the riskiness of the venture. The economic spreadsheet calculator provided with this guide can be used for this purpose.

Planning forage needs

In practice, it can be challenging to combine feed sources varying in yield, quality and grazing period to achieve the desired market weight. Developing a lifetime feed plan for cattle destined for premium markets can be beneficial. This will identify whether the target market weights are achievable with the current feed base available on the property. The first step is to identify the existing feed supply and the demand. Once gaps in the feed supply are identified (either quality or quantity of feed) the next step is to consider the forage options suitable for the land types available and how these could be combined to achieve the growth rates required throughout the year. Tools such as the MLA Feed Demand Calculator, which is free to download from the web, can help calculate and compare the pattern of feed supply and demand on a whole farm basis for a 12-month period. Figure 3 provides a general guide to the time of year that higher quality green feed is available from key forage options in central Queensland, although the exact grazing periods will vary from year to year, according to the amount and timing of rainfall and the grazing pressure applied as well as with location within the region (e.g. Taroom vs Capella). Click here to go straight to indicative figures for likely grazing days, daily liveweight gain, stocking rate and beef production in kg/head and kg/ha from these key forage types.

Preventing waste

Less than complete or optimal usage of the feed from annual forage crops potentially reduces the profit margins of the forage cropping enterprise. This is especially a problem with forage sorghums which, if underutilised, can rapidly become fibrous and less digestible, thus reducing cattle performance. Tactics that may help to minimise wastage include:

- close part of the paddock for hay production
- close a section of the paddock for heavier grazing with other available stock to maintain quality
- use staggered grazing of the same paddock with cattle requiring the highest quality feed receiving the first grazing. For example, animals closest to finishing (the 'tops' of the mob) graze first, the less finished animals (the 'bottoms' of the mob) graze second and if appropriate cows and calves could graze last
- stagger the plantings of summer forages
- plant several varieties with different rates of growth.

Grazing stubbles and failed grain crops

Animal performance on failed grain crops or stubble is extremely variable and largely dependent on the amount of grain on the crop. Additional feed value can come from grazing broad-leaved weeds amongst the crop and in the headlands. Failed grain crops and

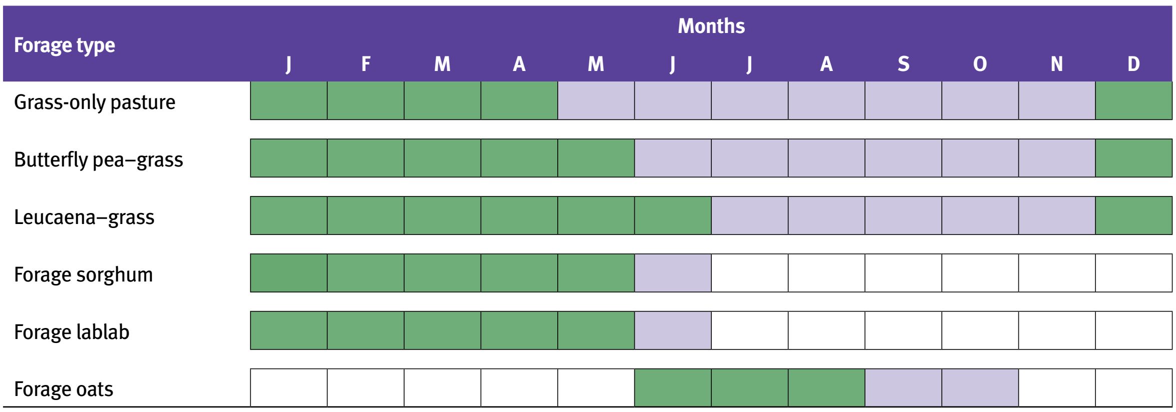

Figure 3. Feed year calendar of forage options in central Queensland. Green indicates the period of higher quality green feed; purple indicates the period of lesser grazing value in terms of quality, within a forage type. Clear boxes indicate periods of nil grazing value.

stubble can provide valuable forage, particularly at a time when other feed is scarce. Animal performance can range from gaining weight to losing weight.

Ley pastures

Ley or short-term pasture phases are used in crop rotations to increase soil organic matter and reduce nitrogen fertiliser requirements in subsequent crop phases. Ley pastures are generally a legume–grass pasture mix grown for two to four years. Ley pastures can provide high quality feed suitable for finishing beef cattle but need to establish and grow quickly. To maximise their feed value as well as the amount of organic matter and nitrogen returned to the soil they must produce high forage yields. Some of the most common legume options used in leys are butterfly pea and burgundy bean in central Queensland and burgundy bean in southern Queensland.

Reducing the proportion of 'non-finishers'

There is variability within every mob of cattle for the time required to reach market specifications. Under some circumstances a proportion of the mob may not reach the target fat cover or carcass weight and have to be either sold unfinished or carried over onto grass pastures. If this happens, it may take an additional year before there is another opportunity to finish them. Non-finishers reduce the profitability of planting and utilising high quality forages. The following are some strategies that may help to reduce the proportion of non-finishers.

Forward condition

It is important to make sure cattle go on to the forage source at an adequate weight and condition to allow them to finish. This is particularly important when utilising annual forage crops that have a shorter grazing period, and less room for error, compared with perennial, legume–grass pasture systems such as leucaena–grass or butterfly pea–grass.

David Sasse

Stocking rate

Stocking rates need to be a compromise between the most effective use of the crop and the required liveweight gain. If the stocking rate is too high, animals can be forced to eat low quality stem and mature leaf material, reducing liveweight gain per head and the length of time the forage source can be grazed. Under these conditions, a higher proportion of the mob may not finish. On the other hand, stocking rates need to be high enough to keep forage crops in a vegetative state and also to optimise liveweight gain per hectare and thus gross margins per hectare.

Supplementation with grain or other energy sources

Providing grain supplements, or other energy supplements such as fortified molasses, to cattle grazing high quality forages is a strategy to improve carcass weights and reduce carryover of stock. Energy supplements also have the effect of decreasing forage intake per beast due to substitution of some supplement for forage in the diet. This decreases the grazing pressure on the forage, allowing either more stock to graze the same area or the grazing period to be extended. The profitability of feeding grain or other supplements should be assessed for the specific market prices of grain and cattle at the time of feeding.

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Useful websites

Beef Cooperative Research Centre: www.beefcrc.com.au

Meat Standards Australia: www.mla.com.au/Marketing-red-meat/Guaranteeing-eating-quality/Meat-Standards-Australia

MLA Feed Demand Calculator: www.mla.com.au/Publications-tools-and-events/Tools-and-calculators/Feed-demand-calculator

5 Getting the agronomy right and growing the feed

Property resources

Paddock selection

Paddock selection, particularly with regard to soil type, has important implications for profitable forage production. Forages will be most productive when grown on better soils—with high water holding capacity and fertility. Suitable soils include those that:

- produce profitable grain crops
- store moisture to a depth of at least 90 cm—loams, clay-loams and clays are all potentially suitable
- supply adequate amounts of nitrogen, phosphorus, potassium and trace elements.

Avoid crusting or hard-setting soils because plant establishment is difficult and continual disturbance quickly degrades soil structure. A legume–grass ley would benefit these soil types.

Soil type variability within potential paddocks is another important consideration, as significant variation in fertility and water holding capacity will make agronomic decisions more difficult and result in variable production across the paddock. Assess potential paddocks for changes in soil type and only develop areas suitable for forage production.

Elevation within the landscape can also have implications for forage production. Floodplains and creek flats or alluvial areas frequently possess better quality soils with higher fertility and water holding capacity compared to uplands and higher ridges. These factors mean greater production potential during the growing season. However, the growing season in these low-lying areas is shorter due to cooler temperatures in spring and autumn and frosts in winter. All summer forages suited to the Fitzroy River catchment of Queensland are adapted to tropical conditions, i.e. hot wet summers and mild winters. In southern Queensland the timing of the first frost (May–June) usually signals the end of the growing season for summer forages. In central Queensland growth of summer forages also generally slows or stops before the first frost (June–July) due to the decrease in mean daily temperatures and low soil moisture at this time of year.

Infrastructure

Another important consideration is the availability of suitable infrastructure for cattle management. Unless forages are to be cut and baled or ensiled, the paddock needs suitable fences, water sources and access to yard facilities for adequate cattle management. If these are not present, it will be necessary to either select another paddock or to install what is required. It is worth thinking about the longevity of fences and other infrastructure that is installed, e.g. electric fences can be used for short-term purposes and movable water troughs allow flexibility of use in multiple paddocks. The ability to muster cattle and easy access to yards is important, particularly to make the most of marketing opportunities as they arise. This might mean using strategies such as installing lane-ways, watering stock outside the paddock and spear-trap gates onto water. For the timely marketing of stock during wet periods livestock carriers require all-weather access to the yards.

Rotational grazing of the forages is ideal to maximise their performance but this also requires additional paddock infrastructure. For example, leucaena–grass pastures are most productive under a high stocking rate, rotational system using a number of smaller paddocks. In addition, for ease of mustering, leucaena rows should align with the direction of cattle movement; alternatively spear-traps onto the water source can be used.

Machinery

The available equipment—either owned or locally for hire—will dictate whether, and how, forages are grown. High quality forages can be successfully grown in either conventionally cultivated or zero till (no cultivation) situations. The type of planter available will have a significant bearing on what tillage system can be used. For example, if a narrow tyne combine planter is the only sowing equipment available, this will limit land preparation to fully cultivated seedbeds with chisel ploughs, scarifiers or offset discs. If zero till is to be practiced for soil conservation purposes, a planter with wide tyne spacing and high breakout pressures, i.e. zero till technology, is required. Using spray-rigs for weed control requires knowledge of application techniques including drift management, product and rate selection and knowing of when to spray weeds (timeliness).

Dealing with soil compaction is another major consideration. In conventionally cultivated situations, deep tillage if often required (particularly on non-cracking soils) to remediate compacted soil layers resulting from either animal traffic during wet periods or machinery used in cutting, baling and ensiling operations. However, deep tillage delays the accumulation of soil water necessary for successful subsequent crops. Although zero tillage systems can potentially accumulate soil moisture more quickly than under conventional cultivation, limiting compaction damage in zero tillage systems is more difficult and often a return to a cultivated fallow is required where compaction is severe.

Basic principles

Preparation and timeliness

The key to successful forage production lies in preparation and timeliness. Plan the forage program well in advance of sowing. Before sowing it is important to plan for and, where practical, address issues such as ensuring the soil surface condition will support strong establishment and responding to weed pressure and nutrient deficiencies. Planning for in-crop weed control is also very important, as inadequate control is often a major contributor to poor forage production. Weeds easily compete with a young, establishing forage crop (especially legumes) if not controlled adequately before sowing or if rain falls soon after planting. This means determining which in-crop herbicide can be used for the potential weed spectrum before sowing. It is also critical that appropriate herbicide rates are used according to the weed species, size and label directions. Producers should seek professional advice in this area to maximise the benefits from herbicide application. Sowing forage mixtures such as forage sorghum and lablab together will significantly limit herbicide options for weed control, so the best strategy is to control the weeds in the previous crops, manage weeds during the fallow period prior to planting and establish a dense, competitive forage crop.

Butterfly pea seedlings

Sample the soil prior to planting to assess the nutrient status and determine the fertiliser application required at planting. This is particularly important for annual forages such as oats, forage sorghum and lablab due to the short growth period and high biomass production. The process of soil sampling, testing, interpretation and product selection can take several weeks to complete so it is critical that sampling is conducted well before planting. Local agronomists or growers with the right equipment (hand auger or corer, soil tubes, cutting tray) can undertake sampling. It is important to ensure representative soil samples, from the top (0–10 cm), middle (10–60 cm) and subsoil (60–90 cm) strata, are collected in each paddock. If different soils types are present, collect separate samples from each area. For cereal forages (e.g. forage oats, wheat and sorghum) the main nutrients to assess, in order of importance, are nitrogen, phosphorus, sulphur, potassium and the trace elements zinc and calcium. The main nutrients of importance for forage legumes are phosphorus, sulphur, zinc, potassium and calcium. Once samples are collected, send them immediately to a nutrient analysis laboratory. A trained agronomist can interpret the results.

Except in irrigated situations, fertiliser is rarely applied in-crop due to the difficulty of application (forages are often tall) and unreliability of gaining a response. Determining nutrient requirements and applying adequate fertilise prior to, or at, planting is easier than after the crop is growing.

Establishment and the risks associated

The old saying ‘you reap what you sow’ is very pertinent to forage production. The planting and establishment phases are the most critical to the success of forage production—get this wrong and production will only be a fraction of the plant’s potential and weed and grazing management will be very difficult. Patchy establishment encourages weeds to take over and the forage will be uneven in height or maturity making it difficult to ascertain the optimal timing of grazing or cutting.

Rainfall in the Fitzroy River catchment of Queensland, while summer dominant, is highly variable. Also, temperatures above 35 °C can occur for days and potentially weeks on end, depleting valuable soil water during long fallow periods, or away from young, establishing forages. To minimise the risk of establishment failures in dryland situations, only sow when there is greater than 75 cm of wet soil and a reasonable chance of follow-up rainfall. Sowing summer forages should ideally occur between December and late February, depending on the forage and intended use. Sow winter forages such as oats, forage wheat or barley no earlier than April in central Queensland and March in southern Queensland, and on 90 cm of soil moisture due to the lower probability of receiving in-crop rainfall.

Monitoring and managing to get the most out of the crop

The key message is: 'do not plant the crop and expect to walk away until cattle are introduced'. There are a number of factors that need to be monitored to get the most out of what has been sown. During the establishment phase growers should:

- inspect the paddock and undertake required weed control measures
- monitor soil insect pests such as false wireworms, cutworms and armyworms that can have devastating impacts on plant populations and subsequent production
- monitor in-crop soil nutrient supply. However, in-crop fertiliser applications can be difficult, and responses are unreliable, so it is preferable to assess and apply nutrients prior to or at planting. Spreading fertiliser ahead of watering is one way to correct pronounced nitrogen deficiencies in irrigated situations. However, this technique is very risky in dryland situations
- monitor the growth of the crop so that cattle can be introduced at the right stage to maximise both forage production and animal performance. Refer to the next section for specific grazing management recommendations for each forage type.

Selecting the most appropriate forage species and systems

There are a number of high quality forages suitable for the Fitzroy River catchment of Queensland. The main forages include:

- perennial, legume–grass pastures: butterfly pea–grass and leucaena–grass
- summer forages: forage sorghum and lablab
- winter forages: oats.

DEEDI Principal Technical Officer, Maurie Conway examines a butterfly pea pasture

Perennial, legume–grass pastures: Butterfly pea (*Clitoria ternatea*) + grass species

Butterfly pea is a tropical, perennial forage legume suited to short-term ley pastures (3–5 years) or medium-term permanent pastures. It performs best in climates with wet, hot summers and mild winters. Butterfly pea is frosted back in winter but regrows in the following summer. The growing season is from spring to late autumn (soil moisture dependant) and provides high quality forage material enabling high animal performance (0.8–1.2 kg/head/day) during the peak growing season.

Benefits

- Perennial legume that persists for many years on a range of soil types although it is particularly suited to clay soils due to their higher water holding capacity
- Easily established due to its large seed and can be sown with conventional crop sowing equipment up to 5 cm deep
- Produces good amounts of highly palatable forage with crude protein concentrations typically between 12–25% in leaves and fine stems
- No bloat concerns
- Can be removed to recommence a cropping program using either cultivation or herbicides and so is highly suited to a ley pasture system
- Prolific producer of high-dormancy seed enabling seedling recruitment over a number of years. This may cause problems in following crops
- Very few insects (soil or plant) attack butterfly pea
- Tolerates periodic heavy grazing and dry periods

Constraints

- Low production on soils with low fertility and/or water holding capacity
- Seed needs to be scarified for adequate germination and even establishment when planted into a prepared seedbed

- Seedlings are slow to establish and so compete poorly with other plants like grasses and broadleaf weeds. Timing of weed control is critical
- Frost or low temperature (< 15 °C mean daily temperature) restricts the growing season and, compared to grasses, butterfly pea can be slow to regrow after winter, particularly if soil moisture is marginal
- Rotational grazing management with rest periods is required for long-term persistence.

Establishment

- Planting situations—sow butterfly pea into either fallow or existing grass situations where a perennial legume is required to restore soil fertility and improve the diet quality available to cattle.
- Sowing methods—sow butterfly pea with either conventional sowing equipment (e.g. combine, air seeder) or into standing stubble with zero tillage planting equipment.
- Sowing time, rate and depth—the best sowing time is during summer when the chance of follow-up rainfall is highest and there is enough time to produce a woody structure (stems etc) before the first frost. This means that December to March is the most suitable sowing window, provided there is 75 cm of soil moisture. However, butterfly pea can be sown earlier into fully wet soil profiles. An adequate plant population will require 7–10 kg/ha of seed to be sown, although rates of 12–15 kg/ha can provide greater weed suppression and maximum forage production in the shortest period of time. Best establishment will occur when seed is planted no deeper than 5 cm into moist soil.
- Seed treatments—for effective nodulation and nitrogen fixation, butterfly pea seed needs to be inoculated with Group 'M' inoculant at planting time.

Nutrition

- Nutrient requirements—like most legumes, butterfly pea requires adequate amounts of phosphorus, sulphur, zinc and other trace elements for effective nitrogen fixation and biomass production.

Example of a typical black cracking clay soil in the Fitzroy River catchment

David Sasse

- Application rates and timing—if a soil test indicates phosphorus levels are below 10 mg/kg, around 40 kg/ha of 'starter' type fertiliser (commonly including phosphorus and zinc) at planting will be required to maximise production.

Pests

- Weed control—butterfly pea seedlings are susceptible to competition so early weed control is very important. In paddocks where high weed numbers occur apply a residual herbicide prior to planting (or post emergent), to control broadleaf and grass weeds for 3–6 months. Also, sowing on narrow rows (25–40 cm) at a high seeding rate can maximise competitiveness of butterfly pea.
- Insects—no control warranted.
- Diseases—no known diseases.

Growth pattern and timing of seasonal production

Growth will start in late September or early October and continue into late autumn, dependant on soil moisture and temperature. Therefore high quality feed will be produced at any time from October up to the first frost.

Managing grazing to maximise plant productivity

Young butterfly pea seedlings will die if subjected to constant heavy grazing. Ideally, allow a new stand to set seed in the first year after sowing. This practice ensures sufficient seed for future regeneration and that a woody frame is produced, providing improved grazing tolerance. Grazing can occur once sufficient biomass is produced and growth will continue while sufficient moisture is present and average daily temperatures are greater than 15 °C. Diet quality will remain high even after the plant flowers as leaves are produced throughout the flowering and pod-filling stages. Sowing a mixture of grasses with butterfly pea will provide a productive, long-term pasture. Grasses utilise the nitrogen that butterfly pea produces, causing the butterfly pea to produce more nitrogen. The grass component of the pasture extends feed availability and provides both additional forage dry matter and ground cover between the legume plants, reducing weeds in the pasture.

Forage yield

Click here to go to indicative figures for forage yield for this forage type.

Cattle weight gain

Click here to go indicative figures for cattle weight gain on this forage type.

Economics

Example economic analyses are provided in chapter 7 for butterfly pea–grass pastures sown in three different locations across the Fitzroy River catchment. Sample spreadsheets are also provided so that different input figures can be used to examine alternative scenarios.

Perennial, legume–grass pastures: Leucaena (*Leucaena leucocephala* ssp. *glabrata*) + grass species

Leucaena is a tropical tree legume that produces large quantities of quality forage. It is most productive during the warmer and wetter (summer) months, enabling high animal performance (> 1 kg/head/day) for 6–9 months.

Benefits

- Highly productive, perennial legume
- Can persist on a range of soil types for more than 30 years
- Produces highly palatable forage that is high in protein (around 22% crude protein in leaves and fine stems)
- When grown with a productive grass, high stocking rates (1 AE/1:5 ha) and weight gains greater than 250 kg/AE/year are possible
- No bloat concerns
- Improves soil fertility through nitrogen fixation
- Deep root system allows the plant to continue growing into dry periods and minimises deep drainage

Constraints

- Low production in low fertility soils due to a high phosphorus requirement
- Needs to be grazed effectively to maximise production and to minimise seed set and the potential for rogue plants outside the planted area
- The growing season stops when average daily temperature falls below 15 °C
- Psyllids (small, sap-sucking insects) can reduce production, particularly in coastal areas or during periods of mild (< 30 °C), humid weather
- Requires significant management effort to achieve adequate establishment
- Cattle need to be drenched with the leucaena rumen fluid inoculum to prevent mimosine and DHP toxicity. If not effectively protected cattle will suffer reduced weight gains

Establishment

- Planting situations—leucaena is suited to situations where a permanent legume is required to improve animal performance.
- Sowing methods—leucaena can be sown into either existing cultivation or grass paddocks. If leucaena is sown into an established grass paddock, either remove all the grass or remove the grass from 4–5 m wide strips of grass using cultivation or herbicide (to leave 3–4 m strips of grass).
- Sowing time, rate and depth—sow leucaena from September through to February. The best time to sow is once the soil profile has more than 75 cm of moisture and the probability of follow-up rain is highest. This means that January to February is the most suitable sowing period. Seed should be sown at 2 kg/ha and deeply enough for moisture to persist around the seed for 5–7 days.
- Seed treatments—leucaena needs to be inoculated with 'desmanthus/leucaena rhizobium' (or strain CB3126) to ensure adequate nodulation and nitrogen fixation.

Leucaena–grass pasture

Nutrition

- Nutrient requirements—leucaena performs best on soils high in phosphorus, sulphur, potassium and trace elements.
- Application rates and timing—a soil test should be taken to identify nutrient limitations. To ensure healthy, vigorous seedlings and a productive plant stand where phosphorus levels are low (< 25 mg/kg) at planting, an application of at least 40 kg/ha of a starter type fertiliser (which includes phosphorus and zinc) at planting is recommended.

Pests

- Weed control—leucaena is a slow growing and non-competitive seedling so weed control prior to and after planting is critical. Control weeds prior to planting using cultivation or herbicides. Apply a residual herbicide post-planting to control grass and broadleaf weeds for up to six months.
- Insects—soil insects can affect the establishment of seedlings and there are a number of products available to control these. In addition, psyllids can devastate established stands during mild, humid conditions. Psyllids can be treated with a systemic insecticide.
- Diseases—leucaena is relatively disease-free. Leucaena does not tolerate water-logging and so soil borne diseases (e.g. phytophthora) might reduce production in poorly drained heavy clay soils.

Growth pattern and timing of seasonal production

Leucaena prefers hot, wet conditions and hence grows most during the spring and summer months. Grazing can commence in spring once sufficient biomass is present and growth will cease in autumn when either soil moisture is depleted or temperatures are below 15 °C average.

Managing grazing to maximise plant productivity

In the first year, grazing should commence once the bulk of the plants are more than 1.5 m tall as grazing earlier than this can stunt the plant, lowering future production. Once established, i.e. in the second year, rotationally graze leucaena to maximise its production and keep the plants to a maximum height of 2 m. This strategy also minimises the likelihood of the plants setting seed and spreading from the intended growing area.

Forage yield

Click here to go to indicative figures for forage yield for this forage type.

Cattle weight gain

Click here to go indicative figures for cattle weight gain on this forage type.

Economics

Example economic analyses are provided in chapter 7 for leucaena–grass pastures sown in three different locations across the Fitzroy River catchment. Sample spreadsheets are also provided so that different input figures can be used to examine alternative scenarios.

Cattle grazing leucaena–grass pasture

Summer forage: Forage sorghum (*Sorghum* spp.)

Forage sorghum is a popular forage due to its high biomass production, wide planting window and growing season and its suitability to a range of soil types. It is relatively drought hardy but good moisture is needed to maximise productive capacity. The quality of feed produced (digestibility and protein content) can vary and is dependant on soil fertility, fertiliser used and the variety sown. Forage sorghum can be grazed at high stocking rates. However, performance of individual animals is typically lower on forage sorghum compared to some other sown forage types.

Benefits

- High biomass production
- Wide planting window and growing season
- Drought tolerant
- Suitable on a range of soil types
- A range of varieties are available to meet a large range of feeding objectives
- Rapid recovery after grazing or cutting when soil water is available

Constraints

- Requires good moisture and high nutrient supply to maximise quantity and quality of biomass produced
- The build up of prussic acid in moisture-stressed crops, particularly young or regrowing crops, can result in reduced animal performance and, in severe cases, can cause fatalities
- Individual animal performance may not be as high as on other sown forage types
- Frost susceptible
- Disease (ergot) can be a problem late in the season
- Intensive grazing management is required to minimise wastage

Establishment

- Planting situations—forage sorghum is an annual crop that provides feed during the summer and autumn periods.
- Sowing methods—plant forage sorghum into a conventionally-tilled seedbed or sow with a zero till seeder in stubble retention situations.
- Sowing time, rate and depth—the planting window extends from early September through to February. Sowing can occur once soil temperatures are 17 °C and rising, with at least 60 cm of soil moisture. Late planted crops have a greater risk of, and need to be managed appropriately to avoid, ergot infection. Sowing rate ranges from 3–8 kg/ha depending on moisture availability and the seed should be sown at a depth of no greater than 5 cm into soil moisture.

- Seed treatments—are typically not warranted. However 'beetle bait' or seed-treated with insecticide is important in situations where soil insects are a problem. Also, if using herbicides that include s-metalochlor (e.g. Dual Gold®) to control weeds, the seed needs to be treated with Concept II® seed safener to avoid damaging the crop.

Nutrition

- Nutrient requirements—for every tonne of biomass produced, around 25 kg/ha of nitrogen, 3 kg/ha of phosphorus, 17 kg/ha potassium and 2 kg/ha of sulphur are required. If a typical crop produces 8 t/ha of biomass then 200 kg/ha of nitrogen is needed (either supplied from the soil or fertiliser).
- Application rates and timing—fertiliser rates will depend on soil fertility, available moisture and the level of production required. Where a soil test indicates nitrogen deficiency and high output is being targeted, rates in excess of 100 kg/ha of nitrogen may be required. Most fertiliser is either applied preplant or at planting (placement away from the seed is required to eliminate seed burn at high rates) due to the difficulties and variable responses achieved applying fertiliser in-crop. Long-term hay or silage production in the same paddock will mean greater nutrient removal as the entire crop is harvested. In these cases higher fertiliser rates than those used in a grazed situation are required to avoid rapid nutrient run-down.

Pests

- Weed control—weed control is required in the fallow using either herbicides or tillage, and in-crop using herbicides. Early in-crop weed control is critical to achieve potential biomass production. Control grass and broadleaf weeds using specific herbicides.
- Insects—in young, establishing crops soil insects such as cutworms and wireworms can cause damage. Control these pests with seed treatments or 'beetle bait'. Generally soil insects are of little concern in established crops.
- Diseases—ergot is the main disease that affects forage sorghum with infection occurring when plants flower during cool (< 25 °C), humid conditions. Crops flowering late in the season (autumn or early winter) are the most susceptible. Ergot pollinates the ovary and initially produces an oozing honey dew then a sclerote forms instead of a seed. Ergot infection therefore does not reduce the amount of feed (leaf and stem) produced. However, animal performance can be impeded if cattle preferentially graze seed-heads.

Forage sorghum

Growth pattern and timing of seasonal production

Forage sorghum grows very quickly under ideal conditions. First grazing can occur at 6–8 weeks of age and regrowth is rapid. Depending on sowing time and soil moisture, grazing can occur periodically throughout the summer and autumn period. The first frost will end the growing season, usually in June. However some varieties such as sweet sorghums do have the ability to overwinter.

Managing grazing to maximise plant productivity

Due to the rapid growth of forage sorghum, grazing management (timing and number of animals) is important for maximising production. Cattle should be introduced when the crop is around 1–1.5 m high and removed before the crop is grazed below 15 cm. Sweet sorghums, or varieties that are used for autumn and early winter feed, can be left longer before commencing grazing due to the higher palatability (or sweetness) of stems.

Forage yield

Click here to go to indicative figures for forage yield for this forage type.

Cattle weight gain

Click here to indicative figures for cattle weight gain on this forage type.

Economics

Example economic analyses are provided in chapter 7 for forage sorghum sown in three different locations across the Fitzroy River catchment. Sample spreadsheets are also provided so that different input figures can be used to examine alternative scenarios.

DEEDI Senior Agronomist (Sown Pastures), Stuart Buck, inspects a lablab pasture

Summer forage: Lablab (*Lablab purpureus*)

Lablab is an annual forage legume that produces high quality forage suitable for finishing cattle. Lablab is best sown on its own early in the summer period. Depending on soil moisture and timing of the first frost, lablab will provide high quality feed into autumn and winter. Cattle can gain more than 1 kg/head/day in the peak growing period and, if the crop has been sown on good soil moisture with follow-up rainfall, they can perform at this level for a number of weeks.

Benefits

- Produces quality feed (highly digestible, high crude protein content feed)
- The most productive annual forage legume available. Has the ability to regrow after grazing or cutting
- Can supply high quality forage when grasses are mature and quality has declined (e.g. in autumn)
- Has a large seed so establishment is relatively easy. Can be sown as a companion crop with a summer-growing cereal forage
- With careful management in the first year (i.e. grazing to prevent flowering and seed set) lablab may regrow and be fed off in the second season
- With adequate rhizobium inoculation, contributes large amounts of nitrogen to the soil which is available for use by subsequent crops

Constraints

- Highly frost sensitive. Leaves die and fall to the ground within two days of frosting, whereas leaves of other tropical legumes take up to a week to fall
- Cattle may take 2–5 days to acquire a taste for lablab forage and suffer slight weight loss unless access to grass is available either on headlands or in an adjoining paddock
- Lower carrying capacity and slower regrowth compared to forage sorghum
- Soils with low levels of phosphorus need to be fertilised to obtain optimum growth.

Establishment

- Planting situations—planting should occur as soon as 75–90 cm of soil moisture is present and once the risk of frost is past.
- Sowing methods—plant lablab either into a conventionally-cultivated seedbed or in zero tillage situations.
- Sowing time, rate and depth—sowing can occur any time between September and February. Sowing prior to Christmas enables higher forage production and more grazing time if follow-up rainfall is adequate. Sowing seed into moisture and no greater than 5 cm deep at 20–30 kg/ha is usually sufficient for a productive crop. To maximise forage production use the higher planting rate for crops planted after late January.
- Seed treatments—lablab seed needs to be inoculated with 'J' strain rhizobium for adequate nodulation and nitrogen fixation.

Nutrition

- Nutrient requirements—if adequately nodulated, nitrogen fertiliser is not required. However, phosphorus, sulphur and zinc are important for nitrogen fixation, vigorous growth and high biomass yields.
- Application rates and timing—if soil nutrient status is unknown, conduct a soil test. As a guide, 40 kg/ha of a starter-type fertiliser with zinc should be applied at planting to maximise production if phosphorus is low.

Pests

- Weed control—broadleaf and grass weeds can significantly lower biomass production, particularly if weeds are competing with young seedlings. Lablab is relatively slow to establish so sowing on narrower rows at a high seeding rate does assist with weed competition but this alone is unlikely to provide adequate control in weedy situations. A number of pre-emergent herbicides are available for grass and broadleaf weed control. However, in-crop herbicide options are limited. Options are very limited when lablab is sown with another crop, for example, forage sorghum.
- Insects—insect control is not generally warranted. However, if planting late (i.e. February) bean fly can attack young seedlings.
- Diseases—lablab is sensitive to phytophthora root rot, which typically occurs in heavier soils where water-logging occurs.

Growth pattern and timing of seasonal production

Lablab is late flowering and will provide good quantities of biomass and hence grazing value through summer and into late autumn, depending on the available soil moisture.

Managing grazing to maximise plant productivity

Grazing can commence around 10 weeks after sowing. However it is important that the plant is at least 45 cm high to ensure an adequate plant frame and enough leaf have been produced. Ideally, grazing should cease once all leaf and small stems have been consumed as the plant will quickly recover and provide another grazing after a short rest period if sufficient moisture is available. This management regime will provide the best opportunity for the crop to perenniate, particularly if grazing pressure prevents flowering and pod set.

Forage yield

Click here to go to indicative figures for forage yield for this forage type.

Cattle weight gain

Click here to go indicative figures for cattle weight gain on this forage type.

Economics

Example economic analyses are provided in chapter 7 for lablab sown in three different locations across the Fitzroy River catchment. Sample spreadsheets are also provided so that different input figures can be used to examine alternative scenarios.

Winter forage: Oats (*Avena sativa*)

Oats is the most widely used winter forage due to its high forage production and quality of feed. Oats is productive at the time of the year when native and sown grass pastures are dormant, enabling good weight gains when cattle would otherwise be maintaining or losing weight. Oats can provide feed from winter through to early spring. However, spring heat and soil moisture dictates the length of the season. In good seasons, multiple grazings can be achieved. However, typically only two or three grazings are achieved at best.

Benefits

- Produces high quality and quantity of forage at a time when grass pastures are dormant and of low quality
- Long growing season when follow-up rain occurs
- Individual animal performance is high and high stocking rates are possible in good seasons
- Relatively simple crop to grow with large seed that establishes easily

Constraints

- For maximum production, oats needs to be fertilised with nitrogen, particularly if grown on long-term forage or cropping country
- Several leaf rust-resistant varieties are available on the market although resistance often breaks down after a few years because of changes in rust races. Seed of rust-resistant varieties may need to be ordered early and is more expensive
- Do not sow oats too early, such as March in central Queensland, because high soil temperatures (>25 °C) at sowing depth can reduce germination and establishment
- Producers have commonly observed that cattle appear to perform better if given access to either hay or a dry grass paddock while grazing oats, although there is no scientific evidence available to support this recommendation

Establishment

- Planting situations—oats can be sown once 90 cm of soil moisture is stored and soil temperatures at seed depth are 15–25 °C.
- Sowing methods—sow oats using either conventional seeders into a cultivated seedbed or by zero tilling into stubble.
- Sowing time, rate and depth—in central Queensland, do not plant oats before the first week in April due to high soil temperatures (above 25 °C) at sowing depth. High temperatures shorten the coleoptile (initial shoot from the seed) length and this significantly reduces the establishment rate. Oats can be sown in late March in southern Queensland. The recommended planting rate is 30–50 kg/ha. Adjust planting rate for germination, seed size and percentage establishment in the field. There are approximately 50 000 seeds per kg, but always check the seed container for the correct seed size and germination. Seed is best sown at 5–7.5 cm depth in row spacings of 18–25 cm. Oats has a longer coleoptile than wheat and barley and is suitable for deep sowing using moisture-seeking tynes.
- Seed treatments—none recommended.

Cattle grazing oats

Heritage seeds

Nutrition

- Nutrient requirements—forage oats producing 1 t/ha of dry matter with a protein content of 22% will remove 35 kg/ha of nitrogen, so nitrogen application is likely to be required. Phosphorus and zinc are also essential nutrients for a productive oats crop.
- Application rates and timing—a soil test is recommended to determine the amount of fertiliser required. If 90 cm of soil moisture is present, up to 50 kg/ha of nitrogen could be required to maximise production. Phosphorus should be applied in deficient situations at around 20–40 kg/ha of product, for example, MAP (mono-ammonium phosphate) or DAP (diammonium phosphate). In general, nutrition requirement and fertiliser rates are similar to those recommended for wheat and barley.

Pests

- Weed control—correct weed control is critical for a productive oats crop. A number of herbicides are registered for use with oats. However some herbicides such as '2,4-D' can have adverse effects at high rates with particular varieties.
- Insects—no significant issues with insects.
- Diseases—the most significant diseases are stem and leaf rust. For grazing purposes, leaf rust is the most important and currently only two or three varieties have significant resistance. These varieties typically sell first, so order early to secure your seed. All available varieties are susceptible to stem rust. However, stem rust is only of practical concern if using the crop for hay or grain. Several fungicides (e.g. Tilt, Folicur) are registered for control of leaf and stem rust in oats crops in Queensland. In most grazing situations, fungicide application is unlikely to be economically viable. However, fungicide control may be worthwhile for high-value hay crops and seed crops, especially for control of stem rust.

Growth pattern timing of seasonal production

The main production period, or grazing time, is from June to September but will depend on planting time, soil moisture, temperature and grazing regime.

Managing grazing to maximise plant productivity

To maximise productivity oats should be grazed heavily and then rested. However, in practice the amount and timing of in-crop rainfall greatly influences grazing management of oats. If grazing commences once secondary roots are established, and before the stems begin to elongate, this will provide the opportunity for multiple grazings. Adequate nitrogen application at planting will also increase the speed of recovery, reduce tiller death and increase overall forage yield. For rapid regrowth, graze oats no lower than 12–15 cm above the ground. Avoid hard grazing as this can remove the growing points and delay subsequent regrowth. If leaf rust infection occurs, graze the crop heavily before the disease becomes severe to reduce the losses. Subsequent regrowth will remain free of symptoms for several weeks, and should be grazed lightly and often.

Forage yield

Click here to go to indicative figures for forage yield for this forage type.

Cattle weight gain

Click here to go indicative figures for cattle weight gain on this forage type.

Economics

Example economic analyses are provided in chapter 7 for oats sown in three different locations across the Fitzroy River catchment. Sample spreadsheets are also provided so that different input figures can be used to examine alternative scenarios.

Oats

Alternative forage options

Silk sorghum (Sorghum spp.)

Silk sorghum has been a popular forage because the seed is cheap and the crop is easy to establish. It persists for 3–5 years and produces moderate to high forage yields, depending on soil nitrogen levels. Annual forage sorghum varieties produce higher forage yields but only survive for one season. Silk will perenniate over a number of years under conservative stocking and with adequate nitrogen supply. Silk sorghum is closely related to Johnson grass so there is always a risk of getting this seed when purchasing silk sorghum. Also, silk sorghum has high weed potential and should not be planted on cropping soils. For high-output forage production situations, forage sorghum varieties are the first and better option. However, silk sorghum can be productive in the right situations with careful grazing management.

Cowpea (Vigna unguiculata)

Cowpea is a summer-growing, annual forage legume that provides high quality forage. Typically, only one grazing is possible from cowpea as regrowth is poor. It is not as productive as lablab, which has the ability to allow multiple grazings under the right soil moisture conditions. Most cowpea varieties are susceptible to root rot diseases when growing in water-logged conditions, the exception being 'Red Caloona'. This variety has root rot resistance and so is a good option in this situation.

Forage wheat (Tricticum aestivum), barley (Hordeum vulgare) and millet (Pennisetum glaucum)

A number of other forage cereal crops are available which can provide high quality forage. These include forage wheat, barley and millets. Forage wheat and barley provide feed at a similar time of the year to oats, whereas millet provides feed at a similar time to forage sorghum.

Forage wheats are adaptable to a range of situations because they are highly palatable and have a wide sowing window. They are also more resistant to leaf and stem rusts than forage oats. However, compared to oats they are a minor crop due to relatively unknown performance and poorer regrowth potential after grazing. Forage wheat produces similar biomass yields to oats up to the first grazing, but subsequent regrowth is much lower than for forage oats. Forage wheat is most commonly planted for hay rather than for grazing.

Forage barley produces high quality forage suitable for grazing, hay or silage production. Under favourable conditions forage yield is similar to oats up to the first grazing but regrowth is much lower than for forage oats. Forage yield can be higher than oats if planting in the cooler months of May and June. The grazing period for forage barley is shorter due to the later sowing time (to minimise rust build-up) and earlier maturity. Barley varieties have better resistance to rust than oats but are susceptible to other diseases (e.g. blotches) that can restrict grazing.

Forage millets are summer-productive forages that belong to the *Pennisetum* genus of grasses. They provide forage at similar times of the year to forage sorghum, and while they do not produce as much plant material, feed quality is higher due to their finer stems. The seed size is small so uniform establishment on clay soils can be difficult. In this situation, rubber tyre rollers, or preferably press-wheels, are essential for adequate establishment. Other advantages of forage millet (when compared with forage sorghum) include significantly faster regrowth providing shorter intervals between grazing and no prussic acid production, reducing the risk of fatalities particularly during water stress situations.

Burgundy bean (Macroptilium bracteatum)

Burgundy bean is a short-term, perennial forage legume well suited to the clay soils in the Fitzroy River catchment. Burgundy bean is highly productive in the first year. However, due to high palatability it usually only persists for 2–3 years. Under central Queensland conditions it is as productive as butterfly pea in the first couple of years. However butterfly pea is more productive (due to longer persistence) in the longer term.

Seca (Stylosanthes scabra), Verano (Stylosanthes hamata) and Caatinga (Stylosanthes seabrana) stylos

Plants in the stylo group are suited to permanent pasture situations where a persistent, long-term legume is required. They are not as productive as other perennial pasture legumes such as butterfly pea, leucaena or burgundy bean. However, they will persist under moderate grazing pressure in poorer quality (lower water holding capacity or lower fertility) soils. Caatinga is the only stylo suited to clay soils, where it can be productive and persistent for longer than 10 years.

Shrubby stylos (i.e. Seca and Siran) are relatively slow to establish but are the most widely adapted stylos and will grow on a range of soils except heavy clays. They are adapted to and persistent on eucalypt woodland soils with low soil phosphorus where animal weight gain can be increased by around 35 kg/year. Caribbean stylos (i.e. Verano and Amiga) are more productive and better suited to the wetter (north and coastal) regions, whereas Seca and Siran are more productive in lower rainfall regions due to better drought tolerance. Quick establishment and higher production from the Caribbean stylos is useful when sown in a mix with shrubby stylos.

Desmanthus (Desmanthus virgatus)

Desmanthus is another forage legume suited to clay soils in permanent pasture situations. It is very persistent and productive on heavy clays soils and will provide high protein forage in situations where other legumes will not persist, for example, heavy brigalow soils with melon-holes. Like the stylos, desmanthus is not as productive in the short term as butterfly pea and burgundy bean but will persist longer in a permanent pasture. Desmanthus and caatinga stylo are the only productive and persistent legumes suited to clay soils. However there are other legumes that are more suited (albeit with shorter persistence) to a high-output forage system.

Lucerne (Medicago sativa)

Lucerne is a temperate legume also suited to the sub-tropics and used in a wide range of grazing systems and on many soil types. It has the advantage over other summer-growing legumes of also producing feed during the winter months although the amount produced depends on the variety grown and soil moisture available. However, bloat can be a significant issue particularly when no other feed is available. Lucerne will only persist for up to four years in fertile, well drained soils, such as alluvial loams and so is only suited to a limited area of central Queensland. Lucerne can play a role in the right situation, however there are other legumes that are better suited to a high-output forage system.

Medics (Medicago spp.)

Medics are winter-growing, annual forage legumes that are highly productive in years where April to August rainfall is above 200 mm. Hence, medics are unsuited to central Queensland conditions due to low and unreliable winter rainfall and short winter seasons. Spring heat significantly lowers seed set and subsequent regeneration potential. In southern Queensland, medics play a significant role in providing quality winter feed as they can persist on the clay soils in this area and they are more adapted to this climate with cooler and longer winters and higher rainfall. Barrel medics are more productive under lower rainfall conditions compared to snail medics. However barrel medics are not as productive in the wetter seasons. Burr medics have naturalised throughout southern Queensland and play an important role in the wetter winter seasons. Overall, medics can provide useful feed at a time when perennial grasses are dormant and of low quality. However, medics are not highly suited to high-output forage systems in the Fitzroy River catchment area.

Cattle grazing oats

Heritage seeds

Annual forage mixes

Sowing a cereal forage and legume mix can in theory provide a more balanced diet for cattle resulting in less wastage of protein. However, in reality, forage mixes are problematic as they are difficult to manage for optimum grazing time and duration of all the forage species in the mix.

Forage sorghum and lablab

Mixing forage sorghum and lablab has been a relatively common commercial practice with the objective being to provide a more balanced diet and for lablab to contribute nitrogen for growth of the forage sorghum. In practice, cattle will preferentially select one species over the other. This lowers the productivity of both species, as one species can get overgrazed and the other underutilised initially and then consumed at a later stage, possibly past its prime. In addition, nitrogen contribution from legumes mainly occurs after leaf fall so that the benefit is only realised once this material is incorporated into the soil and soil microbes have decomposed it, releasing the nitrogen some months later—after the crop has finished!

Oats and medics

Mixing oats and medics is practiced for the same reasons as mixing forage sorghum and lablab—to improve the quality of feed available. In this case, there is relatively little advantage of mixing the two species together as oats can provide high quality forage (high digestibility and protein) on its own. In addition, in central Queensland where winter rainfall is unreliable, the forage production of each species is rarely maximised. Medics are not a reliable winter legume option in central Queensland due to the short winter season and unreliable winter rainfall.

Ley pasture mixes: perennial, legume-grass pastures

Pasture mixes used in a ley system (pasture phase in a crop rotation) can produce high quality forage material and thus result in high animal performance. They also provide soil health benefits with improved organic carbon and nitrogen supply as well as soil structure improvements. To obtain the full benefit from the ley pasture it is essential that a productive grass and legume are grown together. Without a companion grass to drive nitrogen fixation, the legume will only fix enough nitrogen for its own needs, or utilise available soil reserves, having little impact on soil nitrogen or organic carbon levels.

Expected forage yield

The quantity of forage produced will depend on the fertility and water holding capacity of the soil, the amount and distribution of rainfall received and any temperature limitations to growth. Modern plant production models, such as those within the APSIM (Agricultural Production Systems Simulator) modelling framework, are able to utilise regional soil and historical climate data to simulate long-term, average forage production and determine the frequency of suitable planting conditions occuring at any selected location.

As an example, forage biomass production was simulated for three example sites across the target region of the Fitzroy River catchment (see table 6):

- Site 1: South Queensland Brigalow (Taroom–Wandoan area)
- Site 2: Central Queensland Brigalow (Bauhinia–Theodore area)
- Site 3: Central Queensland Open Downs (Capella area).

There has been initial, limited validation work conducted in central Queensland for the annual forage crops. Additional research work proposed in this area will help to build confidence in this modelling output by validating the results with real measured data.

Methods and assumptions used in forage production modelling examples

Specific assumptions used in the forage production modelling examples for the three case study scenarios are summarised in table 7. At each location, 108 years of climate data was used. The GRASP pasture model (Rickert et al. 2000) was used to model 'baseline' grass pastures and the Agricultural Production Systems Simulator (APSIM; Keating et al. 2003) was used for annual forage crops. The annual forage crops were sown each year using a variable sowing rule which required 20 mm of rainfall over three days and 60 mm of plant available soil moisture. Growth of summer forage crops was assumed to end on the first day of frost and growth of oats assumed to end on 1 December each year. For the annual forage crops, each time the crop was removed the soil nitrogen was reset to the assumed base nitrogen level for that site. The forage paddocks remained in fallow during the non-growing season. The APSIM forage modules had been calibrated using physical cutting to mimic grazing. Oats and lablab were cut to a height of 10 cm at floral initiation, or when more than 3000 kg/ha of dry matter had grown. Forage sorghum was cut to a height of 15 cm at flowering or when height was greater than 80 cm. In the modelling of baseline pasture production, an annual utilisation rate of 20% was assumed to account for the effects of grazing. As the perennial legume–grass pastures, butterfly pea–grass and leucaena–grass, cannot currently be modelled with sufficient reliability, estimates of biomass production were based on expert opinion and assessment of measured values in both published and unpublished reports.

Table 6. Forage production of baseline pasture and annual forage crops predicted using GRASP or APSIM and of perennial legume–grass pasture systems estimated by expert opinion for three regional locations in Queensland

	Forage					
	Baseline pasture (buffel or native)	Oats	Forage sorghum	Lablab	Butterfly pea–grass[A]	Leucaena–grass[A]
South Queensland Brigalow (Taroom–Wandoan area)						
Average forage yield (kg DM/ha)	3542	3437	4794	6941	3400	3500 (43% leucaena)
% of years with suitable conditions for sowing	N/A	67	100	100	N/A	N/A
Central Queensland Brigalow (Bauhinia–Theodore area)						
Average forage yield (kg DM/ha)	3523	4663	8856	7460	4000	4500
% of years with suitable conditions for sowing	N/A	67	100	100	N/A	N/A
Central Queensland Open Downs (Capella area)						
Average forage yield (kg DM/ha)	2401	5577	8457	5456	4500	4500
% of years with suitable conditions for sowing	N/A	62	100	93	N/A	N/A

[A] Yield of edible legume (i.e. stems up to 5 mm in diameter for leucaena) and grass.

N/A: estimate not available.

Table 7. Assumptions used in the forage production modelling for the three example case study scenarios

Factor	Site 1: South Queensland Brigalow	Site 2: Central Queensland Brigalow	Site 3: Central Queensland Open Downs
Climate file	Taroom	Banana	Capella
Soil file	Grey vertosol (ApSoil No.86 in APSIM)	Grey vertosol (APSoil No.106 in APSIM)	Black vertosol-Orion (Capella ApSoil No.049 in APSIM)
PAWC (mm)	162	136.5	145.5
Soil depth (mm)	1500	1500	1500
Base nitrogen level (kg/ha)	50[A]	60	40
Fertiliser (kg N/ha)[B]	20	0	40
Planting rules			
Sowing window			
Oats	1 Apr–1 Jun	1 Apr–1 Jun	1 Apr–1 Jun
Forage sorghum	20 Oct–31 Jan	1 Sep–31 Jan	1 Sep–31 Jan
Lablab	15 Oct–31 Jan	1 Sep–31 Jan	1 Sep–31 Jan
Rainfall	20 mm over 3 days	20 mm over 3 days	20 mm over 3 days
Minimum plant available soil water (mm)	60	60	60
Plants/m^2			
Oats	100	100	100
Forage sorghum	20	20	20
Lablab	10	10	10
Crop end criteria			
Oats	1 Dec	1 Dec	1 Dec
Forage sorghum	Min temp <5 °C	Min temp <5 °C	Min temp <5 °C
Lablab	Min temp <5 °C	Min temp <5 °C	Min temp <5 °C

[A] Assume soil has 'run-down' in nitrogen levels due to a greater number of years of cropping and/or planting to buffel pasture relative to Site 2.
[B] Oats and forage sorghum, only.

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6 Cattle management and performance

Feed utilisation

Grazing cattle do not consume all of the dry matter a forage produces. A general recommendation is to utilise only about 20–30% of the total forage yield of perennial pastures such as buffel or butterfly pea–grass pasture to ensure long-term sustainability of the pasture. A greater proportion of an annual forage crop can be utilised if the plants are not required to persist into another season. However, under normal grazing conditions about 50% of total forage crop yield can be lost due to trampling and soiling. Grazing strategies such as strip-grazing and green-lotting can increase utilisation rates. However, these more intensive feeding systems force animals to eat more of the lower quality plant material—stems and old leaves—than they would otherwise select, resulting in lower liveweight gain.

Another factor to consider is that many annual forage crops, particularly forage sorghum, are underutilised if the grazing pressure is too light. In this situation the crop matures rapidly and produces seed heads resulting in a decline in feed value and poor utilisation of the fibrous stems. Using a high stocking rate and grazing early in crop development are strategies that can maintain crops in the higher quality vegetative state, for as long as possible.

Feed quality and cattle intake

Both the quality and quantity of feed that the grazing animal consumes determines individual cattle growth rates on forage. The quality and quantity of feed are related and are influenced by these main factors:

- soil or land type
- fertiliser application
- preplanting and in-crop rainfall
- age of the pasture or forage
- plant species making up the pasture.

Feed quality

A major indicator of feed quality is the digestibility or energy content of the feed. Dry matter digestibility (DMD) is the proportion of the feed that an animal digests in the stomachs, taking into account losses due to material excreted in the faeces. Metabolisable energy (ME) is the energy left after losses in faeces, urine and methane gas are subtracted. Feed quality values are often expressed as DMD, whereas the energy requirements of cattle for maintenance and growth are often expressed in terms of ME requirements.

The digestibility of a forage is related to the proportion of cell wall material—fibre and silica—in the plant. The proportion of less digestible cell wall material increases as plants age. This is associated, in part, with a decline in the leaf to stem ratio within the plant. The nitrogen content of plants also declines with age. Tropical forages generally have higher fibre and silica contents, and are therefore less digestible, than temperate species of the same age and mature grasses are generally less digestible than mature legumes.

Protein and mineral levels must be non-limiting for optimal cattle growth to occur for the given level of energy intake. Generally, when high quality forages are being grazed, the high amount of available green leaf usually means the protein and mineral concentrations in the feed will be non-limiting for growth. This means that energy will be the primary limiting nutrient.

It is important to recognise that the concentration of nutrients in the diet that grazing cattle select is not the same as that in the entire plant. This is because cattle preferentially graze plant species and plant parts and will select a diet higher in quality than the average of the total material on offer.

Obviously, there is a wide range of possible nutrient values for a particular forage or pasture type, depending on the mix of species, cultivar, soil type, fertiliser application, age of pasture and the amount of selection that cattle are allowed. This last factor is related to the stocking rate. However, table 8 gives an example of the concentrations of energy and protein that you can expect in the highest quality component

Table 8. Indicative energy and protein concentrations in green leaf material of major forage and pasture types, as compared with sorghum grain and a protein meal

Forage	Dry matter digestibility (%)	Metabolisable energy (MJ/kg DM)	Crude protein (% DM)
Sorghum grain	89	13.8	10
Cottonseed meal	72	11.3	51
Buffel on brigalow soils, early wet season	60	8.0	17
Oats	80	12.1	32
Forage sorghum	65	9.5	18
Lablab (annual species)	68	9.9	25
Butterfly pea	N/A	N/A	28
Leucaena	56–63	7.9–9.1	29

DM: dry matter
N/A: estimate not available

of the plant—the green, growing leaf material—for some common forage types. It is important to remember that the animals will also select a significant proportion of stem material, depending on the stocking rate, so the nutritive value of the diet will usually be less than the optimum that green leaf material can provide.

Feed intake

The amount of the feed on offer that individual animals consume, i.e. the feed intake, is a result of the interaction of the following factors.

a) Total amount of forage dry matter (DM) on offer

Feed intake can be reduced if the amount of feed on offer is low. Forage dry matter on offer can be expressed in a number of ways, for example:

- kg DM/hectare
- kg DM/beast
- kg DM/animal equivalent (AE)
- kg DM/kg of animal liveweight.

b) Bulk density of the forage

Low bulk density can constrain the ability of the animals to harvest the forage and so limit intake in some situations with tropical grass and legume pastures. For example, in some situations the bulk density of leucaena leaf in leucaena–grass pastures may be low resulting in reduced intake.

c) Feed quality

Generally, the relationship between digestibility and forage dry matter intake is linear, meaning that the more digestible the forage is the more of it an animal can eat. The effect of feed digestibility on intake is largely due to effects on the rate of passage of forage material through the rumen. The more quickly feed is digested, the more quickly it passes out of the rumen, allowing the animal to consume more feed.

d) Palatability of the forage

The palatability of forage components and species influences how strongly animals will select for it within a pasture sward and can affect the intake of individual forage species within a mixed sward as well as total intake in a pure forage sward. For example, some studies show that cattle do not accept lablab well when they are first introduced to the forage. This can result in reduced forage intake, and thus low growth rates, for the first 2–3 weeks of grazing. One strategy to circumvent this problem is to provide access to an adjacent area of grass pasture or another forage source during the early grazing period while cattle are adjusting to the lablab forage. Alternatively, it is possible that cattle may compensate for this low intake in the subsequent weeks of grazing. In another example, the high palatability of the pasture legume burgundy bean causes cattle to heavily select it when growing with grass in a mixed sward. Thus, intakes of legume will be high initially, but will decline over time as burgundy bean is preferentially grazed out of the pasture and replaced with the grass species.

e) Grazing time

The amount of time spent grazing will determine the amount of feed that can be consumed. Environmental and other factors can influence grazing time, expressed as hours per day. Animals can increase the time spent grazing in an attempt to meet their daily feed intake requirements if the amount of feed on offer, or the bulk density of feed, is low.

f) The amount and quality of any feed supplements

Energy, protein and mineral supplements such as grain, protein meals or inorganic mineral mixes, may have different effects on the intake of forage, depending on the quality of the base forage diet and the amount of supplement consumed. For example, providing a grain-based concentrate at moderate to high intake reduces forage intake as grain substitutes for some of the paddock feed. However, even when substitution occurs, the total digestible dry matter intake of the animal is normally increased so animal growth is also increased.

g) Anti-nutritive substances or toxins

Anti-nutritive substances or toxins may be present in some pasture plants or associated weeds and can depress intake. Under certain conditions, such as when hungry or stressed animals gorge on toxic plant species, these toxins can cause illness and death. Examples of anti-nutritive substances include:

- inorganic compounds and minerals such as nitrate, found in lush forages when soil nitrate levels are high and conditions are not suitable for plant growth
- organic compounds such as tannins and alkaloids (e.g. mimosine found in leucaena and prussic acid produced in stressed forage sorghum crops)
- fungal or bacterial toxins (e.g. ergot infections in forage sorghum seed-heads).

h) Animal liveweight, age and physiological state

Older, heavier cattle and gestating or lactating animals consume more feed per beast than younger, lighter stock and thus require a greater grazing area.

i) Previous nutritional and growth history

If cattle undergo a period of severe nutritional restriction, an effect known as compensatory gain can occur once cattle are provided with better nutrition. This results in greater-than-expected cattle weight gains for a given forage type and quality and a given animal weight. It is believed that compensatory growth is primarily a result of increased feed intake, typically 15–30% higher than what would normally be expected.

j) Water quality

It is important to ensure that water sources are clean, free of organic contamination and not too saline (less than 1000 ppm total dissolved solids is desirable) as poor water quality reduces water intake that, in turn, reduces feed intake.

Predicting the amount of feed that animals will consume is a complex task and there are a number of equations provided in the Australian ruminant feeding standards (CSIRO 2007) that can be used for this purpose. However, the existing equations do not provide accurate predictions for intake of tropical forage diets. A rough guide is that animals should consume between 1.5–3% of their body weight as forage DM daily when forage is of high quality.

Energy requirements for growth and feed conversion efficiency

Energy intake drives cattle production and growth. The greater the energy consumed, the greater the animal growth rate. Protein and mineral levels are also important, but often their effect is through increasing the energy intake of the animal.

The total metabolisable energy intake of cattle is determined as the forage intake (kg DM) multiplied by its energy content (MJ/kg DM). Therefore, a forage with higher energy density has a double effect in increasing energy intake as the greater digestibility means cattle can also physically consume more of the forage.

The metabolisable energy intake in excess of that required for maintenance of the animal can be used for growth. Type, breed or genotype, class, size, physiological state (e.g. growing, gestating or lactating) and age of the animal as well as heat or cold stress all influence nutritional requirements for maintenance and production. For example, *Bos indicus* cattle breeds have a lower maintenance energy requirement than *Bos taurus* breeds. In addition, the greater the distance animals have to walk to obtain feed and water, the greater the energy expenditure, reducing the remaining energy available for growth.

A complex interaction of factors affect the efficiency of converting feed energy into weight gain. One factor is the stage of maturity of cattle and the associated changes in the composition of the weight gain. For instance, as cattle increase in age and body weight the ratio of fat to protein in each kg of weight gain increases, decreasing the feed conversion efficiency. For example, older cattle may require 10–12 kg of feed DM per kg of liveweight gain compared to 7–10 kg per kg of liveweight gain for younger stock. In addition, the utilisation of energy in the diet for production becomes more efficient as the metabolisable energy concentration of the feed increases.

A series of equations can be used to predict the metabolisable energy requirements for maintenance and production of cattle under specific situations. These equations are found in feeding standards such as the Australian ruminant feedings standards (CSIRO 2007).

Indicative weight gains on forages

Table 9 provides a general indication of expected animal production for the key, high quality forages of relevance in the Fitzroy River catchment based on an assessment of the available measured values and the considered judgement of DEEDI beef research and extension staff. These values are based on the assumption that forages have been grown and grazed using 'best-practice' agronomic management and represent the expected long-term average performance over both good and bad rainfall years for forages grown on brigalow soils in central Queensland. The expected 'long-term average' values may differ from those stated in table 9, for different soil types and also towards the northern and southern boundaries of the Fitzroy River catchment. The accompanying economic analysis gives an indication of how animal performance may differ for three scenarios encompassing different soil types and geographical location across the catchment.

In general terms, winter fodder crops such as oats can support the highest daily liveweight gains of all forage options over their 'normal' grazing periods because they have higher digestibility than summer fodder crops and tropical perennial grass or legume–grass pastures. However, the summer fodder crop forage sorghum is capable of supporting very high stocking rates and correspondingly the highest beef production in kg/ha/year of all forage options. Combining a perennial legume with a grass pasture provides a system which can support stocking rates, grazing days, daily gains and total beef production per hectare, intermediate between grass-only pasture and annual fodder crops. Legumes, as pure stands or with grass, have the capacity to increase daily liveweight gain

Table 9. Indicative production figures for finishing cattle grazing dryland forages in the Fitzroy River catchment[A]

Forage	Feeding period[B]	Grazing days (days/year)	Daily gain[C] (kg/head)	Stocking rate (AE/ha)[D]	Beef production (kg/head/year)	Beef production (kg/ha/year)[D]
Grass-only pasture						
Buffel–brigalow soils	**Annual**	**365**	**0.46**	**0.33**	**168**	**58**
	Summer	90	0.84		76	
	Autumn	92	0.38		35	
	Winter	92	0.24		22	
	Spring	91	0.38		35	
Queensland bluegrass–open downs soils	**Annual**	**365**	**0.39**	**0.17**	**142**	**26**
	Summer	90	0.77		69	
	Autumn	92	0.34		31	
	Winter	92	0.11		10	
	Spring	91	0.34		31	
Perennial legume + grass						
Butterfly pea–grass	Oct–May	250	0.6	0.8	150	104
Leucaena–grass	Sept–May	270	0.9	0.6	243	138
Summer fodder crops						
Forage sorghum (delayed flowering variety, e.g. sweet jumbo LPA)	Feb–May	120	0.6	3.0	72	185
Lablab (annual spp.)	Dec–May	100	0.8	2.5	80	174
Winter fodder crops						
Oats	Jun–Nov	83	1.1	2.0	91	163

[A] These estimates are based on an assessment of the available measured values and the considered judgement of DEEDI beef research and extension staff. The values are based on the assumption that forages have been grown and grazed using best-practice agronomic management and represent the expected long-term average performance over both good and bad rainfall years for forages grown on brigalow soils in central Queensland.

[B] Summer: December–February, Autumn: March–May, Winter: June–August, Spring: September–November.

[C] Growth rates estimated for HGP-free cattle.

[D] AE (adult equivalent): 450 kg non-lactating beast. Stocking rates for high quality forages are those required to finish heavier cattle. The total beef production has been determined assuming steers are finished to 310 kg carcass weight. Only the area of sown forage has been considered in stocking rate and beef production/ha calculations (i.e. additional areas of grass access that may be provided in association with fodder crops are not included). The beef production for perennial pastures has been calculated using a stocking rate of actual animals/ha determined from stocking rate in AE/ha, at the liveweight of steers at the half-way point of the finishing period.

above that expected from tropical grass species largely due to increasing the digestibility of the diet.

Comparing animal production data from forage systems is an initial step in evaluating forage options. It is important to also assess the economic outcome of utilising a particular forage option. In addition, an assessment of social, environmental and managerial factors is of critical importance in the decision-making process.

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. For example, cattle not supplemented during the winter will often grow at a faster rate during the following summer than similar cattle that received winter supplements (figure 4).

The degree of compensatory growth is variable, ranging from zero to 100% depending on the:

- length and severity of the period of poor nutrition
- level of nutrition available and the duration of improved nutrition following the period of poor nutrition
- age of the animals.

Generally, the more severe the reduction in growth rate (or weight loss) and the better the nutrition offered afterwards, the greater the extent of compensation.

It is believed that compensatory growth is primarily a result of increased feed intake, typically 15–30% higher than what would normally be expected. The mechanisms behind compensatory growth are not fully understood, making it difficult to accurately predict growth rates of cattle exhibiting compensatory growth effects.

The implication of the compensatory growth effect is that cattle should be sold straight off crop or high quality forage. If animals are carried over for another season after feeding, the liveweight advantage of the cattle gained through feeding on high quality forage could be eroded to some extent by compensatory growth. That is, the liveweight advantage of the cattle a season later will be less than it was just after the forage feeding was completed relative to similar cattle that did not graze improved forage, with obvious negative effects on the cost efficacy of forage feeding.

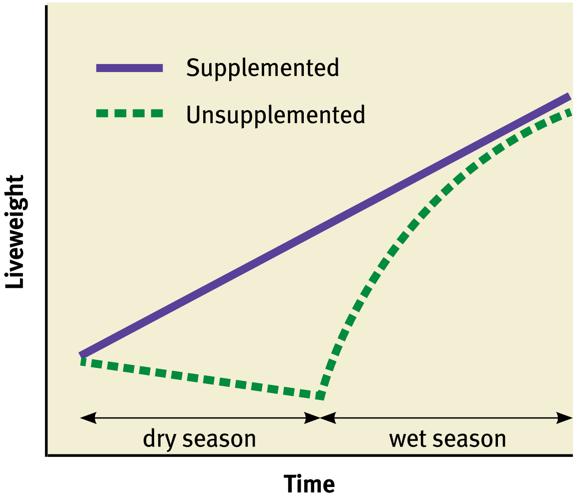


Figure 4. Liveweight of supplemented and un-supplemented cattle over time, showing compensatory gain, or 'catch-up growth' of the un-supplemented cattle during the subsequent period of better quality, wet-season, pasture
(S McLennan, unpublished)

Strategies that may help prevent cattle being carried over for another season after grazing high quality forages include:

- stratifying the cattle into groups based on weight and condition and then targeting feed to those that will have a good chance of meeting the target market specifications
- adjusting stocking rates on the forage to ensure adequate liveweight gain to reach the target finishing weight
- providing grain or other high energy supplements to increase grazing time on the forage and increase energy intake and growth rate.

Growth promotants

Hormonal growth promotants (HGPs) can increase growth rates of cattle by 10–30% and feed conversion efficiency by 5–15%. The increased growth rates can have a significant benefit in enabling the weight-for-age specifications of the target market to be met, particularly when cattle are grazing perennial grass-only pastures. Cattle need to be gaining weight to receive the maximal response from HGPs. The more frequently cattle are treated with a new implant the greater the overall response in liveweight gain. Once an implant program has commenced, it should continue through until slaughter to maximise the growth response.

However, cattle treated with HGPs are excluded from the European Union market. In addition, under some circumstances HGP treatment can make it more difficult to achieve the grading specifications required to achieve maximum price per kg carcass weight. Cattle treated with HGPs are penalised by receiving a lower MSA grading score as well as a higher ossification score than similar non-HGP treated cattle. At present there is no additional penalty under the MSA grading system for more than one HGP treatment, other than possible effects on ossification.

HGPs can also increase carcass leanness by 5–8%. Thus, HGPs may not be beneficial when late maturing genotypes are used to produce beef for markets requiring substantial fat levels at light carcass weights.

Animal health considerations

Good animal husbandry and management is required to decrease the risk of non-nutritional or health factors having a negative affect on growth rates of animals grazing high quality forages. The risk and incidence of the majority of the diseases listed below are minor but it is important to be aware of the potential for these diseases to occur and to take preventative measures where appropriate.

Bovine ephemeral fever (three-day sickness)

Mosquitoes and sandflies spread the arbovirus that causes bovine ephemeral fever, commonly known as three-day sickness. This disease has a relatively high occurrence in central Queensland. The symptoms include fever, shivering, lameness and muscular stiffness, and in extreme cases death. Cattle can take from one day to several weeks to recover, severely reducing growth rates during this period. Fat cattle are more severely affected than cattle in store condition. Vaccination is the only means of prevention with two vaccinations, 2–4 weeks apart, then an annual booster to maintain protection. In central Queensland, outbreaks of three-day sickness commonly occur in October, so timing the annual booster for August is recommended to boost protection prior to the increase in insect numbers.

Enterotoxaemia (pulpy kidney)

The bacteria *Clostridium perfringens* type D causes enterotoxaemia, or pulpy kidney. This bacterium lives in the intestines of normal, healthy cattle. However, sudden changes in feed quality or digestibility resulting when cattle are introduced to highly digestible feed after grazing low quality roughage, can produce conditions in the intestine that allows the bacteria to proliferate. Such highly digestible forages include very lush forage oats, ryegrass and pastures containing medics and clover. The bacteria produce a toxin that can cause convulsions and death. Adult cattle may develop severe bloat before dying.

There are no effective means of treating the disease. Prevention is through use of a vaccine protective against the bacteria in question, such as the 5-in-1 vaccination. After the initial course of two vaccinations, given 4–6 weeks apart, an annual booster dose should be given to coincide with the animals going on to high quality forage. Timing the annual booster so it is given just prior to introducing cattle to the forage is particularly important because the protection the vaccine provides may be as short as three months.

The prevalence of pulpy kidney in central Queensland has traditionally been low, but the risk is there if rapid changes in feed quality occur.

Other clostridial diseases such as blackleg can be stimulated to occur under high quality forage feeding conditions and can be fatal. Most losses occur in cattle less than two years of age although losses can occasionally be seen in older cattle. As for enterotoxaemia, vaccination with a multivalent vaccine (5-in-1 or 7-in-1) is the only effective means of controlling other clostridial diseases, with the exception of botulism, which requires a separate vaccine.

Botulism

Ingestion of the toxin that the bacteria *Clostridum botulinum* produces causes the fatal disease, botulism. Stock are at risk of botulism when they suffer from protein and phosphorus deficiency because this can cause them to chew bones and decaying material that may carry the bacterium.

Generally, under conditions of high quality forage production on better quality soils in central Queensland, cattle should not be protein and phosphorus deficient. However, give consideration to botulism risks if the cattle have been backgrounded on phosphorus deficient country prior to introduction to the higher quality forage or if the forage has been sown on soils marginally deficient in phosphorous. Additionally, accidental cases can occur when feed contaminated with rodent, bird or reptile carcases is fed out or if carcases contaminate the water source.

There are two types of vaccine available to prevent botulism. One is a conventional vaccine that requires a booster 4–6 weeks after the first dose. The other is a single-dose, 'long-range' vaccine that does not require the initial booster. However, both types require an annual booster as protection only lasts for about 12 months.

Mimosine toxicity when grazing leucaena

The toxic amino acid, mimosine is found in the leaves, green pods and seeds of leucaena. The highest concentrations are found in fresh new leucaena growth. Mimosine is rapidly broken down in the rumen to a secondary product called dihydroxypyridine (DHP). However, DHP is also toxic. It can effect the normal functioning of the thyroid gland and thereby ultimately reduce cattle weight gains. The effects are cumulative, meaning that animals grazing large amounts of leucaena over longer time periods will have a greater likelihood of developing signs of toxicity. Mild cases of DHP toxicity are expressed in terms of depressed intakes and reduced growth rates. More severe cases of mimosine and/or DHP toxicity result in hair loss (primarily from the brush of the tail, the pizzle and the poll of the head), lethargy, sores on the skin, excessive salivation, goitre, abortion and death.

The effects of toxicity can be prevented by introducing a bacterium into the rumen of cattle which is capable of degrading DHP to a non-toxic compound. A commercially available bacterial inoculum is produced by DEEDI scientists and distributed from Brian Pastures Research Station near Gayndah. Orders can be lodged by email: rumenfluid@deedi.qld.gov.au or by calling 13 25 23. The recommendations for inoculation are:

- Graze cattle on leucaena for around 10–14 days prior to drenching to ensure mimosine and DHP levels in the rumen are sufficient to ensure survival of the bacterium.
- Drench 10% of the mob with 100 mL of inoculant/beast. The bacterium will spread to the rest of the individuals within the mob within 5–6 weeks.

- Do not dose the water trough with the inoculum as the bacterium is anaerobic (can not live in the presence of oxygen) and is also susceptible to sunlight.
- To prevent the requirement for drenching new animals each time a mob is introduced to leucaena, some previously exposed animals can be carried over and allowed to run with the new mob for 4–6 weeks.

Prussic acid poisoning from sorghum

Under certain conditions, forage sorghum crops can produce dangerous amounts of prussic acid (cyanide). The risk is highest when drought, frost, trampling or other damage such as insect or hail damage has checked growth of the crop. Prussic acid prevents oxygen reaching the animal's tissues. Prussic acid may decrease feed intake, milk production and growth rates and in severe cases can cause death. Most acutely affected animals die quickly, within 15–20 minutes after consuming the forage. Symptoms of acute poisoning include rapid, heavy breathing, frothing at the mouth, muscular twitching, convulsions, staggering and coma.

All sorghums have the potential to induce prussic acid poisoning. However, grain sorghums, sweet forage sorghum and delayed-flowering varieties have a much higher cyanide potential than other varieties. The toxin can be present in dangerous amounts at any growth stage of the crop, with the least risk of cyanide in flowering or seeding plants. Cyanide concentrations above 600 ppm are generally considered hazardous but levels as low as 200 ppm can be dangerous for very hungry animals in a drought.

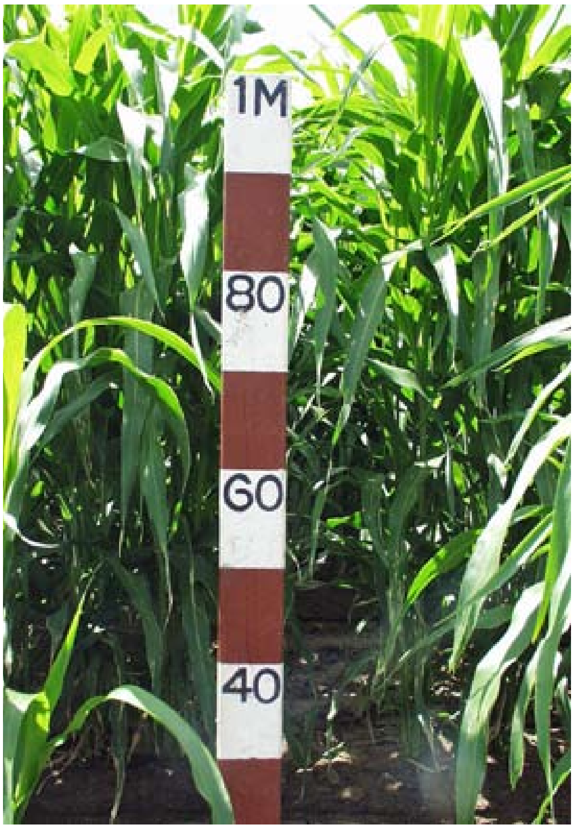
In practice, the number of deaths due to prussic acid poisoning is very small compared to the number of animals grazing forage sorghums. The following guidelines can minimise the risks of toxicity:

- avoid grazing stressed young sorghum plants or stressed regrowth

- delay grazing until plants are over 45 cm for shorter varieties or over 75 cm for tall varieties
- do not put hungry stock onto sorghum crops, particularly if the crop is wilted or stressed
- watch stock for the first hour of grazing and then check on them regularly for the first few days
- keep a supply of sodium thiosulphate on hand for emergency treatment of cyanide poisoning. If any cattle show signs of toxicity or death, drench all cattle immediately with 60 g of sodium thiosulphate in 600 mL of water. Repeat this drench hourly until the animal recovers. Alternatively, a veterinarian can administer the more effective intravenous injection of sodium thiosulphate
- supplement stock on sorghum crops with sulphur (e.g. 10% sulphur in a salt lick). Sorghums are generally low in sulphur but sulphur is required for detoxifying cyanide in the rumen and liver
- test any hay and silage made from sorghums considered high-risk prior to feeding out.

Ergot poisoning from sorghum

Sorghum ergot is caused by a fungus, *Claviceps africana*. Ergot infects sorghum plants during flowering, particularly in cold weather, with a fungal body (sclerote) replacing the ovaries of infected panicles (flowering heads). Sclerotes of *C. africana* contain toxic chemicals, in particular the alkaloid dihydroergosine (DHES) which have caused hyperthermia (or overheating) and reduced growth rates in cattle fed diets containing 1–2 mg DHES/kg.



Little is known about the effect of ergot on livestock grazing on infected forage sorghum. The dose ingested by grazing cattle is dependant on the degree of ergot infection and development in the panicles, dilution with other plant material and animal selection. The risk will be higher if cattle preferentially select infected grain heads. Watch cattle grazing on infected forage sorghum crops closely for signs of ergot poisoning. These include signs of overheating such as excessive salivation, seeking shade and standing in water. Move affected stock quietly onto alternative feed during a cool time of day.

Preferably, graze or cut forage sorghum for silage before flowering, particularly in late summer and early autumn when the risk of ergot infection is highest. In crops that have flowered less than three weeks previously, the amount of DHES consumed by grazing cattle should be below the level that adversely affects weight gain in beef cattle. Ensilation of forage sorghum in the early stages of ergot infection (prior to sclerote formation) further reduces the risk. Trials have showed that alkaloid levels in silage containing ergot-infected seed heads were reduced by about 50% after six weeks.

Nitrate and nitrate poisoning

Under conditions of high soil nitrate levels and slow growth, forage crops can accumulate high levels of nitrates. Forage sorghum, grain sorghum, sudan grass, sudan grass hybrids and pearl millet are well-recognised nitrate accumulators. Rumen microbes break down nitrate to form nitrite which is much more toxic than nitrate, reducing transfer of oxygen to the tissue and causing sudden death in severe cases. Acutely affected animals develop a bluish tinge in their eyes and lips and have a weak, rapid pulse. Other symptoms include increased rate and depth of respiration, muscular twitching, staggering, collapse, convulsions and coma. The blood is typically dark brown.

Plants with more than 1.5% potassium nitrite on a dry matter basis are potentially dangerous to hungry stock. Animals can acclimatise to large concentrations of nitrate if introduced to the forage gradually. However, any sudden increase in feed intake or the feeding of supplements containing monensin can lead to poisoning due to changing the rumen bacteria's capacity to degrade the nitrate.

Poisoned animals found alive can be saved. Intravenous injection of methylene blue, at a dose rate of 2 mg/kg at a concentration of 2–4% in water (20 g in a litre) can prevent and treat nitrate poisoning. It is best if a veterinarian administers the injection.

Use the following strategies to reduce the risk of nitrate and nitrite poisoning:

- analyse feeds and forages for nitrate concentrations prior to grazing
- feed hungry stock on dry roughage or mature grass before providing free-access to potentially risky feed
- prevent hungry stock from grazing recently sprayed weeds
- prevent hungry stock from gorging on highly fertilised crops
- moderate the stocking rate on high-risk crops to minimise the amount of stem consumed because the stem contains the highest concentrations of nitrate
- observe stock frequently after they are introduced to potentially high-risk feeds
- do not graze high-nitrate crops for seven days after periods of rainfall, cloudy days, frosts or high temperatures that cause wilting
- graze stock on high-nitrate crops during sunny afternoons and remove them at night when nitrate levels accumulate
- harvest forages containing high-nitrate levels and feed as silage because the fermentation process during ensilage reduces the nitrate levels.

Hypomagnesaemia (oat tetany)

Hypomagnesaemia occurs mainly in adult cattle, especially cows in the first few months of lactation. It can occur when cattle are suddenly introduced to high quality forage with inherently low magnesium levels, such as oats, especially if they have been fertilised with nitrogen and phosphorus. Although low blood magnesium levels are always present the disorder is complex involving interactions between magnesium, potassium, sodium and nitrogen. Convulsions and death can occur within a few hours. Less acute symptoms include agitation, muscle tremor, staggering, staring eyes and frothing at the mouth.

The threat of hypomagnesaemia can be reduced by giving cattle on highly digestible forages such as oats access to grass pastures and by feeding magnesium supplements, such as Causmag. Treat affected animals with subcutaneous injections of calcium and magnesium.

Internal parasites

Cattle under two years of age can be susceptible to parasites, especially at times of stress such as weaning. As cattle are concentrated on forage crops this favours the build up of internal parasites.

Symptoms of worm burden include:

- rough and dull coat
- loss in condition
- scouring
- sunken eyes
- pale eyes and lips
- bottle jaw (swelling under the jaw).

Use a worm test kit to assess the worm burden of young cattle prior to deciding whether to drench. Kits such as Wormcheck are available at rural services outlets and some veterinary practices. If problem egg counts are detected drench cattle prior to introducing them to clean paddocks. Grazing management techniques such as rotational grazing can help prevent reinfestation from contaminated pastures.

Poisoning from dump sites and weeds

When lush forages form the sole diet, cattle may be attracted to different types of plants or to licking or ingesting materials that they would not normally consume. To prevent poisoning and/or unacceptable chemical residue levels in the beef produced fence off old dump sites to prevent access. Producers should also be wary of the availability of poisonous weeds, such as lantana or poison peach, in the forage grazing area.

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Training courses

The Queensland Department of Employment, Economic Development and Innovation (DEEDI) delivers EDGEnetwork Workshops which are tailored to your local area. Workshops focussing on ruminant nutrition and grazing management strategies include the ‘Nutrition EDGE’ and ‘Grazing Land Management’ courses, respectively. Contact your local DEEDI beef extension officer (on 13 25 23) for more information or find more details at www.mla.com.au.

7

Economic evaluation

Example economic analyses are presented for three sites across the Fitzroy River catchment, representing the South Queensland Brigalow region (Taroom–Wandoan area), the Central Queensland Brigalow region (Bauhinia–Theodore area) and the Central Queensland Open Downs region (Capella area). These three sites have been used as case study sites throughout this guide. Representative data for climate and forage yield at the three sites are given in this guide in chapters 3 and 5, respectively.

The economic results given here are an example of the costs and returns that might be expected for different forages in different regions when used to finish steers. You can use the sample spreadsheets provided with this guide to calculate your own estimates based on your production and input figures and to test alternative scenarios. Detailed instructions on how to use the spreadsheets are included.

The case study examples given here were calculated using a partial budgeting approach and do not include analysis of alternative methods of funding the investment nor the impact on the whole-farm cash flow. These factors should be taken into consideration in making the final investment decision. In addition to the relative economic merit of forage options, an assessment of social, environmental and managerial factors is an important step in the decision-making process. These additional factors are outlined in chapter 8.

General description of the analyses

The three case studies are based on the following areas:

- Site 1: South Queensland Brigalow (Taroom–Wandoan area)
- Site 2: Central Queensland Brigalow (Bauhinia–Theodore area)
- Site 3: Central Queensland Open Downs (Capella area).

Six forage types were modelled at each of the sites:

- the annual forages: oats, sorghum and lablab
- perennial forage systems: butterfly pea–grass (i.e. a mixed sward of butterfly pea and grass) and leucaena–grass
- baseline pasture: buffel grass at Sites 1 and 2, and Queensland bluegrass pasture at Site 3.

Zero till and cultivation methods of fallow weed control were compared for each of the sown forages.

A description of each of the case study sites and the general assumptions used in the analysis are detailed in appendix 1. Cattle production from each of the forage types was assessed, comparing the scenario of steers finished to the same target weight (596 kg liveweight; 310 kg carcass weight) at each site. Cattle were assumed to enter the system at a weight sufficient to reach the target turn-off weight within the specified grazing period, and were valued at this entry weight. The grazing days, stocking rate and daily liveweight gain for each forage at each site were based on an assessment of measured values in both unpublished and published reports and the considered judgement of DEEDI beef research and extension staff. These values are based on the assumption that forages have been grown and grazed using best-practice agronomic management and represent the expected long-term average performance across all seasons.

Gross margins

Agronomic, livestock production and market data were used to produce gross margin (GM) results for each of the annual forages and for the baseline pasture. The GM for an operation is equivalent to the gross income received from sale of cattle less the variable costs incurred. Variable costs include both cattle and forage development costs and are directly attributable to an individual animal or production unit, which varies in proportion to the size of the operation. Examples of cattle costs include purchase cost, freight and animal health expenses. For the annual forage crops (oats, forage sorghum and lablab) the variable costs of planting were subtracted from the net cattle income to calculate a GM for the system.

There were assumed to be no variable costs associated with establishing or maintaining the baseline pastures, therefore the GM for baseline pastures was calculated based only on livestock costs and income. The GM values reported for the baseline pastures are annualised figures although the actual production cycle (from weaning to achieving finishing weights) is greater than one year. The annualised figures were used to allow comparison to the alternative forages that have varying production cycles.

Net cattle income

Net cattle income was calculated for the perennial legume–grass forage systems (butterfly pea–grass and leucaena–grass) in order to allow sensitivity analyses on cattle sale and purchase price and daily liveweight gain, as for the annual forages. The net cattle income was calculated using the gross income from cattle and subtracting livestock costs. The costs associated with forage development were not included in this calculation because these costs do not occur annually. These figures should not be compared directly to the GM calculated for the annual forages.

Sensitivity analyses

Two sets of sensitivity analyses on GM and net cattle income values were conducted assuming the zero till method of fallow weed control. The first set of analyses calculated the change in annual GM or net cattle income per hectare over a range of cattle sale prices and daily cattle liveweight gain. All other variables (e.g. purchase price, stocking rate, grazing days etc) remained the same as in the original analysis. The second set of sensitivity analyses calculated the change in annual GM or net cattle income per hectare over a range of cattle purchase and sale prices ($/kg liveweight and $/kg carcass weight, respectively) with all other variables remaining the same as in the original analysis.

Net present value

The term net present value (NPV) refers to the net returns (income minus costs) over the life of an investment (in this case forage systems), expressed in present day terms.

For the perennial legume–grass forage systems, the planting and establishment costs are incurred in only some years with production benefits occurring beyond those years. To allow comparison of the range of annual and perennial forage systems on the same basis, a discounted cash flow (DCF) was constructed for each of the forage types. A DCF allows future cash flows (costs and income) to be discounted back to a net present value (NPV) so that investments over varying time periods can be compared. The investment with the highest NPV is preferred.

In our analyses, the NPV shows the total net returns over the 30-year period of investment. The annualised NPV was also presented to show the average net annual return from each forage over the 30-year period. An initial discount rate of 7% was assumed, which is a reasonable estimate of the cost of capital in 2010. Sensitivity analyses were also conducted at 6% and 8% to examine the robustness of the results and showed that there was no change in the relative ranking of NPV values. The DCF was calculated over a period of 30 years, which is estimated to be the productive life span of leucaena.

The production income and costs for each of the annual forage crops were adjusted to account for the proportion of years that conditions were suitable for sowing (less than 100% of years for oats at all sites and for lablab at Site 3), while the butterfly pea-grass pasture was planted on a 5-year rotation. Production rates varied over time for the butterfly pea-grass and leucaena-grass systems as a result of the lag between planting and full production. The assumptions used in accounting for these factors are outlined in appendix 1.

Time value of money

The concept behind the NPV methodology is the 'time value of money', that is, the value of money including a given amount of interest earned over a specified length of time. For example, $100 of today's money invested for one year and earning 5% interest will be worth $105 after one year. Therefore, $100 paid now or $105 paid in one year, have the same value to the recipient.

Discounted cash flow

Figure 5 shows how the net cash flow compares to the DCF for the example of investing in leucaena–grass forage. In the first couple of years there are large cash outflows (negative) before income from year 3 makes the cash flow positive. The DCF takes into account the time value of money and shows how money received now is worth more than money received in the future.

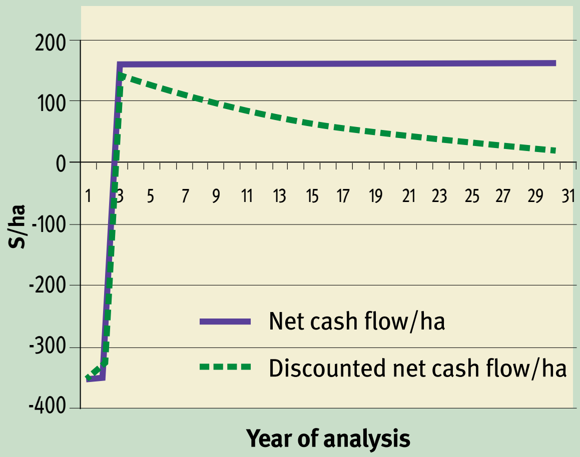


Figure 5. Net cash flow compared to discounted cash flow (DCF) for an investment in leucaena–grass forage

Cumulative cash flow

In addition to the NPV analysis a cumulative cash flow was calculated for each of the forage types (both annual and perennial) by adding the net cash flow (not discounted) for each year, to the year before. The cumulative cash flow shows when cash flows will be positive and negative over the life of the investment to assist in budgeting. Cumulative cash flows should not be used as an indicator of the preferred forage investment. NPV is the most appropriate indicator.

Comparisons across regions

The objective of the economic analyses was to allow comparisons between forages within a region or site, not across the regions. As a result, some assumptions differ between sites. For example, compared to the central Queensland sites, cattle grazing the baseline pasture at the South Queensland Brigalow site were assumed to be joined one month earlier and thus the steers to be one month older at weaning (see appendix 1 for details).

Partial budgets vs. whole-farm analysis

The case study calculations shown here were based on partial budgets comparing the use of improved forages to baseline pasture for a specific enterprise. A partial budget analysis considers only those costs and benefits directly related to the investment activity and does not incorporate indirect impacts on the whole farm. The impact on whole-farm profitability requires consideration of a number of additional factors. For example, improved carrying capacity and faster turnoff may increase the number of breeders required. Additional overheads and significant changes to labour requirements (beyond contract planting etc) should also be considered. As these factors are specific to each individual business it was not possible to examine these in the case studies. Phase 2 of this project will create some whole-farm case studies to examine the impact on whole-farm profitability and to provide a process and tools to assist with more detailed analysis.

Summary of results

The following tables provide a summary of the results from this study. Please note that these are based on partial budget calculations for a specific enterprise and do not consider flow-on effects to whole-farm profitability. For more detailed results for each of the three case study sites please go to the individual sections for:

- Case study 1 – South Queensland Brigalow
- Case study 2 – Central Queensland Brigalow
- Case study 3 – Central Queensland Open Downs

Tables 10–12 show the net present value (NPV) results for all forages and the baseline pasture. The NPV analysis includes all pasture development costs, livestock costs and income over a 30-year period. Net cash flows in each year are discounted back to present values. The summary tables also present the assumed figures for grazing days, stocking rate and animal performance for each forage type.

The results for South Queensland Brigalow (table 10) show that over a 30-year period an investor would receive returns of $1415 per hectare if leucaena–grass (zero till) was planted versus $568 per hectare if they continued to use the existing baseline buffel grass pasture. Note that even though oats produces the greatest annual liveweight gains per hectare, it does not produce the greatest returns. This is due to the requirement to plant annually and the proportion of years in which conditions are not suitable for planting. In addition, oats has a shorter grazing period compared to the perennial legume–grass pastures and this results in a higher cattle purchase price when cattle are finished to the same target weight, as in this example.

Table 10. South Queensland Brigalow: comparison of cattle production and net present value[A] (NPV) for key forage options over a 30-year period

	Forage					
	Baseline pasture (buffel)	Oats	Forage sorghum	Lablab	Butterfly pea–grass	Leucaena–grass
NPV ($/ha)						
Zero till	$568	$388	–$61	–$802	$630	$1415
Cultivation	$568	–$168	–$1027	–$1768	$410	$1301
Liveweight gain (kg/ha/year)[B]	54[C]	202[D]	153	139[D]	99[C]	110[C]
Liveweight gain (kg/head/day)	0.41	1.1	0.55	0.8	0.6	0.9
Stocking rate (AE/ha)	0.33	2.3[D]	2.5	2.3[D]	0.8	0.55
Grazing days (days/year)	365	90	130	90	240	240

The results for Central Queensland Brigalow (table 11) show that over a 30-year period an investor would receive returns of $2444 per hectare if forage sorghum (zero till) was planted versus $679 per hectare if they continued to use the existing baseline buffel grass pasture.

Table 11. Central Queensland Brigalow: comparison of cattle production and net present value[A] (NPV) for key forage options over a 30-year period

	Forage					
	Baseline pasture (buffel)	Oats	Forage sorghum	Lablab	Butterfly pea–grass	Leucaena–grass
NPV ($/ha)						
Zero till	$679	$728	$2444	$799	$1184	$2131
Cultivation	$679	$172	$1478	–$167	$964	$2017
Liveweight gain (kg/ha/year)[B]	58[C]	147[D]	185	157[D]	104[C]	138[C]
Liveweight gain (kg/head/day)	0.43	1.1	0.6	0.8	0.6	0.9
Stocking rate (AE/ha)	0.33	1.8[D]	3.0	2.3[D]	0.8	0.6
Grazing days (days/year)	365	83	120	100	250	270

The results for Central Queensland Open Downs (table 12) show that over a 30-year period an investor would receive returns of $1581 per hectare if leucaena (zero till) were planted versus $285 per hectare if they continued to use the existing baseline buffel grass pasture. Note that even though forage sorghum produces the greatest annual liveweight gain per hectare, it does not produce the greatest returns. This is due to the requirement to plant annually as well as the shorter grazing period compared to the perennial legume–grass pastures which, in turn, results in a higher cattle purchase price when cattle are finished to the same target weight as in this example.

Table 12. Central Queensland Open Downs: comparison of cattle production and net present value[A] (NPV) for key forage options over a 30-year period

	Forage					
	Baseline pasture (native)	Oats	Forage sorghum	Lablab	Butterfly pea–grass	Leucaena–grass
NPV ($/ha)						
Zero till	$285	–$468	$899	$387	$1497	$1581
Cultivation	$285	–$683	$397	–$509	$1282	$1417
Liveweight gain (kg/ha/year)[B]	26[C]	145[D]	203	157[D]	124[C]	138[C]
Liveweight gain (kg/head/day)	0.38	1.1	0.6	0.8	0.65	0.9
Stocking rate (AE/ha)	0.17	2.0[D]	3.0	2.3[D]	0.8	0.6
Grazing days (days/year)	365	76	130	100	270	270

Definition of terms and calculations in tables

[A] Net present value is the sum of discounted values of future income and costs associated with an investment.

[B] Liveweight production figures not adjusted for the percentage of years with unsuitable conditions for sowing oats and lablab or for the time-lag in production after planting the perennial legume-grass forage systems. Note that the economic figures have been adjusted to account for these factors.

[C] Liveweight gain (kg/ha/year) of perennial pastures was calculated using a stocking rate of actual animals/hectare determined from stocking rate in AE/ha, at the liveweight of steers at the half-way point. AE (adult equivalents): 450 kg, non-lactating beast.

[D] Liveweight gain (kg/ha/year) of oats and lablab is the production from total area, including access to grass pasture as 10% of the total grazing area.

Best-bet forage options

The economic analyses based on the example case study sites showed that a leucaena–grass pasture generally provided the highest returns over a 30-year period, under either zero till or cultivation methods of fallow weed control, when compared to other key perennial legume–grass and annual forage options. The exception was the Central Queensland Brigalow scenario under zero till, where leucaena–grass pasture ranked second for NPV, after forage sorghum. In these scenarios there was a lag time of 3–7 years after planting before cash flow from leucaena–grass systems became positive. Leucaena–grass pastures produced a negative cash flow for a greater number of years under the Central Queensland Open Downs scenario than for the South and Central Queensland Brigalow scenarios due to the longer planting schedule assumed for the Open Downs site (planting over five years vs. two). The other perennial, legume–grass pasture examined in this study, butterfly pea–grass, also performed well, ranking second or third in terms of NPV, for the three sites and two methods of fallow weed control.

Forage sorghum produced a high NPV, generally much greater than the baseline pasture, for Central Queensland Brigalow and Central Queensland Open Downs sites in our example scenarios. However, forage sorghum produced negative NPV for the South Queensland Brigalow site. The other annual forage crops, lablab and oats, produced much lower NPV than the legume–grass pastures for all sites and produced lower returns than the baseline pastures for some combinations of site and fallow weed control method.

Other than the cost of planting, other major factors that determined the relative profitability of the forages included the assumed daily cattle liveweight gain and the stocking rate. Sensitivity analyses were not performed on stocking rate for these scenarios. At all three sites, growing annual forages had a relatively high risk of producing negative returns under some livestock sale price and liveweight gain combinations. The risk of producing negative returns was inversely related to the size of the forage GM, which was estimated for the assumed market prices and liveweight gain, in the example scenarios. For example, at the South and Central Queensland Brigalow sites, lablab produced the lowest GM of the annual forages and had the highest risk of producing negative returns. The lower GM for lablab was largely due to its relatively higher planting costs, in particular, the requirement for in-crop chemical weed control using imazethapyr (e.g. Spinnaker), which has a high cost of application per hectare ($70/ha assumed in our scenarios). Sensitivity analyses on net cattle income from perennial legume–grass forages and baseline pasture showed that, at the assumed sale price in the example scenarios, all forages maintained a positive net cattle income across the range of possible liveweight gains. The implications are that if average liveweight gain varies slightly from the assumed values in the example scenarios, returns will remain positive given that all other factors remain constant.

It is important to note that the relative ranking of forages within a site differed for modelled animal production (kg/ha/year) and economic performance in terms of NPV. The liveweight production figures (kg/ha/year) were indicative of the average production for that forage type for years in which the forage was planted and were not adjusted for the percentage of years with unsuitable conditions for planting or for the time-lag in production after planting the perennial legume–grass forage systems. Both of these aspects were accounted for in the economic modelling, producing a more accurate ranking of forages in terms of overall performance. Other factors that were taken into account in the economic analysis and contributed to differences in ranking of forages for NPV vs. animal performance include differences between forages in:

- planting costs (e.g. annuals incur planting costs every year but perennials less regularly)
- seed, fertiliser and chemical costs
- animal health treatments (e.g. 5-in-1 vaccinations for oats and rumen fluid inoculum for leucaena–grass pasture)
- grazing days, which affects purchase price when animals are finished to the same finishing weight as in our examples (e.g. less grazing days means buying animals that are heavier and thus more expensive).

The results described in this report highlight the importance of considering economic performance, in addition to agronomic and livestock performance, when comparing forage options. However, while the economic outcome of using a particular forage option is of critical importance to a beef business, social and environmental factors will also influence management and business decisions. Beef producers also need to consider factors that affect the integration of the chosen forage system into the whole-of-business

and existing property operations. In the economic analyses conducted for these example scenarios, only the scenario of finishing steers has been considered. Other uses of high quality forages include backgrounding or growing out steers prior to the finishing stage and providing high quality feed for special classes of cattle such as cull cows, weaners or replacement heifers. The evaluation of social, environmental and management factors that may influence decisions about whether to invest in improved forage systems is discussed further in chapter 8.

Zero till vs. cultivation methods of fallow weed control

The ranking of forages for NPV differed between zero till and cultivation methods of fallow weed control due to differences in planting costs between the systems. Using the zero till method of fallow weed control produced higher returns than using cultivation for all forages grown at each of the three sites due to the relatively higher operating cost of machinery required for the cultivation systems. However, this result is highly dependent on the assumed chemical, fertiliser and fuel prices, the variations of which were not included in this analysis. Although not examined in this analysis, it is likely that returns when using the zero till fallow weed control method could be more variable than returns under cultivation due to the volatility in chemical costs. The probability of significant rises in planting costs is an area that may be considered in the detailed risk analysis to be conducted in the proposed Phase 2 of this project. Another factor that may influence the relative profitability of the zero till versus the cultivation method of fallow weed control is the use of owner-operated machinery rather than using contract rates as was assumed in our analyses. However, owner-operators should include the costs of owning machinery and their own labour in their calculations when making comparisons of returns relative to baseline pastures.

Differences in ranking of forage NPV between regions

Although it was not our intention that comparisons be made across sites it is worth noting that, in general, the sown forage options at the South Queensland Brigalow site produced lower NPV relative to the central Queensland sites, under the assumptions used in these example scenarios. The exception was oats, which produced higher NPV at the South Queensland Brigalow site than the Central Queensland Open Downs site. The generally lower NPV at the South Queensland Brigalow site were due to relatively higher cattle prices purchased out of Roma saleyards (cf. Gracemere) and greater distances to slaughter at Dinmore (vs. Biloela or Rockhampton meatworks). In addition, with the exception of oats, assumed cattle production (in kg/ha/yr) was lower at the South Queensland site for all sown forage options. This was a result of the assumed soil fertility and climatic differences as defined in appendix 1.

Generally, forages ranked differently between sites, in terms of GM and NPV, due to a combination of factors rather than any single factor.

For example, the GM for forage sorghum was $184/ha for the Central Queensland Brigalow site, $68/ha for the Central Queensland Open Downs site and –$5/ha for the South Queensland Brigalow site. A key difference was that the South Queensland Brigalow site had an assumed stocking rate on forage sorghum of 2.5 AE/ha compared to 3 AE/ha for the Central Queensland Brigalow and Central Queensland Open Downs sites. This reduced the amount of beef produced per hectare from the southern Brigalow site, reducing income generated. In addition, costs differed across the three sites. The Central Queensland Open Downs and South Queensland Brigalow sites were assumed to require nitrogen fertiliser, which significantly increases the cost of planting (both in fertiliser and additional machinery operations). Also, animals were expected to gain only 0.55 kilograms per day on the southern site versus 0.60 kilograms per day on the two central Queensland sites. This may not seem significant but a lower weight gain means a higher entry weight is required to finish cattle within the set time-frame. This means heavier, and therefore more expensive, cattle must be purchased. The higher value of these cattle also increased the cost of interest on livestock capital. Furthermore, it was assumed that cattle in the southern region would be slightly more expensive per kilogram to purchase than central Queensland cattle, based on expected breed type and saleyard prices. The southern region was also assumed to have higher cattle freight costs due to the greater distance to slaughter.

Similar factors explain the differences between other forages across regions. For full details on the assumptions that determined the results reported here please see the tables in appendix 1.

Case study site 1: South Queensland Brigalow (Taroom–Wandoan area)

Results

Annual forages

The gross margins (GM) per hectare for annual forages and baseline pasture grown at the South Queensland Brigalow site are shown in table 13. In this case study the baseline buffel grass pasture produced a higher GM per hectare than the analysed annual forages. Oats grown under zero till was the only annual forage that produced a positive gross margin. The zero till method of fallow weed control produced greater returns than the cultivation system, for all annual forages. Sensitivity analyses for forages grown using the zero till method of fallow weed control showed that all annual forages produced positive GM under some possible liveweight gain and sale price combinations as well as purchase and sale price combinations. Tables 14 and 15 present a sub-set of key results from the sensitivity analyses. The full sensitivity analyses are presented in appendix 2.

Oats had the least risk of producing negative returns due to the relatively higher GM, compared to forage sorghum and lablab, under the assumed liveweight gain and market prices in the scenario.

Table 13. South Queensland Brigalow: comparison of net cattle income, planting costs and gross margins ($/ha/year) for cattle production on baseline pasture or annual forage crops

			Forage		
		Baseline pasture (buffel)	Oats	Forage sorghum	Lablab
Zero till	Net cattle income	$43	$288	$197	$190
	Planting costs	N/A	$246	$202	$250
	Gross margin	**$43**	**$42**	**–$5**	**–$60**
Cultivation	Net cattle income	$43	$288	$197	$190
	Planting costs	N/A	$307	$275	$323
	Gross margin	**$43**	**–$18**	**–$77**	**–$133**

Table 14. South Queensland Brigalow: sensitivity analysis for gross margins ($/ha/year) in relation to daily liveweight gain. Zero till method of fallow weed control was used. The values in bold highlight the GM for the assumed sale price and liveweight gain in the defined scenarios

	Livestock sale price ($/kg carcass weight)	Liveweight gain (kg/head/day)				
Baseline pasture (buffel)		0.33	0.37	**0.41**	0.45	0.49
	$3.10	$34	$39	**$43**	$47	$51
Oats	Livestock sale price ($/kg carcass weight)	0.90	1.00	**1.10**	1.20	1.30
	$3.20	–$26	$8	**$42**	$77	$111
Forage sorghum	Livestock sale price ($/kg carcass weight)	0.35	0.45	**0.55**	0.65	0.75
	$3.20	–$113	–$59	**–$5**	$50	$104
Lablab	Livestock sale price ($/kg carcass weight)	0.60	0.70	**0.80**	0.90	1.00
	$3.20	–$129	–$95	**–$60**	–$26	$9

Table 15. South Queensland Brigalow: sensitivity analysis for gross margins ($/ha/year) in relation to cattle purchase price. Zero till method of fallow weed control was used. The values in bold highlight the GM for the assumed sale price and purchase price in the defined scenarios

	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
Baseline pasture (buffel)		$1.80	$1.90	**$2.00**	$2.10	$2.20
	$3.10	$50	$46	**$43**	$39	$36
Oats	Livestock sale price ($/kg carcass weight)	$1.40	$1.50	**$1.60**	$1.70	$1.80
	$3.20	$271	$157	**$42**	–$72	–$186
Forage sorghum	Livestock sale price ($/kg carcass weight)	1.40	1.50	**1.60**	1.70	1.80
	$3.20	$258	$127	**–$5**	–$136	–$267
Lablab	Livestock sale price ($/kg carcass weight)	$1.40	$1.50	**$1.60**	$1.70	$1.80
	$3.20	$181	$60	**–$60**	–$181	–$301

Perennial forages

Table 16 shows the net cattle income on perennial pastures. This is calculated as the gross cattle income minus livestock costs and does not include any pasture development costs. Gross margins cannot be calculated for perennial pastures in the same way as for annuals as development costs and production returns occur in different years. The cost of establishing the forages is given in table 17. In general, net cattle income remained positive across the range of considered liveweight gains and purchase and sale prices which is significant given the likelihood of variation in these variables across production cycles. Tables 18 and 19 present a sub-set of key results from the sensitivity analyses. The full sensitivity analyses are presented in appendix 2.

Table 16. South Queensland Brigalow: comparison of net cattle income[A] ($/ha/year) for cattle production on baseline pasture and perennial legume-grass forages

	Forage Baseline pasture (buffel)	Butterfly pea–grass	Leucaena–grass
Zero till and cultivation	$43	$139	$159

[A] Net cattle income calculated as gross income from cattle minus livestock costs (purchase costs, animal health etc). The costs of forage development are not accounted for.

Table 17. South Queensland Brigalow: comparison of establishment costs ($/ha) for baseline pasture and perennial legume-grass forages

	Forage Baseline pasture (buffel)	Butterfly pea–grass	Leucaena–grass
Zero till	$N/A	$311	$265
Cultivation	$N/A	$384	$343

Table 18. South Queensland Brigalow: sensitivity analysis for net cattle income ($/ha/year) in relation to daily liveweight gain. Zero till method of fallow weed control was used. The values in bold highlight the net cattle income for the assumed sale price and liveweight gain in the defined scenarios

Baseline pasture (buffel)	Livestock sale price ($/kg carcass weight)	Liveweight gain (kg/head/day) 0.33	0.37	**0.41**	0.45	0.49
	$3.10	$34	$39	**$43**	$47	$51
Butterfly pea–grass	Livestock sale price ($/kg carcass weight)	Liveweight gain (kg/head/day) 0.40	0.50	**0.60**	0.70	0.80
	$3.20	$75	$107	**$139**	$171	$203
Leucaena–grass	Livestock sale price ($/kg carcass weight)	Liveweight gain (kg/head/day) 0.70	0.80	**0.90**	1.00	1.10
	$3.20	$115	$137	**$159**	$181	$203

Table 19. South Queensland Brigalow: sensitivity analysis for net cattle income ($/ha/year) in relation to cattle purchase price. Zero till method of fallow weed control was used. The values in bold highlight the net cattle income for the assumed sale price and purchase price in the defined scenarios

Baseline pasture (buffel)	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight) $1.80	$1.90	**$2.00**	$2.10	$2.20
	$3.10	$50	$46	**$43**	$39	$36
Butterfly pea–grass	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight) $1.40	$1.50	**$1.60**	$1.70	$1.80
	$3.20	$212	$175	**$139**	$103	$67
Leucaena–grass	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight) $1.40	$1.50	**$1.60**	$1.70	$1.80
	$3.20	$201	$180	**$159**	$138	$118

All forages

Table 20 shows the net present value (NPV) for all forages and for the baseline pasture. The NPV analysis includes all pasture development costs, livestock costs and income over a 30-year period. Net cash flows in each year are discounted back to present values. The results showed that over a 30-year period an investor would receive returns of $1415/ha if leucaena (zero till) were planted versus $568/ha if they continued to use the existing baseline buffel grass pasture. Table 20 also shows the assumed cattle production from each of the forage types. Note that even though oats produced the greatest liveweight gain per hectare per year, it did not produce the greatest returns. This is due to the requirement to plant annually and the shorter grazing period compared to perennial legume–grass pastures, which necessitates purchasing heavier animals when finishing at the same target weight, as in our example scenarios.

Table 20. South Queensland Brigalow: comparison of cattle production and net present value[A] (NPV) for key forage options over a 30-year period

		Forage				
	Baseline pasture (buffel)	Oats	Forage sorghum	Lablab	Butterfly pea–grass	Leucaena–grass
NPV ($/ha)						
Zero till	$568	$388	–$61	–$802	$630	$1415
Cultivation	$568	–$168	–$1027	–$1768	$410	$1301
NPV ($/ha/year)						
Zero till	$19	$13	–$2	–$27	$21	$47
Cultivation	$19	–$6	–$34	–$59	$14	$43
Liveweight gain (kg/ha/year)[B]	54[C]	202[D]	153	139[D]	99[C]	110[C]
Liveweight gain (kg/head/day)	0.41	1.1	0.55	0.8	0.6	0.9
Stocking rate (AE/ha)	0.33	2.3[D]	2.5	2.3[D]	0.8	0.55
Grazing days (days/year)	365	90	130	90	240	240

[A] Net present value is the sum of discounted values of future income and costs associated with an investment.

[B] Liveweight production figures not adjusted for the percentage of years with unsuitable conditions for sowing oats and lablab or for the time-lag in production after planting the perennial legume-grass forage systems. Note that the economic figures have been adjusted to account for these factors.

[C] Liveweight gain (kg/ha/year) of perennial pastures was calculated using a stocking rate of actual animals/hectare determined from stocking rate in AE/ha, at the liveweight of steers at the half-way point. AE (adult equivalents): 450 kg, non-lactating beast.

[D] Liveweight gain (kg/ha/year) of oats and lablab is the production from total area, including access to grass pasture as 10% of the total grazing area.

Figures 6 and 7 show the cumulative (not discounted) cash flow for each of the forages and the baseline pasture. As shown in these figures the higher initial investment in leucaena–grass pasture resulted in a negative cash flow for the first four years for the zero till system and five years for the cultivation system, after which cash flow became positive. Butterfly pea–grass pastures showed negative cash flows in some years due to the costs of replanting. The neutral cash flows in some years for oats demonstrates the effect of years in which planting did not occur due to unfavourable seasonal conditions.

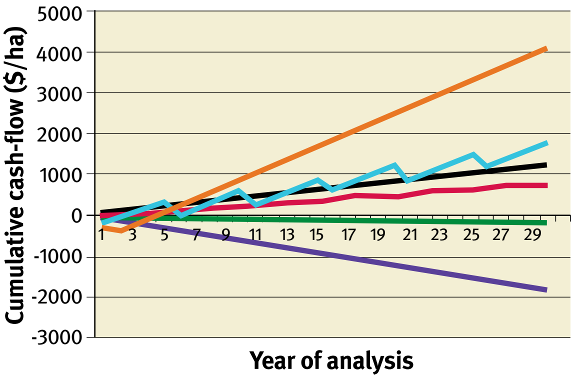


Figure 6. South Queensland Brigalow: cumulative net cash flow over a 30-year period for key forage options using the zero till method of fallow weed control.

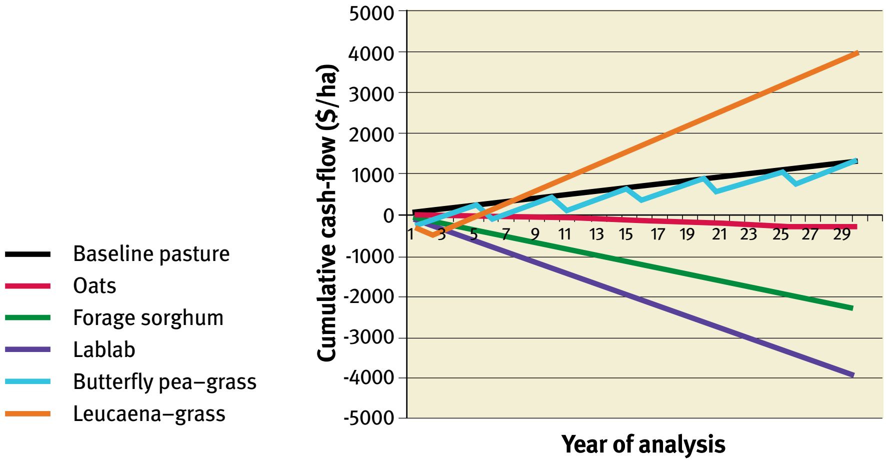


Figure 7. South Queensland Brigalow: cumulative net cash flow over a 30-year period for key forage options using the cultivation method of fallow weed control.

Case study site 2: Central Queensland Brigalow (Bauhinia–Theodore area)

Results

Annual forages

The gross margins (GM) per hectare for annual forages and baseline pasture grown at the Central Queensland Brigalow site are shown in table 21. In this case study forage sorghum produced the highest GM per hectare. The zero till method of fallow weed control produced greater returns than the cultivation system, for all annual forages. Sensitivity analyses for forages grown using the zero till method of fallow weed control showed that annual forages returned negative GM under some possible liveweight gain and sale price combinations and for some purchase and sale price combinations. Lablab had the highest risk of producing negative returns due to the relatively lower GM, compared to forage sorghum and oats, under the assumed liveweight gain and market prices used in the scenario. The lower GM for lablab was largely due to its relatively higher planting costs, in particular the requirement for in-crop chemical weed control using imazethapyr (e.g. 'Spinnaker'), which has a high cost of application per hectare ($70/ha assumed). Tables 22 and 23 present a sub-set of key results from the sensitivity analyses. The full sensitivity analyses are presented in appendix 2

Table 21. Central Queensland Brigalow: comparison of net cattle income, planting costs and gross margins ($/ha/year) for cattle production on baseline pasture or annual forage crops

			Forage		
		Baseline pasture (buffel)	Oats	Forage sorghum	Lablab
Zero till	Net cattle income	$51	$297	$357	$310
	Planting costs	N/A	$217	$173	$250
	Gross margin	**$51**	**$80**	**$184**	**$60**
Cultivation	Net cattle income	$51	$297	$357	$310
	Planting costs	N/A	$278	$246	$323
	Gross margin	**$51**	**$19**	**$111**	**–$13**

Table 22. Central Queensland Brigalow: sensitivity analysis for gross margins ($/ha/year) in relation to daily liveweight gain. Zero till method of fallow weed control was used. The values in bold highlight the GM for the assumed sale price and liveweight gain in the defined scenarios

	Livestock sale price ($/kg carcass weight)	Liveweight gain (kg/head/day)				
Baseline pasture (buffel)		0.34	0.39	**0.43**	0.47	0.52
	$3.10	$41	$46	**$51**	$56	$61
Oats	Livestock sale price ($/kg carcass weight)	0.90	1.00	**1.10**	1.20	1.30
	$3.20	$30	$55	**$80**	$104	$129
Forage sorghum	Livestock sale price ($/kg carcass weight)	0.40	0.50	**0.60**	0.70	0.80
	$3.20	$64	$124	**$184**	$244	$304
Lablab	Livestock sale price ($/kg carcass weight)	0.60	0.70	**0.80**	0.90	1.00
	$3.20	–$16	$22	**$60**	$98	$137

Table 23. Central Queensland Brigalow: sensitivity analysis for gross margins ($/ha/year) in relation to cattle purchase price. Zero till method of fallow weed control was used. The values in bold highlight the GM for the assumed sale price and purchase price in the defined scenarios

	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
Baseline pasture (buffel)		$1.80	$1.90	**$2.00**	$2.10	$2.20
	$3.10	$56	$54	**$51**	$48	$45
Oats	Livestock sale price ($/kg carcass weight)	$1.32	$1.42	**$1.52**	$1.62	$1.72
	$3.20	$261	$170	**$80**	–$11	–$102
Forage sorghum	Livestock sale price ($/kg carcass weight)	1.34	1.44	**1.54**	1.64	1.74
	$3.20	$498	$341	**$184**	$27	–$130
Lablab	Livestock sale price ($/kg carcass weight)	$1.34	$1.44	**$1.54**	$1.64	$1.74
	$3.20	$298	$179	**$60**	–$58	–$177

Perennial forages

Table 24 shows the net cattle income for cattle production on perennial pastures. This is calculated as the gross cattle income minus livestock costs and does not include any pasture development costs. Gross margins can not be calculated for perennial pastures in the same way as for annuals because development costs and production returns occur in different years. The cost of establishing the forages is given in table 25. Net cattle income remained positive across the range of considered liveweight gains and purchase and sale prices, which is significant given the likelihood of variation in these factors across production cycles. Tables 26 and 27 present a sub-set of key results from the sensitivity analyses. The full sensitivity analyses are presented in appendix 2.

Table 24. Central Queensland Brigalow: comparison of net cattle income[A] ($/ha/year) for cattle production on baseline pastures and perennial legume–grass forages

		Forage	
	Baseline pasture (buffel)	Butterfly pea–grass	Leucaena–grass
Zero till and cultivation	$51	$181	$221

[A] Net cattle income calculated as gross income from cattle minus livestock costs (purchase costs, animal health etc). The costs of forage development are not accounted for.

Table 25. Central Queensland Brigalow: comparison of establishment costs ($/ha) for baseline pasture and perennial legume–grass forages

		Forage	
	Baseline pasture (buffel)	Butterfly pea–grass	Leucaena–grass
Zero till	N/A	$311	$265
Cultivation	N/A	$384	$343

Table 26. Central Queensland Brigalow: sensitivity analysis for net cattle income ($/ha/year) in relation to daily liveweight gain. Zero till method of fallow weed control was used. The values in bold highlight the net cattle income for the assumed sale price and liveweight gain in the defined scenarios

	Livestock sale price ($/kg carcass weight)	Liveweight gain (kg/head/day)				
Baseline pasture (buffel)		0.34	0.39	**0.43**	0.47	0.52
	$3.10	$41	$46	**$51**	$56	$61
	Livestock sale price ($/kg carcass weight)	Liveweight gain (kg/head/day)				
Butterfly pea–grass		0.40	0.50	**0.60**	0.70	0.80
	$3.20	$114	$148	**$181**	$214	$247
	Livestock sale price ($/kg carcass weight)	Liveweight gain (kg/head/day)				
Leucaena–grass		0.70	0.80	**0.90**	1.00	1.10
	$3.20	$167	$194	**$221**	$248	$275

Table 27. Central Queensland Brigalow: sensitivity analysis for net cattle income ($/ha/year) in relation to cattle purchase price. Zero till method of fallow weed control was used. The values in bold highlight the net cattle income for the assumed sale price and purchase price in the defined scenarios

	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
Baseline pasture (buffel)		$1.80	$1.90	**$2.00**	$2.10	$2.20
	$3.10	$56	$54	**$51**	$48	$45
	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
Butterfly pea–grass		$1.32	$1.42	**$1.52**	$1.62	$1.72
	$3.20	$252	$216	**$181**	$145	$109
	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
Leucaena–grass		$1.32	$1.42	**$1.52**	$1.62	$1.72
	$3.20	$263	$242	**$221**	$200	$179

All forages

Table 28 shows the net present value (NPV) for all forages and for the baseline pasture. The NPV analysis includes all pasture development costs, livestock costs and income over a 30-year period. Net cash flows in each year were discounted back to present values. The results show that over a 30-year period an investor would receive returns of $2444/ha if forage sorghum (zero till) were planted versus $679/ha if they continued to use the existing baseline buffel grass pasture. Table 28 also shows the assumed cattle production from each of the forage types.

Table 28. Central Queensland Brigalow: comparison of cattle production and net present value[A] (NPV) for key forage options over a 30-year period

		Forage				
	Baseline pasture (buffel)	**Oats**	**Forage sorghum**	**Lablab**	**Butterfly pea–grass**	**Leucaena–grass**
NPV ($/ha)						
Zero till	$679	$728	$2444	$799	$1184	$2131
Cultivation	$679	$172	$1478	–$167	$964	$2017
NPV ($/ha/year)						
Zero till	$23	$24	$81	$27	$39	$71
Cultivation	$23	$6	$49	–$6	$32	$67
Liveweight gain (kg/ha/year)[B]	58[C]	147[D]	185	157[D]	104[C]	138[C]
Liveweight gain (kg/head/day)	0.43	1.1	0.6	0.8	0.6	0.9
Stocking rate (AE/ha)	0.33	1.8[D]	3.0	2.3[D]	0.8	0.6
Grazing days (days/year)	365	83	120	100	250	270

[A] Net present value is the sum of discounted values of future income and costs associated with an investment.

[B] Liveweight production figures not adjusted for the percentage of years with unsuitable conditions for sowing oats and lablab or for the time-lag in production after planting the perennial legume-grass forage systems. Note that the economic figures have been adjusted to account for these factors.

[C] Liveweight gain (kg/ha/year) of perennial pastures was calculated using a stocking rate of actual animals/hectare determined from stocking rate in AE/ha, at the liveweight of steers at the half-way point. AE (adult equivalents): 450 kg, non-lactating beast.

[D] Liveweight gain (kg/ha/year) of oats and lablab is the production from total area, including access to grass pasture as 10% of the total grazing area.

Figures 8 and 9 show the cumulative (not discounted) cash flow for each of the forages and the baseline pasture. As shown in these figures the higher initial investment costs for leucaena–grass pasture resulted in a negative cash flow for the first three years for the zero till system and four years for the cultivation system, after which cash flows became positive. Butterfly pea–grass pastures produced negative cash flows in some years due to the costs of replanting. The neutral cash flows in some years for oats demonstrates the effect of years in which planting did not occur due to unfavourable seasonal conditions. Leucaena–grass planted using zero till produced the greatest cumulative cash flow at the end of the 30-year period although it did not produce the greatest NPV. This difference is explained by the process of discounting in the NPV analysis that puts greater weight on costs (and income) early in the analysis period, as occurs for the perennial, legume–grass forage systems, particularly the leucaena–grass pasture.

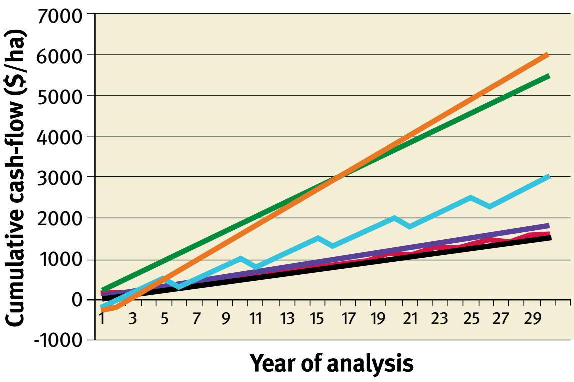
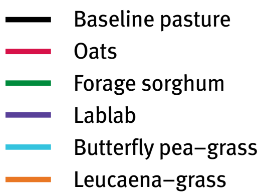


Figure 8. Central Queensland Brigalow: cumulative net cash flow over a 30-year period for forage options using the zero till method of fallow weed control.



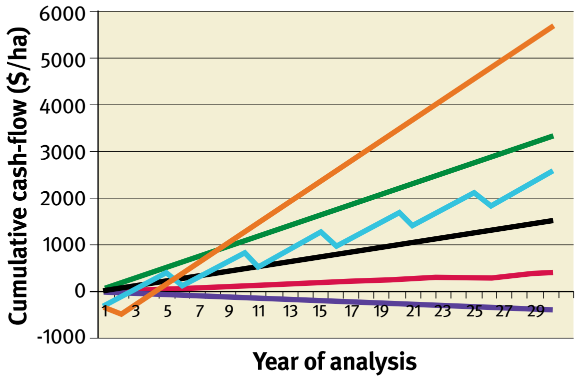


Figure 9. Central Queensland Brigalow: cumulative net cash flow over a 30-year period for forage options using the cultivation method of fallow weed control.

Case study site 3: Central Queensland Open Downs (Capella area)

Results

Annual forages

Table 29 shows the gross margins (GM) for the annual forages and baseline pasture at the Central Queensland Open Downs site. Forage sorghum produced the highest GM per hectare for both zero till and cultivation systems. Sensitivity analyses for forages grown using the zero till method of fallow weed control showed that all annual forages produced negative gross margins under some possible liveweight gain and sale price combinations as well as purchase and sale price combinations. Forage sorghum had the least risk of producing negative returns due to the relatively higher GM, compared to lablab and oats, using the assumed liveweight gain and market prices in the example scenario. Tables 30 and 31 present a sub-set of key results from the sensitivity analyses. The full sensitivity analyses are presented in appendix 2.

Table 29. Central Queensland Open Downs: comparison of net cattle income, planting costs and gross margins ($/ha/year) for cattle production on baseline pasture or annual forage crops

			Forage		
		Baseline pasture (native)	**Oats**	**Forage sorghum**	**Lablab**
Zero till	Net cattle income	$21	$263	$343	$282
	Planting costs	N/A	$319	$275	$250
	Gross margin	**$21**	**–$56**	**$68**	**$31**
Cultivation	Net cattle income	$21	$263	$343	$282
	Planting costs	N/A	$345	$313	$323
	Gross margin	**$21**	**–$82**	**$30**	**–$41**

Table 30. Central Queensland Open Downs: sensitivity analysis for gross margins ($/ha/year) in relation to daily liveweight gain. Zero till method of fallow weed control was used. The values in bold highlight the GM for the assumed sale price and liveweight gain in the defined scenarios

	Livestock sale price ($/kg carcass weight)	Liveweight gain (kg/head/day)				
Baseline pasture (native)		0.31	0.35	**0.39**	0.43	0.47
	$3.10	$17	$19	**$21**	$24	$26
Oats		0.90	1.00	**1.10**	1.20	1.30
	$3.20	–$107	–$82	**–$56**	–$31	–$6
Forage sorghum		0.40	0.50	**0.60**	0.70	0.80
	$3.20	–$62	$3	**$68**	$133	$197
Lablab		0.60	0.70	**0.80**	0.90	1.00
	$3.20	–$45	–$7	**$31**	$70	$108

Table 31. Central Queensland Open Downs: sensitivity analysis for gross margin ($/ha/year) in relation to cattle purchase price. Zero till method of fallow weed control assumed. The values in bold highlight the GM for the assumed sale price and purchase price in the defined scenarios

	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
Baseline pasture (native)		$1.80	$1.90	**$2.00**	$2.10	$2.20
	$3.10	$24	$23	**$21**	$20	$19
Oats		$1.34	$1.44	**$1.54**	$1.64	$1.74
	$3.20	$149	$46	**–$56**	–$159	–$261
Forage sorghum		1.34	1.44	**1.54**	1.64	1.74
	$3.20	$378	$223	**$68**	–$88	–$243
Lablab		$1.34	$1.44	**$1.54**	$1.64	$1.74
	$3.20	$269	$150	**$31**	–$87	–$206

Perennial forages

Table 32 shows the net cattle income for the perennial forage systems. This is calculated as the gross cattle income minus livestock costs and does not include any pasture development costs. Gross margins can not be calculated for perennial forages in the same way as annuals because development costs and production returns occur in different years. The cost of establishing the forages is given in Table 33. Net cattle income remained positive across the range of considered liveweight gains and purchase and sale prices which is significant given the likelihood of variation in these variables across production cycles. Tables 34 and 35 present a sub-set of key results from the sensitivity analyses. The full sensitivity analyses are presented in appendix 2.

Table 32. Central Queensland Open Downs: comparison of net cattle income[A] ($/ha/year) for cattle production on baseline pastures and perennial legume–grass forages

		Forage	
	Baseline pasture (native)	Butterfly pea–grass	Leucaena–grass
Zero till and cultivation	$21	$195	$214

[A] Net cattle income calculated as gross income from cattle minus livestock costs (purchase costs, animal health etc). The costs of forage development are not accounted for.

Table 33. Central Queensland Open Downs: comparison of establishment costs ($/ha) for baseline pasture and perennial legume–grass forages

		Forage	
	Baseline pasture (native)	Butterfly pea–grass	Leucaena–grass
Zero till	N/A	$311	$265
Cultivation	N/A	$384	$343

Table 34. Central Queensland Open Downs: sensitivity analysis for net cattle income ($/ha/year) in relation to daily liveweight gain. Zero till method of fallow weed control was used. The values in bold highlight the net cattle income for the assumed sale price and liveweight gain in the defined scenarios

Baseline pasture (native)	Livestock sale price ($/kg carcass weight)	Liveweight gain (kg/head/day)				
		0.31	0.35	**0.39**	0.43	0.47
	$3.10	$17	$19	**$21**	$24	$26
Butterfly pea–grass	Livestock sale price ($/kg carcass weight)	Liveweight gain (kg/head/day)				
		0.45	0.55	**0.65**	0.75	0.85
	$3.20	$124	$159	**$195**	$231	$267
Leucaena–grass	Livestock sale price ($/kg carcass weight)	Liveweight gain (kg/head/day)				
		0.70	0.80	**0.90**	1.00	1.10
	$3.20	$160	$187	**$214**	$241	$268

Table 35. Central Queensland Open Downs: sensitivity analysis for net cattle income ($/ha/year) in relation to cattle purchase price. Zero till method of fallow weed control was used. The values in bold highlight the net cattle income for the assumed sale price and purchase price in the defined scenarios

Baseline pasture (native)	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
		$1.80	$1.90	**$2.00**	$2.10	$2.20
	$3.10	$24	$23	**$21**	$20	$19
Butterfly pea–grass	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
		$1.34	$1.44	**$1.54**	$1.64	$1.74
	$3.20	$263	$229	**$195**	$162	$128
Leucaena–grass	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
		$1.32	$1.42	**$1.52**	$1.62	$1.72
	$3.20	$256	$235	**$214**	$192	$171

All forages

Table 36 shows the net present value (NPV) for all forages and the baseline pasture. The NPV analysis includes all pasture development costs, livestock costs and income over a 30-year period. Net cash flows in each year are discounted back to present values. The results showed that over a 30-year period an investor would receive returns of $1581/ha if leucaena (zero till) were planted versus $285/ha if they continued to use the existing baseline buffel grass pasture. Table 36 also shows the assumed cattle production from each forage type.

Table 36. Central Queensland Open Downs: comparison of cattle production and net present value[A] (NPV) for key forage options over a 30-year period

		Forage				
	Baseline pasture (native)	Oats	Forage sorghum	Lablab	Butterfly pea–grass	Leucaena–grass
NPV ($/ha)						
Zero till	$285	–$468	$899	$387	$1497	$1581
Cultivation	$285	–$683	$397	–$509	$1282	$1417
NPV ($/ha/year)						
Zero till	$9	–$16	$30	$13	$50	$53
Cultivation	$9	–$23	$13	–$17	$43	$47
Liveweight gain (kg/ha/year)[B]	26[C]	145[D]	203	157[D]	124[C]	138[C]
Liveweight gain (kg/head/day)	0.38	1.1	0.6	0.8	0.65	0.9
Stocking rate (AE/ha)	0.17	2.0[D]	3.0	2.3[D]	0.8	0.6
Grazing days (days/year)	365	76	130	100	270	270

[A] Net present value is the sum of discounted values of future income and costs associated with an investment.

[B] Liveweight production figures not adjusted for the percentage of years with unsuitable conditions for sowing oats and lablab or for the time-lag in production after planting the perennial legume-grass forage systems. Note that the economic figures have been adjusted to account for these factors.

[C] Liveweight gain (kg/ha/year) of perennial pastures was calculated using a stocking rate of actual animals/hectare determined from stocking rate in AE/ha, at the liveweight of steers at the half-way point. AE (adult equivalents): 450 kg, non-lactating beast.

[D] Liveweight gain (kg/ha/year) of oats and lablab is the production from total area, including access to grass pasture as 10% of the total grazing area.

Figures 10 and 11 show the cumulative (not discounted) cash flow for each of the forages and the baseline pasture. As shown in these figures the higher initial investment in leucaena–grass pasture resulted in a negative cash flow for the first six years for the zero till system and seven years for the cultivation system, after which cash flows became positive. Butterfly pea–grass pastures showed negative cash flows in some years due to the costs of replanting. The neutral cash flows in some years for oats demonstrates the effect of years in which planting did not occur due to unfavourable seasonal conditions.

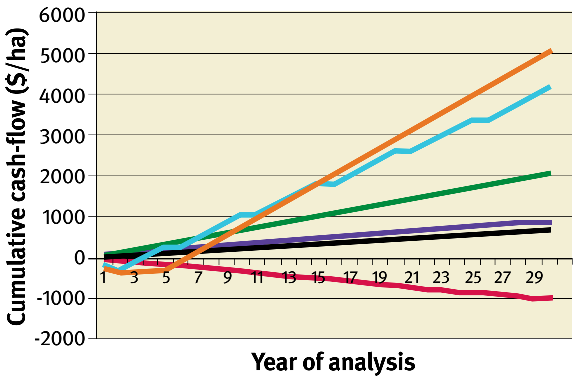


Figure 10. Central Queensland Open Downs: cumulative net cash flow over a 30-year period for forage options using the zero till method of fallow weed control

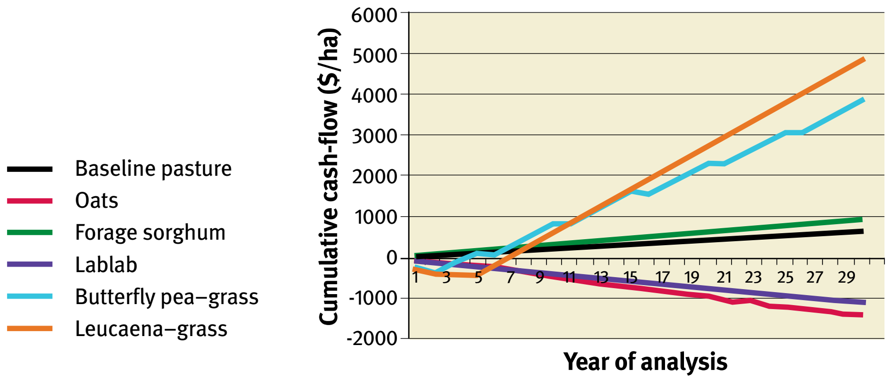


Figure 11. Central Queensland Open Downs: cumulative net cash flow over a 30-year period for forage options using the cultivation method of fallow weed control

8 Evaluation of social, environmental and management factors

The results of the example economic analyses reported in chapter 7 highlight the importance of considering economic performance, in addition to agronomic and livestock performance, when comparing forage options. However, while the economic outcome of using a particular forage option is of critical importance to a beef business, social and environmental factors also influence management and business decisions. Beef producers also need to consider factors that affect the integration of the chosen forage system into the whole-of-business and existing property operations.

Thus, it is important to incorporate a qualitative evaluation of any additional benefits or constraints of the forage options, into any decision making. A summary of some of these additional factors that producers may wish to consider when making a decision about whether or not to incorporate an improved forage system into their business, are listed below.

Strengths/benefits	Constraints/threats
Baseline pasture (native and sown, grass-only pastures i.e. no change from status quo)	
• stable, robust and relatively reliable perennial pasture system • does not require any change of management or additional investment • does not have the climatic risk involved in taking land area out of production for planting to alternative forage options • simple beef management and marketing system • no requirement for specialised agronomic or managerial skills	• lower and more variable quality of the feed relative to annual forage crops and perennial legume–grass pastures • lower stocking rates relative to annual forage crops and perennial grass–legume pastures lower potential liveweight gain/head and gain/ha relative to annual forage crops and perennial legume–grass pastures • less flexibility in cattle marketing options and time of turn-off • limited potential to increase turnover and $/ha from the existing pasture base
Oats	
• can fill a feed gap when the quality of feed provided by grass-only pastures is low in winter and spring • allows cattle to be finished and marketed out-of-season when demand and prices are likely to be higher	• unreliability of autumn/winter rainfall, especially in the northern part of the Fitzroy basin, and thus the risk that the allocated land area will be underutilised. For example, the years with suitable rainfall for sowing oats ranged from 67% at Taroom and Banana to 62% at Capella (based on APSIM modelling using historical rainfall records for the last 108 years) • at the end of the oats season, many cattle are often forced on to the market within a brief time period, causing a market glut and temporary depression in market prices • requires annual planting

<table>
<tr><th>Strengths/benefits</th><th>Constraints/threats</th></tr>
<tr><td colspan="2">Forage sorghum</td></tr>
<tr><td>• can fill a feed gap when the quality of feed from grass-only pastures is low in early summer or can provide carryover winter feed, for example:
– early summer crops could be used to improve the condition of breeders before and during joining
– sweet forage sorghums, which provide stand-over feed into winter, can be used to provide high quality feed for weaners
• provides a large bulk of feed that can be used to reduce grazing pressure on the remainder of the property, allowing strategic spelling of pastures during the summer growing period or to allow feeding of additional, purchased cattle
• the large bulk of lower quality feed produced (relative to other annual forage crops) is well suited to backgrounding cattle prior to the finishing phase</td><td>• difficult to manage for optimum quality and quantity
– the feed quality of sorghum rapidly declines as the crop matures. Using a high stocking rate and grazing early is a strategy to maintain feed quality for as long as possible by keeping the crop in the vegetative state. However, this can be a fairly high-risk strategy under dryland conditions when the in-crop rainfall may not be sufficient to maintain plant growth and the allocated cattle numbers through to finishing weights
• cattle performance can be very variable from year-to-year due to the difficulties in managing the forage for optimum quality
• requires annual planting</td></tr>
<tr><td colspan="2">Lablab</td></tr>
<tr><td>• can fill a feed gap when the quality of feed provided by grass-only pastures is low in autumn
• easy to manage for optimum grazing quality (compared to forage sorghum) with more consistent quality throughout the grazing period
• can reduce nitrogen fertiliser requirements in subsequent grain crop or forage rotations (e.g. forage sorghum) when used as a short-term ley
• under careful grazing management has the potential to overwinter and provide valuable spring feed if sufficient soil moisture is present</td><td>• generally produces less quantity of feed compared to forage sorghum, and hence supports lower stocking rates
• rarely persists for longer than one year and thus requires frequent replanting</td></tr>
<tr><td colspan="2">Butterfly pea–grass</td></tr>
<tr><td>• a medium-term perennial pasture system (5–10 years) negating the requirement for annual forage replanting
• contributes to soil nitrogen levels, halting soil fertility decline in grass pasture systems
• can reduce nitrogen fertiliser requirements in subsequent crop rotations when used as a short- or long-term ley
• enables higher productivity and persistence of grasses with high nitrogen requirements, for example green or Gatton panic, Rhodes and buffel grass</td><td>• can be difficult to manage the pasture so as to maintain an adequate proportion of legume
• reduced life of butterfly pea under difficult situations such as drought, shallow soil depth or heavy grazing pressure</td></tr>
<tr><td colspan="2">Leucaena–grass</td></tr>
<tr><td>• long-term perennial pasture system (>30 years) negating the requirement for replanting annual forage
• relatively robust (can tolerate high stocking rates) and reliable system, even in dry conditions
• contributes to soil nitrogen levels, halting soil fertility decline in grass pasture systems</td><td>• not suited to shallow, infertile soil types
• successful establishment can require a high level of expertise
• can be difficult to achieve optimal leucaena–grass balance and thus optimal animal performance
• under ideal growing conditions leucaena plants can exceed the optimal height for grazing, resulting in additional costs for mechanical slashing
• cattle require the rumen fluid inoculum to prevent mimosine and DHP toxicity reducing cattle weight gains
• additional infrastructure costs may be required, e.g. fencing, trap-gates, laneways and water points
• weed threat when managed inappropriately</td></tr>
</table>

9 Appendices

Appendix 1 — Case study assumptions

A description of each of the case study sites and the general assumptions used in the economic analysis are detailed in tables 37–39. Cattle production from each of the forage types was assessed by comparing the scenario of steers finished to the same target weight (596 kg liveweight; 310 kg carcass weight). The grazing days, stocking rate and daily liveweight gain for each forage at each site were based on an assessment of measured values in both unpublished and published reports and the considered judgement of DEEDI beef research and extension staff. These values are based on the assumption that forages are grown and grazed using best-practice agronomic management and represent the expected long-term average performance over both good and bad rainfall years. The number of possible planting events for oats and lablab was simulated using a biophysical plant production model (Agricultural Production Simulator, or APSIM) to account for the effect of climate variability (using 108 years of climate data) at each location. Click here to access the methods and assumptions used in the forage modelling exercise.

The economic analyses were conducted using the assumption that the same market conditions occur across all forages in each region. The results compare the economic performance of the forages based on the defined set of market assumptions over a 30-year period. Livestock purchase prices were taken from long-term averages at the Roma (Site 1) or Gracemere (Sites 2 and 3) saleyards. The prices used reflect the value of animals (based on weight and age) at the point of entry onto the forage. Livestock sale prices were taken from the long-term averages at the Dinmore meat processing plant. Freight costs were based on 2010 rates from major carriers in each of the relevant regions. Animal health costs were based on 2010 prices. Animal health costs were based on treatments required immediately prior to, or during, forage grazing. For simplicity, and to allow valid comparison to the baseline scenarios, forage preparation and planting costs were based on estimated contract rates.

Table 37. Case study site 1: South Queensland Brigalow (Taroom–Wandoan area) description and assumptions for economic analysis

Factor	Description
General description and assumptions	
Broad land type	Brigalow
Soil type and characteristics	Grey vertosol (ApSoil No. 86 in APSIM) PAWC: 162 mm Soil depth: 1500 mm Base N level: 50 kg N/ha (soil has ‘run-down’ in N levels due to a greater number of years of cropping and/or planting to buffel pasture relative to Site 2)
Cattle enterprise type and target market for comparison across forage types	Finishing steers (approximately 40% *Bos indicus* and 60% *B. taurus* content) for the Jap Ox market specifications to a finishing weight of 596 kg liveweight and 310 kg carcass weight (assuming dressing percentage is 52%). No HGP use
Place of cattle purchase	Roma saleyards
Place of cattle sale	Dinmore meatworks

Factor	Description
Baseline pasture	
Pasture characteristics	Buffel grass (older pastures); minimal tree regrowth
Stocking rate (SR)	1 AE : 3 ha
Feeding period for economic analysis	Weaning to turn-off
Assumptions to determine time to turn off steers at target weight	Join breeders on 1 Nov for 3 months; 318 days from joining to mean calving date; mean calving weight: 35 kg, LWG from birth to weaning: 0.9 kg/head/day; wean on 1 May at 7.5 months and 240 kg
Long-term steer LWG: Annual Summer (D-J-F) Autumn (M-A-M) Winter (J-J-A) Spring (S-O-N)	 159 kg/head/year (0.44 kg/head/day) 0.77 kg/head/day 0.34 kg/head/day 0.22 kg/head/day 0.42 kg/head/day
Calculated grazing days from weaning to turn-off	870
Age at turn-off	36 months
Animal health treatments	5-in-1 x 1 (booster at weaning)
Forage oats	
Sowing window	1 April – 1 June
% of years with suitable conditions for sowing	67
Sowing rate	40 kg/ha
Fertiliser	20 kg N/ha applied at planting
Fallow weed control Zero till Cultivation	 Roundup 1.5 L/ha x 3 applications; 2,4-D Amine 625 0.5 L x 3 applications; Roundup 1.5 L/ha x 1 application preplant. Chisel plough x 1; offset disc plough x 2; scarifier x 1
In-crop weed control (both zero till and cultivation methods)	MCPA LVE 1 L/ha x 1 application
Planter Zero till Cultivation	 Air-seeder, twin bin, spear points and presswheels Air-seeder, twin bin, tyne opener and presswheels
Access to grass pasture	10% of total grazing area
Grazing days on forage	90
Starting cattle weight (kg)	497
LWG (kg/head/day)	1.1
SR (oats area only; AE/ha)	2.5
SR (total grazing area; AE/ha)	2.3
Animal health treatments	5-in-1 x 2
Forage sorghum	
Sowing window	20 October – 31 January
% of years with suitable conditions for sowing	100
Sowing rate	4 kg/ha
Fertiliser	20 kg N/ha applied at planting
Fallow weed control Zero till Cultivation	 Roundup 1.5 L/ha x 3 applications; 2,4-D Amine 625 0.5 L/ha x 3 applications. Chisel plough x 1; offset disc plough x 2; scarifier x 1
In-crop weed control Zero till Cultivation	 Roundup 1.5 L/ha x 1 application with Atrazine 3 L/ha x 1 application post-plant, pre-emerge Atrazine 3 L/ha x 1 application post-plant, pre-emerge
Planter Zero till Cultivation	 Air-seeder, twin bin, spear points with presswheels Air-seeder, twin bin, tyne opener with presswheels
Grazing days on forage	130
Starting cattle weight (kg)	525
LWG (kg/head/day)	0.55
SR (AE/ha)	2.5

Factor	Description
Lablab	
Sowing window	15 October – 31 January
% of years with suitable conditions for sowing	100
Sowing rate	25 kg/ha
Fallow weed control Zero till Cultivation	 Roundup 1.5 L/ha x 3 applications; 2,4-D Amine 625 0.5 L/ha x 3 applications Chisel plough x 1; offset disc plough x 2; scarifier x 1
In-crop weed control Zero till Cultivation	 Roundup 1.5 L/ha x 1 application with Spinnaker 100 g/ha x 1 application post-plant, pre-emerge Spinnaker 100 g/ha x 1 application post-plant, pre-emerge
Planter Zero till Cultivation	 Air-seeder, twin bin, spear points with presswheels Air-seeder, twin bin, tyne opener with presswheels
Access to grass pasture	10% of total grazing area
Grazing days on forage	90
Starting cattle weight (kg)	524
LWG (kg/head/day)	0.8
SR (lablab area only; AE/ha)	2.5
SR (total grazing area; AE/ha)	2.3
Butterfly pea–grass	
Planting schedule over time	Total allocated area sown in Year 1 and this area remained constant over the 30 years of the analysis. Replanting occurred every five years as part of a paddock rotation
Adjustment to account for time-lag in production after planting	For the first year of planting on each occasion, the grazing days were halved but SR and LWG kept constant
Sowing window	15 December – 15 February
% of years with suitable conditions for sowing	100
Sowing rate	10 kg/ha Milgarra; 2 kg/ha tropical grass species
Fallow weed control Zero till Cultivation	 Roundup 1.5 L/ha x 3 applications; 2,4-D Amine 625 0.5 L/ha x 3 applications Chisel plough x 1; offset disc plough x 2; scarifier x 1
In-crop weed control Zero till Cultivation	 Roundup 1.5 L/ha x 1 application with Spinnaker 140 g/ha x 1 application post-plant, pre-emerge Spinnaker 140 g/ha x 1 application post-plant, pre-emerge
Planter Zero till (butterfly pea) Cultivation (butterfly pea) Grass	 Air–seeder, twin bin, spear points with presswheels Air-seeder, twin bin, tyne opener with presswheels Drum seeder (grass planted 12 months later)
Grazing days on forage	240
Starting cattle weight (kg)	452
LWG (kg/head/day)	0.6
SR (AE/ha)	0.8

Factor	Description
Leucaena–grass	
Planting schedule over time	Half the allocated area sown in Year 1 and half in Year 2
Adjustment to account for time-lag in production after planting	Year of planting: no production; year following planting: grazing days were halved but SR and LWG kept constant
Sowing window	1 January – 28 February
% of years with suitable conditions for sowing	100
Sowing rate	2 kg/ha leucaena; 2 kg/ha tropical grass species
Fertiliser and inoculum	At sowing: 40 kg MAP/ha; 120 g innoculum/100 kg seed Maintenance: 100 kg superphosphate/ha every 10 years
Fallow weed control Zero till Cultivation	 Roundup 1.5 L/ha x 3 applications; 2,4-D Amine 625 0.5 L/ha x 3 applications; Roundup 1.5 L/ha x 1 application pre-plant Offset disc plough x 2; scarifier x 2; Roundup 1.5 L/ha x 1 application pre-plant
In-crop weed control (both zero till and cultivation methods)	Spinnaker 140 g/ha x 1 application over ½ the area post-plant, pre-emerge
Planter (both zero till and cultivation methods) Leucaena Grass	 Leucaena planter (precision row crop planter) Drum seeder (at the same time as planting leucaena)
Mechanical cutting	Total area once every 10 years
Grazing days on forage	240
Starting cattle weight (kg)	380
LWG (kg/head/day)	0.9
SR (AE/ha)	0.55
Animal health treatments	Inoculate 10% of the herd at the rate of 100 mL leucaena rumen fluid inoculum/steer

AE: adult equivalent, defined as a 450 kg steer; APSIM: plant production model; LWG: liveweight gain; MAP: mono-ammonium phosphate; N: nitrogen; PAWC: plant available water capacity; SR: stocking rate

Table 38. Case study site 2: Central Queensland Brigalow (Bauhinia–Theodore area) description and assumptions for economic analysis

Factor	Description
General description and assumptions	
Broad land type	Brigalow
Soil type and characteristics	Grey vertosol (Rolleston ApSoil No. 106 in APSIM) PAWC: 136.5 mm Soil depth: 1500 mm Base N level: 60 kg N/ha
Cattle enterprise type and target market for comparison across forage types	Finishing steers (approximately 40% *Bos indicus* and 60% *B. taurus* content) for the Jap Ox market specifications to a finishing weight of 596 kg liveweight and 310 carcass weight (assuming dressing percentage is 52%). No HGP use
Place of cattle purchase	Gracemere saleyards
Place of cattle sale	Biloela meatworks
Baseline pasture	
Pasture characteristics	Buffel grass, minimal tree regrowth
SR	1 AE : 3 ha
Feeding period for economic analysis	Weaning to turn-off
Assumptions to determine time to turn off steers at target weight	Join breeders on 1 Dec for 3 months; 318 days from joining to mean calving date; mean calving weight: 35 kg, LWG from birth to weaning: 0.9 kg/head/day; wean on 1 May at 6.5 months and 213 kg
Long-term, steer LWG: Annual Summer (D-J-F) Autumn (M-A-M) Winter (J-J-A) Spring (S-O-N)	 167 kg/head/year (0.46 kg/head/day) 0.84 kg/head/day 0.38 kg/head/day 0.24 kg/head/day 0.38 kg/head/day
Calculated grazing days from weaning to turn-off	891
Age at turn-off	36 months
Animal health treatments	5-in-1 x 1 (booster at weaning)
Forage oats	
Sowing window	1 April – 1 June
% of years with suitable conditions for sowing	67
Sowing rate	40 kg/ha
Fertiliser	0 kg N/ha
Fallow weed control Zero till Cultivation	 Roundup 1.5 L/ha x 3 applications; 2,4-D Amine 625 0.5 L x 3 applications; Roundup 1.5 L/ha x 1 application pre-plant Chisel plough x 1; offset disc plough x 2; scarifier x 1
In-crop weed control	MCPA LVE 1 L/ha x 1 application
Planter Zero till Cultivation	 Air-seeder, twin bin, spear points and presswheels Air-seeder, twin bin, tyne opener and presswheels
Access to grass pasture	10% of total grazing area
Grazing days on forage	83
Starting cattle weight (kg)	505
LWG (kg/head/day)	1.1
SR (oats area only; AE/ha)	2.0
SR (total grazing area; AE/ha)	1.8
Animal health treatments	5-in-1 x 2

Factor	Description
Forage sorghum	
Sowing window	1 September – 31 January
% of years with suitable conditions for sowing	100
Sowing rate	4 kg/ha
Fertiliser	0 kg N/ha
Fallow weed control Zero till Cultivation	 Roundup 1.5 L/ha x 3 applications; 2,4-D Amine 625 0.5 L/ha x 3 applications. Chisel plough x 1; offset disc plough x 2; scarifier x 1
In-crop weed control Zero till Cultivation	 Roundup 1.5 L/ha x 1 application with Atrazine 3 L/ha x 1 application post-plant, pre-emerge Atrazine 3 L/ha x 1 application post-plant, pre-emerge
Planter Zero till Cultivation	 Air-seeder, twin bin, spear points with presswheels Air-seeder, twin bin, tyne opener with presswheels
Grazing days on forage	120
Starting cattle weight (kg)	524
LWG (kg/head/day)	0.6
SR (AE/ha)	3.0
Lablab	
Sowing window	1 September – 31 January
% of years with suitable conditions for sowing	100
Sowing rate	25 kg/ha
Fallow weed control Zero till Cultivation	 Roundup 1.5 L/ha x 3 applications; 2,4-D Amine 625 0.5 L/ha x 3 applications Chisel plough x 1; offset disc plough x 2; scarifier x 1
In-crop weed control Zero till Cultivation	 Roundup 1.5 L/ha x 1 application with Spinnaker 100 g/ha x 1 application post-plant, pre-emerge Spinnaker 100 g/ha x 1 application post-plant, pre-emerge
Planter Zero till Cultivation	 Air-seeder, twin bin, spear points with presswheels Air-seeder, twin bin, tyne opener with presswheels
Access to grass pasture	10% of total grazing area
Grazing days on forage	100
Starting cattle weight (kg)	516
LWG (kg/head/day)	0.8
SR (lablab area only; AE/ha)	2.5
SR (total grazing area; AE/ha)	2.3

Factor	Description
Butterfly pea–grass	
Planting schedule over time	Total allocated area sown in Year 1 and this area remained constant over the 30 years of the analysis. Re-planting occurred every five years as part of a paddock rotation
Adjustment to account for time-lag in production after planting	For the first year of planting on each occasion, the grazing days were halved but SR and LWG kept constant
Sowing window	15 December – 28 February
% of years with suitable conditions for sowing	100
Sowing rate	10 kg/ha Milgarra; 2 kg/ha tropical grass species
Fallow weed control Zero till Cultivation	 Roundup 1.5 L/ha x 3 applications; 2,4-D Amine 625 0.5 L/ha x 3 applications Chisel plough x 1; offset disc plough x 2; scarifier x 1
In-crop weed control Zero till Cultivation	 Roundup 1.5 L/ha x 1 application with Spinnaker 140 g/ha x 1 application post-plant, pre-emerge Spinnaker 140 g/ha x 1 application post-plant, pre-emerge
Planter Zero till (butterfly pea) Cultivation (butterfly pea) Grass	 Air–seeder, twin bin, spear points with presswheels Air-seeder, twin bin, tyne opener with presswheels Drum seeder (grass planted 12 months later)
Grazing days on forage	250
Starting cattle weight (kg)	446
LWG (kg/head/day)	0.6
SR (AE/ha)	0.8
Leucaena–grass	
Planting schedule over time	Half the allocated area sown in Year 1 and half in Year 2
Adjustment to account for time-lag in production after planting	Year of planting: no production; year following planting: grazing days were halved but SR and LWG kept constant
Sowing window	1 January – 15 March
% of years with suitable conditions for sowing	100
Sowing rate	2 kg/ha Leucaena; 2 kg/ha tropical grass species
Fertiliser and inoculum	At sowing: 40 kg MAP/ha; 120 g innoculum/100 kg seed Maintenance: 100 kg superphosphate/ha every 10 years
Fallow weed control Zero till Cultivation	 Roundup 1.5 L/ha x 3 applications; 2,4-D Amine 625 0.5 L/ha x 3 applications; Roundup 1.5 L/ha x 1 application pre-plant Offset disc plough x 2; scarifier x 2; Roundup 1.5 L/ha x 1 application pre-plant
In-crop weed control (both zero till and cultivation methods)	Spinnaker 140 g/ha x 1 application over ½ the area post-plant, pre-emerge
Planter (both zero till and cultivation methods) Leucaena Grass	 Leucaena planter (precision row crop planter) Drum seeder (at the same time as planting leucaena)
Mechanical cutting	Total area once every 10 years
Grazing days on forage	270
Starting cattle weight (kg)	353
LWG (kg/head/day)	0.9
SR (AE/ha)	0.6
Animal health treatments	Inoculate 10% of the herd at the rate of 100 mL leucaena rumen fluid inoculum/steer

AE: adult equivalent, defined as a 450 kg steer; APSIM: plant production model; LWG: liveweight gain; MAP: mono-ammonium phosphate; N: nitrogen; PAWC: plant available water capacity; SR: stocking rate

Table 39. Case study site 3: Central Queensland Open Downs (Capella area) description and assumptions for economic analysis

Factor	Description
General description and assumptions	
Broad land type	Open Downs
Soil type and characteristics	Black vertosol-Orion (Capella ApSoil No049 in APSIM) PAWC: 145.5 mm Soil depth: 1500 mm Base N level: 40 kg N/ha
Cattle enterprise type and target market for comparison across forage types	Finishing steers (approximately 50% *Bos indicus* and 50% *B. taurus* content) for the Jap Ox market specifications to a finishing weight of 596 kg liveweight and 310 carcass weight (assuming dressing percentage is 52%). No HGP use
Place of cattle purchase	Gracemere saleyards
Place of cattle sale	Rockhampton meatworks
Baseline pasture	
Pasture characteristics	Queensland bluegrass
SR	1 AE : 6 ha
Feeding period for economic analysis	Weaning to turn-off
Assumptions to determine time to turn off steers at target weight	Join breeders on 1 Dec for three months; 318 days from joining to mean calving date; mean calving weight: 35 kg, LWG from birth to weaning: 0.9 kg/head/day; wean on 1 May at 6.5 months and 213 kg
Long-term, steer LWG: Annual Summer (D-J-F) Autumn (M-A-M) Winter (J-J-A) Spring (S-O-N)	 142 kg/head/year (0.39 kg/head/day) 0.77 kg/head/day 0.34 kg/head/day 0.11 kg/head/day 0.34 kg/head/day
Calculated grazing days from weaning to turn-off	1006
Age at turn-off	40 months
Animal health treatments	5-in-1 x 1 (booster at weaning)
Forage oats	
Sowing window	1 April – 1 June
% of years with suitable conditions for sowing	62
Sowing rate	40 kg/ha
Fertiliser	40 kg N/ha applied pre-plant with air-seeder (both zero till and cultivation methods)
Fallow weed control Zero till Cultivation	 Roundup 1.5 L/ha x 3 applications; 2,4-D Amine 625 0.5 L x 3 applications; Roundup 1.5 L/ha x 1 application pre-plant Chisel plough x 1; offset disc plough x 2
In-crop weed control	MCPA LVE 1 L/ha x 1 application
Planter Zero till Cultivation	 Air-seeder, twin bin, spear points and presswheels Air-seeder, twin bin, tyne opener and presswheels
Access to grass pasture	10% of total grazing area
Grazing days on forage	76
Starting cattle weight (kg)	512
LWG (kg/head/day)	1.1
SR (oats area only; AE/ha)	2.2
SR (total grazing area; AE/ha)	2.0
Animal health treatments	5-in-1 x 2

Factor	Description
Forage sorghum	
Sowing window	1 September – 31 January
% of years with suitable conditions for sowing	100
Sowing rate	4 kg/ha
Fertiliser	40 kg N/ha applied pre-plant with air-seeder (both zero till and cultivation methods)
Fallow weed control Zero till Cultivation	 Roundup 1.5 L/ha x 3 applications; 2,4-D Amine 625 0.5 L/ha x 3 applications Chisel plough x 1; offset disc plough x 2
In-crop weed control Zero till Cultivation	 Roundup 1.5 L/ha x 1 application with Atrazine 3 L/ha x 1 application post-plant, pre-emerge Atrazine 3 L/ha x 1 application post-plant, pre-emerge
Planter Zero till Cultivation	 Air-seeder, twin bin, spear points with presswheels Air-seeder, twin bin, tyne opener with presswheels
Grazing days on forage	130
Starting cattle weight (kg)	518
LWG (kg/head/day)	0.6
SR (AE/ha)	3.0
Lablab	
Sowing window	1 September – 31 January
% of years with suitable conditions for sowing	93
Sowing rate	25 kg/ha
Fallow weed control Zero till Cultivation	 Roundup 1.5 L/ha x 3 applications; 2,4-D Amine 625 0.5 L/ha x 3 applications Chisel plough x 1; offset disc plough x 2; scarifier x 1
In-crop weed control Zero till Cultivation	 Roundup 1.5 L/ha x 1 application with Spinnaker 100 g/ha x 1 application post-plant, pre-emerge Spinnaker 100 g/ha x 1 application post-plant, pre-emerge
Planter Zero till Cultivation	 Air-seeder, twin bin, spear points with presswheels Air-seeder, twin bin, tyne opener with presswheels
Access to grass pasture	10% of total grazing area
Grazing days on forage	100
Starting cattle weight (kg)	516
LWG (kg/head/day)	0.8
SR (lablab area only; AE/ha)	2.5
SR (total grazing area; AE/ha)	2.3

Factor	Description
Butterfly pea–grass	
Planting schedule over time	Half the allocated area sown in Year 1 and half in Year 3. This total area then remained constant over the 30 years of the analysis. Replanting occurred every five years as part of a paddock rotation
Adjustment to account for time-lag in production after planting	For the first year of planting on each occasion, the grazing days were halved but SR and LWG kept constant
Sowing window	15 December – 15 March
% of years with suitable conditions for sowing	100
Sowing rate	10 kg/ha Milgarra; 2 kg/ha tropical grass species
Fallow weed control Zero till Cultivation	 Roundup 1.5 L/ha x 3 applications; 2,4-D Amine 625 0.5 L/ha x 3 applications Chisel plough x 1; offset disc plough x 2; scarifier x 1
In-crop weed control Zero till Cultivation	 Roundup 1.5 L/ha x 1 application with Spinnaker 140 g/ha x 1 application post-plant, pre-emerge Spinnaker 140 g/ha x 1 application post-plant, pre-emerge
Planter Zero till (butterfly pea) Cultivation (butterfly pea) Grass	 Air–seeder, twin bin, spear points with presswheels Air-seeder, twin bin, tyne opener with presswheels Drum seeder (grass planted 12 months later)
Grazing days on forage	270
Starting cattle weight (kg)	421
LWG (kg/head/day)	0.65
SR (AE/ha)	0.8
Leucaena–grass	
Planting schedule over time	Plant 1/5th of the allocated area each year from Year 1 to 5
Adjustment to account for time-lag in production after planting	Year of planting: no production; year following planting: grazing days were halved but SR and LWG kept constant
Sowing window	1 January – 31 March
% of years with suitable conditions for sowing	100
Sowing rate	2 kg/ha leucaena; 2 kg/ha tropical grass species
Fertiliser and inoculum	At sowing: 40 kg MAP/ha; 120 g innoculum/100 kg seed Maintenance: 100 kg superphosphate/ha every 10 years
Fallow weed control Zero till Cultivation	 Roundup 1.5 L/ha x 3 applications; 2,4-D Amine 625 0.5 L/ha x 3 applications; Roundup 1.5 L/ha x 1 application pre-plant Offset disc plough x 2; scarifier x 2; Roundup 1.5 L/ha x 1 application pre-plant
In-crop weed control (both zero till and cultivation methods)	Spinnaker 140 g/ha x 1 application over ½ the area post-plant, pre-emerge
Planter (both zero till and cultivation methods) Leucaena Grass	 Leucaena planter (precision row crop planter) Drum seeder (at the same time as planting leucaena)
Mechanical cutting	Total area once every 10 years
Grazing days on forage	270
Starting cattle weight (kg)	353
LWG (kg/head/day)	0.9
SR (AE/ha)	0.6
Animal health treatments	Inoculate 10% of the herd at the rate of 100 mL leucaena rumen fluid inoculum/steer

AE: adult equivalent, defined as a 450 kg steer; APSIM: plant production model; LWG: liveweight gain; MAP: mono-ammonium phosphate; N: nitrogen; PAWC: plant available water capacity; SR: stocking rate

Appendix 2 — Sensitivity tables

Case study site 1: South Queensland Brigalow (Taroom–Wandoan area)

Table 40. South Queensland Brigalow: sensitivity analysis for gross margins ($/ha/year) in relation to cattle sale price and daily liveweight gain. Zero till method of fallow weed control was used. The values in bold highlight the GM for the sale price and liveweight gain used in the defined scenarios

	Livestock sale price ($/kg carcass weight)	Liveweight gain (kg/head/day)				
		0.33	0.37	**0.41**	0.45	0.49
Baseline pasture (buffel)	$2.80	$24	$27	$30	$33	$36
	$2.90	$27	$31	$34	$37	$41
	$3.00	$31	$35	$38	$42	$46
	$3.10	$34	$39	**$43**	$47	$51
	$3.20	$38	$43	$47	$52	$56
	$3.30	$41	$46	$51	$57	$62
	$3.40	$45	$50	$56	$61	$67
	Livestock sale price ($/kg carcass weight)	Liveweight gain (kg/head/day)				
		0.90	1.00	**1.10**	1.20	1.30
Oats	$2.90	–$234	–$203	–$171	–$140	–$109
	$3.00	–$165	–$132	–$100	–$68	–$36
	$3.10	–$96	–$62	–$29	$5	$38
	$3.20	–$26	$8	**$42**	$77	$111
	$3.30	$43	$78	$114	$149	$185
	$3.40	$112	$148	$185	$222	$258
	$3.50	$181	$219	$256	$294	$332
	Livestock sale price ($/kg carcass weight)	Liveweight gain (kg/head/day)				
		0.35	0.45	**0.55**	0.65	0.75
Forage sorghum	$2.90	–$335	–$286	–$237	–$188	–$139
	$3.00	–$261	–$210	–$160	–$190	–$58
	$3.10	–$187	–$135	–$82	–$30	$23
	$3.20	–$113	–$59	**–$5**	$50	$104
	$3.30	–$39	$17	$73	$129	$185
	$3.40	$36	$93	$151	$208	$265
	$3.50	$110	$169	$228	$287	$346
	Livestock sale price ($/kg carcass weight)	Liveweight gain (kg/head/day)				
		0.60	0.70	**0.80**	0.90	1.00
Lablab	$2.90	–$337	–$305	–$274	–$243	–$212
	$3.00	–$268	–$235	–$203	–$171	–$138
	$3.10	–$198	–$165	–$132	–$98	–$65
	$3.20	–$129	–$95	**–$60**	–$26	$9
	$3.30	–$60	–$25	$11	$46	$82
	$3.40	$9	$46	$82	$119	$155
	$3.50	$78	$116	$153	$191	$229

Table 41. South Queensland Brigalow: sensitivity analysis for gross margins ($/ha/year) in relation to cattle sale and purchase price. Zero till method of fallow weed control was used. The values in bold highlight the GM for the assumed sale price and purchase price in the defined scenarios

	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
		$1.80	$1.90	**$2.00**	$2.10	$2.20
Baseline pasture (buffel)	$2.80	$36	$33	$30	$26	$23
	$2.90	$41	$37	$34	$31	$27
	$3.00	$45	$42	$38	$35	$32
	$3.10	$50	$46	**$43**	$39	$36
	$3.20	$54	$51	$47	$44	$40
	$3.30	$58	$55	$51	$48	$45
	$3.40	$63	$59	$56	$52	$49
	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
		$1.40	$1.50	**$1.60**	$1.70	$1.80
Oats	$2.90	$57	–$57	–$171	–$286	–$400
	$3.00	$128	$14	–$100	–$214	–$329
	$3.10	$200	$85	–$29	–$143	–$257
	$3.20	$271	$157	**$42**	–$72	–$186
	$3.30	$342	$228	$114	–$1	–$115
	$3.40	$414	$299	$185	$71	–$44
	$3.50	$485	$371	$256	$142	$28
	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
		$1.40	$1.50	**$1.60**	$1.70	$1.80
Forage sorghum	$2.90	$25	–$106	–$237	–$368	–$500
	$3.00	$103	–$28	–$160	–$291	–$422
	$3.10	$180	$49	–$82	–$213	–$345
	$3.20	$258	$127	**–$5**	–$136	–$267
	$3.30	$335	$204	$73	–$58	–$190
	$3.40	$413	$282	$151	$19	–$112
	$3.50	$491	$359	$228	$97	–$34
	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
		$1.40	$1.50	**$1.60**	$1.70	$1.80
Lablab	$2.90	–$33	–$154	–$274	–$395	–$515
	$3.00	$38	–$82	–$203	–$323	–$444
	$3.10	$109	–$11	–$132	–$252	–$373
	$3.20	$181	$60	**–$60**	–$181	–$301
	$3.30	$252	$131	$11	–$110	–$230
	$3.40	$323	$203	$82	–$38	–$159
	$3.50	$395	$274	$153	$33	–$88

Table 42. South Queensland Brigalow: sensitivity analysis for net cattle income ($/ha/year) in relation to cattle sale price and daily liveweight gain. Zero till method of fallow weed control was used. The values in bold highlight the net cattle income for the assumed sale price and liveweight gain in the defined scenarios

	Livestock sale price ($/kg carcass weight)	Liveweight gain (kg/head/day)				
		0.33	0.37	**0.41**	0.45	0.49
Baseline pasture (buffel)	$2.80	$24	$27	$30	$33	$36
	$2.90	$27	$31	$34	$37	$41
	$3.00	$31	$35	$38	$42	$46
	$3.10	$34	$39	**$43**	$47	$51
	$3.20	$38	$43	$47	$52	$56
	$3.30	$41	$46	$51	$57	$62
	$3.40	$45	$50	$56	$61	$67
	Livestock sale price ($/kg carcass weight)	Liveweight gain (kg/head/day)				
		0.40	0.50	**0.60**	0.70	0.80
Butterfly pea–grass	$2.90	$7	$36	$65	$94	$123
	$3.00	$30	$60	$90	$120	$150
	$3.10	$53	$84	$114	$145	$176
	$3.20	$75	$107	**$139**	$171	$203
	$3.30	$98	$131	$164	$197	$230
	$3.40	$121	$155	$189	$223	$257
	$3.50	$144	$179	$214	$249	$284
	Livestock sale price ($/kg carcass weight)	Liveweight gain (kg/head/day)				
		0.70	0.80	**0.90**	1.00	1.10
Leucaena–grass	$2.90	$68	$88	$108	$128	$148
	$3.00	$84	$105	$125	$146	$166
	$3.10	$100	$121	$142	$164	$185
	$3.20	$115	$137	**$159**	$181	$203
	$3.30	$131	$154	$176	$199	$222
	$3.40	$147	$170	$193	$217	$240
	$3.50	$162	$187	$211	$235	$259

Table 43. South Queensland Brigalow: sensitivity analysis for net cattle income ($/ha/year) in relation to cattle sale and purchase price. Zero till method of fallow weed control was used. The values in bold highlight the net cattle income for the assumed sale price and purchase price in the defined scenarios

	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
		$1.80	$1.90	**$2.00**	$2.10	$2.20
Baseline pasture (buffel)	$2.80	$36	$33	$30	$26	$23
	$2.90	$41	$37	$34	$31	$27
	$3.00	$45	$42	$38	$35	$32
	$3.10	$50	$46	**$43**	$39	$36
	$3.20	$54	$51	$47	$44	$40
	$3.30	$58	$55	$51	$48	$45
	$3.40	$63	$59	$56	$52	$49
	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
		$1.40	$1.50	**$1.60**	$1.70	$1.80
Butterfly pea–grass	$2.90	$137	$101	$65	$29	–$7
	$3.00	$162	$126	$90	$54	$17
	$3.10	$187	$151	$114	$78	$42
	$3.20	$212	$175	**$139**	$103	$67
	$3.30	$236	$200	$164	$128	$92
	$3.40	$261	$225	$189	$153	$117
	$3.50	$286	$250	$214	$177	$141
	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
		$1.40	$1.50	**$1.60**	$1.70	$1.80
Leucaena–grass	$2.90	$150	$129	$108	$87	$66
	$3.00	$167	$146	$125	$104	$83
	$3.10	$184	$163	$142	$121	$101
	$3.20	$201	$180	**$159**	$138	$118
	$3.30	$218	$197	$176	$156	$135
	$3.40	$235	$214	$193	$173	$152
	$3.50	$252	$231	$211	$190	$169

Table 44. Central Queensland Brigalow: sensitivity analysis for gross margins ($/ha/year) in relation to cattle sale price and daily liveweight gain. Zero till method of fallow weed control was used. The values in bold highlight the GM for the assumed sale price and liveweight gain in the defined scenarios

	Livestock sale price ($/kg carcass weight)	Liveweight gain (kg/head/day)				
Baseline pasture (buffel)		0.34	0.39	**0.43**	0.47	0.52
	$2.80	$30	$34	$38	$42	$46
	$2.90	$34	$38	$42	$46	$51
	$3.00	$37	$42	$46	$51	$56
	$3.10	$41	$46	**$51**	$56	$61
	$3.20	$44	$49	$55	$60	$66
	$3.30	$47	$53	$59	$65	$71
	$3.40	$51	$57	$63	$70	$76
Oats	Livestock sale price ($/kg carcass weight)	0.90	1.00	**1.10**	1.20	1.30
	$2.90	–$133	–$110	–$88	–$65	–$43
	$3.00	–$79	–$55	–$32	–$9	$15
	$3.10	–$24	–$0	$24	$48	$72
	$3.20	$30	$55	**$80**	$104	$129
	$3.30	$84	$110	$135	$161	$187
	$3.40	$138	$165	$191	$218	$244
	$3.50	$193	$220	$247	$274	$301
Forage sorghum	Livestock sale price ($/kg carcass weight)	0.40	0.50	**0.60**	0.70	0.80
	$2.90	–$203	–$149	–$95	–$41	$14
	$3.00	–$114	–$58	–$2	$54	$110
	$3.10	–$25	$33	$91	$149	$207
	$3.20	$64	$124	**$184**	$244	$304
	$3.30	$153	$215	$277	$339	$401
	$3.40	$243	$306	$370	$434	$497
	$3.50	$332	$397	$463	$529	$594
Lablab	Livestock sale price ($/kg carcass weight)	0.60	0.70	**0.80**	0.90	1.00
	$2.90	–$223	–$188	–$154	–$119	–$84
	$3.00	–$154	–$118	–$82	–$46	–$11
	$3.10	–$85	–$48	–$11	$26	$63
	$3.20	–$16	$22	**$60**	$98	$137
	$3.30	$53	$92	$131	$171	$210
	$3.40	$121	$162	$203	$243	$284
	$3.50	$190	$232	$274	$316	$358

Table 45. Central Queensland Brigalow: sensitivity analysis for gross margins ($/ha/year) in relation to cattle sale and purchase price. Zero till method of fallow weed control was used. The values in bold highlight the GM for the assumed sale price and purchase price in the defined scenarios

	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
		$1.80	$1.90	**$2.00**	$2.10	$2.20
Baseline pasture (buffel)	$2.80	$44	$41	$38	$35	$32
	$2.90	$48	$45	$42	$39	$36
	$3.00	$52	$49	$46	$44	$41
	$3.10	$56	$54	**$51**	$48	$45
	$3.20	$61	$58	$55	$52	$49
	$3.30	$65	$62	$59	$56	$53
	$3.40	$69	$66	$63	$60	$58
	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
		$1.32	$1.42	**$1.52**	$1.62	$1.72
Oats	$2.90	$94	$3	–$88	–$179	–$270
	$3.00	$150	$59	–$32	–$123	–$214
	$3.10	$206	$115	$24	–$67	–$158
	$3.20	$261	$170	**$80**	–$11	–$102
	$3.30	$317	$226	$135	$44	–$46
	$3.40	$373	$282	$191	$100	$9
	$3.50	$429	$338	$247	$156	$65
	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
		$1.34	$1.44	**$1.54**	$1.64	$1.74
Forage sorghum	$2.90	$220	$62	–$95	–$252	–$409
	$3.00	$313	$155	–$2	–$159	–$316
	$3.10	$405	$248	$91	–$66	–$223
	$3.20	$498	$341	**$184**	$27	–$130
	$3.30	$591	$434	$277	$120	–$37
	$3.40	$684	$527	$370	$213	$56
	$3.50	$777	$620	$463	$306	$149
	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
		$1.34	$1.44	**$1.54**	$1.64	$1.74
Lablab	$2.90	$84	–$35	–$154	–$272	–$391
	$3.00	$155	$36	–$82	–$201	–$320
	$3.10	$226	$108	–$11	–$130	–$248
	$3.20	$298	$179	**$60**	–$58	–$177
	$3.30	$369	$250	$131	$13	–$106
	$3.40	$440	$321	$203	$84	–$35
	$3.50	$511	$393	$274	$155	$37

Table 46. Central Queensland Brigalow: sensitivity analysis for net cattle income ($/ha/year) in relation to cattle sale price and daily liveweight gain. Zero till method of fallow weed control was used. The values in bold highlight the net cattle income for the assumed sale price and liveweight gain in the defined scenarios

	Livestock sale price ($/kg carcass weight)	Liveweight gain (kg/head/day)				
		0.34	0.39	**0.43**	0.47	0.52
Baseline pasture (buffel)	$2.80	$30	$34	$38	$42	$46
	$2.90	$34	$38	$42	$46	$51
	$3.00	$37	$42	$46	$51	$56
	$3.10	$41	$46	**$51**	$56	$61
	$3.20	$44	$49	$55	$60	$66
	$3.30	$47	$53	$59	$65	$71
	$3.40	$51	$57	$63	$70	$76
	Livestock sale price ($/kg carcass weight)	Liveweight gain (kg/head/day)				
		0.40	0.50	**0.60**	0.70	0.80
Butterfly pea–grass	$2.90	$46	$76	$106	$137	$167
	$3.00	$69	$100	$131	$162	$194
	$3.10	$92	$124	$156	$188	$220
	$3.20	$114	$148	**$181**	$214	$247
	$3.30	$137	$171	$206	$240	$274
	$3.40	$160	$195	$230	$266	$301
	$3.50	$182	$219	$255	$292	$328
	Livestock sale price ($/kg carcass weight)	Liveweight gain (kg/head/day)				
		0.70	0.80	**0.90**	1.00	1.10
Leucaena–grass	$2.90	$116	$141	$165	$190	$214
	$3.00	$133	$159	$184	$209	$234
	$3.10	$150	$176	$202	$229	$255
	$3.20	$167	$194	**$221**	$248	$275
	$3.30	$184	$212	$240	$267	$295
	$3.40	$201	$230	$258	$287	$216
	$3.50	$218	$247	$277	$306	$336

Table 47. Central Queensland Brigalow: sensitivity analysis for net cattle income ($/ha/year) in relation to cattle sale and purchase price. Zero till method of fallow weed control was used. The values in bold highlight the net cattle income for the assumed sale price and purchase price in the defined scenarios

	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
		$1.80	$1.90	**$2.00**	$2.10	$2.20
Baseline pasture (buffel)	$2.80	$44	$41	$38	$35	$32
	$2.90	$48	$45	$42	$39	$36
	$3.00	$52	$49	$46	$44	$41
	$3.10	$56	$54	**$51**	$48	$45
	$3.20	$61	$58	$55	$52	$49
	$3.30	$65	$62	$59	$56	$53
	$3.40	$69	$66	$63	$60	$58
	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
		$1.32	$1.42	**$1.52**	$1.62	$1.72
Butterfly pea–grass	$2.90	$178	$142	$106	$71	$35
	$3.00	$203	$167	$131	$96	$60
	$3.10	$227	$192	$156	$120	$85
	$3.20	$252	$216	**$181**	$145	$109
	$3.30	$277	$241	$206	$170	$134
	$3.40	$302	$266	$230	$195	$159
	$3.50	$327	$291	$255	$219	$184
	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
		$1.32	$1.42	**$1.52**	$1.62	$1.72
Leucaena–grass	$2.90	$208	$186	$165	$144	$123
	$3.00	$226	$205	$184	$163	$142
	$3.10	$245	$224	$202	$181	$160
	$3.20	$263	$242	**$221**	$200	$179
	$3.30	$282	$261	$240	$219	$197
	$3.40	$301	$279	$258	$237	$216
	$3.50	$319	$298	$277	$256	$235

Table 48. Central Queensland Open Downs: sensitivity analysis for gross margins ($/ha/year) in relation to cattle sale price and daily liveweight gain. Zero till method of fallow weed control was used. The values in bold highlight the GM for the assumed sale price and liveweight gain in the defined scenarios

	Livestock sale price ($/kg carcass weight)	Liveweight gain (kg/head/day)				
		0.31	0.35	**0.39**	0.43	0.47
Baseline pasture (native)	$2.80	$13	$14	$16	$17	$19
	$2.90	$14	$16	$18	$19	$21
	$3.00	$16	$18	$20	$21	$23
	$3.10	$17	$19	**$21**	$24	$26
	$3.20	$19	$21	$23	$26	$28
	$3.30	$20	$23	$25	$28	$30
	$3.40	$22	$24	$27	$30	$33
	Livestock sale price ($/kg carcass weight)	Liveweight gain (kg/head/day)				
		0.90	1.00	**1.10**	1.20	1.30
Oats	$2.90	–$288	–$265	–$242	–$219	–$196
	$3.00	–$228	–$204	–$180	–$156	–$133
	$3.10	–$167	–$143	–$118	–$94	–$69
	$3.20	–$107	–$82	**–$56**	–$31	–$6
	$3.30	–$46	–$20	$6	$32	$58
	$3.40	$14	$41	$68	$95	$121
	$3.50	$74	$102	$130	$157	$185
	Livestock sale price ($/kg carcass weight)	Liveweight gain (kg/head/day)				
		0.40	0.50	**0.60**	0.70	0.80
Forage sorghum	$2.90	–$329	–$270	–$211	–$152	–$94
	$3.00	–$240	–$179	–$118	–$57	$3
	$3.10	–$151	–$88	–$25	$38	$100
	$3.20	–$62	$3	**$68**	$133	$197
	$3.30	$27	$94	$161	$228	$295
	$3.40	$116	$185	$254	$323	$392
	$3.50	$205	$276	$347	$418	$489
	Livestock sale price ($/kg carcass weight)	Liveweight gain (kg/head/day)				
		0.60	0.70	**0.80**	0.90	1.00
Lablab	$2.90	–$252	–$217	–$182	–$148	–$113
	$3.00	–$183	–$147	–$111	–$75	–$39
	$3.10	–$114	–$77	–$40	–$3	$34
	$3.20	–$45	–$7	**$31**	$70	$108
	$3.30	$24	$63	$103	$142	$182
	$3.40	$93	$133	$174	$215	$255
	$3.50	$162	$203	$245	$287	$329

Table 49. Central Queensland Open Downs: sensitivity analysis for gross margins ($/ha/year) in relation to cattle sale and purchase price. Zero till method of fallow weed control was used. The values in bold highlight the GM for the assumed sale price and purchase price in the defined scenarios

	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
		$1.80	$1.90	**$2.00**	$2.10	$2.20
Baseline pasture (native)	$2.80	$18	$17	$16	$14	$13
	$2.90	$20	$19	$18	$16	$15
	$3.00	$22	$21	$20	$18	$17
	$3.10	$24	$23	**$21**	$20	$19
	$3.20	$26	$25	$23	$22	$21
	$3.30	$28	$27	$25	$24	$23
	$3.40	$30	$29	$27	$26	$25
	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
		$1.34	$1.44	**$1.54**	$1.64	$1.74
Oats	$2.90	−$37	−$140	−$242	−$344	−$447
	$3.00	$25	−$78	−$180	−$283	−$385
	$3.10	$87	−$16	−$118	−$221	−$323
	$3.20	$149	$46	**−$56**	−$159	−$261
	$3.30	$210	$108	$6	−$97	−$199
	$3.40	$272	$170	$68	−$35	−$137
	$3.50	$334	$232	$130	$27	−$75
	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
		$1.34	$1.44	**$1.54**	$1.64	$1.74
Forage sorghum	$2.90	$100	−$56	−$211	−$367	−$522
	$3.00	$193	$37	−$118	−$274	−$429
	$3.10	$286	$130	−$25	−$181	−$336
	$3.20	$378	$223	**$68**	−$88	−$243
	$3.30	$471	$316	$161	$5	−$150
	$3.40	$564	$409	$254	$98	−$57
	$3.50	$657	$502	$347	$191	$36
	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
		$1.34	$1.44	**$1.54**	$1.64	$1.74
Lablab	$2.90	$55	−$64	−$182	−$301	−$420
	$3.00	$126	$8	−$111	−$230	−$348
	$3.10	$198	$79	−$40	−$159	−$277
	$3.20	$269	$150	**$31**	−$87	−$206
	$3.30	$340	$221	$103	−$16	−$135
	$3.40	$411	$293	$174	$55	−$63
	$3.50	$483	$364	$245	$127	$8

Table 50. Central Queensland Open Downs: sensitivity analysis for net cattle income ($/ha/year) in relation to cattle sale price and daily liveweight gain. Zero till method of fallow weed control was used. The values in bold highlight the net cattle income for the assumed sale price and liveweight gain in the defined scenarios

	Livestock sale price ($/kg carcass weight)	Liveweight gain (kg/head/day)				
		0.31	0.35	**0.39**	0.43	0.47
Baseline pasture (native)	$2.80	$13	$14	$16	$17	$19
	$2.90	$14	$16	$18	$19	$21
	$3.00	$16	$18	$20	$21	$23
	$3.10	$17	$19	**$21**	$24	$26
	$3.20	$19	$21	$23	$26	$28
	$3.30	$20	$23	$25	$28	$30
	$3.40	$22	$24	$27	$30	$33
	Livestock sale price ($/kg carcass weight)	Liveweight gain (kg/head/day)				
		0.45	0.55	**0.65**	0.75	0.85
Butterfly pea–grass	$2.90	$56	$88	$121	$154	$186
	$3.00	$78	$112	$146	$179	$213
	$3.10	$101	$136	$171	$205	$240
	$3.20	$124	$159	**$195**	$231	$267
	$3.30	$146	$183	$220	$257	$294
	$3.40	$169	$207	$245	$283	$321
	$3.50	$191	$231	$270	$309	$348
	Livestock sale price ($/kg carcass weight)	Liveweight gain (kg/head/day)				
		0.70	0.80	**0.90**	1.00	1.10
Leucaena–grass	$2.90	$109	$133	$158	$182	$207
	$3.00	$126	$151	$176	$202	$227
	$3.10	$143	$169	$195	$221	$247
	$3.20	$160	$187	**$214**	$241	$268
	$3.30	$177	$204	$232	$260	$288
	$3.40	$194	$222	$251	$279	$308
	$3.50	$210	$240	$269	$299	$328

Table 51. Central Queensland Open Downs: sensitivity analysis for net cattle income ($/ha/year) in relation to cattle sale and purchase price. Zero till method of fallow weed control was used. The values in bold highlight the net cattle income for the assumed sale price and purchase price in the defined scenarios

	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
		$1.80	$1.90	**$2.00**	$2.10	$2.20
Baseline pasture (native)	$2.80	$18	$17	$16	$14	$13
	$2.90	$20	$19	$18	$16	$15
	$3.00	$22	$21	$20	$18	$17
	$3.10	$24	$23	**$21**	$20	$19
	$3.20	$26	$25	$23	$22	$21
	$3.30	$28	$27	$25	$24	$23
	$3.40	$30	$29	$27	$26	$25
	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
		$1.34	$1.44	**$1.54**	$1.64	$1.74
Butterfly pea–grass	$2.90	$188	$155	$121	$87	$54
	$3.00	$213	$179	$146	$112	$78
	$3.10	$238	$204	$171	$137	$103
	$3.20	$263	$229	**$195**	$162	$128
	$3.30	$288	$254	$220	$187	$153
	$3.40	$312	$279	$245	$211	$178
	$3.50	$337	$304	$270	$236	$202
	Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
		$1.32	$1.42	**$1.52**	$1.62	$1.72
Leucaena–grass	$2.90	$200	$179	$158	$137	$115
	$3.00	$219	$198	$176	$155	$134
	$3.10	$237	$216	$195	$174	$153
	$3.20	$256	$235	**$214**	$192	$171
	$3.30	$275	$253	$232	$211	$190
	$3.40	$293	$272	$251	$230	$208
	$3.50	$312	$291	$269	$248	$227