final report

Animal Production

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High-output forage systems for meeting beef markets – Phase 1

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Abstract

This report addresses the issue of how to identify, grow, manage and profitably utilise high quality, speciality forages for growing and finishing beef cattle in the Fitzroy River catchment. Best-practice agronomic management of forages and data for cattle production responses in the target area were reviewed. In addition, existing forage decision support tools were reviewed and recommendations made on an approach to develop a simple animal production model for forages. A partial budgeting approach was used to assess five high quality forages and a baseline pasture option to indicate the relative profitability of key forage options. This was done at each of three sites within the Fitzroy River catchment and for both zero till and cultivation methods of fallow weed control. This information can be used, in conjunction with qualitative assessment of social, managerial and environmental factors and assessment of flow-on effects on whole farm profitability, to help inform decisions about whether, when and how to incorporate various high quality forage systems into a beef production enterprise. A best-practice management guide, *Using high quality forages to meet beef markets in the Fitzroy River catchment,* and a spreadsheet calculator, *ForageCalc,* have been produced and can be used to support decision making.

Executive summary

The recent report "Northern beef situation analysis 2009" (McCosker *et al.* 2010) and enterprise analysis conducted as part of the Department of Employment, Economic Development and Innovation (DEEDI), CQBEEF project in central Queensland have highlighted a significant need and scope for improved turnover and productivity (and hence intensification) from beef enterprises to improve profitability and viability in the longer term. Targeted use of high quality, high-output, forages has the potential to improve profitability of beef enterprises in central and southern Queensland through increasing turnover and productivity. In this project we undertook a desk-top study to collate existing best-practice agronomic information and data for cattle production responses from high quality forages. We have presented this information in a best-practice management guide for producers and their advisors. A review of existing forage decision support tools was also conducted. The project included economic analyses of key forage scenarios at selected sites in central and southern Queensland to assist producers to identify best-bet forage options. In addition, we have formulated a set of research questions for testing in a proposed Phase 2 of the project.

Conclusions and recommendations:

- The agronomic information presented in this report for forages suitable for the target area of the Fitzroy River catchment provides an up-dated collation of best-practice recommendations that can be used by producers or advisors to assist in the evaluation of forage options for a beef business. The associated summary of cattle performance data for these forage systems in the target region demonstrates broad principles and differences between the forages, and is useful in showing the range in animal performance for each of the forage types documented and in highlighting potential management issues for consideration. However, due to the limited nature of the data sets reporting cattle liveweight gain, the variable quality of the data sets and the range of conditions, it is difficult to draw strong conclusions about expected animal performance. This necessitated drawing upon expert opinion to provide a general indication of expected liveweight gain for the key forage types. The collection of additional, high quality liveweight gain data sets, in association with measurement of key forage parameters, would provide more confidence in the indicative performance recommendations and a greater understanding of the relationships between cattle liveweight gain and key variables.

- A key recommendation is that such data be collected from commercial beef properties within the Fitzroy River catchment in a proposed Phase 2 of this project. The objective is to develop an improved understanding of the factors driving the productivity and profitability of high quality forage production systems in central Queensland.

- Several models exist that can reliably predict production of tropical pastures and forages, namely GRASP (DPI&F Brisbane) and plant modules within APSIM (Agricultural Production Systems Simulator), respectively. However, none of the existing animal production models are suitable in their current form for application to grazing cattle consuming tropical pasture and forage diets. The two most relevant are GrazFeed (CSIRO Canberra) developed in Australia and the Cornell Net Carbohydrate and Protein System (CNCPS; Cornell University, NY State, USA). The major limitation of the available animal production models is the amount and type of information required as inputs to describe the pasture or diet. Such information is not readily available under grazing conditions and for heterogeneous tropical pasture systems. As the equations underpinning the ruminant feeding standards and decision support tools have been shown to be generally robust and applicable for tropical diets, this provides confidence that a reliable tool can be developed given that the above limitation can be satisfactorily addressed.

- We recommend that the data collected in the proposed Phase 2 of this project should also be used to help validate and parameterise forage and animal production components of the APSIM simulation platform under field conditions. The data collected in this project will make a valuable contribution to other efforts in this area. We propose that three approaches to developing an animal production module within APSIM be investigated. The most appropriate model should then be used to develop a simple decision support tool to allow comparison of beef cattle performance and profitability for a range of forage options.

- The economic analyses reported here (for five high quality forages and a baseline pasture system, at each of three sites within the Fitzroy River catchment and under both zero till and cultivation methods of fallow weed control) provide information on the relative ranking of forages in terms of gross margin, net cattle income and net present value as well as an indication of sensitivity to changes in market price and animal performance. This information can be used, in conjunction with a qualitative assessment of social, managerial and environmental factors, and an assessment of flow-on effects on whole farm profitability, to help inform decisions about whether, when and how to incorporate various high quality forage systems into a beef production enterprise.

- In Phase 2 of this project we propose to build on the partial budgets conducted in Phase 1 to develop whole farm case studies to examine the effect of high quality forage systems on whole farm profitability.

Industry benefits:

- The information collated and the results derived from this project have been developed into a best-practice management guide, *Using high quality forages to meet beef markets in the Fitzroy River catchment*, produced in CD-ROM format. This guide brings together information on:
    - the selection, agronomy and management of forages
    - indicative forage yields at key sites across the Fitzroy River catchment
    - expected content of principal nutrients in forages and their relationship to cattle performance
    - indicative cattle growth rates from a range of high quality forages
    - approaches to incorporating high quality 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.

  This guide can be used by cattle producers and their advisors to improve knowledge and skills and support decision-making about the most profitable use of high quality forages as part of a beef enterprise. The guide will be up-dated and revised with new information obtained in Phase 2 of this project to produce a second edition by 30 December 2013.

- A spreadsheet calculator, *ForageCalc,* has been produced and accompanies the best-practice guide on CD-ROM. The calculator allows users to calculate the economic performance of key forage systems using their own input variables relevant to their individual businesses. This tool will be up-dated and revised with new information obtained in Phase 2 of this project to produce a second edition by 30 December 2013.

Contents

1 Background

The recent report "Northern beef situation analysis 2009" (McCosker *et al.* 2010) and enterprise analysis conducted as part of the Department of Employment, Economic Development and Innovation (DEEDI), CQBEEF project in central Queensland have highlighted significant need and scope for improved turnover and productivity (and hence intensification) from beef enterprises in order to improve profitability and to remain viable in the longer term. High land prices that are now plateauing or declining, high debt levels, increasing interest rates and the continuing cost-price squeeze are key factors that will continue to put pressure on beef businesses into the future. Targeted use of high quality, or high-output, forages has the potential to improve the profitability of beef enterprises in central and southern Queensland through increasing enterprise turnover and productivity.

Beef production from 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, heavier cattle. For these reasons, production systems that enable cattle to be finished more quickly are important in increasing beef producers' ability to meet market specifications for high value beef and for increasing turnover of cattle, both aspects contributing to increased profitability of beef businesses.

Targeted use of high quality, speciality forages can provide an alternative to grain finishing in producing high quality beef and supporting robust and reliable production systems under the more variable climate conditions of the future. High feed grain prices are likely to be a continuing trend into the future due to world grain shortages, climate change and increasing demand for grain for bio-fuel production. This leads to challenges for the economic viability of feedlot finishing of cattle based on high-grain diets in southern and central Queensland.

Additional benefits of efficient and profitable forage finishing systems include:

- increased ability to the meet tighter market specifications for high value beef and to meet the new MSA (Meat Standards Australia) grassfed beef grading standards that are being developed
- allowing for more options and flexibility in choosing target markets (for example improved growth rates in winter and spring will improve industry supply chains and producer production and marketing options)
- reduced methane emissions due to increased animal productivity and thus lower output of methane per unit of product.

To enable a larger number of beef producers to more effectively use areas of intensively developed forages as part of an annual feed plan to meet target market specifications, more definitive and accessible information is required on:

- the selection, agronomy and management of suitable forages according to land and soil types and current and forecast weather conditions
- predicting cattle growth rates from a range of high quality forages for specified breed, age, weight and forage characteristics
- how to incorporate high quality forages into a feed plan to produce the target growth rates required to meet market specifications for one or more market options
- comparative economic information to allow objective comparison of various forage options.

In this project we undertook a desk-top study to collate existing best-practice agronomic information, as well as data for cattle production from high quality forages, and to present it in a more useable format for use by both producers and their advisors. We also reviewed forage and animal models and decisions support tools and their potential for predicting animal performance from the target forage systems. The project included detailed economic analyses of key forage scenarios at selected sites in central and southern Queensland to assist producers in identification of best-bet forage options. In addition, we have formulated a set of research questions for testing in future proposed work (Phase 2).

2 Project objectives

For the target study area of the Fitzroy River catchment, to:

1. Review, collate and document best-practice agronomic information for high-output forages and summarise available data for cattle production responses from forage systems.

2. Review and document existing forage decision support tools and recommend an approach for developing a simple animal production model for forages.

3. Complete and document a detailed economic analysis of forage options at selected sites in central and southern Queensland, based on the existing information.

4. Identify best-bet forage options in the target study area of the Fitzroy basin, which has been defined as ranging from the Capella area in the north to the Taroom-Wandoan area in the south.

5. Formulate a set of optimal forage strategies, research questions and hypotheses for testing in future case study work (Phase 2).

6. Produce a comprehensive methodology and project design including Gantt chart and worksheet outlining the outcomes and targets over the course of possible Phase 2 work.

7. Produce a draft “Best-Practice Management Guide” (produced in a multi-media CD format).

3 Review and collation of best-practice agronomic information for high-output forages and summary of available data for animal production responses from forage systems

3.1 Introduction

Beef production is the major land use in the Fitzroy River catchment occurring on around 13 million ha or approximately 89% of the catchment and with livestock slaughterings accounting 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 supporting production of high quality forages suitable for backgrounding and finishing cattle. Forages capable of producing these higher growth rates include both summer and winter annual forage crops and perennial legume-grass pasture systems such as butterfly pea-grass and leucaena-grass pastures.

Targeted use of such high quality forages can improve the profitability of beef enterprises in the Fitzroy River catchment of Queensland. This occurs through increasing enterprise turnover and productivity and providing a viable alternative to grain finishing in the production of high 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 review collates best-practice information and data on forage agronomy and management as well as available data for cattle production for the target area of the Fitzroy River catchment. This information is part of a wider collation of information used to produce a best-practice management guide for producers and advisers, '*Using high quality forages to meet beef markets in the Fitzroy River catchment*'. Additional information on other aspects relevant to cattle production from high quality forage systems that has been included in the best-practice management guide include estimated forage yields at key sites across the target region, expected principal nutrient content of forages and their relationship to animal performance, approaches to incorporating high quality 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 and example economic analyses. The best-practice agronomic information in this review has been written in the style intended for the best-practice management guide and thus references have not been cited in the text although the reference material drawn upon has been has been provided in the bibliography in section 9 of this report.

3.2 Why use high quality forages?

Beef production from 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 in increasing a beef producer's ability to meet market specifications for high value beef and for increasing turnover of cattle, both aspects contributing 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.

3.2.1 Benefits

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

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

Grass-legume pasture systems have additional advantages through:

- ability to halt declining soil fertility in grass pasture systems by contributing to soil nitrogen levels
- reducing nitrogen fertiliser requirements in subsequent crop rotations for those that can be used as short or long term leys (e.g., butterfly pea and burgundy bean)
- enabling higher productivity and longer persistence of grasses with high nitrogen requirements, for example Green or Gatton Panic, Rhodes and buffel grass.

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

- allowing more options and flexibility in choosing target markets and timing of turn-off
- grazing pressure on the remainder of the property can be reduced 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
- excess forage can be conserved as hay or silage in good years.

3.2.2 Constraints

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

- the availability of suitable arable land
- the expertise involved in land preparation, planting and weed control
- the costs of crop or pasture establishment failures
- unreliability resulting from variable seasonal conditions
- difficulties integrating more intensive forage systems into the business and existing property operations
- uncertainty about the short and long-term profitability of the activity.

3.3 The land resource

The fertility and the 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.

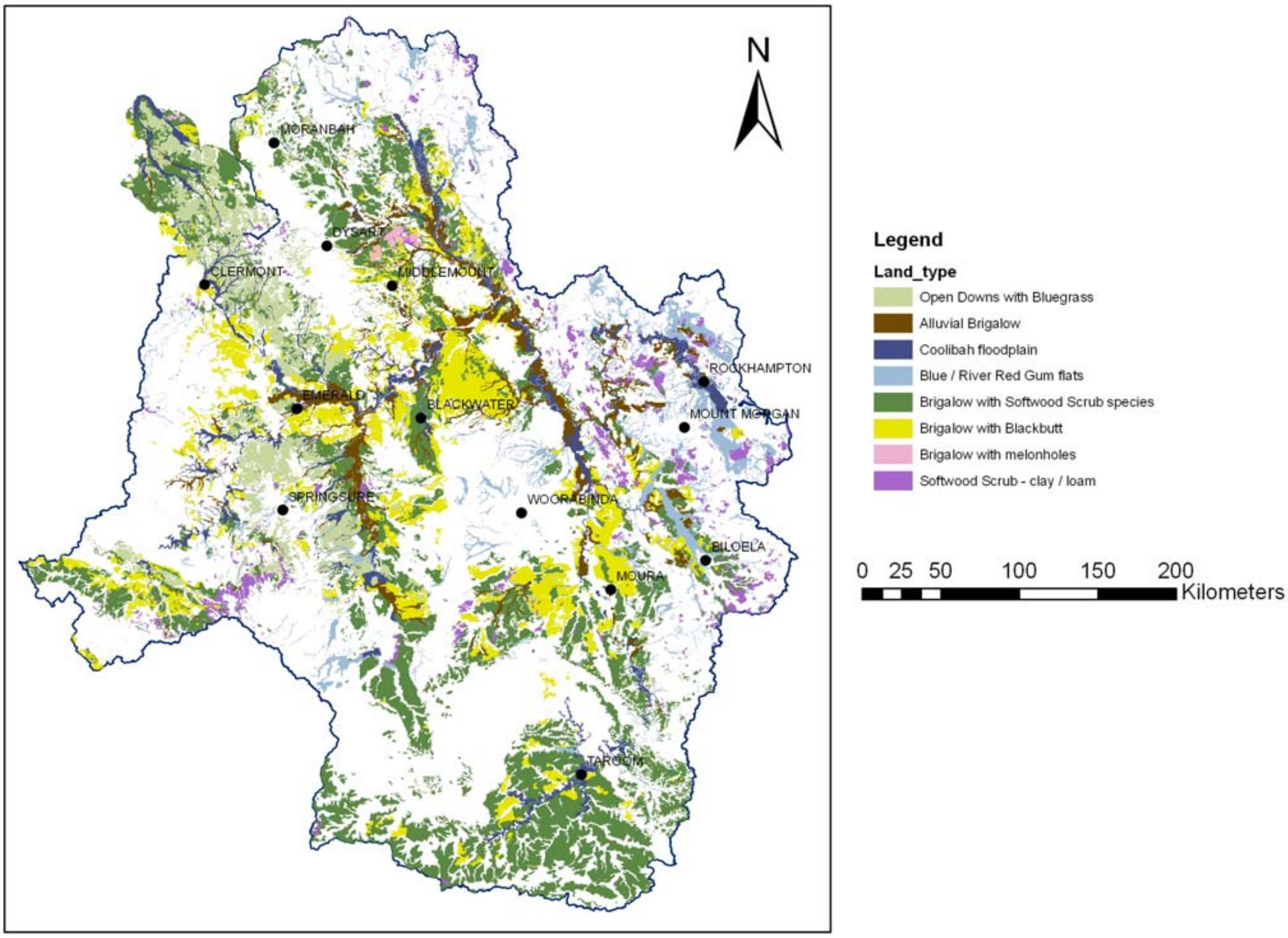

Figure 1. Land types with suitability for high quality sown pasture and forage crop production in the Fitzroy River catchment.

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, 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, angelton 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	• 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***

Land type	Land use and management recommendations	Land use limitations	Suitable sown forages
• ***water availability***: low to moderate			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 • Caribbean and shrubby stylos should only be planted 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
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

Land type	Land use and management recommendations	Land use limitations	Suitable sown forages
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 • teatree should not be cleared to minimise saline seepages • 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

Adapted from Land types of Qld CD version 1.2, 2008; N: nitrogen, P: phosphorus.

3.4 Getting the agronomy right and growing the feed

3.4.1 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 be beneficial on 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 southern and central 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 knowledge 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.

3.4.2 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 addressing 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.

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 a representative soil sample, from the top (0–10 cm), middle (10–60 cm) and subsoil (60–90 cm) strata, is 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 lab. 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 undertaking 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.

3.4.3 Selecting the most appropriate forage species and systems

There are a number of high quality forages that are 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.

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.
- 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.

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 risk of bloat
- 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.

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 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.

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 - seed treatments are typically not warranted. However ‘beetle bait’ or seed-treated 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.

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.

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.

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.

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.

Alternative forage options

Silk sorghum (Sorghum spp.)

Silk sorghum has been a popular forage because the seed is cheap seed 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 that 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-logging 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 4 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.

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 both or 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.

3.5 Animal production responses from high quality forage systems

A collation of available animal growth rate data from high quality forage systems and also from 'baseline' pastures (native or sown grass pastures) in the target region of the Fitzroy River catchment, is presented in the accompanying Excel spreadsheet, '*B.NBP.0496_LWG data for high quality forages.xls*'. The scope of this review includes cattle performance data for summer and winter annual forage crops as well as perennial legume-grass pasture systems with the potential to increase cattle growth rates above those expected from native and sown grass-only pastures. Data for 'baseline pastures' (either sown grasses, predominantly buffel grass, or native pastures on open downs) was included for comparison. The data was primarily drawn from studies in the Fitzroy River catchment. However, additional data sets from outside the target region have been included, where it was deemed relevant (e.g., relevant soil type) or where they provide a very good data set (e.g., study conducted over a number of years or with accompanying measurements of pasture and diet quality). Studies conducted at Brian Pastures Research Station, near Gayndah, often fall into the latter category and have been included where relevant. Both published and unpublished data has been included in this compilation. This includes experimental data gathered on research stations under controlled conditions as well as that from producer demonstration sites on commercial properties, including personal communications. In addition, reports providing an average figure for liveweight gain as a summary of unpublished measurements have been included where the source data could not be located. Table 2 provides a summary of the scope of the review.

Box-and-whisker diagrams were produced using Genstat 12th edition (Payne *et al.* 2009) to summarise the data. For each plot, the box spans the interquartile range of the values in the variate, so that the middle 50% of the data lie within the box, with a line indicating the median. Whiskers extend beyond the ends of the box to the most extreme values within a distance of 1.5 times the interquartile range beyond the quartiles, or the maximum value if that is smaller. Individual outliers are plotted with a cross. Outliers at a distance of 1.5 to 3 times the interquartile range beyond the quartiles are plotted in green font, while outliers at a distance of greater than 3 times the interquartile range beyond the quartiles are plotted in red font. The number next to each outlier refers only to its number in the data set and is not of any other relevance. Figure 2 summarises daily cattle liveweight gain data for the four major forage categories of: grass-only pastures, legume-grass pastures, summer fodder crops and winter fodder crops. Figure 3 presents cattle liveweight gain data for sown grass pastures on brigalow soils and for individual forage species for which there were sufficient data records (i.e. >10).

Table 2. Summary of the scope of the data collated as part of the review of animal production responses from forages in the Fitzroy River catchment

Forage species	Number of references/sources	Number of data sets/experiments	Range of years of data collection
	Grass-only pasture – brigalow soils [A]		
Sown grass pastures, predominantly buffel grass	20	71	1962 - 2009
	Grass-only pasture – open downs soils		
Queensland bluegrass	1	1	1998 - 2004
	Legume + perennial grass pastures		
Caatinga stylo-grass	4	8	1998 - 2005
Desmanthus-grass	2	4	1991 - 1999
Butterfly pea-grass	5	41	1998 - 2005
Burgundy bean-grass	1	5	1998 - 2002
Macrotyloma daltonii CPI 60303	1	3	1998 - 2000
Vigna trilobata CPI 13671	1	3	1998 - 2000
Leucaena-grass	13	50	1972 - 2009
	Summer fodder crops		
Forage sorghum[A]	9	50	1968 - 2009
Lablab	9	33	1973 - 2009
	Winter fodder crops		
Oats[A]	7	16	1968 - 1995
Forage barley	1	5	1972 - 1974
Forage wheat	1	1	1972
Safflower	1	3	1972 - 1974
Rape (*Brassica spp.)*	1	3	1972 - 1974

[A] Includes data sets from duplex soils within the brigalow region that originally supported brigalow scrub and associated vegetation. However, data from forages grown on duplex soil types has not been included in the statistical analysis.

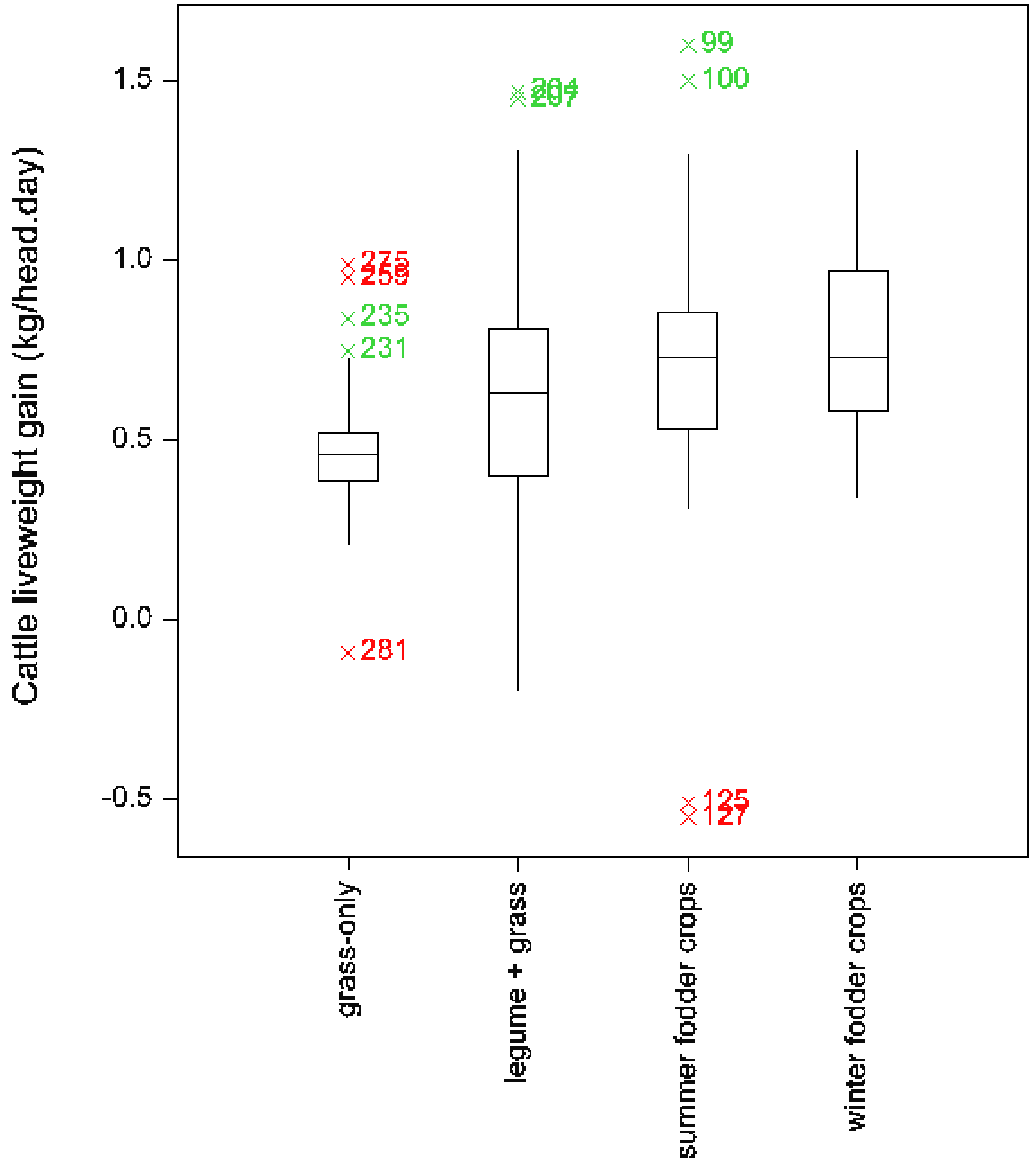

Figure 2. Cattle daily liveweight gain values grouped in four major forage categories of: grass-only pastures (n = 53), legume + grass pastures (n = 82), summer fodder crops (n = 116), winter fodder crops (n = 25), where n = the number of data records. Explanation of box-and-whisker diagram given in the text (p. 30).

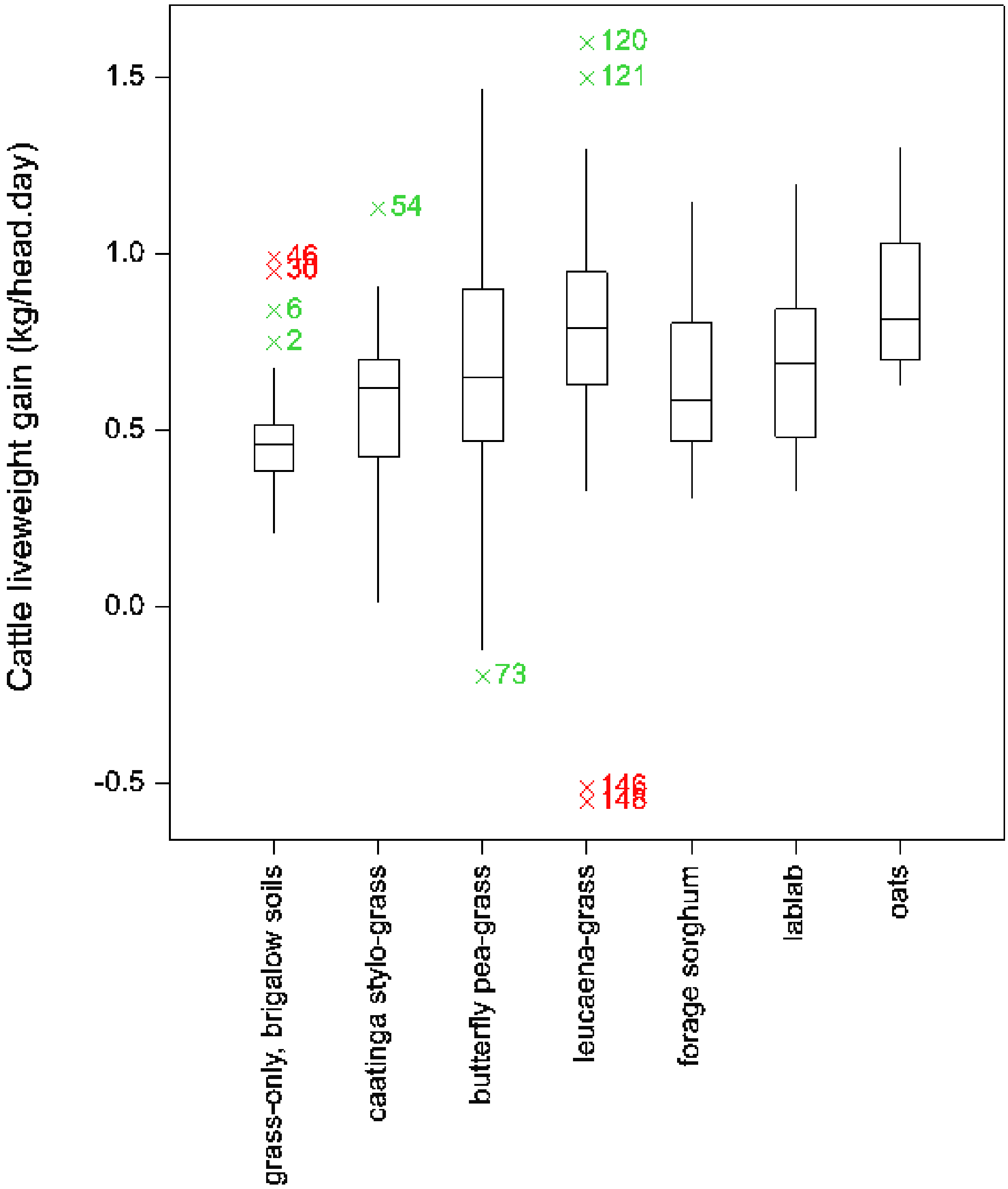

Figure 3. Cattle daily liveweight gain values for individual forage types with sufficient data records for representation (i.e. >10): grass-only pastures on brigalow soils (n = 49), caatinga-stylo-grass pastures (n = 15), butterfly pea-grass pastures (n = 49), leucaena-grass pastures (n = 53), forage sorghum (n = 40), lablab (n = 23), oats (n = 14) where n = the number of data records. Explanation of box-and-whisker diagram given in the text (p.30).

Interpretation of the data in this collation is problematic due to the limited number of data sets recording cattle liveweight gain for the forages of interest, the variable quality of the data sets and the range of conditions under which the studies were conducted. For instance, the following are all important factors influencing cattle growth rate and for which there were considerable variability across the data sets in the compilation:

- forage species and variety within category
- soil type (note that data sets collected for forages grown on duplex soils have been incorporated in the spreadsheet collation exercise but not in the statistical summary)
- age of pasture or cultivation from the time of clearing the original vegetation
- rainfall

- agronomic management including fertiliser application, weed control, suitability of planting conditions, etc
- proportion of sown forage in the total grazing area
- time of season and the length of grazing period during which measurements were taken;
- stocking rate
- grazing management, for example continuous vs. rotational grazing
- cattle factors such as age, weight, sex, breed, growth history (i.e. compensatory growth), use of hormonal growth promotants or supplements.

For example, the grazing period over which measurements of liveweight gain were made varied considerably, with the following range for the four major forage groupings: 34 to 645 days for grass-only pastures, 21 to 324 days for legume-grass pastures, 19 to 374 days for summer fodder crops and 24 to 130 days for winter fodder crops. It was not possible to align cattle liveweight data for the perennial pasture systems with season (e.g., winter) due to inconsistent grazing periods, which traversed seasons, and infrequent weighing of cattle.

In addition to the limitations described above, there was often insufficient supporting data describing both the forage base and the grazing animal to aid in interpretation and comparison of the results across studies. Nevertheless, the compilation of data demonstrates broad principles and differences between the forages and is useful in showing the range in animal performance for each of the forage types documented and in highlighting potential management issues for consideration.

3.5.1 Grass-only pasture ('baseline' pasture)

The data collated for grass-only pastures was collected over a 48-year period and ranges from pastures established immediately after clearing brigalow scrub, to pastures 27 years old. A long-term study of changes in productivity of cleared brigalow lands (The Brigalow Catchment Study, http://www.derm.qld.gov.au/science/projects/brigalow/index.html; Cowie *et al.* 2007; Radford *et al.* 2007) has quantified the productivity decline in sown grass pastures after establishment. This study showed that pasture dry matter, measured at the end of the growing season, declined from an initial high of *ca*. 8000 kg/ha to about 4000 kg/ha 21 years after clearing, with a rapid initial decline during the first 3 years. The study also showed that liveweight gain per hectare declined by 38% during years 2 to 11 following clearing, with beef productivity data confounded after this time due to reductions in stocking rate over time. This productivity decline in sown grass pastures is well documented and is attributed principally to reduced nitrogen availability rather than a net loss of total soil nitrogen (Radford *et al.* 2007).

Some data for grass pastures and forages (oats and forage sorghum) grown on duplex soils was included in the compilation when these soil types originally supported brigalow and associated scrubs. It is now well known that although duplex soils in the brigalow bioregion originally supported forage cropping and highly productive sown grass pastures, these soils have an inherently faster productivity decline, probably due to lower initial fertility and declining soil structure, and are now no longer widely used for forage cropping. The data included in this review for forages grown on duplex soils was collected soon after clearing the original vegetation and pasture establishment. Thus it is probable that forage productivity had not yet been affected by declining fertility. For consistency, data from forages grown on duplex soils has been excluded from the statistical analysis of results.

The open downs soils are typically lower in total nitrogen and phosphorus than the brigalow soils with correspondingly lower expected grass and cattle production. Due to the paucity of data for forages grown on open downs soils, it was not possible to clearly demonstrate this effect here. There were no available data sets for native pastures grown on open downs soils in the target region of the Fitzroy River catchment. Hence, a data set is presented from Brian Pastures

Research Station for Queensland bluegrass pasture grown on a similar soil type to that found on the open downs of central Queensland.

The data demonstrates the wide range in liveweight gain of cattle within and between years due to seasonal variation in rainfall. Within the Fitzroy River catchment mean annual rainfall ranges from 500 to 700 mm with high variability from year to year. Approximately 70% of annual rainfall falls within the summer period. Consequently, winter-spring is a period of lower daily liveweight gain relative to the summer period, primarily due to the lower rainfall but also to lower temperatures with frost affecting the growth of tropical, C_4, grasses. As stated previously, it was not possible to align cattle liveweight gain data with season (e.g. winter) due to inconsistent grazing periods, which traversed seasons, and infrequent weighing of cattle.

3.5.2 Legume-grass pastures

Several experiments have demonstrated the significant liveweight gain benefit attributable to the incorporation of tropical legumes adapted to heavy textured cropping soils, into grass pastures. Where estimates have been made of the diet of cattle consuming perennial, legume-grass pastures (e.g. Dixon and Coates 2008), the data has indicated that cattle can select a diet higher in crude protein and digestibility than that of cattle grazing grass-only pastures. This increased diet quality, coupled with increases in the achievable stocking rate, explains the improvements in animal production per head and per hectare.

In an experiment conducted at Brian Pastures Research Station near Gayndah, Clem (2004) found that in the first year of establishment there was no increase in animal production from butterfly pea-grass and caatinga stylo-grass pastures compared with sown grass pastures without a legume component, but the benefit thereafter generally ranged from 20-40 kg of liveweight gain/ha for the following 4 years. Once the same pastures had been established for 5 years, Hill *et al.* (2009) documented weight gain differences between pasture systems of similar magnitude to those reported by Clem (2004). Hill *et al.* (2009) reported an annual liveweight benefit to legume of 112 and 72 kg/head for caatinga stylo and butterfly pea-grass pasture with moderate legume content, respectively (mean of 2 years) and 76 kg/head for butterfly pea pastures with low levels of legume (1 year of data collection only) when stocking rate was constant across pastures at 0.8 head/ha. The authors concluded that differences between pastures were probably associated with the availability of legume, with peak consumption of legume occurring as the pasture matured during the late wet and early dry seasons. In general, the differences between pasture types were least during the period of fastest growth (December to March) when the quality of the grass pasture was also high, and also lower during the wetter year of the 2-year experiment.

Clem (2004) conducted a major, replicated experiment comparing cattle production from eight pure legume or legume-grass pastures over 4 years. All pure legume pastures (including perennial legumes and annual legumes that regenerate from seed each year) were recolonised with grass or weeds to varying extents. The annual legumes *Macrotyloma daltonii* and *Vigna trilobata* successfully regenerated from seed each year but regular spraying for weed control was necessary. *M. daltonii* had lower palatability and produced lower liveweight gain than other pastures despite high forage yields. *V. trilobata* was noticeably the most palatable of the legumes and produced high steer growth rates. Both butterfly pea and caatinga stylo persisted and combined well with perennial grasses. Burgundy bean was more palatable than butterfly pea and produced similar liveweight gain per hectare and per day. However, the legume content of the former pasture declined over time and consequently butterfly pea was found to be more persistent than burgundy bean. Cattle growth rates on butterfly pea-grass and caatinga stylo-grass pasture were similar to growth rates on butterfly pea and burgundy bean planted without grass. However, grazing periods were longer and stocking rates lower than for the annual and perennial legume forages planted without grass. Given the difficulties of managing *M. daltonii* and *V. trilobata*, Clem (2004) concluded that it was doubtful that they offer any advantages over the more perennial burgundy bean, butterfly pea or caatinga stylo.

The replicated trials such as those of Clem (2004) and Hill *et al.* (2009), carried out on one site over several years, are valuable, as comparisons between data sets from different experiments on different sites can be problematic due to the many variables applying, as described previously. The different data sets for perennial legume-grass pastures are particularly difficult to compare due to the considerable variation in percentage of legume in the pasture and the variability in the time period over which measurements were made. For example, some measurements report growth over the summer growing period only, while others report average annual growth rates over the entire season.

Comparing data between experiments using leucaena-grass pastures is particularly problematic due to the differences in leucaena row width, grass pasture species and pasture yield in the inter-rows and treatment or otherwise of cattle with leucaena rumen fluid inoculum. In addition, the leucaena data set includes a number of reports obtained as personal communication from producers with little supporting data to assist in interpretation. A study by Dixon and Coates (2008) supports the work of Petty (1997) and Galgal (2002) which indicates that even when the amount of leucaena forage available varied widely, leucaena usually comprised 35-60% of the diet selected in leucaena-grass pastures. However, Dixon and Coates (2008) documented high daily liveweight gain (>0.7 kg/head.day) across a wide range in the proportion of leucaena in the diet (10–91%), indicating that a high daily liveweight gain can occur irrespective of the diet percentage of leucaena. The likely explanations for this lack of a general relationship between percentage of leucaena in the diet and daily liveweight gain in this particular study included: a) a high quality diet provided by the grass component of the diet when growing conditions are favourable as in early wet season; b) low total feed on offer limiting daily weight gain even when the proportion of the leucaena in the diet is high; and c) total dry matter intake of the animals being constrained by the ability of the animals to harvest leucaena when the bulk density of leucaena is low.

3.5.3 Summer fodder crops

Data was available for only two summer fodder crops: forage sorghum and lablab, both of which were well represented in available data sets relative to other forage types. It is well known that the considerable year-to-year variability in the performance of cattle on forage sorghum crops is associated with difficulties in managing forage sorghum for optimal quality and quantity, as the quality of the feed declines rapidly as the crop matures. Using a high stocking rate and grazing early in crop development to keep the crop in a vegetative state are strategies used to maintain high feed quality for as long as possible. 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 to thus support the allocated cattle numbers through to targeted finishing weights. A number of studies within the data collation (Silvey and Feraris 1987; French *et al.* 1988a,c) examined the effect of stocking rate on animal performance and it was generally concluded that the effects of differences between stocking rates were not significant or consistent between years. Additionally, in a study by French *et al.* (1988c), cattle performance under a rotational grazing system was not consistently better than continuous grazing and the authors concluded that the additional expense of a rotational grazing system was not justified.

A number of the studies documenting performance of cattle grazing lablab indicated that there were palatability or acceptance problems in the initial weeks of grazing. Experiments conducted at Brigalow Research Station near Theodore over the period 1973-1976 (Graham *et al.* 1986) clearly indicated that slow acceptance in the first 2-3 weeks of grazing caused initial low liveweight gain which was followed by a rapid increase in liveweight gain after this period. It was recommended that access to grass pasture or another forage source be provided during the early grazing period to improve performance. The authors reported that planting 84% of the total area to lablab gave similar results to planting 100% of the area. Similar problems were not observed by Clem (2004) or Whitbread and Clem (2004) for a study conducted at Brian Pastures Research Station where steers grazed lablab planted on 100% of the area. This study compared eight legumes or legume-grass pastures (including the legumes lablab, *M. daltonii*, *V. trilobata*, butterfly pea and burgundy bean), each replicated twice. The authors reported that lablab was the most reliable and easily managed of the legumes studied and also produced the greatest liveweight gain per day and per hectare. One study by Graham *et al*. (1986), compared performance of cattle grazing either lablab or forage sorghum (cv. Zulu) and concluded that there was no significant difference in liveweight gain between the forages, despite lablab yields being only one-fifth that of Zulu sorghum.

3.5.4 Winter fodder crops

Few reports (seven in total) were found giving animal performance data for cattle grazing winter fodder crops relevant to the target region and only one of these studies was conducted as a replicated trial on a research station under controlled conditions. This study by French *et al.* (1988b) compared the performance of cattle grazing forage oats, barley, wheat, safflower and rape grown on Brigalow Research Station over the period 1972-1974. Unfortunately, below average rainfall was experienced during the study with only 3 years of grazing possible out of six attempts, and in the 3 successful years plantings were later than recommended. In this study rape and safflower were generally associated with lower liveweight gains in cattle than the other forages, with stock consistently slow to begin grazing these forages resulting in severe early weight losses which were not recovered. The authors of this study concluded that the type of crop or cultivar planted was less important than agronomic practices and that winter forage crops were unreliable in the central Queensland environment. Similarly, Wildin *et al.* (1982) concluded that winter forage crops such as oats which rely on autumn/winter rain for establishment, are unreliable 5 in 10 years in central Queensland.

Modern plant production models, such as those within the APSIM (Agricultural Production Systems Simulator; Keating *et al.* 2003) modelling framework, are able to utilise regional soil and historical climate data to simulate long-term, average forage production and the frequency of conditions suitable for planting at any selected location. As reported in section 5, the APSIM software system was used in our desk-top study as part of the construction of scenarios for economic analysis, to determine the proportion of years with suitable conditions for sowing forage oats at three locations from south to north in the Fitzroy River catchment. Using 108 years of historical climate data, the model predicted that suitable conditions for planting an oats crop occurred in 67% of years at Taroom and Banana, and 62% of years at Capella.

3.5.5 General indication of expected animal performance from forages

As discussed, due to the limited nature of the data sets recording cattle liveweight gain for the forages of interest, the variable quality of the data sets and the range of conditions under which the studies were conducted, it is not meaningful to take a simple arithmetic mean of the animal performance figures and use this as an indicator of expected animal performance on that forage type. Table 3 provides a general indication of expected animal production for the key, high quality forages relevant to 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 3, for different soil types and also towards the northern and southern boundaries of the region of interest. The accompanying economic analysis (section 5) gives an indication of how forage and animal performance may differ for three scenarios encompassing different soil types and geographical location across the target region.

In general terms, and as is well known, winter fodder crops such as oats can support the highest daily liveweight gains of all forage options over their ‘normal’ grazing periods due to being higher in digestibility than summer fodder crops and tropical (C_4) 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 above that expected from C_4 forage species largely due to increasing the digestibility of the diet.

The comparative 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 and this is explored in three case study scenarios in the accompanying report detailing economic analyses (section 5). In addition to the relative economic merit of forage options, an assessment of social, environmental and managerial factors is of critical importance in the decision-making process. These factors are also discussed in section 5.

3.6 Conclusions

The agronomic information presented here for forages relevant to the target area of the Fitzroy River catchment provides an up-dated collation of best-practice recommendations that can be used by producers or advisors to assist in the evaluation of forage options for a beef business. The associated summary of cattle performance data for these forage systems, when grown in the target region, demonstrates broad principles and differences between the forages and is useful in showing the range in animal performance for each of the forage types documented and in highlighting potential management issues for consideration. However, due to the limited nature of the data sets recording cattle liveweight gain for the forages of interest, the variable quality of the data sets and the range of conditions under which the studies were conducted, it is difficult to draw strong conclusions about expected animal performance. This necessitated drawing upon expert opinion to provide a general indication of expected liveweight gain for the key forage types. The collection of additional, high quality liveweight gain data sets, in association with measurement of key forage parameters, would provide more confidence in the indicative performance recommendations and a greater understanding of the relationships between cattle liveweight gain and key variables.

Table 3. Indicative figures for finishing cattle grazing dryland forages in the Fitzroy River catchment [A]

Forage	Feeding period [B]	Grazing days	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 to February; Autumn: March to May; Winter June to August; Spring: September to November.

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

[D] AE (animal 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 carcase 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.

4 Review of existing forage decision support tools and recommendation on an approach for developing a simple animal production model for forages

4.1 Introduction

The ability to predict the performance of cattle grazing high quality pastures and forages, based on soil, climate, forage and cattle characteristics, would give beef producers and their advisors better information upon which to base management and business decisions. A model or decision support tool (DST), with these capabilities, would allow beef producers to objectively examine and assess, for their specific business, a range of scenarios for incorporating high quality forages into their production systems, in a more flexible and tailored approach than is possible with a best-practice guide or report. Such a tool would enable producers to develop a better understanding of how they can best utilise their various land types, through investigating questions such as:

- What is the comparable forage production, cattle performance and profitability of various forage options given the land capability, seasonal outlook and target beef markets?
- Is it likely to be profitable to plant the speciality forage of interest given the land capability, seasonal outlook and target beef markets?
- What are the outputs and gross margins from high quality forage options compared with grass-only pasture?

While it is important that the outputs from such a model or tool should be of sufficient accuracy for the desired application, of additional value, is the ability to improve understanding of the underlying biology and economic drivers of the beef production system. By comparing model output over a range of key input parameters, producers and advisors can develop a better understanding of the principles and relative importance of factors driving their forage and animal production systems which will further support objective and informed decision making. This has been shown to be the case when the cropping system DST tool, Whopper Cropper (Nelson *et al*. 1999), has been used in discussion forums with grain growers as part of the DEEDI, Central Queensland Sustainable Farming Systems Project (CQSFS), (M. Conway, *pers comm*.). A further benefit of the use of simulation models and derivative DST's in this context is the ability to quantify the level of risk, resulting from seasonal climatic variability, associated with various management options.

While a complex underlying model is generally necessary to achieve reasonable accuracy of predictions, these models are often too complex for extension professionals and primary producers to operate simply and easily and this can be a contributing factor to the poor uptake and use of models by industry, which has been the case historically. The development of more user-friendly DST's that facilitate access to complex model output and are supported and promoted by extension staff and/or industry consultants are required to facilitate widespread use and adoption by industry. An example of a successful DST is the cropping simulation tool, Whopper Cropper, which was developed from the output of plant production modules within the APSIM modelling framework (The Agricultural Production Systems Simulator; Keating *et al.* 2003), and extended through the DEEDI, CQSFS project and by grain industry consultants. There are currently no such tools or models being successfully applied to predict cattle performance, and support adoption of improved management practices, in tropical pasture or forage grazing systems.

4.2 Existing tools and their suitability for predicting cattle production from tropical forage systems

A summary of existing models and DSTs available for predicting pasture, forage and cattle production and for examining feed-planning options is presented in Table 4. Only those tools with potential for application under Australian conditions and that are also currently available and supported have been tabulated. The exception is the DST, Feedman, which has been included despite being no longer available because of its relevance to the high quality forage systems and target region of interest in our project.

4.2.1 Pasture and forage production models

An accurate prediction of pasture or forage biomass production in the region of interest is the first step in simulating production of grazing cattle. GrassGro (Moore *et al.* 1997), APSIM (McCown *et al.* 1996; Keating *et al.* 2003), GRASP (Littleboy and McKeon 1997; McKeon *et al.* 2000) and the SGS Pasture Model/DairyMod/EcoMod suite contain Australian plant production models that utilise regional soil and historical climate data (Johnson *et al.* 2003, Johnson *et al.* 2008). GrassGro, GRASP and APSIM also allow the incorporation of seasonal weather forecast information (e.g. SOI phase forecasting system of Stone *et al.* (1996)). Both GrassGro and the SGS Pasture Model/DairyMod/EcoMod suite were designed and validated for temperate pasture systems across southern Australia or New Zealand and as a result would probably require extensive re-parameterisation before reliably simulating tropical pasture or forage growth. However, the APSIM modelling framework includes plant modules for many relevant annual forage crops and some pasture types which have been developed and validated within the central Queensland environment, which is the target region of interest in our current project. Additionally, GRASP has been calibrated for over 40 tropical perennial grass pasture communities in Queensland although it has not been validated for modified land types such as improved, fertilised or irrigated pastures or for annual species.

4.2.2 Animal production models

Most existing models available to predict cattle growth rate are based on ruminant feeding standards which give basic equations for predicting metabolisable energy (ME) and metabolisable protein (MP) intake and their efficiency of use for maintenance and growth. The British (AFRC 1993), French (INRA 1989), Dutch (Tamminga *et al.* 1994), American (NRC 2000) and Australian (CSIRO 2007) feeding standards have all been developed on temperate forage systems and usually with *Bos taurus* cattle. Studies such as those conducted by Thompson (1996), Bolam (1998), McLennan (2005) and Dove *et al.* (2010) have shown that the existing models based on the feeding standards are generally poor in predicting the performance of cattle grazing tropical forages, primarily due to difficulties in accurately predicting the diet composition, or nutrient value, and the intake of pasture. In fact, Thompson (1996), after examining the ability of a range of available models to predict animal performance in tropical forage systems concluded that a system based on expert opinion appeared to be as reliable as any of the model outputs.

McLennan (2005) conducted a study to evaluate the ability of two existing models, GrazFeed (Freer *et al.* 1997; Freer *et al.* 2010), developed in Australia, and the Cornell Net Carbohydrate and Protein System (CNCPS; Fox *et al.* 2004) developed in the USA, for ability to predict the performance of cattle grazing tropical pastures. Existing data sets from experiments with *Bos indicus* crossbred steers were used to evaluate the models. The author concluded that the underlying equations used in the feeding standards and models to predict energy utilisation for cattle growth were sound. However, neither model was currently suited to use with cattle grazing tropical pasture systems due to their poor ability to predict cattle liveweight gain when intake was unknown and had to be predicted from diet composition. In particular, the relationship between intake and digestibility, which forms the basis of all predictive equations, did not appear to be appropriate for tropical forages. Some recent modifications have been made to the model to incorporate an improved regression of intake on digestibility for C_4 grasses (M. Freer, *pers comm*.). However, at this stage the modifications have not been tested. To our knowledge, the Grazfeed model has not been validated for the types of high quality tropical forages of interest in our project. Forage crops, for example such as sorghum and lablab, are less heterogeneous than sown or native tropical pasture systems and it is possible that cattle production from these forage systems may be able to be predicted more reliably with the Grazfeed approach to predicting intake and diet quality.

Although the Australian model, Grazfeed, offers the most potential for investigation and, if necessary, modification to allow prediction of cattle performance grazing high quality sown forages in tropical Australian environments, several other concerns have been raised by McLennan (2005). In that study, an additional source of error in predicting intake was the under-prediction of microbial protein, a major contributor to MP intake, which limited intake and thus resulted in under-prediction of liveweight gain. In addition, the study by McLennan (2005) highlighted several problems with the Australian feeding standards, which underpin GrazFeed, with errors in predicting maintenance energy requirements of cattle (ME_m), in particular relating to breed effect and effect of ME intake, and in predicting the efficiency of use of energy in excess of maintenance for growth (k_g).

The Davis Growth Model (Oltjen *et al.* 1986), INRA Growth Model (Hoch and Agabriel 2004) and Decision Evaluator for the Cattle Industry (USDA, Clay Centre, Nebraska) are examples of models designed to predict cattle growth and carcass parameters from assumed intake and diet quality parameters. These models were developed for American or European cattle production systems and do not attempt to predict intake of pasture by grazing cattle. However, the output from models simulating forage and subsequent animal production could be used as inputs to these types of protein and fat deposition models to examine carcass parameters and likely market suitability of the cattle to be finished on forage systems.

Three herd-economic simulation models, Breedcow and Dynama (Holmes 1993) and Enterprise (MacLeod and McIvor 2008; MacLeod *et al.* 2009) have been included in the summary given in Table 4 for completeness although these models do not attempt to estimate liveweight gain, but use an assumed liveweight gain as an input. These models have been designed to evaluate the economic implications of different management practices relevant to north Australian beef cattle herds. Examining the effects of changes to forage systems, on herd structure and enterprise economics, is an important final step in the evaluation of forage options. The output from models simulating forage and subsequent animal production could be used to provide more reliable inputs into herd-economic models to make this final assessment on the economic implications of various forage options.

Simple empirical relationships for predicting liveweight gain

In addition to the more complex models for predicting animal production detailed in Table 4, a number of investigators have examined the predictive value of more simple empirical relationships between pasture and/or diet variables and animal production under tropical Australian rangeland conditions. As reviewed by ‘t Mannetje and Ebersohn (1980), the intake and growth rates of grazing animals are dependant on a complex interaction of factors including herbage species and availability, legume content, canopy structure, digestibility, protein and mineral content of the pasture, grazing behaviour and other animal and environmental factors. However, the major factors limiting animal production from tropical and sub-tropical pastures were concluded to be the amount of green material, the amount of legume in the pasture and the mineral composition.

Although Siebert and Hunter (1977) were able to accurately predict cattle growth rates on native grass and *Stylosanthes*-grass pastures in northern Queensland using the nitrogen concentration of the diet (from extrusa samples collected from oesophageal-fistulated cattle), a number of other studies have found the strongest relationships with growth rate to be green grass leaf or total green material in the pasture.

Work by t'Mannetje (1974) showed that, with cattle grazing buffel grass and buffel-siratro pastures on brigalow soils in southern Queensland, liveweight gain was related to total green material, green grass or green legume content in the pasture. McLennan (1997) found that average daily liveweight gain, on buffel grass pastures on brigalow soils in central Queensland, was not correlated with total yield of pasture, green material or of stylo but was correlated with yield of green grass leaf and proportion of green grass leaf in the pasture.

Most recently, Hill *et al.* (2009) examined a number of pasture attributes, estimated by faecal NIRS, for their ability to directly predict liveweight gain of cattle grazing sown grass pasture or a number of legume-grass pastures in southern Queensland. Green leaf mass, green leaf %, adjusted green leaf % (adjusted for inedible woody legume stems), diet crude protein and diet dry matter digestibility were the most useful predictors of liveweight gain, accounting for 77, 74, 80, 63 and 60% of the variation in daily liveweight gain when the data were pooled across pasture types and drafts. However, in this work the regression standard error indicated that the 95% prediction intervals were quite large, at approximately +/- 0.42-0.64 kg/head.day, indicating that the derived regression relationships would have limited application for estimating cattle growth rate under practical conditions. It was concluded that animal factors, such as compensatory growth effects, were having a major influence on growth rate and that predictions of growth rate based only on pasture or diet attributes were unlikely to be accurate or reliable.

Hirata *et al.* (1993) developed a more detailed model for predicting cattle liveweight gain from forage availability, climatic conditions and both pasture and cattle attributes. Potential intake was determined from cattle attributes, employing the equations described by SCA (1990), and then modified by pasture yield, diet digestibility and air temperature to predict intake. Diet digestibility was estimated from relationships developed with herbage allowance which were expressed as empirical functions of climatic conditions or pasture attributes. The model was calibrated and validated against data from a long-term grazing experiment on green panic-dominant pastures on brigalow soil in southern Queensland. When validated, the model tended to overestimate liveweight gain as the proportion of green panic in the pasture decreased. This occurred as the model did not consider species composition and had been calibrated to data from years when green panic was dominant.

In addition, to the empirical models described above, the pasture production model GRASP contains a simple empirical animal production model developed using data from grazing experiments over a range of locations, climatic conditions and stocking rates in the coastal black speargrass zone. In a simulation study comparing both monthly and annual liveweight gain models (McKeon *et al.* 2000), the monthly model over-estimated annual liveweight gain, which was postulated to be due to the inability of the model to correctly represent the possible effects of compensatory growth or gut fill changes over the short time-step.

The results and conclusions from the experiments described above demonstrate the major limitations of a simple empirical approach in predicting cattle growth rate for grazing animals: firstly the limited value of the relationships outside the specific pasture conditions, environment and animal factors used to produce the data set and secondly the difficulty in accounting for animal factors such as compensatory gain. A further consideration in constructing a useful empirical function is that its robustness is reliant on having sufficient accuracy, range and quantity of experimental data for its derivation.

Feed planning tools

While it was not our intention in this project to develop a new feed planning tool, several relevant feed planning and budgeting tools have been described in Table 4. Feedman is a particularly relevant to the forages and region targeted in this project. However, it is no longer commercially available or supported. The MLA Feed Demand Calculator (MLA, CSIRO, DJM Livestock Consultants) and Dairy Predict (Walker and Simpson 2006) are tools which may have application to our project's target region of central Queensland but have been developed for temperate and southern Queensland dairy systems, respectively. Stocktake (DEEDI) calculates short-term forage budgets for Queensland grazing lands and in addition supports assessment of land condition and long-term carrying capacity. QuikIntake (DEEDI, S. McLennan) is another tool developed for north Australian grazing systems and predicts intake from known liveweight gain and an estimate of diet digestibility, using equations from the Australian feed standards. The purpose of this model is to inform stocking rate decisions.

4.3 Conclusions

While several models exist that can reliably predict production of tropical pastures and forages (namely GRASP and plant modules within APSIM, respectively) none of the existing animal production models are suitable in their current form for application to grazing cattle consuming tropical pasture and forage diets. The major limitation of the available animal production models, the two most relevant being GrazFeed and CNCPS, is the amount and type of information required as inputs to describe the pasture or diet, which is not readily available under grazing conditions and for heterogeneous tropical pasture systems. As the equations underpinning the ruminant feeding standards and decision support tools have generally been shown to be robust and applicable for tropical diets, this provides confidence that a reliable tool can be developed given that the above limitation is investigated and addressed.

4.4 Recommendations

We propose to test, evaluate and validate a number of animal production simulation approaches within the APSIM modelling framework to improve the capability to predict performance of cattle grazing the target forages of interest. APSIM is very well supported by research groups nationally and locally and the relevant plant production modules have been parameterised and validated for central Queensland soils, climate and a number of key forage types of interest (e.g. oats, forage sorghum and lablab). Furthermore, recent work has incorporated GRASP functions within the APSIM framework, to allow simulation of tropical pasture production. A further reason for selecting the APSIM framework is that it allows a great degree of flexibility in defining and testing a wide range of management practices at the crop and farm scale. The proposed work in Phase 2 of this project will add value to existing efforts by DEEDI and CSIRO to further develop the animal production simulation capabilities of the APSIM framework.

As discussed above, the major limitations in formulating a suitable beef production module are:

- ability to predict the quality of forage on offer;
- ability to predict the quality of forage selected by the grazing animal;
- ability to predict the quantity of the forage consumed (i.e. intake).

More research is required to provide biologically-based equations for predicting the growth rate of grazing cattle consuming tropical forage diets. The development of such relationships, largely improved relationships between digestibility and intake, for tropical forages and the ability to predict selective grazing is a task requiring significant resources and financial input. In the absence of such resources, we propose that the following three approaches be investigated in our project.

Approach 1: Develop and validate a simple feed conversion efficiency-based approach to estimating cattle liveweight gain

APSIM-simulated forage biomass will be converted into an estimate of cattle liveweight gain through a simple relationship with forage utilisation, ME content of edible forage and feed conversion efficiency.

Approach 2: Validate and parameterise the GRASP daily liveweight gain model

APSIM-simulated forage biomass will be used as an input to the daily liveweight gain model in GRASP, operating within the APSIM environment. This approach is already operational and appears promising, but needs to be validated against measured data sets. Note that the GRASP daily liveweight gain model is not currently used for providing an estimate of liveweight gain in GRASP as an annual liveweight gain model provided a better estimate for the extensive, perennial pasture systems for which GRASP was designed.

Approach 3: Assess the feasibility and, if practical, validate and parameterise Grazfeed

The feasibility of using APSIM-simulated forage biomass as an input to the animal model, GrazFeed will be investigated. If this approach is practical, within the scope and resources of this project, GrazFeed will also be validated and parameterised as for Approach 1 and 2. GrazFeed is the most suitable animal model available for predicting cattle growth in Australian systems and is based on the Australian feeding standards, but the limited testing with tropical pastures has shown problems. To our knowledge, the model has not been validated for the types of high quality tropical forages of interest in our project and it is possible that cattle production from these more homogenous forage systems could be predicted more reliably.

Once the three approaches described above have been tested, the most appropriate model will be used to develop a simple DST (similar to the existing cropping simulation tool Whopper Cropper) to allow comparison of forage options for beef producers. Whopper Cropper is a good example of a DST with successful adoption and is used widely used by producers, consultants and advisors throughout the northern grains region. This tool was built from APSIM output and has been extended and supported through the DEEDI, CQSFS project. The proposed new DST for forages would be similarly be extended and supported through existing DEEDI, CQSFS and CQBEEF frameworks.

APSIM plant modules use historical climate records to obtain a long term perspective on the impact of climate variability on crop and pasture yields and frequency of suitable planting conditions. A DST based on output from this model would inform long-term decision making about whether or not to plant forages and which forage species give the greatest potential profitability with an acceptable level of risk/reliability. This is a different approach to a tool designed to evaluate tactical management options based on measured or estimated parameters in an existing pasture or forage system.

The evaluation of the models as described above is dependent on having suitable measured data sets for the validation process. It is proposed that in Phase 2 of this project objective liveweight gain and economics data will be gathered from commercial beef producers and supported by detailed and scientific characterisation of the forage on offer and associated land capability, management and climate information. Such detailed data sets for the forages and region of the interest, do not currently exist.

Table 4. Summary of existing animal production, forage and feed-planning models and decision support tools

Tool	Description	Limitations
Pasture and forage production models		
GrassGro (CSIRO, Canberra; Moore *et al.* 1997)	• A pasture growth and soil moisture sub-model is combined with the animal models GrazFeed and LambAlive, also from the CSIRO, GRAZPLAN suite, to form the GrassGro decision support tool. • Designed for temperate pasture systems across southern Australia. • Driven by inputs of daily historical climate data to allow examination of day-to-day, seasonal and annual variability in production and economic outcomes. • Also provides access to constantly updated weather inputs giving the capacity to test tactical management options as a season develops. • Contains region-specific databases of background information on land capability and climate. • Can be applied to range of spatial units, from single or multiple paddocks to river catchments and landscapes. • AusFarm is an extension of GrassGro, designed for investigating more complex systems, typically at the whole farm level, with multiple enterprises combining several livestock and cropping operations. AusFarm incorporates crop models and has a modular design allowing inclusion of models from different research teams representing additional crop, livestock and management systems. • User friendly but training and experience required to use it effectively. Sold mainly to consultants. • Well supported by research groups. • Commercially available.	• Not able to predict pasture growth for tropical pasture systems. • Region-specific soil and climate information tailored to southern Australia.
APSIM (Agricultural Production Systems sIMulator) (APSRU joint venture group, Toowoomba; McCown *et al.* 1996; Keating *et al.* 2003) (Note: model	• Daily time-step, point-scale, process-based, plant production modelling framework. • The modelling framework allows the user to choose a set of plant and soil sub-models from the suite available. This framework allows the integration of models derived in disparate research efforts, enabling research from different disciplines to be integrated. • Originally developed for annual grain crops. Plant modules are now available for most annual fodder crops and some	• Currently only a simple, unvalidated module available for predicting the performance of cattle grazing the tropical forages of interest (i.e. the GRASP daily time-step animal LWG model). • Requires extensive training and advanced knowledge of plant growth and soil processes to use the modelling framework. However, model output has been used to produce the user-friendly DST, Whopper Cropper designed for grain growers in Central Queensland.

Tool	Description	Limitations
output has been used to produce the decision support tool, Whopper Cropper)	pastures. • Extremely flexible and customisable management options available. • Ongoing development of animal modelling capabilities currently in progress. • APSFarm is a whole farm implementation of APSIM with multiple paddocks and allows analysis of economics and whole farm issues such as matching land use to land capability and optimising the enterprise mix. • Currently supported by a large research group internationally, nationally and locally.	
GRASP (DERM, Qld; Littleboy and McKeon 1997; McKeon *et al*. 2000)	• Dynamic, deterministic, point-based model of soil-water, grass growth and animal production (sheep and cattle), developed and validated on tropical, perennial grass pastures and calibrated for over 40 pasture communities in Queensland. • The grass-pasture production model runs on a daily time-step using daily climate inputs. • Predicts growth and yield of plant components (i.e. leaf, stem and green, dead). • Contains a daily LWG model that is used to estimate pasture utilisation and its effect on subsequent pasture growth but not to provide an estimate of LWG as such. • Annual, empirical LWG model used to provide LWG estimates with predictions a function of the utilisation and the number of green days (days where growth is not severely limited by solar radiation, soil water, temperature or nitrogen supply).	• Simple animal production model. • Annual LWG time-step. Currently being adapted to a monthly time-step, essentially by allocating annual LWG to months. • Pasture model developed and calibrated for extensive perennial pastures (i.e. native grasses and buffel grass) and may not adequately simulate production of annual species in more intensive management situations without extensive re-parameterisation. • Not designed as a user-friendly, decision-support tool; experience and training required.
SGS Pasture Model, DairyMod and EcoMod (IMJ Consulants, Armidale; Johnson *et al.* 2003; Johnson *et al.* 2008)	• Mechanistic, biophysical pasture simulation models. • Designed and parameterised for temperate Australian or New Zealand (NZ) pasture systems. • This suite of models each has the same underlying biophysical structure and model code. The differences are primarily in the available stock classes and customised management routines (SGS Pasture Model: cattle and sheep; DairyMod: dairy cattle; EcoMod: NZ pasture industries). • Include modules for pasture growth and utilisation by grazing animals, water and nutrient dynamics, animal	• Not designed or parameterised for sub-tropical/tropical pasture systems. • Potential intake determined as a function of assumed pasture digestibility. This approach is problematic for tropical pasture systems.

Tool	Description	Limitations
	physiology and production and a range of options for pasture management, irrigation and fertiliser application. • Use historical climate data from nominated locations to predict forage growth. • Whole farm, multi paddock models with up to 100 independent paddocks. • Incorporate feeding of concentrates and conserved forages. • Animal growth model is ME-based. • Predicted pasture intake is a function of available pasture, potential intake and ME requirement. Potential intake is calculated in terms of digestibility of the available herbage mass. • Free to download from the web. • Currently supported and maintained.	
	Animal production models	
GrazFeed (CSIRO, Canberra; Freer *et al.* 2010)	• Static, daily animal biology and production DST for grazing ruminants. • Developed and validated in temperate Australia. • Based on the equations from Australian feeding standards (CSIRO 2007 and SCA 1990). • Equations that link ME (& CP) intake and LWG. • Predicts forage intake using variables including forage mass and height, digestibility, legume content, and N content for pastures of low digestibility. • User friendly and able to be used off-the-shelf by producers and consultants. • Well supported by research groups. • Commercially available.	• Poor prediction of LWG for cattle grazing tropical pastures when intake is not known and must be predicted from diet composition. • Detailed description of the pasture/diet required as model inputs. • Poor prediction of diet quality from pasture description with tropical pastures. • Generally poor relationships between diet composition parameters and intake for tropical pasture diets resulting in under-prediction of intake of tropical pasture diets. Some recent modifications have attempted to improve predictions for C_4 grasses but as the result is, as yet, untested. • Under-prediction of microbial CP production for tropical pasture diets. • Under-prediction of LWG for tropical pastures when a deficiency of rumen degradable protein in the diet is predicted, due to the reduction in predicted intake. • Some concerns with prediction of the maintenance requirements of animals, particularly with regard to breed effect and effect of metabolisable energy intake.
Cornell Net Carbohydrate and Protein System (CNCPS) (Cornell University, NY State, USA; Fox	• Two levels: Empirical or mechanistic model. • Predicts LWG from assumed intake and feed quality. • Based on the USA Feeding Standards. • Designed for housed animals and not easily applied to the grazing situation in that it requires an intake estimate and	• Poor prediction of LWG for cattle grazing tropical pastures when intake is not known and must be predicted from diet composition. • Detailed description of the pasture/diet required as model inputs and generally poor relationships between intake and diet composition

Tool	Description	Limitations
et al. 2004)	detailed description of the diet. • Well supported by research groups. • Commercially available.	parameters for tropical pasture diets. • Moderate user knowledge and experience required for effective use. • Not adapted to Australian units and beef production systems.
Davis Growth Model (University of California, Davis; Oltjen *et al*. 1986)	• Dynamic, mechanistic steer growth model designed to predict protein and fat deposition in growing cattle. • Predicts LWG and carcass parameters from assumed ME intake. • Based on fundamental biological model describing growth of individual mammalian organs and tissues.	• Doesn't predict intake. • Not adapted for *Bos indicus* cattle. • Not adapted to Australian units and beef production systems. • Underestimates body fat deposition during feeding restriction periods.
INRA Growth Model (IGM) (INRA, France; Hoch and Agabriel 2004)	• Dynamic, mechanistic steer growth model designed to predict protein and fat deposition in growing cattle. • Predicts LWG and carcass parameters from assumed ME intake. • Based on fundamental biological processes underlying growth and development.	• Doesn't predict intake. • Not adapted for *Bos indicus* cattle. • Not adapted to Australian units and beef production systems. • Overestimates body fat at low MEI and underestimates body fat at high MEI. • Does not take into account ME concentration (MEC) of the diet and thus does not simulate different growth trajectories for same MEI but different MEC.
Decision Evaluator for the Cattle Industry (DECI) (USDA, Clay Centre, Nebraska; http://www.ars.usda.gov/services/software/download.htm)	• Predicts LWG and carcass parameters from assumed intake and diet quality parameters. • Designed to evaluate strategic decisions affecting marketing endpoints for a single herd of breeding females. • Based on the USA feeding standards.	• Doesn't predict intake. • Pasture production model not included and pasture resources currently user-defined. • Not adapted to Australian units and beef production systems.
Breedcow (DEEDI, Townsville; Holmes 1993)	• Static, herd-dynamic model designed to evaluate the effect of different management options on herd structure and profitability. • User specifies annual growth rates. • Commercially available and supported.	• LWG is an input not an output. • The economic output is reliant on the user's best estimate of biological input data with no biological allowance in the model for rainfall, forage production, LWG or different classes of stock.
Dynama (DEEDI, Townsville; Holmes 1993)	• 10-year, Dynamic, whole-property, herd-dynamic model designed to evaluate the effect different management options on herd structure and profitability over time. • User specifies annual growth rates. • Commercially available and supported.	• LWG is an input not an output. • The economic output is reliant on the user's best estimate of biological input data with no biological allowance in the model for rainfall, forage production, LWG or different classes of stock.
Enterprise (CSIRO, Brisbane; MacLeod and	• Herd economic simulation model designed to evaluate the economic implications of alternative rangeland management practices and changing climatic conditions.	• LWG is an input, not an output. • Model uses GRASP determination of animal LWG which utilises a very simple animal production model. • The single LWG from GRASP is

Tool	Description	Limitations
McIvor 2008; MacLeod *et al.* 2009)	• Dynamic: models herd structure and economics for an enterprise over a period of up to 100 years. • Inputs: GRASP-derived climate, pasture growth, stocking rate and LW change. • Currently supported and in use by research groups.	allocated to all classes of cattle and thus may result in some errors in predicted branding and mortality rates. • Not commercially available.
Feed planning tools		
Feedman (Rickert *et al*. 1996; Thompson 1996; QDPI & UQ)	• Evaluates feeding options for growing cattle in terms of forage utilisation, animal performance, market options and economics in the "endowed zone" of central and south-east Queensland. • Caters for 27 "land types and 42 forage types including oats, lablab, sorghum, leucaena, stylo, medics, lucerne, grain crop stubbles, temperate grasses, sown and native pasures. • Mathematical descriptions of underlying biology of plant growth derived from GRASP. • Inputs: likely rainfall, characteristics and area of soil in paddocks, type of pasture or forage, tree density, costs and prices. • Tables of assumed LWG for a range of pasture types and regions. • Generic model with default values put in by the designers.	• Assumed figures for LWG are based on 'expert opinion' of the expected average daily gain of a 440 kg, 2 year-old, Brahman/Hereford cross steer or dry cow grazing each of the available forage options in a region. • The estimate of LWG is based on an animal grazing medium fertility soil, at a conservative stocking rate in an average season. An annual expectation has been created which is apportioned to months of the year. • No allowance for variation in animal performance as a result of SR, breed, age, sex or weight of stock. • Does not allow for changes in DMI as forage quality changes. • Not dynamic. • Model now not commercially available or supported.
MLA Feed Demand Calculator (Beef) (MLA, CSIRO, DJM Livestock Consultants; http://www.mla.com.au/TopicHierarchy/IndustryPrograms/SouthernBeef/Morebeeffrompastures/MLA+Feed+Demand+Calculator.htm)	• Microsoft Excel spreadsheet tool. • Calculates and compares the pattern of feed supply and demand on a whole farm basis for a 12-month period. • Based on the more detailed DSTs, GrazFeed and GrassGro. • Tailored for southern, temperate pastures systems but with inclusion of 3 Qld sites: St. George, Roma and Goondwindi. • Free to download from the web.	• Based on GrazFeed so the same problems would exist in predicting growth rates of cattle grazing, non-temperate pasture systems. • Not adapted for central Queensland and tropical forage systems.
Dairy Predict (DEEDI, Gatton; Walker and Simpson 2006)	• Feed-base and enterprise planning tool developed for the sub-tropical dairy industry. • Evaluates the effects of different forages, herd sizes, calving patterns and supplementary feeding strategies on individual dairy farm gross margins. • The database contains monthly dry matter production and ME content for a range of sub-tropical, and some temperate, forages.	• Intakes calculated based on ME requirement for nominated production targets and not calculated according to forage quality or diet composition. • Not adapted for beef cattle production systems.

Tool	Description	Limitations
	• The data base includes forage growth and production data derived from DairyMod which uses daily climate files from a nominated locality to predict forage growth. This allows the best, average and worst years to be compared. • ME requirement is calculated using NRC and ARC ruminant feeding standards and is based on user-defined production targets. • There is a potential DM intake constraint built in for biologically unrealistic production targets and animal LW. • Free to download from the internet.	
Stocktake (DEEDI, http://www.dpi.qld.gov.au/27_11643.htm)	• A paddock-scale land condition monitoring and management package. • Designed as a decision-support tool for grazing land managers. • Calculates short-term forage budgets. • Supports assessment of land condition and long-term carrying capacity. • Pasture intake is assumed to be 2.2% of animal liveweight but can be varied by the user within the range 1.5 – 2.5% for short-term forage budgeting.	• Pasture intake is an input not an output.
QuikIntake (DEEDI, Brisbane; S McLennan)	• Excel spreadsheet tool. • Predicts intake from known LWG and an estimate of diet digestibility (e.g. from faecal NIRS). • Purpose is to inform stocking rate decisions. • Based on the Australian feeding standards.	• LWG is an input not an output. • May over-predict intake due to "errors" in the feeding standard equations.

ARC: Agricultural Research Council (UK ruminant feeding standards); CP: crude protein; LWG: liveweight gain; ME: metabolisable energy; NRC: National Research Council (USA ruminant feeding standards).

5 Economic analysis of forage options in the Fitzroy River catchment

5.1 Methodology

5.1.1 General description of the analysis

Detailed economic analyses were conducted for three case study sites across the target region of the Fitzroy River catchment, representing the South Queensland Brigalow region (Taroom-Wandoan area; Site 1), the Central Queensland Brigalow region (Bauhinia-Theodore area; Site 2) and the Central Queensland Open Downs region (Capella area; Site 3). Six forage types were modelled at each of the sites, including:

- the annual forages: oats, sorghum and lablab,
- the perennial forage systems: butterfly pea-grass and leucaena-grass, and
- baseline pasture for comparison: buffel grass at Sites 1 and 2, and Queensland bluegrass pasture at Site 3.

These forage options were targeted for analysis due to being the most important forages currently grown and utilised throughout the Fitzroy River catchment. 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 Tables 5-7. 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). 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 (see section 3). 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.

To help inform the assessment of cattle production from forages, forage biomass production and the number of possible planting events was simulated using biophysical models to account for the effect of climate variability (using 108 years of climate data) at each location. The GRASP pasture model (Rickert *et al.* 2000) was used to model the baseline 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 3 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 re-set 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 (see section 3).

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.

5.1.2 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 gross margin 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.

5.1.3 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.

5.1.4 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 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.

5.1.5 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 Tables 5-7.

5.1.6 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.

5.1.7 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 1 month earlier and thus the steers to be 1 month older at weaning (see Tables 5-7 for details).

5.1.8 Partial budgets vs. whole farm analysis

The economic analyses reported here were conducted using a partial budgeting approach which considers only those costs and benefits directly related to the investment and does not incorporate analysis of alternative methods of funding the investment nor the impact on whole farm cash-flow. These factors should be taken into consideration in making the final investment decision. The impact on whole farm profitability requires consideration of additional factors such as, for example, the effect of improved carrying capacity and faster turnoff in increasing 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. In addition social, environmental and managerial factors may also influence the decision-making process. These additional factors are outlined in section 5.2.7.

Table 5. 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
Baseline pasture	
Pasture characteristics	Buffel grass (older pastures); 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 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 1st 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 to 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 pre-plant. 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

Factor	Description
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
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. Re-planting occurred every 5 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

Factor	Description
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
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: animal 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 6. 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 No106 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 1st 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 to 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
Forage sorghum	

Factor	Description
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
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 5 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	 Roundup 1.5 L/ha X 3 applications; 2,4-D Amine 625 0.5 L/ha X 3

Factor	Description
Cultivation	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: animal 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 7. 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 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 1st 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 to 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
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. Re-planting occurred every 5 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	

Factor	Description
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: animal 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.

5.2 Results and discussion

The results and discussion of relative forage performance at individual case study sites are reported in a separate section for each of the three sites. General discussion of the results can be found in sections 5.2.4-5.2.6. The annual and monthly distribution of rainfall and maximum and minimum temperatures are shown in Tables 8, 18, and 28 for all available years of historical data at selected weather station sites relevant to each of the case study sites. Average forage production, modelled over 108 years of historical climate data, at each of the three sites is shown in Tables 9, 19 and 29, and key production and economic performance data is given in Tables 10-17, 20-27 and 30-37 and in Figures 4-9.

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

Long-term, mean annual rainfall for the South Queensland Brigalow site was 671.1 mm with the highest rainfall totals occurring during the months of December to February and the lowest during August. Average minimum temperature was lowest during July and average maximum temperature highest during January (Table 8). Model simulations based on regional, long-term climate data and soil data showed lablab to produce the highest average forage yield per hectare, approximately twice that produced from baseline buffel grass pastures (Table 9). Forages ranked from highest to lowest in terms of predicted yield per hectare were: lablab > forage sorghum > baseline, buffel grass pastures > leucaena-grass > oats > butterfly pea-grass. Conditions were suitable for sowing oats in only 67% of years over the 108-year cycle.

Table 8. 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 temperature (^{0}C)	33.7	32.8	31.67	28.8	24.5	21.5	21.0	23.0	26.7	29.9	31.8	33.5	28.2
Minimum temperature (^{0}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 9. South Queensland Brigalow: 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)	**Oats**	**Forage sorghum**	**Lablab**	**Butterfly pea-grass[A]**	**Leucaena-grass[A]**
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

[A] Yield of edible legume (i.e. stems up to 5 mm in diameter for leucaena) and grass.
N/A: estimate not available.

At the South Queensland Brigalow site, all annual forage crops produced a lower GM per hectare than the baseline, buffel grass pasture (Table 10). Furthermore, with the exception of oats grown under the zero till system, all annual forage crops produced negative GM. 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 11 and 12). 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 10. 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 11. 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 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
$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	$67
Oats					
Livestock sale price ($/kg carcass weight)	**Liveweight gain (kg/head.day)**				
	0.90	1.00	**1.10**	1.20	1.30
$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	$332
Forage sorghum					
Livestock sale price ($/kg carcass weight)	**Liveweight gain (kg/head.day)**				
	0.35	0.45	**0.55**	0.65	0.75
$2.90	-$335	-$286	-$237	-$188	-$139
$3.00	-$261	-$210	-$160	-$109	-$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	$346
Lablab					
Livestock sale price ($/kg carcass weight)	**Liveweight gain (kg/head.day)**				
	0.60	0.70	**0.80**	0.90	1.00
$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 12. 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.

Baseline pasture (buffel)					
Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
	$1.80	$1.90	**$2.00**	$2.10	$2.20
$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	$49
Oats					
Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
	$1.40	$1.50	**$1.60**	$1.70	$1.80
$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	$28
Forage sorghum					
Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
	$1.40	$1.50	**$1.60**	$1.70	$1.80
$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	-$34
Lablab					
Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
	$1.40	$1.50	**$1.60**	$1.70	$1.80
$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

Net cattle income calculations for the perennial pastures showed that leucaena-grass pasture produced net cattle income 1.1 times greater than for butterfly pea-grass pasture and 3.7 times greater than for the baseline pasture (Table 13). 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 15 and 16). The cost of establishing the forages is given in Table 14. It cost more per hectare to establish butterfly pea-grass pasture than leucaena-grass pasture. Establishing both perennial legume-grass pastures cost more when using the cultivation rather than the zero till method of fallow weed control.

Table 13. South 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	$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 14. 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 15. 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.

Baseline pasture (buffel)					
Livestock sale price ($/kg carcass weight)	**Liveweight gain (kg/head.day)**				
	0.33	0.37	**0.41**	0.45	0.49
$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	$67
Butterfly pea-grass					
Livestock sale price ($/kg carcass weight)	**Liveweight gain (kg/head.day)**				
	0.40	0.50	**0.60**	0.70	0.80
$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	$284
Leucaena-grass					
Livestock sale price ($/kg carcass weight)	**Liveweight gain (kg/head.day)**				
	0.70	0.80	**0.90**	1.00	1.10
$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 16. 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 GM 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
$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	$49
Butterfly pea-grass					
Livestock sale price ($/kg carcass weight)	**Purchase price ($/kg liveweight)**				
	$1.40	$1.50	**$1.60**	$1.70	$1.80
$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	$141
Leucaena-grass					
Livestock sale price ($/kg carcass weight)	**Purchase price ($/kg liveweight)**				
	$1.40	$1.50	**$1.60**	$1.70	$1.80
$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

The NPV calculations showed that utilising leucaena-grass pastures, planted using either zero till or cultivation methods, over a 30-year period produced much greater returns than planting, or utilising, the alternative forages (Table 17). Leucaena-grass pastures produced NPV results 2.3-2.5 times greater than the baseline pasture. Butterfly pea-grass pasture also produced greater returns than the baseline pasture under the zero till, but not the cultivation, method. All annual forages performed worse than the baseline pasture over the 30-year time period, with all, except oats grown under the zero till system, producing negative returns. The ranking of forage NPV for the zero till system was: leucaena-grass > butterfly pea-grass > baseline pasture > oats > forage sorghum > lablab. The ranking of forage NPV for the cultivation system was the same as that for zero till, except that the ranking of butterfly-pea grass and baseline pasture was reversed.

Annual animal liveweight gain per hectare for the range of forages studied produced a different ranking than for NPV: oats > forage sorghum > lablab > leucaena-grass > butterfly pea-grass > baseline pasture (Table 17). 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 necessitated purchasing heavier animals when finishing at the same target weight, as in our example scenarios.

Table 17. 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	$1,415
Cultivation	$568	-$168	-$1,027	-$1,768	$410	$1,301
NPV ($/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 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 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 the total area, including access to grass pasture as 10% of the total grazing area.

Figures 4 and 5 show the cumulative (not discounted) cash-flow for each of the forages and the baseline pasture. The higher initial investment in leucaena-grass pasture resulted in a negative cash-flow for the first 4 years for the zero till system and 5 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 while neutral cash-flows in some years for oats demonstrates the effect of years in which planting did not occur due to unfavourable seasonal conditions.

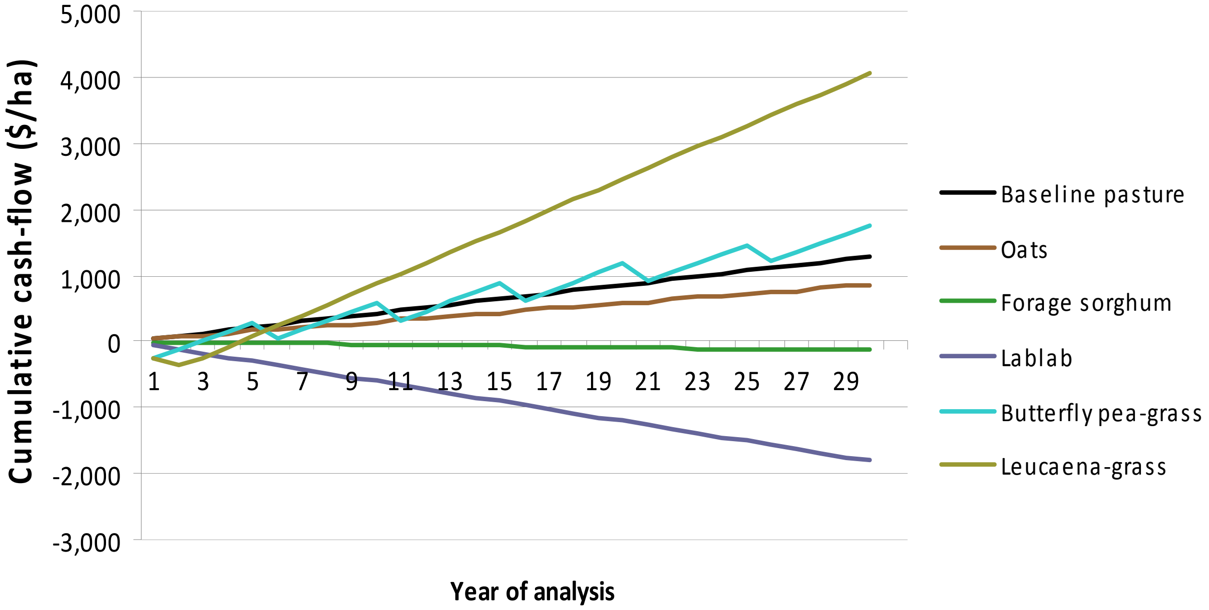

Figure 4. South Queensland Brigalow: cumulative net cash-flow over a 30-year period for key forage options using the zero till method of fallow weed control.

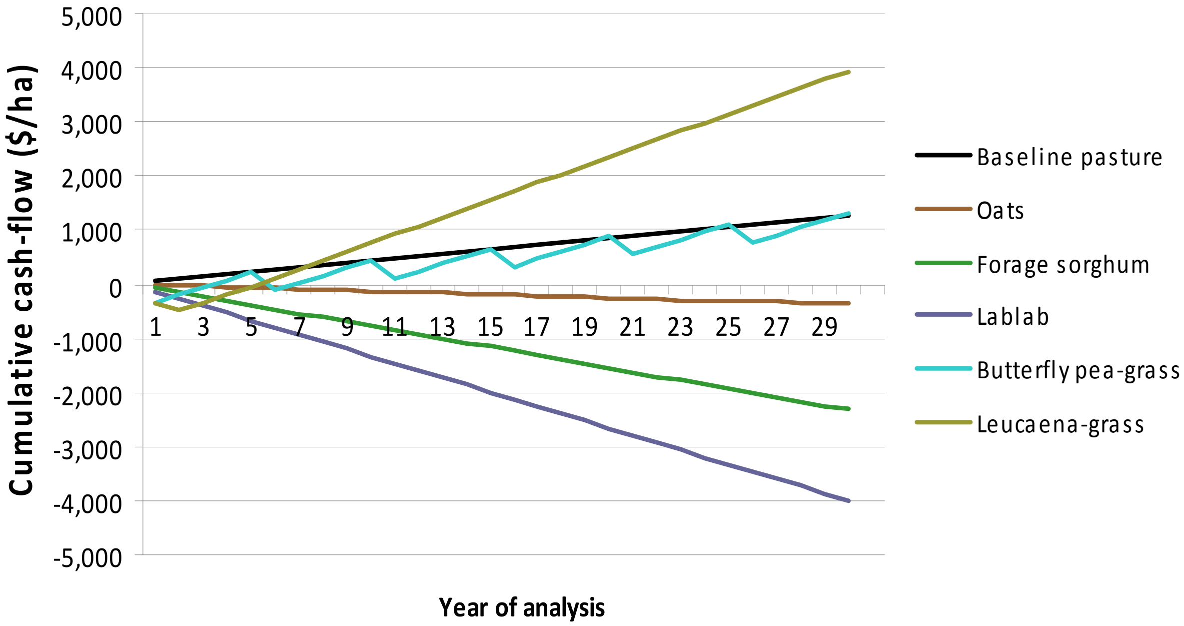

Figure 5. South Queensland Brigalow: cumulative net cash-flow over a 30-year period for key forage options using the cultivation method of fallow weed control.

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

Long-term, mean annual rainfall for the Central Queensland Brigalow site was 663.8 mm with the highest rainfall totals occurring during the months of December to February and the lowest during August (Table 18). Average minimum temperature was lowest during July and average maximum temperature highest during January (Table 18). Model simulations based on regional, long-term climate data and soil data showed forage sorghum to produce the highest average forage yield per hectare, approximately 2.5 times that produced from baseline, buffel grass pastures (Table 19). Forages ranked from highest to lowest in terms of yield per hectare were as follows: forage sorghum > lablab > oats > leucaena-grass > butterfly pea-grass > baseline, buffel grass pastures. Conditions were suitable for sowing oats in only 67% of years over the 108-year modelling cycle.

Table 18. 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 temperature (^{0}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 temperature (^{0}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 19. Central Queensland Brigalow: forage production of baseline pasture and annual forage crops predicted using GRASP or APSIM and of perennial legume-grass pastures estimates by expert opinion

	Forage					
	Baseline pasture (buffel)	**Oats**	**Forage sorghum**	**Lablab**	**Butterfly pea-grass[A]**	**Leucaena-grass[A]**
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

[A] Yield of edible legume (i.e. stems up to 5 mm in diameter for leucaena) and grass.
N/A: estimate not available.

At the Central Queensland Brigalow site, GM calculated for annual forage crops and baseline pasture showed that forage sorghum had the highest GM per hectare for the zero till system, followed by oats, lablab and then the baseline pasture which had a GM 3.6 times less than that for forage sorghum (Table 20). For the cultivation system, the ranking differed with oats and lablab both producing lower GM than for the baseline pasture, and with the lablab GM being negative. 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 as well as purchase and sale price combinations (Tables 21 and 22). 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 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 (for example as in the commercial product, 'Spinnaker') which has a high cost of application per hectare ($70/ha assumed).

Table 20. 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 21. 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.

Baseline pasture (buffel)					
Livestock sale price ($/kg carcass weight)	**Liveweight gain (kg/head.day)**				
	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)	**Liveweight gain (kg/head.day)**				
	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)	**Liveweight gain (kg/head.day)**				
	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)	**Liveweight gain (kg/head.day)**				
	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 22. 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

Baseline pasture (buffel)

Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
	$1.80	$1.90	**$2.00**	$2.10	$2.20
$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

Oats

Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
	$1.32	$1.42	**$1.52**	$1.62	$1.72
$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

Forage sorghum

Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
	$1.34	$1.44	**$1.54**	$1.64	$1.74
$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

Lablab

Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
	$1.34	$1.44	**$1.54**	$1.64	$1.74
$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

Net cattle income calculations for cattle production on perennial pastures showed that the leucaena-grass pasture produced net cattle income 1.2 times greater than for the butterfly pea-grass pasture and 4.3 times greater than for the baseline pasture (Table 23). 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 25 and 26). The cost of establishing the forages is given in Table 24. It cost more per hectare to establish butterfly pea-grass pasture than leucaena-grass pasture. Establishing both perennial, legume-grass pastures cost more when using the cultivation rather than the zero till method of fallow weed control.

Table 23. 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 24. 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 25. 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

Baseline pasture (buffel)					
Livestock sale price ($/kg carcass weight)	**Liveweight gain (kg/head.day)**				
	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	$76
Butterfly pea-grass					
Livestock sale price ($/kg carcass weight)	**Liveweight gain (kg/head.day)**				
	0.40	0.50	**0.60**	0.70	0.80
$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	$328
Leucaena-grass					
Livestock sale price ($/kg carcass weight)	**Liveweight gain (kg/head.day)**				
	0.70	0.80	**0.90**	1.00	1.10
$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	$316
$3.50	$218	$247	$277	$306	$336

Table 26. 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 GM 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
$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	$58
Butterfly pea-grass					
Livestock sale price ($/kg carcass weight)	**Purchase price ($/kg liveweight)**				
	$1.32	$1.42	**$1.52**	$1.62	$1.72
$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	$184
Leucaena-grass					
Livestock sale price ($/kg carcass weight)	**Purchase price ($/kg liveweight)**				
	$1.32	$1.42	**$1.52**	$1.62	$1.72
$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

The NPV calculations showed that for the zero till system, planting forage sorghum over a 30 year period produced a higher return than planting, or utilising, the alternative forages, (Table 27). Leucaena-grass pasture produced the greatest NPV under the cultivation system. All sown forages performed better than the baseline pasture over the 30-year time period, except oats and lablab under cultivation, with lablab producing a negative NPV. The ranking of forage NPV for the zero till system was: forage sorghum > leucaena-grass > butterfly pea-grass > lablab > oats > baseline pasture. The ranking of forage NPV for the cultivation system was: leucaena-grass > forage sorghum > butterfly pea-grass > baseline pasture > oats > lablab. These differences in ranking are largely due to the high cost of planting forages in a cultivation system, with a relatively greater effect on the profitability of annual forages.

Annual animal liveweight gain per hectare for the range of forages studied produced a different ranking than for NPV: forage sorghum > lablab > oats > leucaena-grass > butterfly pea-grass > baseline, buffel grass pasture (Table 27).

Table 27. 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	$2,444	$799	$1,184	$2,131
Cultivation	$679	$172	$1,478	-$167	$964	$2,017
NPV ($/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 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 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 the 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. The higher initial investment in leucaena resulted in a negative cash-flow for the first 3 and 4 years in the zero till and cultivation systems, respectively, after which cash-flow became positive. Butterfly pea-grass pastures produced negative cash-flows in some years due to the costs of replanting while 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.

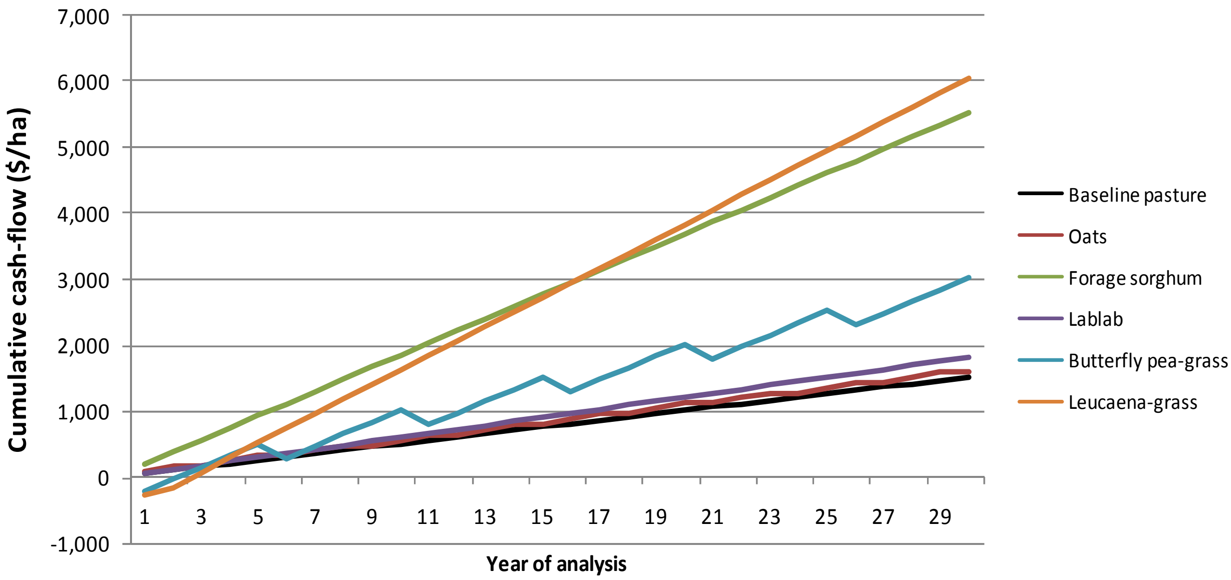

Figure 6. Central Queensland Brigalow: cumulative net cash-flow over a 30-year period for forage options using the zero till method of fallow weed control.

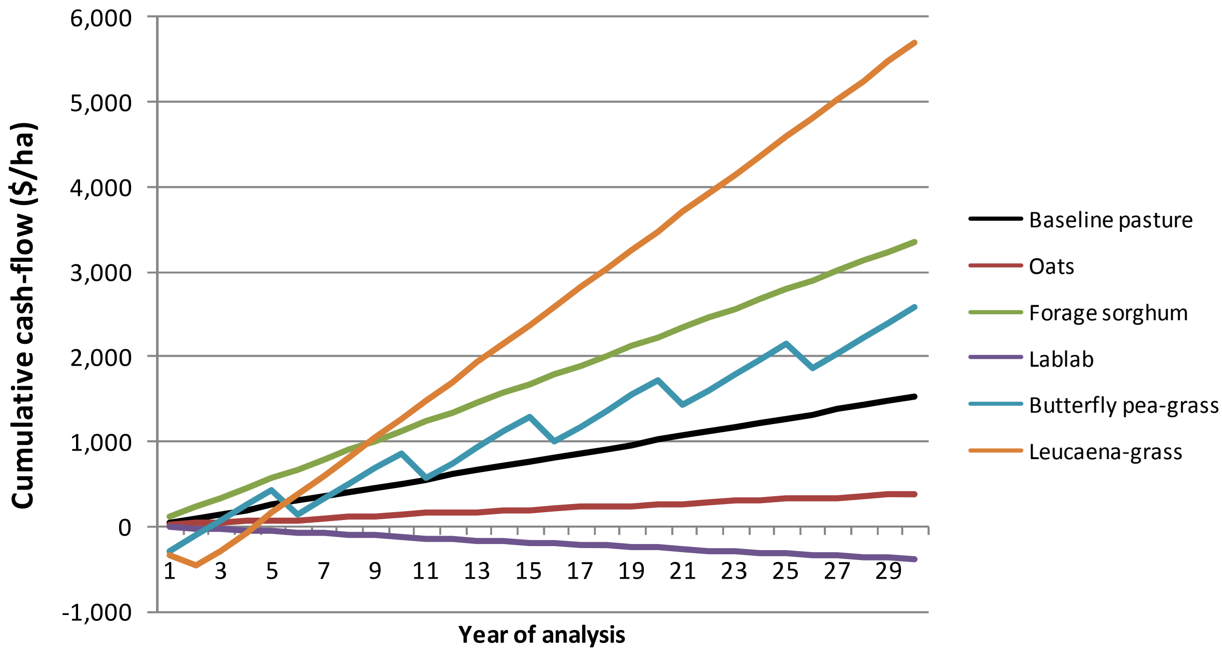

Figure 7. Central Queensland Brigalow: cumulative net cash-flow over a 30-year period for forage options using the cultivation method of fallow weed control.

5.2.3 Case study site 2: Central Queensland Open Downs (Capella area)

Long-term, mean annual rainfall for the Central Queensland Open Downs site was 583.9 mm with the highest rainfall totals occurring during the months of December to February and the lowest during August and September (Table 28). Average minimum temperature was lowest during July and average maximum temperature highest during December. Model simulations based on regional, long-term climate data and soil data showed forage sorghum to produce the highest average forage yield per hectare, approximately 3.5 times that produced from baseline, native grass pastures (Table 29). Forages ranked from highest to lowest in terms of yield per hectare were: forage sorghum > oats > lablab > leucaena-grass and butterfly pea-grass > baseline pasture. Conditions were suitable for sowing oats and lablab in only 62 and 93% of years, respectively, over the 108-year cycle.

Table 28. 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 temperature (^{0}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 temperature (^{0}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

Table 29. Central Queensland Open Downs: forage production of baseline pasture and annual forage crops predicted using GRASP or APSIM and of perennial, legume-grass pasture systems estimated based on expert opinion

	Forage					
	Baseline pasture (native)	**Oats**	**Forage sorghum**	**Lablab**	**Butterfly pea-grass[A]**	**Leucaena-grass[A]**
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.

At the Central Queensland Open Downs site, GM calculated for annual forage crops and baseline pasture showed that forage sorghum had the highest GM per hectare for both zero till and cultivation systems (Table 30). Under the zero till system, lablab also produced a higher GM than for the baseline pasture but oats produced a lower, and negative, GM. Under the cultivation system, both lablab and oats produced lower GM than the baseline pasture, which were negative. 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 (Tables 31 and 32). Forage sorghum had the least risk of producing negative returns due to the relatively higher GM, compared to lablab and oats, under the assumed liveweight gain and market prices in the example scenario.

Table 30. 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 31. 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

Baseline pasture (native)					
Livestock sale price ($/kg carcass weight)	**Liveweight gain (kg/head.day)**				
	0.31	0.35	**0.39**	0.43	0.47
$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	$33
Oats					
Livestock sale price ($/kg carcass weight)	**Liveweight gain (kg/head.day)**				
	0.90	1.00	**1.10**	1.20	1.30
$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	$185
Forage sorghum					
Livestock sale price ($/kg carcass weight)	**Liveweight gain (kg/head.day)**				
	0.40	0.50	**0.60**	0.70	0.80
$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	$489
Lablab					
Livestock sale price ($/kg carcass weight)	**Liveweight gain (kg/head.day)**				
	0.60	0.70	**0.80**	0.90	1.00
$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 32. 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.

Baseline pasture (native)					
Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
	$1.80	$1.90	**$2.00**	$2.10	$2.20
$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	$25
Oats					
Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
	$1.34	$1.44	**$1.54**	$1.64	$1.74
$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	-$75
Forage sorghum					
Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
	$1.34	$1.44	**$1.54**	$1.64	$1.74
$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	$36
Lablab					
Livestock sale price ($/kg carcass weight)	Purchase price ($/kg liveweight)				
	$1.34	$1.44	**$1.54**	$1.64	$1.74
$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

Net cattle income calculations for legume-grass pastures showed that leucaena-grass pasture produced net cattle income 1.1 times greater than for butterfly pea-grass pasture and 10.2 times greater than for baseline pasture (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 35 and 36). The cost of establishing the forages is given in Table 34. It cost more per hectare to establish butterfly pea-grass pasture than leucaena-grass pasture. Establishing both perennial, legume-grass pastures cost more when using the cultivation rather than the zero till method of fallow weed control.

Table 33. 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 34. 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 35. 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.

Baseline pasture (native)					
Livestock sale price ($/kg carcass weight)	**Liveweight gain (kg/head.day)**				
	0.31	0.35	**0.39**	0.43	0.47
$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	$33
Butterfly pea-grass					
Livestock sale price ($/kg carcass weight)	**Liveweight gain (kg/head.day)**				
	0.45	0.55	**0.65**	0.75	0.85
$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	$348
Leucaena-grass					
Livestock sale price ($/kg carcass weight)	**Liveweight gain (kg/head.day)**				
	0.70	0.80	**0.90**	1.00	1.10
$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 36. 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 GM 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
$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	$25
Butterfly pea-grass					
Livestock sale price ($/kg carcass weight)	**Purchase price ($/kg liveweight)**				
	$1.34	$1.44	**$1.54**	$1.64	$1.74
$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	$202
Leucaena-grass					
Livestock sale price ($/kg carcass weight)	**Purchase price ($/kg liveweight)**				
	$1.32	$1.42	**$1.52**	$1.62	$1.72
$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

The NPV calculations showed that planting a leucaena-grass pasture produced a higher return than planting, or utilising, the alternative forages (Table 37). Butterfly pea-grass pasture and forage sorghum also performed better than the baseline pasture over the 30-year time period for both zero till and cultivation systems. Lablab performed better than the baseline pasture only under the zero till system, while oats produced negative returns under both zero till and cultivation systems. The ranking of forage NPV for the zero till system was: leucaena-grass > butterfly pea-grass > forage sorghum > lablab > baseline pasture > oats. The ranking of forage NPV for the cultivation system was: leucaena-grass > butterfly pea-grass > forage sorghum > baseline pasture > lablab > oats. These differences in ranking are largely due to the high cost of planting forages in a cultivation system, with a relatively greater effect on the profitability of annual forages.

Annual animal liveweight gain per hectare for the range of forages studied produced a different ranking than for NPV: forage sorghum > lablab > oats > leucaena-grass > butterfly pea-grass > baseline pasture (Table 37).

Table 37. Central Queensland Open Downs: comparison of cattle production and net present value[A] (NPV) for key forage options

	Forage					
	Baseline pasture (native)	**Oats**	**Forage sorghum**	**Lablab**	**Butterfly pea-grass**	**Leucaena-grass**
NPV ($/ha)						
Zero till	$285	-$468	$899	$387	$1,497	$1,581
Cultivation	$285	-$683	$397	-$509	$1,282	$1,417
NPV ($/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 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 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 the 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. In the first 12-14 years of the 30-year cycle butterfly pea-grass pasture produced a higher cumulative cash-flow than for leucaena. However, the requirement to replant butterfly pea every 5 years resulted in a higher cumulative cash-flow for leucaena-grass (cf. butterfly pea-grass) at the end of the 30-year period. The higher initial investment in leucaena resulted in a negative cash-flow for the first 6 and 7 years in the zero till and cultivation systems, respectively, after which cash-flow became positive. Butterfly pea-grass pastures produced negative cash-flows in some years due to the costs of replanting while neutral cash-flows in some years for oats demonstrates the effect of years in which planting did not occur due to unfavourable seasonal conditions.

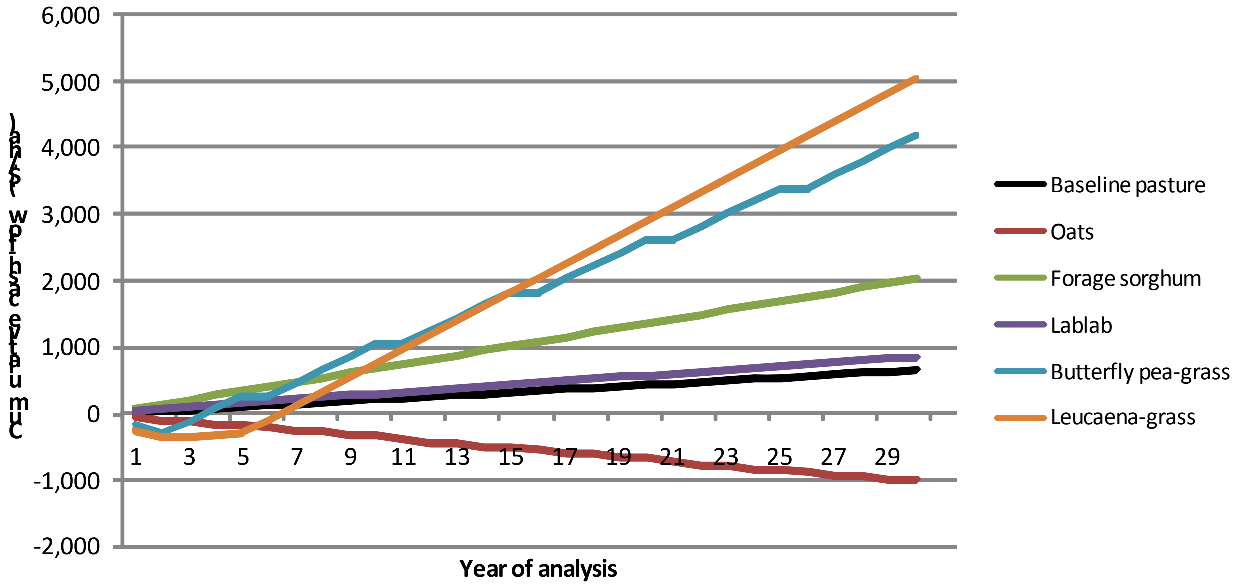

Figure 8. Central Queensland Open Downs: cumulative net cash-flow over a 30-year period for forage options using the zero till method of fallow weed control.

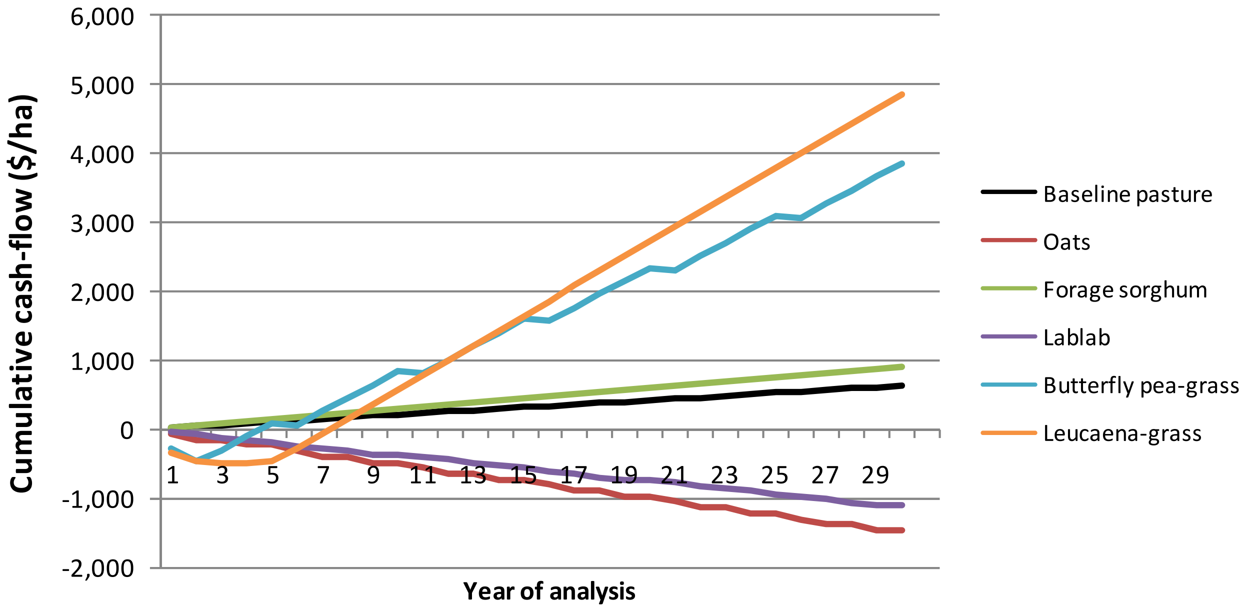

Figure 9. Central Queensland Open Downs: cumulative net cash-flow over a 30-year period for forage options using the cultivation method of fallow weed control.

5.2.4 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 5 years vs. 2). 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).

5.2.5 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 in their calculations when making comparisons of returns relative to baseline pastures.

5.2.6 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 in terms of GM and NPV between sites due to a combination of factors rather than any single factor. For example, the GM for forage sorghum planted using the zero till method of fallow weed control 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.

5.2.7 Evaluation of social, environmental and managerial factors

The economic 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.

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 (Table 38).

Table 38. A summary of strengths/benefits and constraints/threats associated with using key sown forages and baseline pasture for beef production

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
Forage sorghum	

• 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:
  o early summer crops could be used to improve the condition of breeders before and during joining
  o 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
	• difficult to manage for optimum quality and quantity
	  o 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

Strengths/benefits	Constraints/threats
produced (relative to other annual forage crops) is well suited to backgrounding cattle prior to the finishing phase	
Lablab	
• 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	• 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
Butterfly pea–grass	
• 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	• 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

Strengths/benefits	Constraints/threats
Leucaena–grass	
• 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	• 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

5.3 Conclusions

The economic analyses reported here, for five high quality forages and a baseline pasture system, at each of three sites within the Fitzroy River catchment and under both zero till and cultivation methods of fallow weed control, provide information on the relative ranking of forages in terms of GM, net cattle income and NPV as well as an indication of sensitivity to changes in market price and animal performance. This information can be used, in conjunction with a qualitative assessment of social, managerial and environmental factors, and an assessment of flow-on effects on whole farm profitability, to help inform decisions about whether or not to incorporate various high quality forage systems into a beef production enterprise.

6 Success in achieving objectives

Objective 1: Review, collate and document best-practice agronomic information for high-output forages and summarise available data for cattle production responses from forage systems.

Achieved. The review of best-practice agronomic information for high-output forages and summary of available data for cattle production responses from forage systems is presented in section 3 of this report. In addition a collation of the individual datasets reporting animal growth rates from high quality forage systems and also from 'baseline' pastures (native or sown grass pastures) in the target region of the Fitzroy River catchment, is presented in an Excel spreadsheet, *B.NBP.0496_LWG data for high quality forages.xls*, which has been submitted in conjunction with this report.

Objective 2: Review and document existing forage decision support tools and recommend an approach for developing a simple animal production model for forages.

Achieved. The review of existing forage decision support tools and recommendation on approach for developing a simple animal production model for forages is presented in section 4 of this report.

Objective 3: Complete and document a detailed economic analysis of forage options at selected sites in central and southern Queensland, based on the existing information.

Achieved. The detailed economic analysis of forage options at selected sites in central and southern Queensland is presented in section 5 of this report.

Objective 4: Identify best-bet forage options in the target study area of the Fitzroy basin, which has been defined as ranging from the Capella area in the north to the Taroom-Wandoan area in the south.

Achieved. The best-bet forage options in the target study area of the Fitzroy basin, as identified from the economic analyses, are reported and discussed in section 5.2.4 of this report.

Objective 5: Formulate a set of optimal forage strategies, research questions and hypotheses for testing in future case study work (Phase 2).

Achieved. The objectives and research questions for testing in future case study work in Phase 2 of this project are presented in the Appendix 1 (section 10.1) of this report.

Objective 6: Produce a comprehensive methodology and project design including Gantt chart and worksheet outlining the outcomes and targets over the course of possible Phase 2 work.

Achieved. The methodology, project design and Gantt chart for the proposed Phase 2 of this project are presented in Appendix 1 (section 10.1) of this report.

Objective 7: Produce a draft "Best-Practice Management Guide" (produced in a multi-media CD format).

Achieved. A best-practice management guide has been produced, *Using high quality forages to meet beef markets in the Fitzroy River catchment*, in CD-ROM format and has been submitted to MLA in conjunction with this report.

7 Impact on meat and livestock industry – Now and in five years time

- The information collated and the results derived from this project have been presented in a user-friendly guide, *Using high quality forages to meet beef markets in the Fitzroy River catchment*, produced in CD-ROM format. This guide brings together information on:
  - the selection, agronomy and management of forages
  - indicative forage yields at key sites across the Fitzroy River catchment
  - expected content of principal nutrients in forages and their relationship to cattle performance
  - indicative cattle growth rates from a range of high quality forages
  - approaches to incorporating high quality 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.

  This guide can be used by cattle producers and their advisors to improve knowledge and skills and support decision-making about the most profitable use of high quality forages as part of a beef enterprise. The guide will be up-dated and revised with new information obtained in Phase 2 of this project to produce a second edition by 30 December 2013.

- A spreadsheet calculator, *ForageCalc,* has been produced and accompanies the best-practice guide on CD-ROM. The calculator will allow innovative producers, looking for new directions for their business, to calculate the economic performance of key forage systems using their own input variables relevant to their individual businesses. This tool will be up-dated and revised with new information obtained in Phase 2 of this project to produce a second edition by 30 December 2013.

8 Conclusions and recommendations

8.1 Conclusions

- The agronomic information presented here for forages relevant to the target area of the Fitzroy River catchment provides an up-dated collation of best-practice recommendations that can be used by producers or advisors to assist in the evaluation of forage options for a beef business. The associated summary of cattle performance data for these forage systems, when grown in the target region, demonstrates broad principles and differences between the forages and is useful in showing the range in animal performance for each of the forage types documented and in highlighting potential management issues for consideration. However, due to the limited nature of the data sets recording cattle liveweight gain for the forages of interest, the variable quality of the data sets and the range of conditions under which the studies were conducted, it is difficult to draw strong conclusions about expected animal performance. This necessitated drawing upon expert opinion to provide a general indication of expected liveweight gain for the key forage types. The collection of additional, high quality liveweight gain data sets, in association with measurement of key forage parameters, would provide more confidence in the indicative performance recommendations and a greater understanding of the relationships between cattle liveweight gain and key variables.

- While several models exist that can reliably predict production of tropical pastures and forages (namely GRASP and plant modules within APSIM, respectively) none of the existing animal production models are suitable in their current form for application to grazing cattle consuming tropical pasture and forage diets. The major limitation of the available animal production models, the two most relevant being GrazFeed and CNCPS, is the amount and type of information required as inputs to describe the pasture or diet, which is not readily available under grazing conditions and for heterogeneous tropical pasture systems. As the equations underpinning the ruminant feeding standards and decision support tools have generally been shown to be robust and applicable for tropical diets, this provides confidence that a reliable tool can be developed given that the above limitation is investigated and addressed.

- The economic analyses reported here, for five high quality forages and a baseline pasture system, at each of three sites within the Fitzroy River catchment and under both zero till and cultivation methods of fallow weed control, provide information on the relative ranking of forages in terms of GM, net cattle income and NPV as well as an indication of sensitivity to changes in market price and animal performance. This information can be used, in conjunction with a qualitative assessment of social, managerial and environmental factors, and an assessment of flow-on effects on whole farm profitability, to help inform decisions about whether or not to incorporate various high quality forage systems into a beef production enterprise.

8.2 Recommendations

- In view of the paucity of definitive data currently available we propose that in a proposed Phase 2 of this project objective cattle liveweight gain data be gathered from commercial beef properties within the Fitzroy River catchment and supported by detailed and scientific characterisation of the forage on offer and associated land capability and rainfall information. As demonstrated in this report, such detailed data sets for the forages and region of interest do not currently exist and would provide an excellent data set with which to test and validate the indicative animal performance figures given in this report and to improve understanding of the underlying biological principles driving the productivity of forage production systems in the Fitzroy River catchment.

- We recommend that the data collected in Phase 2 also be used to help validate and parameterise forage and animal production components of the APSIM simulation platform under field conditions. The data collected in this project will make a valuable contribution to other efforts in this area. We propose that three approaches to developing an animal production module with APSIM be investigated and the most appropriate model then used to develop a simple decision support tool to allow comparison of beef cattle performance and expected profitability for a range of forage options.

- We propose that in Phase 2 of this project supporting data be collected from commercial co-operator properties to enable:

    - validation and improvement of the economic spreadsheet calculator developed in Phase 1 to conduct partial budgeting of forage options
    - development of whole farm case studies to examine the effect of high quality forage systems on whole farm profitability, with due consideration of, for example:
        - cost of investment required for establishment
        - effects on the herd turnover
        - provision of high quality, out-of-season feed.

- The new knowledge and understanding of factors driving the productivity and profitability of forage production systems in central Queensland should be used to create an information package that can be used to improve the knowledge and skills of central Queensland beef producers. This package should include a revised and up-dated version of the best-practice management guide developed in Phase 1, the revised economic spreadsheet calculator, and the forage decision support tool.

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10 Appendices

10.1 Appendix 1: Input cost details for economic analysis

10.1.1 Cattle input costs

Table 39. Cattle input costs for the economic case study analysis reported in Section 5

			South Queensland Brigalow					
	Units	**Comments**	**Leucaena-grass**	**Butterfly pea-grass**	**Lablab**	**Forage sorghum**	**Oats**	**Baseline (buffel)**
Sale price	$/kg	52% dressed	$3.20	$3.20	$3.20	$3.20	$3.20	$3.10
Purchase price	$/kg		$1.60	$1.60	$1.60	$1.60	$1.60	$2.00
Freight In	$/head	Roma - Wandoan	$10.00	$10.00	$10.00	$10.00	$10.00	$10.00
Freight out	$/head	Wandoan - Dinmore	$40.00	$40.00	$40.00	$40.00	$40.00	$40.00
Interest on livestock capital	$/head	7%	$36.82	$39.47	$15.79	$22.84	$15.42	$119.96
Animal health costs								
Inoculum	$/bottle	Treat 10% herd	$10.64	N/A	N/A	N/A	N/A	N/A
Levies	$/head		$5.00	$5.00	$5.00	$5.00	$5.00	$5.00
5-in-1	$/head		N/A	N/A	N/A	N/A	$0.76	$0.38

Central Queensland Brigalow								
	Units	**Comments**	**Leucaena-grass**	**Butterfly pea-grass**	**Lablab**	**Forage sorghum**	**Oats**	**Baseline pasture (buffel)**
Sale price	$/kg	52% dressed	$3.20	$3.20	$3.20	$3.20	$3.20	$3.10
Purchase price	$/kg		$1.52	$1.52	$1.54	$1.54	$1.52	$2.00
Freight In	$/head	G'mere – Rolleston	$15.00	$15.00	$15.00	$15.00	$15.00	$15.00
Freight out	$/head	Rolleston – Biloela	$25.00	$25.00	$25.00	$25.00	$25.00	$25.00
Interest on livestock capital	$/head	7%	$39.57	$40.03	$17.13	$20.70	$14.01	$118.44
Animal health costs								
Inoculum	$/bottle	Treat 10% herd	$10.64	N/A	N/A	N/A	N/A	N/A
Levies	$/head		$5.00	$5.00	$5.00	$5.00	$5.00	$5.00
5-in-1	$/head		N/A	N/A	N/A	N/A	$0.76	$0.38
Central Queensland Open Downs								
	Units	**Comments**	**Leucaena-grass**	**Butterfly pea-grass**	**Lablab**	**Forage sorghum**	**Oats**	**Baseline (native)**
Sale price	$/kg	52% dressed	$3.20	$3.20	$3.20	$3.20	$3.20	$3.10
Purchase price	$/kg		$1.52	$1.54	$1.54	$1.54	$1.54	$2.00
Freight In	$/head	G'mere - Capella	$17.50	$17.50	$17.50	$17.50	$17.50	$17.50
Freight out	$/head	Capella - R'ton	$35.00	$35.00	$35.00	$35.00	$35.00	$35.00
Interest on livestock capital	$/head	7%	$39.57	$42.48	$17.13	$22.31	$12.97	$130.59
Animal health costs								
Inoculum	$/bottle	Treat 10% herd	$10.64	N/A	N/A	N/A	NA	N/A
Levies	$/head		$5.00	$5.00	$5.00	$5.00	$5.00	$5.00
5-in-1	$/head		N/A	N/A	N/A	N/A	$0.76	$0.38

10.1.2 Planting input costs

Table 40. Planting input costs for the South Queensland Brigalow economic case study analysis reported in Section 5

					No. of Applications	
		Rate	$	Unit	Zero till	Cultivation
Lablab						
Machinery Operations	Boomspray		$12.00		4	1
	Chisel plough		$37.00			1
	Offset Disc tiller		$37.00			2
	No-till Seeder		$45.00		1	1
	Cultivator		$35.00			1
Seed	Lablab	25.0	$2.00	/kg	1	1
Herbicide	Roundup CT	1.50	$4.50	/L	4	
	Spinnaker	0.10	$700.00	/kg	1	1
	Amine 625	0.50	$6.82	/L	3	
Forage sorghum						
					No. of Applications	
		Rate	$	Unit	Zero till	Cultivation
Machinery Operations	Chisel plough		$37.00			1
	Offset Disc tiller		$37.00			2
	Cultivator		$35.00			1
	No-till Seeder		$45.00		1	1
	Boomspray		$12.00		4	1
Fertiliser	Urea	0.04347	$660.00	/tonne	1	1
Seed	Sorghum (Forage)	4.0	$6.00	/kg	1	1
Herbicide	Roundup CT	1.50	$4.50	L	4	
	Amine 625	0.50	$6.82	L	3	
	Gesaprim	3.00	$6.33	L	1	1
Oats						
					No. of Applications	
		Rate	$	Unit	Zero till	Cultivation
Machinery Operations	Chisel plough		$37.00			1
	Offset Disc tiller		$37.00			2
	Cultivator		$35.00			1
	No-till Seeder		$45.00		1	1
	Boomspray		$12.00		5	1
Seed	Oat seed	40.0	$1.65	/kg	1	1
Fertiliser	Urea	0.04347	$660.00	/tonne	1	1
Herbicide	MCPA LVE	1.00	$9.00	/L	1	1
	Amine 625	0.50	$6.82	/L	3	
	Roundup CT	1.50	$4.50	/L	4	

Leucaena-grass						
					No. of Applications	
		Rate	$	Unit	Zero till	Cultivation
Machinery Operations	Offset Disc tiller		$37.00			2
	Cultivator		$35.00			2
	Boomspray		$12.00		5	2
	Grass Planter		$10.00		1	1
	Leucaena Planter		$12.00		1	1
Seed	Leucaena	2.0	$15.40	/kg	1	1
	Grass seed	2.0	$17.00	/kg	1	1
Fertiliser	Starterphos (MAP)	0.04	$780.00	/tonne	1	1
Herbicide	Roundup CT	1.50	$4.50	/L	4	1
	Amine 625	0.50	$6.82	/L	3	
	Spinnaker[A]	0.14	$700.00	/kg	0.5	0.5
Inoculum		250g	$19.80	/100kg seed	1	1
Maintenance	Spreader		$8.00		1	1
	Superphosphate	0.1	$580.00	/tonne	1	1
	Chopping		$75.00		1	1
Butterfly pea-grass						
					No. of Applications	
		Rate	$	Unit	Zero till	Cultivation
Machinery Operations	Chisel plough		$37.00			1
	Offset Disc tiller		$37.00			2
	Cultivator		$35.00			1
	No-till Seeder		$45.00		1	1
	Grass Planter		$10.00		1	1
	Boomspray		$12.00		4	1
Seed	Butterfly Pea	10.0	$3.85	/kg	1	1
	Grass seed	2.0	$17.00	/kg	1	1
Herbicide	Spinnaker	0.14	$700.00	/kg	1	1
	Roundup CT	1.50	$4.50	/L	4	
	Amine 625	0.50	$6.82	/L	3	

[A] Leucaena: Spinnaker applied to only half paddock because only applied to planting rows. Roundup and amine applied to whole paddock.

Table 41. Planting input costs for the Central Queensland Brigalow economic case study analysis reported in Section 5

					No. of Applications	
		Rate	$	Unit	Zero till	Cultivation
Lablab						
Machinery Operations	Boomspray		$12.00		4	1
	Chisel plough		$37.00			1
	Offset Disc tiller		$37.00			2
	No-till Seeder		$45.00		1	1
	Cultivator		$35.00			1
Seed	Lablab	25.0	$2.00	/kg	1	1
Herbicide	Roundup CT	1.50	$4.50	/L	4	
	Spinnaker	0.10	$700.00	tonne	1	1
	Amine 625	0.50	$6.82	/L	3	
Forage sorghum						
		Rate	$	Unit	Zero till	Cultivation
Machinery Operations	Chisel plough		$37.00			1
	Offset Disc tiller		$37.00			2
	Cultivator		$35.00			1
	No-till Seeder		$45.00		1	1
	Boomspray		$12.00		4	1
Seed	Sorghum (Forage)	4.0	$6.00	/kg	1	1
Herbicide	Roundup CT	1.50	$4.50	L	4	
	Gesaprim	3.00	$6.33	L	1	1
	Amine 625	0.50	$6.82	/L	3	
Oats						
		Rate	$	Unit	Zero till	Cultivation
Machinery Operations	Chisel plough		$37.00			1
	Offset Disc tiller		$37.00			2
	Cultivator		$35.00			1
	No-till Seeder		$45.00		1	1
	Boomspray		$12.00		5	1
Seed	Oat seed	40.0	$1.65	/kg	1	1
Herbicide	MCPA LVE	1.00	$9.00	/L	1	1
	Amine 625	0.50	$6.82	/L	3	
	Roundup CT	1.50	$4.50	/L	4	

Leucaena-grass						
					No. of Applications	
		Rate	**$**	**Unit**	**Zero till**	**Cultivation**
Machinery Operations	Offset Disc tiller		$37.00			2
	Cultivator		$35.00			2
	Boomspray		$12.00		5	2
	Grass Planter		$10.00		1	1
	Leucaena Planter		$12.00		1	1
Seed	Leucaena	2.0	$15.40	/kg	1	1
	Grass seed	2.0	$17.00	/kg	1	1
Fertiliser	Starterphos (MAP)	0.04	$780.00	/tonne	1	1
Herbicide	Roundup CT	1.50	$4.50	/L	4	1
	Amine 625	0.50	$6.82	/L	3	
	Spinnaker[A]	0.14	$700.00	/kg	0.5	0.5
Inoculum		250g	$19.80	/100kg seed	1	1
Maintenance	Spreader		$8.00		1	1
	Superphosphate	0.1	$580.00	/tonne	1	1
	Chopping		$75.00		1	1
Butterfly pea-grass						
					No. of Applications	
		Rate	**$**	**Unit**	**Zero till**	**Cultivation**
Machinery Operations	Chisel plough		$37.00			1
	Offset Disc tiller		$37.00			2
	Cultivator		$35.00			1
	No-till Seeder		$45.00		1	1
	Grass Planter		$10.00		1	1
	Boomspray		$12.00		4	1
Seed	Butterfly Pea	10.0	$3.85	/kg	1	1
	Grass seed	2.0	$17.00	/kg	1	1
Herbicide	Amine 625	0.50	$6.82	/L	3	
	Spinnaker	0.14	$700.00		1	1
	Roundup CT	1.50	$4.50	/L	4	

[A] Leucaena: Spinnaker applied to only half paddock because only applied to planting rows. Roundup and amine applied to whole paddock.

Table 42. Planting input costs for the Central Queensland Open Downs economic case study analysis reported in Section 5

					No. of Applications	
Lablab						
		Rate	$	Unit	Zero till	Cultivation
Machinery Operations	Chisel plough		$37.00			1
	Offset Disc tiller		$37.00			2
	Boomspray		$12.00		4	1
	No-till Seeder		$45.00		1	1
	Cultivator		$35.00			1
Seed	Lablab	25.0	$2.00	/kg	1	1
Herbicide	Roundup CT	1.50	$4.50	/L	4	
	Spinnaker	0.10	$700.00	kg	1	1
	Amine 625	0.50	$6.82	/L	3	
Forage sorghum						
					No. of Applications	
		Rate	$	Unit	Zero till	Cultivation
Machinery Operations	Chisel plough		$37.00			1
	Offset Disc tiller		$37.00			2
	No-till Seeder		$45.00		1	1
	Boomspray		$12.00		4	1
Fertiliser	Urea	0.086	$660.00	/tonne	1	1
Seed	Sorghum (Forage)	4.0	$6.00	/kg	1	1
Herbicide	Roundup CT	1.50	$4.50	/L	4	
	Gesaprim	3.00	$6.33	/L	1	1
	Amine 625	0.50	$6.82	/L	3	
Oats						
					No. of Applications	
		Rate	$	Unit	Zero till	Cultivation
Machinery Operations	Chisel plough		$37.00			1
	Offset Disc tiller		$37.00			2
	No-till Seeder		$45.00		1	1
	Boomspray		$12.00		5	1
Seed	Oat seed	40.0	$1.65	/kg	1	1
Fertiliser	Urea	0.086	$660.00	/tonne	1	1
Herbicide	MCPA LVE	1.00	$9.00	/L	1	1
	Amine 625	0.50	$6.82	/L	3	
	Roundup CT	1.50	$4.50	/L	4	

Leucaena-grass						
					No. of Applications	
		Rate	**$**	**Unit**	**Zero till**	**Cultivation**
Machinery Operations	Offset Disc tiller		$37.00			2
	Cultivator		$35.00			2
	Boomspray		$12.00		5	
	Boomspray		$12.00			2
	Grass Planter		$10.00		1	1
	Leucaena Planter		$12.00		1	1
Seed	Leucaena	2.0	$15.40	/kg	1	1
	Grass seed	2.0	$17.00	/kg	1	1
Fertiliser	Starterphos (MAP)	0.04	$780.00	/tonne	1	1
Herbicide	Roundup CT	1.50	$4.50	/L	4	1
	Roundup CT	1.50	$4.50	/L		7
	Amine 625	0.50	$6.82	/L	3	
	Spinnaker[A]	0.14	$700.00	/kg	0.5	0.5
Inoculum		250g	$19.80	/100kg seed	1	1
Maintenance	Spreader		$8.00		1	1
	Superphosphate	0.1	$580.00	/tonne	1	1
	Chopping		$75.00		1	1
Butterfly pea-grass						
					No. of Applications	
		Rate	**$**	**Unit**	**Zero till**	**Cultivation**
Machinery Operations	Chisel plough		$37.00			1
	Offset Disc tiller		$37.00			2
	Cultivator		$35.00			1
	No-till Seeder		$45.00		1	1
	Grass Planter		$10.00		1	1
	Boomspray		$12.00		4	1
Fallow spraying	Roundup CT	1.50	$4.50	/L	4	
Seed	Butterfly Pea	10.0	$3.85	/kg	1	1
	Grass seed	2.0	$17.00	/kg	1	1
Herbicide	Amine 625	0.50	$6.82	/L	3	
	Spinnaker	0.14	$700.00	kg	1	1

[A] Leucaena: Spinnaker applied to only half paddock because only applied to planting rows. Roundup and amine applied to whole paddock.

10.2 Appendix 2: Phase 2 proposal

10.2.1 Background

The objective of the proposed Phase 2 of the project is to provide more definitive information, understanding and recommendations on the integration and management of high quality sown forage systems for producing high quality beef in central Queensland.

We propose to engage with commercial co-operators to collect objective data on current practices of utilising key forage systems. This data will include measurement of animal performance in conjunction with detailed and objective characterisation of the forage on offer. The data will be linked with associated land capability and climate information and collection of actual financial information to allow detailed economic analyses.

This new information will be used, in conjunction with the existing information documented in the desk-top study of Phase 1, to produce an improved and up-dated practical guide to forage management, for use by cattle producers and their advisors, to inform decision making about the most profitable use of high quality forages as part of a beef enterprise.

The data collected at the case study sites will also be used to help validate and parameterise forage and animal production components of the APSIM simulation platform under field conditions. The data collected in this project will make a valuable contribution to other efforts in this area. Output from the APSIM model will be used to develop a simple decision support tool (DST) to allow comparison of beef cattle performance and expected profitability for a range of forage options.

Phase 2 of the project will also is to provide a focal point for industry engagement and demonstration through use of the co-operator case study and demonstration sites and through linking in to CQBEEF and CQSFS activities. This participatory, on-farm, RD&E approach has proven through the very successful CQSFS project to provide rapid adoption pathways.

10.2.2 Project objectives

- To develop an improved understanding of the factors driving the productivity and profitability of high quality forage production systems in central Queensland.

- To develop an information package that can be used to improve the knowledge and skills of central Queensland beef producers in the profitable incorporation of forages into their production systems.

10.2.3 Research questions

- What is the range of forage and animal performance from high quality forage systems in central Queensland and how are these influenced by soil type, climate and management?

- What is the relative profitability of key, high quality, annual and perennial forage systems in central Queensland and what are the key factors driving their profitability?

- What is the effect of high quality forage systems on whole farm profitability of central Queensland beef enterprises with due consideration of, for example:
    - cost of investment required for establishment,
    - effects on the herd turnover, and
    - provision of high quality, out-of-season feed.

10.2.4 Methodology and project design

Key activities:

- Monitor forage and animal production at 12 sites in central Queensland over two summer and winter seasons.
- Validate the assumptions and conclusions about crop, pasture, animal and economic performance that resulted from the Phase 1 desk-top study and analyses.
- Incorporate the new information in an up-dated and revised version of the best-practice management guide, '*Using high quality forages to meet beef markets in the Fitzroy River catchment*', including whole farm economic analyses based on real data from the case study sites.
- Test, evaluate and help validate three approaches to incorporating animal production simulation capabilities within the APSIM modelling framework and use the most appropriate model to develop a simple DST to allow comparison of forage options for beef producers.
- Engage with industry and extend new knowledge through use of demonstration sites, field days and workshops.

Project design:

- Timeline

The project will run for 3 years: January 2011 - December 2013. With an initial set-up phase of several months and final analysis and write-up phase of 8 months, this allows for 2 years of winter forage data collection (2011 and 2012) and 2 years of summer forage data collection (2011/12 and 2012/13). A timeline-line detailing activities, milestones and outcomes is provided in the accompanying Gantt chart (section 10.1.5).

- Co-operator and demonstration sites

Phase 2 of this project will involve gathering data from producer co-operator sites (we envisage that this could involve sites located on between 4-12 individual businesses. These businesses will be concentrated in two central Queensland geographical areas coinciding with the two central Queensland regions studied in the desk-top analysis of Phase 1, namely the central Queensland brigalow area and the central Queensland open downs. We will focus our data collection on the six key forage types studied in the Phase 1 desk-top analysis, i.e. oats, forage sorghum, lablab, butterfly pea-grass pasture, leucaena-grass pasture and 'baseline pasture' (buffel grass on brigalow soils and native pasture on the open downs soils) for comparison. There will be one co-operator site for each forage type within each of the two regions (i.e. 12 forage 'paddocks' or 'sites') and 2 years of data collection (i.e. 24 data sets in total).

In addition to these primary co-operator sites in central Queensland, we will engage two commercial beef enterprises to act as demonstration and secondary data collection sites within the Taroom-Wandoan area in southern Queensland (to correspond with the south Queensland brigalow region of the Phase 1 desk-top study). The objective at these sites is to gather production and economic performance data for oats, forage sorghum and leucaena forage systems in southern Queensland that will be used to compare with the assumptions and results of the Phase 1 desk-top study. We do not expect to be able to support intensive data collection at these sites (as is intended in central Queensland) due to the limitations of the financial resources (high costs of data collection and travel) and the lack of available staff in this area to provide in-kind support to the project. These southern Queensland sites will have an important purpose of providing a focal point for industry engagement and demonstration.

- Economic analyses

There are two aspects of the economic analyses proposed for Phase 2:

1. The spreadsheet calculator developed in Phase 2 will be validated, up-dated and improved. It will be used to produce partial budgets for example forage scenarios which will be presented in the best-practice management guide. In addition, it will be made available, in conjunction with the best-practice management guide, to allow producers to enter their own input figures and derive output specific to their enterprises.

2. Three whole farm case studies will be conducted to examine the effect of high-output forage systems on whole farm profitability. The effect on the whole farm profitability of growing a) winter forage, b) summer forage, c) perennial forages, and d) all classes of forage will be investigated. The case studies will focus on key issues identified during the course of Phase 2. These case studies will incorporate:
   - dynamic herd modelling
   - cash-flow budgets
   - net present value
   - return on investment
   - impact on business turnover
   - risk analysis, and
   - optimum utilisation of fodder produced by adjustment of stocking rates or fodder conservation, within the limitations of the models and datasets available.

The whole farm case studies will be constructed using information from key co-operator sites. The revised best-practice management guide will include a detailed description of the process and methodology used to develop the whole farm case studies. Along with the spreadsheets, these example whole farm case studies will allow producers to develop their own in-depth analysis specific to their particular beef business.

- Development of an animal production module within APSIM and a forage DST

This project will help test, evaluate and validate a number of animal production simulation approaches within the APSIM modelling framework to improve the capability to predict performance of cattle grazing the target forages of interest. APSIM is very well supported by research groups nationally and locally and the relevant plant production modules have been parameterised and validated for central Queensland soils, climate and a number of key forage types of interest (e.g. oats, forage sorghum and lablab). Furthermore, recent work has incorporated GRASP functions within the APSIM framework, to allow simulation of tropical pasture production. An additional advantage of the APSIM framework is that it allows a great degree of flexibility in defining and testing a wide range of management practices at the crop and farm scale. The proposed work in this project will add value to existing efforts by DEEDI and CSIRO to further develop the animal production simulation capabilities of the APSIM framework.

The following three approaches will be investigated:
Approach 1. *Develop and validate a simple feed conversion efficiency based approach to estimating cattle liveweight gain*
Approach 2. *Validate and parameterise the GRASP daily liveweight gain model*
Approach 3. *Assess the feasibility and, if practical, validate and parameterise GrazFeed.*

The Grazfeed model has not been well validated for the types of high quality tropical forages of interest in this project and it is possible that cattle production from these more homogenous forage systems could be predicted more reliably than for other tropical forage diets which have proved problematic from the perspective of modelling animal production.

Once the three approaches described above have been tested, the most appropriate model will be used to develop a simple DST (similar to the existing cropping simulation tool "WhopperCropper") to allow comparison of forage options for beef producers.

The evaluation of the models as described above is dependent on having suitable measured data sets for the validation process and such detailed data sets for the forages and region of the interest do not currently exist. In this project the data sets will be derived from the co-operator sites.

- Industry engagement and extension

We propose to run:

- o three field days over the life of the project (e.g. one in each of the three 'regions' (central Queensland brigalow, central Queensland open downs and south Queensland brigalow).
- o three workshops at the end of the project to disseminate project results including the economic calculator and DST (e.g. one in each of the three regions).

10.2.5 Gantt chart

	2011				2012				2013			
Activities, milestones and outcomes	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Milestone 1: 1 Jan 2011. Execution of agreement												
Appoint technical officer												
Engage producer co-operators												
Prepare field sites, project equipment and materials												
Collect first winter season of data for oats and perennial forages												
Milestone 2: 30 Sept 2011. Report on progress												
Collect first summer and autumn season of data for summer and perennial forages												
Conduct 3 field days, with a target of one in each of CQ Brigalow, CQ Open Downs and SQ Brigalow regions												
Collect second winter season of data for oats and perennial forages												
Milestone 3: 30 Sept 2012. Report on progress												
Collect second summer and autumn season of data for perennial and summer forages												
Milestone 4: 30 Sept 2013. **4.1** Completed all data collection and associated chemical, economic and data analyses. **4.2** Completed modifications to APSIM modelling platform. **4.3** Draft "Best-practice management guide" submitted to MLA.												
Deliver 3 workshops to disseminate project results, information package and tools												
Milestone 5: 30 Dec 2013. **5.1** Publication of "Best-practice management guide". **5.2** Completed development of decision support tool. **5.3** Submit Final Report												

Key:
Activities
Milestones
Outcomes/deliverables