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High-output forage systems for meeting beef markets – Phase 2

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Abstract

This project investigated the relative profitability of six forage options for backgrounding or finishing cattle in the Fitzroy River catchment of Queensland. Data was collected at 24 forage sites on commercial properties over 2011-2014. Whole-farm economic case studies were developed with five co-operators. The factors affecting profitability were further investigated through constructed forage scenarios. This work has provided a better understanding of the expected forage, animal and economic performance from key forage options under commercial management conditions. Under current market and cost conditions, perennial legume-grass pastures, particularly leucaena-grass, had a significant advantage over perennial grass pasture and annual forages in terms of profitability. However, legume-grass pastures were not as profitable as grain cropping when grain cropping was a feasible alternative. Annual forages were unable to add economic value to the beef enterprise due to their higher average growing costs when compared to perennial forages. Existing models could not accurately predict forage and animal production from annual forage crops. A prototype decision support tool was developed. A producer guide to forage use, and gross margin spreadsheets for forages grown in three sub-regions of the Fitzroy River catchment, have been developed and will support informed decision making with regard to forage use.

Executive summary

Northern beef producers are under increasing pressure to find strategies to increase income and profitability. Targeted use of high quality forages is one option with potential to improve the profitability of beef businesses through increased turnover and output. However, there has been uncertainty about the relative forage, animal and economic performance of various forage options. This project examined the relative production and profitability of key high quality forage options, compared with a perennial grass 'baseline', within the Fitzroy River catchment of Queensland. Results from this project have been used to develop an information package to support decision making about the most profitable use of high quality forages. The ability to use forage and animal models to develop a decision support tool (DST) was investigated and a prototype tool developed.

A study designed to benchmark forage production systems on commercial beef co-operator properties was conducted in the Fitzroy River catchment. This study brings together, for the first time, data sets for forage and associated animal production, as well as gross margins, for commercial beef enterprises in Queensland. In total 24 individual forage sites (or paddocks) were monitored on 12 producer co-operator properties in three sub-regions within the catchment area: Central Queensland Open Downs (Emerald-Capella area), Central Queensland Brigalow (Biloela-Rolleston area), and South Queensland Brigalow (Taroom-Wandoan area). In Central Queensland Open Downs and Central Queensland Brigalow, the forage types studied were three annuals (oats, forage sorghum and lablab), two perennial legume-grass pastures (leucaena-grass and butterfly pea-grass), and a perennial grass pasture to provide a baseline for comparison to the more highly productive forage options. In the South Queensland Brigalow region only four of these forage types were studied, these being oats, forage sorghum, leucaena-grass and the baseline, perennial grass pasture.

In total, 31 individual data sets were collected during 2011-2014. The producers at each site used their routine management practices and were not asked to change practices, other than measuring cattle liveweight gain if they did not already do so. At each forage site, data were collected to document and understand forage, animal and economic performance. In addition, more comprehensive farm case studies were conducted with five beef producers to provide a better understanding of the effects of forage options on business profitability. Finally, example gross margin analyses were constructed for scenarios based on the same three regions and the six forage types monitored on the co-operator sites. This was to allow the performance of forages to be examined over a longer time-frame and to allow standard management practices to be assumed. The main conclusions from the co-operator sites and associated economic studies were:

- Sown annual, and perennial legume-grass, forages can substantially increase beef output compared to perennial grass pastures.
    - Leucaena-grass pastures resulted in the highest average total beef production (198 kg/ha/annum across all sites and years) of all forage systems monitored. Production from leucaena-grass pastures was 2.6 times greater than the average annual beef production from perennial grass pastures (76 kg/ha/annum). Furthermore, there was less variability between sites and years in total beef production from leucaena-grass pastures compared to butterfly pea-grass pastures or perennial grass-only pastures.
    - The next highest average total beef production was for butterfly pea-grass pastures (125 kg/ha/annum).
    - Forage sorghum, despite producing twice as much forage biomass as the other two annual forages, oats and lablab, on average resulted in only slightly higher total beef production (108 vs. 93 and 99 kg/ha/annum, respectively). This was due to poor utilisation of forage sorghum biomass in many instances as well as a lower quality diet.

- There was a wide range in profitability, in terms of paddock gross margin, for annual and perennial forage options in the Fitzroy River catchment. In broad terms:
  - Leucaena-grass sites had the highest average gross margin ($184/ha/annum across all sites and years).
  - Butterfly pea-grass produced the second highest average gross margin: $143/ha/annum.
  - Oats forage produced a higher average gross margin ($131/ha/annum) than perennial grass pasture ($98/ha/annum).
  - Forage sorghum and lablab resulted in lower average gross margins than for perennial grass pasture ($54 and $44/ha/annum, respectively).
- Farm economic case studies showed that, under current market and cost conditions:
  - Perennial legume-grass pastures have a significant economic advantage over perennial grass pasture and annual forages.
  - However, high-output perennial legume-grass forages are not as profitable as grain cropping, when grain cropping is a feasible alternative.
  - The effect of annual forages on farm profitability was marginal, and the increase in business risk significant.
  - Where high-output annual forages are currently grown successfully and grain crops are a realistic option, it is most likely that grain crops will provide substantially greater economic returns than the alternative annual forage crop.
  - Where grain crops are not an alternative and grass pasture is the alternative option under consideration, annual forages are a high cost option with high timeliness requirements that may only add value to the beef enterprise if the opportunity cost of plant and unpaid labour are excluded.
- Results from gross margin analyses for constructed scenarios, in which best-practice management was assumed and a long-term seasonal view taken, supported the conclusions from the commercial co-operator sites and farm case studies.

The data sets from co-operator field sites were used to test and evaluate approaches for incorporating forage and animal modelling capabilities within the APSIM modelling framework. The GRASP model, operating within the APSIM framework, predicted biomass of perennial grass pasture in both un-grazed and grazed areas satisfactorily. While oats biomass in un-grazed areas was predicted satisfactorily in APSIM, forage sorghum and lablab biomass was under-predicted. The effects of grazing on all forage crops were poorly predicted. The GrazFeed model, based on the Australian feeding standards for ruminants, under-predicted liveweight gain of cattle grazing forage crops. A simple forage utilisation equation to predict total liveweight gain per hectare was deemed to be most appropriate for use in a simple DST, although the predictions are currently limited by the inaccuracies of the underlying forage crop models. A prototype decision support tool, *ForageARM,* has been developed as an example of what might be possible should further work to improve model predictions be undertaken.

Industry benefits

The information derived from this project has been developed into an extension package. A guide to forage use, *Feeding forages in the Fitzroy*, brings together information on the agronomy, management, cattle production and economic performance from high quality forages. It will be made available to beef producers electronically and as a printed booklet. A series of Excel spreadsheets presenting forage gross margin calculations are intended to complement the printed guide. They contain the constructed gross margins for forages grown in three regions of the catchment and can be used to test alternative scenarios based on the users' own input variables relevant to their individual businesses.

Preliminary project findings were presented to 97 producers and industry personnel at three field days across the region in the April 2014. A total of 54% of the attendees indicated that they intended to make changes to their operation based on the information presented. Significant interest was expressed by participants in receiving further information, including the final report and forage guide once available. Furthermore, requests were received from other producer groups for additional field days, or information sessions, to present the project findings. This has already commenced as part of the Grazing Best Management Practice (Grazing BMP) program.

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1 Background

The Fitzroy River catchment is an important beef producing area of northern Australia. This region occupies approximately 50% of the Queensland portion of the Brigalow Belt bioregion, which supports a large percentage of northern Australia's sown pastures and 32% of northern Australia's beef herd (Peck *et al.* 2014). Beef production is the major land use in the Fitzroy River catchment, utilising around 12.3 million hectares or approximately 85% of the catchment and with cattle production accounting for 66% of the total value of agricultural production (ABS 2014a,b).

The recent report, '2013 Northern beef situation analysis' (McLean *et al.* 2014), concluded that the majority of northern beef producers are not generating sufficient profits to fund current and future liabilities. This report confirms previous observations by McCosker *et al.* (2010) and enterprise analysis conducted as part of the Department of Agriculture and Fisheries (DAF), CQ *BEEF* project in central Queensland (Gowen *et al.* 2009), which also highlighted the need for beef producers to better understand the profit drivers for their business and to focus on increasing income through increasing 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 and at a heavier weight can be important in increasing beef producers' ability to meet market specifications for high value beef and for increasing turnover and output of beef, both aspects contributing to increased productivity and profitability of beef businesses.

Three of the four major land types in the Fitzroy River catchment, Brigalow, Alluvial and Open downs, have soils capable of growing high quality forages suitable for backgrounding and finishing cattle. Targeted use of high quality forages has the potential to improve the profitability of beef enterprises in the Fitzroy River catchment of Queensland through increasing enterprise turnover and productivity, and providing a viable alternative to grain finishing for 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 budgeting, marketing, and an understanding of the financial implications for the business. The review by Bowen *et al.* (2010) demonstrated a paucity of definitive data documenting forage, cattle and economic performance from high quality forages in the Fitzroy River catchment. The current project included a major study designed to benchmark forage production systems on commercial properties with the objective of improving the understanding of expected forage, animal and economic performance, and the key drivers of profitability, within these systems.

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 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. DSTs also provide 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 DAF 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. There are currently no such tools or models being successfully applied to predict cattle performance, and to support adoption of improved management practices, in tropical pasture or forage grazing systems. As part of the current project, a study was conducted to test and evaluate approaches for incorporating forage and animal production simulation capabilities within the APSIM modelling framework. The most appropriate approach was used to develop a prototype DST for comparing forage options.

This is the second phase of a project designed to examine the relative production and profitability of alternative forage options for backgrounding or finishing cattle in the Fitzroy River catchment of Queensland. The major objective of Phase 2 was to provide more definitive information, understanding and recommendations on the integration and management of high quality sown forage systems in the Fitzroy River catchment of Queensland. This report provides an overview of the methodology, results and discussion associated with the four components of the project. The full reporting of the two major studies is provided in Appendix 1 and 2 of this report. The forage best practice guide, gross margin spreadsheets and DST are provided separately.

2 Project objectives

The project objectives were as set out below.

By 30 November 2014:

1. Validated through producer co-operator and demonstration sites, the expected forage, animal and economic performance reported in the desk-top study of Phase 1.
2. Produced a revised version of the 'Best-practice guide to forage use for growing and finishing beef cattle', incorporating the new information from Phase 2 of the project (in booklet and CD format), for use by producers and agricultural advisors. The guide will include an up-dated and revised 'spreadsheet calculator' to allow partial budgeting of forage options, as well as example whole-farm economic analyses based on real data from the co-operator sites.
3. Used real data collected on the co-operator properties to test, evaluate and help validate three approaches to incorporating animal production simulation capabilities within the APSIM framework.
4. Used the most appropriate model from step 3 to develop a decision support tool (similar to the existing cropping simulation tool 'WhopperCropper') to allow comparison of forage options for beef producers.

3 Forage, animal and economic performance on commercial beef cattle properties in the Fitzroy River catchment *(full report in Appendix 1)*

This study was designed to benchmark forage production systems on commercial beef co-operator properties with the objective of improving the understanding of expected forage, animal and economic performance, and the key drivers of profitability, within these systems.

3.1 Methodology

In total, 24 individual forage sites were established on 12 producer co-operator properties across the Fitzroy River catchment from 2011 to 2014. The forage sites were selected in three regions within the catchment area: Central Queensland Open Downs (Emerald-Capella area), Central Queensland Brigalow (Biloela-Rolleston area), and South Queensland Brigalow (Taroom-Wandoan area). In Central Queensland Open Downs and Central Queensland Brigalow, the forage types studied were the annuals: oats, forage sorghum and lablab, the perennial legume-grass pastures: leucaena-grass and butterfly pea-grass, and a perennial grass pasture to provide a baseline for comparison to the more highly productive forage options. In the South Queensland Brigalow region only four of these forage types were studied: oats, forage sorghum, leucaena-grass and baseline, perennial grass pasture. Seasonal conditions and difficulties in engaging suitable co-operators limited the number of forage by region by year combinations possible over the study period. A summary of the number of data sets collected over the period 2011-2014 is given in Table 1. The producers at each site used their routine management practices and were not asked to change practices for the project, other than measuring cattle liveweight gain if they did not already do so.

Table 1. Summary of forage data sets collected over the period 2011-2014 in the Fitzroy River catchment

CQOD: Central Queensland Open Downs, CQB: Central Queensland Brigalow, SQB: South Queensland Brigalow

	Annual forages			Perennial forages		
	Oats	Forage sorghum	Lablab	Leucaena-grass	Butterfly pea-grass	Perennial grass
Region and number of data sets	CQOD x 2 CQB x 3 SQB x 3	CQOD x 1 CQB x 2 SQB x 2	CQOD x 1 CQB x 1	CQOD x 2 CQB x 2 SQB x 2	CQOD x 2 CQB x 1	CQOD x 3 CQB x 1 SQB x 3

At each forage site, detailed data was collected to:

- record all paddock and livestock operations (e.g. planting and maintenance operations, cattle movements and treatments);
- characterise the soil and measure soil fertility (soil type, depth, nutrient composition, plant available water capacity and moisture at planting);
- measure rainfall and temperature, using on-site weather stations where possible or otherwise property records or the nearest BOM station;
- monitor forage biomass, species composition in perennial pastures, plant composition (e.g. % green leaf) and nutrient composition (crude protein (CP) and dry matter digestibility (DMD)) in both the grazed paddock and fenced, un-grazed exclosures;

- monitor the quality of the diet selected by cattle over time, in terms of CP and DMD, using faecal near infrared reflectance spectroscopy (NIRS) technology;
- estimate the proportion of C_3 plant species (oats, legumes and other non-C_4 grass species) selected by cattle, using delta carbon analysis of faecal samples;
- characterise the cattle (breed, age, sex, grazing history) and measure cattle liveweight change;
- record all costs and returns associated with the paddock to enable a representative paddock gross margin to be calculated. The gross margin was calculated as the gross income received from the sale of cattle less the variable costs incurred in the enterprise, but excluding fixed or overhead costs.

In addition, more complete economic analyses, or farm case studies, were conducted with five beef producers across the Fitzroy River catchment who were currently extensively using forages and who were considered competent and highly experienced in the production systems that prevail in their region. This analysis considered the business operation with and without forages and compared the net profit generated by alternative operating systems. Furthermore, adjustments were incorporated to account for changes in unpaid labour, herd structure and capital likely to occur as a result of changes to the overall production system.

The gross margins for the scenarios constructed in Phase 1 of this project (Bowen *et al.* 2010) were re-calculated using the same gross margin approach used for the co-operator sites, to allow better comparison with the commercial property gross margins. These constructed scenarios were based on the same three regions within the Fitzroy River catchment, and the same six forage types, as for the co-operator sites. These gross margins, as well as those for the co-operator sites, were calculated two ways. The first method is relevant to producers who own the machinery required to plant forages. This method uses 'owner rates' to calculate forage costs and thus overhead costs were excluded from the gross margin. The second approach is relevant when producers use contractors to plant forages. In this method a pseudo 'contract rate' was used to cost machinery operations so that overhead costs, in addition to operating and labour costs, were apportioned on a per hectare basis for the use of machines.

3.2 Results and discussion

Appendix 1 of this report brings together, for the first time, data sets for forage and associated animal production, as well as gross margins, for commercial beef enterprises in Queensland. Farm case studies, as well as constructed scenarios where variables could be held constant, provided further insights into the profitability of sown forages. A summary of the main findings follows, including two summary tables (Table 2 and Table 3) showing key data from the co-operator sites and the constructed economic scenarios. More detailed results and discussion is provided in Appendix 1.

3.2.1 Co-operator sites

3.2.1.1 Forage production

- Forage sorghum crops produced the greatest biomass of all forage types: 19,307 kg DM/ha average across sites, for the un-grazed exclosure. On average, oats and lablab forage crops produced a similar peak biomass under exclosure, which was approximately half that for forage sorghum: 8,184 and 9,637 kg DM/ha, respectively.
- Edible leucaena presentation yield (including stems up to 5 mm in diameter), averaged over the period of monitoring, was in same order as for the total butterfly pea presentation yield: 417 and 528 kg DM/ha, respectively.

- Perennial grass presentation yield, averaged over the duration of monitoring, ranged from 2,186-5,620 kg DM/ha across 13 individual annual data sets for perennial sites. The biomass measurements for grass growing with the perennial legumes, leucaena or butterfly pea, were in the same order as for the perennial grass-only sites.
- Oats forage, provided in association with varying areas of perennial grass, resulted in the greatest average diet quality in terms of CP and DMD (12.3% DM and 63%, respectively), closely followed by leucaena-grass forage sites (CP 12.0% DM and DMD 59%) and lablab forage sites which were also associated with variable areas of perennial grass (CP 11.5% DM, DMD 59%). Perennial grass sites resulted in the lowest average diet CP and DMD of all forage types (6.6% DM and 55%, respectively).
- Leucaena-grass forage resulted in the greatest average total grazing days per annum of all annual and perennial forage types: 284 days/annum. All three annual forage crop types were grazed for greater than 100 days/annum, on average.
- Soil fertility was generally low at all sites but, nevertheless, fertiliser application was not common practice. It is likely that both soil nitrogen and phosphorus fertility may be limiting production of many annual forage crops in the Fitzroy River catchment. Phosphorus fertility may be limiting production of perennial legume-grass pastures.
- Very high stocking rates were used by commercial producers on some perennial grass-only paddocks in some years (e.g. 0.64 and 0.87 AE/ha over 476 and 364 days, respectively). Furthermore, some of these pastures were showing signs of nitrogen rundown, in terms of pasture composition and yield, and would benefit from legume inclusion. The observations of the project team are that this scenario appears to be typical of many perennial grass pastures across the Fitzroy River catchment.

3.2.1.2 Animal production

- On average, annual forages and perennial legume-grass pastures resulted in higher beef output (kg/ha/annum) compared to that from perennial grass-only pasture.
- Leucaena-grass sites produced the greatest average total beef production of all forage types: 198 kg/ha/annum, which was 2.6 times greater than the average annual beef production from perennial grass pasture (76 kg/ha/annum).
- Butterfly pea-grass sites ranked second for total beef production (125 kg/ha/annum).
- The average total beef production for the three types of annual forage crop was in the range of 93-108 kg/ha/annum.
- Forage sorghum, despite producing twice as much forage biomass as the other annual forages, oats and lablab, on average resulted in similar total beef production. This was due to poor utilisation of forage sorghum biomass in many instances as well as a lower quality diet and hence lower individual animal production.
- Grazing management practices may be limiting productivity and profitability of annual forage crops in the Fitzroy River catchment, particularly for forage sorghum crops which are difficult to manage to optimise forage quality and therefore animal production. Commonly, grazing commenced once the forage sorghum crops were already mature and, at several sites, stocking rates were too low to prevent the crop maturing.
- Some producers are not inoculating cattle grazing leucaena-grass pastures with the rumen fluid inoculum, or using carrier cattle. This may be causing sub-clinical mimosine and dihydroxypyridine toxicity, which will reduce cattle growth rates.
- Hormonal growth promotants (HGPs) were not commonly used in cattle grazing the high quality forages monitored in this project. There was often insufficient information available from the co-operators on cattle price data and target markets to accurately

discern the reasons for the lack of use of HGPs and whether this could be decreasing potential profits.

- Monitoring of cattle weight gain during grazing periods on high quality forages may allow more optimal timing of sale. Many producers contacted in the process of engaging co-operators for this project commented that they do not usually monitor weight gain of cattle on forages. Those producers that do monitor weight gain generally only weigh at the start and end of a grazing period.
- A significant proportion of cattle grazing annual forage crops in this project were not sold directly to market but were returned to perennial grass pastures after grazing the crop. This was either because: the forage was being used to spell pastures (particularly for forage sorghum crops), weaners or younger cattle were fed, or a proportion of the mob did not attain desired finishing weights or fat cover. In these cases, the gross margins calculated were not actually realised by the producers as, although the cattle were valued upon exiting the forage, they were not actually sold. For these cases, the true economic benefit of feeding the annual forage crops would have to be determined on an individual basis by examining the effect on the profit of the whole farm business. In particular, where cattle graze perennial pastures in the summer season after grazing a forage oats crop it is highly likely that compensatory gain effects would erode most of the liveweight advantage provided by forage oats. This would likely make the venture unprofitable when considered in the context of overall farm profitability.

3.2.1.3 Economic performance

Gross margins

Gross margins are the first step in determining the effect of sown forages on farm profit. They show whether the forage activity itself makes a profit or a loss, at the paddock level.

- There was a wide range in profitability of annual and perennial forage options both within and across forage types.
- Profitability was the combined result of forage and beef production (kg/ha), forage costs, and cattle price margin (sale price less purchase price). These factors were, in turn, influenced by management, seasonal and market factors.
- There was no single, over-riding factor that determined the profitability of forage systems. This confirms the importance of optimising all contributing factors in order to maximise profitability of sown forage systems. However, the higher average profitability of perennial legume-grass pastures compared to annual forages was primarily due to the combined effects of lower average forage costs and high productivity.
- Leucaena-grass sites had the highest average gross margin ($184/ha/annum) averaged across all sites and years.
- Butterfly pea-grass produced the second highest average gross margin: $143/ha/annum.
- Oats forage produced a higher average gross margin ($131/ha/annum) than perennial grass pasture ($98/ha/annum).
- Forage sorghum and lablab resulted in lower average gross margins than for perennial grass pasture ($54 and $44/ha/annum, respectively).

Farm case studies

Farm economic case studies examined the value of the sown forage systems to the 'whole farm' or business, relative to other alternatives which could also be undertaken such as grazing perennial grass pasture or growing a grain crop. These analyses applied integrated herd and steady state economic models to compare the net profit generated by alternative systems and account for changes in such factors as unpaid labour, herd structure and capital that would be likely to occur. The insights into the profitability of forages, provided by five case studies conducted with producers in the Fitzroy River catchment, can be summarised as follows:

- Under current market and cost conditions:
  - Perennial legume-grass pastures have a significant economic advantage over perennial grass pasture and annual forages.
  - However, high-output perennial legume-grass forages are not as profitable as grain cropping, when grain cropping is a feasible alternative.
  - The effect of annual forages on farm profitability can be marginal, and the increase in business risk significant, requiring a careful assessment of the role of annual forages in improving overall profitability.
  - Where high-output annual forages are currently grown successfully and grain crops are a realistic option, it is most likely that grain crops will provide substantially greater economic returns than the alternative annual forage crop.
  - Where grain crops are not an alternative and grass pasture is the alternative option under consideration, annual forages are a high cost option with high timeliness requirements that may only add value to the beef enterprise if the opportunity cost of plant and unpaid labour are excluded.

3.2.2 Constructed scenarios

Example gross margin analyses were conducted for constructed scenarios based on the same three regions and six forage types monitored on the co-operator sites. These scenarios allowed the performance of forages to be modelled over a longer time-frame, hence taking out the variation due to seasonal and market fluctuations. In addition, standard management practices, based on what was deemed best-practice, were assumed.

- Forage gross margins were the result of a complex interaction of factors with the major variables determining the profitability of forages being the:
  - daily cattle liveweight gain, stocking rate, and number of grazing days on the forage, the combined result of which is total beef production per hectare;
  - cost of planting;
  - cattle buying and selling price (cattle price margin).

  These results are in accord with the conclusions from the co-operator sites.
- Leucaena-grass pasture produced the highest gross margins when compared to other key perennial legume-grass and annual forage options. This was in agreement with the results from the co-operator sites.
- Butterfly pea grass also performed well with the average ranking for gross margin being second out of the six forage options studied.
- Forage sorghum produced the highest gross margins of the annual forages, calculated using owner rates, for Central Queensland Brigalow and Central Queensland Open Downs sites. These results assume a high utilisation of forage sorghum biomass.

However, this was shown at the co-operator sites to be difficult to achieve. Forage sorghum produced a negative gross margin for the South Queensland Brigalow site, in part due to the lower production expected in this area.

- Oats and lablab also produced higher gross margins, calculated using owner rates, than for the perennial grass pasture in each region, except for lablab in South Queensland Brigalow.
- When contract rates rather than owner rates were used to calculate gross margins, forage costs were on average 1.5 times more expensive for the annual forages, 1.4 times more expensive for butterfly pea-grass and 1.1 times more expensive for leucaena-grass pastures. This resulted in annual forages being more marginal for profitability when contract rates were used, with the average gross margins across the three regions being negative for all three annual forage types.
- The marginal profitability of the annual forages when contract rates were used is in line with the conclusions from the whole farm economic analyses, which indicate that growing annual forages may not be the most profitable enterprise option.

Table 2. Co-operator sites: summary by forage type of key forage, animal and economic performance data
Values are the average (and range), across data sets, for each forage type. Maximum value in each row highlighted yellow

	Annual forages			Perennial forages		
	Oats	Forage sorghum	Lablab	Leucaena-grass	Butterfly pea-grass	Perennial grass
Number of data sets (full 12-month periods for perennials)	8	5	2	5	3	5
Peak biomass in the un-grazed exclosures (kg DM/ha)[A]	8,184 (4,939-16,456)	19,307 (9,573-35,598)	9,637 (5,021-14,253)	n/a	n/a	n/a
Forage biomass measurements in the grazed paddocks (kg DM/ha)[B]	4,555 (2,278-5,425)	12,150 (2,069-30,197)	6,014 (5,484-6,543)	*Leucaena*: 417 (196-744) *Grass*: 3,809 (2,700-5,620)	*Butterfly pea*: 528 (143-1,138) *Grass*: 4,591 (3,480-5,519)	3,702 (2,186-4,549)
Total grazing days per annum or total period	116 (91-158)	107 (52-139)	107 (103-111)	284 (140-476)	181 (139-223)	224 (0-476)
Diet CP (% DM)	12.3 (8.4-14.7)	8.8 (6.6-10.3)	11.5 (9.9-13.0)	12.0 (9.6-13.8)	9.7 (7.5-12.7)	6.6 (5.6-7.0)
Diet DMD (%)	63 (55-66)	55 (52-58)	59 (58-59)	59 (44-64)	59 (58-59)	55 (53-57)
Total LWG (kg/ha per annum or total grazing period) per total grazing area	93 (38-144)	108 (41-253)	99 (41-156)	198 (129-306)	125 (50-245)	76 (0-169)
Forage costs ($/ha per annum) per forage area only; owner rates[C]	136 (93-193)	96 (16-169)	99 (85-113)	34 (17-47)	21 (21-21)	2 (0-5)
Gross margin ($/ha per annum or total grazing period) per total grazing area; owner rates	131 (54-197)	54 (-48-243)	44 (38-50)	184 (90-304)	143 (34-379)	98 (-5-285)

CP: crude protein; DM: dry matter, DMD dry matter digestibility; LWG: liveweight gain.
[A]These figures are the maximum biomass measured in fenced (non-grazed) exclosure sites and are an indication of the total biomass grown during the grazing period.
[B]These figures are the peak biomass measured in the paddock for annuals, and the average biomass measured in the grazed paddock over the duration of monitoring for perennials. They do not indicate the total biomass grown during that period due to being the net result of what was grown and what was consumed by grazing livestock. Figures for leucaena biomass represent only the edible material (i.e. leaves and stems up to 5 mm in diameter).
[C]Annual forage costs for perennials were calculated by amortising establishment and maintenance costs (determining an average annual cost over the life of the forage).

Table 3. Constructed scenarios: comparison of the effect of using owner rates or contract rates on forage costs and gross margins
Values are the average (and range), across three regions, for each forage type. Maximum value in each row highlighted yellow

	Annual forages			Perennial forages		
	Oats	Forage sorghum	Lablab	Leucaena-grass	Butterfly pea-grass	Perennial grass
			Forage costs per forage area only ($/ha)			
Owner rates	174 (144-200)	168 (138-194)	170 (170-170)	41 (40-42)	58 (58-58)	0 (0-0)
Contract rates	266 (223-298)	260 (217-292)	248 (248-248)	45 (44-46)	83 (83-83)	0 (0-0)
			Gross margin per total grazing area ($/ha)			
Owner rates	81 (35-123)	76 (-14-159)	63 (6-105)	146 (107-169)	89 (59-110)	44 (27-56)
Contract rates	-2 (-54-52)	-16 (-113-80)	-8 (-65-34)	142 (103-165)	64 (34-84)	44 (27-56)

4 Best-practice guide to forage use in the Fitzroy River catchment *(electronic, print-ready version provided separately)*

In Phase 1 of this project: 'High-output forage systems for meeting beef markets – Phase 1', (Bowen *et al.* 2010), a draft best-practice management guide to forage use was produced called: 'Using high quality forages to meet beef markets in the Fitzroy River catchment'. A spreadsheet calculator, 'ForageCalc', was also produced to allow comparison of the economic performance of key forage options. These tools were intended for use by producers and agricultural advisors. An objective of Phase 2 of this project was to revise and up-date this guide and the economic spreadsheet calculator, incorporating new information from Phase 2. These products were intended to be the key extension outputs from this project.

4.1 Description of the best-practice guide

The revised guide, which will be made available as a printed booklet, is called: *Feeding forages in the Fitzroy. A guide to profitable beef production in the Fitzroy River catchment*. The revised guide was written and compiled by three of the project team: Maree Bowen, Stuart Buck and Fred Chudleigh. This guide brings together information on:

- selection, agronomy and management of suitable forages;
- example forage yields across the Fitzroy River catchment;
- expected nutrient content of 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 give the best opportunity to achieve the target growth rates and liveweights required to meet market specifications;
- non-nutritional factors that can affect liveweight gain;
- example gross margin analysis at key sites across the catchment to provide objective comparisons of various forage options;
- the effect of sown forages on the whole farm profitability; and
- summary data collected from 24 commercial co-operator forage sites across the Fitzroy River catchment during 2011-2014.

The major modifications to the Phase 1 version of the guide are outlined below.

- The economics sections of the guide were completely revised (Chapters 7 and 8 in the revised version). The original economic analyses conducted for constructed, example scenarios in Phase 1 of this project were revised to reflect our improved understanding of forage systems and best management practice. Rather than presenting separate gross margins for zero till and full cultivation, a single figure, representative of 'minimal till (cultivation and chemical application) was calculated. This more accurately reflects the fallow weed control methods used by the majority of commercial producers in the Fitzroy River catchment to grow forage, as revealed by the producer co-operator sites. Adjustments were also made, where necessary, to better reflect current input costs. Instead of the 'net present values' presented in the Phase 1 version of the guide, amortised gross margins were presented to provide results in a format that is more widely understood by producers as well as to allow better comparison with results from the

Phase 2 co-operator sites. In addition to the gross margin analyses for the constructed scenarios, the revised economics section of the guide also includes general results and conclusions from the five whole-farm economic case studies that were conducted as part of Phase 2 of this project.

- A new chapter (Chapter 9) has been added to the guide, presenting a summary of the measured data from the co-operator field sites across the Fitzroy River catchment. This chapter includes key messages and conclusions from the co-operator sites as well as a one page summary for each of the 24 sites.

Three Microsoft Excel spreadsheets now accompany this guide, one for each of the regions of focus across the Fitzroy River catchment: Central Queensland Open Downs (Emerald-Capella area), Central Queensland Brigalow (Biloela-Rolleston area) and South Queensland Brigalow (Taroom-Wandoan). These spreadsheets contain the example gross margins for the constructed scenarios presented in the guide. They can also be used to test alternative scenarios based on individual property production and input figures. These economic spreadsheets reflect the revised approach to conducting the economic analyses, as described above. Gross margins have now been calculated two ways using both ‘contract’ and ‘owner’ costs for forage planting.

4.2 Discussion

Prior to publishing the Phase 1 version of the guide, which was available in electronic format only, the original authors (Maree Bowen, Stuart Buck and Rebecca Gowen) conducted an extensive review process, seeking feedback and input from a large number of DAF staff with skills covering agronomy, animal production and economics:

- **Soils and agronomy expertise:** Maurie Conway, Bob Clem, Brian Johnston, Rodney Collins, Bruce Winter, Dale Kirby, Bruce Radford (Department of Environment and Resource Management), Richard Routley (part of the Phase 1 project team), Jyoteshna Owens (part of the project team);
- **Animal production expertise:** Richard Holroyd, Stu McLennan, Rob Dixon, Russ Tyler, Bernie English, Ken Murphy, Mick Sullivan, Rick Whittle, Kay Taylor, Lindy Symes, Tim Emery (part of the project team), Byrony Daniels (part of the project team);
- **Economics expertise:** Peter Donaghy, Fred Chudleigh (not part of the project team in Phase 1).

Constructive feedback was received from this process, which helped to improve the Phase 1 version. The main criticism of the Phase 1 version was the difficulty in understanding the economic analyses. Hence the major objective, for Phase 2 of the project, of re-visiting the economic analyses and economics section of the guide.

In light of the extensive review process already conducted prior to releasing the Phase 1 version of the guide, the Phase 2 version was reviewed on a smaller scale. In addition to input into specific areas from many of the same DAF staff listed above, a more complete review of the guide was conducted by: two agronomists, including one consultant agronomist external to the department (Maurie Conway and Rob Badmann, respectively); a consultant animal production/husbandry expert (Russ Tyler); and two beef producers (Allan Austin and David Thornberry). The feedback was used to improve the revised version.

It is intended that the revised guide to forage use, *Feeding forages in the Fitzroy*, and the accompanying gross margin spreadsheets, will be a useful resource for beef producers and their advisors in the Fitzroy River catchment. These tools are intended to support and assist decision making of beef producers in relation to the most suitable forage options for their land type/s and purpose. The impending release of these products was promoted at a series of three project field days held in April 2014, with considerable interest expressed by attendees in receiving copies, once available. Further promotion of these extension tools will occur through the DAF Grazing Best Management Practice (Grazing BMP) program and through general DAF extension activities. This extension process has already commenced.

5 Evaluation of forage and animal modelling capabilities for forages grown in the Fitzroy River catchment *(full report in Appendix 2)*

The objective of this aspect of the project was to test and evaluate approaches for incorporating forage and animal production modelling simulation capabilities within the APSIM modelling framework (Agricultural Production Systems Simulator; McCown *et al.* 1996; Keating *et al.* 2003) with the objective of using the most appropriate approach to develop a simple DST. There were two components to this work. The first involved validating APSIM model predictions of forage biomass yield against data collected from the commercial co-operator field sites detailed in Appendix 1 of this report. The second involved testing three approaches to predicting liveweight gain from forages, using the data collected at the co-operator sites. This is the first time that these models have been tested against measured experimental data for grazed, high quality forages in northern Australia.

5.1 Evaluation of forage modelling capabilities

5.1.1 Methodology

Modelling was completed for 14 annual forage sites, and three perennial grass sites, where measured data were available to compare pasture biomass and, for the annual forages, also components such as green leaf, green stem, dead leaf, dead stem and seed head. APSIM was used for simulating the annual forage cropping systems of oats, sorghum and lablab. A version of the GRASP pasture model (Littleboy and McKeon 1997; McKeon *et al*. 2000) that is incorporated within the APSIM framework was used for modelling perennial grass production.

5.1.2 Results and discussion

The forage models in APSIM have been built from limited data sets and have not been as widely used or tested as the grain crop models. Results from our evaluation have been variable. Generally, APSIM predicted un-grazed oats biomass satisfactorily, with reasonable prediction of measured biomass over time for six out of eight oats sites. However, the forage growth models for forage sorghum and lablab under-predicted the un-grazed biomass production for all sites. The forage sorghum and lablab models in APSIM have been developed from a more limited pool of data sets than for the oats model and our results indicate a need to improve the models for forage sorghum and lablab to provide more reliable results.

The effects of grazing on annual forage crops were poorly predicted, due to under-prediction of the effects of grazing, particularly trampling, in reducing biomass production. There is presently only a rudimentary equation in the APSIM forage models to alter forage biomass production due to grazing, and no algorithm to account for the effects of trampling.

These aspects require improvement before model output for grazed forages can be used with any confidence. The findings and data from the measured field sites detailed in Appendix 1 could be used to improve the annual forage crop models for both un-grazed and grazed forages in the future. The GRASP model, operating within the APSIM framework, predicted biomass of perennial grass pasture, in un-grazed and grazed areas, satisfactorily.

5.2 Evaluation of animal modelling capabilities

5.2.1 Methodology

Three approaches to modelling animal production were examined. The first was the evaluation of the Tropical Version 5.0.5 of the GrazFeed model (CSIRO 2014) described by Freer *et al.* (2012) and based on the Australian feeding standards for ruminants (CSIRO 2007). The second approach was to investigate the use of the simple GRASP daily liveweight gain model (GRAZ; Littleboy and McKeon 1997; McKeon *et al.* 2000). In addition, a simple forage utilisation equation was used for predicting liveweight gain (LWG) using simulated total biomass production and forage-specific parameters for residual biomass in the grazed paddock, biomass utilisation, and efficiency of feed utilisation:

Total paddock LWG (kg/ha) = [total biomass (kg DM/ha) – residual (kg DM/ha)] x biomass utilisation x efficiency of feed utilisation.

5.2.2 Results and discussion

Testing of three approaches to incorporating animal production simulation capabilities within the APSIM framework indicated that a simple 'feed conversion efficiency' approach was the most appropriate. However, the accuracy of total liveweight gain predictions is currently limited by inaccuracies in APSIM-simulated biomass yield in grazed paddocks for annual forage crops.

The GrazFeed model was considered unsuitable for the purposes of predicting beef production from annual forages grown under central Queensland conditions. A total of 26 data sets for grazed annual forage crops including oats, forage sorghum and lablab, were used to test the model, using faecal NIRS-derived estimates of diet DMD and CP as the key inputs of forage quality. Daily cattle liveweight gain was under-predicted for 25 out of 26 data sets with the under-prediction most extreme for cattle grazing forage oats due to the algorithm relating DMD to intake giving a lower prediction of intake compared to tropical forages, given the same DMD. Our results support the findings of others, including most recently McLennan and Poppi (2005) and McLennan (2014), who have also shown that the Australian feeding standards and GrazFeed consistently under-predict the liveweight gain of cattle consuming tropical forages, or conversely, over-estimate intake for a given liveweight change. However, the poor agreement of predicted with observed results for the temperate forage, oats, was unexpected.

The simple GRASP daily liveweight gain model was considered to add little value as a tool to predict animal production for our purposes due to not using biomass production as an input and requiring user-estimated liveweight gain as an input.

6 Development of decision support tool to compare forage options within the Fitzroy River catchment *(web-based link to ForageARM provided separately)*

An objective of the project was to develop a DST for use by beef producers and their advisors to assist with identifying the most suitable forage options for their land type/s and purpose. It builds on the preceding components of the project where measured forage and animal data on commercial beef properties were used to test existing forage and animal models.

Two options were examined. One was to utilise the recently developed C-Farm (Grain and Graze) tool, where the concept was to incorporate additional functionality within this tool to enable the different forage options to be compared economically. Preliminary investigations showed that this option would require significant effort to overcome inherent problems within the forage, animal and economic components of the model. Hence this option was not pursued. The second option was to produce a web-based tool similar to the existing cropping simulation tool 'Whopper Cropper' (Nelson *et al.* 1999). As part of this second approach, forage and animal models were evaluated as described in the preceding section of this report and Appendix 2. Although limitations were identified for both the forage and animal models, a web-based decision support tool called *ForageARM* has been developed as a prototype.

6.1 Description of the decision support tool: ForageARM

ForageARM has been built in the same manner as the Whopper Cropper tool, in that output from the plant models within the APSIM framework were used to build, or 'populate' the tool. APSIM model runs were completed for five forage types by nine land types by 13 locations across the Fitzroy River catchment. The model-estimated forage production was based on 100 years of historical climate data. The forage types were restricted to those for which plant growth models had been constructed and include: oats, forage sorghum, lablab, native perennial grass pasture and buffel grass pasture. Animal production predictions, in terms of an estimate of kg liveweight gain/ha were incorporated by using a simple 'forage utilisation' equation as described in the preceding section and in Appendix 2.

This tool allows users to compare forage options for their selected location and to examine potential effects of management decisions on forage yield and animal production by assessing 'what if' scenarios, such as level of nitrogen fertiliser application. The forage and animal production outputs from this tool can be used to assist in selection of appropriate input figures for the associated gross margin spreadsheet calculators also produced as part of this project.

ForageARM is provided as a web-based tool. The web page also has access to CropARM (formally Whopper Cropper) and ClimateARM (formally Rainman) functionality.

6.1.1 Structure of ForageARM

- ForageARM is a web site that allows the user to analyse data relating to forage options within the Fitzroy River catchment area.
- The web site acts as a front end for an online data server that has access to 155,844 individual modelling results. Each result is the product of a unique combination of environmental factors and management options that have been processed using the APSIM modelling framework.

- Five forage options have been modelled: three cropping options and two perennial grass pastures.
- The user can select the combination of environmental factors and management options that they wish to view. The resulting combination of selections are displayed as either biomass production (kg/ha) or beef production (kg/ha). The results can be displayed using one of four chart types:
    - box plots
    - bar charts
    - cumulative distribution function
    - probability exceedance charts.

The results can be viewed singly, or compared with other combinations for example comparing the beef production of forage sorghum vs. lablab for a particular location.

6.1.2 Inputs by user

(i) Site

There are 13 sites from the Fitzroy River catchment area that have been modelled. The user can select one or more of these sites for analysis. Selection of a site determines which set of climate data is used by the model. The sites (in alphabetical order) are as follows: Banana, Bauhinia, Biloela, Capella, Clermont, Dysart, Emerald, Rolleston, Springsure, Taroom, Theodore, Wandoan and Wowan.

(ii) Forage

The model was run using five different forage types. Three of them are cropping options: oats, forage sorghum, and lablab. The remaining two represent perennial grass pastures: native pasture and buffel grass.

(iii) Scenario

Each combination of site and forage will present a list of possible environmental factors and management options from which the user can select. Each unique set of options is referred to as a ‘scenario’. It is possible to select multiple scenarios allowing the user to compare many different management options.

- Perennial grass pasture scenario options:
    - soil – nine possible soils
    - stocking rate – three possible rates for each grass
    - cattle entry weight – five possible entry weights.
- Cropping scenario options:
    - soil – nine possible soils
    - cattle entry weight – five possible entry weights
    - sowing options:
        - sowing date – five to seven possibilities, depending on location
        - fertiliser applied – eight possible fertiliser rates

  - available soil water – three possible starting waters.

6.1.3 Assumptions

(i) Oats

- the soil water profile is reset at the start of every year, as is the initial nitrogen
- sowing density: 100 plants/m2
- sowing depth: 30 mm
- cultivar: Coolibah
- row spacing: 300 mm.

(ii) Forage sorghum

- the soil water profile is reset at the start of every year, as is the initial nitrogen
- sowing density: 20 plants/m^2
- sowing depth: 30 mm
- cultivar: Sugargraze
- row spacing: 500 mm.

(iii) Lablab

- the soil water profile is reset at the start of every year, as is the initial nitrogen
- sowing density: 10 plants/m^2
- sowing depth: 40 mm
- cultivar: Highworth
- row spacing: 500 mm.

6.1.4 Limitations

- The ability to model pasture growth with reasonable accuracy means that the stocking rate of cattle can be used as an input for native pasture and buffel grass. However, the lack of accuracy when modelling the effects of grazing upon forage crops means that more advanced management options such as stocking rate, length of grazing time, and the timing of grazing commencement could not be reliably predicted for forage crops. This, as well as the poor ability of the underlying APSIM model to predict un-grazed biomass production in the first instance, for forage sorghum and lablab, provides the major limitation to widespread use of the tool. It is recommended that the tool be used as a prototype which shows what might be possible rather than being released for public use in its current state.
- Each input factor has a limited number of possible values that are fixed and cannot be changed. For instance, stocking rate for buffel grass has only three possible values.
- There are only 13 sites currently available for analysis.
- The available list of forage options does not include leucaena or butterfly pea as there are no models currently available that would predict biomass growth for mixed swards of butterfly pea-grass or leucaena-grass.

- Economics have not been included as an output. However, economic calculations in the form of Excel spreadsheets have been provided separately (see Section 4).

6.2 Discussion

Confidence in the accuracy of output from this tool is limited by the underlying models used to populate the tool. The plant growth model for the perennial grass forage options was the Australian plant production model, GRASP, operating within the APSIM modelling framework. This model has been calibrated for over 40 tropical perennial grass pasture communities in Queensland (Rickert *et al.* 2000). In contrast, the plant growth models within APSIM for the annual forage crops, oats, sorghum and lablab are based on very limited data sets. The evaluation work conducted in this project, and described Appendix 2, indicated some biases in the biomass predictions for annual forage crops and difficulties in accurately predicting the effects of grazing on total biomass growth. The findings and data from our measured field sites could be used to improve the models in the future. There were insufficient resources allocated in this project to undertake any modifications to the modelling platform. There are currently no plant growth models available to predict biomass growth for mixed swards of butterfly pea-grass or leucaena-grass, which are arguably the most important forage options in use in the region. As the animal production model, GrazFeed, based on the Australian feeding standards for ruminants, could not satisfactorily predict animal growth at our measured field sites, the prediction of animal production from grazed forages in ForageARM is based on a simple forage utilisation equation and thus will only give an estimate for the purposes of basic comparison with other scenarios.

Nevertheless, the purpose of such a tool is not to provide extremely accurate predictions of forage biomass and cattle growth rates as that is not possible without a detailed knowledge of seasonal conditions into the future, and the ability to adequately quantify the effect on growth rate of specific cattle factors, such as compensatory growth. This tool does, however, allow the user to make broad, relative comparisons of three annual forage crops with perennial grass pasture, either native or buffel, and to examine a range of 'what if' scenarios. The predictions of relative forage yield and cattle production can be used in conjunction with detailed information provided in the associated 'best-practice' guide to forage use, and the gross margin spreadsheet calculators, both developed in this project, to support decision making about the most appropriate choice of forage for a user's particular purpose. This tool should be viewed as prototype, providing a framework which can be built upon and improved as further data sets become available and as improvements to the underlying plant and animal models are made.

7 Conclusions and recommendations

7.1 Forage, animal and economic performance on commercial beef cattle properties in the Fitzroy River catchment

7.1.1 Conclusions

i. Sown annual and perennial legume-grass forages can substantially increase beef output compared to that from perennial grass pastures.

   - Leucaena-grass pastures resulted in the highest average total beef production (198 kg/ha/annum across all sites and years) of all options investigated in this project. Average annual beef production from leucaena-grass pastures was 2.6 times greater than that from perennial grass pastures (76 kg/ha/annum). Furthermore, there was less variability between sites and years in total beef production from leucaena-grass pastures compared to butterfly pea-grass pastures or perennial grass-only pastures (coefficient of variation was 36% for leucaena-grass, 84% for butterfly pea-grass and 97% for perennial grass-only).
   - The next highest average total beef production was for butterfly pea-grass pastures (125 kg/ha/annum).
   - Forage sorghum, despite producing twice as much forage biomass as the other annual forages, oats and lablab, on average resulted in only slightly higher total beef production (108 vs. 93 and 99 kg/ha/annum, respectively) due to generally poor utilisation of biomass and a lower quality diet.

ii. Of the sites monitored, soil fertility was generally low and fertiliser application was not common practice. It is likely that soil nitrogen and/or phosphorus fertility may be limiting production of many annual forage crops in the region. Phosphorus fertility may be limiting production of perennial legume-grass pastures. Whilst forage and animal production are currently sufficient to produce positive paddock gross margins in most cases, soil fertility levels will eventually reach levels where reductions in forage and beef production result in significantly reduced profitability.

iii. Grazing management appears to be limiting productivity and profitability of many annual forage crops in the Fitzroy River catchment, particularly forage sorghum crops. Commonly, grazing commenced once the forage sorghum crops were already mature, with subsequent stocking rates being too low to prevent the crop maturing.

iv. Some producers are not inoculating cattle grazing leucaena-grass pastures with the rumen fluid inoculum, or using carrier cattle. This may be causing sub-clinical mimosine and dihydroxypyridine toxicity which will reduce cattle growth rates.

v. HGPs were not commonly used in cattle grazing the forages monitored in this project. There was often insufficient information available from the co-operators on cattle price data and target markets to accurately discern the reasons for the lack of use of HGPs and whether this could be decreasing potential profits, but this warrants further attention.

vi. Many producers do not monitor weight gain of cattle grazing high quality forages designed to promote high growth rates. Better monitoring of cattle weight gain during grazing periods on high quality forages may allow more optimal timing of sale.

vii. A significant proportion of cattle grazing annual forage crops in this project were not sold directly to market but returned to perennial grass pastures after grazing the crop. Where cattle graze perennial grass pastures in the summer season after grazing a forage oats crop it is highly likely that compensatory gain effects would erode any liveweight advantage provided by forage oats and would likely make the venture unprofitable when considered in the context of overall farm profitability.

viii. Very high stocking rates were used on some perennial grass-only paddocks in some years. Furthermore, some of these pastures were showing signs of nitrogen rundown, in terms of pasture composition and yield, and would benefit from legume inclusion. This scenario appears to be typical of many perennial grass pastures across the Fitzroy River catchment.

ix. There was a wide range in profitability, in terms of paddock gross margin, for annual and perennial forage options in the Fitzroy River catchment. There was no single, over-riding factor that determined the profitability of forage systems.

- Leucaena-grass sites had the highest average gross margin: $184/ha/annum, averaged across all sites and years.
- Butterfly pea-grass produced the second highest average gross margin: $143/ha/annum.
- Oats forage produced a higher average gross margin ($131/ha/annum) than perennial grass pasture ($98/ha/annum).
- Forage sorghum and lablab resulted in lower average gross margins than for perennial grass pasture ($54 and $44/ha/annum, respectively).

x. Farm economic case studies, to determine the effect of sown forages on farm profitability, showed that under current market and cost conditions:

- Perennial legume-grass pastures have a significant economic advantage over perennial grass pasture and annual forages.
- However, high-output perennial legume-grass forages are not as profitable as grain cropping, when grain cropping is a feasible alternative.
- The effect of annual forages on farm profitability can be marginal, and the increase in business risk significant, requiring a careful assessment of the role of annual forages in improving overall profitability.
- Where high-output annual forages are currently grown successfully and grain crops are a realistic option, it is most likely that grain crops will provide substantially greater economic returns than the alternative annual forage crop.
- Where grain crops are not an alternative and grass pasture is the alternative option under consideration, annual forages are a high cost option with high timeliness requirements that may only add value to the beef enterprise if the opportunity cost of plant and unpaid labour are excluded.

xi. Results from gross margin analyses for constructed scenarios, in which best-practice management was assumed and a long-term seasonal view taken, support the conclusions from the commercial co-operator sites which indicate that:

- Forage gross margins are the result of a complex interaction of factors encompassing aspects of forage and animal production, input costs, and market prices.
- Leucaena-grass pastures produced the highest gross margins when compared to other perennial legume-grass and annual forage options.
- Butterfly pea grass pastures also performed well, with the average ranking for gross margin being second out of the six forage options studied.
- The marginal profitability of the annual forages when contract rates are used is in line with the conclusions from the whole farm economic analyses which indicate that growing annual forages may not provide the most profitable enterprise.

7.1.2 Recommendations

i. That the relatively higher profitability of perennial legume-grass pastures, compared to perennial grass pasture or annual forage crops, be publicised to beef producers. In addition, the relatively higher profitability of grain cropping, compared to utilisation of any sown forage, should be emphasised.

ii. That the importance of conducting appropriate economic analysis, to determine the effect of utilising a sown forage option on business profitability, be publicised widely to producers. The gross margin Excel spreadsheets developed as part of this project are a tool which can be used as a first step in assessing the profitability of sown forage options, although whole farm business analysis should also be conducted as a subsequent step. Such economic analysis can be complicated to conduct and understand and thus producers may need to seek specialist services and support. An increased awareness and understanding of relevant tools and approaches can be promoted and supported through DAF extension programs and activities, including the FutureBeef and Grazing BMP programs.

iii. That sensitivity analysis of important variables affecting the profitability of forages, especially cattle price margin, be conducted to highlight circumstances where premium markets may make some forage options more profitable.

iv. That whole of life growth path studies for cattle (from weaning to marketing) be carried out with the aim of identifying the most economical combination of forage types, and the optimal timing of access to improved forages, to exploit compensatory growth effects. A major difficulty in the analysis of whole-farm and long-term effects of forage options on both cattle production and economic returns is the effect of compensatory growth on cattle performance through the growth path to slaughter. Despite the importance of compensatory growth, and decades of work including the recent project NBP.0391, this phenomenon is poorly understood in the context of northern cattle production systems. Therefore it is recommended that future work in this area of forage options encompass, as far as possible, the consequences of the compensatory gain effect.

v. That the generally low nitrogen and phosphorus status of most soils across the Fitzroy River catchment be publicised to beef producers as well as the likely implications for forage and animal production.

vi. Following on from the recommendation above, that a detailed study be carried out towards better quantifying the responses to nitrogen and to phosphorus fertiliser, for annual forage crops as well as perennial legume-grass pastures. Any such study should include measurement of forage, grazing cattle, and economic responses.

vii. That 'best-management practices' for forage use be promoted to producers, to improve awareness of the effects on profitability of factors such as grazing management, rumen fluid inoculation of cattle grazing leucaena, and monitoring of cattle weight gain, as well as the potential economic benefits of HGP use. The extension products produced as part of this project, such as the producer guide and gross margin spreadsheets, can be used to facilitate this knowledge transfer. These tools and information can be promoted and supported through DAF extension programs and activities, including the FutureBeef and Grazing BMP programs.

7.2 Best-practice guide to forage use in the Fitzroy River catchment

7.2.1 Conclusions

i. A revised guide to forage use has been produced: *Feeding forages in the Fitzroy. A guide to profitable beef production in the Fitzroy River catchment*. The guide brings together information on agronomy, management, cattle production and economic performance from high quality forages. It will be made available, free of charge, to beef producers as a printed booklet and will also be available electronically, through the FutureBeef website.

ii. Three Microsoft Excel spreadsheets have also been constructed to complement the printed guide and contain the example gross margins for the constructed scenarios presented in the guide. Each spreadsheet relates to one of the three regions of focus across the Fitzroy River catchment: Central Queensland Open Downs (Emerald-Capella area), Central Queensland Brigalow (Biloela-Rolleston area) and South Queensland Brigalow (Taroom-Wandoan). These spreadsheets can be used to test alternative scenarios based on individual property production and input figures.

7.2.2 Recommendations

i. That the information package, consisting of the printed forage guide and the gross margin spreadsheets, be made freely available to producers and their advisors. These products should be promoted and supported through DAF extension programs and activities, including the FutureBeef and Grazing BMP programs.

7.3 Evaluation of forage and animal modelling capabilities for forages grown in the Fitzroy River catchment

7.3.1 Conclusions

i. The APSIM model predicted un-grazed oats biomass satisfactorily. However, the forage growth models for forage sorghum and lablab under-predicted, un-grazed biomass production for all data sets.

ii. The effects of grazing on all annual forage crops were poorly predicted due to under-prediction of the effects of grazing in reducing biomass production.

iii. The GRASP model, operating within the APSIM framework, predicted biomass of perennial grass pasture, in un-grazed and grazed areas, satisfactorily.

iv. There is currently little confidence in the use of the GrazFeed, or the Australian feeding standards, for predicting animal liveweight gain from high quality forages, including the temperate forage oats, grown in the Fitzroy River catchment of Queensland. Daily cattle liveweight gain was under-predicted for 25 out of 26 data sets covering the annual forages, oats, forage sorghum and lablab. The under-prediction was most extreme for cattle grazing forage oats due to the algorithm relating DMD to intake giving a lower prediction of intake compared to tropical forages, given the same DMD.

v. The simple GRASP daily liveweight gain model was considered unsuitable for use in a decision support tool for comparing annual forage crops due to not using biomass production as an input and requiring user-estimated liveweight gain as an input.

vi. The simple forage utilisation equation was deemed to be the most appropriate approach for estimating cattle production in a simple DST, although the accuracy of total liveweight gain (kg/ha) predictions are currently limited by inaccuracies in simulating the effect of grazing on annual forages within APSIM.

7.3.2 Recommendations

i. That the data from the measured field sites, which was used to evaluate the models, be used to improve the annual forage crop models. In addition, as further data sets become available, these should also be used for this purpose.

ii. That improvement is made to the rudimentary equation in APSIM which alters forage biomass production due to grazing. In particular, an algorithm is required to account for the effects of trampling on forage growth.

iii. That further investigation be undertaken to understand why the Australian feeding standards and the GrazFeed model under-predict liveweight gain for cattle grazing forages grown in northern Australia and to make the necessary changes to improve predictions overall.

7.4 Development of a decision support tool to compare forage options within the Fitzroy River catchment

7.4.1 Conclusions

i. A DST, ForageARM, has been developed using output from the plant models within the APSIM framework, and a simple forage utilisation equation to predict cattle liveweight gain per hectare. This tool has been provided as a web-based tool with the link available upon request. The tool allows comparison of forage yield and animal production for the annual forages oats, sorghum and lablab and for perennial grass pasture.

7.4.2 Recommendations

i. That the ForageARM DST be treated as a prototype, which can provide broad comparisons of three annual forage crops with perennial grass pasture and which can be used to examine a range of scenarios.

ii. That the DST be built upon and improved as improvements to the underlying plant and animal models are made.

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The project team has included the following DAF staff:

Dr Maree Bowen (Principal Research Scientist, Ruminant Nutrition)
Stuart Buck (Senior Agronomist, Sown Pastures)
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High-output forage systems for meeting beef markets – Phase 2

Appendix 1:

Forage, animal and economic performance on commercial beef cattle properties in the Fitzroy River catchment

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

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Glossary of terms and abbreviations

AE	adult equivalent; a 450 kg, non-lactating animal, calculated as liveweight to the power of 0.75
APSIM	Agricultural Production Systems Simulator; a modelling framework historically developed for predicting grain crop production but now also with modules for forage crops and perennial grasses
BOM	Bureau of Meteorology
C	carbon
C_3 species	species other than tropical grasses, including oats, legumes and browse from trees and shrubs
Cattle price margin	sale price of cattle less the purchase price ($/kg liveweight)
Cl	chloride
CP	crude protein; (N x 6.25)
CQB	Central Queensland Brigalow; (Biloela-Rolleston area), one of three regions in the Fitzroy River catchment used to focus co-operator sites or constructed scenarios
CQOD	Central Queensland Open Downs; (Emerald-Capella area) one of three regions in the Fitzroy River catchment used to focus co-operator sites or constructed scenarios
d	day/s
DAF	Department of Agriculture and Fisheries
DM	dry matter
DMD	dry matter digestibility
Forage costs	the costs of forage establishment and maintenance. For butterfly pea-grass and leucaena-grass pastures that have a productive life of more than one year, the establishment costs were amortised (added as an average annual cost) in the calculation of the gross margin
Gross margin – contract rates	the gross income received from the sale of cattle less the variable costs incurred, including labour costs of machinery operations but not of handling livestock; calculated using a pseudo contract rate to cost actual machinery operations used by the co-operator
Gross margin – owner rates	the gross income received from the sale of cattle less the variable costs incurred, including labour costs of machinery operations but not of handling livestock; calculated as if plant and machinery is owned by the business with overhead costs excluded from the gross margin
ha	hectare
HGP	hormonal growth promotant

LW	liveweight
LWG	liveweight gain
mths	months
N	nitrogen
n/a	not applicable or not available
NIRS	near infrared reflectance spectroscopy
P	phosphorus
Pdk	paddock
PAWC	plant available water capacity; the quantity of water that the plant species can extract from the soil
SE	standard error; a statistical term that measures the amount of variation in a dat a set and t herefore the accuracy with which the data sample represents the population
SQB	South Queensland Brigalow; (Taroom-Wandoan area), one of three regions in the Fitzroy River catchment used to focus co-operator sites or constructed scenarios
SR	stocking rate

List of forage species

Annual forage crops

Forage oats	*Avena sativa*
Forage sorghum	*Sorghum* spp.
Lablab	*Lablab purpureus*

Perennial introduced legumes

Butterfly pea	*Clitoria ternatea*
Leucaena	*Leucaena leucocephala* spp. *glabrata*
Seca stylo	*Stylosanthes scabra* var. *seca*

Perennial introduced grasses

Bambatsi panic	*Panicum coloratum*
Buffel grass	*Pennisetum ciliare*
Creeping bluegrass	*Bothriochloa insculpta*
Green panic	*Panicum maximum* var. *trichoglume*
Indian bluegrass	*Bothriochloa pertusa*
Purple pigeon grass	*Setaria incrassata*
Rhodes grass	*Chloris gayana*
Sabi grass	*Urochloa mosambicensis*
Silk sorghum	*Sorghum* spp.

Annual introduced grasses

Sweet summer grass	*Brachiaria eruciformis*

Perennial native grasses

Black speargrass	*Heteropogon contortus*
Forest bluegrass	*Bothriochloa bladhii*
Native panic	*Panicum buncei*
Queensland bluegrass	*Dicanthium sericeum*
Windmill grass	*Chloris truncate*

1 Introduction

The Fitzroy River catchment is an important beef producing area of Queensland. This region occupies approximately 50% of the Queensland portion of the Brigalow Belt bioregion, which supports a large percentage of northern Australia's sown pastures and 32% of northern Australia's beef herd (Peck *et al.* 2014). Beef production is the major land use in the Fitzroy River catchment, occurring on around 12.3 million hectares or approximately 85% of the catchment and with cattle production accounting for 66% of the total value of agricultural production (ABS 2014a,b).

The recent report, '2013 Northern beef situation analysis' (McLean *et al.* 2014), concluded that the majority of northern beef producers are not generating sufficient profits to fund current and future liabilities. This report confirms previous observations by McCosker *et al.* (2010) and enterprise analysis conducted as part of the Department of Agriculture and Fisheries (DAF), CQ *BEEF* project in central Queensland (Gowen *et al.* 2009), which also highlighted the need for beef producers to better understand the profit drivers for their business and to focus on increasing income through increasing 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 and at a heavier weight can be important in increasing beef producers' ability to meet market specifications for high value beef and for increasing turnover and output of beef, both aspects contributing to increased productivity and profitability of beef businesses.

Three of the four major land types in the Fitzroy River catchment, Brigalow, Alluvial and Open downs, have soils capable of growing high quality forages suitable for backgrounding and finishing cattle. Forages capable of producing the higher growth rates required for backgrounding and finishing include summer and winter annual forage crops and perennial legume–grass pasture systems. Targeted use of high quality forages has the potential to improve the profitability of beef enterprises in the Fitzroy River catchment of Queensland through increasing enterprise turnover and productivity, and providing a viable alternative to grain finishing for 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 budgeting, marketing, and an understanding of the financial implications for the business. The review by Bowen *et al.* (2010) demonstrated a paucity of definitive data documenting forage, cattle and economic performance from high quality forages in the Fitzroy River catchment. The current study was designed to benchmark forage production systems on commercial beef co-operator properties with the objective of improving the understanding of expected forage, animal and economic performance, and the key drivers of profitability, within these systems.

2 Methodology

2.1 Co-operator site selection

In total, 24 individual forage sites were established on 12 producer co-operator properties across the Fitzroy River catchment from 2011 to 2014. The forage sites were selected in three regions within the catchment area: Central Queensland Open Downs (Emerald-Capella area), Central Queensland Brigalow (Biloela-Rolleston area), and South Queensland Brigalow (Taroom-Wandoan area). In Central Queensland Open Downs and Central Queensland Brigalow, the forage types studied were the annuals: oats, forage sorghum and lablab, the perennial legume-grass pastures: leucaena-grass and butterfly pea-grass, and a perennial grass pasture to provide a baseline for comparison to the more highly productive forage options. In the South Queensland Brigalow region only four of these forage types were studied: oats, forage sorghum, leucaena-grass and baseline perennial grass pasture. Seasonal conditions and difficulties in engaging suitable co-operators limited the number of forage x region x year combinations possible over the study period. A summary of the number of data sets collected over the period 2011-2014 is given in Table 1. The producers at each site used their normal management practices and were not asked to change practices for the project, other than measuring cattle liveweight gain if they did not already do so.

Table 1. Summary of forage data sets collected over the period 2011-2014 in the Fitzroy River catchment

CQOD: Central Queensland Open Downs, CQB: Central Queensland Brigalow, SQB: South Queensland Brigalow

	Annual forages			Perennial forages		
	Oats	Forage sorghum	Lablab	Leucaena-grass	Butterfly pea-grass	Perennial grass
Region x number of data sets	CQOD x 2 CQB x 3 SQB x 3	CQOD x 1 CQB x 2 SQB x 2	CQOD x 1 CQB x 1	CQOD x 2 CQB x 2 SQB x 2	CQOD x 2 CQB x 1	CQOD x 3 CQB x 1 SQB x 3

2.2 Recording paddock operations and activities

All activities that occurred at each of the 24 forage sites were recorded and documented as best possible. Most critically, this included details of forage planting and maintenance operations, and cattle movements and treatments. All costs and returns associated with the paddock were documented to enable a representative paddock gross margin to be calculated. Where costs and returns were not able to be obtained from the producer, these were estimated using locally relevant price information.

2.3 Soil characterisation

The land and soil type at each co-operator site was classified according to the Queensland Government Land Management manuals (Gillespie *et al.* 1991; Thwaites and Maher 1993). Soil cores were taken across each paddock, using a hydraulic soil sampling rig, to a maximum depth of 120 cm. The soil cores were sub-sampled and analysed for soil nutrient and water content at key times relevant to the forage type and the factor being monitored. Concentrations of nitrate nitrogen (nitrate N), organic carbon (Organic C), phosphorus (P; Colwell bicarbonate extraction) and chloride (Cl) in 0–10 cm and 10 cm to rooting depth of soil were determined by a commercial laboratory (Incitec, Melbourne) using techniques described by Rayment and Lyons (2011). Representative plant available water capacity (PAWC) values were estimated for each site based on measured values for similar soils in the DAF Central Queensland Sustainable Farming Systems soil database. The PAWC of the soil is defined as the quantity of water that the target plant can extract from the soil when the soil profile is full. The plant available water at planting was determined by measuring the volumetric water content (which accounts for soil bulk density) and subtracting the amount of water left in the soil at the end of grazing when the plant had extracted all it could, with adjustment for rainfall (i.e. the crop lower limit).

2.4 Rainfall and temperature

If possible an on-site weather station (Hastings Tinytag Data Logger) was erected, in a fenced forage exclosure, which automatically logged rainfall and temperature data. If an on-site weather station was not available, producer rainfall records were used, if considered reliable, or otherwise data from the closest Bureau of Meteorology (BOM) weather station. Temperature data is not presented in this report but was used in the model evaluation study described in Appendix 2 of this Final Report.

2.5 Forage production and quality

The forage biomass (presentation yield) was assessed in the grazed paddock at intervals over the grazing period by cutting 10–20 (depending on paddock size and heterogeneity), 0.25 m^2 quadrats for annual crops (oats, forage sorghum and lablab) and by a modified BOTANAL procedure (Tothill *et al.* 1992) for the butterfly pea-grass pasture and perennial grass pasture sites and for the perennial grass portion of the annual forage and leucaena-grass pasture sites. The biomass of edible leucaena forage was assessed by plucking or stripping all edible leucaena (including green stems approximately ≤ 5 mm thickness) in a 2 m section of a row in each of four areas considered to be representative of the paddock. Annual forage crop and leucaena biomass is reported per hectare of area planted to forage rather than per the total grazing area. For annual crops, an average height of the forage within each cut quadrat was determined, where possible, by use of a measuring tape or ruler. Where possible, on each sampling occasion for annual forages, representative subsamples were sorted to determine the proportions of green leaf, dead leaf, green stem, dead stem and seed head or pod components. In perennial grass areas, the modified BOTANAL procedure was used to assess the plant species composition and the proportion of each quadrat biomass as green material in categories (0-20%, 21-40%, 41-60%, 61-80%, and 81-100%). After planting, fenced exclosure sites (9 m x 9 m) were established at all sites, except leucaena-grass sites, to exclude cattle. On each occasion that biomass was sampled in the grazed paddock, four randomly selected quadrats were also cut in the exclosure for biomass determination and, where possible, for sorting into plant components. The dry weight of all forage samples was determined by oven drying at 65^0C to constant weight so that forage biomass could be expressed as kg dry matter (DM)/ha.

Dried forage samples were milled through a 4 mm screen followed by a 1 mm screen in a Christy and Norris laboratory mill and then to < 1 mm with a Model 1093 Cyclotec mill, Foss Tecator AB, Hoganas, Sweden. Forage samples for which there were only small quantities of material were only milled through the Cyclotec mill. Forage samples taken from the grazed paddock were analysed for total N content by a combustion method (Sweeney 1989) with an Elementar Rapid-N combustion analyser (Elementar Analysensysteme GmbH, Hanau, Germany) calibrated using AR-grade aspartic acid. In addition, all forage samples were redried (60^0C for 18 h) and then scanned on a Foss 6500 Near Infrared Spectrometer spinning-cup system (FOSS NIRSystems Inc., Maryland USA) to estimate N and *in vivo* dry matter digestibility (DMD) content. The N values determined by wet chemistry on the paddock forage samples were used to strengthen the near infrared reflectance spectroscopy (NIRS) calibration set for future use.

2.6 Animal production

Cattle liveweight records were provided by the producer co-operators for each site, with a minimum requirement of a start and exit liveweight, and ideally with one or two additional intermediate liveweight measurements. On some occasions only a subset of animals grazing the forage were monitored for weight change. Additionally, due to various on-farm constraints that arose, some co-operators were only able to obtain group or mob weights rather than individual weights. Carcase data was obtained, where available, from animals sent for slaughter after exiting the forage site.

At intervals throughout the grazing period faecal samples were collected in the paddock from a minimum of 10, but preferably 20, fresh dung pats. These samples were oven dried at 65^0C and processed as described for forage samples prior to analysis by NIRS. Diet quality in terms of total N and *in vivo* DMD was estimated using the methods described by Coates (2004) and Dixon and Coates (2005).

All dried and milled faecal samples, except those taken from cattle grazing forage sorghum forage, were further milled to fine powder in a ball mill prior to determination of δ^{13}C, using a continuous flow system consisting of a Delta V Plus mass spectrometer connected with an Thermo Flush 1112 via Conflo IV (Thermo-Finnigan, Germany). The percentage of diet as C_3 forage species was then determined according to the methods described by Norman *et al.* (2009), accounting for diet-tissue discrimination of -1 unit as determined by Jones *et al.* (1979) and accounting for the average measured difference in digestibility between C_3 and C_4 species which was determined for each forage type, as described above. A representative cross-section of samples from all forage types and regions (leaf material for C_3 species and 'grab' leaf and stem material from C_3 perennial grass species) were analysed for δ^{13}C using the same procedures as that for faecal samples to determine the δ^{13}C typical of the forage species in our study. The average δ^{13}C ± standard error (SE) for C_3 forage species was oats: -28.1 ± 0.38‰, lablab: -30.1 ± 0.60‰, butterfly pea: -31.0 ± 0.42‰ and leucaena: -28.3 ± 0.38‰ and for C_4 species (predominantly perennial grass species) was
-14.4 ± 0.10‰.

2.7 Economic analysis

2.7.1 Gross margins for co-operator sites

Gross margins were calculated for each forage data set (other than the two perennial data sets which did not extend to a full 12-month period) to allow comparison of the economic performance of forages, both across sites and with the scenarios constructed in Phase 1 of this project (Bowen *et al.* 2010). The gross margins were calculated based on the actual forage and cattle management at each site. In some cases, only a proportion of the total cattle grazing the forage site were monitored for weight gain. For these sites, assumptions based on the best available information were made to estimate the total cattle liveweight gain from the paddock and thus a total paddock gross margin. Each site was characterised by its own combination of management decisions, seasonal influences and market prices, and thus the economic results should be interpreted in the context of the site's background information. The gross margins are presented as an annual gross margin, expressed as \$/ha/annum. Perennial forage crop gross margins include a share of the costs of establishing that forage based on the expected life of the forage and the estimated costs of establishment. Gross margins were calculated using two methods for each forage site.

Method 1: gross margins with machinery operations costed at owner rates
The first method is relevant when producers own the machinery required to plant forages. This method was the typical gross margin approach based on the allocation of variable costs

to enterprises or activities and includes an allowance for the labour costs associated with machinery operation (labour costed at $25/hour). The gross margins were calculated as the gross income received from the sale of cattle less the variable costs. Variable costs included both livestock costs and costs of forage development. Where appropriate, the costs of establishing long-lived forages were included as an annualised variable cost. The forage costs used in the gross margin calculation were calculated as if plant and machinery were owned by the business with overhead costs excluded from the gross margin.

Cattle were valued in and out of the forage paddock regardless of whether they were already owned by the property initially or retained on-property after grazing finished at the site. Cattle were either valued at their actual purchase or sale prices, where the data was available from the co-operator, or they were valued at the ruling market price paid at the nearest store or fat selling centre to the trial site, at the closest and most relevant date available. The livestock value into the paddock, for stock purchased immediately prior to grazing the forage, was calculated as the landed purchase cost, accounting for transport and buying costs. The value of stock already owned by the business was determined as the current market price less all selling expenses that would be required to sell the stock and realise that value. Total livestock costs thus included purchase cost, animal health expenses, sale levies, freight and the opportunity cost of livestock capital. Labour costs of handling the livestock were excluded on the basis that such livestock costs are unlikely to differ significantly between forage types on an annual basis. The opportunity cost involved in owning the cattle was accounted for by calculating the amount of interest that could have been received on the livestock capital if the forage enterprise had not been undertaken (interest rate of 5% assumed) and subtracting this amount from the gross margin.

For forage systems such as butterfly pea-grass and leucaena-grass that have a productive life of more than one year and/or have establishment costs that contribute to production over a number of years, the establishment costs were amortised (added as an average annual cost) in the calculation of the gross margin. The amortisation process includes the opportunity cost of the capital applied in the pasture establishment process in the calculation of the gross margin plus an allowance for the value of any grazing foregone during the establishment period of the perennial forage. This method allows a broad comparison of the gross margins received from annual forage crops with forages that have longer production periods. However, we recommend that more detailed investment analysis techniques be applied prior to making investment decisions about whether to invest in long-lived forage crops. Such analysis techniques should incorporate the riskiness of the investment, the timing of costs and returns and the effect on whole farm cash-flow and profitability. Changes to operating costs and labour requirements should also be considered where necessary.

Method 2: gross margins with machinery operations costed at contract rates

The second method of calculating gross margin is relevant when producers use contractors to plant forages. This method was the same as for Method 1 but incorporated a pseudo "contract" rate to cost machinery operations. The contract rate apportions overhead, operating and labour costs on a per hectare basis for the use of the machines or combinations of machines. To this figure, an allowance for contractor profit and minor travel costs is added. The final figure approximates the rate that could be charged by a farmer who was asked to do some work on a contract basis for a neighbour and who also wanted to recover a proportional share of the costs of owning and operating the machines, plus the labour associated with the activity, plus some small measure of profit. The contract rate does not represent what should be charged by a contracting business to undertake the same activity as that form of business would incur different costs.

2.7.2 Gross margins for Phase 1 scenarios ('constructed scenarios')

The gross margins for the scenarios constructed in Phase 1 of the project (Bowen *et al.* 2010) were re-calculated, using Methods 1 and 2 described above, to allow better comparison with the gross margins determined for the co-operator sites. The example gross margins, for what are hereafter referred to as 'constructed scenarios', were based on the same three regions within the Fitzroy River catchment as for co-operator sites. The same six forage types outlined above were modelled at each of the sites.

A description of each of these constructed scenarios and the general assumptions used in the analysis are given in Table 29-Table 31 in the Addendum of this report. Some of the assumed input figures from Phase 1 were altered to reflect our improved understanding of these forage systems and best management practice but the cattle weight gain, days of grazing, livestock costs and price assumptions have predominantly been maintained. More detailed information, including unit costs, can be obtained from the Microsoft Excel spreadsheets which accompany this Final Report. A more detailed summary of the results for these constructed scenarios is given in the guide produced as part of this project: 'Feeding forages in the Fitzroy. A guide to profitable beef production in the Fitzroy River catchment'.

The growing costs of the forages in the constructed scenarios were based on a mixture of chemical and mechanical, fallow weed control methods. This was done to match current industry practice. Cattle production from each of the forage types was assessed by using a scenario where steers were finished to the same target weight: 596 kg liveweight (310 kg carcass weight). Cattle were assumed to enter the system at a starting 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 experienced 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 long-term average performance for a forage crop that is successfully planted. No allowance has been made for the potential cropping frequency of the annual forages at any of the locations.

2.7.3 Farm case studies

As paddock gross margins are only the first step in determining the effect of sown forages on farm profitability, more complete economic analyses, or 'farm case studies' were conducted with five beef producers across the Fitzroy River catchment who were currently extensively using forages in their production system. Case studies were used to identify and model the core management practices already in place and, once that was done, the manager was asked to nominate changed management practices that may improve the profitability of the property. The key question posed to case study participants was "what would you do if you did not grow forages?". All of the property managers were considered to be competent and highly experienced in the productions systems that prevail in their region.

The possible paradox evident in this approach is that we were asking managers to nominate improvements to a system that they probably felt was already close to optimal. Fortunately, the nature of the managers interviewed was to continually seek improvement in what they are doing. The role of the case study process was to identify ways to optimise economic efficiency but they also provided insight into:

- what managers currently saw as the best options to improve the profitability of the business;

- some of the financial and technical constraints that limited their capacity to implement change; and
- some of the knowledge gaps relating to what was driving the herd performance indicators produced during the analyses.

The case study analyses relied upon the construction of a scenario budget that identified the "base case" for the operation of the business, or the "without change" scenario. Starting with what was known by the manager before moving on to estimating the impact of change was seen as the best way of building knowledge of how the business currently works. The base case budget considered the current forage system and its benefits and the "with change" budgets described the performance of the most acceptable alternative system(s). The co-operator decided the alternative system(s) to be considered and described the expected performance of that system under their management. In most cases it was necessary to construct a herd model, a series of activity budgets to cover each alternative activity, and some estimate of the change in capital equipment and labour necessary to implement the potential change. Fixed or overhead costs incurred by the farm business that did not change were ignored.

All changes to systems were modelled as two steady states with one state representing the average output of the without change scenario and the other state representing the average output of the with change scenario - once it is fully implemented. This steady state method is a valid way of quickly comparing the potential benefits of a change but does not easily account for the time taken to implement the change and the timing of any capital costs or deficits incurred in making the change. The steady state profit budgeting method applied was considered to be adequate for the purposes of the case studies undertaken.

3 Results and discussion for individual co-operator sites

3.1 Oats (*Avena sativa*)

3.1.1 Central Queensland Open Downs, Oats 2011

(S 22.78940, E 148.21071; between Capella and Dysart)

Two adjacent paddocks (A and B) with the same soil type, forage preparation and planting dates were utilised for finishing the one group of cattle using Drover forage oats sown on 28/04/11. Cattle were first placed in Paddock A (forage area of 16 ha with access to additional grass paddock of 142 ha) for 2.5 weeks and then moved to paddock B (forage area of 22 ha with access to the same additional grass paddock of 142 ha). After being originally cleared of timber in 1982 these paddocks were used for growing cereal crops, such as sorghum and sunflower, for approximately 22 years. Cereal and legume forages have been grown in the paddocks for the last 7 years and utilised for growing or fattening cattle. A summary of key site details are given in Table 2 and Fig. 1-Fig. 8.

Table 2. Site details. Central Queensland Open Downs, Oats 2011
For definitions of abbreviations, see Glossary of terms and abbreviations

Factor	Details		
Soil characterisation			
Broad land type	Open Downs (Waterford land system)		
Soil type and characteristics	Open Downs cracking clay (Vertosol) on basalt PAWC: 220 mm Soil depth: 90 cm		
Soil nutrient levels at planting		**0–10 cm**	**10–90 cm**
Paddock A Paddock B	Nitrate N (mg/kg)	6 7	4 6
Paddock A Paddock B	Nitrate N total (kg/ha)	44 56	
Paddock A Paddock B	P (mg/kg)	16 15	n/a n/a
Paddock A Paddock B	Organic C (%)	1.3 1.1	n/a n/a
Paddock A Paddock B	Cl (mg/kg)	21 17	14 11
Paddock A Paddock B	Plant available water (mm)	206 202	

Factor	Details
Paddock preparation and forage sowing details	
Planting date	28/04/11
Sowing rate	32 kg/ha
Fertiliser	None
Fallow weed control	Minimal till (cultivation and chemical application)
Total in-crop rainfall	110.0 mm (28/04/11–25/10/11; combination of Capella Post Office (BOM Station 35016) and on-site weather station data)
Forage production	
Oats green leaf at start of grazing	74% of biomass, 13.1% CP, 81% DMD
Oats peak biomass	Paddock: 5,180 kg DM/ha, Exclosure: >4,939 kg DM/ha
% oats in the diet	83% (Days 14-85 of grazing period)
Average diet quality	61% DMD (Days 14-85 of grazing period)
Average perennial grass presentation yield	n/a
Grazing management and animal production	
Comments	An initial group of 89, 2.5 year-old steers grazed Paddock A for 2.5 weeks prior to entering Paddock B. A second group of 40, 1.5-year old cattle entered Paddock B after a month and a half. Cattle were removed from Paddock B in 3 groups as they reached target weight and condition. Some entry and exit weights were not linked with individual cattle identification, precluding calculation of SE.
Cattle type monitored for weight gain	Steers; 89 ca. 2.5 years at entry and 40 ca. 1.5 years old at entry; ca. 50% *B. indicus* content
Animal health treatments	None
Feeding period	20/07/11–25/10/11 (97 days)
Proportion of the total grazing area as oats forage	13%
Average SR (oats area only)	4.6 AE/ha
Average SR (total grazing area)	0.6 AE/ha
2.5-year old steers	
Grazing days over which LW was measured	34 (20/07/11–23/08/11)
Number of cattle in weight gain dataset	88
Average entry LW (± SE)	622 (± 0.5) kg
Average exit LW (± SE)	646 (± 0.5) kg
Average LWG	0.70 kg/head/day
1.5-year old steers	
Grazing days over which LW was measured	42 (13/09/11–25/10/11)
Number of cattle in weight gain dataset	40
Average entry LW	462 kg
Average exit LW	502 kg
Average LWG	0.95 kg/head/day
Total LWG (forage area only)	282 kg/ha/annum (Note: forage only 13% of total area)
Total LWG (total grazing area)	38 kg/ha/annum

Factor	Details	
Economic performance		
	Forage area only ($/ha/annum)	**Total grazing area ($/ha/annum)**
Gross margin - owner rates	**403**	**54**
Forage costs	193	26
Gross margin - contract rates	**285**	**38**
Forage costs	310	42
CONSTRUCTED SCENARIO (10% total area as perennial grass)		
Gross margin - owner rates	**39**	**35**
Forage costs	200	180
Gross margin - contract rates	**-60**	**-54**
Forage costs	298	268

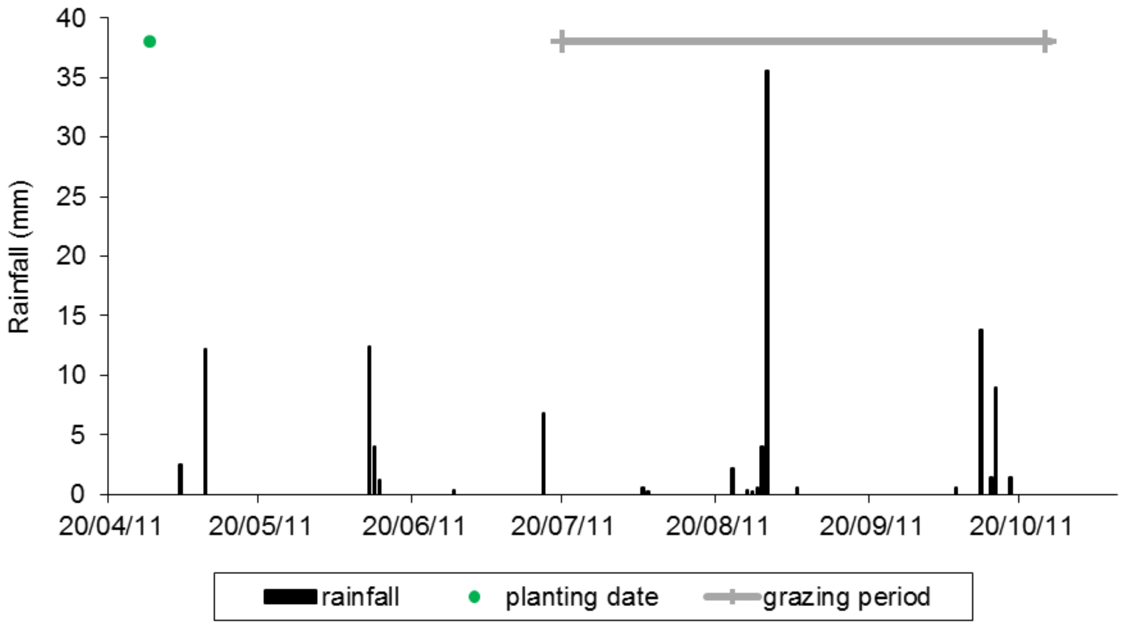

Fig. 1. Daily rainfall (mm) over the in-crop period (28/04/11–25/10/11) and until the final forage sampling (08/11/11). Measured at Capella Post Office (BOM Station 35016; 28/04/11–26/07/11) and on-site weather station (27/07/11–08/11/11). Planting date and grazing period shown.

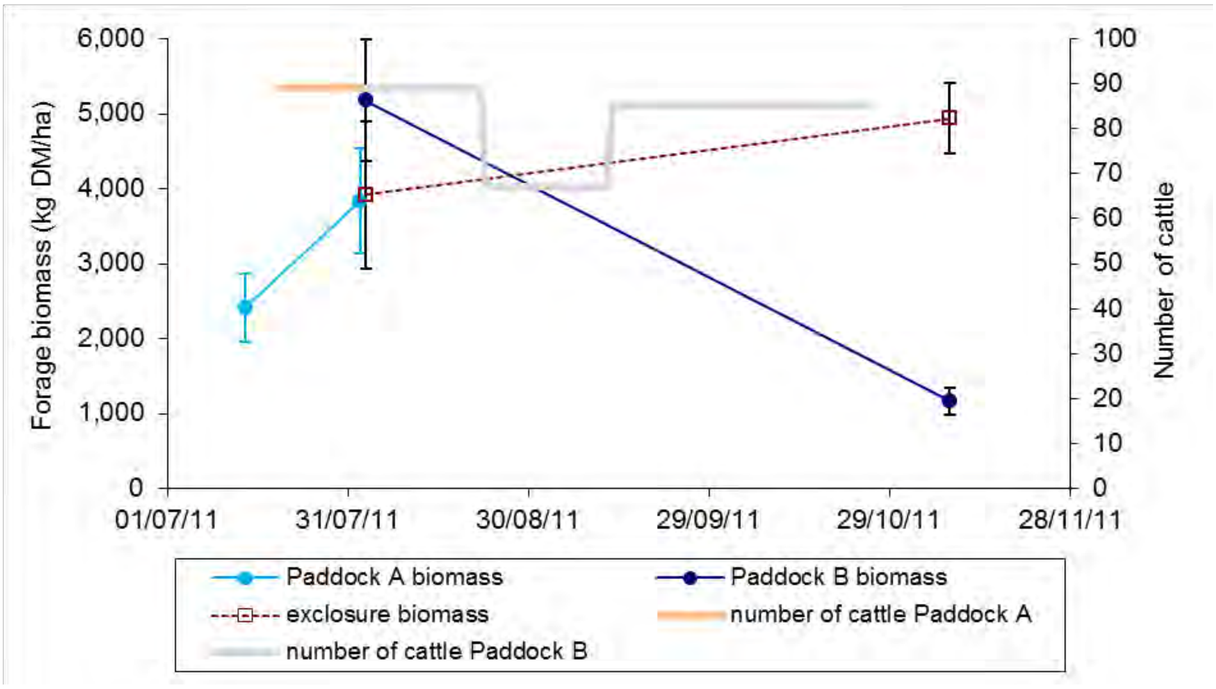

Fig. 2. Forage biomass (kg DM/ha; mean ± SE) in the paddock and exclosure, and cattle numbers during the grazing period (20/07/11–25/10/11). On the 03/08/11, the oats biomass is presented for Paddock A as cattle exited and for Paddock B as cattle entered. There was no exclosure erected in Paddock A due to the short grazing period.

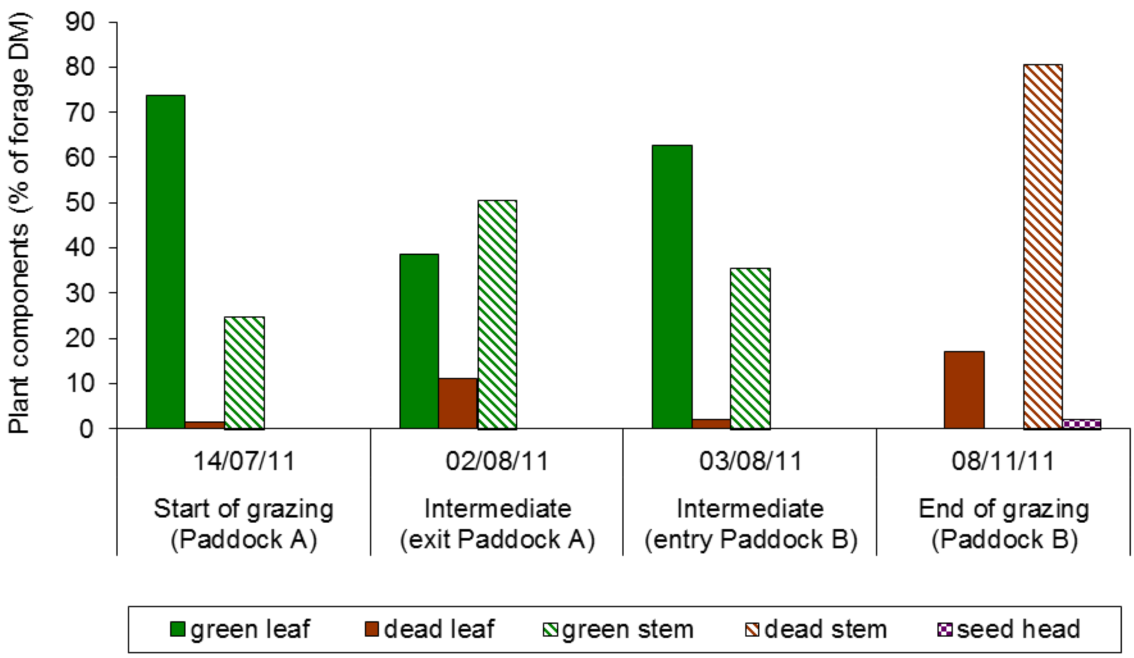

Fig. 3. Plant component composition (% of total forage DM) in the paddock during the grazing period (20/07/11–25/10/11). On the 02/08/11 plant composition data is presented for Paddock A as cattle exited, and on the 03/08/11 for Paddock B as cattle entered.

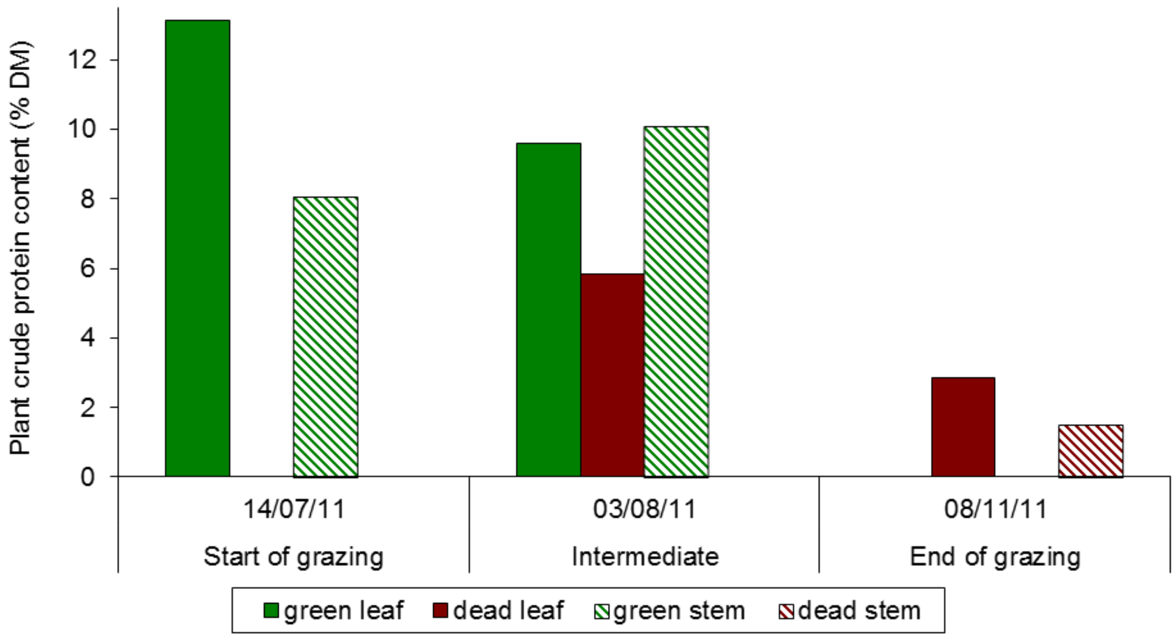

Fig. 4. Crude protein content (% DM) of forage oats plant components in the paddock over the grazing period (20/07/11–25/10/11).

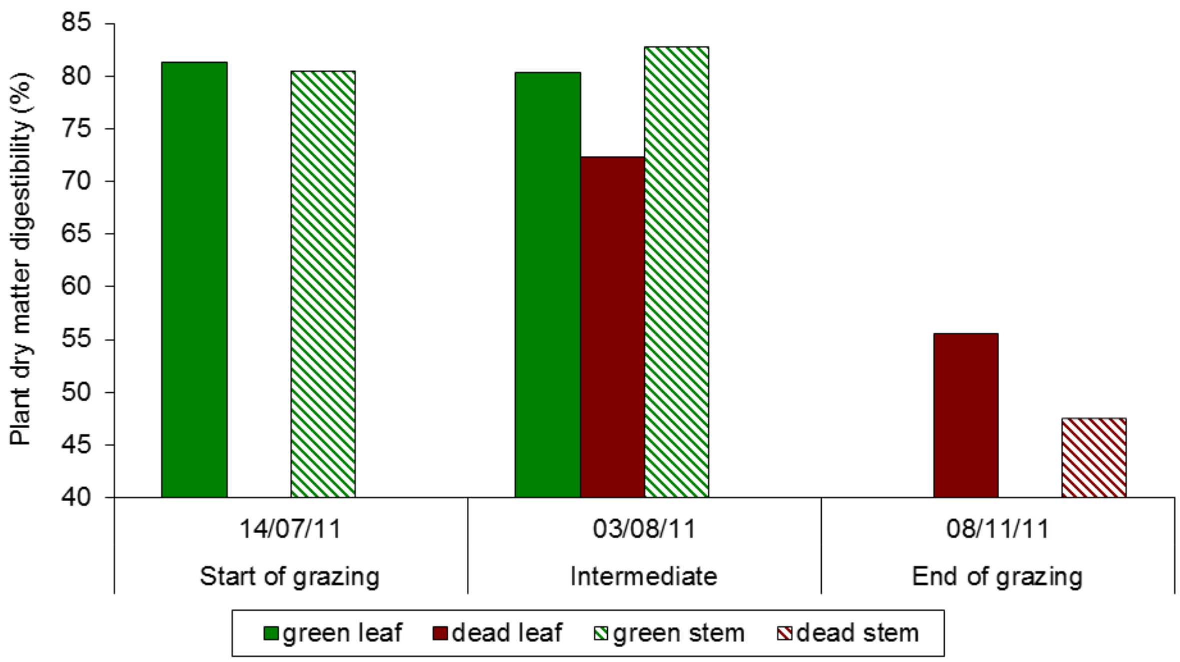

Fig. 5. Dry matter digestibility (%) of forage oats plant components in the paddock over the grazing period (20/07/11–25/10/11).

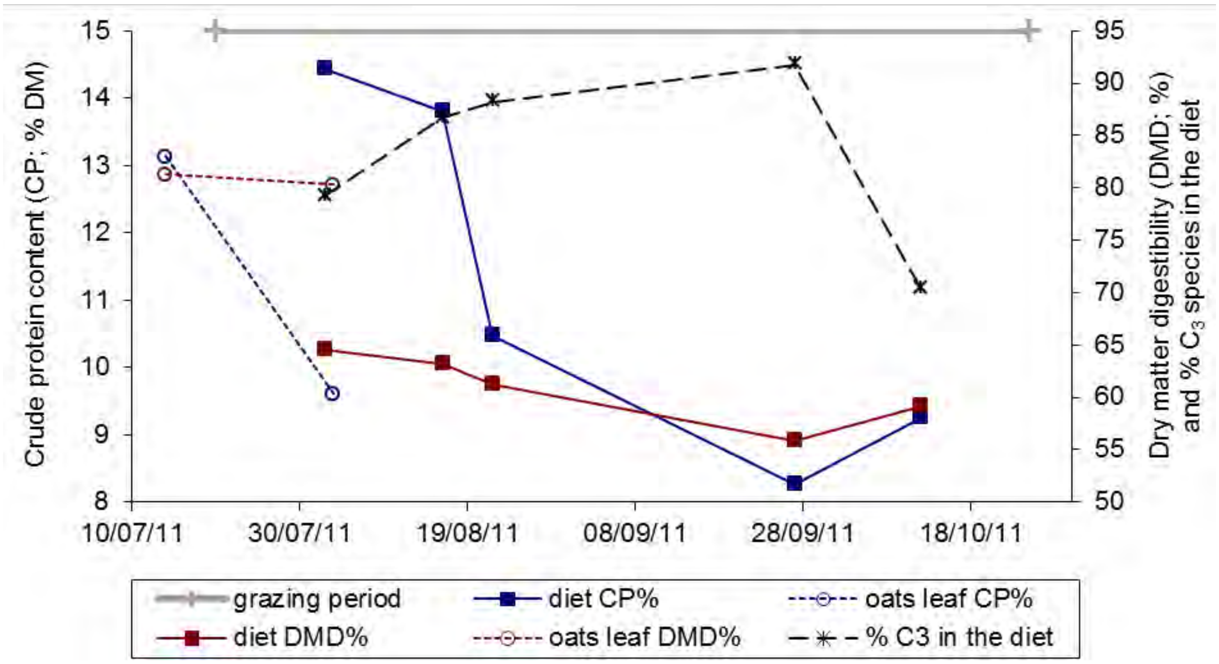

Fig. 6. Diet crude protein (CP) content (% DM) and dry matter digestibility (DMD; %) for grazing cattle predicted from faecal NIRS; measured CP and DMD content of oats green leaf in the paddock; and the % of the diet as C_3 forage, predicted from $\delta^{13}C$ content in the faeces. Grazing period shown.

Fig. 7. Oats crop, 14/07/11; 6 days prior to the start of grazing.

Fig. 8. Cattle grazing oats paddock, 26/07/11; 6 days after start of grazing.

The soil characteristics were typical of the target region (Table 2). Soil nutrient analyses prior to planting indicated that both A and B paddocks contained low to moderate levels of major nutrients, reflecting inherent nutrients levels, cropping history and farm management. Organic C levels in the top 10 cm were moderate at 1.3 and 1.1% and P levels were low at 16 and 15 mg/kg. Subsoil Cl was very low (11 and 14 mg/kg), typical of this soil type. The 2011 forage oats crop was planted using minimal till (cultivation and chemical application). Nitrogen fertiliser was not applied to either paddock with the producer indicating a preference for managing soil nutrients using forage rotations incorporating legumes. However, plant available N was low to moderate (44 and 56 kg/ha for Paddocks A and B, respectively) and would have been insufficient to achieve the maximum oats biomass yield possible given the available soil water available at planting (202-206 mm; 0-90 cm) which was close to capacity. Total in-crop rainfall was 110.0 mm. Of this total, 70.6 mm was received during the 97-day grazing period (Fig. 1).

Grazing commenced in Paddock A when the oats crop was in the tillering stage and still developing, at only 2,415 kg DM/ha biomass (Fig. 7). There was an increase in paddock biomass (to 3,834 kg DM/ha) measured over the 19-day grazing period in Paddock A (Fig. 2). Despite the increase in total biomass, the proportion of green leaf declined from 74% of plant DM at the start of grazing in Paddock A to 39% of plant DM on day 19 when the cattle were removed, with green stem then forming the greatest proportion of plant DM at 50% (Fig. 3). The biomass in Paddock B when cattle were moved into this area from Paddock A, was 5,180 kg DM/ha and decreased over the grazing period to 1,166 kg DM/ha. Green leaf formed the greatest proportion of the plant biomass at start of grazing in paddock B (63% of DM) and this declined to 0% at the end of the grazing period, with dead stem forming the greatest proportion of total plant biomass (81% of DM). The forage oats biomass in the Paddock B exclosure site at the end of grazing was higher than at the start of grazing: 4,939 vs. 3,923 kg DM/ha. However, it seems likely that, since an intermediate measurement wasn't taken, the maximum forage biomass was not detected.

Plant chemical analysis (Fig. 4 and Fig. 5) showed, on average, very little difference between green oats leaf and stem in CP and DMD content, with oats green leaf being 13.1% CP and 81% DMD at the starting of grazing measurements. The quality of available oats forage had declined considerably by the end of the grazing period, when dead stem formed the major portion of the biomass and contained only 1.5% CP and was 47% DMD. The declining forage quality over the grazing period is reflected in the declining trend of predicted diet CP and DMD over time (Fig. 6).

Although the area of oats forage formed only a small proportion of the total grazing area (13%), $\delta^{13}C$ analysis of faecal samples showed that C_3 species, assumed to be primarily oats forage, formed the major proportion of the diet (70–92% over the grazing period; Figure 6). The higher dietary CP levels, predicted from faecal NIRS, than CP levels in oats leaf are difficult to explain as the quality of the perennial grass pasture is expected to have been low at this time (analyses not available). In particular, the difference of 4.8% CP between green oats leaf and predicted dietary CP on 03/08/11 is considerable. It is possible that the faecal NIRS calibration sets for predicting dietary CP are unreliable at these low CP levels of oats forage due to the poor representation of such C_3 forage diets in the calibration data sets. It is also possible that some C_3 species were present in the perennial grass area, to which the cattle also had access, and these may have been contributing to a higher dietary CP than that measured in green oats leaf.

The grazing period for this crop (97 days) was greater than that assumed in the constructed scenario for the Central Queensland Open Downs region (Table 29; 76 days). In addition, the average stocking rate on this crop (4.6 AE/ha; forage area only) was twice that assumed in the constructed scenario: 2.2 AE/ha. However, cattle at this site were given access to a large additional perennial grass area (87% of the total grazing area) which resulted in a stocking rate over the entire grazing area of only 0.6 AE/ha.

The initial group of 89, 2.5 year-old steers grazing the oats forage would have been close to their mature size and weight upon entry (622 kg; Fig. 8) with a correspondingly lower potential liveweight gain per unit of energy intake compared to a younger animal (CSIRO 2007). The relatively low average daily liveweight gain of these steers over the initial 34-day period of grazing (0.7 kg/head/day) would appear to reflect this (cf. 1.1 kg/head/day assumed for 512 kg steers in the constructed scenario for Central Queensland Open Downs oats; Table 29). The second group of 40, 1.5 year-old steers (462 kg liveweight at entry) performed appreciably better, averaging 1.0 kg/head/day over the final 42 days of the grazing period, despite the oats crop drying off and declining in CP and digestibility content towards the end of the grazing period. The total beef production from this site was high when expressed per forage area only but low when expressed per total grazing area (282 vs. 38 kg/ha/annum, respectively).

Cattle production from this site resulted in a profitable outcome with a gross margin for the total grazing area of $54/ha calculated using owner rates and $38/ha using contract rates. When the gross margin was expressed per hectare of forage area, it was appreciably higher at $403/ha and $285/ha using owner rates or contract rates, respectively. The negative gross margin calculated for the constructed scenario for this region (-$54/ha, contract rates) contrasts with the positive gross margin calculated using contract rates for the current site, despite the beef production for the total grazed area being 3.8 times lower than that assumed for the constructed scenario (38 vs. 143 kg/ha/annum, respectively). Forage costs at this site (expressed per forage area only) were similar to that assumed in the constructed scenario ($193 vs. $200/ha, owner rates) but were relatively high compared to the other oats sites monitored in this project. The average cattle price margin at this site was positive at $0.16/kg liveweight (vs. $0.12 in the constructed scenario). This site demonstrates that there appears to be financial benefit in providing a small area of high quality forage in conjunction with a large area of lower quality perennial grass pasture. At this site, providing 13% of the total grazing area as oats forage doubled the gross margin compared to what is expected from perennial grass pasture in this region ($54 vs. $27/ha for gross margins calculated using owner rates). This gross margin of $27/ha for cattle production from perennial grass pasture was that calculated for the Open Downs region in the constructed scenario (Table 29). However, as not all steers grazing this crop were sold at the end of the grazing period (23, 2.5 year-old steers and all 40, 1.5 year-old steers were retained on the property after forage grazing finished) the gross margin calculated here was not actually realised by the producer. It is possible that compensatory gain effects over the following wet season may have eroded any liveweight advantage provided by the oats forage to the retained cattle.

3.1.2 Central Queensland Brigalow, Oats 2011

(S 24.708898, E 149.420161; near Bauhinia)

This site was a ca. 60 ha paddock planted to 47 ha of Dawson forage oats on 22/03/11. The site had originally been cleared of timber in the 1960s, then re-cleared in 1984 and cropped almost continuously with wheat or sorghum until being cropped with forage oats over the last 6 years. A summary of key site details are given in Table 3 and Fig. 9-Fig. 15.

Table 3. Site details. Central Queensland Brigalow, Oats 2011
For definitions of abbreviations, see Glossary of terms and abbreviations

<table>
<tr><th>Factor</th><th colspan="3">Details</th></tr>
<tr><td colspan="4">Soil characterisation</td></tr>
<tr><td>Broad land type</td><td colspan="3">Brigalow (Thornby land system)</td></tr>
<tr><td>Soil type and characteristics</td><td colspan="3">Brown cracking clay (Vertosol)
PAWC: 180 mm
Soil depth: 120 cm</td></tr>
<tr><td rowspan="7">Soil nutrient levels at planting but after fertiliser application</td><td></td><td>0–10 cm</td><td>10–120 cm</td></tr>
<tr><td>Nitrate N (mg/kg)</td><td>23</td><td>7</td></tr>
<tr><td>Nitrate N total (kg/ha)</td><td colspan="2">134</td></tr>
<tr><td>P (mg/kg)</td><td>10</td><td>n/a</td></tr>
<tr><td>Organic C (%)</td><td>0.8</td><td>n/a</td></tr>
<tr><td>Cl (mg/kg)</td><td>18</td><td>280</td></tr>
<tr><td>Plant available water (mm)</td><td colspan="2">175</td></tr>
<tr><td colspan="4">Paddock preparation and forage sowing details</td></tr>
<tr><td>Planting date</td><td colspan="3">22/03/11</td></tr>
<tr><td>Sowing rate</td><td colspan="3">25 kg/ha</td></tr>
<tr><td>Fertiliser</td><td colspan="3">28 kg N/ha</td></tr>
<tr><td>Fallow weed control</td><td colspan="3">Minimal till (cultivation and chemical application)</td></tr>
<tr><td>Total in-crop rainfall</td><td colspan="3">260.5 mm (22/03/11–31/10/11; combination of Bauhinia Downs Store (BOM Station 35007) and on-site weather station data)</td></tr>
<tr><td colspan="4">Forage production</td></tr>
<tr><td>Oats green leaf at start of grazing</td><td colspan="3">77% of biomass, 21.4% CP, 80% DMD</td></tr>
<tr><td>Oats peak biomass</td><td colspan="3">Paddock: 2,278 kg DM/ha, Exclosure: 6,609 kg DM/ha</td></tr>
<tr><td>% oats in the diet</td><td colspan="3">64% (Days 23-138 of grazing period)</td></tr>
<tr><td>Average diet quality</td><td colspan="3">66% DMD (Days 23-138 of grazing period)</td></tr>
<tr><td>Average perennial grass presentation yield</td><td colspan="3">ca. 10,000 kg DM/ha over the grazing period; dry season, mature pasture with some green leaf at the commencement of grazing. Major species: buffel 85%, Indian bluegrass 10%, other perennial grasses 5% (sabi, purple pigeon, green panic).</td></tr>
</table>

Factor	**Details**	
Grazing management and animal production		
Comments	Cattle entered the forage in 2 different groups during the period and were removed in 3 different groups as they reached the target condition and weight.	
Cattle type monitored for weight gain	Steers; ca. 2.5 years old at entry; ca. 50% *B. indicus* content	
Animal health treatments	None	
Feeding period	26/05/11–31/10/11 (158 days)	
Average grazing days over which LW was measured *(range)*	82 *(25–158)*	
Proportion of the total grazing area as oats forage	78%	
Average SR (oats area only)	1.9 AE/ha	
Average SR (total grazing area)	1.5 AE/ha	
Number of cattle in weight gain dataset	116	
Average entry LW (± SE)	566 (± 0.4) kg	
Average exit LW (± SE)	605 (± 0.3) kg	
Average LWG (± SE)	0.47 (± 0.002) kg/head/day	
Total LWG (forage area only)	113 kg/ha/annum	
Total LWG (total grazing area)	89 kg/ha/annum	
Number of cattle in carcase dataset	114	
Average carcase weight (± SE)	327 (± 0.2) kg	
Average carcase dentition (± SE)	4.1 (± 0.01)	
Average carcase fat depth (± SE)	19.6 (± 0.06) mm	
Economic performance		
	Forage area only ($/ha/annum)	**Total grazing area ($/ha/annum)**
Gross margin - owner rates	**93**	**73**
Forage costs	164	128
Gross margin - contract rates	**16**	**12**
Forage costs	241	188
CONSTRUCTED SCENARIO (10% total area as perennial grass)		
Gross margin - owner rates	**137**	**123**
Forage costs	144	129
Gross margin - contract rates	**58**	**52**
Forage costs	223	200

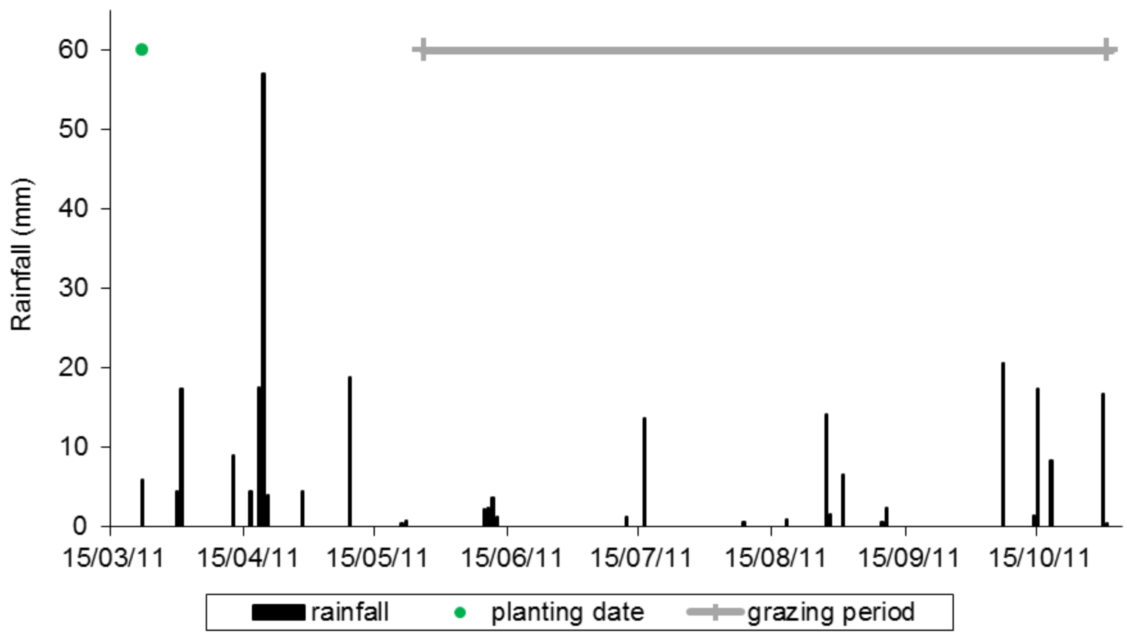

Fig. 9. Daily rainfall (mm) over the in-crop period (22/03/11–31/10/11) and until the final forage sampling (03/11/11). Measured at Bauhinia Downs Store (BOM Station 35007; 22/03/11–18/05/11) and on-site weather station (19/05/11–03/11/11). Planting date and grazing period shown.

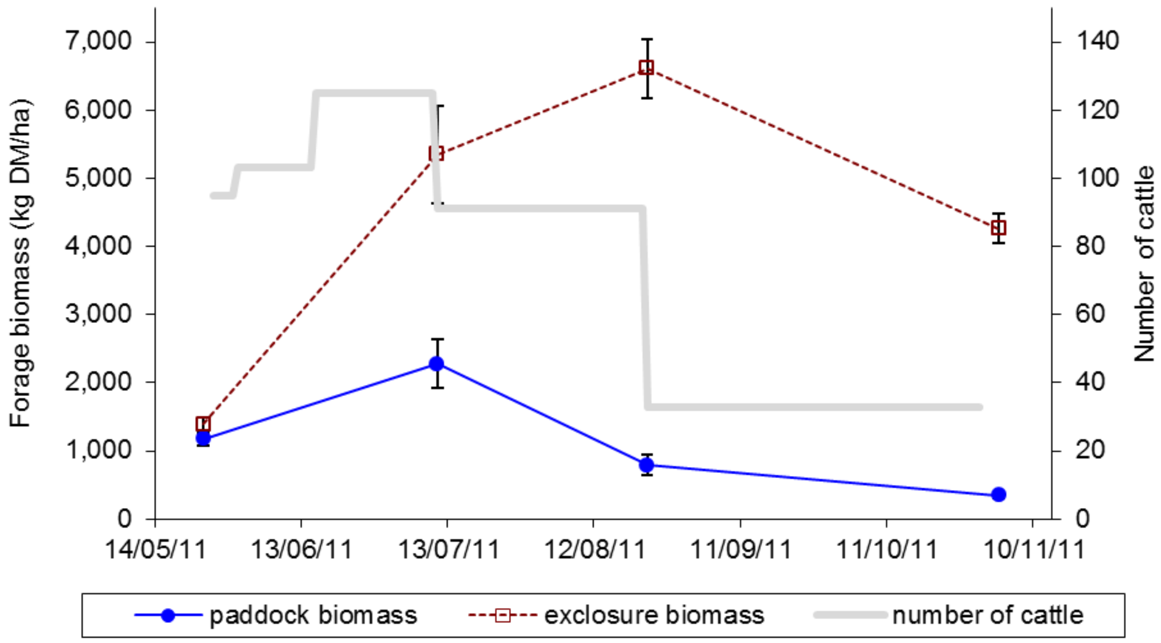

Fig. 10. Oats biomass (kg DM/ha; mean ± SE) in the paddock and exclosure, and cattle numbers during the grazing period (26/05/11–31/10/11).

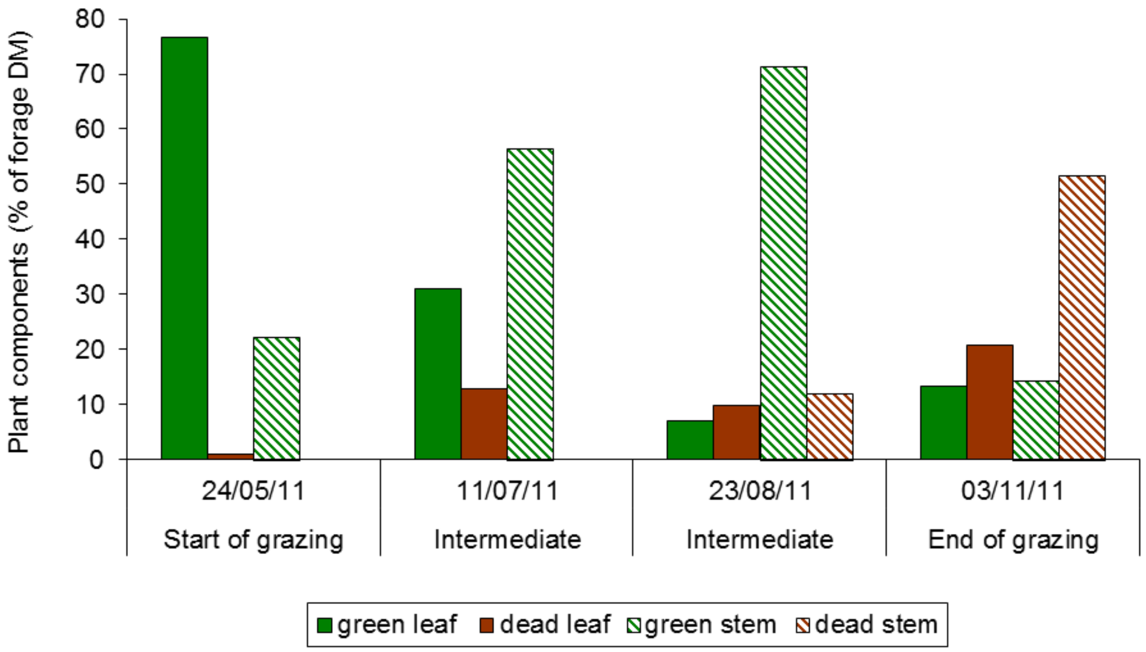

Fig. 11. Plant component composition (% of total forage DM) in the paddock during the grazing period (26/05/11–31/10/11).

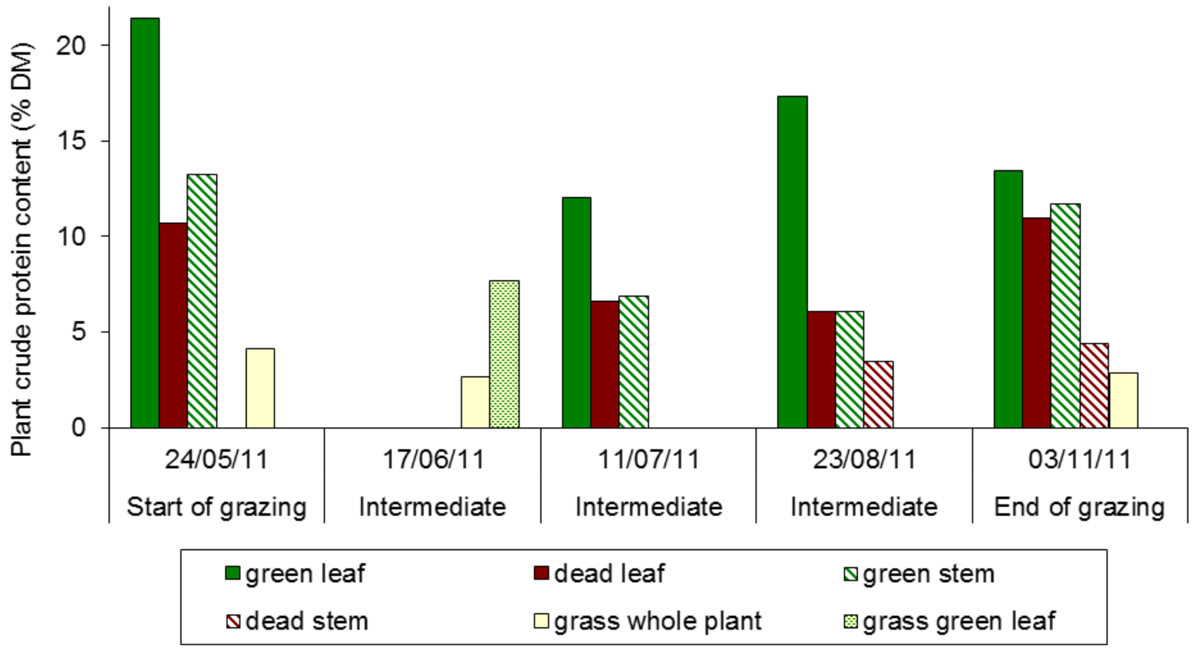

Fig. 12. Crude protein content (% DM) of forage oats plant components in the paddock, and of the perennial grass whole plant and green leaf in the paddock, over the grazing period (26/05/11–31/10/11).

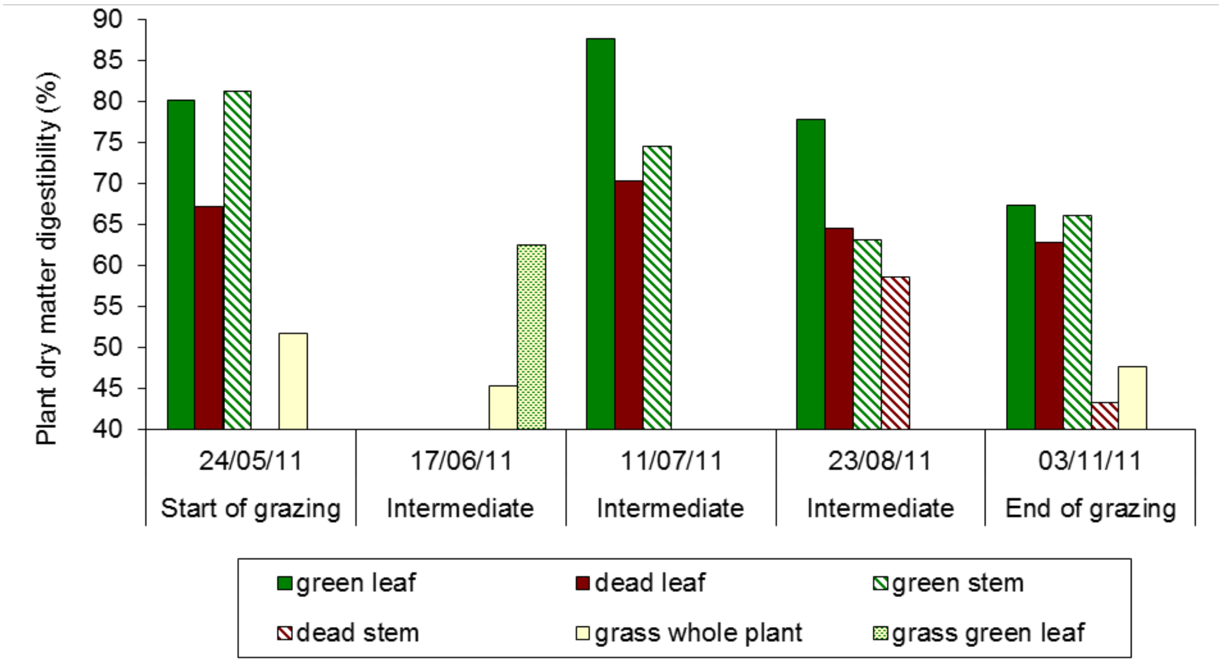

Fig. 13. Dry matter digestibility (%) of forage oats plant components in the paddock and of the perennial grass whole plant available in the paddock over the grazing period (26/05/11-31/10/11).

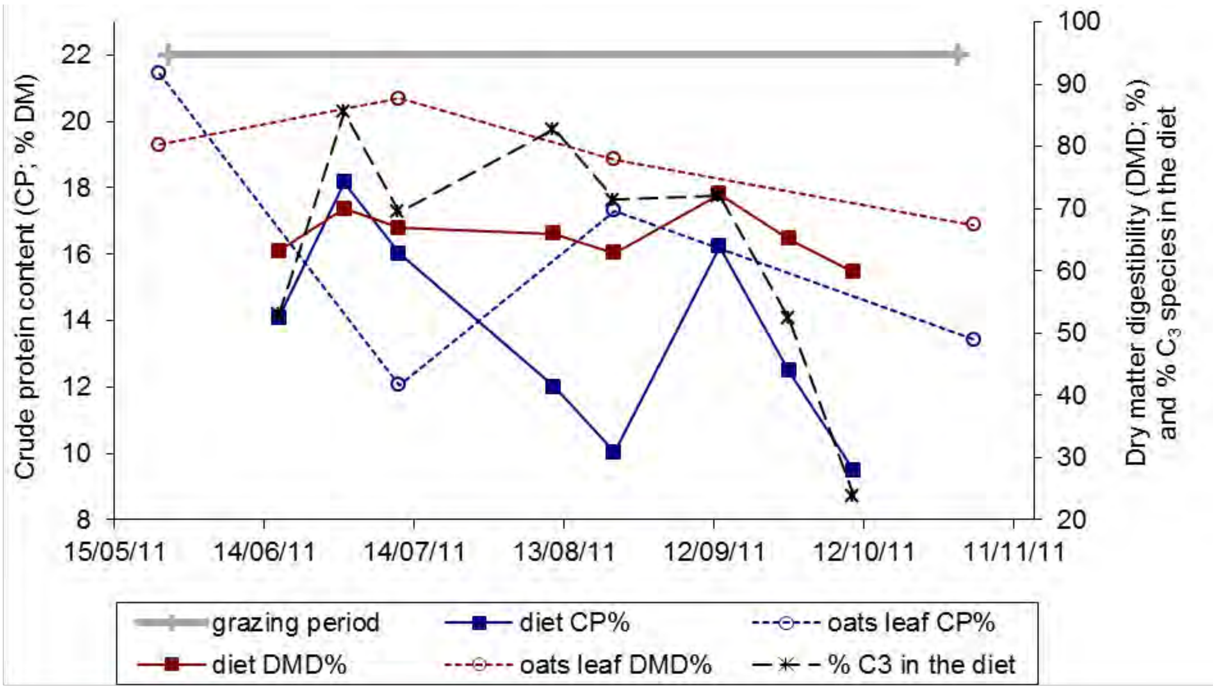

Fig. 14. Diet crude protein (CP) content (% DM) and dry matter digestibility (DMD; %) for grazing cattle predicted from faecal NIRS; measured CP and DMD content of oats green leaf in the paddock; and the % of the diet as C_3 forage, predicted from $\delta^{13}C$ content in the faeces. Grazing period shown.

Fig. 15. Cattle grazing oats paddock, 17/06/11; 22 days after the start of grazing.

The soil characteristics at this site were typical of the target region (Table 3). Soil nutrient analyses prior to planting, but after fertiliser application, indicated that the paddock contained moderate levels of the major nutrients, reflecting inherent nutrient levels, the long cropping history and previous and current fertiliser applications. Organic C and P levels were marginal to low, in line with the long history of continuous cropping at this site. Subsoil Cl levels were typical of the soil type and are at levels that would not significantly affect plant growth. The oats crop was planted using a combination of cultivation and chemical application (minimal till) and N fertiliser was applied at a rate of 28 kg N/ha. Total in-crop rainfall was 260.5 mm. Of this total, 144.3 mm was received between planting and start of grazing and 116.2 mm was received during the 158-day grazing period (Fig. 9).

While the oats biomass in the exclosure was high, peaking at 6,609 kg DM/ha in late August, the biomass in the paddock was kept low by heavy grazing pressure, peaking at only 2,278 kg DM/ha in mid-July (Fig. 10 and Fig. 15). Grazing commenced at only 1,177 kg DM/ha when the crop was still developing, resulting in the stocking rate being higher than the capacity of the forage to sustain, as evident by the need to reduce cattle numbers twice during the grazing period (Fig. 10). The observed decrease in biomass in the exclosure over the final months of grazing (23/08/11-03/11/11) can be explained by the likely detachment and loss of plant parts and mature grain as the plants senesced. Such losses could have been the result of rain, wind, or animals consuming and damaging the grain heads, or from loss of senesced plant parts during collection. Green leaf as a proportion of total plant material dropped from 77% prior to first grazing to 31% after 46 days of grazing and 7% after 89 days of grazing (Fig. 11). By the end of the grazing period (158 days) dead stem formed the greatest proportion of plant material at 52%.

Plant chemical analysis (Fig. 12 and Fig. 13) demonstrates the generally higher CP and DMD of the green oats leaf material compared to that of stem in this crop, the exception being the start and end of grazing DMD values which were similar for green leaf and stem components. The quality of available oats forage had declined considerably by the end of the grazing period, when dead stem formed the major portion of the biomass and contained only 4.4% CP and was 48% DMD. The declining forage quality over the grazing period is reflected in the generally declining trend of predicted diet CP and DMD over time (Fig. 14).

Faecal NIRS predictions of the DMD and CP content of the diet selected by the grazing steers indicate generally lower dietary DMD and CP content than that of green oats leaf, confirming that the cattle were likely to be selecting a significant proportion of stem and dead plant material in their diet (Fig. 14). In addition, $\delta^{13}C$ analysis of faecal samples showed that cattle were also consuming a proportion of perennial grass pasture as part of their diet (Fig. 14) which was considerably lower in CP and DMD content than oats forage (Fig. 12 and Fig. 13). Although C_3 species, assumed to be primarily forage oats, generally formed the major part of the diet during the grazing period (average 64%), this had dropped to around 24% of the diet by the end of the grazing period which is consistent with the low levels of total oats biomass and proportion of green oats leaf available at this time.

Although the average stocking rate on this crop was similar to that assumed in the constructed scenario for the Central Queensland Brigalow region (1.9 vs. 2.0 AE/ha, respectively, for the forage area only; Table 30) the grazing period was considerably greater: 158 vs. 83 days, respectively. Cattle at this site were given access to a greater area of perennial grass pasture than that assumed in the constructed scenario: 22 vs. 10%.

The daily liveweight gain of cattle measured at this co-operator site was less than half that assumed in the constructed scenario (0.47 vs. 1.1 kg/head/day). The liveweight gain expressed per hectare of forage area only or total grazing area was also considered to be low at 113 kg/ha/annum or 89 kg/ha/annum, respectively. It is likely that early and heavy grazing reduced plant growth and the quantity and quality of plant material available for consumption by the grazing animals. Feeding standards indicate that as herbage biomass falls below about 3,000 kg DM/ha, it becomes progressively more difficult for grazing cattle to satisfy their potential intake (CSIRO 2007). The oats biomass in the paddock was well below this level for the entire grazing period. Another potential contributor to the lower than expected steer growth rates was that the steers were apparently close to their mature weight and size upon entry to the oats: average of 566 kg liveweight upon entry and 605 kg at exit (cf. 505 kg and 596 kg, respectively in the constructed scenario for this region) with a corresponding decrease in the liveweight gain per unit of energy intake (CSIRO 2007).

The forage crop produced a profitable outcome with a gross margin for the total grazing area of \$73/ha calculated using owner rates and \$12/ha using contract rates. However, these gross margins are amongst the lowest measured for oats sites in this project, with the gross margin expressed per total grazing area and using contract rates being the lowest of all eight oats sites. Furthermore, the gross margin expressed using owner rates and over the total grazing area was 1.7 times less than the corresponding gross margin calculated for the constructed scenario of growing oats in Central Queensland Brigalow region (\$123/ha). Forage costs, calculated using owner rates, were higher than planting costs assumed for the oats constructed scenario for this region: \$164 vs. 144/ha, for the forage area only. In addition, the planting costs were towards the higher end of the range of all eight oats sites monitored. The cattle price margin was positive at \$0.06/kg liveweight. Approximately 7% of steers grazing this crop were not sold at the end of the grazing period but retained on property. Thus the gross margin calculated here was not actually realised by the producer. It is possible that compensatory gain effects over the following wet season may have eroded any liveweight advantage provided by the oats forage to the retained cattle.

3.1.3 South Queensland Brigalow, Oats 2011

(S 25.55286, E 149.36633; between Taroom and Roma)

This site was a 125 ha paddock planted to 85 ha of Moola forage oats on 10/04/11. The site had been farmed for forage production for ca. 30 years. This site was located in the same paddock as the South Queensland Brigalow Oats 2012 and 2013 sites. A summary of key site details are given in Table 4 and Fig. 16-Fig. 22.

Table 4. Site details. South Queensland Brigalow, Oats 2011
For definitions of abbreviations, see Glossary of terms and abbreviations

Factor	Details		
Soil characterisation			
Broad land type	Brigalow (Eurombah land system)		
Soil type and characteristics	Brown cracking clay (Vertosol) PAWC: 180 mm Soil depth: 120 cm		
Soil nutrient levels at planting		**0–10 cm**	**10–90 cm**
	Nitrate N (mg/kg)	7	3
	Nitrate N total (kg/ha)	42	
	P (mg/kg)	16	n/a
	Organic C (%)	1.1	n/a
	Cl (mg/kg)	18	140
	Plant available water (mm)	150	
Paddock preparation and forage sowing details			
Planting date	10/04/11		
Sowing rate	33.6 kg/ha		
Fertiliser	None		
Fallow weed control	Full cultivation		
Total in-crop rainfall	325.3 mm (10/04/11–26/10/11; property records, 1.5 km from site)		
Forage production			
Oats green leaf at start of grazing	35% of biomass, 4.5% CP, 83% DMD		
Oats peak biomass	Paddock: 4,723 kg DM/ha; Exclosure: 5,704 kg DM/ha		
% oats in the diet	63% (Days 29-86 of grazing period)		
Average diet quality	55% DMD (Days 29-86 of grazing period)		
Average perennial grass presentation yield	ca. 6,000 kg DM/ha average over the grazing period; dry season, mature pasture with some green leaf at the commencement of grazing. Major species: buffel grass (>95%).		

Factor	Details
Grazing management and animal production	
Comments	Cattle entered the forage in 2 different groups during the period and were removed in 2 different groups according to weight strata. Only a subset of the total number grazing the paddock was monitored for weight gain: 112 out of 123 were monitored over the first 63 days after which 87 cattle were removed and 36 were monitored for a further 28 days. In addition, a further 149 head of cattle grazed the paddock for the final 28 days with 124 head of these monitored for weight gain. The 1st group of cattle were grazing grass pasture prior to entry to the forage paddock, while the 2nd group grazed another oats paddock prior to entry.
Cattle type monitored for weight gain	Steers; ca. 18–24 months old at entry; ca. 25% *B. indicus* content
Animal health treatments	At initial entry to forage the cattle were vaccinated against clostridial diseases (5-in-1), received a pour-on for fly and lice control (Elanco® Demize pour-on for cattle) and were implanted with a 100-day HGP.
Feeding period	27/07/11–26/10/11 (91 days)
Proportion of the total grazing area as oats forage	68%
Average SR (forage area only)	1.9 AE/ha
Average SR (total grazing area)	1.3 AE/ha
First 63 days of grazing (27/07/11-28/09/11)	
Number of cattle in weight gain dataset	112
Average entry LW (± SE)	523 (± 7.2) kg
Average exit LW (± SE)	573 (± 7.0) kg
Average LWG (± SE)	0.79 (± 0.031) kg/head/day
Total 91 days of grazing (27/07/11-26/10/11)	
Number of cattle in weight gain dataset	36 (these were also part of the data set for the first 63 days)
Average entry LW (± SE)	427 (± 5.7) kg
Average exit LW (± SE)	502 (± 5.3) kg
Average LWG (± SE)	0.83 (± 0.039) kg
Additional 124 steers added for final 28 days of grazing (28/09/11-26/10/11)	
Number of cattle in weight gain dataset	124
Average entry LW (± SE)	520 (± 3.7) kg
Average exit LW (± SE)	527 (± 3.7)kg
Average LWG (± SE)	0.24 (± 0.053) kg/head/day
Average for the entire grazing period	
Total LWG (forage area only)	92 kg/ha/annum
Total LWG (total grazing area)	63 kg/ha/annum

Factor	Details	
Economic performance		
	Forage area only ($/ha/annum)	**Total grazing area ($/ha/annum)**
Gross margin - owner rates	**290**	**197**
Forage costs	93	63
Gross margin - contract rates	**250**	**170**
Forage costs	133	90
CONSTRUCTED SCENARIO (10% total area as perennial grass)		
Gross margin - owner rates	**95**	**85**
Forage costs	178	160
Gross margin - contract rates	**-4**	**-3**
Forage costs	276	249

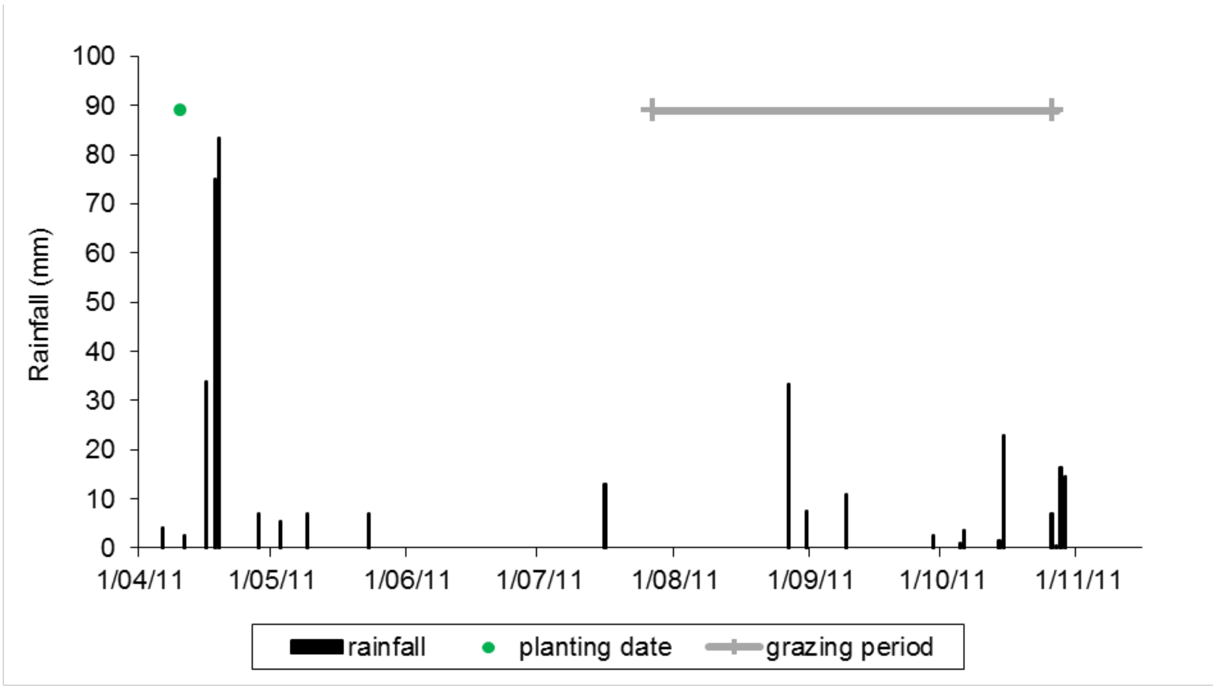

Fig. 16. Daily rainfall (mm) over the in-crop period (10/04/11–26/10/11). Measured on property, 1.5 km from the trial paddock. Planting date and grazing period shown.

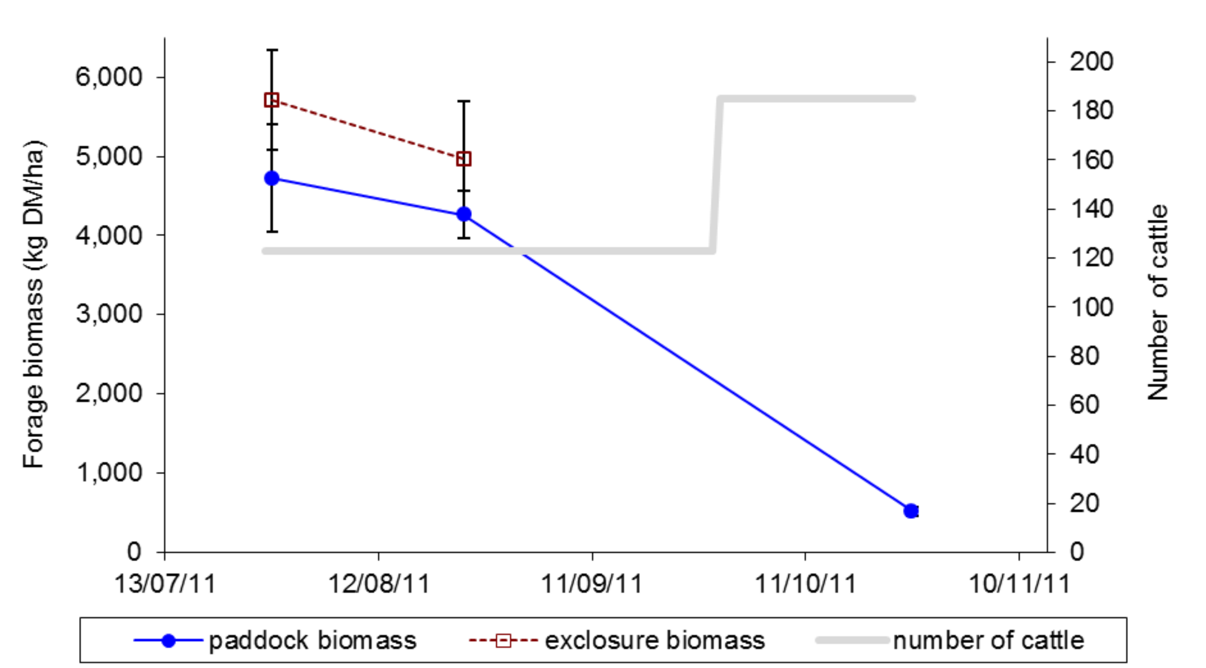

Fig. 17. Oats biomass (kg DM/ha; mean ± SE) in the paddock and exclosure, and cattle numbers during the grazing period (27/07/11–26/10/11). Data for the exclosure site at the end of the grazing period was not available.

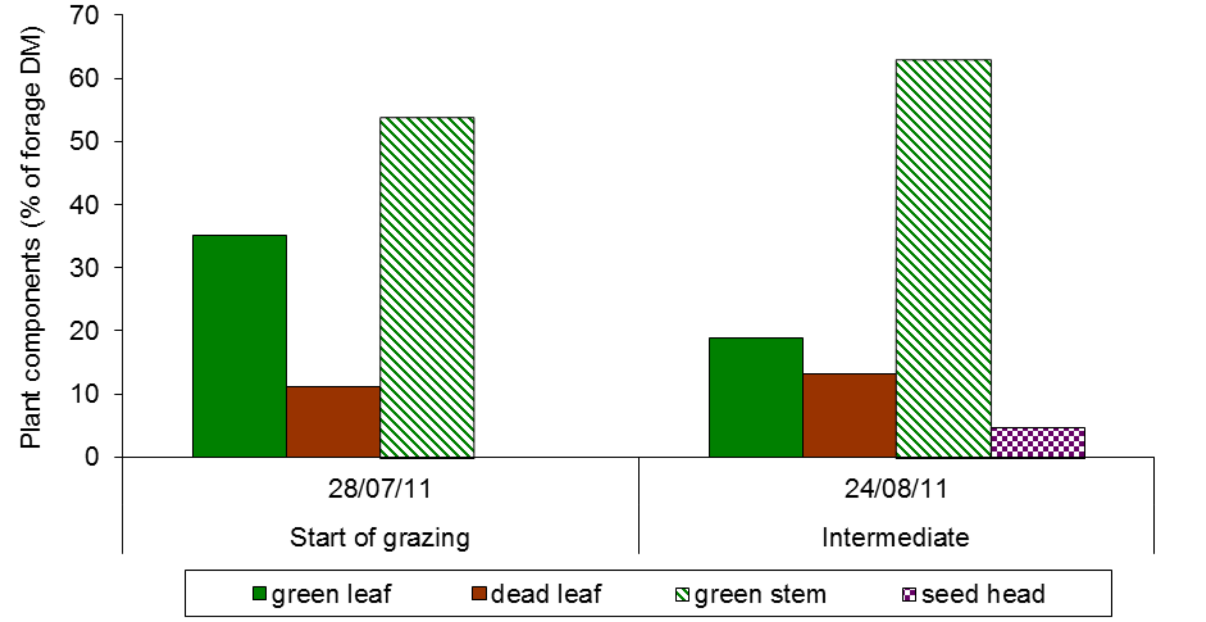

Fig. 18. Plant component composition (% of total forage DM) in the paddock during the grazing period (27/07/11–26/10/11). End of grazing data was not available.

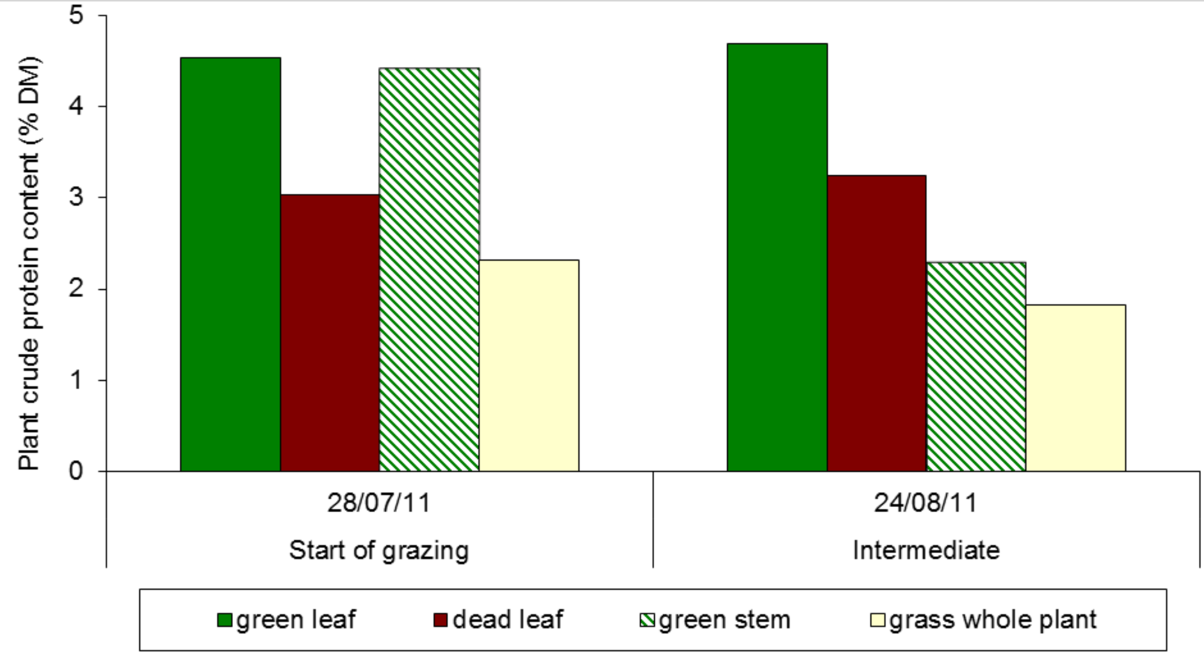

Fig. 19. Crude protein content (% DM) of forage oats plant components in the paddock, and of the perennial grass whole plant in the paddock, over the grazing period (27/07/11–26/10/11). End of grazing data was not available.

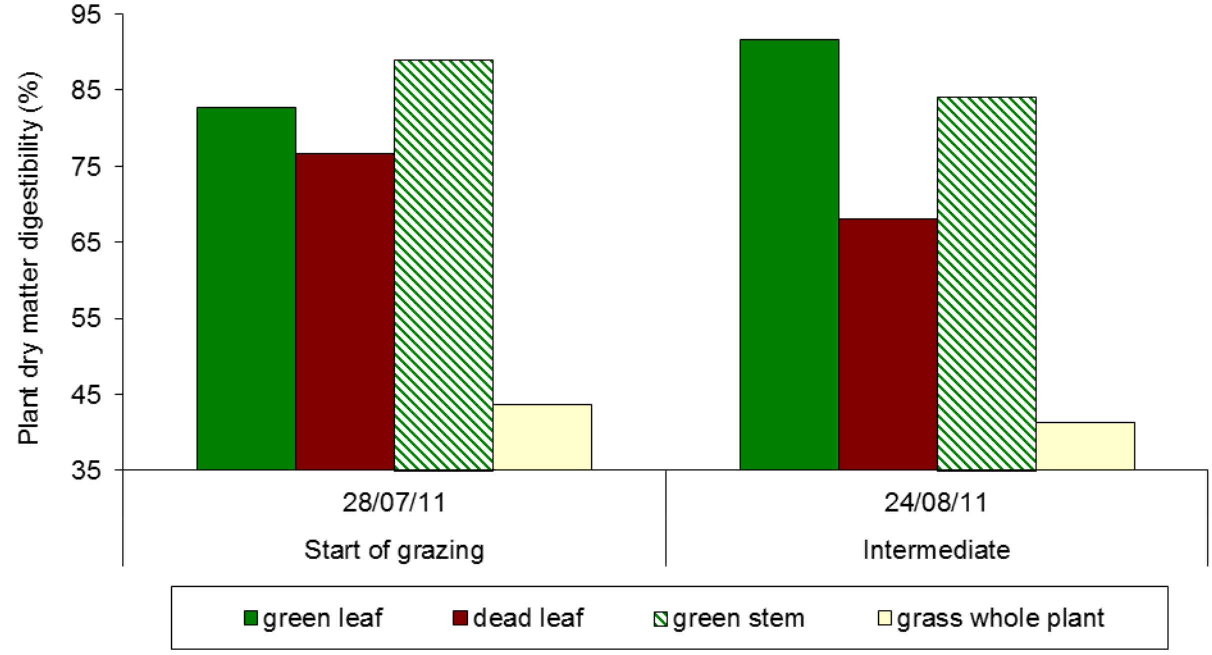

Fig. 20. Dry matter digestibility (%) of forage oats plant components in the paddock and of the perennial grass whole plant available in the paddock, over the grazing period**.** End of grazing data was not available.

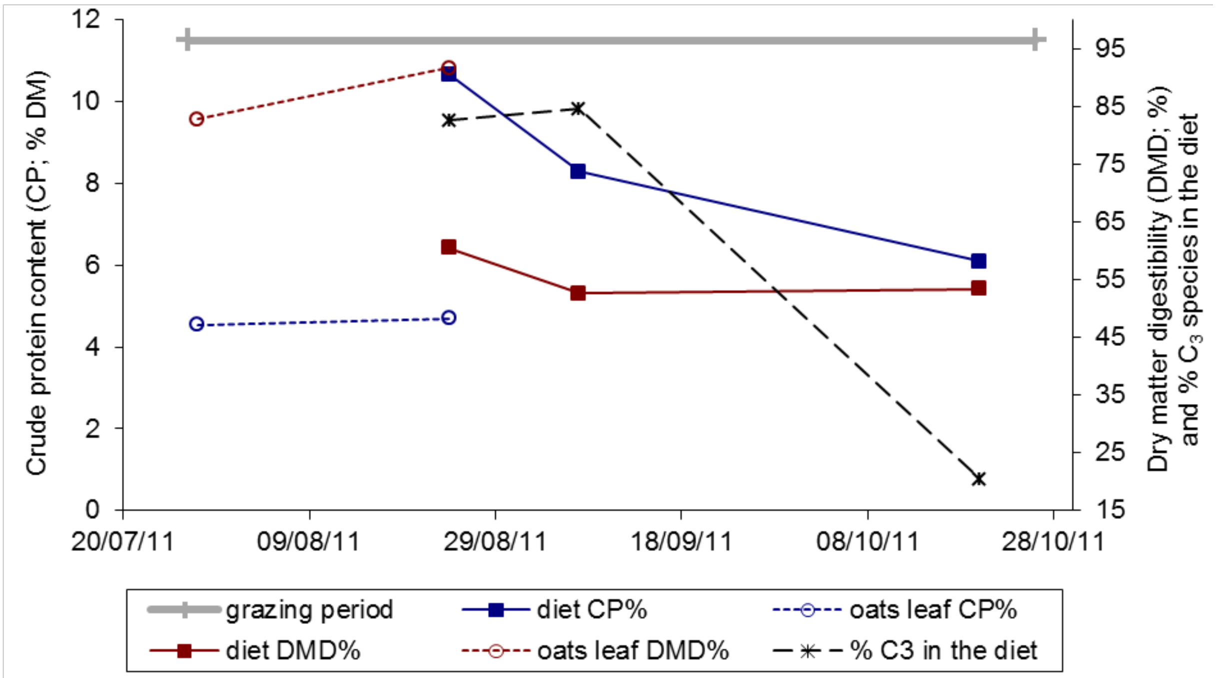

Fig. 21. Diet crude protein (CP) content (% DM) and dry matter digestibility (DMD; %) for grazing cattle predicted from faecal NIRS; measured CP and DMD content of oats green leaf in the paddock; and the % of the diet as C_3 forage, predicted from $\delta^{13}C$ content in the faeces. Grazing period shown.

Fig. 22. Cattle grazing oats paddock, 24/08/11; 28 days after start of grazing.

Soil nutrient analyses prior to planting indicated that the paddock contained low levels of the major nutrients (Table 4), reflecting inherent nutrient levels, the long cropping history and lack of historical fertiliser application. Consistent with past crop management, no N fertiliser was applied to this crop. However, given the high soil-moisture levels and subsequent yellowing of the foliage (Fig. 22), fertiliser may have provided beneficial responses relative to the cost. The organic C level was moderate at 1.1% (0-10 cm) and the P concentration was also moderate at 16 mg/kg (0-10 cm). Chloride concentrations increased with depth of the soil profile to a concentration of 140 mg/kg in the subsoil (10-90 cm depth) but were at levels that would not significantly affect plant growth. The 2011 crop was planted using full cultivation techniques during the fallow period. Total in-crop rainfall was 325.3 mm. Of this total, 234.5 mm was received between planting and the start of grazing and 90.8 mm was received during the 91-day grazing period (Fig. 16).

When grazing commenced the oats crop was fully developed and the biomass in the paddock was relatively high (4,723 kg DM/ha; Fig. 17). The proportions of leaf and stem in the forage reflect this, with a greater proportion of stem than leaf at commencement of grazing (54 vs. 35% DM; Fig. 18). The paddock oats biomass decreased over time with progressive grazing, as expected with a fully grown crop. This is in contrast to the results for the 2011 Central Queensland Brigalow oats site where biomass initially increased during the grazing period as a result of grazing starting at a much earlier stage of development (biomass only 1,177 kg DM/ha). The rate of decrease in biomass in the exclosure over the first 27 days of grazing was similar to that in the paddock and can be explained by a similar rate of detachment of leaves from the fully grown crop within the exclosure as compared to the grazed plant. Compared to the 2011 Central Queensland Brigalow oats site, the detachment of leaf in the exclosure may have been exacerbated due to N deficiency.

Chemical analysis of forage components (Fig. 19 and Fig. 20) indicated that while oats green leaf and stem DMD was high, both the oats forage and perennial grass available in the trial paddock were low in CP during the grazing period. Oats green leaf contained only around 4.5% CP even at the start of grazing. The associated perennial grass was also low in CP, as expected during the dry season (whole plant 2.3% CP at the start of the grazing period). Similar to the Central Queensland Open Downs Oats 2011 site, dietary CP levels predicted from faecal NIRS were considerably higher than that of the oats green leaf (Fig. 21) with a difference of 6% CP between green oats leaf and predicted dietary CP on 24/08/11. It is possible that the faecal NIRS calibration sets for predicting dietary CP are unreliable at these low CP levels of oats forage due to the poor representation of such C_3 forage diets in the calibration data sets. It is also possible that some C_3 species were present in the perennial grass area, to which the cattle also had access, and these may have been contributing to a higher dietary CP than that measured in green oats leaf or perennial grass. Analysis of faecal samples for $\delta^{13}C$ concentration indicated that the steers were consuming a proportion of perennial grass in their diet. Initially oats forage comprised 83% of the diet (Fig. 21) but this dropped to 20% by the end of the grazing period which is consistent with the low levels of total oats biomass and proportion of green oats leaf available at this time.

Compared to the constructed scenario for the South Queensland Brigalow region (Table 31) cattle at this site grazed the forage oats for a similar period (ca. 90 days) and were stocked at a slightly lighter density per hectare of forage area (1.9 vs. 2.5 AE/ha) with access to a greater area of grass pasture (32 vs. 10% of total grazing area). Cattle entered the forage at a heavier liveweight than that in the constructed scenario (523 vs. 497 kg). Whilst the average daily liveweight gain of the initial group of steers (0.79–0.83 kg/head/day) was reasonable, the performance of the additional group of 124 steers added for the final 28 days of grazing was poor (0.26 kg/head/day). The forage and faecal analyses indicate that the quantity of oats biomass and the diet quality was decreasing during this latter stage of the grazing period. However, 28 days is a relatively short time over which to monitor liveweight gain, and the results may have been influenced by a range of factors such as gut fill effects on weight measurements and time taken for cattle to adjust to the new paddock. The total beef production of 63 kg/ha/annum per total grazing area, was relatively low compared to the majority of other oats sites monitored.

Cattle production from oats at this site during 2011 resulted in a profitable outcome with a gross margin for the total grazing area of $197/ha calculated using owner rates and $170 using contract rates. The gross margin calculated for the constructed scenario for this region was negative (-$3/ha, contract rates) which contrasts with the positive gross margin calculated using contract rates for this current site, despite beef production from the total grazed area being 3 times lower than that assumed for the constructed scenario (63 vs. 197 kg/ha/annum, respectively). The relatively low costs of planting forage at this site of $93/ha of forage area only, owner rates (compared to $178/ha for the constructed scenario) are a major contributor to the higher profitability of oats at this site compared with the constructed scenario. The lower costs of planting forage at this site were due to the use of larger machinery and implements with a subsequently lower cost per hectare as well as generally lower input costs, for example, no fertiliser application. The cattle price margin for the owned steers at this site was also favourable at $0.20/kg liveweight. A portion of the steers grazing this crop were not sold at the end of the grazing period and would have grazed perennial grass pastures over the following wet season. Thus the gross margin calculated here was not actually realised by the producer. It is possible that compensatory gain effects over the following wet season may have eroded any liveweight advantage provided by the oats forage to the retained cattle.

3.1.4 Central Queensland Brigalow, Oats 2012

(S 24.3932, E 148.498; near Rolleston)

This site was a ca. 603 ha paddock of which 340 ha was planted to a combination of Aladdin (70%) and Genie (30%) forage oats over the period 15/03/12-05/04/12. Although falling within the Central Queensland Brigalow region, this site is more typical of the Open Downs land type. The site had originally been cleared of timber in 2004 and cropped annually with forage oats since 2004 with this 2012 crop being the 9th oats crop in the paddock. This site was located on the same commercial property as the subsequent Central Queensland Brigalow Oats site in 2013 and the 2011-12 Central Queensland Brigalow Forage sorghum site. A summary of key site details are given in Table 5 and Fig. 23-Fig. 30). As this site was located after sowing, data for soil water and nutrient content at planting was not able to be collected. In May (before start of grazing) part of the forage paddock was flooded for 3 days. The crop at the bottom of the paddock (approximately 10% of the total crop area) was completely inundated and did not recover.

Table 5. Site details. Central Queensland Brigalow, Oats 2012
For definitions of abbreviations, see Glossary of terms and abbreviations

Factor	Details
Soil characterisation	
Broad land type	Open downs and heavy clay alluvial
Soil type and characteristics	Black cracking clay (Vertosol) PAWC: average 180 mm Soil depth: average 90 cm
Paddock preparation and forage sowing details	
Planting date	15/03/12-05/04/12
Sowing rate	25 kg/ha
Fertiliser	None
Fallow weed control	Zero till
Total in-crop rainfall	257.6 mm (15/03/12–03/10/12; combination of Albinia Downs (BOM Station 35209) and on-site weather station data)
Forage production	
Oats green leaf at start of grazing	65% of biomass, 14.9% CP, 77% DMD
Oats peak biomass	Paddock: 4,263 kg DM/ha, Exclosure: 16,456 kg DM/ha
% oats in the diet	100% (Day 42 of grazing period)
Average diet quality	65% DMD (Day 42 of grazing)
Average perennial grass presentation yield	2,904 kg DM/ha measured at the end of the grazing period (02/10/12) with 32% of the total quadrats assessed as having 81–100% green biomass. Major species: Queensland bluegrass 71%, buffel 20% and other species 9%.

Factor	Details
Grazing management and animal production	
Comments	Nine groups of cattle grazed the paddock (873 in total). The majority of the cattle were either steers or spayed heifers and either 2 or 3 years old at entry. Cattle entered the paddock in 1 group and were progressively removed in 3 groups according to weight strata, cattle type and feed availability. Only a proportion of these cattle (28% of total cattle numbers), from 3 of the groups, was monitored for weight gain. Group (mob) weights, only, were available, precluding calculation of SE. All cattle monitored for weight gain had grazed a forage sorghum crop prior to entering the oats paddock. Grain bins were added to the forage paddock for the last 51 days of grazing (from the 13/08/12) containing a mix of sorghum, wheat and feedlot premix and, later, whole cottonseed. Weight data was only available prior to grain bins being added to the paddock.
Cattle type monitored for weight gain	All home-bred cattle, 164 steers ca. 3 years old at entry; 40 steers and 40 spayed heifers, ca. 2 years old at entry, ca. 25-30% *B. indicus* content
Animal health treatments	Coopers® Amitik cattle dip and spray
Feeding period	15/06/12–03/10/12 (110 days)
Proportion of the total grazing area as oats forage	56%
Average SR (oats area only)	1.7 AE/ha
Average SR (total grazing area)	1.0 AE/ha
3-year old steers	
Grazing days over which LW was measured	59 (15/06/12–13/08/12)
Number of cattle in weight gain dataset	164
Average entry LW	518 kg
Average exit LW	610 kg
Average LWG	1.55 kg/head/day
First 30 days of grazing	
Average LWG	1.69 kg/head/day
Next 29 days of grazing	
Average LWG	1.40 kg/head/day
2-year old steers	
Grazing days over which LW was measured	30 (15/06/12–15/07/12)
Number of cattle in weight gain dataset	40
Average entry LW	416 kg
Average exit LW	467 kg
Average LWG	1.69 kg/head/day

Factor	Details	
2-year old spayed heifers		
Grazing days over which LW was measured*)*	30 (15/06/12–15/07/12)	
Number of cattle in weight gain dataset	40	
Average entry LW	361 kg	
Average exit LW	427 kg	
Average LWG	2.19 kg/head/day	
Total LWG (forage area only; includes weight gain from grain feeding for last 51 days of 110-day period)	257 kg/ha/annum Note: this is an estimate only	
Total LWG (total grazing area; includes weight gain from grain feeding for last 51 days of 110-day period)	144 kg/ha/annum Note: this is an estimate only	
Economic performance		
	Forage area only ($/ha/annum)	**Total grazing area ($/ha/annum)**
Gross margin - owner rates	**256**	**144**
Forage costs	102	58
Cost of grain feeding	54	30
Gross margin - contract rates	**222**	**125**
Forage costs	136	77
CONSTRUCTED SCENARIO (10% total area as perennial grass)		
Gross margin - owner rates	**137**	**123**
Forage costs	144	129
Gross margin - contract rates	**58**	**52**
Forage costs	223	200

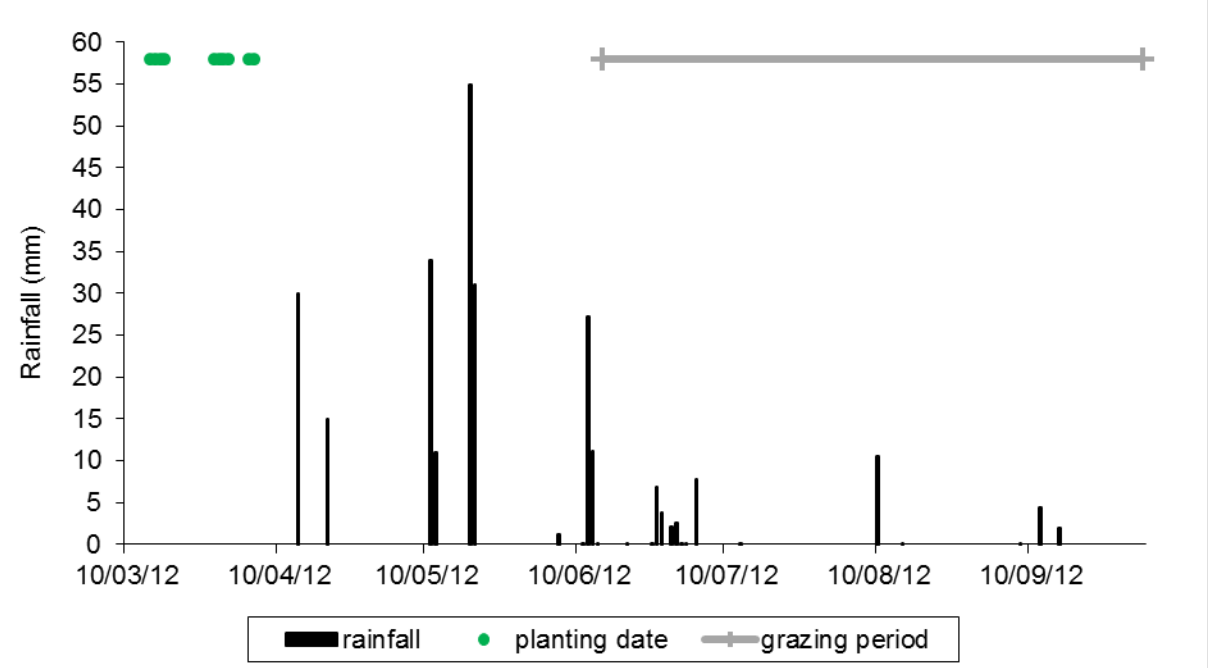

Fig. 23. Daily rainfall (mm) over the in-crop period (15/03/12–03/10/12). Measured at Albinia Downs (BOM Station 35209; 15/03/12–16/06/12, and 02/10/12–03/10/12) and on -site weather station (17/06/12–01/10/12). Planting dates and grazing period shown.

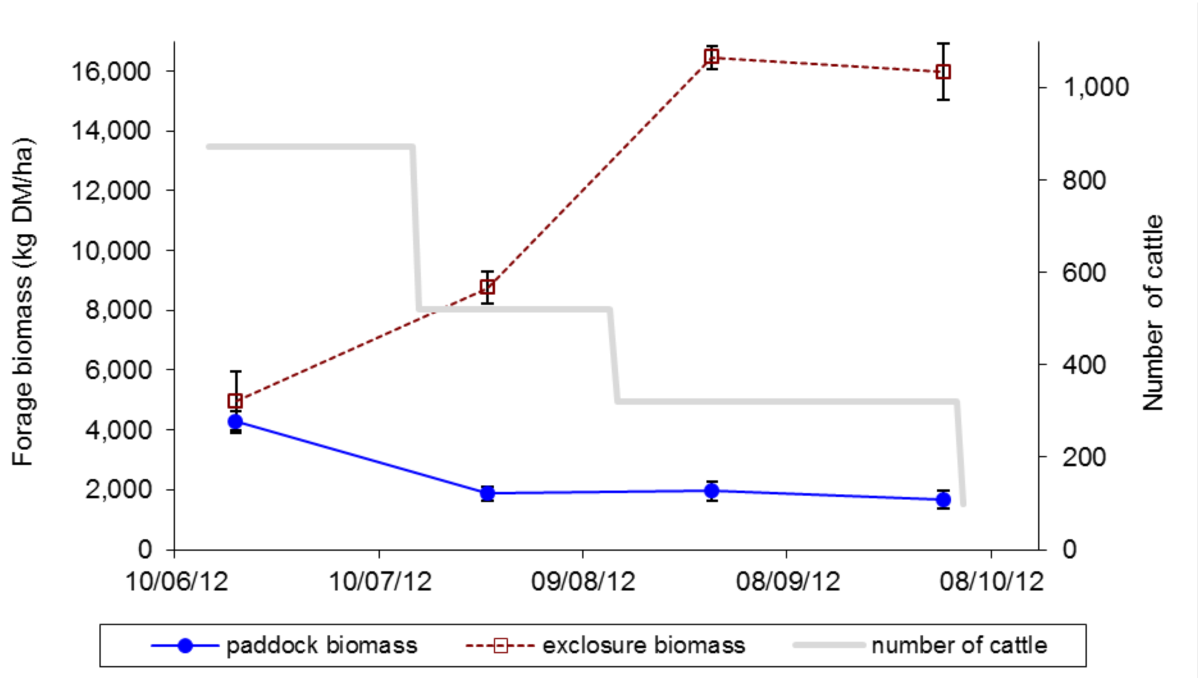

Fig. 24. Oats biomass (kg DM/ha; mean ± SE) in the paddock and exclosure, and cattle numbers during the grazing period (15/06/12–03/10/12).

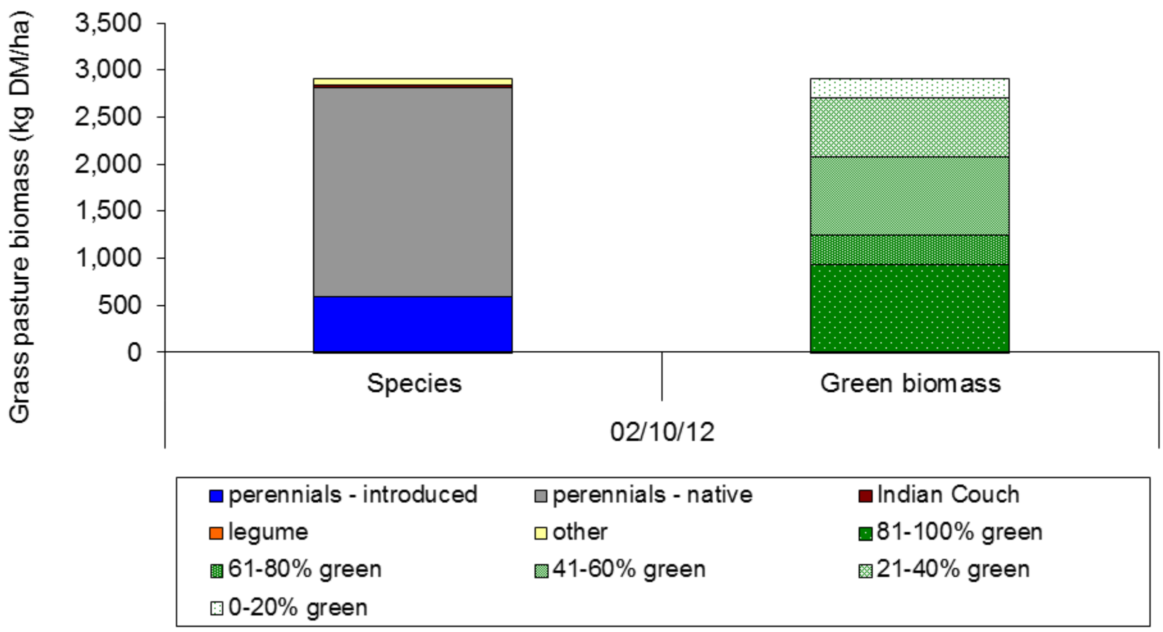

Fig. 25. Perennial pasture species composition (Species) and proportion of green material in the pasture (Green biomass) on 02/12/12 shown as a proportion of total pasture biomass (kg DM/ha).

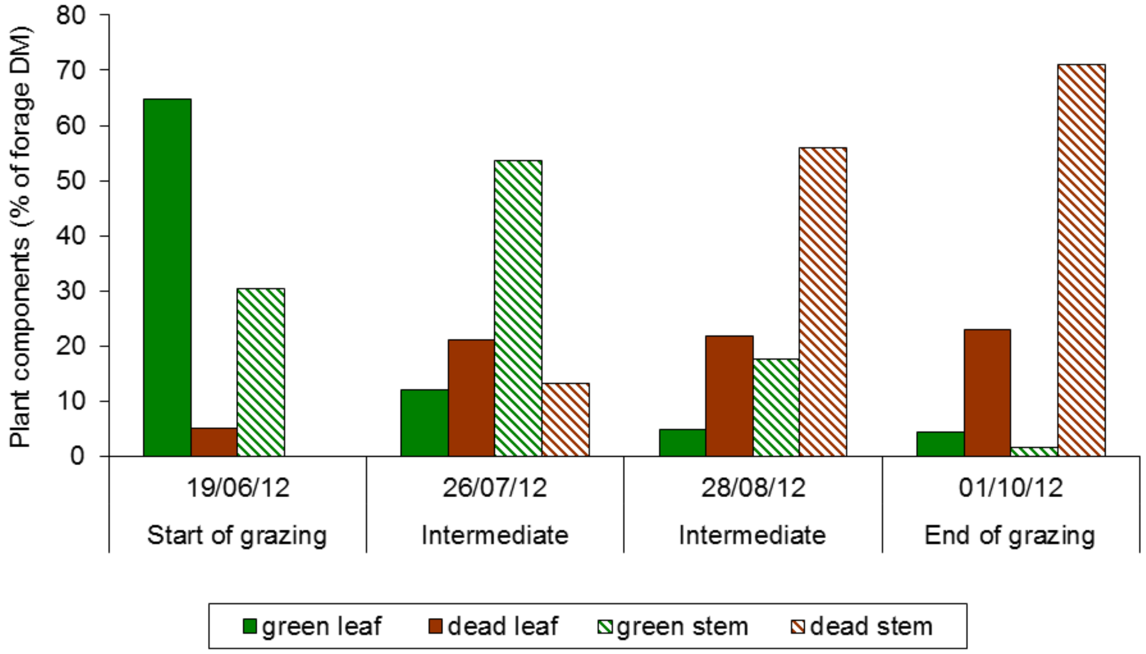

Fig. 26. Plant component composition (% of total forage DM) in the paddock during the grazing period (15/06/2012–03/10/2012).

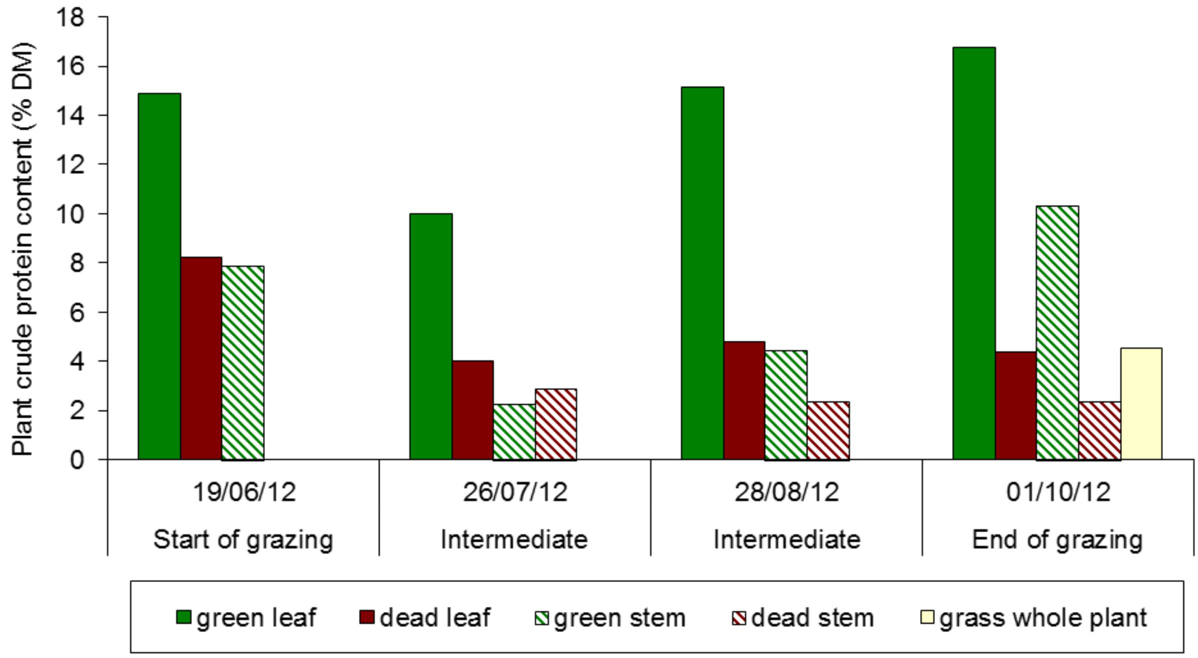

Fig. 27. Crude protein content (% DM) of forage oats plant components in the paddock, and of the perennial grass whole plant in the paddock over the grazing period (15/06/12–03/10/12).

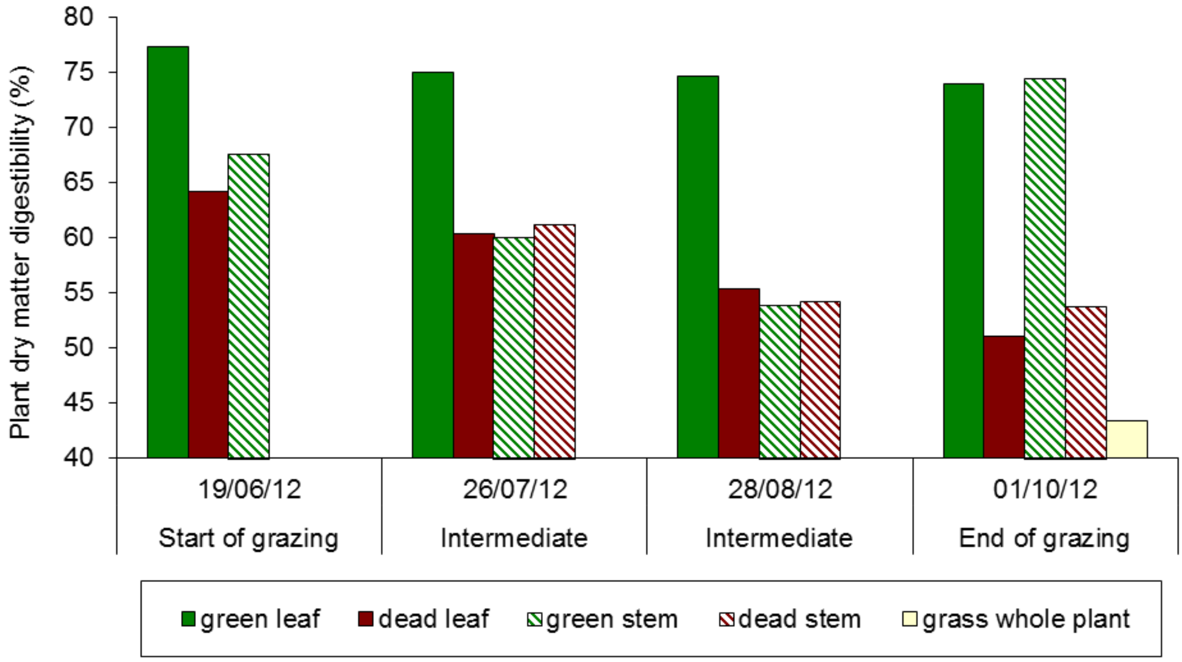

Fig. 28. Dry matter digestibility (%) of forage oats plant components in the paddock and of the perennial grass whole plant available in the paddock over the grazing period (15/06/12–03/10/12).

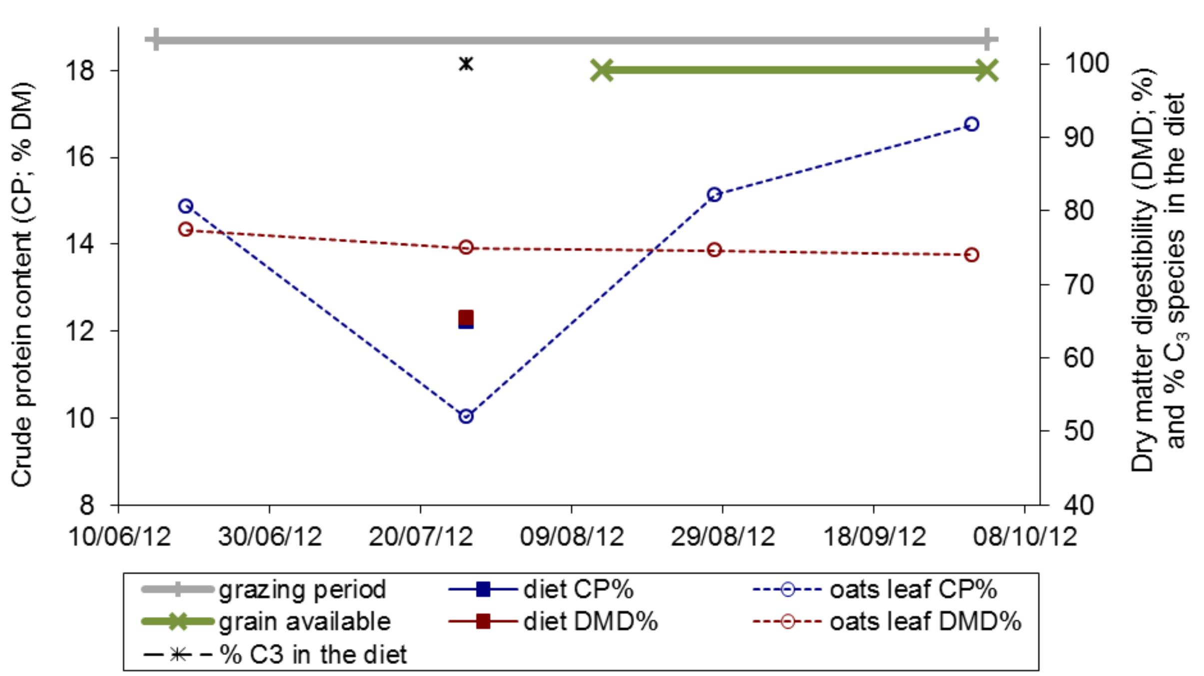

Fig. 29. Diet crude protein (CP) content (% DM) and dry matter digestibility (DMD; %) for grazing cattle predicted from faecal NIRS; measured CP and DMD content of oats green leaf in the paddock; and the % of the diet as C_3 forage, predicted from $\delta^{13}C$ content in the faeces. Grazing period and period of grain feeding shown. Grain bins were added to the paddock from 13/08/12.

Fig. 30. Cattle grazing oats paddock, 26/07/12; 41 days after the start of grazing.

The paddock contained black cracking clay soils with high water holding capacity. As the site was located after sowing no soil nutrient data was available prior to planting. The oats crop was planted using zero tillage methods. Nitrogen fertiliser was not applied. Total in-crop rainfall was 257.6 mm. Of this total 176.0 mm fell between planting and grazing and 81.6 mm fell during the 110-day grazing period (Fig. 23).

When grazing commenced, the oats crop was still developing (mid-tillering), although biomass in the paddock was relatively high (4,263 kg DM/ha; Fig. 24). The proportion of green leaf was approximately double that of green stem at the commencement of grazing (65 vs. 30% DM; Fig. 26, indicating that the oats plants were not fully mature. While biomass peaked in the exclosure at 16,456 kg DM/ha on 28/08/12, biomass in the paddock had fallen to 1,867 kg DM by the 26/07/12, 37 days after the start of grazing, and remained close to this level for the remainder of the grazing period (until 01/10/12). The proportion of green leaf in the paddock had also dropped sharply by the 26/07/12, to 12% (vs. 54% of green stem). The peak biomass in the exclosure was more than double that measured at the other oats sites and, in this regard, was unexpected. However, the exclosure biomass measurements were consistent with corresponding forage height measurements which increased from 55 cm at the start of grazing to 160 cm at peak biomass. The forage sorghum yield reported for this same property for the 2011/12 season was also very high relative to other sites and published reports. Pacific seeds oats variety trials near Roma in south west Queensland and in the Lockyer Valley in south east Queensland show total cumulative dry matter yield to be in the range of 5,700-9,800 kg DM/ha (Stuart 2002). Furthermore, the oats yields in published reports fall within the range 1,100-7,700 kg DM/ha for south west Queensland (Bell *et al.* 2012) and 810-7,380 kg DM/ha for the Darling Downs area of southern Queensland (Chataway *et al.* 2011a). However, Muldoon (1986) reported high yields for irrigated oats grown near Trangie, New South Wales, in the range of 16,000-20,000 kg DM/ha.

Plant chemical analysis (Fig. 27 and Fig. 28) demonstrate the generally higher CP and DMD of green oats leaf material compared to that of stem in this crop, the exception being the end of grazing DMD values which were similar for green leaf and stem components. The quality of available oats forage had declined considerably by the end of the grazing period, when dead stem formed the major portion of the biomass and contained only 2.4% CP and was 54% DMD. Visual assessments of the available perennial grass pasture on 02/10/12 at the end of the grazing period indicated that around 32% of total quadrats assessed contained 81-100% green biomass (Fig. 25). However, the CP and DMD content of the perennial grass whole plant was still relatively low (Fig. 27 and Fig. 28). Analysis of faecal samples for $\delta^{13}C$ concentration on Day 42 of grazing (26/07/12) indicated that the cattle were consuming around 100% of their diet as C_3 forage, assumed to be primarily forage oats, at this time (Fig. 29 and Fig. 30). Crude protein content of green leaf on this date was similar to that predicted in the diet of grazing cattle (10 vs. 12% CP).

In comparison to the constructed scenario for the Central Queensland Brigalow region (Table 30), cattle at this site were stocked at a lower density per hectare of forage area (1.7 vs. 2.0 AE/ha) and had access to a greater additional area of perennial grass pasture (44% vs. 10% of total grazing area) as well as grain for the last 51 days of the grazing period. The cattle monitored for weight gain were only monitored for the first 30-59 days of grazing (compared to 83 days in the constructed scenario), prior to the commencement of grain feeding. The 3 year old steers commenced grazing at a slightly greater starting liveweight to that in the constructed scenario (518 vs. 505 kg) but gained 1.55 kg/head/day over 59 days (compared to 1.1 kg/head/day over 83 days assumed in the constructed scenario). The younger, 2-year old steers and spayed heifers showed even higher growth rates (1.69 and 2.19 kg/head/day, respectively).

The high oats content in the diet, combined with the high availability of green oats leaf at the commencement of grazing and the moderate stocking rates, is consistent with high cattle growth rates. However, the very high growth rates greater than 1.5 kg/day are unexpected. As the cattle monitored for weight gain had previously grazed the forage sorghum paddock monitored for this project (Central Queensland Brigalow, Forage sorghum 2011-12) with low average growth rates of 0.23–0.37 kg/day over 112 days, it is possible that they may have been showing some compensatory growth once introduced to the higher quality forage oats paddock. The second 29 days of grazing for the 3-year old steers also resulted in very high growth rates (1.40 kg/day, compared to 1.69 kg/day for the first 30 days) indicating that gut fill effects on starting liveweight measurements were not likely to be the cause of inflated daily weight gain measurements. The total beef production from this site was the highest of all monitored oats sites when expressed per total grazing area (144 kg/ha/annum) although this did include the benefit from grain feeding for the last 51 days of the grazing period.

Cattle production from oats at this site resulted in a profitable outcome with a gross margin for the total grazing area of \$144/ha calculated using owner rates and \$125/ha using contract rates. This result is consistent with the very high cattle growth rates and total estimated beef production per hectare, relative to other sites. The cost of planting forage at this site, expressed per hectare of forage area only (\$102/ha, owner rates), were also moderate. The average cattle price margin was \$0.10/kg liveweight. A portion of cattle grazing this crop were not sold at the end of the grazing period but were retained on the property. Thus the gross margin calculated here was not actually realised by the producer. It is possible that compensatory gain effects over the following wet season may have eroded any liveweight advantage provided by the oats forage to the retained cattle.

3.1.5 South Queensland Brigalow, Oats 2012

(S 25.55286, E 149.36633; between Taroom and Roma)

The site was a 125 ha paddock planted to 85 ha of Genie forage oats on 17/04/12. The site had been farmed for forage production for ca. 30 years. This site was located in the same paddock as the South Queensland Brigalow Oats 2011 and 2013 sites. A summary of key site details are given in Table 6 and Fig. 31-Fig. 38.

Table 6. Site details. South Queensland Brigalow, Oats 2012
For definitions of abbreviations, see Glossary of terms and abbreviations

Factor	Details		
Soil characterisation			
Broad land type	Brigalow (Eurombah land system)		
Soil type and characteristics	Brown cracking clay (Vertosol) PAWC: 180 mm Soil depth: 120 cm		
Plant available water at planting	73 mm		
Soil nutrient levels at end of grazing		**0–10 cm**	**10–120 cm**
	Cl (mg/kg)	26	300
Paddock preparation and forage sowing details			
Planting date	17/04/12		
Sowing rate	33.6 kg/ha		
Fertiliser	None		
Fallow weed control	Zero till		
Total in-crop rainfall	287.5 mm (17/04/12–19/11/12; property records, 1.5 km from site)		
Forage production			
Forage green leaf at start of grazing	n/a		
Forage peak biomass	Paddock: 4,921 kg DM/ha, Exclosure: >7,182 kg DM/ha		
% oats in the diet	72% (Days 17-139 of grazing period)		
Average diet quality	62% DMD (Days 17-139 of grazing period)		
Average perennial grass presentation yield	7,400 kg DM/ha average over the grazing period. The percentage of the biomass that was green increased over the grazing period. Major species: buffel (99.6% of the biomass) and native legume (0.4%).		

Factor	**Details**	
Grazing management and animal production		
Comments	134 cattle grazed the forage for the first 79 days with 129 of these monitored for weight gain. A second group of 69 cattle grazed the forage for the final 59 days of grazing. Entry weights were not available for the second group. The 1st group of cattle grazed buffel grass pasture prior to forage entry. The 2nd group grazed another oats paddock prior to entering the trial paddock and their entry weight to the trial paddock was estimated from previous weight data to enable total paddock liveweight gain to be estimated for the trial paddock. After exiting the trial paddock, the 1st group of cattle grazed another oats paddock whilst the 2nd group of cattle were sent to slaughter (Dinmore meat processing plant; MSA compliance was attained with 50% of the cattle; ca. 95% were within the 0–2 teeth category at slaughter).	
Cattle type monitored for weight gain	Steers; ca. 18–24 months old at entry; ca. 25% *B. indicus* content	
Animal health treatments	At entry to forage (the cattle were vaccinated against clostridial diseases (5-in-1), received a pour-on for fly and lice control (Elanco® Demize pour-on for cattle) and were implanted with a 100-day HGP.	
Feeding period	04/07/12–19/11/12 (138 days)	
Grazing days over which LW was measured	79 (04/07/12–21/09/12)	
Proportion of the total grazing area as oats forage	68%	
Average SR (oats area only)	1.4 AE/ha	
Average SR (total grazing area)	1.0 AE/ha	
First 79 days of grazing:		
Number of cattle in weight gain dataset	129	
Average entry LW (± SE)	449 (± 2.3) kg	
Average exit LW (± SE)	565 (± 3.3) kg	
Average LWG (± SE)	1.47 (± 0.024)) kg/head/day	
Total LWG (forage area only)	208 kg/ha/annum	
Total LWG (total grazing area)	141 kg/ha/annum	
Economic performance		
	Forage area only ($/ha/annum)	**Total grazing area ($/ha/annum)**
Gross margin - owner rates	**231**	**157**
Forage costs	109	74
Gross margin - contract rates	**201**	**136**
Forage costs	139	95
CONSTRUCTED SCENARIO (10% total area as perennial grass)		
Gross margin - owner rates	**95**	**85**
Forage costs	178	160
Gross margin - contract rates	**-4**	**-3**
Forage costs	276	249

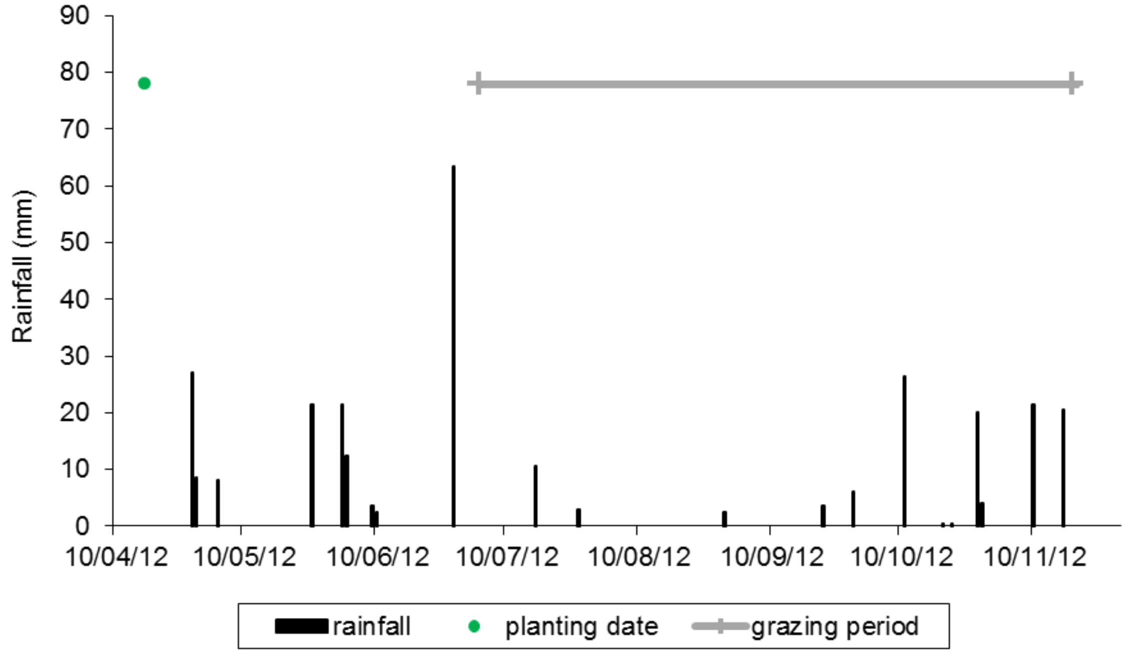

Fig. 31. Daily rainfall (mm) over the in-crop period (17/04/12–19/11/12). Measured on property, 1.5 km from the trial paddock. Planting date and grazing period shown.

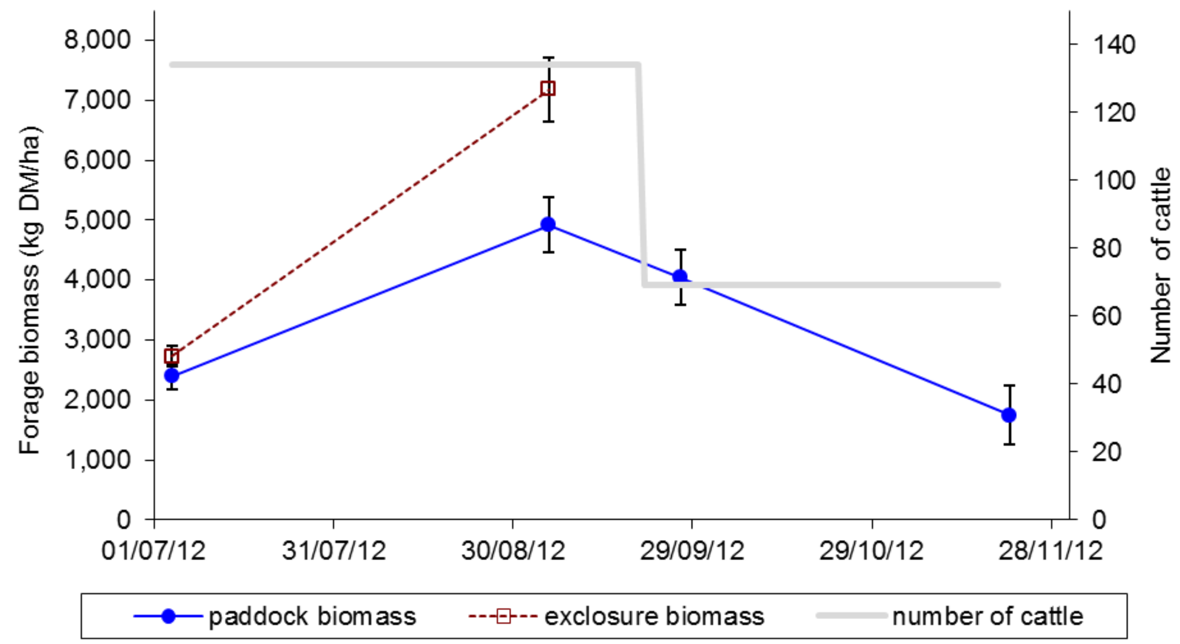

Fig. 32. Oats biomass (kg DM/ha; mean ± SE) in the paddock and exclosure, and cattle numbers during the grazing period (04/07/12–19/11/12). Note: the exclosure was observed to have been lightly grazed when sampled on the 05/09/12. Exclosure samples were not available for the remaining sampling dates due to inadvertent grazing of the exclosure area.

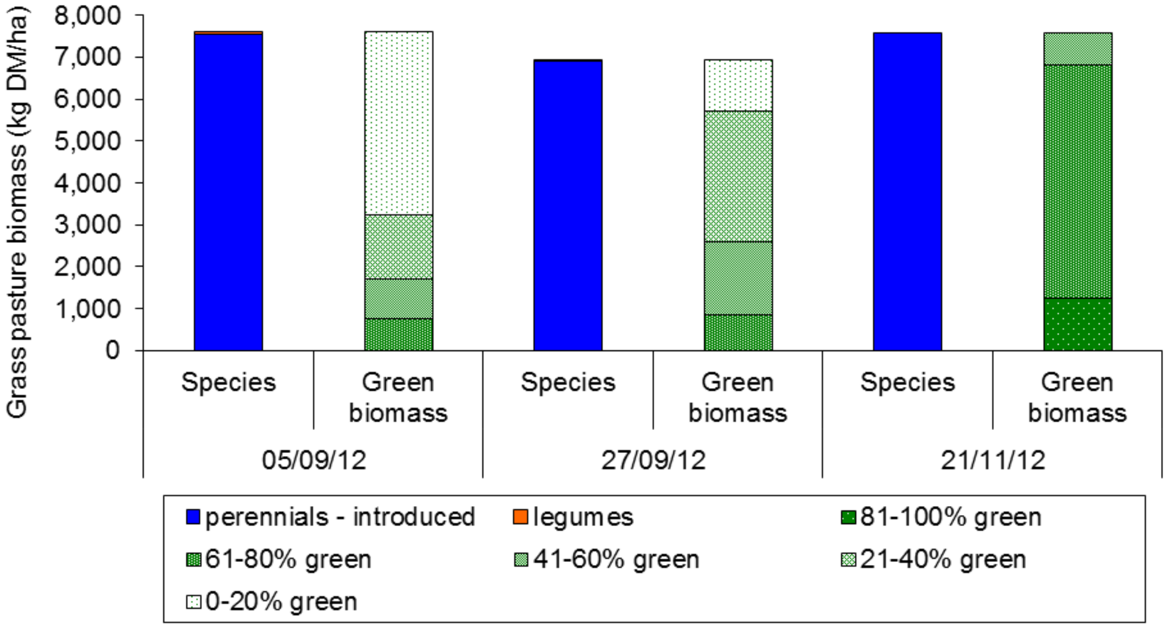

Fig. 33. Perennial pasture species composition (Species) and proportion of green material in the pasture (Green biomass) shown as a proportion of total pasture biomass (kg DM/ha).

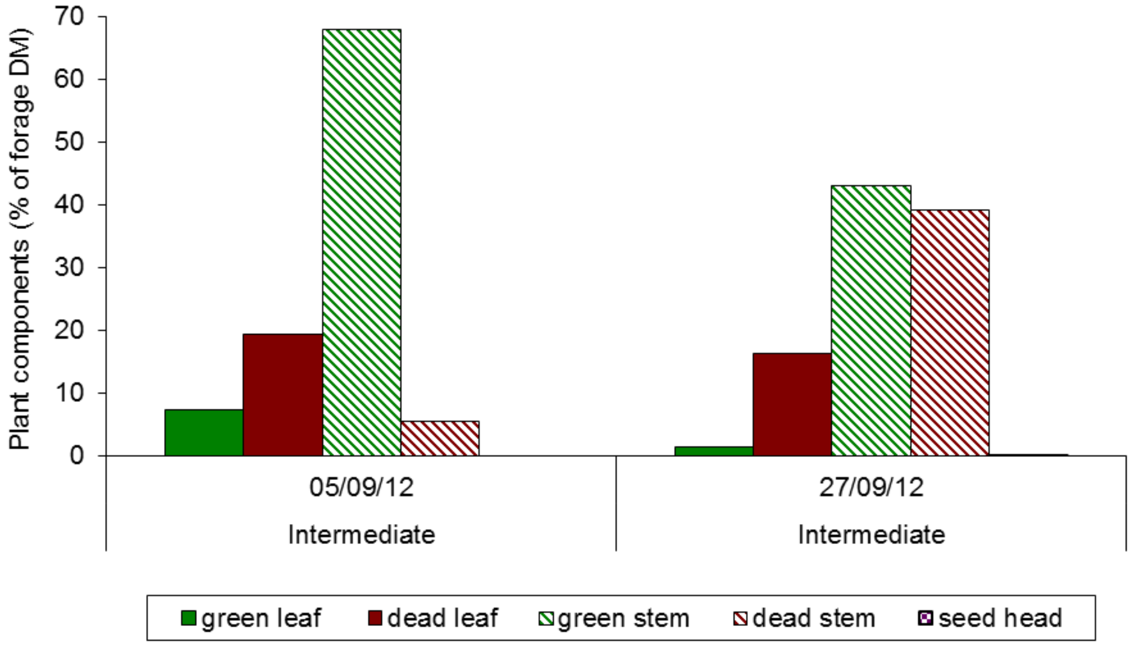

Fig. 34. Plant component composition (% of total forage DM) in the paddock during the grazing period (04/07/12–19/11/12).

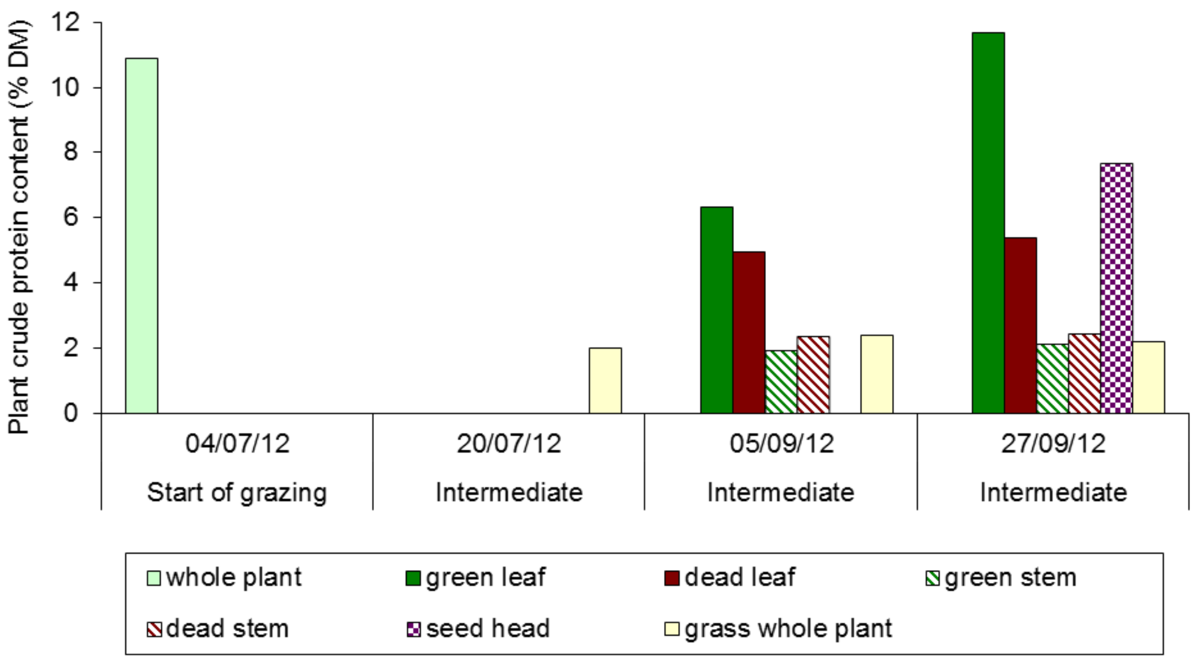

Fig. 35. Crude protein content (% DM) of forage oats whole plant and components in the paddock, and of perennial grass whole plant in the paddock, over the grazing period (04/07/12–19/11/12). End of grazing data was not available.

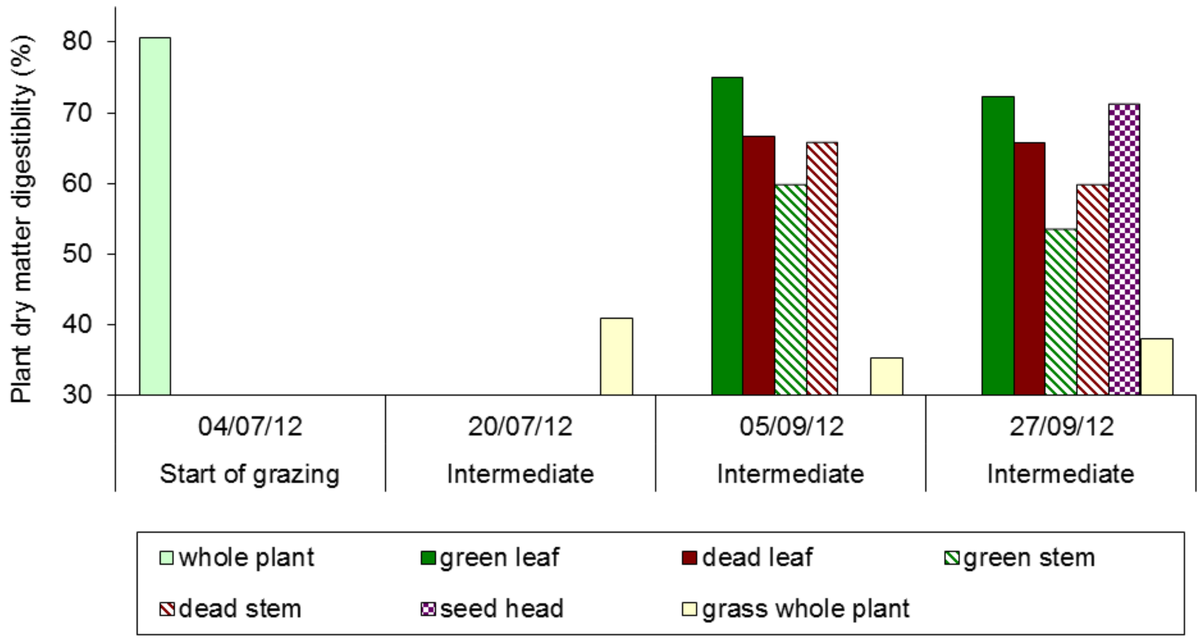

Fig. 36. Dry matter digestibility (%) of forage oats whole plant and components in the paddock, and of perennial grass whole plant in the paddock, over the grazing period (04/07/12–19/11/12). End of grazing data was not available.

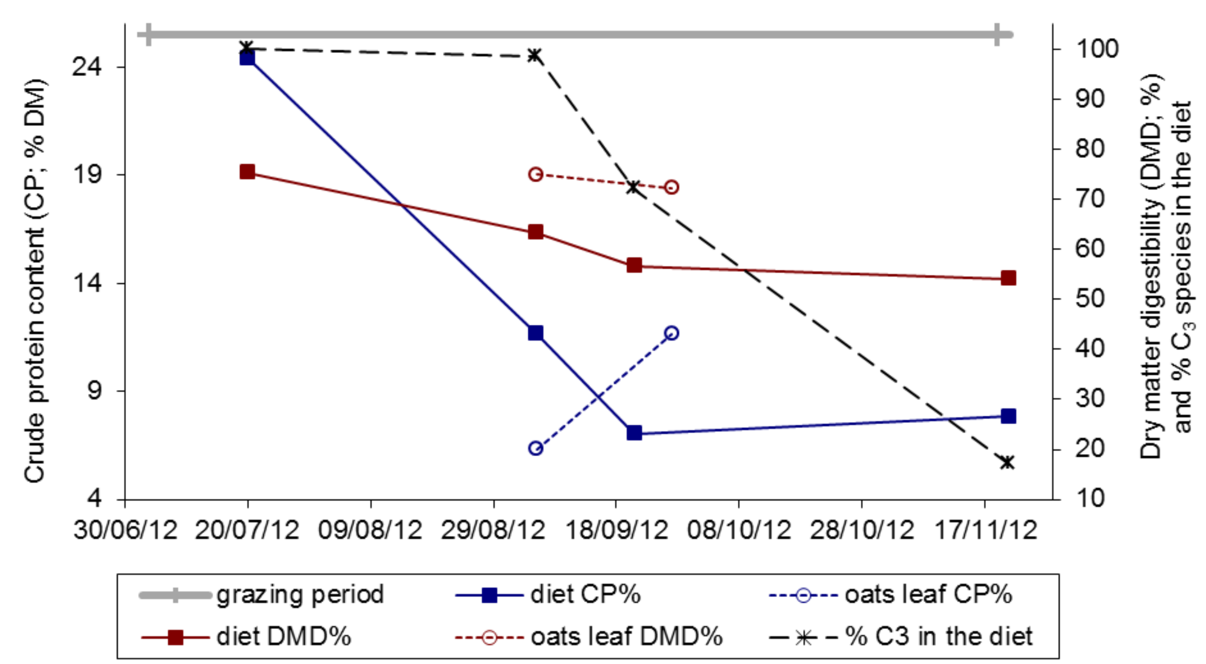

Fig. 37. Diet crude protein (CP) content (% DM) and dry matter digestibility (DMD; %) for grazing cattle predicted from faecal NIRS; measured CP and DMD content of oats green leaf in the paddock; and the % of the diet as C_3 forage, predicted from $\delta^{13}C$ content in the faeces. Grazing period shown.

Fig. 38. Cattle grazing oats paddock, 20/07/12; 16 days after start of grazing.

Samples for soil nutrient analyses were unable to be collected prior to planting. However general growth and biomass yields, together with plant health (colour), indicated that the paddock contained adequate levels of the major nutrients given the available soil water levels and rainfall. Consistent with past crop management, N fertiliser was not applied to this crop. Unlike the 2011 crop at the same site, the 2012 oats crop was planted using the zero till method of fallow weed control. Total in-crop rainfall was 287.5 mm, with 168.5 mm falling prior to grazing and 119.0 mm falling during the grazing period (Fig. 31).

Grazing commenced when the oats biomass was 2,391 kg DM/ha (Fig. 32) and the crop was still developing. The biomass in both the exclosure and the paddock increased to a peak of 7,182 and 4,921 kg DM/ha, respectively measured on the 05/09/12, 63 days after the start of grazing. It is likely that peak biomass was not detected as the exclosure appeared to have been lightly grazed and this was also the case on subsequent sampling occasions. The biomass in the paddock steadily decreased from day 63 of grazing, reaching 1,746 kg DM/ha by day 138. By day 63 of grazing (05/09/12), green leaf in the paddock was only 7.4% of the biomass DM, with green stem being 67.9% of the biomass (Fig. 34). On the 27/09/12, 85 days after the start of grazing, green leaf formed only 1.3% of biomass with green stem and dead stem making up the majority of the biomass (43.0% and 39.1%, respectively). The percentage of the available grass pasture biomass assessed as being green increased over the grazing period with the percentage of total quadrats scored as having 61-80% green biomass increasing from 10% on 05/09/12 to 73% on 21/11/12 (Fig. 33).

Chemical analysis of the forage samples showed that oats DMD content was high and much greater than DMD measurements of perennial grass whole plant samples (Fig. 36). Crude protein analyses (Fig. 35) showed that the 2012 forage oats green leaf CP was higher than that in the 2011 crop (6.3–11.7 % vs. 4.7% CP for intermediate grazing samples). Unfortunately, samples of green leaf from start of grazing of the 2012 crop were not available. However, the CP content of the whole oats plant at the start of grazing (10.9% CP) indicates that the green leaf component may have been between 12–13% CP, compared to 4.5% CP for start of grazing samples for the 2011 crop. As soil samples were not available prior to planting the 2012 crop it is not possible to compare soil total nitrate N concentrations between the 2012 and 2011 crops. Nitrogen fertiliser was not applied in either year. However, the different rainfall patterns during the fallow period of each crop could explain the higher plant CP concentrations in the 2012 oats crop. The very high rainfall during the 2010-11 summer fallow period would have resulted in relatively high leaching of soil nitrate leading to low planting N supply. The rainfall during the 2011-12 summer fallow period was less than in 2010-11 and so less N leaching would have occurred.

Dietary CP levels predicted from faecal NIRS were in the range of the CP levels of green leaf for the only comparable sampling occasions, which were during September 2009 (6.3–11.7% CP; Fig. 37). The predicted dietary CP content of 24.4% on 20/07/12 seems unexpectedly high given the anticipated maximum green leaf CP content of around 12–13% CP. Similar to results for the 2011 crop, the perennial grass pasture available in the forage oats paddock was low in CP during the grazing period (2.0–2.4% CP in the whole plant). It is possible that the faecal NIRS calibration sets for predicting dietary CP are unreliable at these low CP levels of oats forage due to the poor representation of such C_3 forage diets in the calibration data sets. It is also possible that the C_3 species present in the perennial grass area, to which the cattle also had access (0.39% of the perennial pasture biomass was native legumes), may have been contributing to a higher dietary CP than that measured in green oats leaf. Analysis of faecal samples for $\delta^{13}C$ concentration indicated that the steers were consuming around 100% oats forage in their diet until at least Day 63 of grazing (05/09/12), although this proportion had dropped to 72% by 21/09/12 and 17% by 21/11/12 (Fig. 37) which is consistent with the decreasing levels of total oats biomass and the low proportion of green oats leaf available over time.

The grazing period for this crop was relatively long (138 days compared to 91 days for the 2011 crop in the same paddock). However, the average stocking rate was correspondingly lower (1.0 versus 1.3 AE/ha, for the total grazing area). In addition, cattle commenced grazing the 2012 crop at an earlier stage of development compared to the 2011 crop which was fully developed at the start of grazing. Cattle were given access to the same additional grass area (32% of the total grazing area) as in the previous year.

Cattle entered the forage at a lower liveweight than in the previous year (449 vs. 523 kg) and lower than that assumed in the constructed scenario for this region (497 kg; Table 31). Liveweight gain measured over the initial 79 days of grazing was almost double that measured for similar 18-24 month-old cattle over the first 63 days of grazing in the previous year (1.47 vs. 0.79 kg/head/day) and also greater than that assumed in the constructed scenario (1.1 kg/head/day over 90 days). The higher quality of the 2012 oats forage compared to the 2011 crop (younger stage of development at start of grazing with a greater proportion of leaf and higher CP and DMD) as well as the lower starting cattle liveweight are likely contributing factors to the higher growth rates seen for the 2012 oats crop. Similar to the performance of cattle on the 2011 crop, it is possible that some compensatory growth effects were contributing to the higher-than expected growth rates of the steers as they had been grazing dry season perennial grass pasture prior to entry to the forage. In addition, a weight gain benefit due to the HGP is expected. The total beef production of 141 kg/ha of total grazing area was relatively high compared to the majority of other oats sites monitored.

Cattle production from oats at this site during 2012 resulted in a profitable outcome with a gross margin for the total grazing area of $157/ha calculated using owner rates and $136/ha using contract rates. The gross margin for calculated for the constructed scenario for this region was negative when contract rates were used: -$3/ha. This contrasts with the positive gross margin calculated for this current site using contract rates, despite beef production from the total grazed area being 1.4 times lower than that assumed for the constructed scenario (141 vs. 197 kg/ha/annum, respectively). The relatively low cost of planting forage at this site of $109/ha of forage area only, owner rates, (compared to $178/ha for the constructed scenario) is the major contributor to the higher profitability of oats at this site compared with the constructed scenario. The lower costs of planting forage at this site were due to the use of larger machinery and implements with a subsequently lower cost per hectare as well as generally lower input costs, for example, no fertiliser application. The cattle price margin for the owned steers at this site was also positive at $0.08/kg liveweight. As the first group of steers were not sold at the end of the grazing period in this paddock but were moved to another oats paddock, the gross margin calculated here was not actually realised by the producer but reflects the value added to the cattle by grazing this oats paddock.

3.1.6 Central Queensland Open Downs, Oats 2013

(S 23.262, E 148.309; near Emerald)

This site was a ca. 140 ha paddock planted to Aladdin forage oats on 20/04/13. For the last 39 days of the 92-day grazing period, access was also provided to an adjacent, 210 ha butterfly pea-grass paddock. The adjacent grass paddock was planted in February 2013 to butterfly pea and a grass mix containing bambatsi panic, Rhodes and buffel grass. The sown grasses had not germinated well at the time of monitoring and introduced annual, sweet summer grass was prevalent between the rows of butterfly pea. The oats paddock had been originally cleared of timber, including mountain coolibah, brigalow and bauhinia, in the 1980s. Following clearing until 2003 the paddock had been cropped with grain crops. The current owners have cropped the paddock since 2003 with forage crops including lablab, forage sorghum and oats. This site was located on the same commercial property as the Central Queensland Open Downs Lablab 2011-12, Butterfly pea-grass 2012-14, Leucaena-grass 2012-14, and Perennial grass 2011-14 sites. A summary of key site details are given in Table 7 and Fig. 39-Fig. 48.

Table 7. Site details. Central Queensland Open Downs, Oats 2013
For definitions of abbreviations, see Glossary of terms and abbreviations

<table>
<tr><th>Factor</th><th colspan="3">Details</th></tr>
<tr><td colspan="4">Soil characterisation</td></tr>
<tr><td>Broad land type</td><td colspan="3">Open downs</td></tr>
<tr><td>Soil type and characteristics</td><td colspan="3">Black cracking clay (Vertosol)
PAWC: 180 mm
Soil depth: 90 cm average (120 cm maximum)</td></tr>
<tr><td rowspan="7">Soil nutrient levels at planting but after fertiliser application</td><td></td><td>0-10 cm</td><td>10-120 cm</td></tr>
<tr><td>Nitrate N (mg/kg)</td><td>37</td><td>5.9</td></tr>
<tr><td>Nitrate N total (kg/ha)</td><td colspan="2">118</td></tr>
<tr><td>P (mg/kg)</td><td>15</td><td>6</td></tr>
<tr><td>Organic C (%)</td><td>1.1</td><td>0.63</td></tr>
<tr><td>Cl (mg/kg)</td><td><10</td><td>14</td></tr>
<tr><td>Plant available water (mm)</td><td colspan="2">100</td></tr>
<tr><td colspan="4">Paddock preparation and forage sowing details</td></tr>
<tr><td>Planting date</td><td colspan="3">20/04/13</td></tr>
<tr><td>Sowing rate</td><td colspan="3">25 kg/ha</td></tr>
<tr><td>Fertiliser</td><td colspan="3">32 kg N/ha prior to planting</td></tr>
<tr><td>Fallow weed control</td><td colspan="3">Cultivation</td></tr>
<tr><td>Total in-crop rainfall</td><td colspan="3">78.2 mm (20/04/13–22/10/13; weather station records, ca. 6.6 km from site)</td></tr>
<tr><td colspan="4">Forage production</td></tr>
<tr><td>Oats green leaf at start of grazing</td><td colspan="3">67% of biomass, 11.4% CP, 77% DMD</td></tr>
<tr><td>Oats peak biomass</td><td colspan="3">Paddock: 5,425 kg DM/ha, Exclosure: 12,010 kg DM/ha</td></tr>
<tr><td>% oats in the diet</td><td colspan="3">89% (Days 11-74 of grazing period)</td></tr>
<tr><td>Average diet quality</td><td colspan="3">66% DMD (Days 11-74 of grazing period)</td></tr>
<tr><td>Average perennial pasture presentation yield</td><td colspan="3">1,962 kg DM/ha (only one assessment made on 03/10/13). Major species: Butterfly pea 53%, sweet summer grass 28%, silk sorghum 12% and weeds 7%.</td></tr>
</table>

Factor	Details	
Grazing management and animal production		
Comments	A total of 290 steers entered the paddock on 22/07/13 and 13 heavier steers entered the paddock on 18/09/13 for the last month of grazing. Access to a 210 ha butterfly pea-grass paddock was provided for the last 39 days of grazing. All cattle were removed together on 22/10/13. A total of 288 steers exited to the NAPCO, Wainui feedlot. The main group had grazed perennial grass pastures prior to entering the oats paddock and the additional 13 steers had grazed a butterfly pea-grass paddock prior to entering.	
Cattle type monitored for weight gain	Steers; ca. 20-24 months at entry, either NAPCO Kynuna or Alexandria Composite (ca. 13-38% *B. indicus*)	
Animal health treatments	Coopers® Amitik cattle dip and spray (22/07/13) for the 290 steers of the main group	
Feeding period	22/07/13–22/10/13 (92 days)	
Proportion of the total grazing area as oats forage	Average: 83% (100%: first 66 days of grazing, 40%: last 26 days of grazing)	
Average SR (oats area only)	2.0 AE/ha	
Average SR (total grazing area)	1.2 AE/ha	
Group 1 – full grazing period		
Grazing days over which LW was measured	92 (22/07/13-22/10/13)	
Number of cattle in weight gain dataset	280	
Average entry LW (± SE)	383 (± 0.9) kg	
Average exit LW (± SE)	469 (± 1.4) kg	
Average LWG (± SE)	0.93 (± 0.013) kg/head/day	
Group 2 – last 34 days only		
Grazing days over which LW was measured	34 (18/09/13-22/10/13)	
Number of cattle in weight gain dataset	12	
Average entry LW (± SE)	454 (± 6.3) kg	
Average exit LW (± SE)	464 (± 6.4) kg	
Average LWG (± SE)	0.28 (± 0.094) kg/head/day	
Total LWG (forage area only)	177 kg/ha/annum	
Total LWG (total grazing area)	108 kg/ha/annum	
Economic performance		
	Forage area only ($/ha/annum)	**Total grazing area ($/ha/annum)**
Gross margin - owner rates	**214**	**131**
Forage costs	158	97
Gross margin - contract rates	**150**	**92**
Forage costs	221	135
CONSTRUCTED SCENARIO (10% total area as perennial grass)		
Gross margin - owner rates	**39**	**35**
Forage costs	200	180
Gross margin - contract rates	**-60**	**-54**
Forage costs	298	268

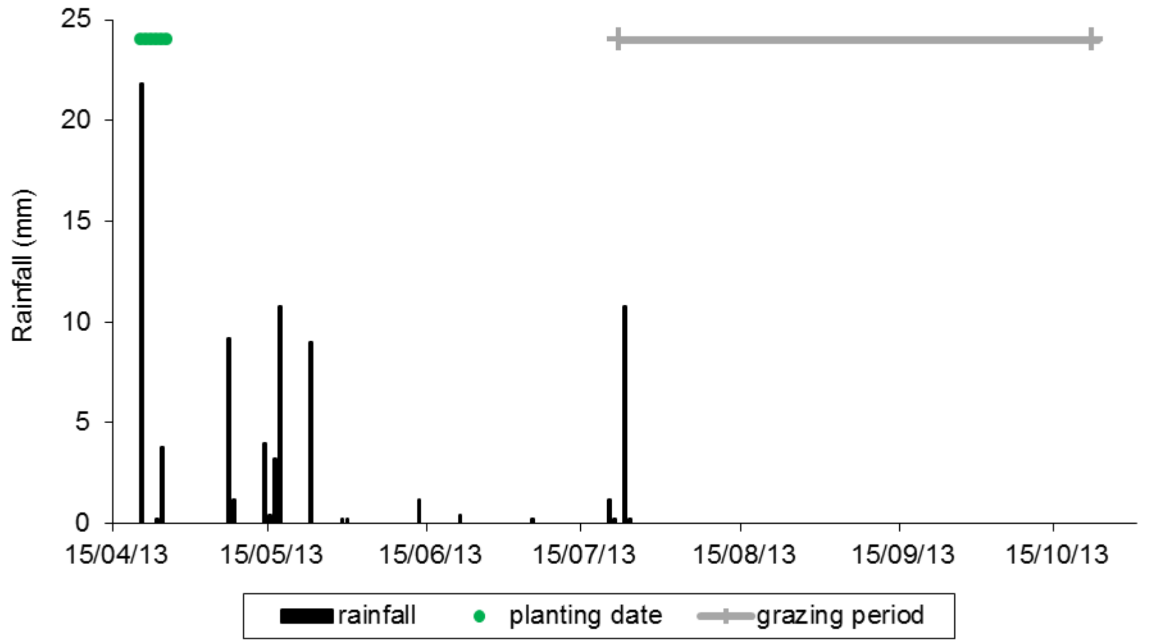

Fig. 39. Daily rainfall (mm) over the in-crop period (20/04/13-22/10/13). Measured on property, 6.6 km from the site. Planting dates and grazing period shown.

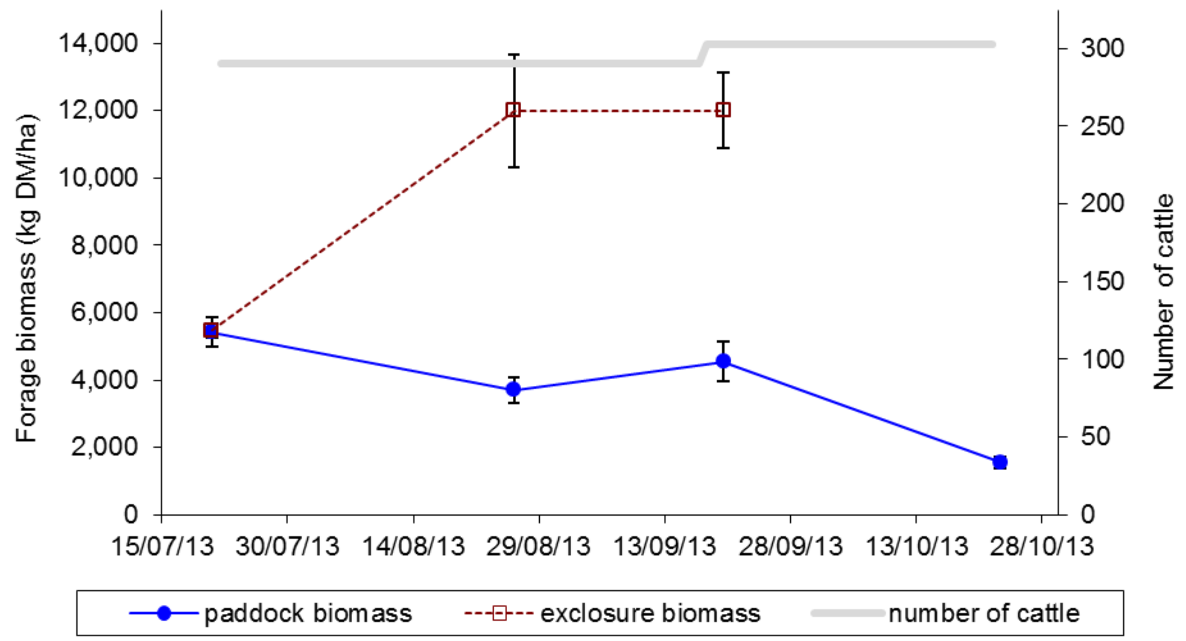

Fig. 40. Oats biomass (kg DM/ha; mean (± SE) in the paddock and exclosure, and cattle numbers during the grazing period (22/07/13-22/10/13). From the 13/09/13 access was also provided to an adjacent 210 ha butterfly pea-grass paddock.

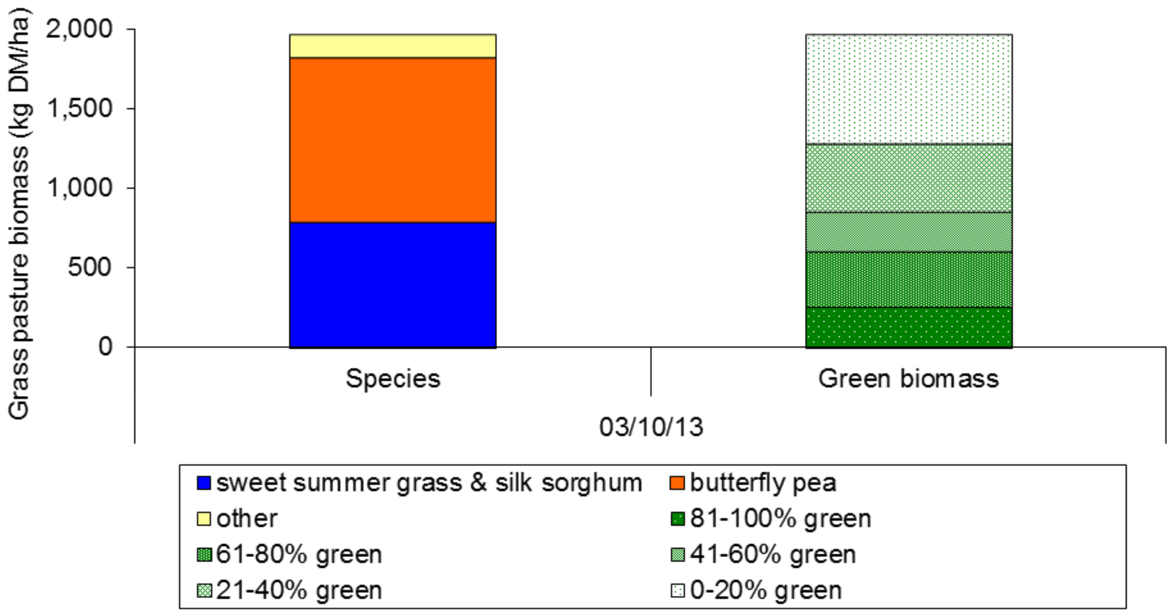

Fig. 41. Perennial pasture species composition (Species) and proportion of green material in the pasture (Green biomass) on 03/10/13 shown as a proportion of total pasture biomass (kg DM/ha). This data relates to the adjacent butterfly pea-grass paddock provided in conjunction with the oats forage for the last 39 days of grazing.

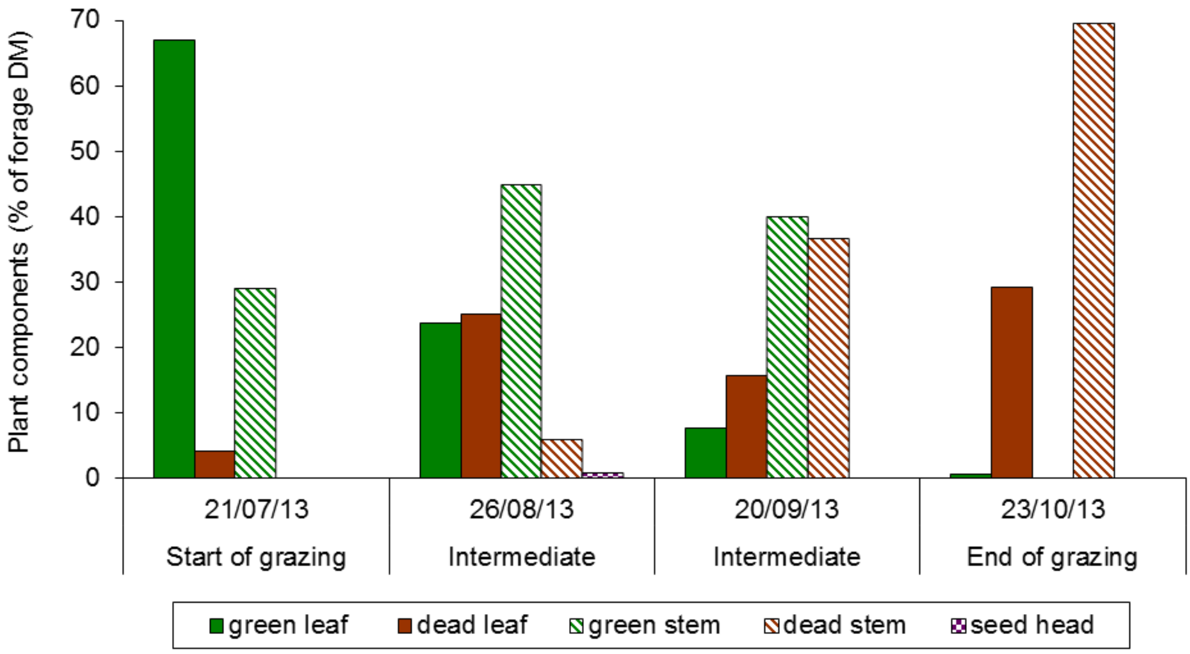

Fig. 42. Plant component composition (% of total forage DM) in the paddock during the grazing period (22/07/13-22/10/13).

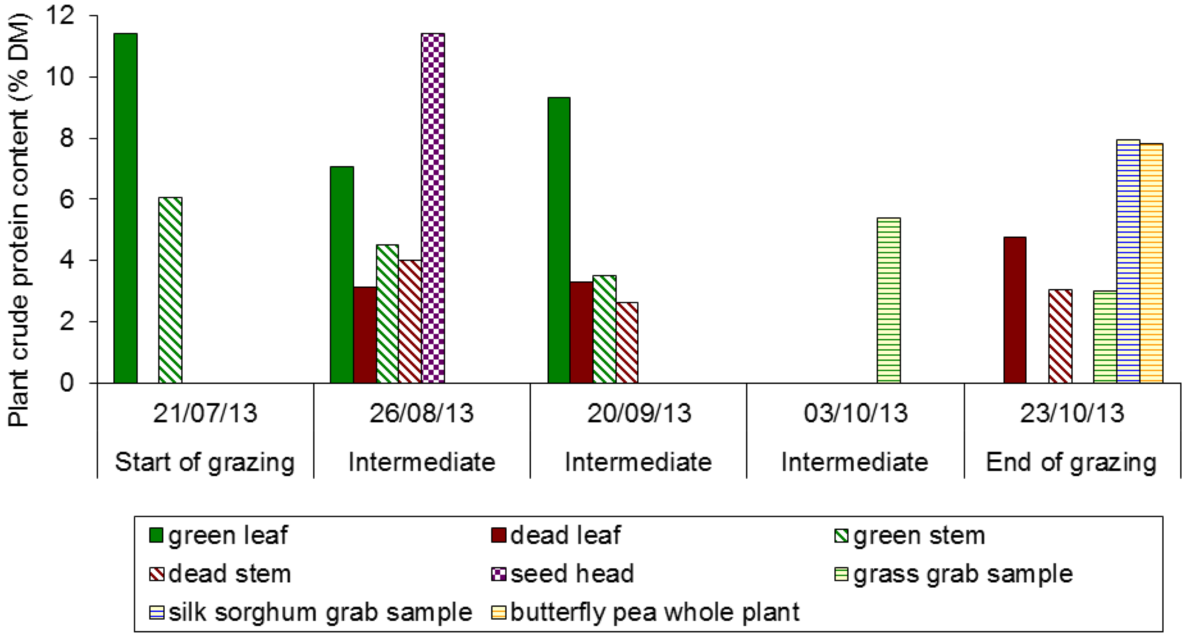

Fig. 43. Crude protein content (% DM) of forage oats plant components in the paddock, and of perennial grass and legume samples in the adjacent perennial grass paddock to which the cattle had access, over the grazing period (22/07/13-22/10/13).

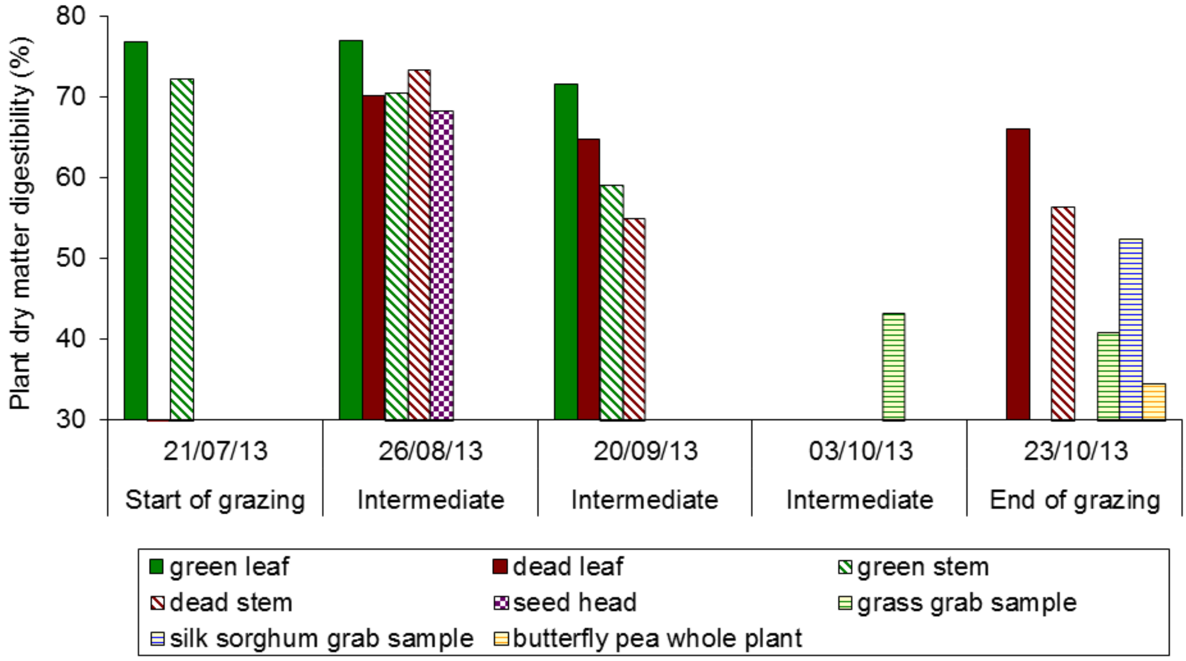

Fig. 44. Dry matter digestibility (%) of forage oats plant components in the paddock, and of perennial grass and legume samples in the adjacent perennial grass paddock to which the cattle had access, over the grazing period (22/07/13-22/10/13).

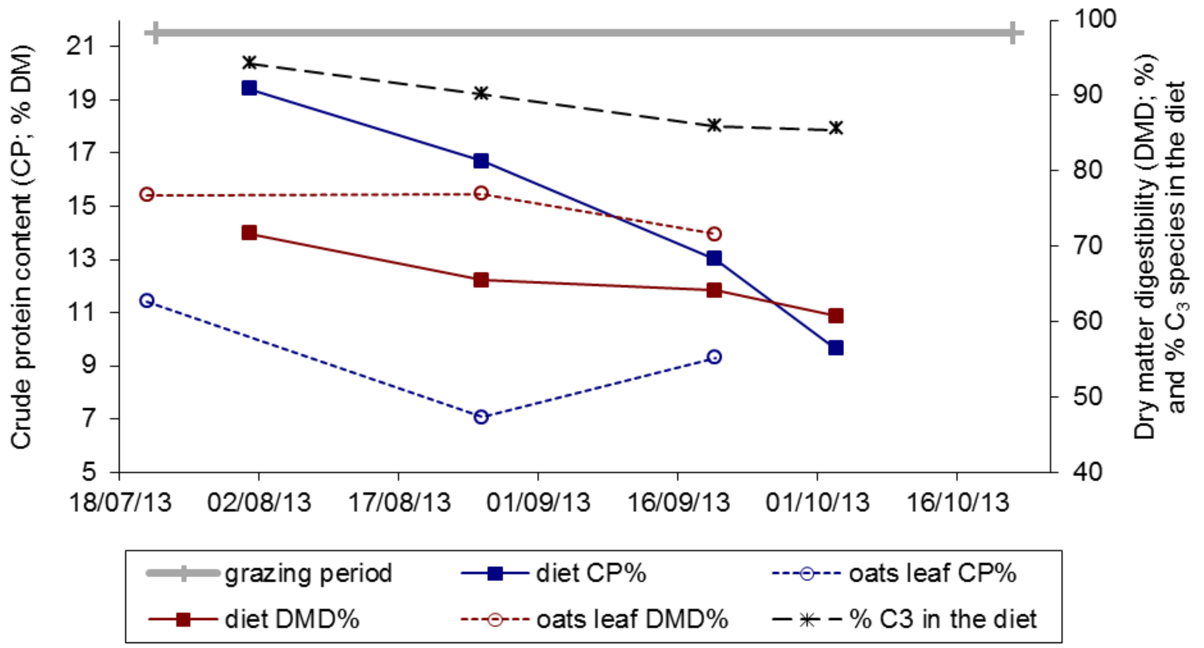

Fig. 45. Diet crude protein (CP) content (% DM) and dry matter digestibility (DMD; %) for grazing cattle predicted from faecal NIRS; measured CP and DMD content of oats green leaf in the paddock; and the % of the diet as C_3 species, predicted from $\delta^{13}C$ content in the faeces. Grazing period shown.

Fig. 46. Oats paddock, 21/07/13; 1 day prior to the start of grazing.

Fig. 47. Cattle on oats paddock, 03/10/13; after 73 days of grazing, remaining oats forage visible in the background.

Fig. 48. Butterfly pea-grass paddock, 03/10/13; which the cattle also had access to after the first 53 days grazing.

The soil type in this paddock was typical of Open Downs black cracking clay with moderate depth (90 cm, average). Soil P levels were low, indicating a history of past grain cropping and/or no recent P fertiliser application. Organic C levels were moderate. Available N levels after fertiliser addition were high, and considered to be sufficient to produce a high yielding forage oats crop with moderate protein levels. Total in-crop rainfall was 78.2 mm. Of this total, 67.2 mm fell between planting and grazing and 11 mm fell during the 92-day grazing period (Fig. 39).

When grazing commenced the oats crop was in the mid to late tillering phase and still developing (Fig. 46). Measurements taken 1 day prior to the start of grazing indicated that the average height of oats across the paddock was 36 cm and yield was 5,425 kg DM/ha (Fig. 40). The proportion of green leaf in the forage exceeded that of green stem 1 day prior to the start of grazing (67 vs. 29 % of forage DM; Fig. 42), indicating that the oats plants were not fully mature. While the oats biomass in the exclosure increased to a peak of 12,010 kg DM/ha, the biomass in the grazed paddock was kept below its starting biomass during the grazing period, decreasing to a minimum of 1,563 kg DM/ha at the end of grazing measurements on 23/10/13 at which time the forage DM consisted of 70% dead stem and 29% dead leaf. The biomass yield of oats in the un-grazed exclosure was high relative to published values for oats grown in Queensland. Pacific seeds oats variety trials near Roma in south west Queensland and in the Lockyer Valley in south east Queensland show total cumulative dry matter yield to be in the range of 5,700 to 9,800 kg DM/ha (Stuart 2002). Furthermore, the oats yields in fall within the range 1,100-7,700 kg DM/ha for south west Queensland (Bell *et al.* 2012) and 810-7,380 kg DM/ha for the Darling Downs area of southern Queensland (Chataway *et al.* 2011a). However, Muldoon (1986) reported high yields for irrigated oats grown at Trangie, New South Wales, in the range of 16,000-20,000 kg DM/ha.

The total biomass in the adjacent area of butterfly pea-grass pasture, provided for the last 39 days of the 92-day grazing period, was quite low at 1,962 kg DM/ha (Fig. 41). On the 03/10/13, 35% of the butterfly pea-grass pasture biomass was assessed as being 0-20% green, 52% as 21-80% green and 13% as 81-100% green. The grass component of the pasture was largely dry, dead material with majority of the green material consisting of young butterfly pea plants, as shown in Fig. 48.

Chemical analyses of the forage samples showed that oats green leaf material was always higher in CP and DMD content that that of green stem and that the quality of all individual plant components decreased over time, as did the proportion of green leaf in the total biomass (Fig. 42, Fig. 43 and Fig. 44).

Analysis of faecal samples for $\delta^{13}C$ concentration over the grazing period indicated that the cattle were consuming 89% of their diet as C_3 forage, assumed to be primarily oats, for at least the first 73 days of grazing (Fig. 45). From Day 54 of grazing, consumption of butterfly pea from the adjacent grass paddock could also have been contributing to the proportion of C_3 forage in the diet. The estimated percentage of the diet as oats ranged from a maximum of 94% on day 10 of grazing (01/08/13) to a minimum of 85% on day 73 of grazing (03/10/13). Although for practical measurement purposes, 100% of the forage paddock was assumed to be planted to forage oats, there was a road running 2/3 of the way through the paddock with several metres of perennial grass growing on either side. The faecal $\delta^{13}C$ results for the first 53 days of grazing, prior to access to the adjacent butterfly pea-grass paddock, support the observation that the cattle grazed this small area of perennial grass heavily. No further faecal samples were available for the final 19 days of grazing. Observations by the property manager indicated that the cattle spent the majority of their time in the oats paddock right up until the end of grazing when cattle were removed.

Predictions of DMD in the diet of grazing cattle were closely aligned with the percentage of oats in the diet (Fig. 45). The CP content predicted in the diet of grazing cattle on Days 36 and 61 of grazing were considerably higher (2.4 and 1.4 times higher, respectively) than concentrations measured in oats green leaf on the same dates. The predicted diet CP on days 11, 36 and 61 of grazing (range 19-13% CP) were also higher than the CP measured in oats green leaf just prior to start of grazing: 11% CP. Given the observation that the small area of perennial grass pasture available in conjunction with the oats forage for the first 53 days of grazing had minimal green leaf at this time of year, this prediction of dietary CP is difficult to explain. This possible over-prediction of diet CP, particularly when oats forage CP concentrations are low, is also evident for a number of the other oats sites studied in this project. It is possible that the faecal NIRS calibration sets for predicting dietary CP are unreliable at low CP levels of oats forage due to poor representation of such C_3 forages in the calibration data sets. It is also possible that some C_3 species were present in the perennial grass area and these may have been contributing to a higher dietary CP than that measured in green oats leaf.

In comparison to the constructed scenario constructed for Central Queensland Open Downs region (Table 29), cattle at this site were stocked at a similar density per hectare of forage area (2.0 vs. 2.2 AE/ha) although they had access to a much greater additional area of perennial grass pasture for the last 39 days of the grazing period (60% vs. 10% of total grazing area). The main group of cattle monitored for weight gain (280 head; Group 1) were measured over the entire 92-day grazing period, compared to 76 days of grazing which was assumed in the constructed scenario. Group 1 commenced grazing at a lower average starting liveweight to that in the constructed scenario (383 vs. 512 kg) and gained 0.93 kg/head/day over 92 days compared to the assumed 1.1 kg/head/day over 76 days in the constructed scenario. The growth rate of the 12 steers introduced for the last 34 days of the grazing period was considerably lower at 0.28 kg/head/day. The estimated total beef production per hectare at this site (177 kg/ha when attributed to the forage area alone and 108 kg/ha when attributed to the total grazing area (average area, weighted according to grazing days)) was within the range of what was assumed in the constructed scenario (157 kg/ha for the forage area alone and 143 kg/ha for total grazing area), given differences in availability of additional perennial grass pasture.

Although cattle were turned off at feedlot entry weights rather than at finishing weights, cattle production from oats at this site resulted in a profitable outcome with the gross margin for the total grazing area being $131/ha calculated using owner rates or $92/ha calculated using contract rates. Forage costs were within the middle of the range of that calculated for other sites: $158/ha of forage area only (owner rates) and lower that assumed in the constructed scenario for this region ($200/ha, contract rates). The starting value of owned steers at this site was very low ($1.13/kg liveweight, in the paddock) as grazing commenced during the bottom of the cattle market crash in 2013. Thus the relatively high cattle price margin of $0.37/kg liveweight was a major contributor to the positive gross margin as compared to the negative gross margin calculated using contract rates for the constructed scenario (-$54/ha of total grazing area). As the majority (99%) of steers grazing this oats site were sold to a feedlot upon exiting the paddock, the gross margin calculated here would be close that actually received.

3.1.7 Central Queensland Brigalow, Oats 2013

(S 24.445, E 148.548; near Rolleston)

This site was a ca. 101 ha paddock planted to 79 ha of Genie forage oats over the period 18/03/13-19/03/13 with access also provided to an adjoining 122 ha perennial, native grass paddock. Although falling within the Central Queensland Brigalow region, this site is more typical of the Open Downs land type. The cultivated paddock had originally been cleared of timber, including bloodwood, tea tree and Moreton bay ash in the 1970s. Following clearing, the paddock had been cropped annually with mainly grain crops. The current owners purchased the property in 1999 and since this time have planted mainly forage crops in this paddock, with some grain crops. No fertiliser was applied to the paddock prior to 1999. This site was located on the same commercial property as the Central Queensland Brigalow Oats 2012 site and Central Queensland Forage sorghum 2011-12 site. A summary of key site details are given in Table 8 and Fig. 49-Fig. 57

Table 8. Site details. Central Queensland Brigalow, Oats 2013
For definitions of abbreviations, see Glossary of terms and abbreviations

Factor	Details		
Soil characterisation			
Broad land type	Open downs and heavy clay alluvial		
Soil type and characteristics	Black cracking clay (Vertosol) PAWC: average 180 mm Soil depth: average 90 cm		
Soil nutrient levels at planting but after fertiliser application		**0-10 cm**	**10-90 cm**
	Nitrate N (mg/kg)	9.4	n/a
	Nitrate N total (kg/ha)	n/a	
	P (mg/kg)	32	n/a
	Organic C (%)	0.68	n/a
	Cl (mg/kg)	10	n/a
	Plant available water (mm)	118	
Paddock preparation and forage sowing details			
Planting date	18/03/13-19/03/13		
Sowing rate	25 kg/ha		
Fertiliser	55 kg N/ha		
Fallow weed control	Zero till		
Total in-crop rainfall	125.0 mm (18/03/13–01/11/13; Property records, ca. 7 km from site)		
Forage production			
Oats green leaf at start of grazing	55% of biomass, 16.3% CP, 77% DMD		
Oats peak biomass	Paddock: 4,476 kg DM/ha, Exclosure: >5,965 kg DM/ha		
% oats in the diet	78% (Days 17-113 of grazing period)		
Average diet quality	64% DMD (Days 17-113 of grazing period)		
Average perennial grass presentation yield	3,448 kg DM/ha (average of assessments made on 01/10/13 and 22/10/13). Major species: Queensland bluegrass 53%, windmill 23%, native panic 10%, buffel 9% and other species 5%.		

Factor	Details
Grazing management and animal production	
Comments	Three groups of cattle grazed this paddock (192 in total). Approximately half were purchased cattle, ca. 2 years old at entry; the remainder were home-bred cattle with ca. half of this group 2 years old and the other half 3 years old at entry. Cattle entered the paddock in 1 group and were removed in 2 groups according to weight strata, cattle type and feed availability. All except for 15 steers were sold to the Teys Biloela abattoir upon exiting the paddock. Only 26% of the total cattle number, split evenly between the 2 home-bred cattle age groups, was monitored for weight gain for the first 96 days of the 143-day grazing period before being slaughtered on 16/09/13. All cattle had grazed native pasture prior to entering the oats paddock. Grain bins were added to the forage paddock from the 17/08/13, containing 9 t of a mix of sorghum, wheat and feedlot premix and whole cottonseed. The grain mix was all consumed in about 10 days.
Cattle type monitored for weight gain	Home-bred steers; 22 steers 30-34 months old at entry; 18 steers 18-22 months old at entry; ca. 25-30% *B. indicus* content
Animal health treatments	Coopers® Amitik cattle dip and spray (11/06/13)
Feeding period	11/06/13–01/11/13 (143 days)
Proportion of the total grazing area as oats forage	36%
Average SR (oats area only)	2.2 AE/ha
Average SR (total grazing area)	0.8 AE/ha
Mixed 2 and 3-year old steers	
Grazing days over which liveweight was measured	96 (11/06/13-15/09/13)
Number of cattle in weight gain dataset	40 (22, 3-year old steers and 18, 2-year old steers)
Average entry liveweight (± SE)	503 (± 8.4) kg
Average exit liveweight (± SE)	590 (± 8.1) kg
Average LWG (± SE)	0.91 (± 0.034) kg/head/day
First 50 days of grazing	
Average LWG (± SE)	1.09 (± 0.039) kg/head/day
Next 46 days of grazing	Grain bins available for 10 days in this period (4.7 kg grain/head/day)
Average LWG (± SE)	0.70 (± 0.065) kg/head/day
Number of cattle in carcase dataset	39 (of the 40 monitored for weight gain)
Average carcase weight (± SE)	313 (± 4.63) kg
Average carcase dentition (± SE)	3.3 (0.31)
Average carcase fat depth (± SE)	13.0 (± 0.75) mm
Total LWG (forage area only; includes weight gain from grain feeding ca. 47 kg grain/head)	228 kg/ha/annum Note: this is an estimate only
Total LWG (total grazing area; includes weight gain from grain feeding ca. 47 kg grain/head)	81 kg/ha/annum Note: this is an estimate only

Factor	Details	
Economic performance		
	Forage area only ($/ha/annum)	**Total grazing area ($/ha/annum)**
Gross margin - owner rates	**497**	**177**
Forage costs	175	62
Cost of grain feeding	34	12
Gross margin - contract rates	**433**	**154**
Forage costs	239	85
CONSTRUCTED SCENARIO (10% total area as perennial grass)		
Gross margin - owner rates	**137**	**123**
Forage costs	144	129
Gross margin - contract rates	**58**	**52**
Forage costs	223	200

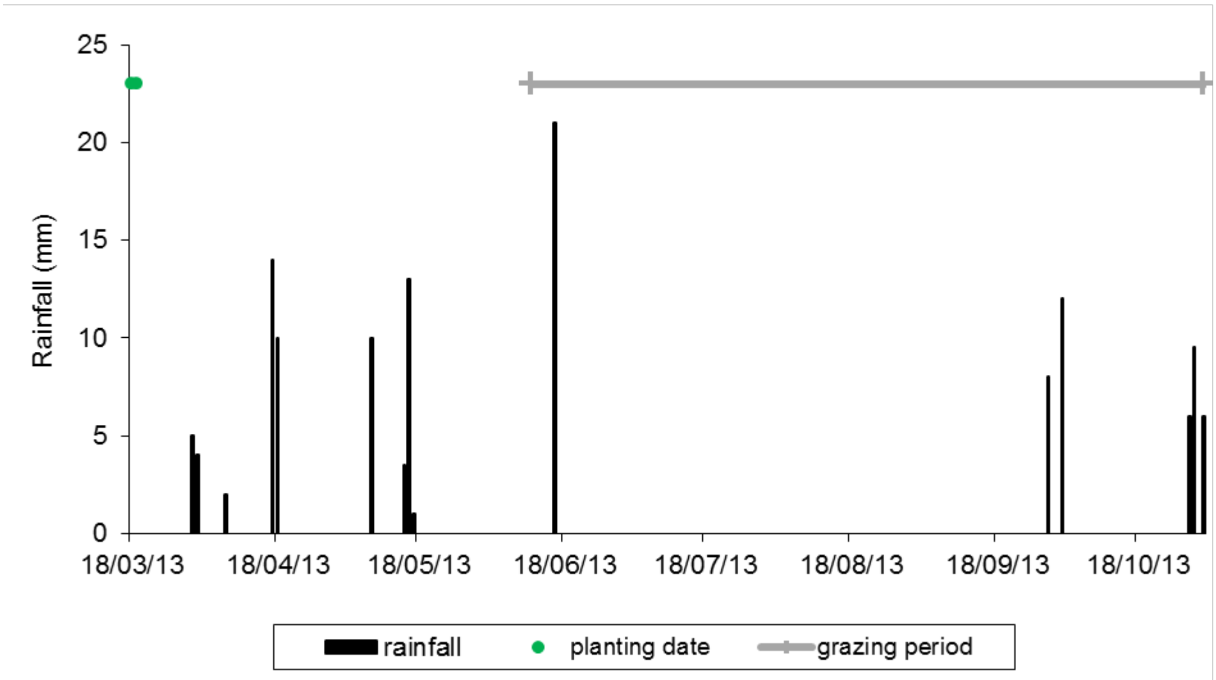

Fig. 49. Daily rainfall (mm) over the in-crop period (18/03/13-01/11/13). Measured on property, ca. 7 km from site. Planting date and grazing period shown.

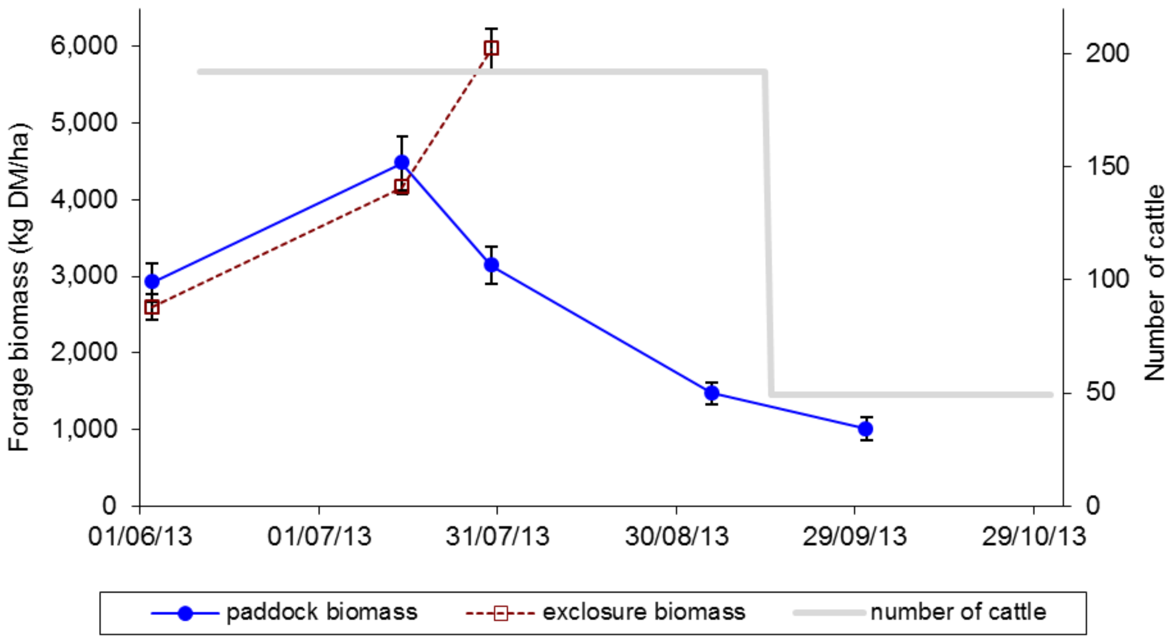

Fig. 50. Oats biomass (kg DM/ha; mean ± SE) in the paddock and exclosure, and cattle numbers during the grazing period (11/06/13-01/11/13). The final measurements of the oats forage were taken on 01/10/13 as after this time the cattle were only observed grazing in the adjacent perennial grass area (final perennial grass pasture assessment was taken on 22/10/13). No exclosure measurements were taken after 30/07/13 as the exclosure was inadvertently grazed after this time.

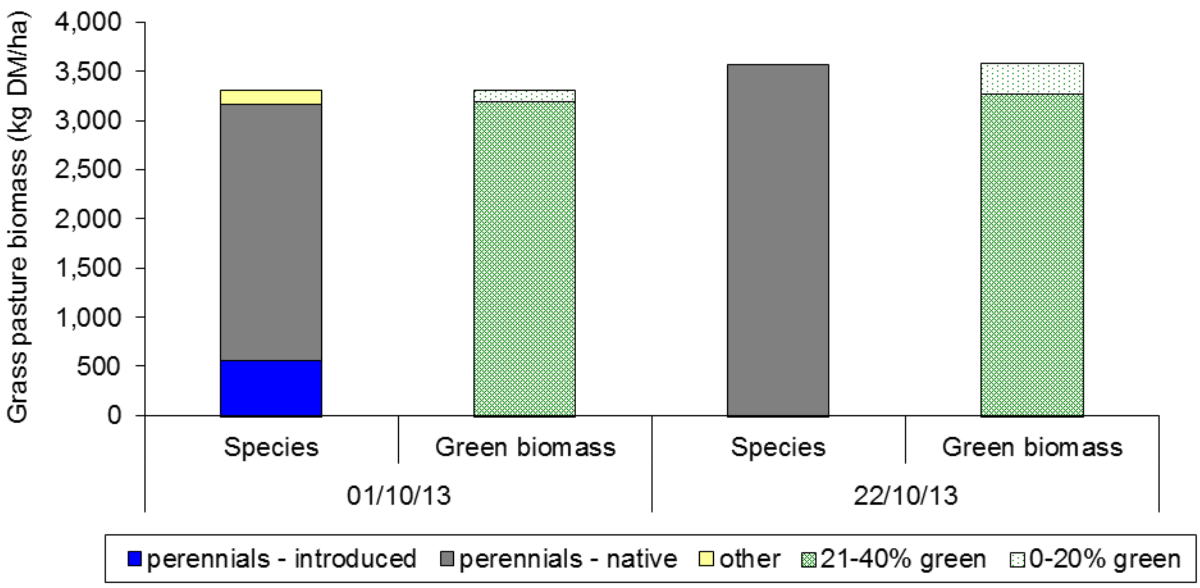

Fig. 51. Perennial pasture species composition (Species) and proportion of green material in the pasture (Green biomass) shown as a proportion of total pasture biomass (kg DM/ha). Native perennial grasses consisted primarily of Queensland bluegrass and native panic; introduced perennial grass was buffel.

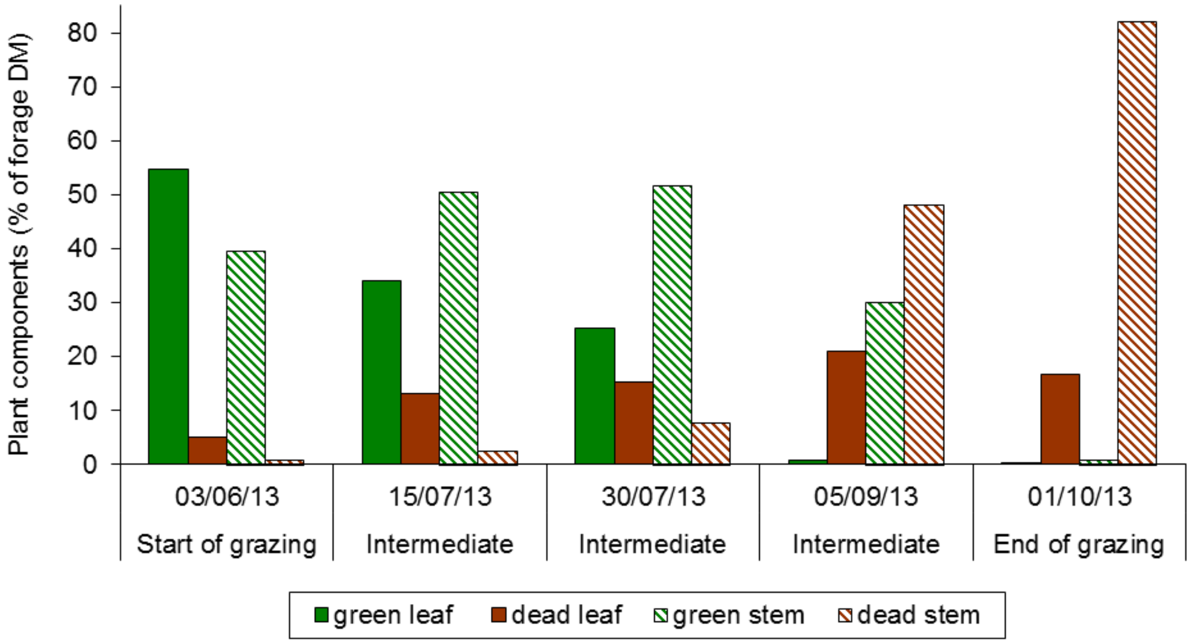

Fig. 52. Plant component composition (% of total forage DM) in the paddock during the grazing period (11/06/13-01/11/13). The final measurements of the oats forage were taken on 01/10/13 as after this time the cattle were only observed grazing in the adjacent perennial grass area (final perennial grass pasture assessment was taken on 22/10/13).

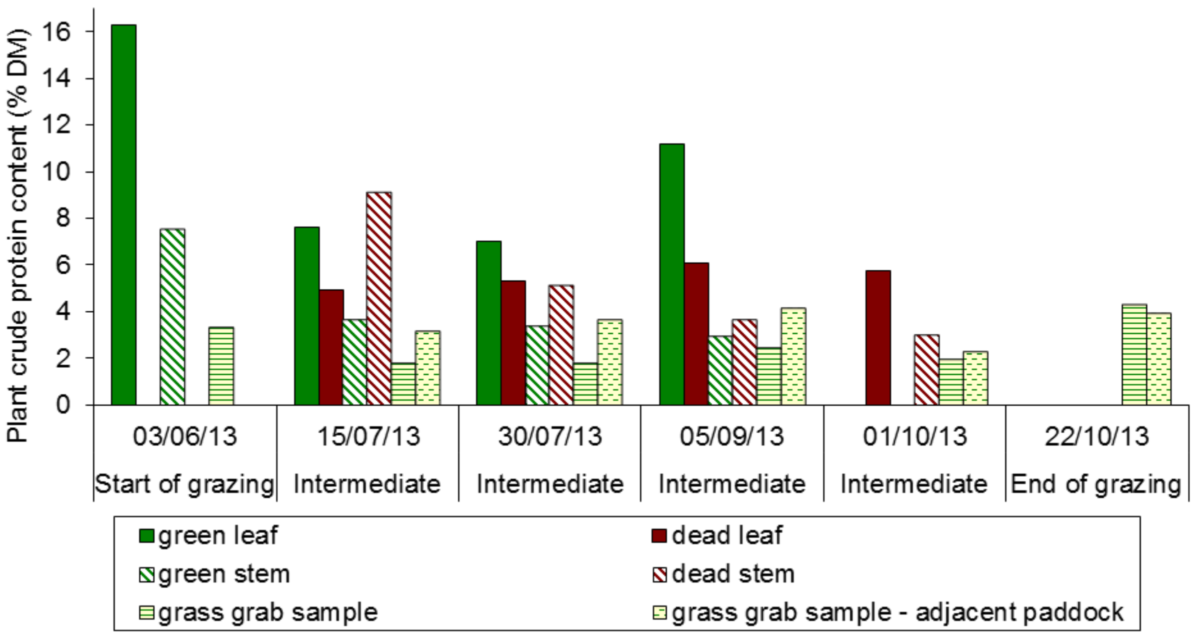

Fig. 53. Crude protein content (% DM) of forage oats plant components in the paddock, and of perennial grass grab samples in the forage paddock and the adjacent perennial grass paddock to which the cattle had access, over the grazing period (11/06/13-01/11/13). Samples were not taken from the forage oats on the 22/10/13 as there was no visual change in forage biomass and quality from 01/10/13, after which cattle were only observed grazing in the adjacent perennial grass area.

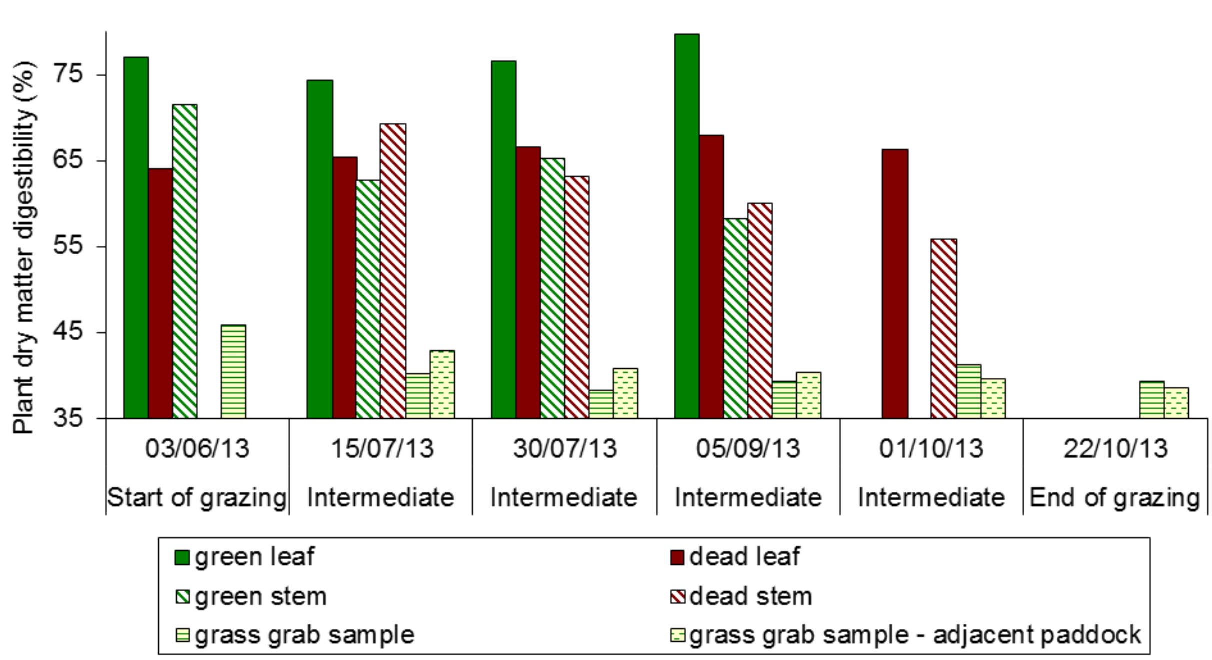

Fig. 54. Dry matter digestibility (%) of forage oats plant components in the paddock, and of perennial grass grab samples in the forage paddock and the adjacent perennial grass paddock to which the cattle had access, over the grazing period (11/06/13-01/11/13). Samples were not taken from the forage oats on the 22/10/13 as there was no visual change in forage biomass and quality from 01/10/13, after which cattle were only observed grazing in the adjacent perennial grass area.

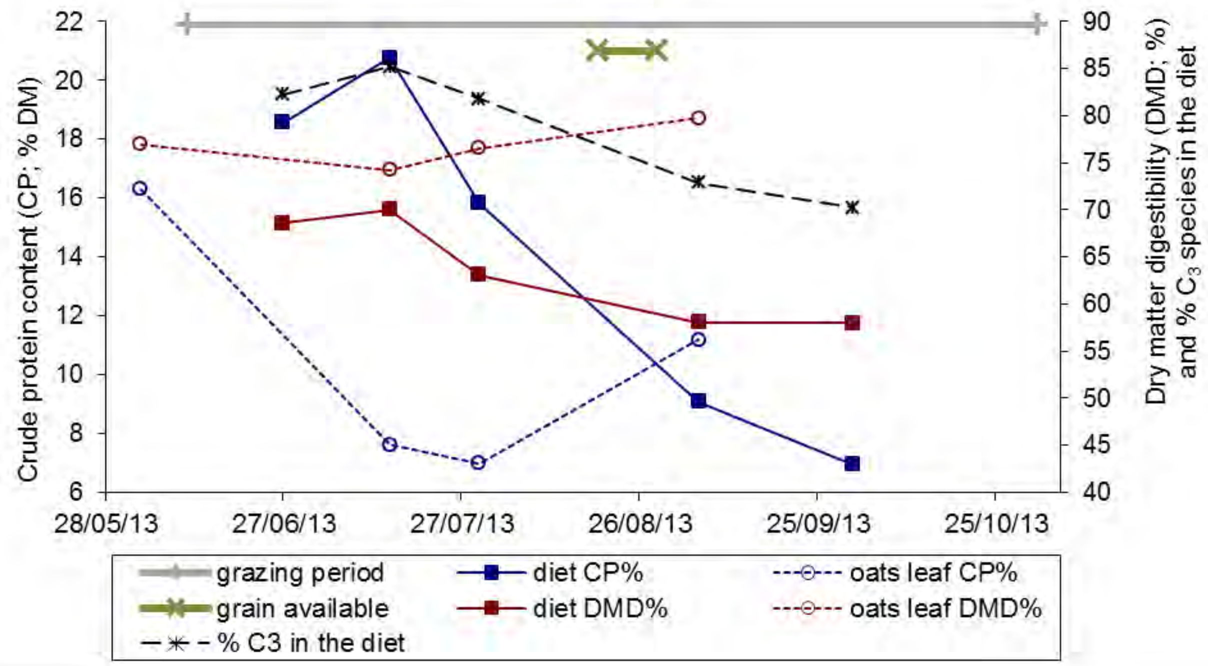

Fig. 55. Diet crude protein (CP) content (% DM) and dry matter digestibility (DMD; %) for grazing cattle predicted from faecal NIRS; measured CP and DMD content of oats green leaf in the paddock; and the % of the diet as C_3 forage, predicted from $\delta^{13}C$ content in the faeces. Grain bins were added to the paddock for 10 days from 19/08/13. Grazing period and period of grain feeding shown.

Fig. 56. Oats crop, 03/06/13; 8 days prior to the start of grazing.

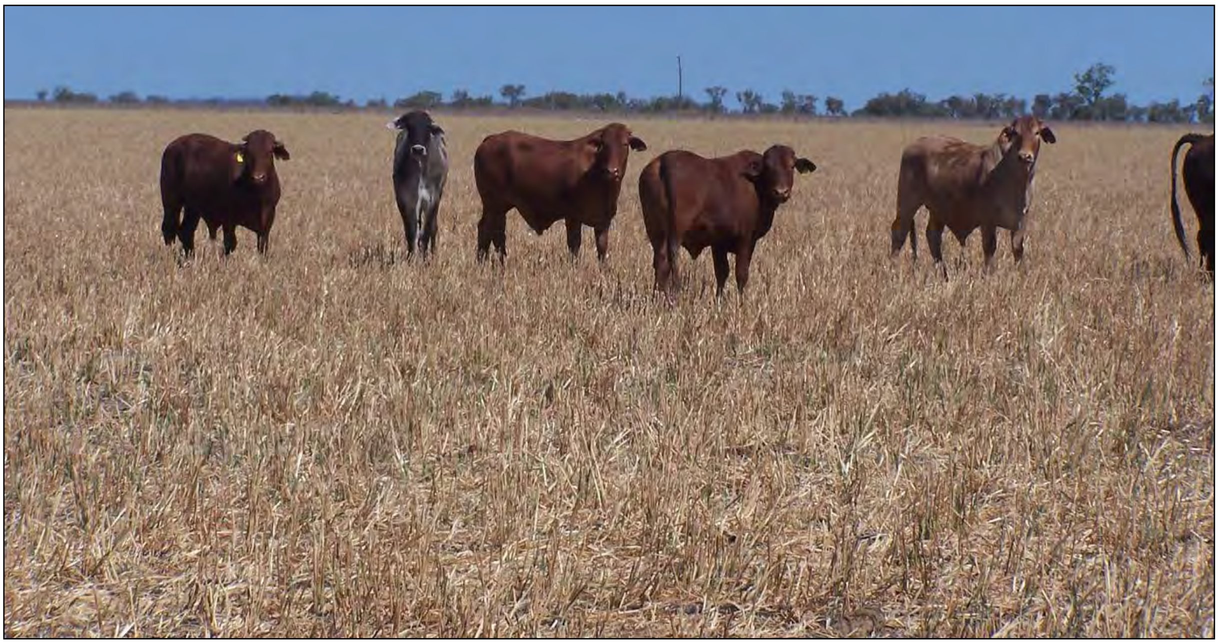

Fig. 57. Cattle grazing oats, 05/09/13; 10 days prior to the removal of the first group for slaughter which included 39 of the 40 steers monitored for liveweight gain.

The paddock contained black cracking clay soils with high water holding capacity. Soil P levels were high. However, N levels were moderate to low, even after the addition of fertiliser at the rate of 55 kg N/ha. The organic C levels were also low, indicating that the soil could only supply low quantities of N. The oats crop was planted using zero tillage methods. Total in-crop rainfall was 125.0 mm. Of this total 62.5 mm fell between planting and grazing and 62.5 mm fell during the 143-day grazing period (Fig. 49).

When grazing commenced the oats crop was in the mid to late tillering phase and still developing (Fig. 56). Measurements taken 8 days prior to the start of grazing indicated that the average height of oats across the paddock was 56 cm and yield was 2,918 kg DM/ha (Fig. 50). The proportion of green leaf in the forage exceeded that of green stem 8 days prior to the start of grazing (55 vs. 40 % of total forage DM; Fig. 52), indicating that the oats plants were not fully mature. The biomass in the grazed paddock continued to increase at the same rate as that in the exclosure for the first 34 days of grazing to a peak of 4,476 kg DM/ha and then decreased sharply, decreasing to a minimum of 1,007 kg DM/ha by the final measurement taken on 01/10/13 at which time the forage consisted of 82% dead stem and 17% dead leaf. The highest biomass in the exclosure was measured on 30/07/13, at 5,965 kg DM/ha. However, the exclosure was inadvertently grazed after the 30/07/13 preventing further useful biomass measurements. As not all plants had started to flower on the 30/07/13 sampling date, it can be deduced that the forage was approaching, but had not quite attained, peak biomass.

Plant chemical analysis (Fig. 53 and Fig. 54) showed that oats green leaf material was always higher in CP and DMD than green stem, and considerably higher in quality than the grab samples of perennial grass material. The CP content of green leaf material at the start of grazing was relatively high compared to the majority of other oats sites monitored as part of this project (16.3% DM) and was only exceeded by the Central Queensland Brigalow 2011 oats site (21.4% DM). However green leaf CP had declined to 7.6% DM by Day 35 of grazing (15/07/13). The quality (in terms of CP and DMD) of the available oats forage declined considerably over the grazing period due to declining CP content of the individual plant components over time as well as declining proportion of high quality green leaf material in the biomass (Fig. 57). The native perennial grass paddock made available to cattle during the grazing period consisted of largely dry and dead material, with 97 and 91% of quadrats being assessed as being 21-40% green on 01/10/13 and 22/10/13, respectively (Fig. 51).

Analysis of faecal samples for $\delta^{13}C$ concentration over the grazing period indicated that the cattle were consuming over 80% of their diet as C_3 forage, assumed to be oats, for at least the first 49 days of grazing (Fig. 55). The percentage of the diet as oats ranged from a maximum of 85% on Day 35 of grazing (15/07/13) to a minimum of 70% on Day 113 of grazing (01/10/13). Predictions of DMD in the diet of grazing cattle were closely aligned with the percentage of oats in the diet. No further faecal samples were available for the final 31 days of grazing during which cattle were observed to be primarily grazing in the adjacent perennial grass area. The CP content predicted in the diet of grazing cattle on Days 35 and 50 of grazing were considerably higher (2.7 and 2.3 times higher, respectively) than concentrations measured in oats green leaf on the same dates. The predicted diet CP on Day 35 of grazing (21% DM) was also higher than the CP measured in oats green leaf just prior to start of grazing: 16% DM. Given that the perennial grass pasture available in conjunction with the oats forage had minimal green leaf at this time of year, this prediction of dietary CP is difficult to explain. This likely over-prediction of diet CP, particularly when oats forage CP concentrations are low is also evident for a number of the other oats sites studied in this project. It is possible that the faecal NIRS calibration sets for predicting dietary CP are unreliable at low CP levels of oats forage due to poor representation of such C_3 forages in the calibration data sets. It is also possible that C_3 species present in the perennial grass area, to which the cattle also had access, may have been contributing to a higher dietary CP than that measured in green oats leaf.

In comparison to the constructed scenario constructed for the Central Queensland Brigalow region (Table 30), cattle at this site were stocked at a similar density per hectare of forage area (2.2 vs. 2.0 AE/ha) although they had access to a much greater additional area of perennial grass pasture (64% vs. 10% of total grazing area). The cattle monitored for weight gain were measured over the first 96 days of grazing (compared to 83 days in the constructed scenario). The mixed 2 and 3-year old steers commenced grazing at a similar average starting liveweight to that in the constructed scenario (503 vs. 505 kg) and gained 0.91 kg/head/day over the 96 days compared to the assumed 1.1 kg/head/day over 83 days in the constructed scenario. As expected, the cattle growth rates over the first 50 days of grazing, when green oats leaf was still ≥ 25% of the biomass DM, was higher than the average over the longer period of 96 days: at 1.09 cf. 0.91 kg/head/day, respectively. The total beef production expressed per total grazing area (81 kg/ha) was only moderate despite the long grazing period (143 days) and good early cattle growth rates. This was due to the low stocking rate and low cattle growth rates over the last 53 days of the grazing period (estimated as 0.57 kg/head/day).

The costs of planting forage at this site, expressed per hectare of forage area only ($175/ha, owner rates) was at the higher end of the range measured for the other oats sites monitored and higher than the cost assumed in the constructed scenario for this region ($144/ha). However, cattle production from oats at this site resulted in a profitable outcome with the gross margin for the total grazing area ($177/ha, owner rates), being the second highest of all oats sites monitored, despite the relatively low proportion of the total grazing area planted to oats forage (36%) and some grain feeding towards the end of the grazing period. The very low steer ‘purchase price’ or starting value of $1.37/kg liveweight in the paddock, and thus the good cattle price margin of $0.45/kg liveweight, is the primary explanation for the favourable gross margin at this site. The gross margin expressed using owner rates and over the whole grazing area was 1.4 times greater than the corresponding gross margin calculated for the constructed scenario of growing oats in the Central Queensland Brigalow region ($123/ha). Furthermore, at this site, providing 36% of the total grazing area as oats forage more than tripled the gross margin compared to what is expected as representative from perennial grass pasture in this region (Table 30): $177 vs. $56/ha for gross margins calculated using owner rates. However, as a portion of the cattle grazing this crop were not sold at the end of the grazing period but retained on the property, the gross margin calculated here was not actually realised by the producer. It is possible that compensatory gain effects over the following wet season may have eroded any liveweight advantage provided by the oats forage to the retained cattle.

3.1.8 South Queensland Brigalow, Oats 2013

(S 25.55286, E 149.36633; between Taroom and Roma)

The site was a 125 ha paddock planted to 85 ha of Aladdin forage oats over 03/04/13–04/04/13. The site had been farmed for forage production for ca. 30 years. This site was located in the same paddock as the South Queensland Brigalow Oats 2011 and 2013 sites. A summary of key site details are given in Table 9 and Fig. 58-Fig. 66.

Table 9. Site details. South Queensland Brigalow, Oats 2013
For definitions of abbreviations, see Glossary of terms and abbreviations

Factor	Details		
Soil characterisation			
Broad land type	Brigalow (Eurombah land system)		
Soil type and characteristics	Brown cracking clay (Vertosol) PAWC: 180 mm Soil depth: 120 cm		
Soil nutrient levels at planting		**0–10 cm**	**10–120 cm**
	Nitrate N (mg/kg)	11	n/a
	Nitrate N total (kg/ha)	14.4	n/a
	P (mg/kg)	36	n/a
	Organic C (%)	1.1	n/a
	Cl (mg/kg)	12.0	n/a
	Plant available water (mm)	72	
Paddock preparation and forage sowing details			
Planting date	03/04/13-04/04/13		
Sowing rate	33.6 kg/ha		
Fertiliser	None		
Fallow weed control	Minimal till (cultivation and chemical application)		
Total in-crop rainfall	107.8 mm (03/04/13–05/11/13; property records, 1.5 km from site)		
Forage production			
Forage green leaf at start of grazing	54% of the biomass, 10.4% CP, 76% DMD		
Forage peak biomass	Paddock: 5, 175 kg DM/ha, Exclosure: 6, 605 kg DM/ha		
% oats in the diet	65% (Days 24-91 of grazing period)		
Average diet quality	61% DMD (Days 24-91 of grazing period)		
Average perennial grass presentation yield	4,866 kg DM/ha (average of assessments made on 26/07/13 and 25/09/13). Major species: buffel (97%).		

Factor	**Details**	
Grazing management and animal production		
Comments	A total of 91 steers grazed the forage for 98 days with 87 of these (96%) monitored for weight gain. After exiting the trial paddock all steers were sent to slaughter (Dinmore meat processing plant; cattle were not graded for MSA).	
Cattle type monitored for weight gain	Steers; ca. 18–24 months old at entry; ca. 25% *B. indicus* content	
Animal health treatments	At entry to forage the cattle were vaccinated against clostridial diseases (5-in-1), received a pour-on for fly and lice control (Elanco® Demize pour-on for cattle) and were implanted with a 100-day HGP.	
Feeding period	30/07/13–05/11/13 (98 days)	
Grazing days over which LW was measured	98 (30/07/13–05/11/13)	
Proportion of the total grazing area as oats forage	68%	
Average SR (oats area only)	1.3 AE/ha	
Average SR (total grazing area)	0.9 AE/ha	
Number of cattle in weight gain dataset	87	
Average entry LW (± SE)	528 (± 3.2) kg	
Average exit LW (± SE)	641 (± 4.3) kg	
Average LWG (± SE)	1.15 (± 0.025) kg/head/day	
Total LWG (forage area only)	121 kg/ha/annum	
Total LWG (total grazing area)	82 kg/ha/annum	
Economic performance		
	Forage area only ($/ha/annum)	**Total grazing area ($/ha/annum)**
Gross margin - owner rates	**173**	**118**
Forage costs	94	64
Gross margin - contract rates	**136**	**92**
Forage costs	131	89
CONSTRUCTED SCENARIO (10% total area as perennial grass)		
Gross margin - owner rates	**95**	**85**
Forage costs	178	160
Gross margin - contract rates	**-4**	**-3**
Forage costs	276	249

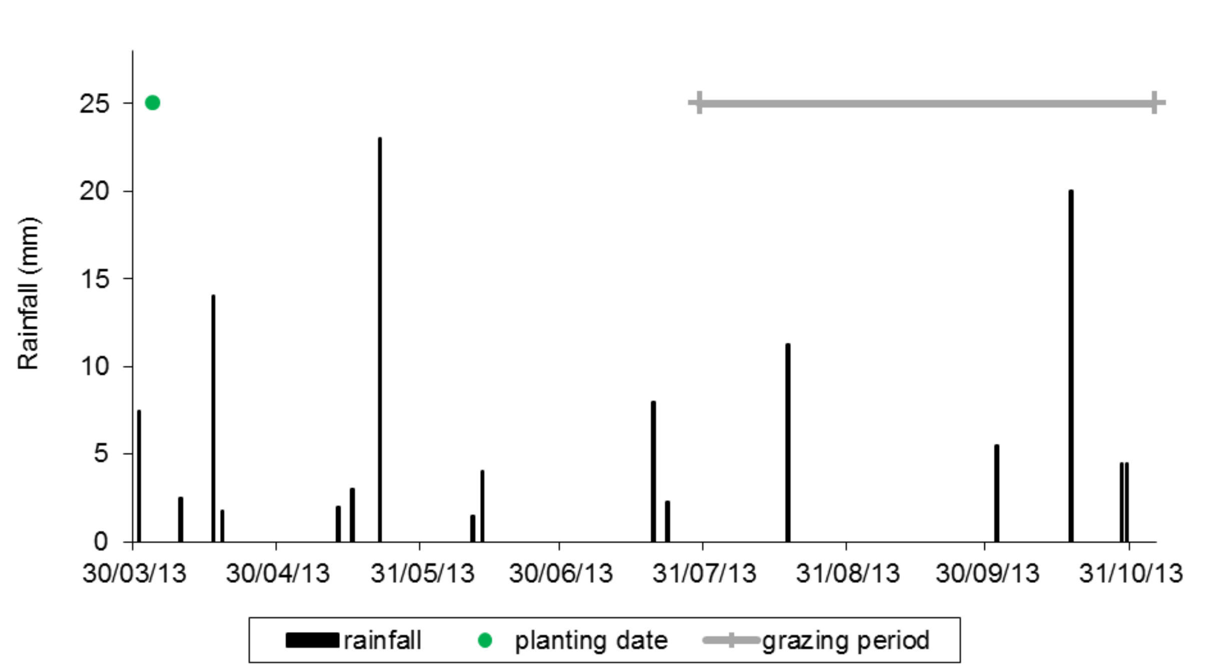

Fig. 58. Daily rainfall (mm) over the in-crop period (03/04/13–05/11/13). Measured on property, 1.5 km from the trial paddock. Planting date and grazing period shown.

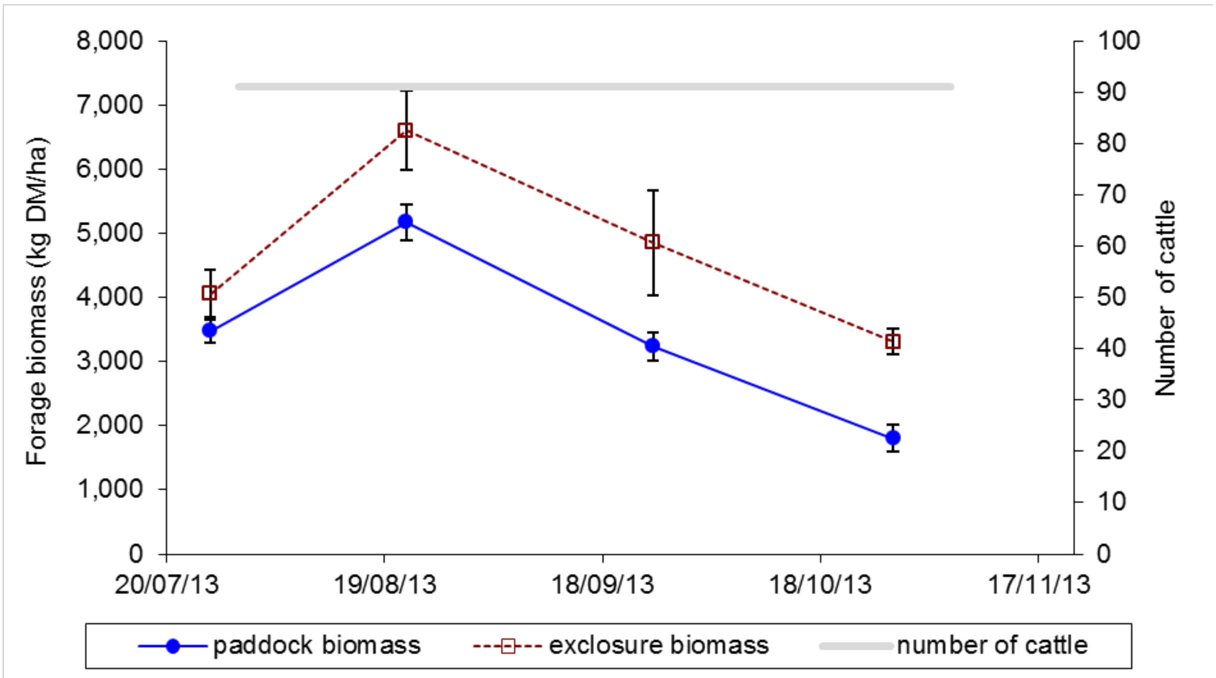

Fig. 59. Oats biomass (kg DM/ha; mean ± SE) in the paddock and exclosure, and cattle numbers during the grazing period (30/07/13–05/11/13).

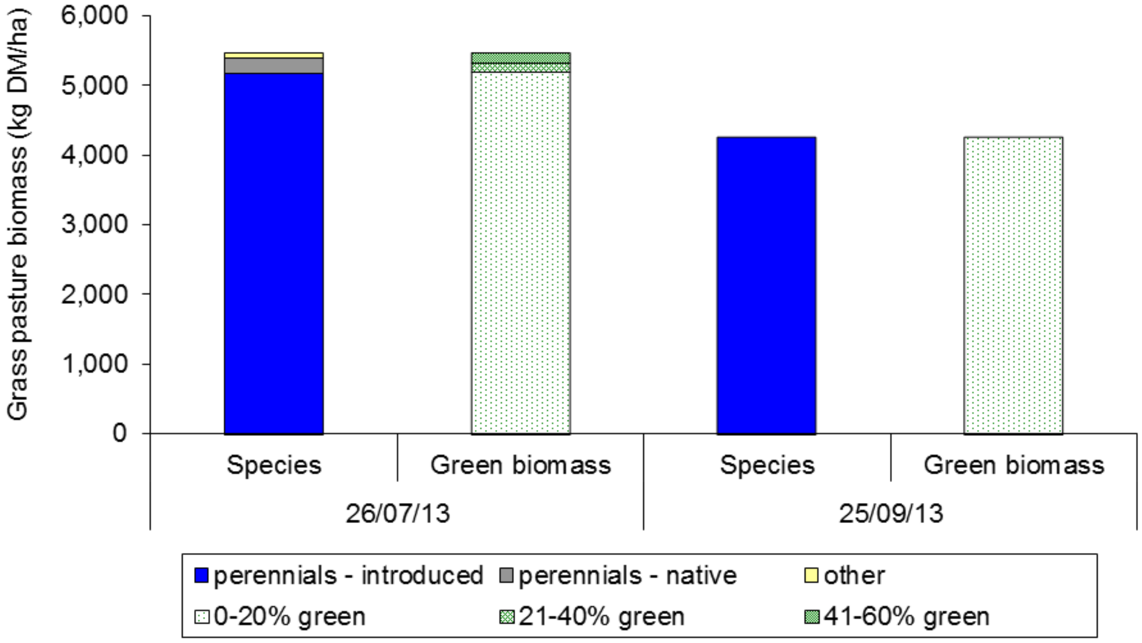

Fig. 60. Perennial pasture species composition (Species) and proportion of green material in the pasture (Green biomass) shown as a proportion of total pasture biomass (kg DM/ha). Introduced perennial grasses consisted of buffel; native perennial grasses consisted of Queensland bluegrass.

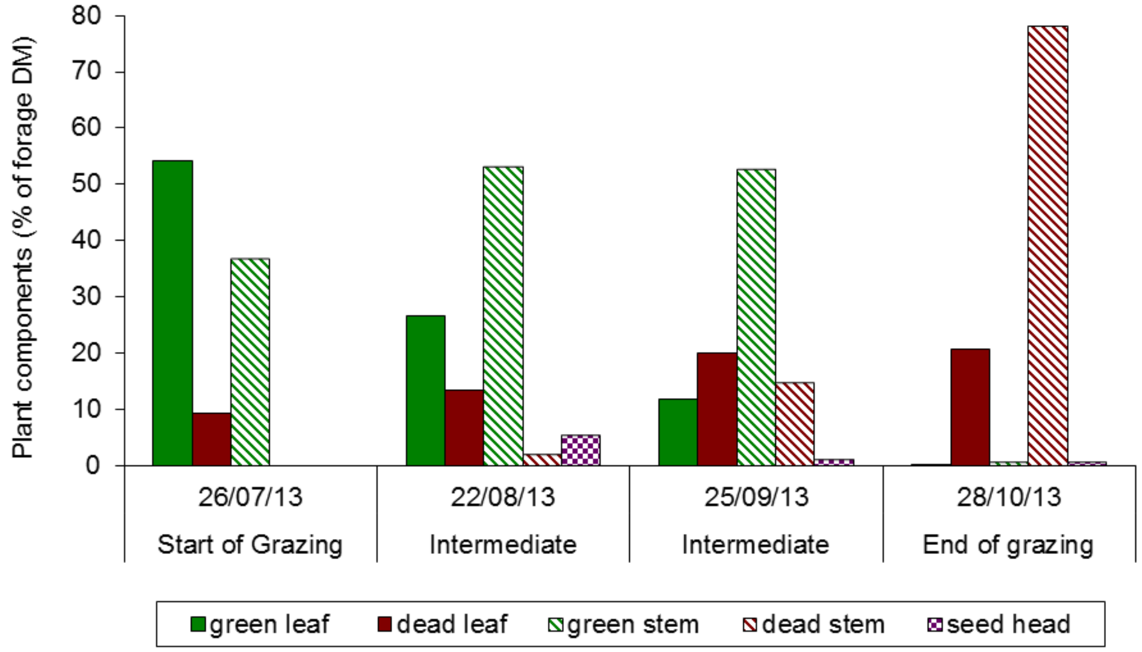

Fig. 61. Plant component composition (% of total forage DM) in the paddock during the grazing period (30/07/13–05/11/13).

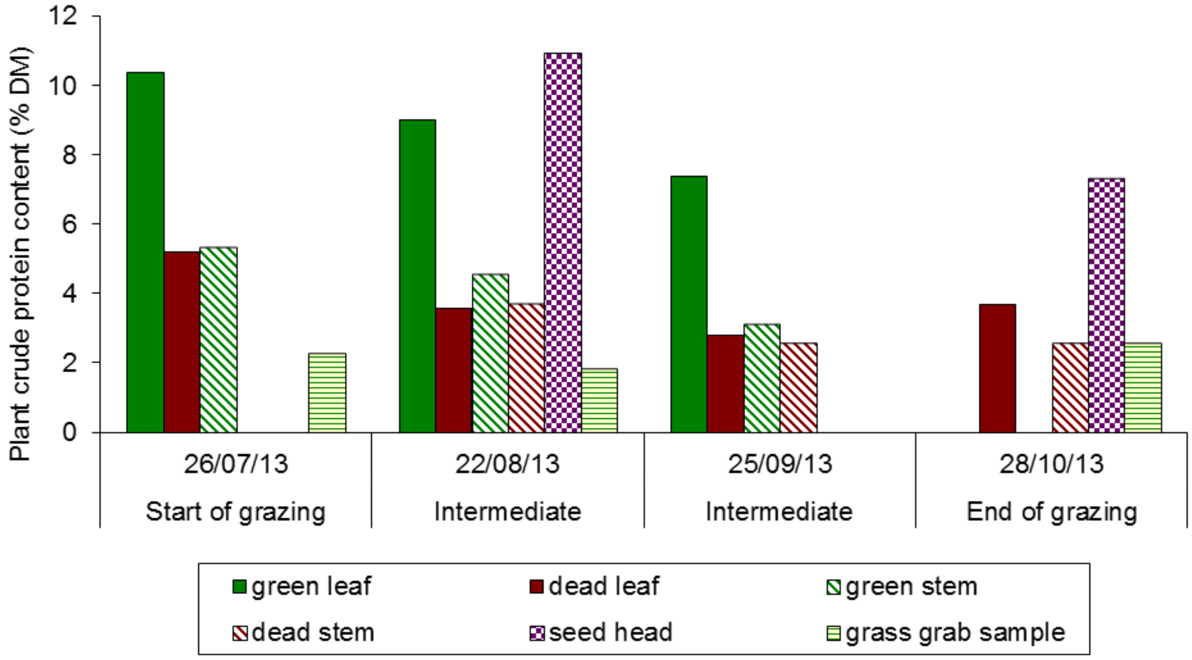

Fig. 62. Crude protein content (% DM) of forage oats plant components, and of perennial grass grab samples, in the paddock, over the grazing period (30/07/13–05/11/13).

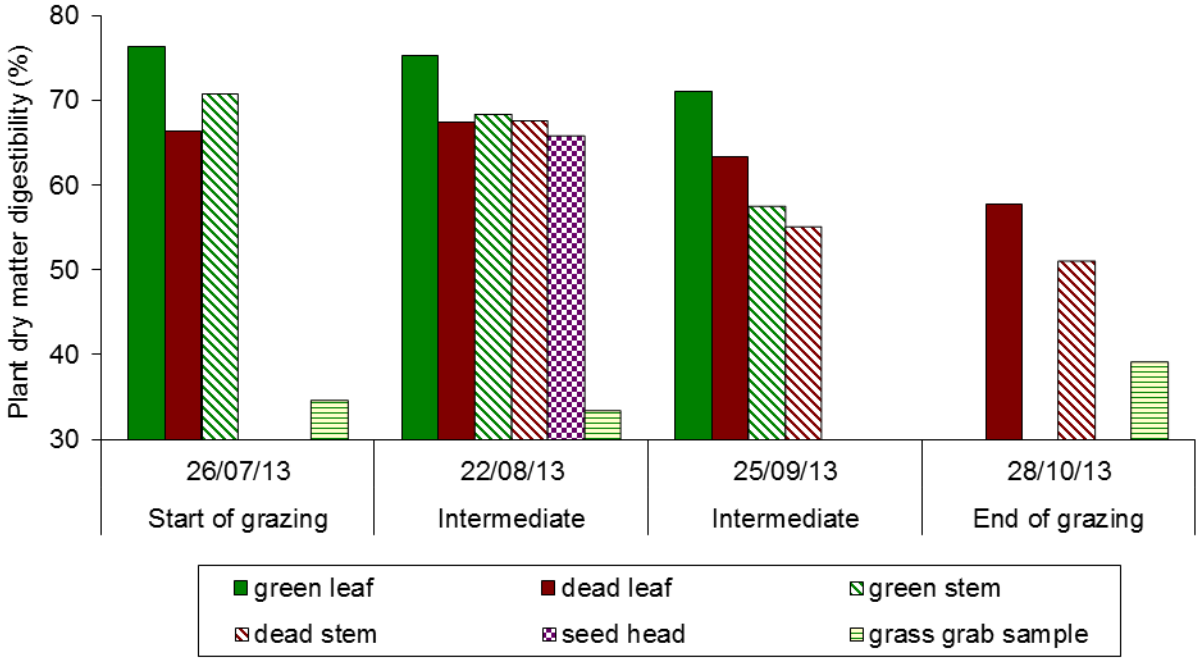

Fig. 63. Dry matter digestibility (%) of forage oats plant components, and of perennial grass grab samples, in the paddock, over the grazing period (30/07/13–05/11/13).

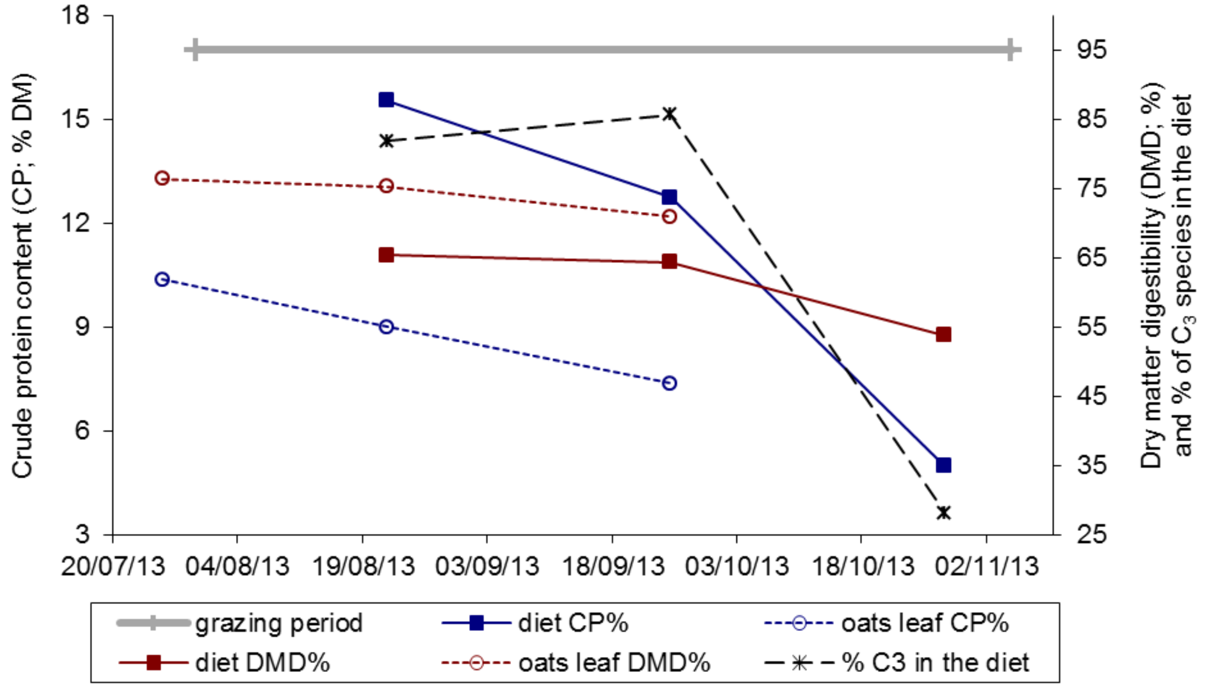

Fig. 64. Diet crude protein (CP) content (% DM) and dry matter digestibility (DMD; %) for grazing cattle predicted from faecal NIRS; measured CP and DMD content of oats green leaf in the paddock; and the % of the diet as C_3 forage, predicted from $\delta^{13}C$ content in the faeces. Grazing period shown.

Fig. 65. Oats crop, 26/07/13; 4 days prior to start of grazing.

Fig. 66. Oats crop with high presence of the weed Common sowthistle/milk thistle (*Sonchus oleraceus*), 26/07/13; 4 days prior to start of grazing.

Soil chemical analyses were not available for the full soil profile. However, the concentrations of nitrate-N in the top 10 cm (14 kg/ha) were sufficient to enable adequate early crop growth given the soil moisture available at the time (Fig. 65). Consistent with past crop management, N fertiliser was not applied to this crop. While the 2011 crop at the same site was planted using full cultivation and the 2012 crop was planted using the zero till method of fallow weed control, the 2013 crop was planted using minimal till with one cultivation and one chemical application occurring during the fallow period. The plant available water at sowing was less than half capacity but sufficient for good early plant growth. However, the plant available soil moisture in the top 10 cm was relatively low (7.5 mm), presumably due to full disturbance cultivation during the fallow and again at planting. Low soil moisture levels in the top 10 cm are likely to have caused the observed slow and patchy establishment of the crop. Subsequent rainfall after sowing then allowed strong competition from the weed common sowthistle (or milk thistle; *Sonchus oleraceus*). An in-crop spray (01/07/13) killed the common sowthistle, although the weeds did take some time to die (Fig. 66). Total in-crop rainfall was 107.8 mm, with 62.0 mm falling prior to grazing and 45.8 mm falling during the 98-day grazing period (Fig. 58).

Due to the difficulty in obtaining representative samples as a result of high weed presence and poor definition of row spacing, it is likely that there was some sampling bias towards forage areas with lower weed content and therefore that forage biomass was overestimated at this site. Grazing commenced when the estimated oats biomass was 3,478 kg DM/ha (Fig. 59), about half-way through the crop's development. The proportion of green leaf in the forage exceeded that of green stem just prior to the start of grazing (54 vs 37% DM; Fig. 61), indicating that the oats plants were not fully mature. The biomass in both the exclosure and the paddock increased to a peak of 6,605 and 5,175 kg DM/ha, respectively measured on the 22/08/13, 23 days after the start of grazing. The biomass in the paddock steadily decreased from Day 24 of grazing, reaching 1,805 kg DM/ha by Day 91. The biomass in the exclosure decreased at the same rate as in the paddock. It seemed likely that some inadvertent light grazing of the exclosure had occurred. In addition, the detachment and loss of plant parts and mature grain as the plants senesced would have contributed to the measured decrease in exclosure biomass over time. Such losses could have been the result of rain, wind, or animals consuming and damaging the grain heads, or from loss of senesced plant parts during collection. The proportion of green oats leaf in the forage biomass decreased over time in the grazed paddock from 54% of the DM (4 days prior to the start of grazing) to 0.3% of the DM on Day 91 of grazing when dead stem made up the bulk of the biomass (78%).

Chemical analysis of the forage samples (Fig. 62 and Fig. 63) showed that this 2013 forage oats green leaf CP (7.4-10.4% DM) was in the range of that measured for the 2012 crop (6.3–11.7% CP) and much higher than for the 2011 (4.5-4.7% CP). Nitrogen fertiliser was not applied in any of the 3 years. As maximum exclosure biomass for the 2011 oats crop (ca. 5,700 kg /ha) was at least 900 kg/ha lower than that recorded in subsequent years, the different rainfall patterns during the fallow period of each crop presumably explain the higher plant CP concentrations in the 2012 and 2013 oats crops. The very high rainfall during the 2010-11 summer fallow period would have resulted in relatively high leaching of soil nitrate leading to low planting N supply. The rainfall during the 2011-12 and 2012-13 summer fallow period was less than in 2010-11 and so less N leaching would have occurred. The perennial grass made available to cattle during the grazing period consisted of largely dry and dead material, with > 95% of the perennial grass biomass was assessed as being 0-20% green on 26/07/13 and 25/09/13 (Fig. 60). Grab samples of perennial grass had correspondingly very low CP and DMD concentrations (1.8-2.6% DM and 33-39%, respectively; Fig. 62 and Fig. 63).

Analysis of faecal samples for $\delta^{13}C$ concentration indicated that the steers were consuming 82% and 86% oats forage in their diet on 22/08/13 and 25/09/13, respectively (Day 24 and 58 of grazing), (Fig. 64). On these same dates, dietary CP levels predicted from faecal NIRS (15.6% and 12.7% CP) were considerably higher (1.7 times) than concentrations measured in oats green leaf on the same dates (9.0% and 7.4% CP, respectively). Given that the perennial grass pasture available in conjunction with the oats forage had minimal green leaf at this time of year and that grab samples of perennial grass had correspondingly very low CP concentrations, this prediction of dietary CP is difficult to explain. This likely over-prediction of diet CP, particularly when oats forage CP concentrations are low is also evident for a number of the other oats sites studied in this project. It is possible that the faecal NIRS calibration sets for predicting dietary CP are unreliable at low CP levels of oats forage due to poor representation of such C_3 forages in the calibration data sets. It is also possible that C_3 species present in the perennial grass area, to which the cattle also had access, may have been contributing to a higher dietary CP than that measured in green oats leaf. By the end of the grazing period (Day 91), the % of C_3 species in the diet (assumed to be primarily oats) had dropped to only 28%, in line with the low forage biomass, which was primarily dead stem, at this time.

The grazing period for this crop (98 days) was similar to that for the 2011 crop (91 days) but less than for the 2012 crop (138 days), all of which were grown in the same paddock. However, the average stocking rate on the 2013 crop (1.3 AE/ha; forage area only) was similar to the 2012 crop (1.4 AE/ha; forage area only) but lower than the 2011 crop (1.9 AE/ha; forage area only). Cattle were given access to the same additional grass area (32% of the total grazing area) in all 3 years.

Cattle entered the forage at a similar liveweight to the 2011 year (528 vs. 523 kg) but higher than for the 2012 year (449 kg) and higher than that assumed in the constructed scenario for this region (497 kg; Table 31). Liveweight gain measured over the entire 98 days of grazing (1.15 kg/head/day) was intermediate between growth rates measured for similar 18-24 month-old cattle over the 79 days of grazing in 2012 (1.47 kg/head/day) and the first 63 days of grazing in the 2011 (0.79 kg/head/day). Similarly, total liveweight gain from the total grazing area (82 kg/ha) was intermediate between that calculated for 2011 and 2012 crops (63 and 141 kg/ha, respectively). The daily liveweight gain was similar to that assumed in the constructed scenario (1.1 kg/head/day over 90 days) but total liveweight gain was lower due to the much higher stocking rates assumed in the constructed scenario (2.3 AE/ha on the total grazing area (vs. 0.9 AE/ha at this site) resulting in 121 kg/ha from the total grazing area. In the constructed scenario forage was planted to 90% of the total area vs. 68% at this site.

Cattle production from oats at this site during 2013 resulted in a profitable outcome with a gross margin for the total grazing area of $118/ha calculated using owner rates and $92/ha calculated using contract rates. The gross margin calculated for the constructed scenario for this region was negative when contract rates were used (-$3/ha). This contrasts with the positive gross margin calculated using contract rates for this current site, despite beef production from the total grazed area being 2.4 times lower than that assumed for the constructed scenario (82 vs. 197 kg/ha/annum respectively). The relatively low cost of planting forage at this site of $94/ha of forage area only, owner rates, compared to $178/ha for the constructed scenario) is a major contributor to the higher profitability of oats at this site compared to the constructed scenario. The lower costs of planting forage at this site were due to the use of larger machinery and implements with a subsequently lower cost per hectare as well as generally lower input costs, for example, no fertiliser application. The cattle price margin for the owned steers at this site was also favourable at $0.23/kg liveweight. As all steers that grazed this paddock were sent to slaughter at the end of the grazing period, the gross margin calculated here was actually realised by the producer.

3.2 Forage sorghum (*Sorghum spp.*)

3.2.1 Central Queensland Brigalow, Forage sorghum 2011-12

(S 24.429, E 148.544; near Rolleston)

The site was a 603 ha paddock planted to 365 ha of Sugargraze forage sorghum over the period 18/12/11–23/12/11. Although falling within the Central Queensland Brigalow region, this site is more typical of the Open Downs land type. The site had been originally cleared of timber in 1999-2000 and cropped for 8 of the following 12 years with mainly forage sorghum. A forage sorghum and lablab mix was sown in the paddock in 2005 and 2011. None of these previous crops had any fertiliser application. This site was located on the same commercial property as for the Central Queensland Brigalow Oats 2012 and 2013 sites. A summary of key site details are given in Table 10 and Fig. 67-Fig. 74.

Table 10. Site details. Central Queensland Brigalow, Forage sorghum 2011-12
For definitions of abbreviations see Glossary of terms and abbreviations

Factor	Details		
Soil characterisation			
Broad land type	Open Downs and heavy clay alluvial		
Soil type and characteristics	Black cracking clay (Vertosol) PAWC: average 180 mm Soil depth: average 90 cm		
Soil nutrient levels at planting but after fertiliser application		**0–10 cm**	**10–120 cm**
	Nitrate N (mg/kg)	7.9	5.5
	Nitrate N total (kg/ha)	90.4	
	P (mg/kg)	23	n/a
	Organic C (%)	1.0	n/a
	Cl (mg/kg)	10	22
	Plant available water (mm)	110.2	
Paddock preparation and forage sowing details			
Planting date	18/12/11–23/12/11		
Sowing rate	5.5 kg/ha		
Fertiliser	49 kg N/ha		
Fallow weed control	Minimal till (cultivation and chemical application)		
Total in-crop rainfall	501.6 mm (18/12/11–15/06/13; combination of Albinia Downs (BOM Station 35209) and on-site weather station data)		
Forage production			
Sorghum green leaf at start of grazing	19.6% of biomass, 14.2% CP, 68% DMD		
Sorghum peak biomass	Paddock: 30,197 kg DM/ha, Exclosure: >35,598 kg DM/ha		
Average diet quality	6.6% CP, 53% DMD (Days 11-113 of grazing period)		
Average perennial grass presentation yield	7,711 kg DM/ha at the start of the grazing period. Major species: Queensland bluegrass (39% of biomass), black speargrass (38%), buffel (21%) and broad leaf weeds (2%).		

Factor	Details	
Grazing management and animal production		
Comments	Seven groups of cattle (832 in total) grazed the paddock as one mob, for the entire grazing period. The cattle were either steers or spayed heifers and either 1 or 2 years old at entry to forage. O nly a proportion of these cattle (29%), from 3 of the groups, were monitored for weight gain. Mob weights only, were available for entry and exit weights, precluding calculation of a SE. At the end of the grazing period all cattle were moved into an oats forage paddock which was also monitored as part of this project.	
Cattle type monitored for weight gain	All home-bred cattle; 164 steers, ca. 2 years old at entry; 40 steers and 40 spayed heifers, ca. 1 year old at entry. The heifers were spayed immediately prior to start of grazing in the forage sorghum paddock. All cattle ca. 25-30% *B. indicus* content.	
Animal health treatments	Coopers® Amitik cattle dip and spray	
Feeding period	24/02/12–15/06/12 (112 days)	
Grazing days over which LW was measured	112 (24/02/12–15/06/12)	
Proportion of the total grazing area as forage sorghum	61%	
Average SR (forage area only)	2.2 AE/ha	
Average SR (total grazing area)	1.3 AE/ha	
2-year old steers		
Number of cattle in weight gain dataset	164	
Average entry LW	477 kg	
Average exit LW	518 kg	
Average LWG	0.37 kg/head/day	
1-year old steers		
Number of cattle in weight gain dataset	40	
Average entry LW	383 kg	
Average exit LW	416 kg	
Average LWG	0.30 kg/head/day	
1-year old spayed heifers		
Number of cattle in weight gain dataset	40	
Average entry LW	335 kg	
Average exit LW	361 kg	
Average LWG	0.23 kg/head/day	
Total LWG (forage area only)	87 kg/ha/annum; (Note: this is an estimate only)	
Total LWG (total grazing area)	53 kg/ha/annum; (Note: this is an estimate only)	
Economic performance		
	Forage area only ($/ha/annum)	**Total grazing area ($/ha/annum)**
Gross margin - owner rates	**20**	**12**
Forage costs	169	102
Gross margin - contract rates	**-78**	**-47**
Forage costs	267	162
CONSTRUCTED SCENARIO (0% total area as perennial grass)		
Gross margin - owner rates	**159**	**159**
Forage costs	138	138
Gross margin - contract rates	**80**	**80**
Forage costs	217	217

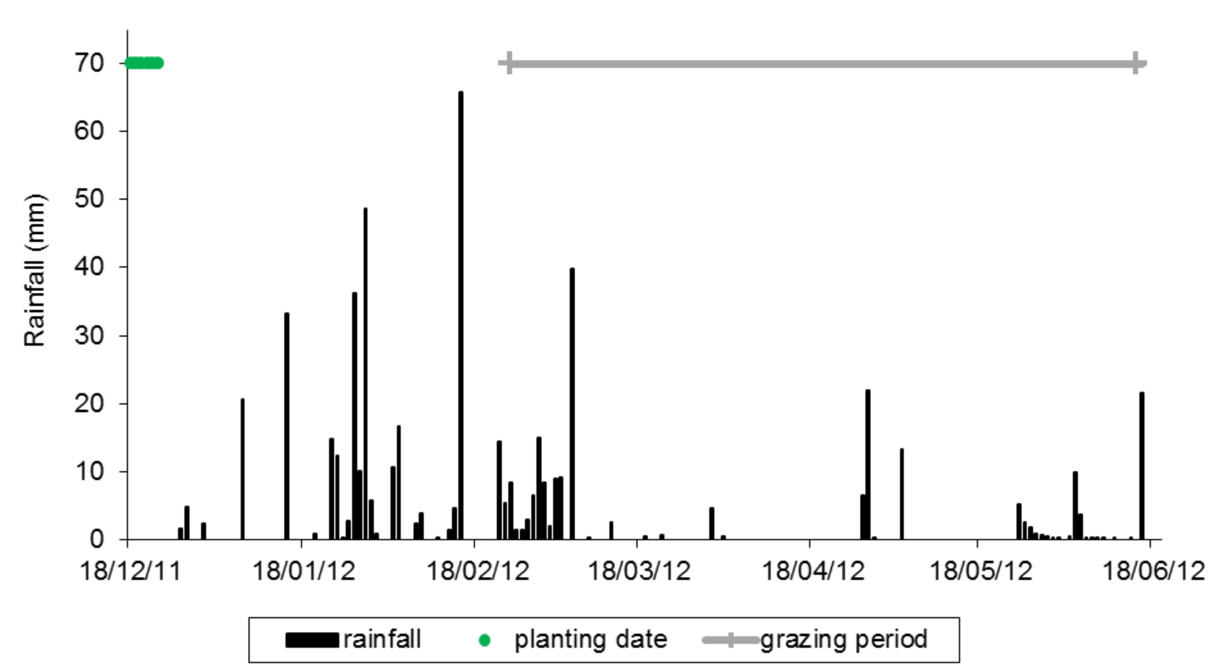

Fig. 67. Daily rainfall (mm) over the in-crop period (18/12/11–15/06/12) and until the final forage sampling (19/06/12). Measured at Albinia Downs (BOM Station 35209; 18/12/11–21/12/11, and 17/06/12–19/06/12) and on-site weather station (22/12/11–16/06/12). Planting dates and grazing period shown.

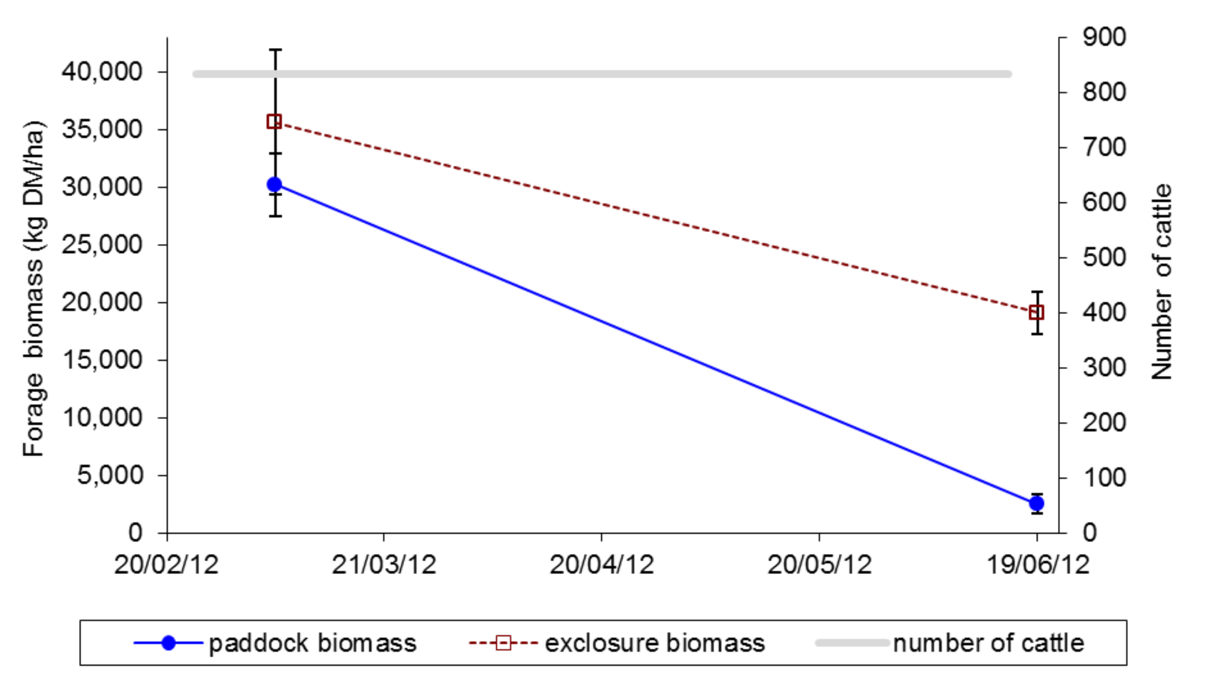

Fig. 68. Forage sorghum biomass (kg DM/ha; mean ± SE) in the paddock and exclosure, and cattle numbers during the grazing period (24/02/12–15/06/12).

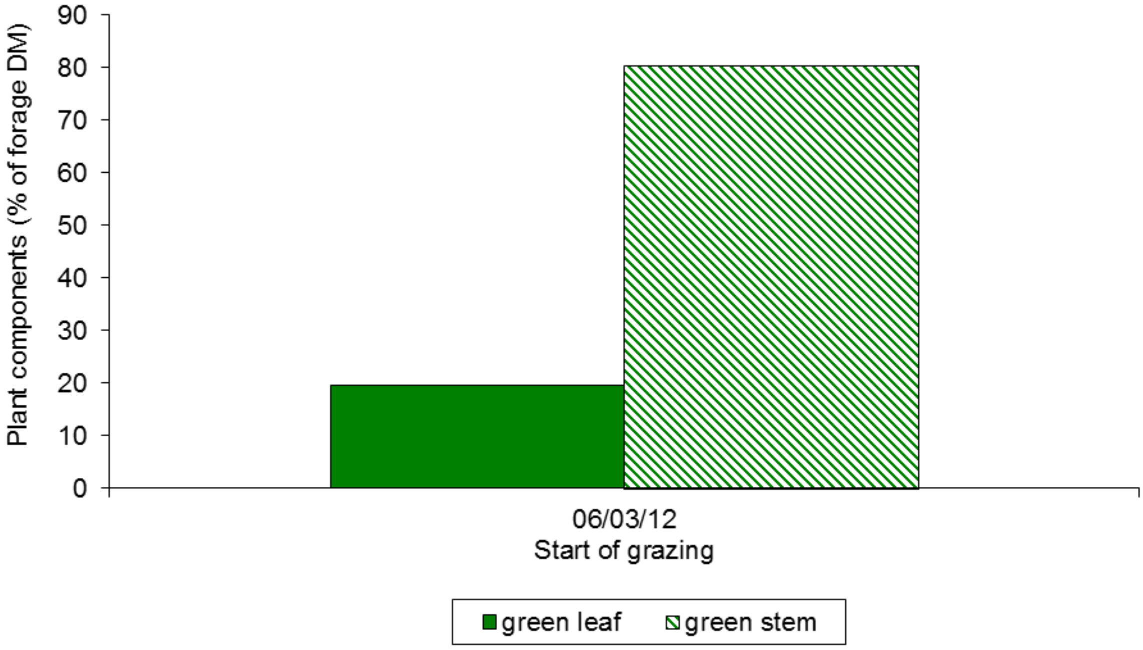

Fig. 69. Plant component composition (% of total forage DM) in the paddock during the grazing period (24/02/12–15/06/12).

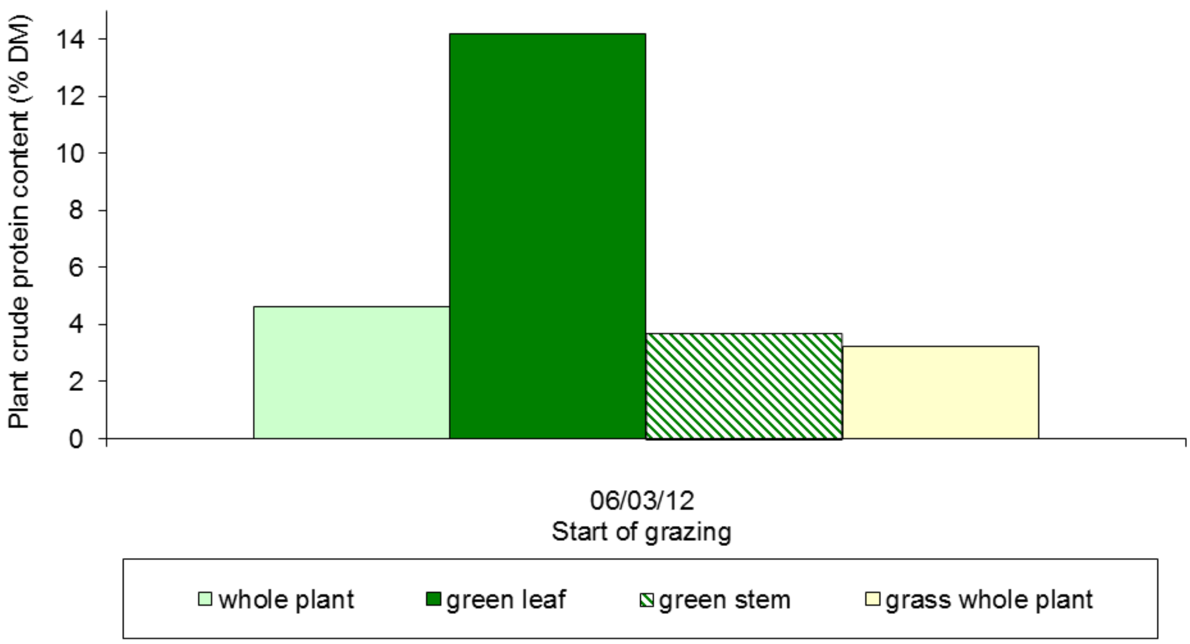

Fig. 70. Crude protein content (% DM) of forage sorghum whole plant and components in the paddock, and of perennial grass whole plant in the paddock, during the grazing period (24/02/12–15/06/12).

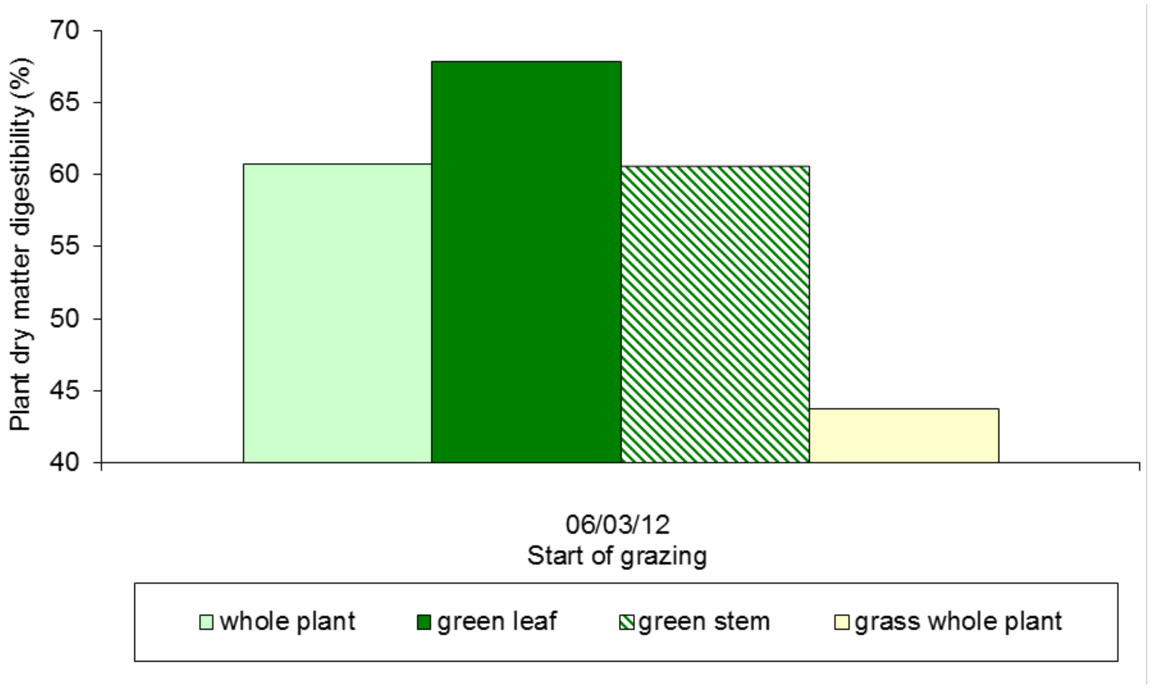

Fig. 71. Dry matter digestibility (%) of forage sorghum whole plant and components in the paddock, and of perennial grass whole plant in the paddock, during the grazing period (24/02/12–15/06/12).

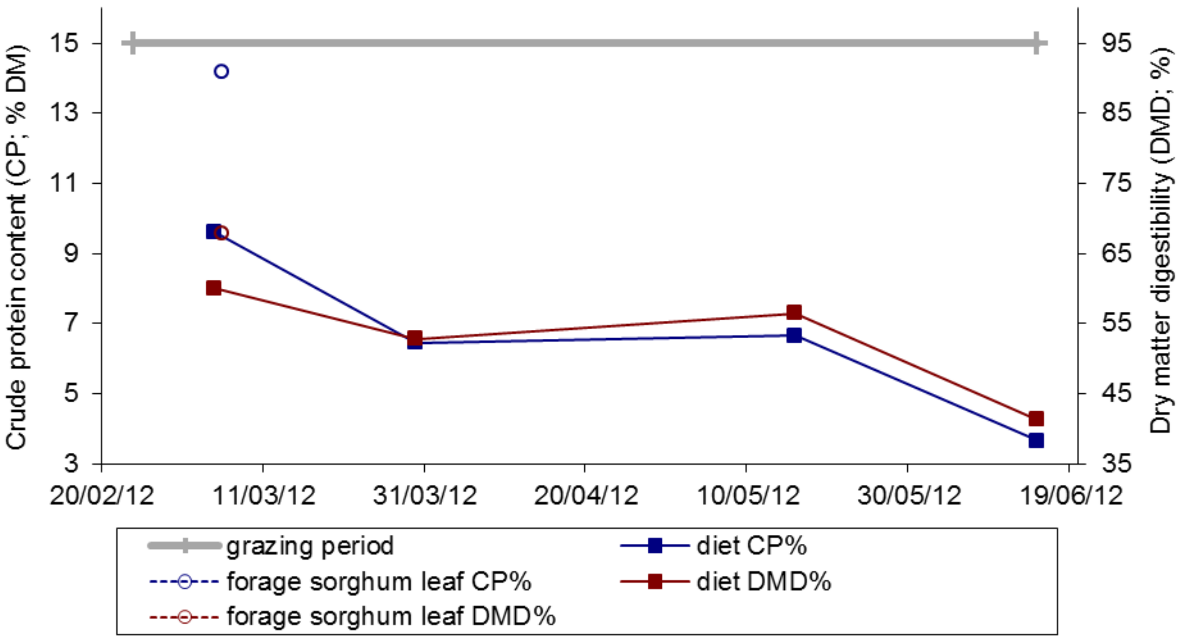

Fig. 72. Diet crude protein (CP) content (% DM) and dry matter digestibility (DMD; %) for grazing cattle predicted from faecal NIRS, and CP content and DMD of forage sorghum green leaf in the paddock. Grazing period shown.

Fig. 73. Forage sorghum crop, 05/03/12; 10 days after start of grazing.

Fig. 74. Cattle grazing the forage sorghum site, 05/03/12; 10 days after start of grazing.

Soil nutrient analysis prior to planting indicated that the paddock contained low to moderate levels of the major nutrients, reflecting inherent nutrient levels, the 8-year cropping history and lack of historical fertiliser application. Nitrogen fertiliser was applied at the rate of 49 kg N/ha which was calculated to provide sufficient N for crop growth given the level of available soil moisture. Organic C levels were moderate at 1% and P levels were moderate at 23 mg/kg (0-10 cm). Subsoil Cl was low (22 mg/kg), typical of this soil type. The forage sorghum crop was planted using minimal till (cultivation and chemical application). Total in-crop rainfall was 501.6 mm. Of this total, 320.2 mm fell between planting and commencement of grazing and 181.4 mm fell during the 112-day grazing period (Fig. 67).

Grazing of the crop commenced just prior to head emergence at 30,197 kg DM/ha biomass (Fig. 68) and a height of 316 cm, which was estimated be about 6 weeks later than ideal for optimising forage quality. This is corroborated by plant component proportions measured at the start of grazing indicating that the proportion of green leaf formed only 19.6% of the biomass DM with green stem forming the remaining 80,4% (Fig. 69). Forage biomass in the paddock had declined to 2,516 kg DM/ha by the end of the 112-day grazing period. Forage biomass in the exclosure also declined over the grazing period (from 35,598 to 19,104 kg DM/ha) which is likely to be caused by detachment and loss of plant parts and mature grain as the plants senesced. Such losses could have been the result of rain, wind or animals consuming and damaging the grain heads, or from loss of senesced plant parts during collection. However, it seems likely that maximum forage biomass was not detected since an intermediate measurement wasn't taken at the grain fill stage of the crop. The start of grazing biomass measurements were approximately double the highest biomass measurements recorded in the South Queensland Brigalow 2011-12 crop. However, the biomass measurements are consistent with the forage heights recorded, i.e. 30,197 kg DM/ha and 316 cm at start of grazing for this site versus 16,604 kg DM/ha and 178 cm at the South Queensland Brigalow 2011-12 site. While the same variety was sown at both sites, the Central Queensland Brigalow 2011-12 crop was sown at a higher seeding rate than the South Queensland Brigalow 2011-12 crop (5.5 vs. 2.3 kg/ha), had greater plant available water at planting (110 vs. 53 mm) and received higher rainfall between planting and start of grazing (320 vs. 275 mm). These factors are likely to be the explanation for the much higher yields at this site. The oats yield on this same property in the 2012 season (Central Queensland Brigalow, Oats 2012) was also very high relative to other sites and published reports. The very high forage sorghum yield at this site exceeds biomass yields measured as cumulative growth from plant biomass cuts in south-west Queensland (range 6,800-22,200 kg DM/ha; Bell *et al.* 2012) and the Darling Downs region of southern Queensland (range 3,050-14,410 kg DM/ha; Chataway *et al.* 2011b). Our values are also high relative to the Sugargraze forage sorghum yields measured in Pacific Seeds forage variety trials in south east Queensland: 9,900 and 11,600 kg DM/ha (Stuart 2002). However, a similar yield of 33,000 kg DM/ha was obtained from an irrigated late flowering sweet sorghum hybrid grown near Trangie, near New South Wales (Muldoon 1985).

The daily liveweight gain of cattle measured at this site (0.23–0.37 kg/head/day over 112 days) was around half that assumed in the constructed scenario for forage sorghum grown in the Central Queensland Brigalow region (0.6 kg/head/day over a similar period of 120 days; Table 30). This is despite the cattle being younger with lower starting weights (335-477 kg) when compared to those in the constructed scenario (524 kg).

It is evident that the quality of the forage sorghum was the limiting factor for cattle growth rates at this site. The sorghum was already quite mature at the start of grazing with a low proportion of green leaf (19.6%) and correspondingly low total plant CP and DMD (4.6 % DM and 60.7%, respectively), (Fig. 69, Fig. 70, Fig. 71 and Fig. 73). The perennial grass whole plant samples were lower in quality than the forage sorghum whole plant samples when assessed at the start of the grazing period (Fig. 70 and Fig. 71). The diet DMD, predicted from faecal NIRS, was 60% at the start of grazing and only 41% on 15/06/12 at the end of the 112-day grazing period (Fig. 72). Furthermore, diet CP content, predicted from faecal NIRS, dropped from 9.6% at the start of grazing to 3.7% at the end of the grazing period. The height of forage at commencement of grazing (316 cm) was over twice that considered ideal for optimising plant and animal productivity (100–150 cm; Bowen *et al.* 2010) and together with the propensity of the variety to produce thick stems (Stuart 2002) would account for the low quality of the forage. Furthermore, the stocking rate on the forage sorghum area was only 2.2 AE/ha (1.3 AE/ha on the total grazing area), which is well below stocking rate of 3.0 AE/ha assumed in the constructed scenario which was based on what was deemed best practice management.

The 1-year old heifers monitored at this site had a growth rate 23% less than that of steers from the same age cohort. The heifers were spayed immediately prior to entry to the forage sorghum crop and this may have caused weight gains to have been lower than if they had been entire (Jeffery *et al.* 1997; Jubb *et al.* 2003; McCosker *et al.* 2010; Petherick *et al.*

2011). The total beef production from this site of 53 kg/ha was low due to the combined effect of low daily cattle growth rates and low stocking rate.

Cattle production from forage sorghum at this site resulted in marginal profitability with the gross margin being only $12/ha when calculated using owner rates and -$47/ha when calculated using contract rates. This result is consistent with the relatively low cattle growth rates and total estimated beef production per hectare. In addition, the cattle price margin was only $0.10/kg liveweight and the forage costs calculated using owner rates ($169/ha expressed per forage area only) were high compared to other sites monitored in the 2011-12 season. The high planting costs were a result of the fertiliser application to this crop as well as the requirement for two cultivation operations (one using a chisel plough and one using offsets) due to the ground being very hard prior to planting. As all cattle grazing this crop were moved into an oats forage paddock at the end of the grazing period rather than being sold, the gross margin calculated for this site was not actually realised by the producer. Furthermore, any additional value of forage sorghum in allowing perennial pastures to be spelled over the wet season, and thus in increasing the carrying capacity of property, is not accounted for in the gross margin analysis.

3.2.2 South Queensland Brigalow, Forage sorghum 2011-12

(S 25.899, E 149.664; near Taroom)

The site was a ca. 77.7 ha paddock planted to 56.5 ha of Sugargraze forage sorghum over 02/12/11–18/12/11. The site had been farmed for forage production for ca. 20 years with primarily forage oats but also some forage sorghum for silage production in earlier years. None of these previous crops had any fertiliser application. A summary of key site details are given in Table 11 and Fig. 75-Fig. 81.

Table 11. Site details. South Queensland Brigalow, Forage sorghum 2011-12
For definitions of abbreviations see Glossary of terms and abbreviations

<table>
<tr><th>Factor</th><th colspan="3">Details</th></tr>
<tr><td colspan="4">Soil characterisation</td></tr>
<tr><td>Broad land type</td><td colspan="3">Brigalow</td></tr>
<tr><td>Soil type and characteristics</td><td colspan="3">Brown cracking clay (Vertosol)
PAWC: 180 mm
Soil depth: 120 cm</td></tr>
<tr><td rowspan="7">Soil nutrient levels at planting</td><td></td><td>0–10 cm</td><td>10–90 cm</td></tr>
<tr><td>Nitrate N (mg/kg)</td><td>12</td><td>5.7</td></tr>
<tr><td>Nitrate N total (kg/ha)</td><td colspan="2">81</td></tr>
<tr><td>P (mg/kg)</td><td>17</td><td>n/a</td></tr>
<tr><td>Organic C (%)</td><td>1.4</td><td>n/a</td></tr>
<tr><td>Cl (mg/kg)</td><td>24</td><td>550</td></tr>
<tr><td>Plant available water (mm)</td><td colspan="2">53</td></tr>
<tr><td colspan="4">Paddock preparation and forage sowing details</td></tr>
<tr><td>Planting date</td><td colspan="3">02/12/11–18/12/11</td></tr>
<tr><td>Sowing rate</td><td colspan="3">2.3 kg/ha</td></tr>
<tr><td>Fertiliser</td><td colspan="3">None</td></tr>
<tr><td>Fallow weed control</td><td colspan="3">Full cultivation</td></tr>
<tr><td>Total in-crop rainfall</td><td colspan="3">375.0 mm (02/12/11–08/06/12; property records, ca. 1.5 km from site)</td></tr>
<tr><td colspan="4">Forage production</td></tr>
<tr><td>Sorghum green leaf at start of grazing</td><td colspan="3">30% of biomass, 11.4% CP, 66% DMD</td></tr>
<tr><td>Sorghum peak biomass</td><td colspan="3">Paddock: 16,604 kg DM/ha, Exclosure: 14,814 kg DM/ha</td></tr>
<tr><td>Average diet quality</td><td colspan="3">10.3% CP, 57% DMD (Days 15-60 of grazing period)</td></tr>
<tr><td>Average perennial grass presentation yield</td><td colspan="3">Estimate of grass yield not available. Major species: Buffel, Queensland bluegrass, green panic.</td></tr>
</table>

Factor	Details	
Grazing management and animal production		
Comments	Two groups of cattle grazed the paddock, as one mob, for the entire grazing period (181 head in total). The cattle were steers and either 2.3 or 1.3 years old at entry to the forage. Of the 167 1-year old steers and 14 2-year old steers, 95% and 43% were monitored for weight gain, respectively. All steers grazed buffel grass pasture prior to forage entry. The 2-year old steers were moved to an oats paddock at the end of the forage sorghum grazing whilst the 1-year old steers returned to buffel pasture.	
Cattle type monitored for weight gain	Steers; either 2.3 or 1.3 years old at entry; ca. 30% *B. indicus* content	
Animal health treatments	At entry to forage the cattle were vaccinated against clostridial diseases (5-in-1).	
Feeding period	21/02/12–08/06/12 (108 days)	
Grazing days over which LW was measured	108 (21/02/12–08/06/12)	
Proportion of the total grazing area as forage sorghum	73%	
Average SR (forage area only)	3.3 AE/ha	
Average SR (total grazing area)	2.4 AE/ha	
2-year old steers		
Number of cattle in weight gain dataset	6	
Average entry LW (± SE)	549 (± 6.7) kg	
Average exit LW (± SE)	565 (± 12.7) kg	
Average LWG (± SE)	0.15 (0.040) kg/head/day	
1-year old steers		
Number of cattle in weight gain dataset	160	
Average entry LW (± SE)	427 (3.4) kg	
Average exit LW (± SE)	491 (3.4) kg	
Average LWG (± SE)	0.59 (0.010) kg/head/day	
Total LWG (forage sorghum area only)	192 kg/ha/annum	
Total LWG (total grazing area)	140 kg/ha/annum	
Economic performance		
	Forage area only ($/ha/annum)	**Total grazing area ($/ha/annum)**
Gross margin - owner rates	**333**	**243**
Forage costs	125	91
Gross margin - contract rates	**268**	**196**
Forage costs	190	139
CONSTRUCTED SCENARIO (0% total area as perennial grass)		
Gross margin - owner rates	**-14**	**-14**
Forage costs	172	172
Gross margin - contract rates	**-113**	**-113**
Forage costs	270	270

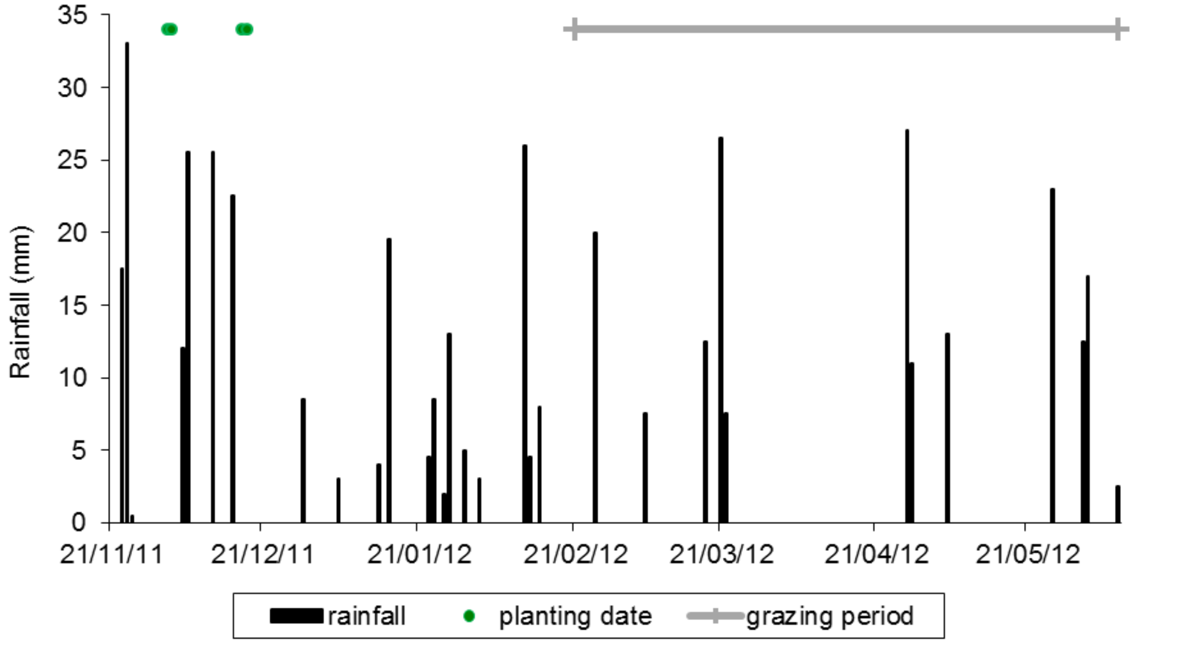

Fig. 75. Daily rainfall (mm) over the in-crop period (02/12/11–08/06/12). Measured on property, ca. 1.5 km from the trial paddock. Planting dates and grazing period shown.

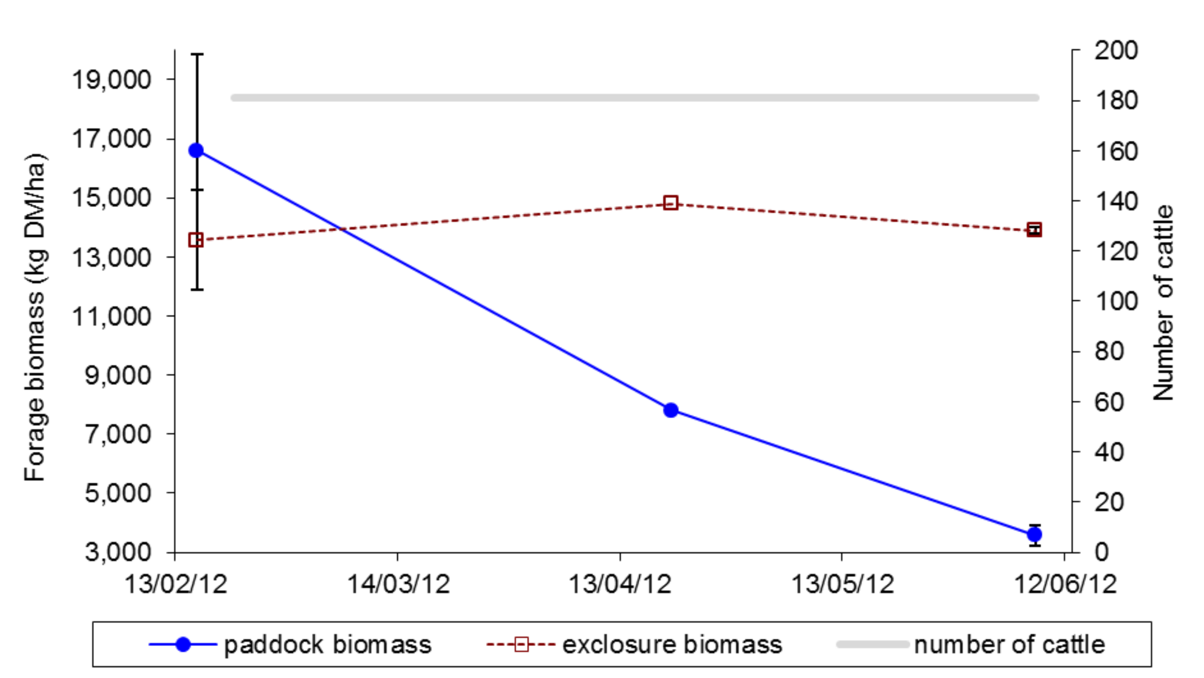

Fig. 76. Forage sorghum biomass (kg DM/ha; mean ± SE) in the paddock and exclosure, and cattle numbers during the grazing period (21/02/12–08/06/12).

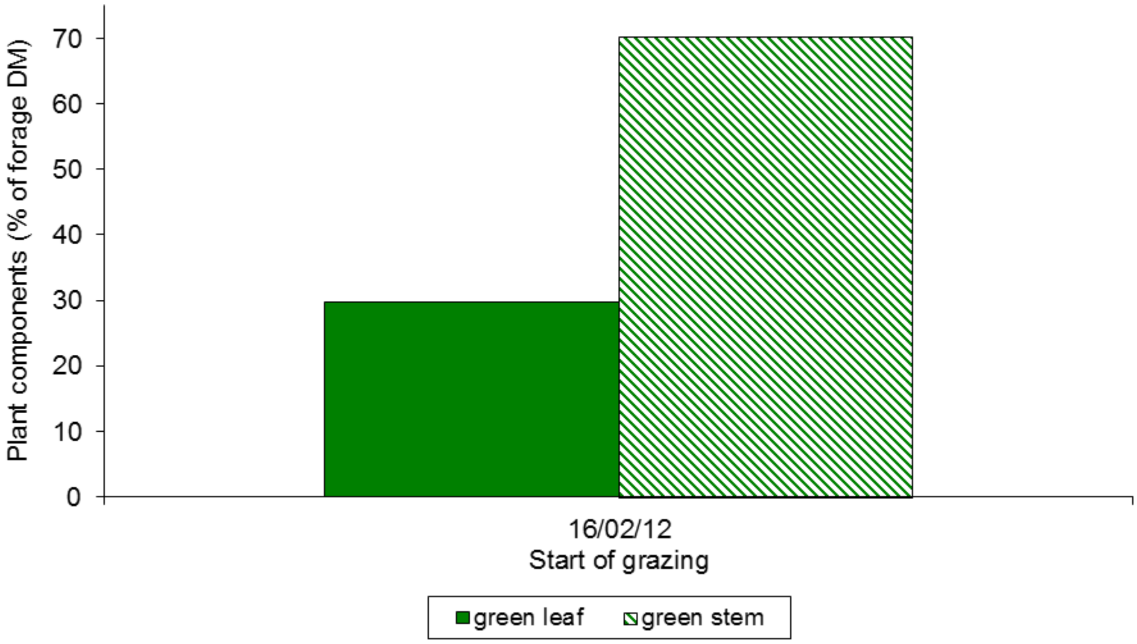

Fig. 77. Plant component composition (% of total forage DM) in the paddock during the grazing period (21/02/12–08/06/12).

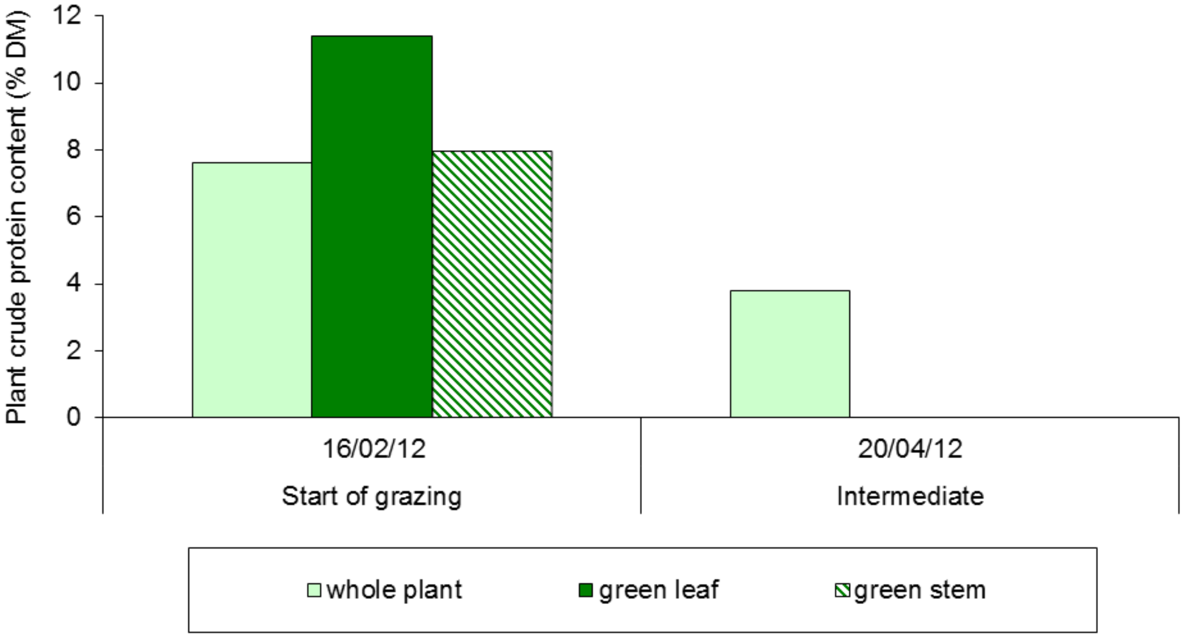

Fig. 78. Crude protein content (% DM) of forage sorghum whole plant and components in the paddock during the grazing period (21/02/12–08/06/12).

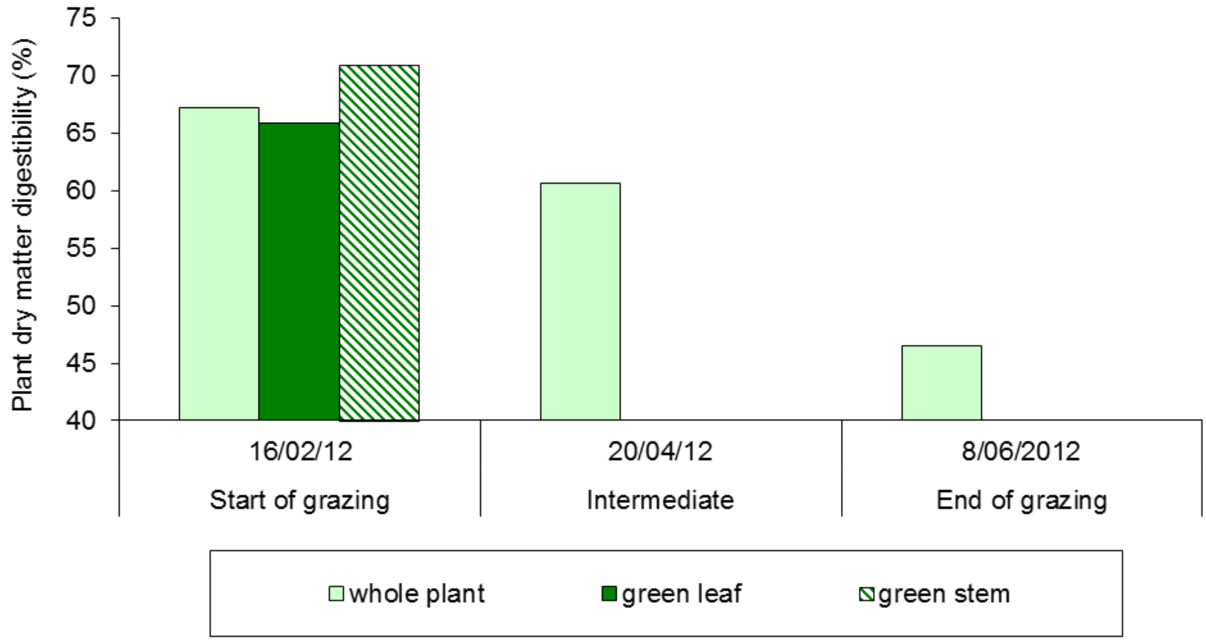

Fig. 79. Dry matter digestibility (%) of forage sorghum whole plant and components in the paddock during the grazing period (21/02/12–08/06/12).

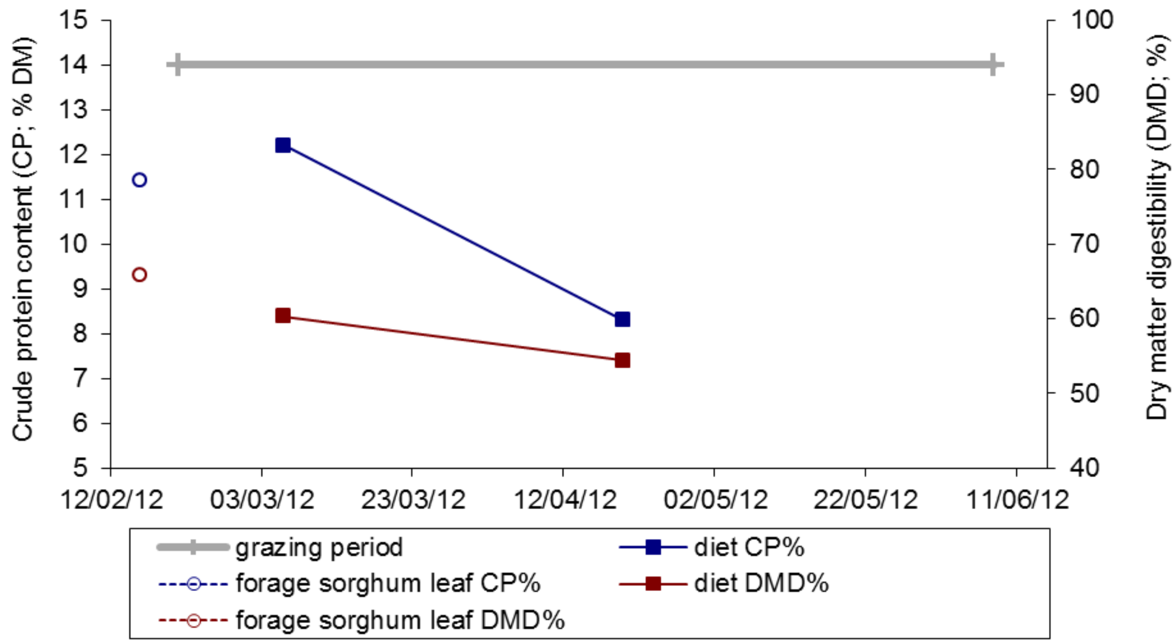

Fig. 80. Diet crude protein (CP) content (% DM) and dry matter digestibility (DMD; %) for grazing cattle predicted from faecal NIRS, and CP content and DMD of forage sorghum green leaf in the paddock. Grazing period shown.

Fig. 81. Forage sorghum exclosure, 16/02/12; (5 days prior to start of grazing).

Soil nutrient analysis prior to planting indicated moderate levels of N and P. The forage sorghum crop was planted using full cultivation. Nitrogen fertiliser was not applied. Total in-crop rainfall was 375 mm. Of this total, 195 mm fell prior to start of grazing and 180 mm fell during the grazing period (Fig. 75).

Grazing of the crop commenced at the late tillering stage prior to head emergence at 16,600 kg DM/ha biomass in the paddock (Fig. 76 and Fig. 81) and a height of 178 cm. Similar to the Central Queensland Brigalow forage sorghum crop for 2011-12, the forage was already quite mature at start of grazing with green leaf forming only 30% of the biomass and green stem 70% (Fig. 77). The high stem content is consistent with the propensity of the variety to produce thick stems (Stuart 2002). Forage biomass in the paddock had declined to 3,566 kg DM/ha by the end of the 108-day grazing period.

Plant chemical analysis (Fig. 78 and Fig. 79) showed that sorghum green leaf and whole plant CP and DMD was already relatively low at start of grazing and decreased, as expected, over the grazing period. The diet DMD was 60% on Day 15 of the grazing period and had decreased to 54% by Day 60 (Fig. 80). Diet CP decreased from 12.2 to 8.3% over the same period. Neither plant nor faecal samples were available for the final 49 days of the 108-day grazing period.

The daily liveweight gain of 1-year old steers grazing the forage sorghum paddock (0.59 kg/head/day) was similar to that assumed in the constructed scenario for forage sorghum grown in the South Queensland Brigalow region (0.55 kg/head/day). However, the weight gain of the six, 2-year old steers was much lower: 0.15 kg/head/day. The starting liveweight of the 1-year old steers were lower (428 kg), and of the 2-year old steers heavier (549 kg), than that assumed in the case study scenario (525 kg). The grazing period for steers at this site was less than that assumed in the case study (108 compared to 130 days) however, the stocking rate was higher (3.3 AE/ha vs. 2.5 AE/ha, when considering the forage area alone). In contrast to the Central Queensland Brigalow forage sorghum crop for 2011-12, the stocking rate relative to available biomass was much higher and it can be inferred that this allowed forage quality to be maintained at a level sufficient to sustain reasonable cattle growth rates and beef production per hectare (140 kg/ha for the total grazing area).

Cattle production from forage sorghum at this site resulted in a profitable outcome with the gross margin for the total grazing area being $243/ha calculated using owner rates and $196/ha using contract rates. This profitable result was in part due to the relatively low planting costs ($125/ha, calculated using owner rates for the forage area only). In addition, the reasonable beef production per hectare (140 kg/ha for the total grazing area) and positive cattle price margin of $0.12/kg liveweight contributed to the positive gross margin. As none of the cattle grazing this forage crop were sold at the end of the grazing period, the gross margin calculated for this site was not actually realised by the producer. Furthermore, any additional value of forage sorghum in allowing perennial grass pastures to be spelled over the wet season, and thus in increasing the carrying capacity of the property, is not accounted for in the gross margin analysis.

3.2.3 Central Queensland Open Downs, Forage sorghum 2012-13

(S 22.978, E 147.884; near Capella)

The forage paddock was a 255 ha paddock planted to 229 ha of Sugargraze forage sorghum on 10/02/13. The forage paddock had been originally cleared of timber in the 1960s and then used as a cultivation paddock to grow grain sorghum, sunflower, wheat or forage sorghum for ca. 40 years. During the entire grazing period cattle were also given access to an adjacent perennial grass paddock of 130 ha, consisting of 81.4 ha of buffel grass and 48.6 ha of silk sorghum. Observations by the producer indicated that the cattle did not spend a lot of time grazing in this adjacent grass paddock and mainly utilised it for its water point and as an area to camp or rest. From 20/05/13, after 33 days of grazing, access was also provided to an additional perennial grass paddock (largely buffel grass) of 100 ha. This second grass paddock was observed to be utilised by the cattle which spent an increasing amount of time there as the forage sorghum crop biomass and quality declined. A summary of key site details are given in Table 12 and Fig. 82-Fig. 90.

Table 12. Site details. Central Queensland Open Downs, Forage Sorghum 2012-13
For definitions of abbreviations see Glossary of terms and abbreviations

<table>
<tr><th>Factor</th><th colspan="3">Details</th></tr>
<tr><td colspan="4">Soil characterisation</td></tr>
<tr><td>Broad land type</td><td colspan="3">Brigalow undulating plain</td></tr>
<tr><td>Soil type and characteristics</td><td colspan="3">Black cracking clay (Vertosol), not as heavy as for the Open Downs land type
PAWC: average 180 mm
Soil depth: average 90 cm</td></tr>
<tr><td rowspan="7">Soil nutrient levels at planting</td><td></td><td>0-10 cm</td><td>10-120 cm</td></tr>
<tr><td>Nitrate N (mg/kg)</td><td>6</td><td>n/a</td></tr>
<tr><td>Nitrate N total (kg/ha)</td><td>6.9</td><td>n/a</td></tr>
<tr><td>P (mg/kg)</td><td>16</td><td>n/a</td></tr>
<tr><td>Organic C (%)</td><td>1.3</td><td>n/a</td></tr>
<tr><td>Cl (mg/kg)</td><td>10</td><td>n/a</td></tr>
<tr><td>Plant available water (mm)</td><td colspan="2">n/a</td></tr>
<tr><td colspan="4">Paddock preparation and forage sowing details</td></tr>
<tr><td>Planting date</td><td colspan="3">10/02/13</td></tr>
<tr><td>Sowing rate</td><td colspan="3">8 kg/ha</td></tr>
<tr><td>Fertiliser</td><td colspan="3">None</td></tr>
<tr><td>Fallow weed control</td><td colspan="3">Zero till</td></tr>
<tr><td>Total in-crop rainfall</td><td colspan="3">190 mm (10/02/13–19/08/13; combination of Capella Post Office (BOM Station 35016) and on-site weather station data)</td></tr>
<tr><td colspan="4">Forage production</td></tr>
<tr><td>Sorghum green leaf at start of grazing</td><td colspan="3">23% of biomass, 14.3% CP, 65% DMD</td></tr>
<tr><td>Sorghum peak biomass</td><td colspan="3">Paddock and Exclosure: 9,573 kg DM/ha</td></tr>
<tr><td>Average diet quality</td><td colspan="3">7.2% CP, 52% DMD (Days 3-97 of grazing period)</td></tr>
<tr><td>Average perennial grass presentation yield</td><td colspan="3">6,488 kg DM/ha (average of assessments made on 22/05/13, 24/06/13 and 22/07/13). Major species: buffel (99%).</td></tr>
</table>

Factor	Details	
Grazing management and animal production		
Comments	A total of 350 steers grazed the forage for 124 days with 19 of these (5.4%) monitored for weight gain. A total of 128 of the steers were sent to slaughter at Teys Biloela abattoir 39 days after exiting the forage.	
Cattle type monitored for weight gain	Steers; ca. 24 months old at entry; Santa Gertrudis x Droughtmaster, ca. 44% *B. indicus* content	
Animal health treatments	None	
Feeding period	17/04/13–19/08/13 (124 days)	
Grazing days over which liveweight was measured	124 (17/04/13–19/08/13)	
Proportion of the total grazing area as forage sorghum	50%	
Average SR (forage area only)	1.7 AE/ha	
Average SR (total grazing area)	0.9 AE/ha	
Number of cattle in weight gain dataset	19	
Average entry liveweight (± SE)	507 (± 7.8) kg	
Average exit liveweight (± SE)	561 (± 7.6) kg	
Average LWG (± SE)	0.43 (± 0.019) kg/head/day	
Total LWG (forage area only)	82 kg/ha/annum	
Total LWG (total grazing area)	41 kg/ha/annum	
Economic performance		
	Forage area only ($/ha/annum)	**Total grazing area ($/ha/annum)**
Gross margin - owner rates	**87**	**41**
Forage costs	24	12
Gross margin - contract rates	**61**	**29**
Forage costs	50	24
CONSTRUCTED SCENARIO (0% total area as perennial grass)		
Gross margin - owner rates	**82**	**82**
Forage costs	194	194
Gross margin - contract rates	**-$16**	**-$16**
Forage costs	$292	$292

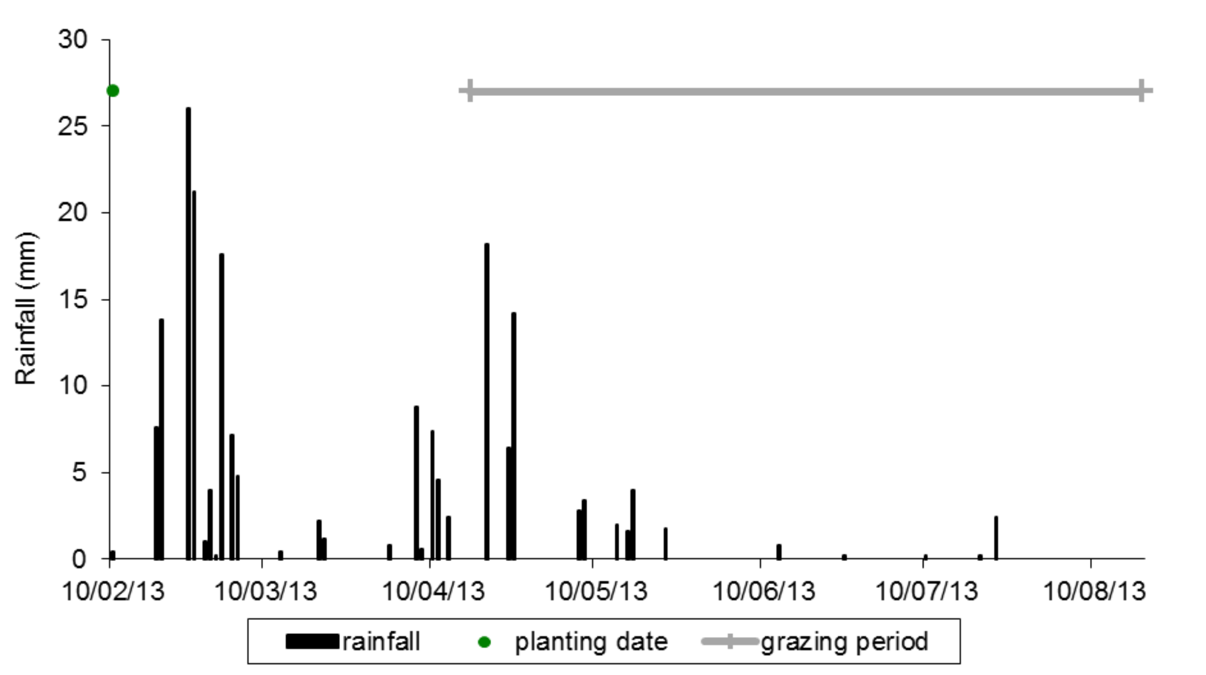

Fig. 82. Daily rainfall (mm) over the in-crop period (10/02/13–19/08/13). Measured at Capella Post Office (BOM Station 35016; 10/02/13-12/03/13, and 22/07/13-19/08/13) and on-site weather station (13/03/13-21/07/13). Planting date and grazing period shown.

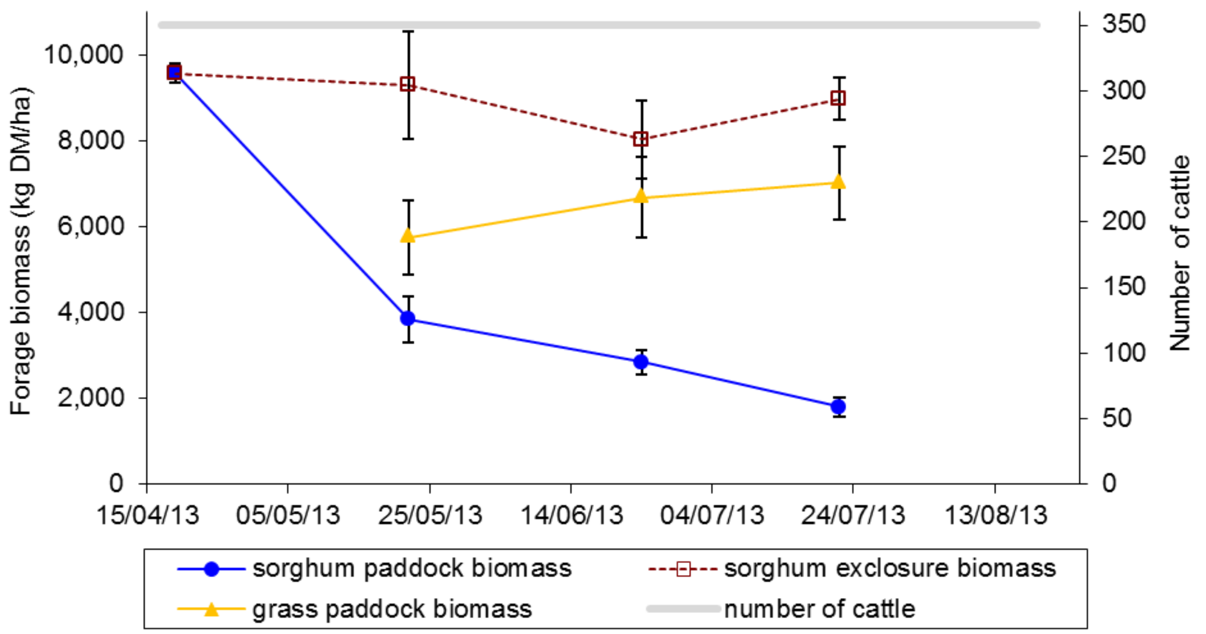

Fig. 83. Forage sorghum biomass (kg DM/ha; mean ± SE) in the paddock and exclosure, and cattle numbers during the grazing period (17/04/13–19/08/13). No forage samples were taken during the last 28 days of grazing when only unpalatable material remained in the forage paddock and cattle were observed to be primarily grazing in the adjacent buffel grass paddock.

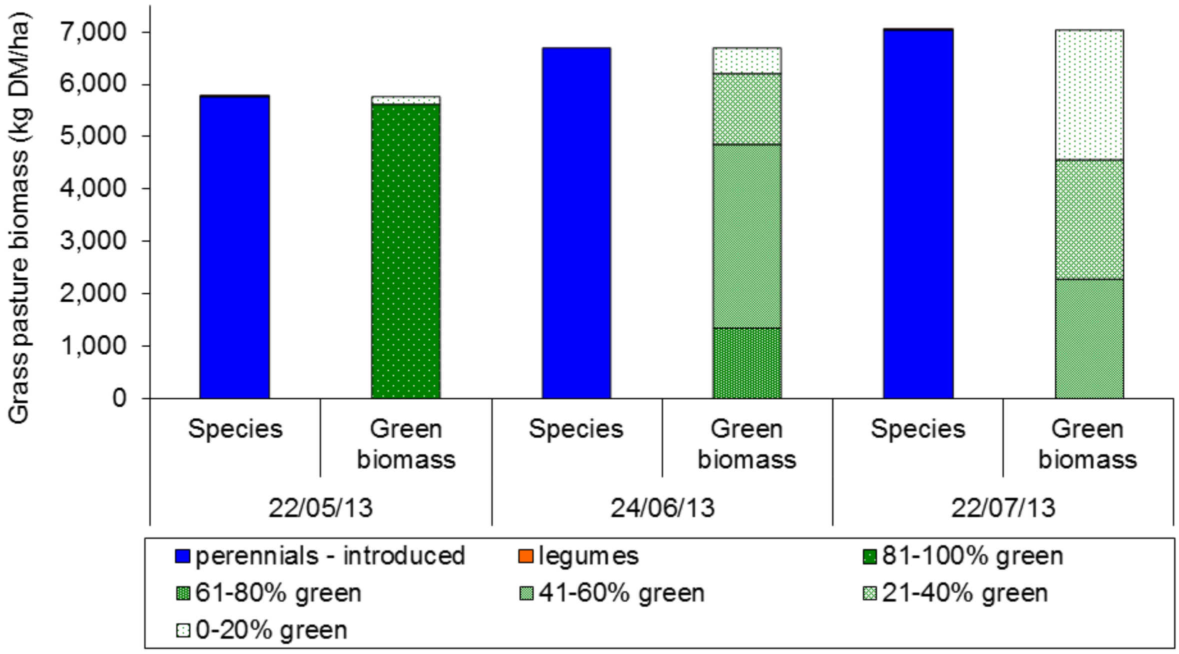

Fig. 84. Perennial pasture species composition (Species) and proportion of green material in the pasture (Green biomass) shown as a proportion of total pasture biomass (kg DM/ha). Introduced perennial grasses consisted of buffel; legumes were native species.

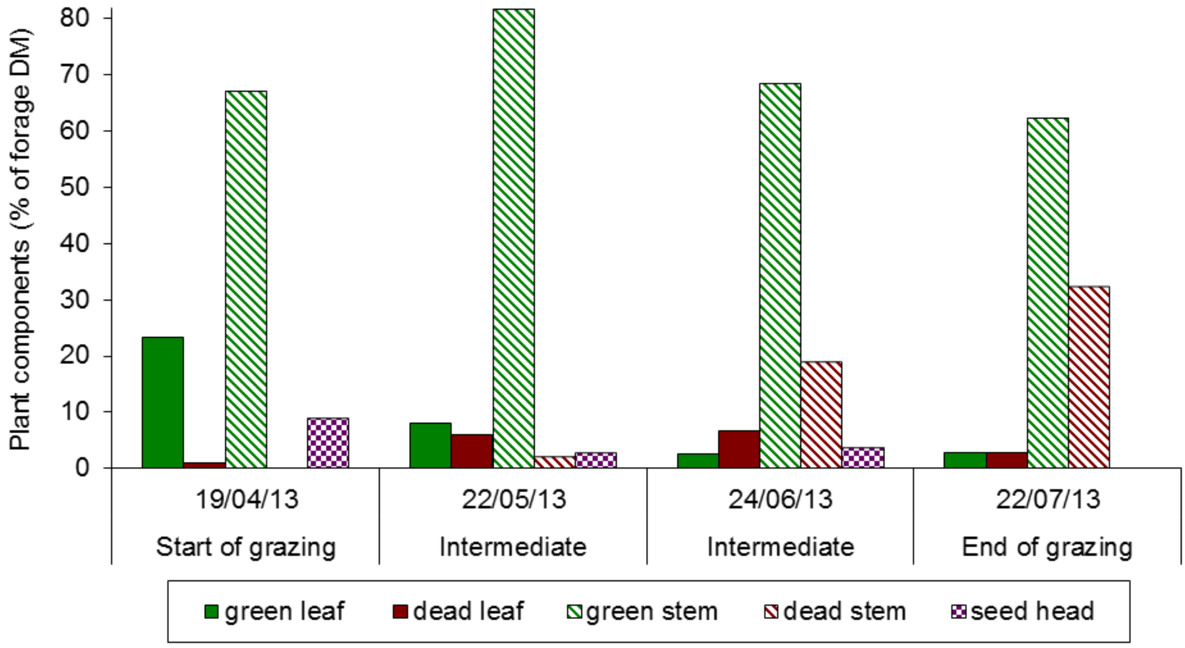

Fig. 85. Plant component composition (% of total forage DM) in the paddock during the grazing period (17/04/13–19/08/13). No forage samples were taken during the last 28 days of grazing when only unpalatable material remained in the forage paddock and cattle were observed to be primarily grazing in the adjacent buffel grass paddock.

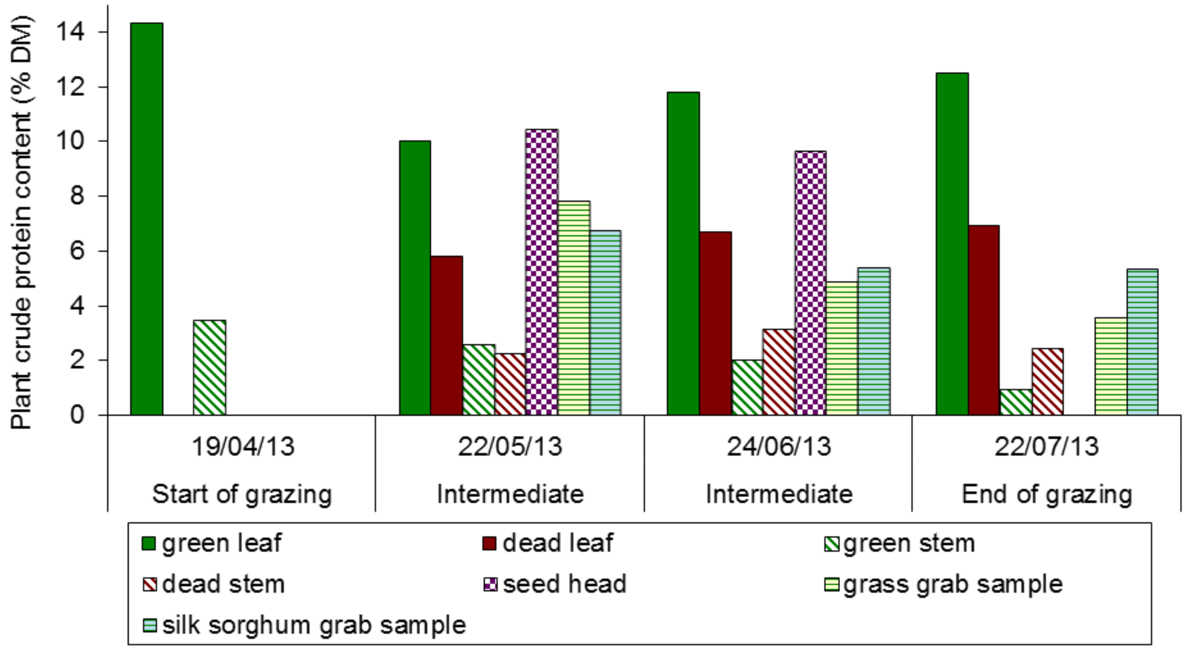

Fig. 86. Crude protein content (% DM) of forage sorghum plant components in the paddock, and of perennial grass and silk sorghum grab samples in the paddock, over the grazing period (17/04/13-19/08/13).

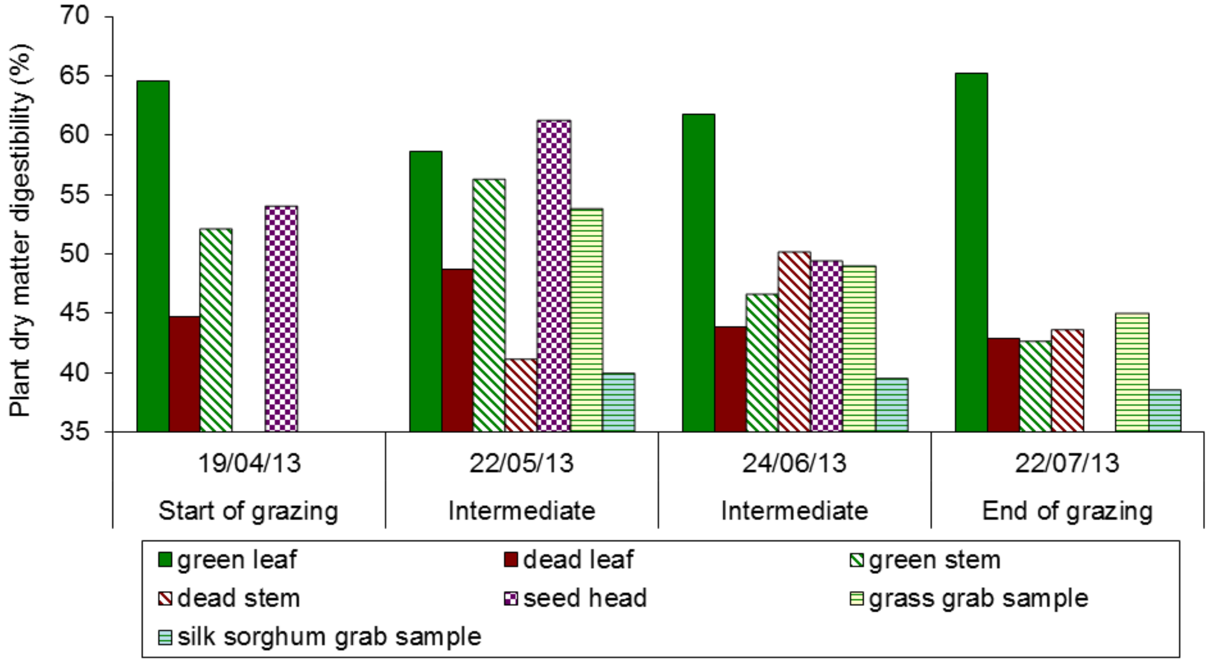

Fig. 87. Dry matter digestibility (%) of forage sorghum plant components in the paddock, and of perennial grass and silk sorghum grab samples in the paddock, over the grazing period (17/04/13-19/08/13).

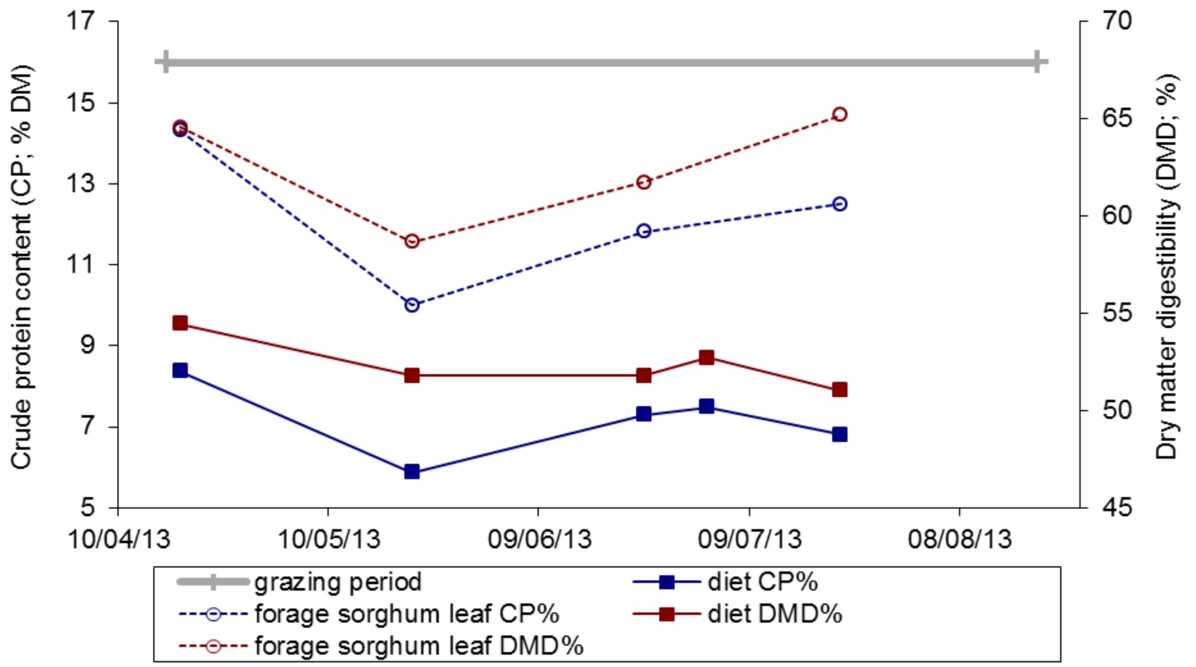

Fig. 88. Diet crude protein (CP) content (% DM) and dry matter digestibility (DMD; %) for grazing cattle predicted from faecal NIRS; and measured CP and DMD content of forage sorghum green leaf in the paddock. Grazing period shown.

Fig. 89. Forage sorghum crop, 19/04/13; 2 days after the start of grazing.

Fig. 90. Forage crop and cattle, 22/07/13; Day 97 of grazing.

Soil chemical analyses were not available for the full soil profile. However, the concentration of nitrate-N in the top 10 cm (6.9 kg/ha) was low and it can be inferred that the concentration of nitrate-N was low throughout the soil profile due to low plant CP levels during the grazing period. Phosphorus levels were also marginal to low, at 16 mg/kg. This crop received no N fertiliser and the zero till method of fallow weed control was used. Although soil water measurements were not available prior to planting, it was evident that the soil profile was not full at this time due to some weeds present at planting. Total in-crop rainfall was 190.4 mm, with 132.2 mm falling prior to grazing and 58.2 mm falling during the 124-day grazing period (Fig. 82).

Grazing commenced just prior to seed head emergence when the forage sorghum biomass was 9,573 kg DM/ha (Fig. 83 and Fig. 89) and the height was 238 cm, which was estimated to about 4 weeks later than ideal for optimising forage quality. This is corroborated by plant component proportions measured at the start of grazing indicating that proportion of green leaf formed only 23% of the biomass DM with green stems forming the major portion of the biomass at 67% (Fig. 85). The starting forage biomass in this paddock was much less than that measured at the two, 2011-12 forage sorghum sites (30,197 and 16,604 kg DM/ha) despite the seeding rate at this site being higher at 8 kg/ha (cf. 5.5 and 2.3 kg/ha for the two 2011/12 sites, respectively). Sugargraze was the variety used at all three sites. The likely cause of the lower biomass at the current site was poor establishment, and thus low plant density, resulting from some competition from weeds at planting, seed sown in relatively wide rows and poor seed-soil contact.

Forage biomass in the paddock had declined to 1,809 kg DM/ha by the end of the 124-day grazing period. Forage biomass in the exclosure also declined over the grazing period (from 9,573 kg DM/ha to 8,975 kg DM/ha at the end of grazing measurement) which is likely to have been caused by detachment and loss of plant parts and mature grain as the plants senesced. Such losses could have been the result of rain, wind, or animals consuming and damaging the grain heads, or from loss of senesced plant parts during collection. The second sampling occasion occurred at the grain fill stage of the crop which would be expected to coincide with the maximum forage biomass in the exclosure. However, as the variability (as measured by standard error) between exclosure biomass samples on this date was very high, and exceeded the difference between the biomass measurements taken on the first and second sampling occasions, it is likely that there was no difference between the biomass measured on the two sampling occasions. The biomass measurement taken on the third sampling occasion in the exclosure was lower than at the final sampling date, at 8,031 kg DM/ha which is likely due to variability within the exclosure area and the difficulty in capturing a representative sub-sample. Ergot was present in forage sorghum seed heads in both the exclosure and paddock from the second sampling occasion (22/05/13).

The proportion of green forage sorghum leaf in the biomass decreased over time in the grazed paddock from 23% of the DM (2 days after the start of grazing) to 2.7% of the DM on Day 97 of grazing, when green and dead stem made up the bulk of the biomass (62 and 32% of the DM, respectively). Plant chemical analysis (Fig. 86 and Fig. 87) indicated that there was a large difference in quality between forage sorghum leaf and stem. At the start of the grazing period, the CP concentration in green stem material was 24% of that in green leaf (3.4 vs. 14.3% CP respectively). Furthermore, the DMD of green stem was 81% of that in green leaf (52 vs. 65%, respectively). Perennial grass biomass in the adjacent paddock averaged 6,488 kg DM/ha over the grazing period with the proportion of green material decreasing over time (Fig. 84). On the 22/05/13, 97% of perennial grass quadrats were assessed as being 81-100% green whilst by the 22/07/13, 100% of quadrats were assessed as being <61% green. As expected, the CP concentrations in 'grab' samples of perennial grass decreased over this same period from 7.8% CP on the 22/05/13 to 3.6% CP on 22/07/13. Similarly, silk sorghum grab samples decreased in CP from 6.8% CP on 22/05/13 to 5.3% on 22/07/13.

Predictions of diet CP concentrations from faecal NIRS analysis indicated that diet CP and DMD concentrations were highest at the start of grazing at 8.4% DM and 54%, respectively (Fig. 88). Diet DMD was closely linked to diet CP, which also followed the general trend for forage sorghum green leaf CP content which dropped to its lowest level after 35 days of grazing (22/05/13). The increase in forage sorghum quality after this time may have been due to the decreased stocking rate on the forage sorghum after 20/05/13, when the second buffel grass paddock of 100 ha was also provided.

The grazing period for this crop (124 days) was similar to that assumed in the constructed scenario for the Central Queensland Open Downs region (120 days; Table 29). However, the average stocking rate (1.7 AE/ha; forage area only) was much less than that assumed in the constructed scenario (3.0 AE/ha). Cattle at this site were also given access to the large additional perennial grass area (50% of the total grazing area, on average), which resulted in a stocking rate over the entire grazing area of only 0.9 AE/ha.

The daily weight gains of the subset of 2-year old steers monitored over the entire 124-day grazing period (0.43 kg/day) was in line with the low proportion of high quality green leaf available in the forage sorghum biomass and the correspondingly low values for diet CP and DMD. Although lower than the assumed growth rate of 0.6 kg/head/day for the constructed scenario, the daily weight gains at this site were within the range of that measured at other forage sorghum field sites in this project. The low stocking rate at this site resulted in the overall beef production being very low when expressed as either per forage area only or per total grazing area: 82 and 41 kg/ha/year, respectively.

Cattle production from forage sorghum at this site resulted in a profitable outcome with a gross margin for the total grazing area of $41/ha calculated using owner rates and $29/ha using contract rates. The gross margin calculated using contract rates for the constructed scenario for this region was negative (-$16/ha). This contrasts with the positive gross margin calculated using contract rates for this current site, despite beef production from the total grazed area being 4.9 times lower than that assumed for the constructed scenario (41 vs. 199 kg/ha/annum, respectively). The very low forage costs at this site of $24/ha for the forage area only (owner rates), compared to $194/ha for the constructed scenario, are the primary reason for the higher profitability of forage sorghum at this site. The cattle price margin at this site was $0.10, with the value of owned steers at entry to forage being $1.55/kg liveweight and the sale price being $1.65/kg liveweight. As only a portion of the cattle grazing this forage crop were sold at the end of the grazing period, the gross margin calculated for this site was not actually realised by the producer. Furthermore, any additional value of forage sorghum in allowing perennial grass pastures to be spelled over the wet season, and thus in increasing the carrying capacity of the property, is not accounted for in the gross margin analysis.

3.2.4 Central Queensland Brigalow, Forage sorghum 2012-13

(S 24.536, E 148.560; near Rolleston)

The site was a 246 ha paddock planted to 198 ha of Sugargraze forage sorghum on ca. 03/12/12. The site had been originally cleared of timber in ca. 1990 and cropped since 1992 with either forage or grain crops. A summary of key site details are given in Table 13 and Fig. 91-Fig. 99. This paddock was divided into 3 sections through which the cattle were rotated during the grazing period.

Table 13. Site details. Central Queensland Brigalow, Forage sorghum 2012-13
For definitions of abbreviations see Glossary of terms and abbreviations

<table>
<tr><th>Factor</th><th colspan="3">Details</th></tr>
<tr><td colspan="4">Soil characterisation</td></tr>
<tr><td>Broad land type</td><td colspan="3">Alluvial plain</td></tr>
<tr><td>Soil type and characteristics</td><td colspan="3">Heavy loam/light-medium clay
PAWC: 180 mm
Soil depth: 120 cm</td></tr>
<tr><td rowspan="7">Soil nutrient levels at planting but after fertiliser application</td><td></td><td>0–10 cm</td><td>10–120 cm</td></tr>
<tr><td>Nitrate N (mg/kg)</td><td>21</td><td>2</td></tr>
<tr><td>Nitrate N total (kg/ha)</td><td colspan="2">64</td></tr>
<tr><td>P (mg/kg)</td><td>130</td><td>n/a</td></tr>
<tr><td>Organic C (%)</td><td>1.8</td><td>n/a</td></tr>
<tr><td>Cl (mg/kg)</td><td>12</td><td>10</td></tr>
<tr><td>Plant available water (mm)</td><td colspan="2">93.7</td></tr>
<tr><td colspan="4">Paddock preparation and forage sowing details</td></tr>
<tr><td>Planting date</td><td colspan="3">03/12/12</td></tr>
<tr><td>Sowing rate</td><td colspan="3">4.5 kg/ha</td></tr>
<tr><td>Fertiliser</td><td colspan="3">40 kg N/ha</td></tr>
<tr><td>Fallow weed control</td><td colspan="3">Minimal till (cultivation and chemical application)</td></tr>
<tr><td>Total in-crop rainfall</td><td colspan="3">275 mm (03/12/12–17/06/13;
Rolleston airport (BOM Station 35129)</td></tr>
<tr><td colspan="4">Forage production</td></tr>
<tr><td>Sorghum green leaf at start of grazing</td><td colspan="3">56.8% of biomass, 13.3% CP, 64% DMD</td></tr>
<tr><td>Sorghum peak biomass</td><td colspan="3">Paddock: 2,308 kg DM/ha,
Exclosure: 17,243 kg DM/ha</td></tr>
<tr><td>Average diet quality</td><td colspan="3">10.1% CP, 58% DMD
(Days 4-113 of grazing period)</td></tr>
<tr><td>Average perennial grass presentation yield</td><td colspan="3">3,371 kg DM/ha (average of assessments made on 30/03/1, 21/05/13 and 17/06/13). Major species: buffel (29% of biomass), forest bluegrass (21%), sabi (17%).</td></tr>
</table>

Factor	Details	
Grazing management and animal production		
Comments	Two groups of steers (1000 in total) grazed the paddock, with 600 steers grazing the paddock for entire period of 139 da ys (Group 1) and a s econd group (Group 2) of 400 steers grazing the paddock from Day 13-33. T he paddock was divided into 3 sections through which the cattle were rotated during the grazing period. Only 9 head of cattle, from Group 1, were monitored for weight gain and only over the first 33 days of the grazing period. The starting weights were adjusted for assumed gut fill effects of 5% LW. All cattle were grazing buffel grass pastures prior to entering the forage paddock and w ere returned to perennial grass pastures at the completion of the forage grazing period.	
Cattle type monitored for weight gain	Steers; Group 1, ca. 12-18 months old at entry; Group 2, ca. 12 months old at entry. All cattle ca. 50-70% *B. indicus* content	
Animal health treatments	None	
Feeding period	29/01/13-17/06/13 (139 days)	
Grazing days over which LW was measured	33 (29/01/13-03/03/13)	
Proportion of the total grazing area as forage sorghum	80%	
Average SR (forage area only)	3.3 AE/ha	
Average SR (total grazing area)	2.6 AE/ha	
Group 1 steers		
Number of cattle in weight gain dataset	9	
Average entry LW (± SE)	336 (± 10.2) kg; adjusted for gut fill effects	
Average exit LW (± SE)	373 (± 11.7) kg	
Average LWG (± SE)	1.11 (± 0.126) kg/head/day	
Total LWG (forage area only)	316 kg/ha/annum Note: this is an estimate only	
Total LWG (total grazing area)	253 kg/ha/annum Note: this is an estimate only	
Economic performance		
	Forage area only ($/ha/annum)	**Total grazing area ($/ha/annum)**
Gross margin - owner rates	**-60**	**-48**
Forage costs	144	116
Gross margin - contract rates	**-99**	**-80**
Forage costs	184	148
CONSTRUCTED SCENARIO (0% total area as perennial grass)		
Gross margin - owner rates	**159**	**159**
Forage costs	138	138
Gross margin - contract rates	**80**	**80**
Forage costs	217	217

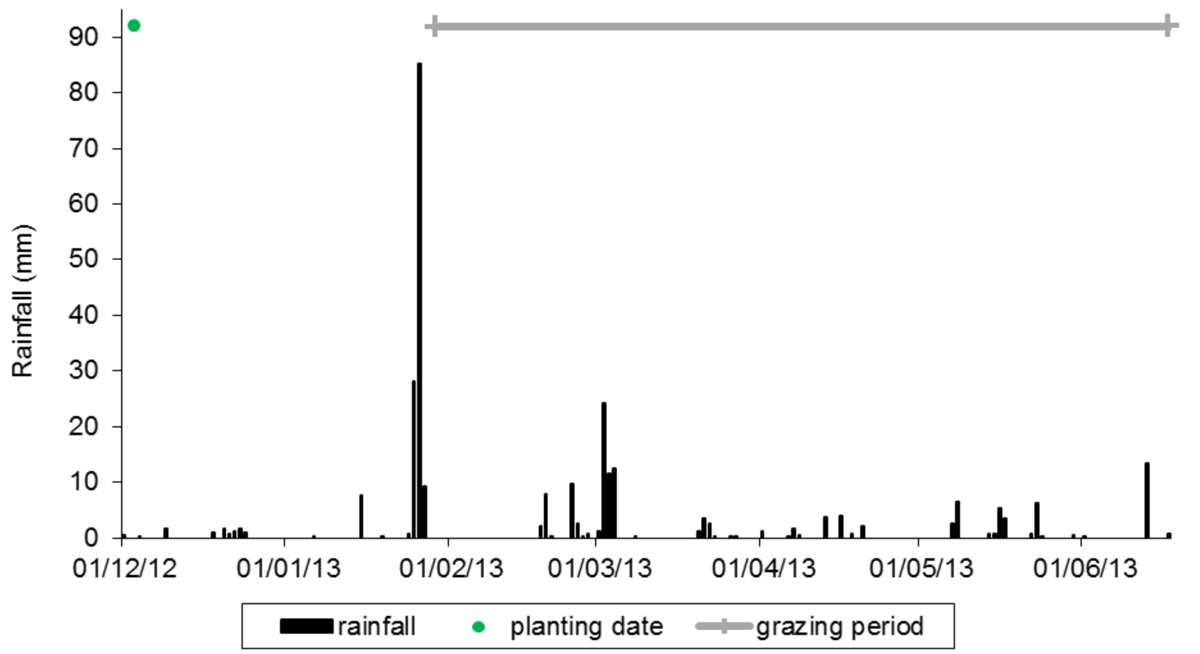

Fig. 91. Daily rainfall (mm) over the in-crop period (03/12/12–17/06/13). Measured at Rolleston airport (BOM Station 35129). Planting date and grazing period shown.

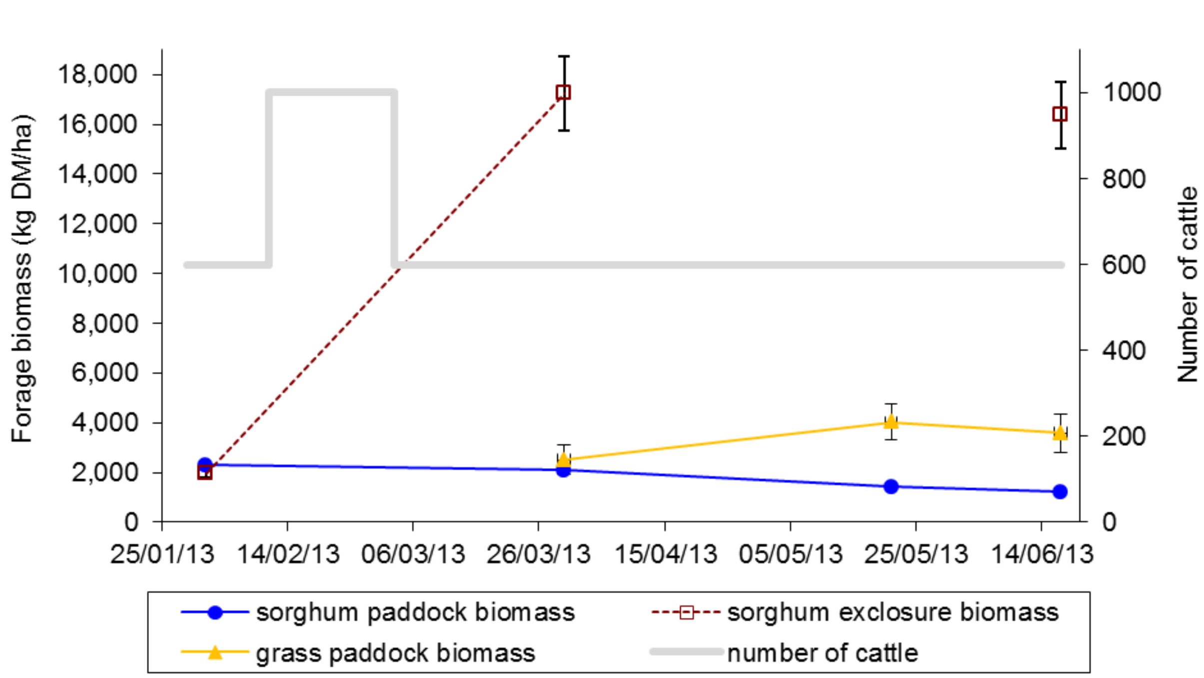

Fig. 92. Forage sorghum biomass (kg DM/ha; mean ± SE) in the paddock and exclosure, and cattle numbers during the grazing period (29/01/13-17/06/13).

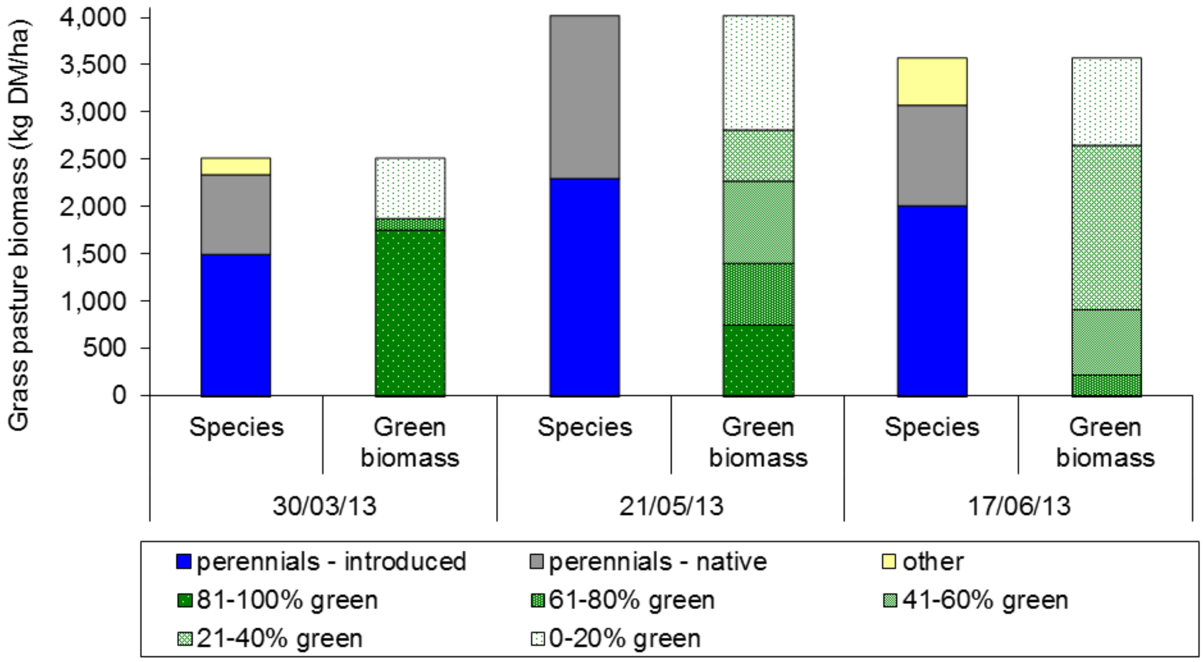

Fig. 93. Perennial pasture species composition (Species) and proportion of green material in the pasture (Green biomass) shown as a proportion of total pasture biomass (kg DM/ha). Introduced perennial grasses mainly consisted of buffel, sabi; and green panic; native perennial grasses were mainly forest bluegrass; 'other' species were mainly weeds, sedges and nut grass.

Fig. 94. Plant component composition (% of total forage DM) in the paddock during the grazing period (29/01/13-17/06/13).

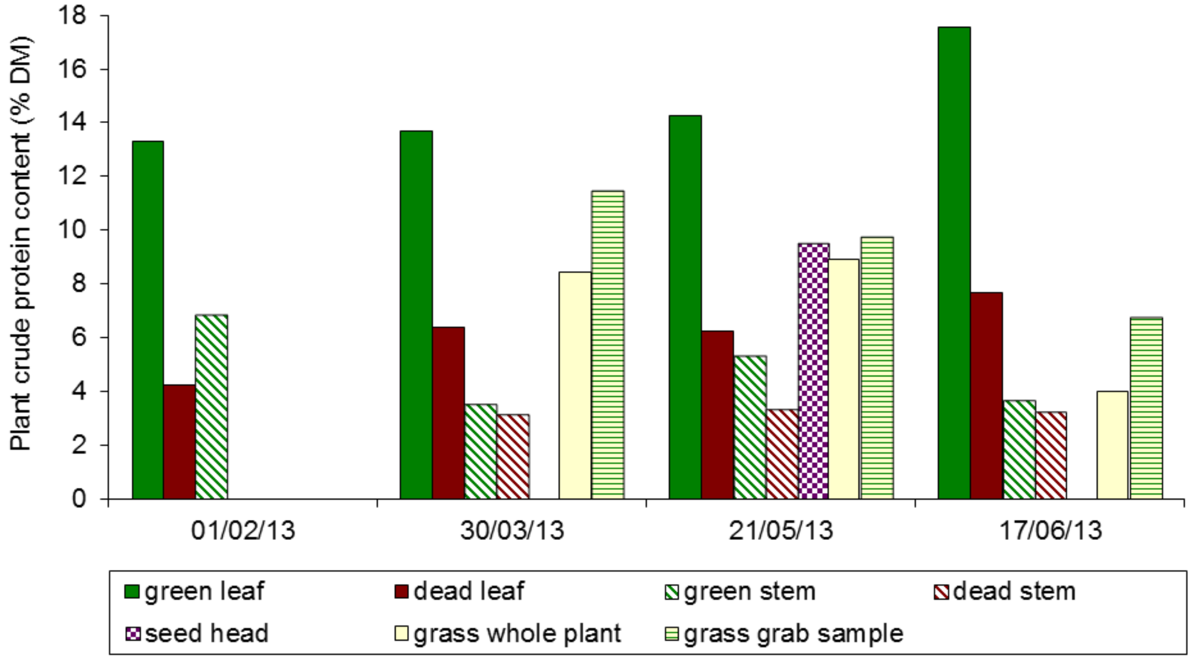

Fig. 95. Crude protein content (% DM) of forage sorghum whole plant and components in the paddock, and of perennial grass whole plant in the paddock, during the grazing period (29/01/13-17/06/13).

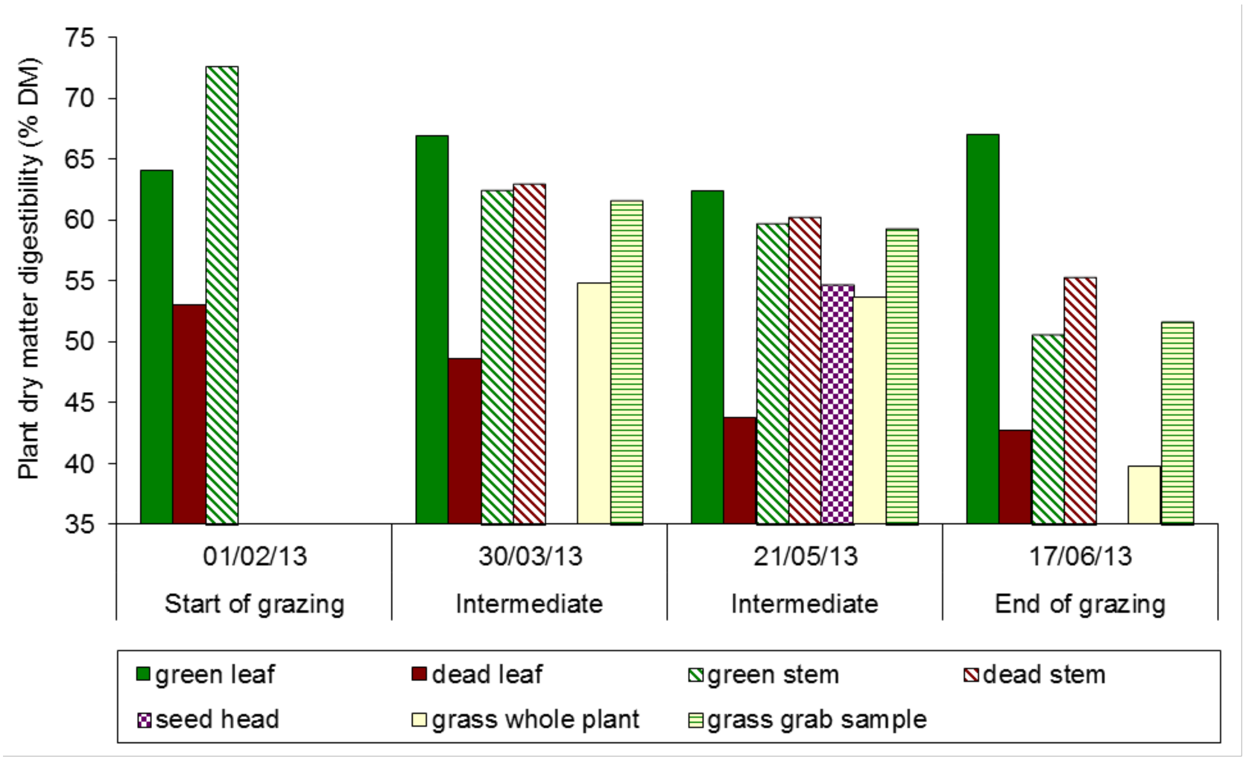

Fig. 96. Dry matter digestibility (%) of forage sorghum plant components in the paddock, and of perennial grass whole plant and grab samples in the paddock, during the grazing period (29/01/13-17/06/13).

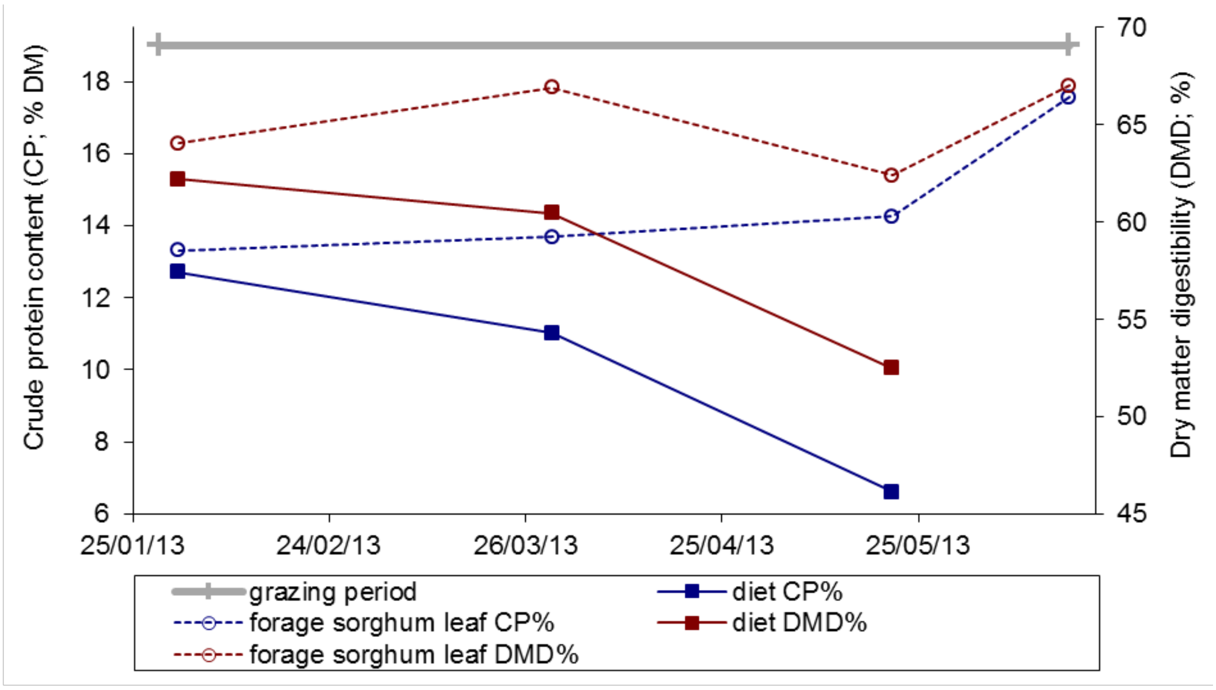

Fig. 97. Diet crude protein (CP) content (% DM) and dry matter digestibility (DMD; %) for grazing cattle predicted from faecal NIRS, and CP content and DMD of forage sorghum green leaf in the paddock. Grazing period shown.

Fig. 98. Forage sorghum crop, 01/02/13; 3 days after start of grazing. Photo taken from within fenced exclosure.

Fig. 99. Cattle grazing the forage sorghum site, 30/03/13; 60 days after start of grazing.

Soil nutrient analysis measured at planting but after fertiliser application showed very high levels of P: 130 mg/kg in the top 10 cm. This level is typical of loam alluvial soils where significant deposition has occurred over millennia and provides sufficient supply to meet crop needs for years to come. However, the paddock contained low levels of soil N, even after the application of N fertiliser at 40 kg N/ha. Given the starting soil moisture and in-crop rainfall, the amount of N present at planting time was insufficient to meet the crop's requirements. However, the mineralisation of N in-crop from the medium-high levels of organic C (1.8%) would alleviate the low starting levels. Subsoil Cl was low (10 mg/kg), typical of this soil type. The forage sorghum crop was planted using minimal till (cultivation and chemical application). Total in-crop rainfall was 275.0 mm. Of this total, 140.2 mm fell between planting and commencement of grazing and 134.8 mm fell during the 139-day grazing period (Fig. 91).

Grazing of the crop commenced during vegetative growth at 2,208 kg DM/ha biomass (Fig. 92 and Fig. 98) and a height of 82 cm, which was considered an ideal stage of grazing for optimising forage quality. This is corroborated by plant component proportions measured at the start of grazing indicating that the proportion of green leaf formed 56.8% of the biomass DM with green stem forming the remaining 42.6% (Fig. 94). The forage biomass was kept below the starting biomass for the duration of the grazing period, with biomass being 1,225 kg DM/ha on 17/06/13 at the end of the grazing period. However, forage biomass in the exclosure increased to a peak of 17,243 kg DM/ha on the 30/03/13.

The rotational grazing of the forage area appeared to optimise the quality of the forage with re-growth of green leaf occurring during the grazing period, as evident in Fig. 94. Forage measurements were taken in one of the three sections of the paddock, only. The proportion of green leaf had decreased to 7.5% by Day 60 of the grazing period but had increased to 23% by Day 112. By the end of the grazing period (Day 139) dead stem formed the greatest portion of the biomass at 77% with green stem the next 18%. Plant chemical analyses taken at the start of grazing indicate that green leaf CP was 13.3% and DMD was 64%, respectively (Fig. 95 and Fig. 96). There was generally a large difference between green leaf and stem in quality, particularly with regard to CP content. The anomaly was the start of grazing DMD measurement which showed green leaf to be less digestible than stem at this time. Grab samples of the available perennial grass pasture showed the CP and DMD content to be 11.4% DM and 62%, respectively on Day 60 of grazing, with quality decreasing over the grazing period. This pattern was also evident in the visual assessment of the proportion of green material in the grass pasture area (Fig. 93). On Day 60 of grazing (30/03/13), 70% of the biomass was assessed as being 81-100% green, whilst by the end of the grazing period (Day 139) 0% of the biomass was assessed as being 81-100% green with 48% assessed as being 21-40% green.

Predictions of diet CP concentrations from faecal NIRS indicated that diet CP was 12.7% DM on Day 4 of the grazing period and had decreased to 6.6% by Day 112 (Fig. 97). Similarly, predictions of diet DMD decreased from 62% to 52% over the same period. Unfortunately, very little information is available to document cattle performance over the grazing period. In order to enable estimates of total beef production and a gross margin for this paddock, it was assumed that cattle did 0.5 kg/head/day over the final 106 days of the grazing period. The weight gains from the small number of cattle weighed over the first 33 days appeared to have been biased by gut fill effects, with the entry weight assumed to be an empty weight and the exit weight a full weight. The raw data gave a weight gain of 1.6 kg/head/day over the first 33 days. However, if the entry weight is adjusted for 5% gut fill losses then the adjusted weight gain is 1.1 kg/head/day. This liveweight gain figure for the first 33 days is greater than what is typically reported for the entire grazing period on forage sorghum crops (Bowen *et al*. 2010), but this crop was grazed at an ideal stage for quality and rotational grazing enabled forage quality to be optimised. Furthermore, the monitoring period for weight gain was over the first 30 days when the proportion of high quality green leaf was at its highest. It is also possible that some compensatory gain effects were contributing to the high measured weight gains as cattle were grazing dry season buffel grass pastures prior to entering the forage.

The grazing period for this crop of 139 days was longer than that assumed in the constructed scenario for the Central Queensland Brigalow region (120 days; Table 30). The average stocking rate was higher than the constructed scenario when the forage area only is considered: 3.3 vs. 3.0 AE/ha but lower when the stocking rate is expressed per total grazing area: 2.6 vs. 3.0 AE/ha. The estimate of total beef production from this site is relatively high compared to that for the constructed scenario and other monitored forage sorghum sites at 316 and 253 kg/ha/annum per forage area and per total grazing area, respectively. However, this result should be considered with caution due to the lack of measured liveweight gain data at this site and the resulting reliance on estimated figures for weight gain.

Cattle production from forage sorghum at this site resulted in a negative gross margin, being -$48/ha when calculated using owner rates and -$80/ha when calculated using contract rates, for the total grazing area. This unprofitable result was despite the very high estimated total liveweight gain from this paddock and the moderate forage costs of $144/ha (expressed per forage area only and using owner rates). The negative cattle price margin (-$0.02/kg liveweight) was the cause of the negative gross margin. However, any additional value of forage sorghum in allowing perennial pastures to be spelled over the wet season, and thus in increasing the carrying capacity of the property, is not accounted for in the gross margin analysis. As all cattle grazing this crop were moved onto perennial grass pastures at the end of the grazing period rather than being sold, the gross margin calculated for this site was not actually realised by the producer.

3.2.5 South Queensland Brigalow, Forage sorghum 2012-13

(S 25.899, E 149.664; near Taroom)

The site was a ca. 77.7 ha paddock planted to 56.5 ha of Sugargraze forage sorghum over 02/12/11–18/12/11 and allowed to return in the 2013 summer season after spraying in mid November 2012 with Nufarm Amicide® 625 and Farmozine 900 WG herbicides. The site was the same forage sorghum crop as that monitored as the South Queensland Brigalow Forage sorghum 2011-12 site. The site had been farmed for forage production for ca. 20 years with primarily forage oats but also some forage sorghum for silage production in earlier years. None of the previous crops had any fertiliser application. A summary of key site details are given in Table 14 and Fig. 100-Fig. 106.

Table 14. Site details. South Queensland Brigalow, Forage sorghum 2012-13
For definitions of abbreviations see Glossary of terms and abbreviations

Factor	Details
Soil characterisation	
Broad land type	Brigalow
Soil type and characteristics	Brown cracking clay (Vertosol) PAWC: 180 mm Soil depth: 120 cm
Paddock preparation and forage sowing details	
Total rainfall from removal of cattle from the original crop to end of grazing of the return crop	413 mm (09/06/12-11/04/13; property records, ca. 1.5 km from site)
Forage production	
Sorghum peak biomass	Paddock: 2,069 kg DM/ha
Average diet quality	10.0% CP, 57% DMD (Days 4-52 of grazing period)
Average perennial grass presentation yield	Estimate of grass yield not available. Major species: Buffel, Queensland bluegrass, green panic.

Factor	Details
Grazing management and animal production	
Comments	Three groups of cattle grazed the paddock, as one mob, for the entire grazing period (87 head in total). A total of 35 x 2.3 year old steers, 43 x 1.3 year old steers and 9 x 1.3 year old heifers grazed the forage. A total of 30 of the 2.3 year old steers and 41 of the 1.3 year old steers were monitored for weight gain. All cattle grazed buffel grass pasture prior to forage entry. The 1 year old steers were sent to slaughter at Dinmore abattoir 10 days after exiting the forage. The 2 year old steers and heifers were returned to buffel pasture.
Cattle type monitored for weight gain	Steers; either 2.3 or 1.3 years old at entry; ca. 30% *B. indicus* content.
Animal health treatments	At entry to forage all cattle were treated with Zoetis Supona® buffalo fly insecticide
Feeding period	18/02/13-11/04/13 (52 days)
Grazing days over which LW was measured	52 (18/02/13-11/04/13)
Proportion of the total grazing area as forage sorghum	73%
Average SR (forage area only)	1.6 AE/ha
Average SR (total grazing area)	1.2 AE/ha
2-year old steers	
Number of cattle in weight gain dataset	30
Average entry LW (± SE)	563 (± 4.2) kg
Average exit LW (± SE)	600 (± 5.5) kg
Average LWG (± SE)	0.70 (± 0.049) kg/head/day
1-year old steers	
Number of cattle in weight gain dataset	41
Average entry LW (± SE)	397 (± 6.8) kg
Average exit LW (± SE)	454 (± 6.8) kg
Average LWG (± SE)	1.1 (± 0.042) kg/head/day
Total LWG (forage sorghum area only)	74 kg/ha/annum
Total LWG (total grazing area)	54 kg/ha/annum

Economic performance		
	Forage area only ($/ha/annum)	**Total grazing area ($/ha/annum)**
Gross margin - owner rates	**30**	**22**
Forage costs	16	12
Gross margin - contract rates	**27**	**20**
Forage costs	19	14
CONSTRUCTED SCENARIO (0% total area as perennial grass)		
Gross margin - owner rates	**-14**	**-14**
Forage costs	172	172
Gross margin - contract rates	**-113**	**-113**
Forage costs	270	270

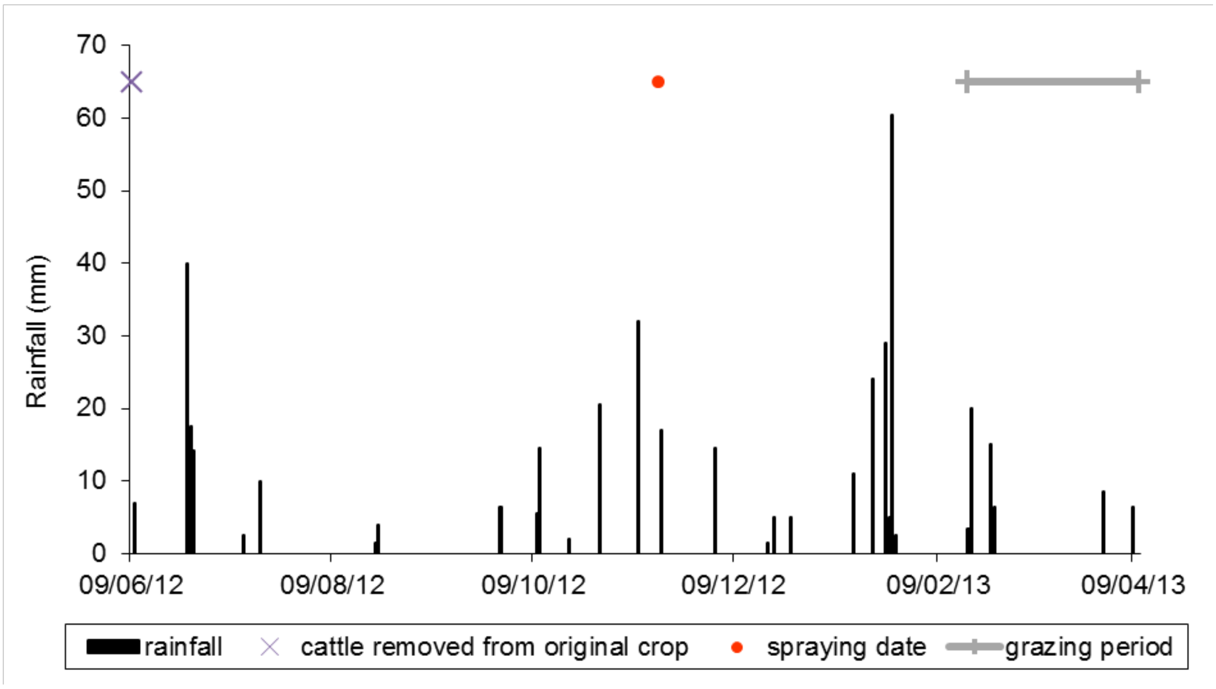

Fig. 100. Daily rainfall (mm) over the 'in-crop' period, from removal of cattle from the original crop to end of grazing of the return crop (09/06/12-11/04/13). Measured on property, ca. 1.5 km from the trial paddock. Date of cattle removal from original crop, spraying date and grazing period shown.

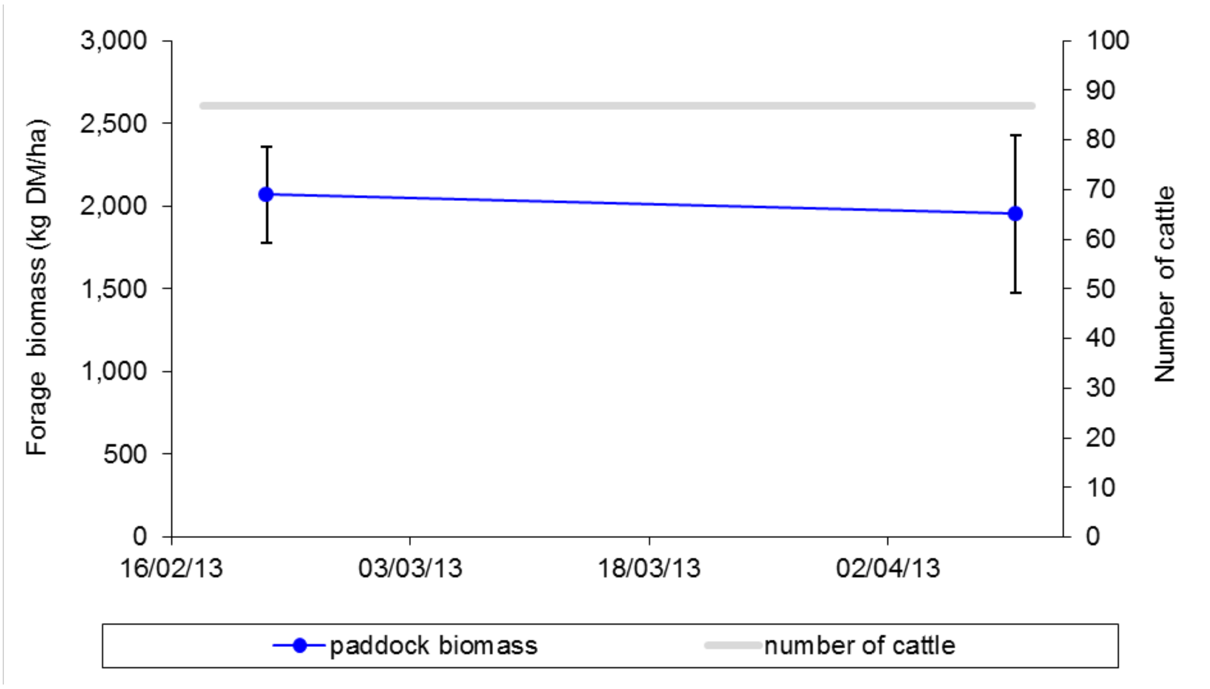

Fig. 101. Forage sorghum biomass (kg DM/ha; mean ± SE) and cattle numbers during the grazing period (18/02/13-11/04/13).

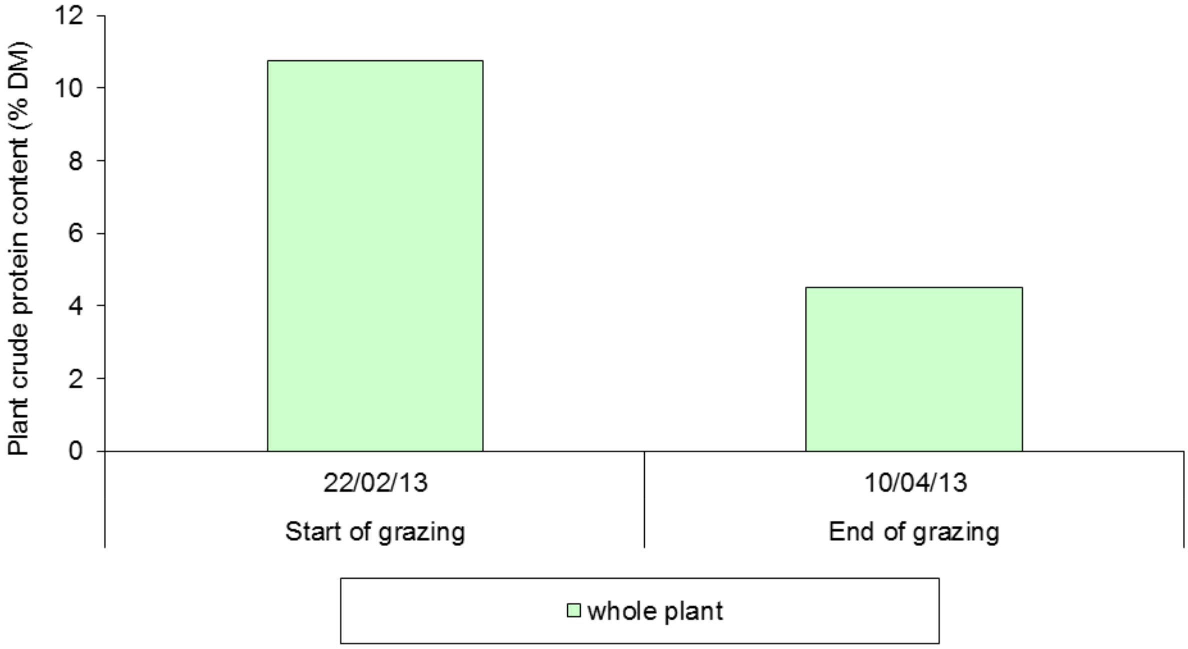

Fig. 102. Crude protein content (% DM) of forage sorghum whole plant in the paddock during the grazing period (18/02/13-11/04/13).

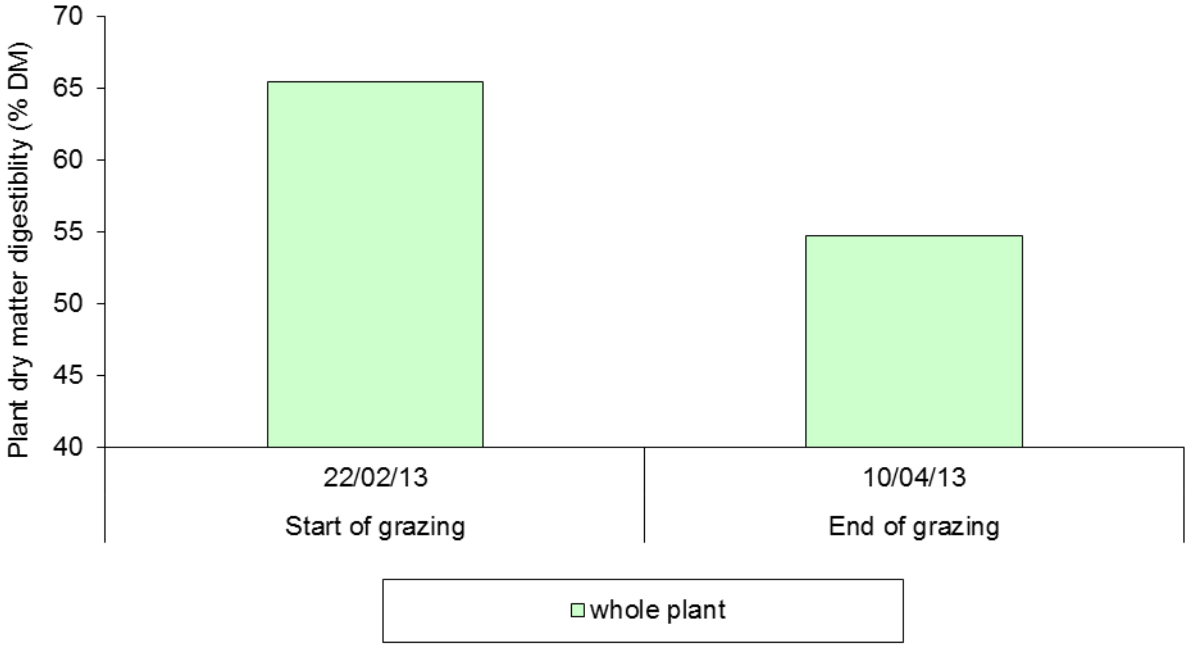

Fig. 103. Dry matter digestibility (%) of forage sorghum whole plant in the paddock during the grazing period (18/02/13-11/04/13).

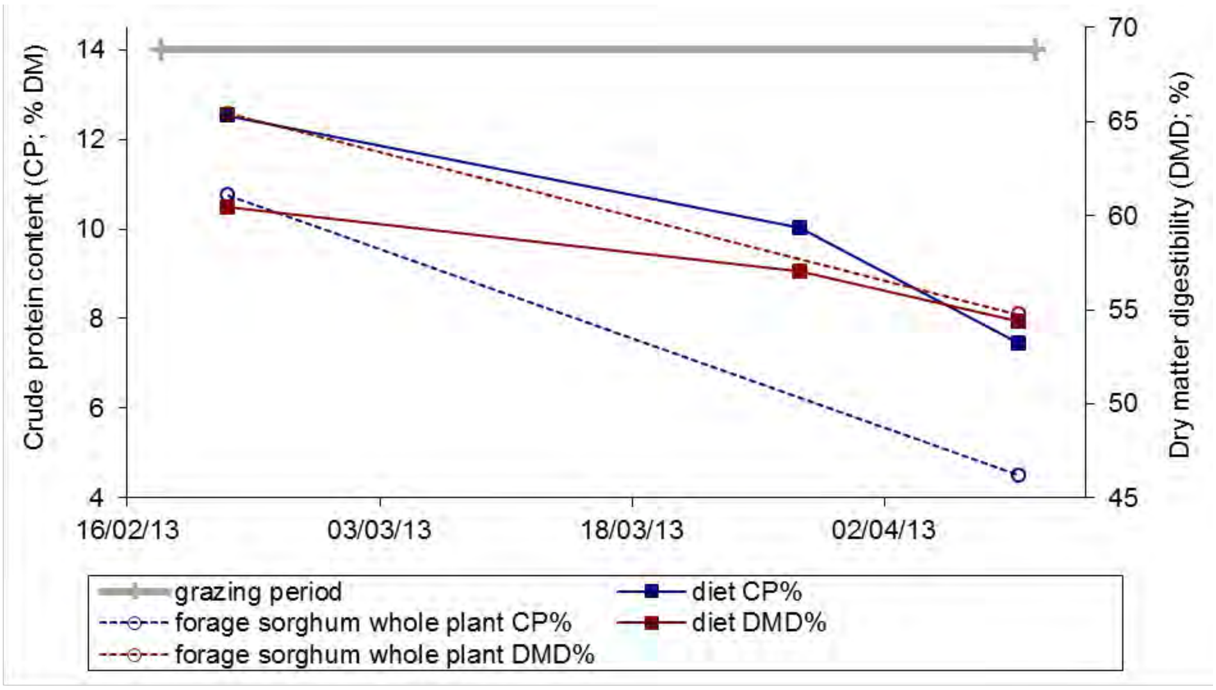

Fig. 104. Diet crude protein (CP) content (% DM) and dry matter digestibility (DMD; %) for grazing cattle predicted from faecal NIRS, and CP content and DMD of forage sorghum whole plant in the paddock. Grazing period shown.

Fig. 105. Forage sorghum return crop, 22/02/13; 4 days after the start of grazing.

Fig. 106. Forage sorghum return crop and cattle, 10/04/13; 1 day prior to the end of the 52-day grazing period.

Soil nutrient analysis prior to planting the original crop in 2011-12 (South Queensland Forage sorghum 2011-12 site) indicated moderate levels of N and P. The forage sorghum crop had been planted using full cultivation and N fertiliser was not applied. Herbicide application in mid November 2012 was the only additional paddock operation for the return crop. Total rainfall from removal of cattle from the original crop to the end of the grazing period for the return crop was 413 mm (Fig. 100). Of this total, 353 mm fell prior to start of grazing and 60 mm fell during the grazing period.

Grazing of the return crop commenced with a biomass of 2,069 kg DM/ha (Fig. 101 and Fig. 105). This value was ca. 12.5% of the starting biomass of the original crop grazed in 2012. The lower yield is typical of return crops due to a reduced ability to tiller (Muldoon 1985) as well as lower plant population and vigour which is in turn caused by trampling and plant death as well as reduced N supply. A likely reduced N supply is caused by no fallow period prior to the growing period as well as weed competition. Forage biomass in the paddock had declined to 1,955 kg DM/ha by the end of the 52-day grazing period. No quantitative assessments were made of the perennial grass (largely buffel) biomass in the 27% of the paddock not planted to forage. However, observations indicated that the perennial grass was also green and of high quality at the start of the grazing period.

Plant chemical analysis (Fig. 102 and Fig. 103) showed that sorghum whole plant CP and DMD was already relatively low at start of grazing and decreased, as expected, over the grazing period. These values for whole plant CP and DMD were similar to corresponding values measured for the original 2011-12 crop at similar times during the grazing period. The diet CP for grazing cattle was 12.5% on Day 5 of the grazing period and had decreased to 7.5% by Day 53 (Fig. 104). Diet DMD decreased from 60 to 54% over the same period. These values are also very similar to diet quality estimates from the original 2011-12 crop over a similar time period (Day 15-60 of grazing).

The daily liveweight gain of 1-year old steers grazing the forage sorghum return crop (1.1 kg/head/day) was twice that assumed in the constructed scenario for forage sorghum grown in the South Queensland Brigalow region (0.55 kg/head/day; Table 31) and almost twice values measured for 1-year old steers grazing the crop in the first season after planting

(2011-12; 0.59 kg/head/day). However, the grazing period for the return crop was only 52 days vs. 108 days in the 2011-12 season and the 130 days assumed in the constructed scenario. The weight gain of the 2-year old steers was 64% of the value measured for 1-year old steers: 0.70 kg/head/day. The starting liveweight of the 1-year old steers was lower (397 kg), and of the 2-year old steers heavier (563 kg), than that assumed in the constructed scenario (525 kg). In addition to short grazing period on this return crop, the stocking rate was low (1.6 AE/ha when considering the forage area alone and 1.2 AE/ha when expressed per the total grazing area). The total liveweight gain for this paddock in the 2012-13 year was 74 kg/ha/annum when expressed per forage area only and 54 kg/ha/annum when expressed per the total grazing area. These values were 39% of the weight gain from the crop in the 2011-12 season which is expected due to the much lower starting biomass of the return crop.

Cattle production from the forage sorghum return crop resulted in a positive gross margin of $22/ha of total grazing area calculated using owner rates or $20/ha calculated using contract rates. Despite the low paddock or 'forage' costs associated with the return crop of $16/ha of forage area only (owner rates) or $19/ha of forage area only (contract rates), the relatively low total beef production of 54 kg/ha and average cattle price margin of $0.01 reduced profitability of the return crop relative to the original crop grazed the previous season. As only 49% of cattle grazing this crop were sent to slaughter soon after exiting the forage, the gross calculated at this site was not actually realised by the producer. Furthermore, any additional value of forage sorghum in allowing perennial grass pastures to be spelled over the wet season, and thus in increasing carrying capacity of the property, is not accounted for in the gross margin analysis.

3.3 Lablab (*Lablab purpureus*)

3.3.1 Central Queensland Open Downs, Lablab 2011-12

(S 23.304, E 148.277; near Emerald)

The site was a ca. 229 ha paddock planted to 219 ha of Dolichos lablab cv. Highworth on 17/12/11. The site had been first cultivated in 2003-04 and then cropped annually with either: forage sorghum (3 out of 6 years), lablab (2 out of 6 years) or oats (1 out of 6 years). The site was located on the same commercial property as the Central Queensland Open Downs Oats 2013, Butterfly pea-grass 2012-14, Leucaena-grass 2012-14, and Perennial grass 2011-14 sites. After the first 41 days of the grazing period access was provided to an adjacent perennial grass paddock (285 ha) for the final 62 days of grazing. The additional grass paddock contained a mixture of native pastures (primarily Queensland bluegrass), buffel and other introduced perennial species and a small proportion of the introduced legume butterfly pea. The additional grass paddock had been planted to butterfly pea in 2005 and in 2006 seeded with Biloela and Gayndah buffel grass, Bambatsi panic and Katambora Rhodes grass. The co-operator observed that cattle spent the majority of time in the lablab paddock rather than the additional grass paddock. Cattle were monitored for liveweight gain over the last 62 or 54 days of the 103-day grazing period. A summary of key site details are given in Table 15 and Fig. 107-Fig. 113.

Table 15. Site details. Central Queensland Open Downs, Lablab 2011-12
For definitions of abbreviations see Glossary of terms and abbreviations

Factor	Details		
Soil characterisation			
Broad land type	Heavy clay alluvial		
Soil type and characteristics	Black cracking clay (Vertosol) PAWC: 240 mm Soil depth: 120 cm		
Soil nutrient levels at planting		**0-10 cm**	**10-110 cm**
	Nitrate N (mg/kg)	21	1.7
	Nitrate N total (kg/ha)	45.8	
	P (mg/kg)	23	n/a
	Organic C (%)	0.86	n/a
	Cl (mg/kg)	12	120
	Plant available water (mm)	99.8	
Paddock preparation and forage sowing details			
Planting date	17/12/11		
Sowing rate	22 kg/ha		
Fertiliser	None		
Fallow weed control	Minimal till (cultivation and chemical application)		
Total in-crop rainfall	576.0 mm (17/12/11–13/06/12; property records, 7.3 km from trial paddock)		

Factor	Details
Forage production	
Lablab green leaf at start of grazing	32% of biomass, 26.5% CP, 77% DMD
Lablab peak biomass	Paddock: 5,484 kg DM/ha, Exclosure: > 5,021 kg DM/ha
% lablab in the diet	31% (Day 29 of grazing period)
Average diet quality	9.9% CP, 58% DMD (Day 29, only, of grazing period)
Average perennial grass presentation yield	Biomass data unavailable. Major species in the forage paddock and the additional 285 ha grass paddock: Queensland bluegrass, buffel, butterfly pea.
Grazing management and animal production	
Comments	Cattle entered the paddock in 2 separate groups on 02/03/12 and 12/03/12 (560 in total) and were progressively removed in 3 groups as they reached target background weights for feedlot entry. Only 34% of cattle were monitored for individual liveweight gain over the last 54 or 62 days of the grazing period. All cattle had grazed perennial grass prior to entering the lablab paddock. After the first 41 days of the grazing period, access was provided to an adjacent perennial grass paddock (285 ha) for the final 62 days of grazing.
Cattle type monitored for weight gain	Steers; ca. 20–24 months at entry; either NAPCO Kynuna or Alexandria Composite; ca. 13-38% *B. indicus.*
Animal health treatments	Coopers® Amitik cattle dip and spray to all a cattle returning to the paddock on 12/04/12.
Feeding period	02/03/12–13/06/12 (103 days)
Proportion of the total grazing area as lablab forage	43% (for the final 62 days of grazing when liveweight gain was measured)
Average SR (lablab area only)	1.5 AE/ha
Average SR (total grazing area)	0.6 AE/ha (for the final 62 days of grazing when liveweight gain was measured)
Final 62 days of grazing	
Grazing days over which LW was measured	62 (12/04/12–13/06/12)
Number of cattle in weight gain dataset	94
Average entry LW (± SE)	439 (± 3.2)kg
Average exit LW (± SE)	489 (± 3.7) kg
Average LWG (± SE)	0.81 (± 0.028) kg/head/day
Final 54 days of grazing	
Grazing days over which LW was measured	54 days (20/04/12–13/06/12)
Number of cattle in weight gain dataset	97
Average entry LW (± SE)	458 (± 1.9) kg
Average exit LW (± SE)	492 (± 2.3) kg
Average LWG (± SE)	0.64 (± 0.025) kg/head/day
Total LWG (forage area only)	96 kg/ha/annum
Total LWG (total grazing area)	41 kg/ha/annum

Factor	Details	
Economic performance		
	Forage area only ($/ha/annum)	**Total grazing area ($/ha/annum)**
Gross margin - owner rates	**89**	**38**
Forage costs	85	36
Gross margin - contract rates	**47**	**20**
Forage costs	127	54
CONSTRUCTED SCENARIO (10% total area as perennial grass)		
Gross margin - owner rates	**86**	**77**
Forage costs	170	153
Gross margin - contract rates	**7**	**7**
Forage costs	248	223

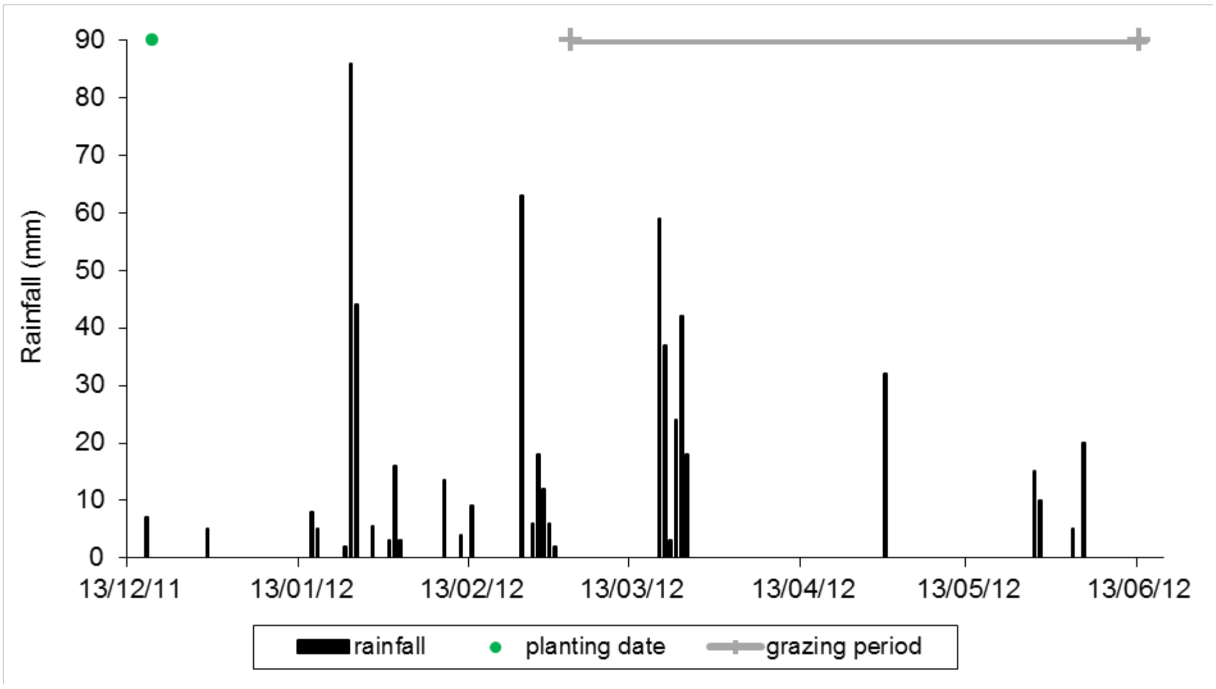

Fig. 107. Daily rainfall (mm) over the in-crop period (17/12/11–13/06/12). Measured on property, 7.3 km from the trial paddock. Planting date and grazing period shown.

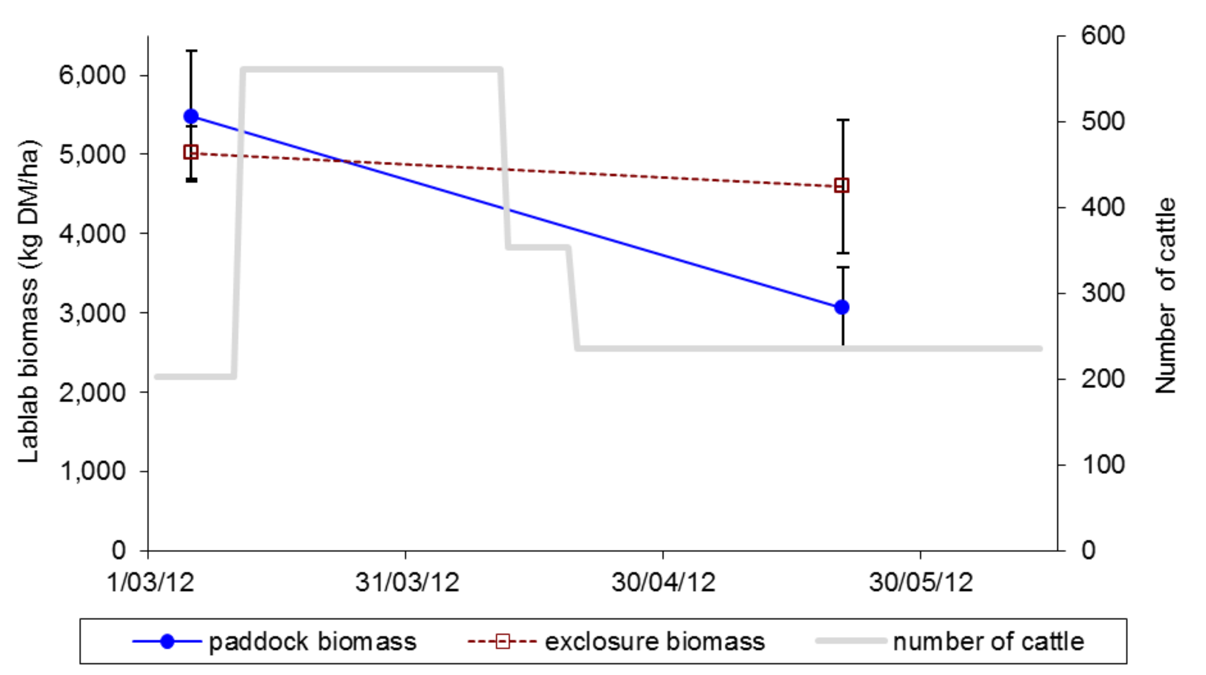

Fig. 108. Lablab biomass (kg DM/ha; mean ± SE) in the paddock and exclosure, and cattle numbers during the grazing period (02/03/12–13/06/12).

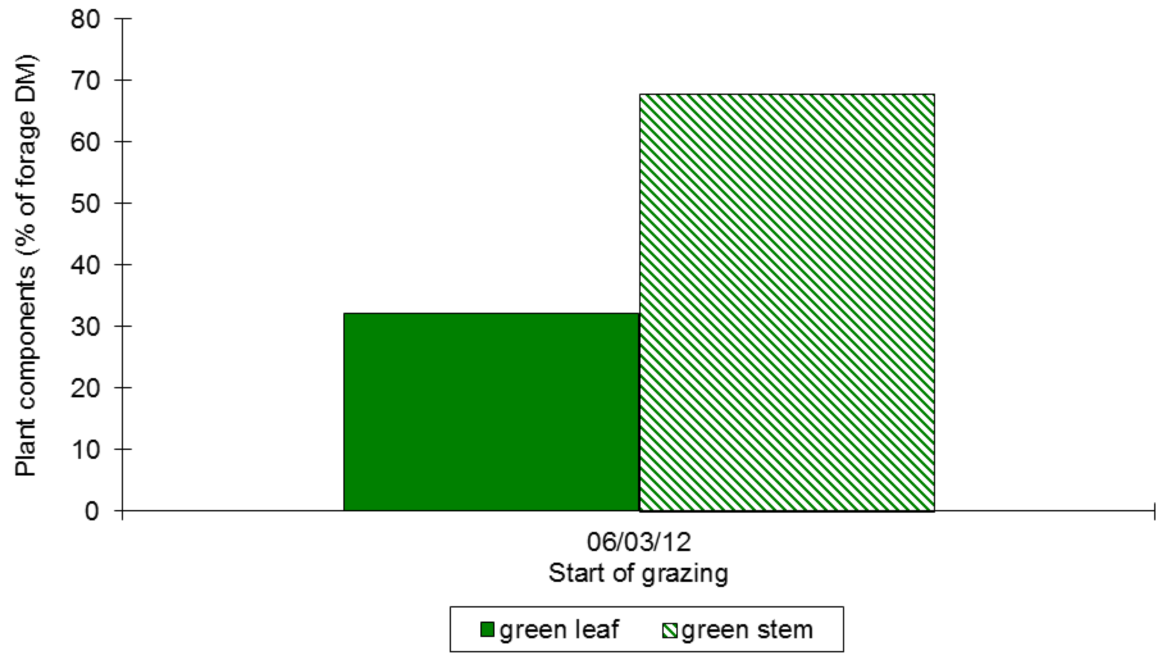

Fig. 109. Plant component composition (% of total forage DM) in the paddock during the grazing period (02/03/12–13/06/12).

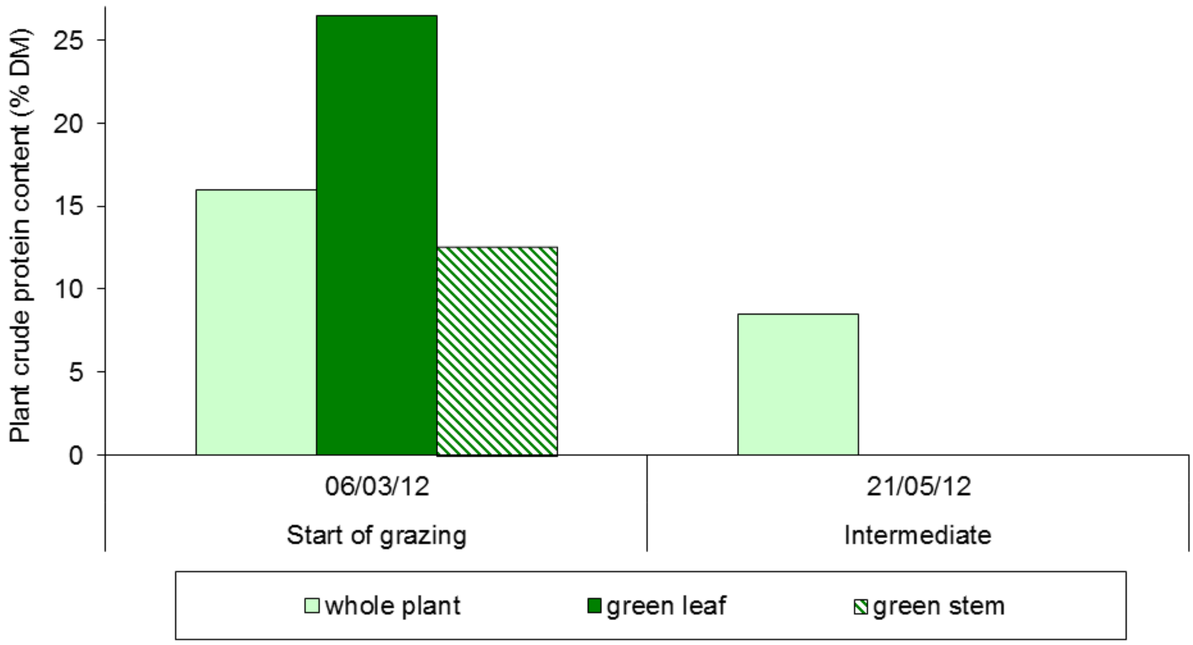

Fig. 110. Crude protein content (% DM) of lablab whole plant and components in the paddock during the grazing period (02/03/12–13/06/12).

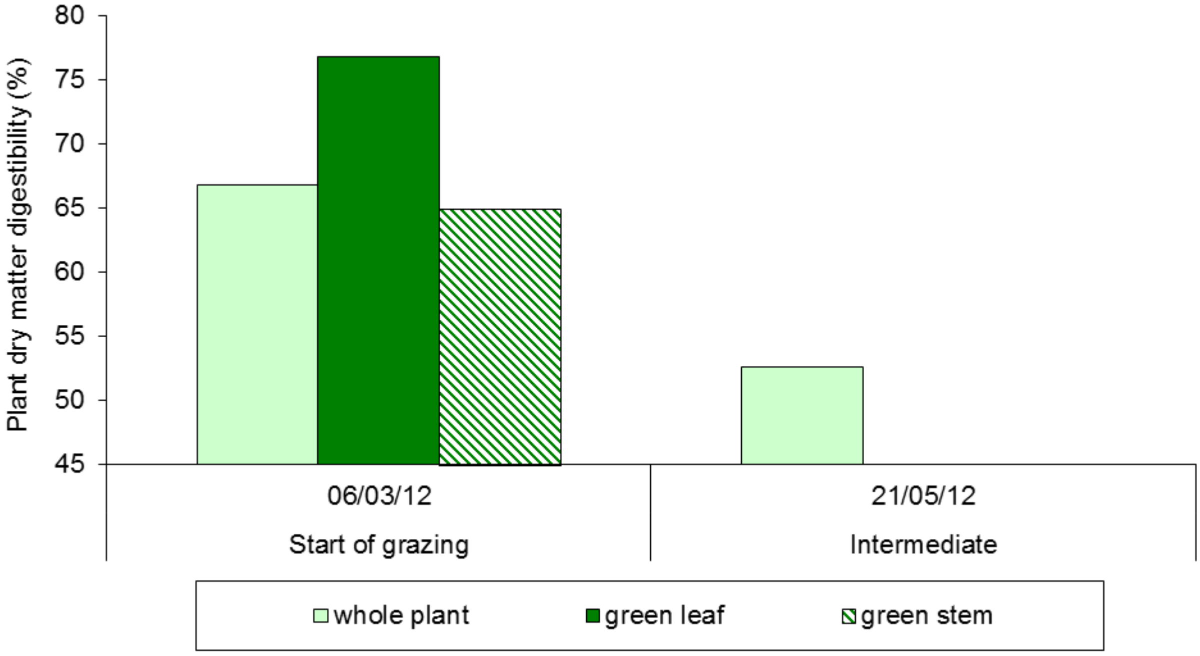

Fig. 111. Dry matter digestibility (%) of lablab whole plant and components in the paddock during the grazing period (02/03/12–13/06/12).

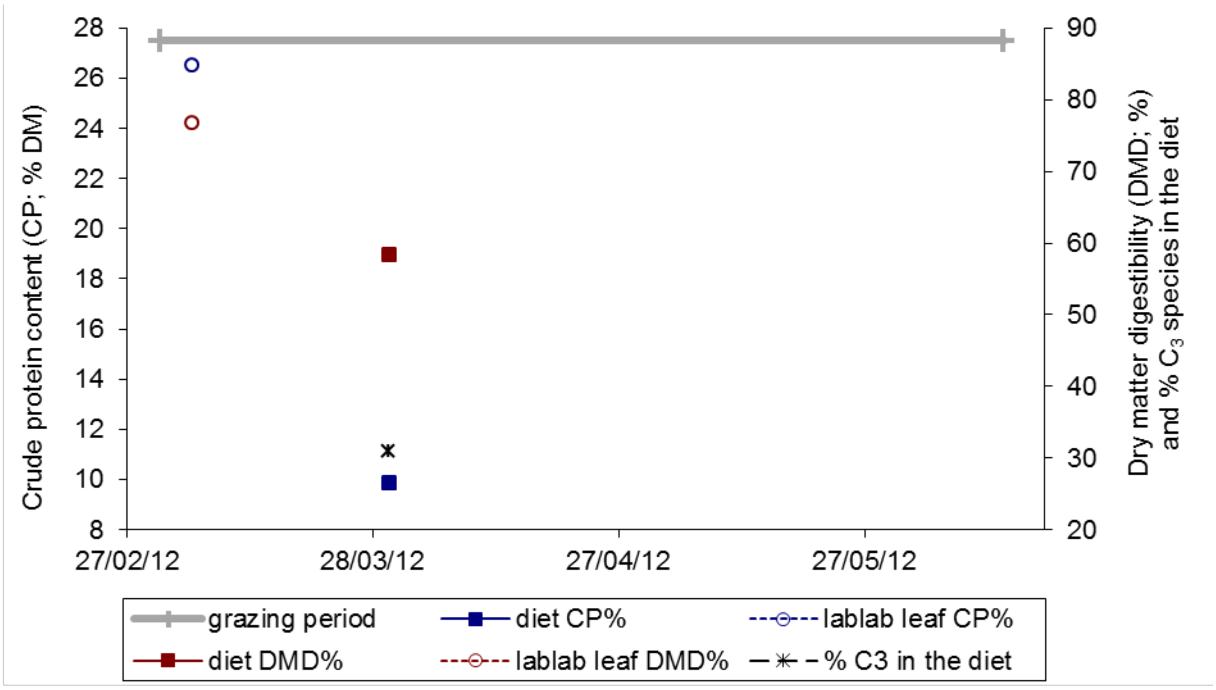

Fig. 112. Diet crude protein (CP) content (% DM) and dry matter digestibility (DMD; %) for grazing cattle predicted from faecal NIRS, and CP content and DMD of lablab green leaf in the paddock; and the % of the diet as C_3 forage, predicted from $\delta^{13}C$ content in the faeces. Only one faecal sample was available, taken after 28 days of grazing. Grazing period shown.

Fig. 113. Lablab crop, 06/03/12; 4 days after start of grazing.

At planting, the soil moisture profile was about half full, which was sufficient to produce good initial crop growth. Soil nutrient levels prior to planting indicated that the paddock contained enough P to maximise forage yields given the soil moisture and in-crop rainfall. Total in-crop rainfall was 576.0 mm (Fig. 107). Of this total, 311 mm fell between planting and commencement of grazing and 265 mm fell during the 103-day grazing period.

When grazing commenced the lablab crop had a biomass 5,484 kg DM/ha and this had decreased to 3,059 kg DM/ha after 80 days of grazing (Fig. 108 and Fig. 113). Biomass measurements were not available for the end of the grazing period which was after an additional 23 days of grazing. Green leaf formed only 32% of the plant DM at the start of the grazing period while green stem formed 68% of the plant DM (Fig. 109). Plant chemical analysis indicated that there was a large difference between lablab leaf and stem in quality (Fig. 110 and Fig. 111). At the start of the grazing period, the CP concentration in green stem material (12.6%) was 48% of that in the green leaf (26.5%) and the DMD of green stem (65%) was 12 units lower than for leaf (77%). The only faecal sample taken, on Day 29 of grazing, indicated that the cattle were consuming approximately 31% of the diet as C_3 species, assumed to be largely lablab (Fig. 112). The estimated diet CP content was 9.9% and diet DMD was 58%. Whilst no plant component proportions were available for the lablab in the paddock at the intermediate forage sampling date (after 80 days of grazing), photographs indicate that there was little green leaf material left at this stage. Whole plant chemical analyses corroborate this and indicate that the overall CP and DMD levels had decreased by 47% and 21%, respectively over the first 80 days of grazing. Unfortunately, no faecal samples were collected after access was given to the additional grass paddock, which would otherwise allow determination of the proportion of C_3 species in the diet.

Despite the drop in available, high-quality lablab leaf over the grazing period, steer weight gains measured over the final 62 days of the 103-day grazing period were in the range of that expected for steers grazing lablab forage: 0.81 kg/head/day. This is the same daily liveweight gain as that assumed in the constructed scenario for lablab grown in the Central Queensland Open Downs region (Table 29). However, the stocking rate on the lablab forage area was much lower at this site (1.5 AE/ha) compared to that assumed in the constructed scenario (2.5 AE/ha) and starting steer weights were also considerably lower at 439 vs. 516 kg in the constructed scenario. The second group of steers which were monitored for the final 54 days of the 103-day grazing period had a lower weight gain of 0.64 kg/head/day. However, this second group also had a higher starting weight of 458 kg. The large additional area of perennial grass pasture (57 % of the total grazing area) made available after the initial 41 days of grazing the lablab forage complicates interpretation of the cattle weight gains. The estimated total beef production per hectare at this site (96 kg/ha from the forage area alone and 41 kg/ha from the entire grazing area) is low compared to what was assumed for lablab forage in the constructed scenario: 171 kg/ha for the forage area alone. However, planting 43% of the area to lablab forage at this site produced 1.6 times greater beef production per hectare than what is expected from perennial grass pasture in this region: 41 vs. 25 kg/ha/year.

The use of lablab at this site resulted in a profitable outcome with a gross margin for the total grazing area of $38/ha calculated using owner rates and $20/ha calculated using contract rates. This gross margin is less than that calculated for the constructed scenario for this region: $77/ha of total grazing area (owner rates). The forage costs calculated using owner rates for the forage area only ($85/ha) were lower than that assumed in the constructed scenario ($170/ha). The cattle price margin was positive at $0.12/kg liveweight. At this site, providing 43% of the total grazing area as lablab forage provided a gross margin 1.4 times greater than what would have been expected from perennial grass pasture in this region: $38/ha vs. $27/ha (calculated using owner rates).

3.3.2 Central Queensland Brigalow, Lablab 2012-13

(S 24.211, E 149.862; near Baralaba)

The site was a ca. 87 ha paddock planted to 64 ha of Dolichos lablab cv. Highworth on 06/02/13. The site had been originally cleared of timber in the late 1950's and first cultivated around 1960. The paddock had been cropped from around 1960 to 1990 and then used as a grass paddock for around 20 years until cropped with cotton in 2010-11 and wheat in 2012. A summary of key site details are given in Table 16 and Fig. 114-Fig. 122.

Table 16. Site details. Central Queensland Brigalow, Lablab 2012/13
For definitions of abbreviations see Glossary of terms and abbreviations

<table>
<tr><th>Factor</th><th colspan="3">Details</th></tr>
<tr><td colspan="4">Soil characterisation</td></tr>
<tr><td>Broad land type</td><td colspan="3">Brigalow scrub</td></tr>
<tr><td>Soil type and characteristics</td><td colspan="3">Medium clay
PAWC: 160 mm
Soil depth: 120 cm</td></tr>
<tr><td rowspan="7">Soil nutrient levels 5 weeks after planting</td><td></td><td>0-10 cm</td><td>10-110 cm</td></tr>
<tr><td>Nitrate N (mg/kg)</td><td>6.7</td><td>n/a</td></tr>
<tr><td>Nitrate N total (kg/ha)</td><td colspan="2">n/a</td></tr>
<tr><td>P (mg/kg)</td><td>15</td><td>n/a</td></tr>
<tr><td>Organic C (%)</td><td>0.62</td><td>n/a</td></tr>
<tr><td>Cl (mg/kg)</td><td>10</td><td>n/a</td></tr>
<tr><td>Plant available water (mm)</td><td colspan="2">76</td></tr>
<tr><td rowspan="4">Soil nutrient levels at end of grazing</td><td></td><td>0-10 cm</td><td>10-110 cm</td></tr>
<tr><td>Nitrate N (mg/kg)</td><td>3.3</td><td>1.4</td></tr>
<tr><td>Nitrate N total (kg/ha)</td><td colspan="2">26</td></tr>
<tr><td>Cl (mg/kg)</td><td>10</td><td>37</td></tr>
<tr><td colspan="4">Paddock preparation and forage sowing details</td></tr>
<tr><td>Planting date</td><td colspan="3">06/02/13</td></tr>
<tr><td>Sowing rate</td><td colspan="3">15 kg/ha</td></tr>
<tr><td>Fertiliser</td><td colspan="3">None</td></tr>
<tr><td>Fallow weed control</td><td colspan="3">Zero till</td></tr>
<tr><td>Total in-crop rainfall</td><td colspan="3">328.0 mm (06/02/13-06/08/13; property records measured 100 m from the forage paddock)</td></tr>
<tr><td colspan="4">Forage production</td></tr>
<tr><td>Lablab green leaf at start of grazing</td><td colspan="3">58% of biomass, 18.0% CP, 72% DMD</td></tr>
<tr><td>Lablab peak biomass</td><td colspan="3">Paddock: 6,543 kg DM/ha, Exclosure: 14,253 kg DM/ha</td></tr>
<tr><td>% lablab in the diet</td><td colspan="3">76% (Days 16-107 of grazing period)</td></tr>
<tr><td>Average diet quality</td><td colspan="3">13.0% CP, 59% DMD (Days 16-107 of grazing period)</td></tr>
<tr><td>Average perennial grass presentation yield</td><td colspan="3">3,224 kg DM/ha average over the grazing period (range: 1,612-4,465 kg DM/ha); major species were the introduced perennial grasses buffel, sabi, green panic.</td></tr>
</table>

Factor	Details
Grazing management and animal production	
Comments	Cattle entered the paddock in 2 separate groups (156 in total). A total of 113, 18-24 month old steers entered on 17/04/13 after grazing leucaena and 44, 8-10 month old steers and heifers entered on 29/06/13 after grazing perennial grass. A total of 62 of the 113 steers were removed after 90 days of grazing for feedlot entry. Of the remaining 51 head, 18 were sent to Teys Biloela abattoir at the end of the 111-day grazing period (06/08/13).
Cattle type monitored for weight gain	111 Brangus steers ca. 18-24 months at entry; 20 Brahman cross heifers ca. 8-10 months at entry; 23 Brahman cross steers ca. 8-10 months at entry.
Animal health treatments	None
Feeding period	17/04/13-06/08/13 (111 days)
Proportion of the total grazing area as Lablab forage	73%
Average SR (lablab area only)	1.8 AE/ha
Average SR (total grazing area)	1.3 AE/ha
All 2-year old steers	
First 90 days of grazing	
Grazing days over which LW was measured	90 (17/04/13–16/07/13)
Number of cattle in weight gain dataset	111
Average entry LW (± SE)	410 (± 2.9) kg
Average LWG (± SE)	1.22 (± 0.019) kg/head/day
Subset 2-year old steers	
Total 111 days of grazing	
Grazing days over which LW was measured	111 (17/04/13–06/08/13)
Number of cattle in weight gain dataset	51
Average entry LW (± SE)	421 (± 5.3) kg
Average LWG (± SE)	0.98 (± 0.028) kg/head/day
First 90 days of grazing	
Average LWG (± SE)	1.20 (± 0.032) kg/head/day
Next 21 days of grazing	
Average LWG (± SE)	0.06 (± 0.073) kg/head/day
Weaner steers	
Final 38 days of grazing period	
Grazing days over which LW was measured	38 (29/06/13–06/08/13)
Number of cattle in weight gain dataset	23
Average entry LW (± SE)	270 (± 7.1) kg
Average LWG (± SE)	0.68 (± 0.044) kg/head/day

Factor	Details	
Grazing management and animal production		
Weaner heifers		
Final 38 days of grazing period		
Grazing days over which LW was measured	38 (29/06/13–06/08/13)	
Number of cattle in weight gain dataset	20	
Average entry LW (± SE)	225 (± 5.6) kg	
Average LWG (± SE)	0.61 (± 0.047) kg/head/day	
Total annual LWG (forage area only)	212 kg/ha/annum	
Total LWG (total grazing area)	156 kg/ha/annum	
Economic performance		
	Forage area only ($/ha/annum)	**Total grazing area ($/ha/annum)**
Gross margin - owner rates	**68**	**50**
Forage costs	113	82
Gross margin - contract rates	**21**	**15**
Forage costs	160	117
CONSTRUCTED SCENARIO (10% total area as perennial grass)		
Gross margin - owner rates	**117**	**105**
Forage costs	170	153
Gross margin - contract rates	**38**	**34**
Forage costs	248	223

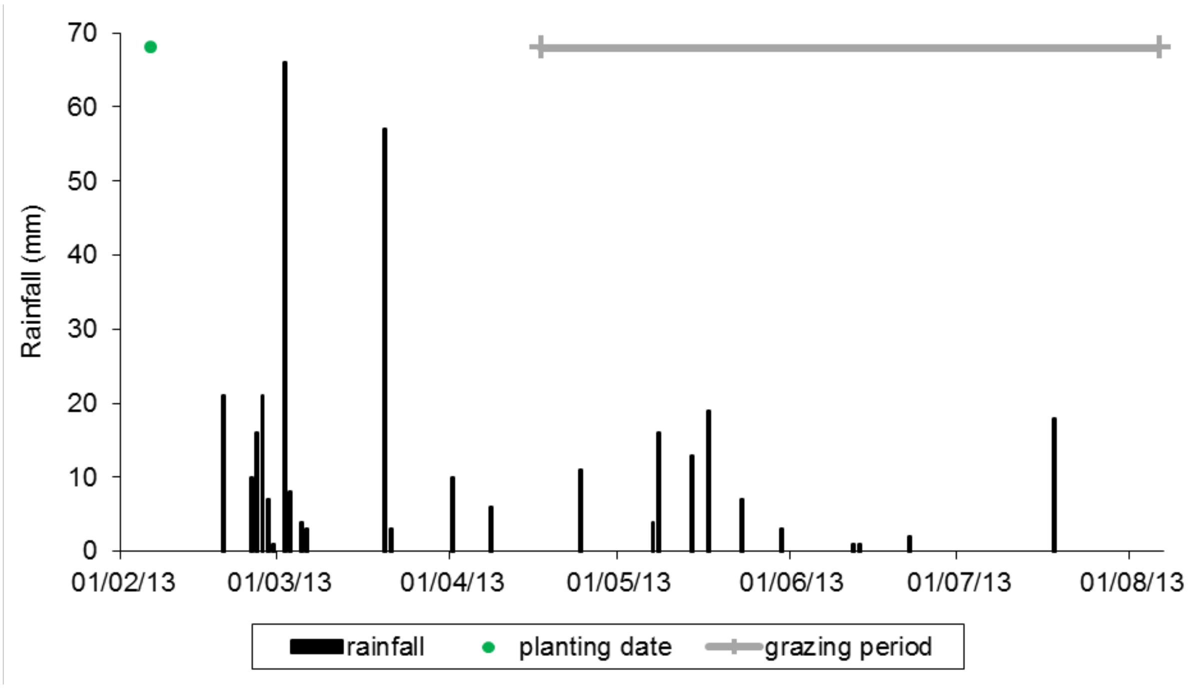

Fig. 114. Daily rainfall (mm) over the in-crop period (06/02/13–06/08/13). Measured on property ca. 100 m from the lablab paddock. Planting date and grazing period shown.

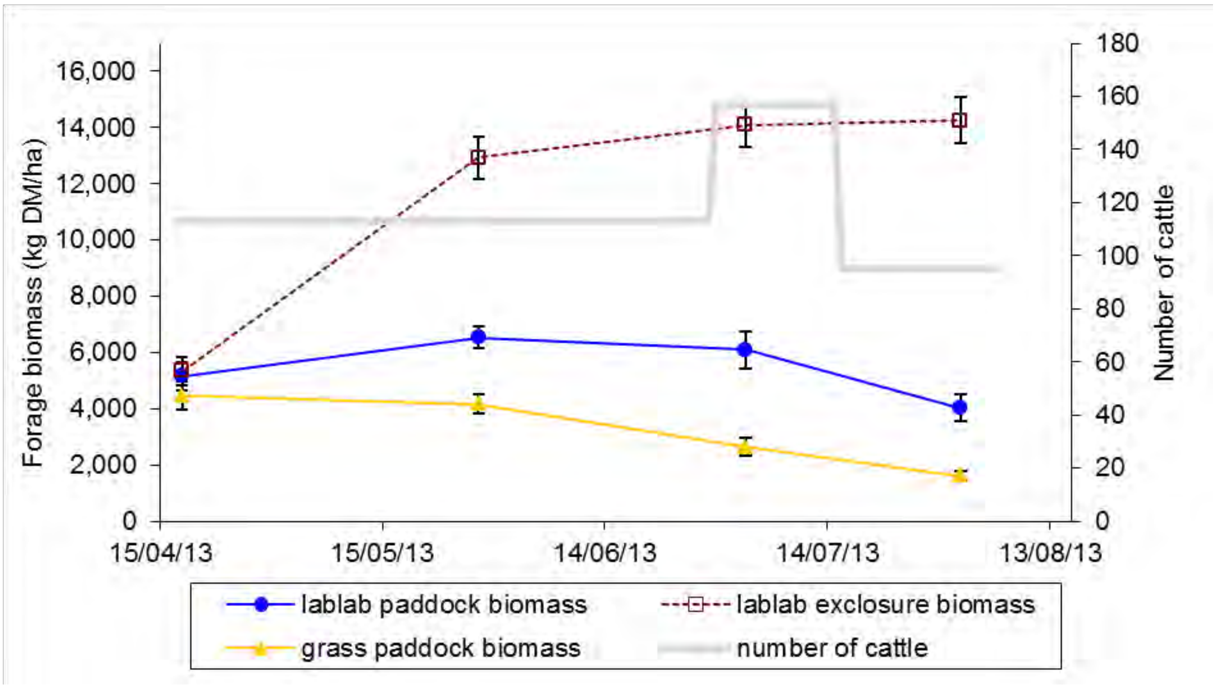

Fig. 115. Lablab biomass (kg DM/ha; mean ± SE) in the paddock and the exclosure, grass biomass in the paddock, and cattle numbers, during the grazing period (17/04/13-06/08/13).

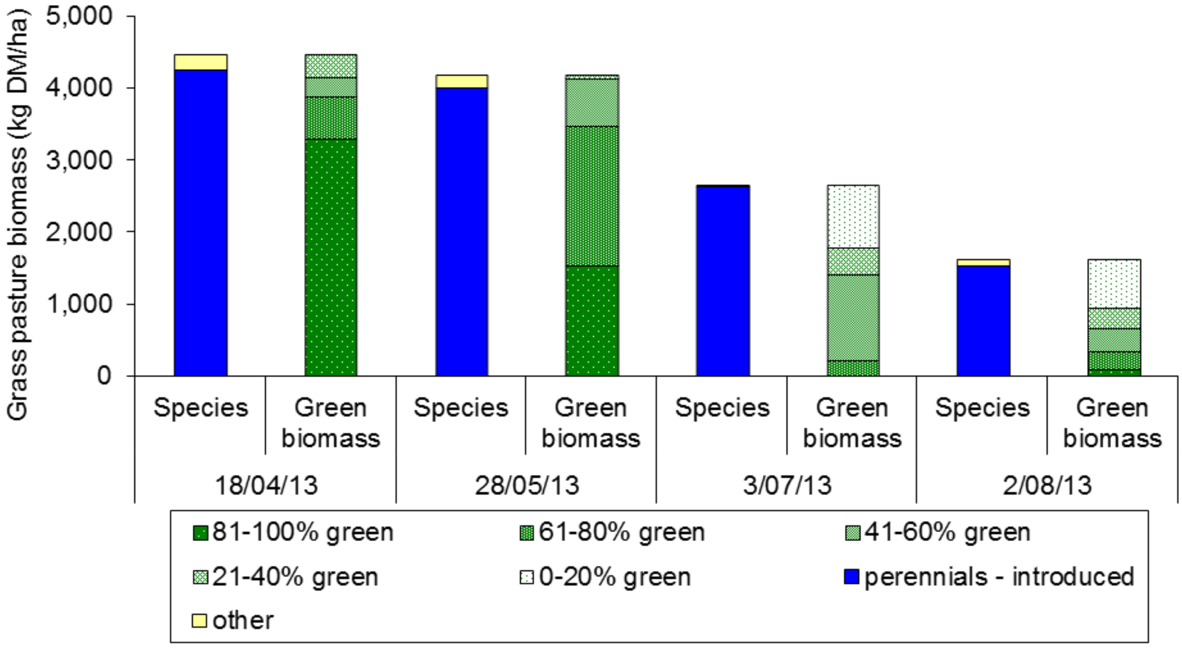

Fig. 116. Perennial pasture species composition (Species) and proportion of green material in the pasture (Green biomass) shown as a proportion of total pasture biomass (kg DM/ha). Introduced perennial grass species consisted primarily of buffel, sabi, and green panic. Other species consisted primarily of weeds.

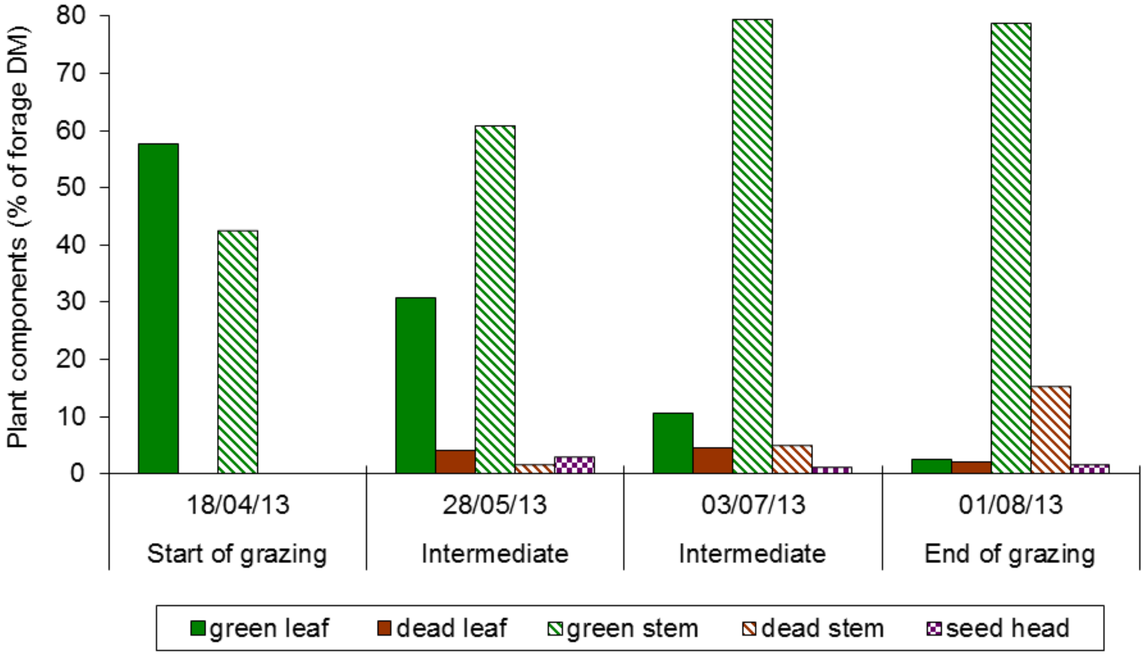

Fig. 117. Plant component composition (% of total forage DM) in the paddock during the grazing period (17/04/13-06/08/13).

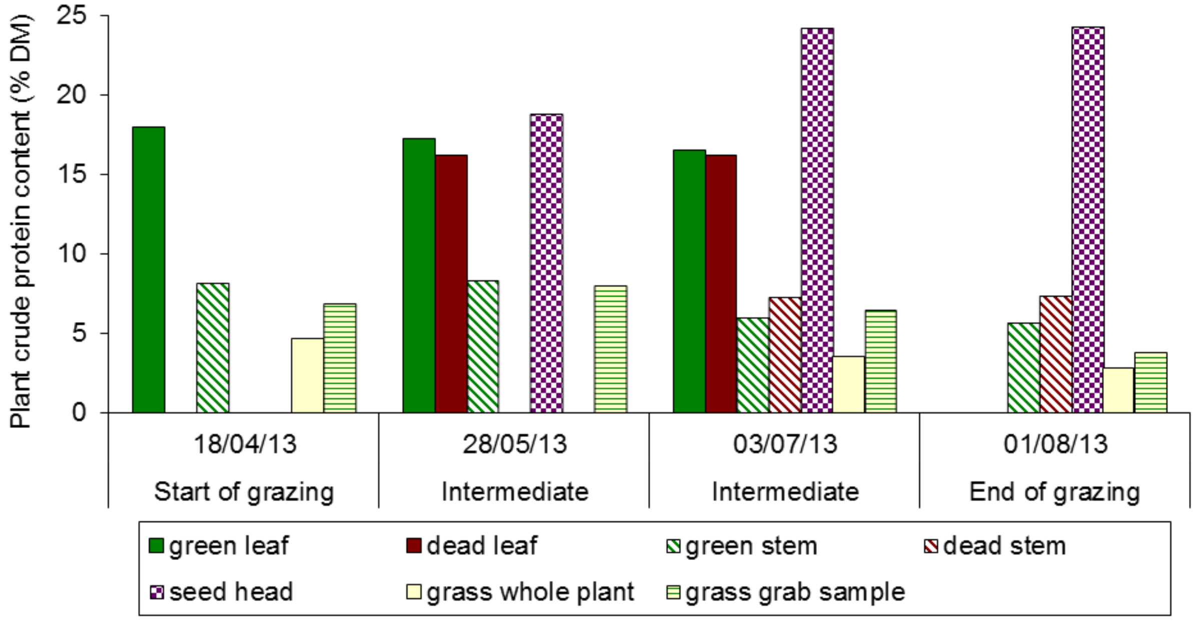

Fig. 118. Crude protein content (% DM) of lablab plant components, and perennial grass whole plant and grab samples, in the paddock during the grazing period (17/04/13-06/08/13).

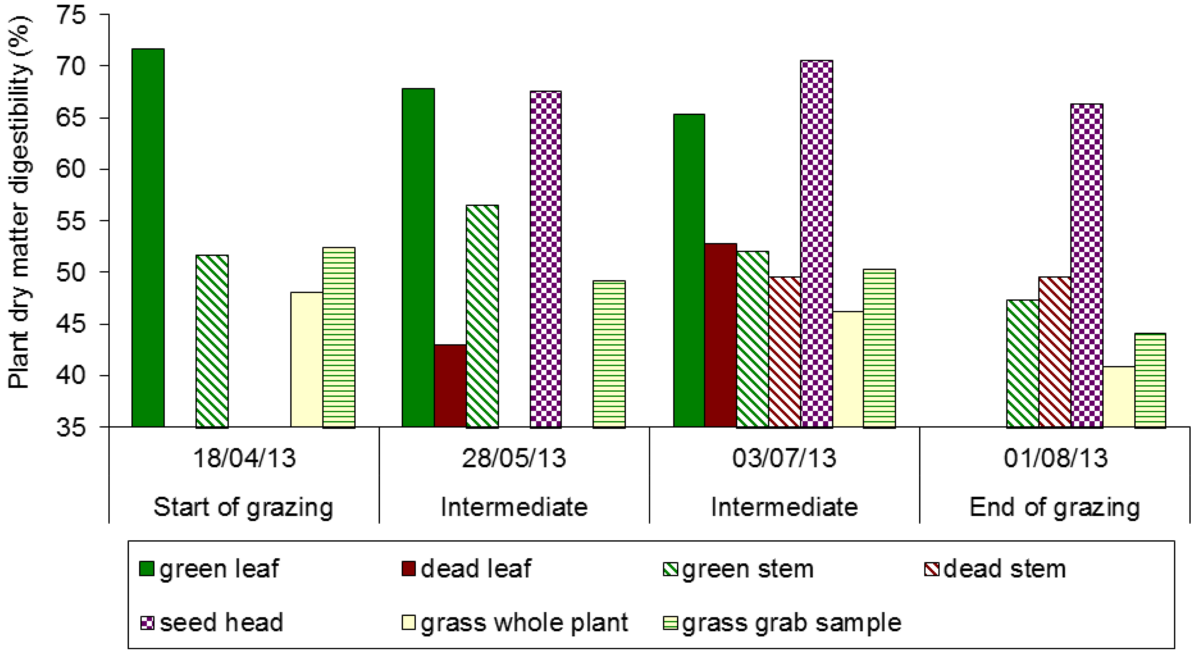

Fig. 119. Dry matter digestibility (%) of lablab plant components, and perennial grass whole plant and grab samples, in the paddock during the grazing period (17/04/13-06/08/13).

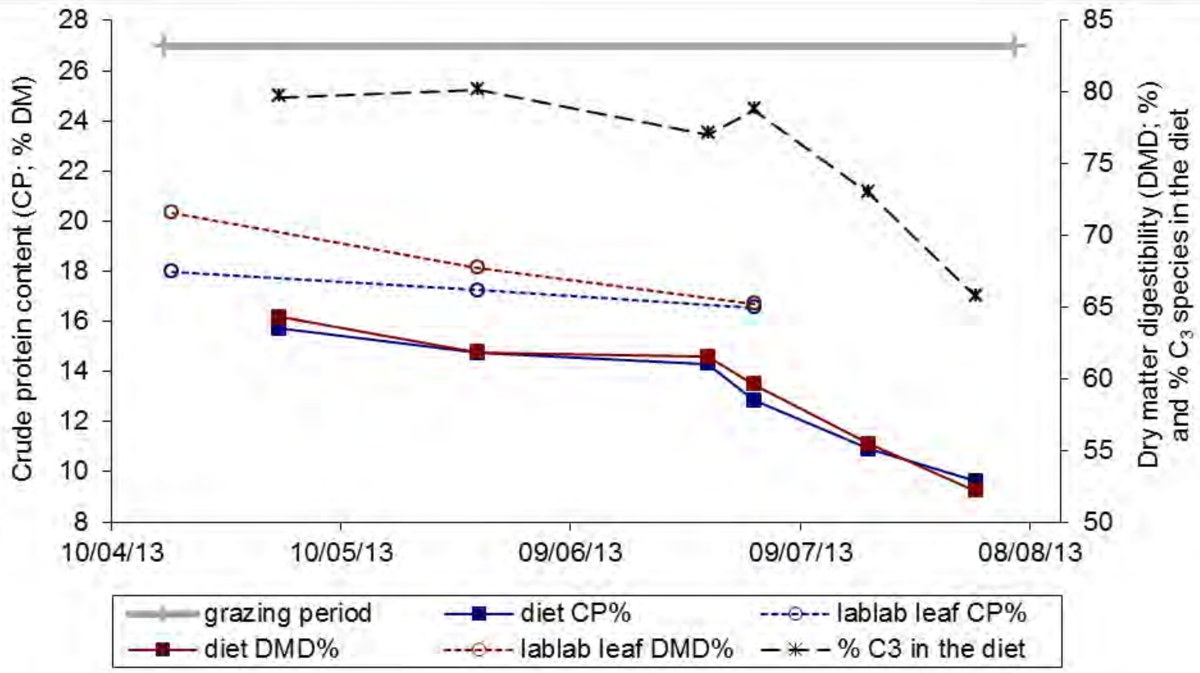

Fig. 120. Diet crude protein (CP) content (% DM) and dry matter digestibility (DMD; %) for grazing cattle predicted from faecal NIRS, measured CP and D MD content of lablab green leaf in the paddock; and the % of the diet as C_3 forage, predicted from δ13C content in the faeces. Grazing period shown.

Fig. 121. Cattle on lablab paddock, 24/04/13; 7 days after start of grazing.

Fig. 122. Cattle on lablab paddock, 12/08/13; end of grazing.

Soil measurements were taken about 5 weeks after sowing and at that time the soil moisture profile was over half full. This was sufficient to produce good initial crop growth and with good early in-crop rain, provided enough moisture for the crop to produce a large amount of dry matter. Soil nutrient levels prior to planting indicated that there was adequate P to meet the requirements of the crop. However, measurements of subsoil nitrate-N concentrations were not available to allow an assessment of adequacy of total nitrate-N concentrations. Given the low organic C concentrations (0.6% in the top 0-10 cm) and a history of cropping with grains and cotton, it is probable that soil N levels were initially low. This supposition is supported by the light green colour of plants at the start of grazing and by the relatively low CP concentration of leaf material (18.0% CP at start of grazing cf. 26.5% for the Central Queensland Open Downs 2011-12 lablab crop). Total in-crop rainfall was 328 mm (Fig. 114). Of this total, 233 mm fell between planting and commencement of grazing and 95 mm fell during the 111-day grazing period.

When grazing commenced the lablab crop had a biomass 5,164 kg DM/ha which decreased to 4,039 kg DM/ha by the end of the 111-day grazing period (Fig. 115, Fig. 121 and Fig. 122). Lablab biomass in the fenced exclosure increased to a peak of 14,253 kg DM/ha by the end of the grazing period. Green leaf formed 58% of the plant DM at the start of the grazing period, but this had decreased to 3% of the DM in the grazed paddock by the end of grazing period when green stem formed the greatest proportion of the biomass at 79% (Fig. 117). Plant chemical analysis indicated that there was a large difference between lablab leaf and stem in quality (Fig. 118 and Fig. 119). At the start of the grazing period, the CP concentration in green stem material (8.1% DM) was 44% of that in the green leaf (18.0% DM). Correspondingly, the DMD concentration in green stem material (52%) was 28% of that in the green leaf (72%). Perennial grass biomass in the grass area of the paddock decreased from 4,465 kg DM/ha at the start of grazing to 1,612 kg DM/ha at the end of the grazing period (Fig. 116).

Analysis of faecal samples for $\delta^{13}C$ concentration indicates that cattle were eating between 77-80% of the diet as lablab up until Day 78 of grazing (Fig. 120). This had decreased to 73% of the diet by Day 93 of grazing and to 66% by Day 107 of grazing (01/08/13). Predictions of diet CP concentrations from faecal NIRS analysis indicate that diet CP concentration was 15.7% on Day 15 of grazing (02/05/13), decreasing to 9.6% by Day 106 of grazing (01/08/13).

The drop in available, high-quality lablab leaf, and hence diet quality (CP and DMD), over the grazing period is reflected in the daily weight gains of a subset of 2-year old steers monitored over the whole 111-day grazing period. The average daily weight gain of this group decreased from an average 1.2 kg/head/day over the first 90 days of grazing, to 0.06 kg/head/day over the final 21 days of grazing. However, the weaner steers and heifers introduced to the paddock for the final 38 days of the 111-day grazing period still achieved reasonable weights gains of 0.65 kg/head/day over this period. Whilst the 2-year old steers had grazed leucaena-grass pasture prior to entering the lablab paddock, the weaners had grazed perennial grass pasture and so may have been exhibiting some compensatory gain effects.

The average stocking rate, expressed either per forage area alone (1.8 AE/ha), or per the total grazing area (1.3 AE/ha), was considerably lower than that assumed in the constructed scenario for lablab grown in the Central Queensland Brigalow region (2.5 and 2.3 AE/ha for the forage area alone and total grazing area, respectively; Table 30Table 30) whilst the grazing days were marginally greater (111 vs. 100 days). The daily liveweight gain over the majority of the grazing period was 1.5 times greater than that assumed in the constructed scenario (1.22 kg/head/day over 90 days vs. 0.8 kg/head/day over 100 days). The overall beef production per hectare for the total grazing area was similar to that assumed in the constructed scenario: 156 vs. 157 kg/ha/year, despite the difference in area planted to lablab (73 vs. 90%).

The use of lablab at this site resulted in a profitable outcome with a gross margin for the total grazing area of $50/ha calculated using owner rates and $15 /ha using contract rates. However, this gross margin is less than half of that calculated for the constructed scenario, although beef production from the total grazed area was similar and forage costs at this site were 0.66 of that calculated in the constructed scenario ($113 vs.$170/ha, calculated using owner rates for the forage area only). The explanation for the lower profitability of lablab at this site versus the constructed scenario is a lower per hectare net cattle income at this site, caused by a negative average cattle price margin of - $0.14/kg LW. As a large proportion of cattle grazing this crop were not sold at the end of the grazing period but retained on-property, the gross margin calculated here was not actually realised by the producer.

3.4 Leucaena (*Leucaena leucocephala spp. glabrata*) + grass species

3.4.1 Central Queensland Open Downs, Leucaena-grass pasture February 2012 – February 2014

(S 23.272, E 148.259; near Emerald)

The site was a 262 ha paddock, with 216 ha planted to leucaena and perennial grasses including Rhodes, buffel, bambatsi panic and Queensland bluegrass present in the inter-rows and naturalised over the remainder of the paddock (46 ha) which included a creek and trees. Prior to 2003 the paddock had been used for organic grain cropping. From 2003 to 2007 the paddock was used for either forage sorghum or lablab cropping. On 06/02/08, 82% of the paddock area was planted with Cunningham leucaena seed at a rate of 2 kg/ha, with single rows on 10 m centres. Perennial grasses including buffel, bambatsi panic and Rhodes were sown in the inter-rows at a rate of 4.5 kg/ha. The paddock received P fertiliser at planting but hadn't received any maintenance P since. The leucaena received maintenance chopping in mid-January 2011 and on 30/05/13. This site was located on the same commercial property as the Central Queensland Open Downs Oats 2013, Lablab 2011-12, Butterfly pea-grass 2012-14 and Perennial grass 2011-14 sites. During the period of monitoring, this paddock was used as part of a rotation with three other leucaena paddocks. Over the 2 years of monitoring, large groups of cattle were rotated through these paddocks with the average grazing period in the target paddock being 23 days. The same cattle were not kept in the rotation during any one period, with different mobs entering and exiting periodically to maintain suitable grazing pressure and exiting as cattle reached feedlot entry weight. The daily weight gain of groups of cattle is reported for the entire period they grazed leucaena, although this includes time spent in leucaena paddocks other than the target paddock. However, only the weight gain attributed to the target paddock is presented as the 'Total annual LWG' and used in the calculation of a gross margin for this site. A summary of key site details are given in Table 17 and Fig. 123-Fig. 131.

Table 17. Site details. Central Queensland Open Downs, Leucaena-grass pasture 2012-14
For definitions of abbreviations see Glossary of terms and abbreviations

Factor	Details	
Soil characterisation		
Broad land type	Open downs	
Soil type and characteristics	Black cracking clay (Vertosol) PAWC: 240 mm Soil depth: 120 cm	
Soil nutrient levels at site establishment (March 2012)		**0–10 cm**
	P (mg/kg)	11
	Organic C (%)	1.5
Forage production		
Average edible leucaena biomass	214 (range: 17-769) kg DM/ha	
Average perennial grass presentation yield	4,870 (range: 2,776-10,182) kg DM/ha. Major species: introduced perennial grasses bambatsi panic, buffel and rhodes (65, 13 and 11% of the biomass, respectively), and the native perennial grass Queensland bluegrass (10% of the biomass)	
Leucaena in the diet	47% (Days 37-733 of monitoring period)	
Average edible leucaena quality	24.2% CP, 65% DMD (Days 13-733 of monitoring period)	
Average diet quality	12.9% CP, 63% DMD (Days 37-733 of monitoring period)	

Factor	Details
Grazing management and animal production	
Comments	Grazing history in target paddock 1st 12 months (23/02/12-28/02/13): • Group 1: 23/02/12-28/03/12 (34 days); 622 steers, 18-20 months at entry • Spelled: 29/03/12-14/05/12 (46 days) • Group 2: 15/05/12-12/06/12 (28 days); 492 steers, 19-26 months at entry • Spelled: 13/06/12-23/09/12 (102 days) • Group 2: 24/09/12-10/10/12 (16 days); 492 steers, 23-30 months at entry • Spelled: 11/10/12-14/11/12 (34 days) • Group 2: 15/11/12-27/11/12 (12 days); 20 lightest steers, 25-32 months at entry • Groups 2 and 3: 28/11/12-23/12/12 (25 days); 404 steers; 384 Group 3 steers 14 months at entry • Spelled: 24/12/12-11/02/13 (49 days) • Group 3: 12/02/13-28/02/13 (16 days); 496 steers; 16 months at entry 2nd 12 months (01/03/13-27/02/14) • Group 3: 01/03/13-03/04/13 (33 days); 602 steers; 17 months at entry • Group 3: 04/04/13-28/05/13 (54 days); 502 steers; 18 months at entry • Group 3: 29/05/13-07/06/13 (9 days); 181 steers; 20 months at entry • Spelled: 08/06/13-05/08/13 (58 days) • Group 4: 06/08/13-22/08/13 (16 days); 312 steers; 20-26 months at entry; additional 230-ha leucaena paddock also open • Group 4: 23/08/13-30/09/13 (38 days); 312 steers; 21-27 months at entry • Spelled: 01/10/13-10/11/13 (40 days) • Group 4: 11/11/13-22/11/13 (11 days); 429 steers; 23-29 months at entry • Spelled: 23/11/13-20/01/14 (58 days) • Group 5: 21/01/14-05/02/14 (15 days); 504 steers; 15 months at entry • Spelled: 06/02/14-27/02/14 (21 days)
Cattle type monitored for weight gain	All cattle either NAPCO Kynuna or Alexandria Composite; ca. 13-38% *B. indicus*
Animal health treatments	Coopers® Amitik cattle dip and spray to all cattle as they exit the leucaena rotation for the NAPCO feedlot. One mob of 106 Group 3 steers was also treated with Amitik on entry to the leucaena rotation. Cattle were not given the leucaena rumen fluid inoculum but were exposed to carrier animals. All cattle arriving on this property as weaners are given an Elanco Compudose® 400 HGP implant which would have still been active for many of the steers upon entry to the leucaena.
Total monitoring period	23/02/12-27/02/14 (735 days)
Proportion of the total area planted to leucaena	82%

Factor	Details
Grazing management and animal production	
Average SR – 1st 12 months	0.64 AE/ha (1 AE : 1.57 ha)
Average SR – 2nd 12 months	0.81 AE/ha (1 AE : 1.23 ha)
Group 2 – (20 lightest), 25-32 month-old steers, Spring 2012 and Summer 2013	
Grazing days over which LW was measured	78 (15/11/12-01/02/13)
Number of cattle in weight gain data set	18
Average entry LW (± SE)	426 (± 3.1) kg
Average exit LW (± SE)	455 (± 4.7) kg
Average LWG (± SE)	0.38 (± 0.036) kg/head/day
Group 3 – 14 month-old steers 2012/13 Summer	
Grazing days over which LW was measured	93 (28/11/12-01/03/13)
Number of cattle in weight gain dataset	283
Average entry LW (± SE)	409 (± 1.8) kg
Average exit LW (± SE)	446 (± 1.8) kg
Average LWG (± SE)	0.40 (± 0.009) kg/head/day
Group 3 – 17 month-old steers 2013 early Autumn	
Grazing days over which LW was measured	34 (01/03/13-04/04/13)
Number of cattle in weight gain dataset	94
Average entry LW (± SE)	414 (± 1.9) kg
Average exit LW (± SE)	466 (± 2.3) kg
Average LWG (± SE)	1.53 (± 0.036) kg/head/day
Group 3 – 18 month-old steers 2013 mid-late Autumn (sub-group exiting to feedlot)	
Grazing days over which LW was measured	54 (04/04/13-28/05/13)
Number of cattle in weight gain dataset	34
Average entry LW (± SE)	465 (± 3.8) kg
Average exit LW (± SE)	500 (± 4.5) kg
Average LWG (± SE)	0.65 (± 0.048) kg/head/day
Group 3 – 18 month-old steers 2013 mid-late Autumn (sub-group returned to leucaena)	
Grazing days over which LW was measured	55 (04/04/13-29/05/13)
Number of cattle in weight gain dataset	57
Average entry LW (± SE)	459 (± 2.6) kg
Average exit LW (± SE)	481 (± 3.0) kg
Average LWG (± SE)	0.40 (± 0.027) kg/head/day
Group 4 – 18-24 month-old steers 2013 Winter and Spring	
Grazing days over which LW was measured	194 (30/05/13-10/12/13)
Number of cattle in weight gain dataset	17
Average entry LW (± SE)	364 (± 5.3) kg
Average exit LW (± SE)	424 (± 8.7) kg
Average LWG (± SE)	0.31 (± 0.025) kg/head/day
Group 4 – 20-26 month-old steers 2013 Winter and Spring	
Grazing days over which LW was measured	141 (22/07/13-10/12/13)
Number of cattle in weight gain dataset	269
Average entry LW (± SE)	356 (± 1.0) kg
Average exit LW (± SE)	415 (± 1.1) kg
Average LWG (± SE)	0.41 (± 0.007) kg/head/day
Group 5 – 14 month-old steers 2013/14 Summer	
Grazing days over which LW was measured	77 (12/12/13-27/02/14)
Number of cattle in weight gain dataset	433
Average entry LW (± SE)	336 (± 2.5) kg
Average exit LW (± SE)	424 (± 2.7) kg
Average LWG (± SE)	1.14 (± 0.014) kg/head/day
Total annual LWG – 1st 12 months	148 kg/ha/annum (23/02/12-28/02/13)
Total annual LWG – 2nd 12 months	234 kg/ha/annum (01/03/13-27/02/14)

Factor	Details	
Economic performance		
	1st 12 months (23/02/12-28/02/13), ($/ha/annum)	**2nd 12 months (01/03/13-27/02/14), ($/ha/annum)**
Gross margin - owner rates (total grazing area)	**142**	**192**
Forage costs (forage area only)	35	35
Gross margin - contract rates (total grazing area)	**140**	**191**
Forage costs (forage area only)	37	37
CONSTRUCTED SCENARIO		
Gross margin - owner rates	**163**	**163**
Forage costs	40	40
Gross margin - contract rates	**159**	**159**
Forage costs	44	44

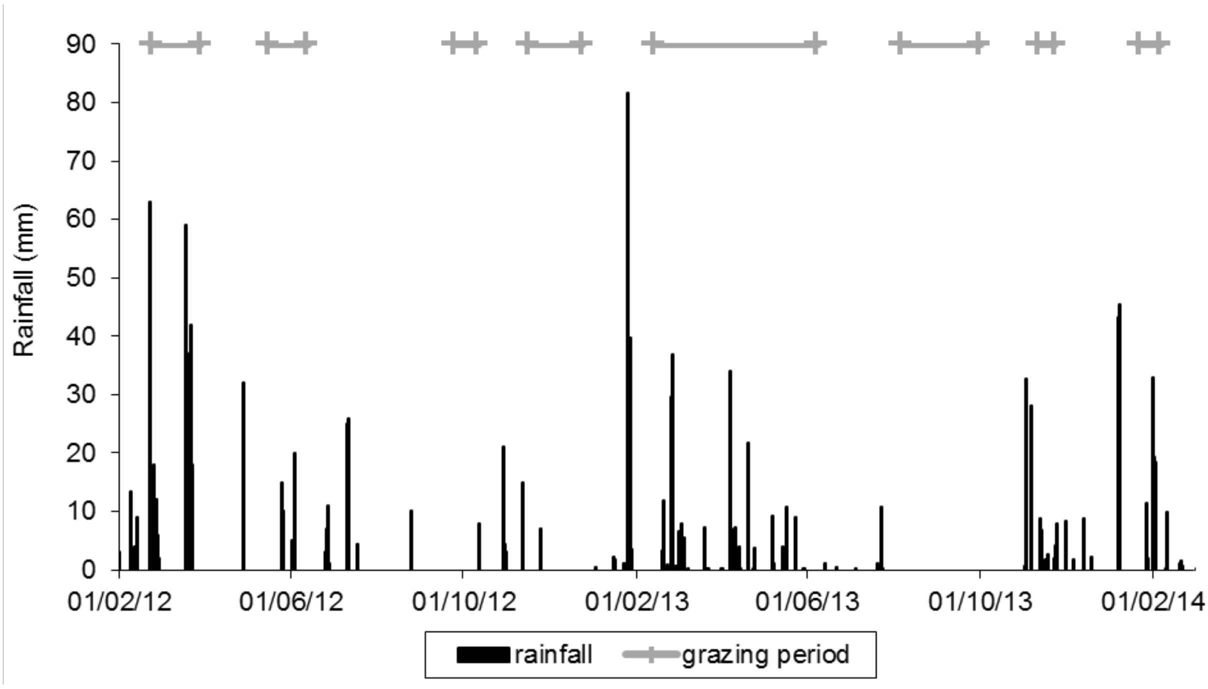

Fig. 123. Daily rainfall (mm) over the monitoring period (23/02/12-27/02/14). Measured on property ca. 8.2 km from the paddock (23/02/12-31/12/12) and with an on-site weather station in the neighbouring butterfly pea paddock ca. 6.6 km from the paddock (01/01/13-27/02/14). G razing periods shown.

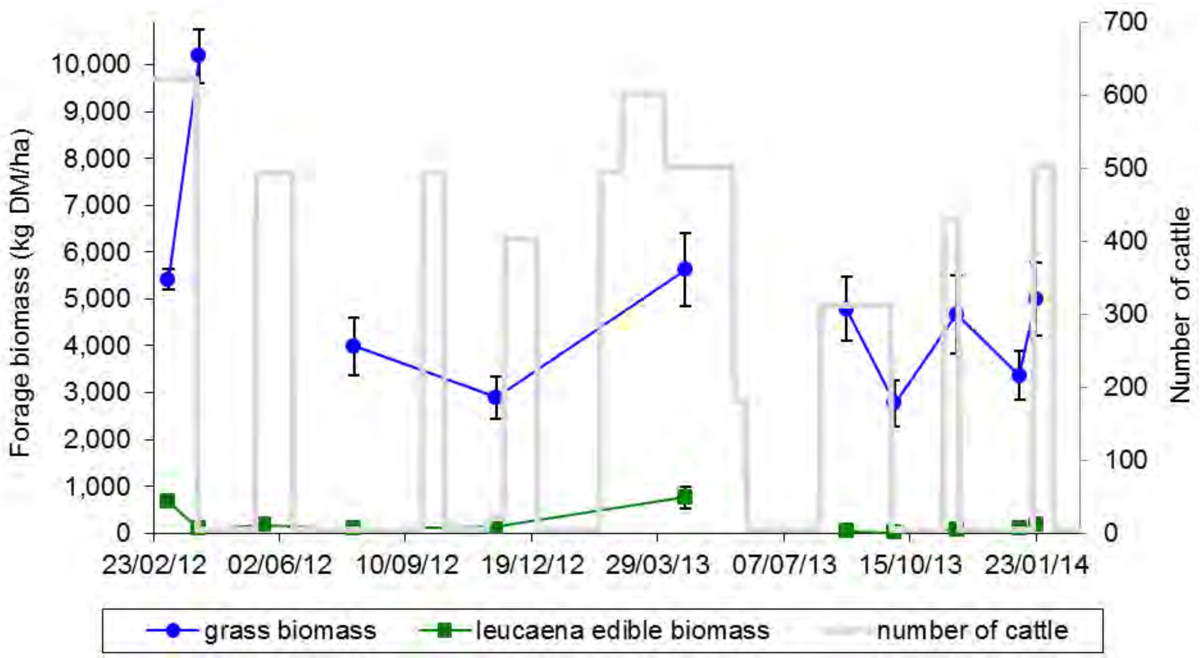

Fig. 124. Grass biomass (kg DM/ha; mean ± SE) in the leucaena inter-rows and biomass of edible leucaena (kg DM/ha; mean ± SE), including green stems up to 5 mm in diameter, during the monitoring period (23/02/12-27/02/14). Leucaena was chopped on 30/05/13. Cattle numbers during the monitoring period also shown.

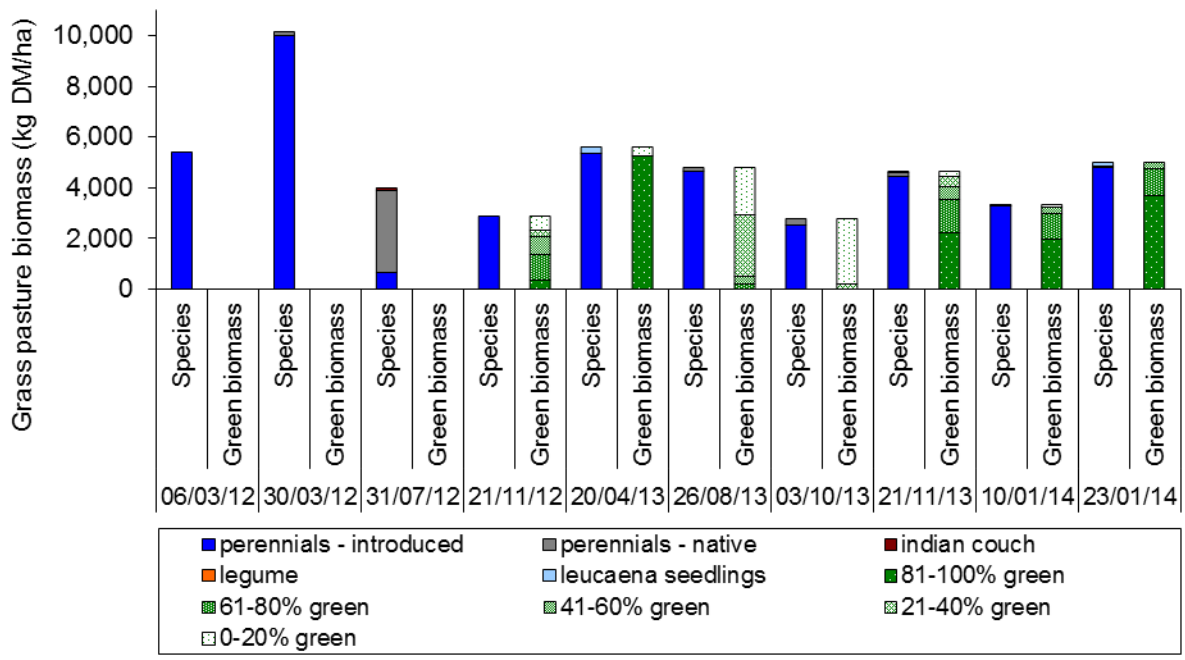

Fig. 125. Perennial grass pasture composition (Species) and proportion of green material in the pasture (Green biomass) shown as a proportion of total pasture biomass (kg DM/ha). Assessments were made in the leucaena inter-rows only. Introduced perennial grasses consisted of primarily Rhodes (average 65% of the biomass), buffel (average 13% of the biomass average), and bambatsi panic (average 11% of the biomass). Native perennial grass was Queensland bluegrass (average 10% of the biomass). Green biomass was only assessed from the 21/11/12 sampling onwards.

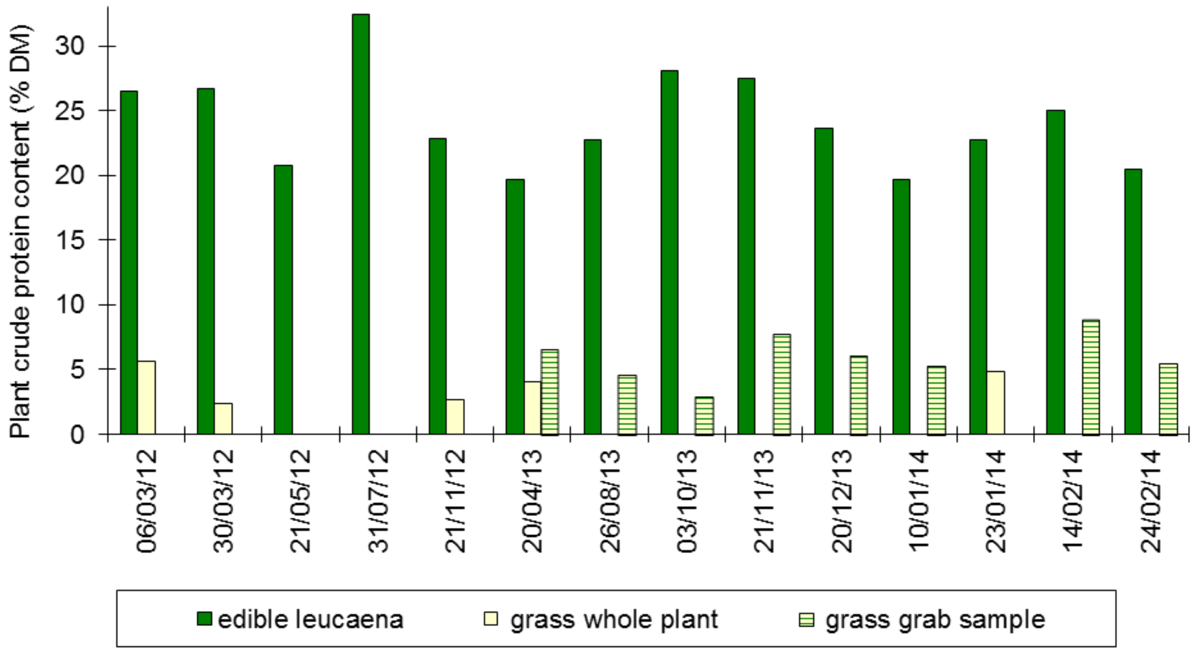

Fig. 126. Crude protein content (% DM) of edible leucaena (leaf and green stems up to 5 mm in diameter), perennial grass whole plant samples and 'grab' samples of perennial grass during the monitoring period (23/02/12-27/02/14). Samples taken on 20/12/13, 14/02/14 and 24/02/14 were from other leucaena paddocks in the rotation (i.e. not the target paddock) to represent what the cattle had available for consumption at that time.

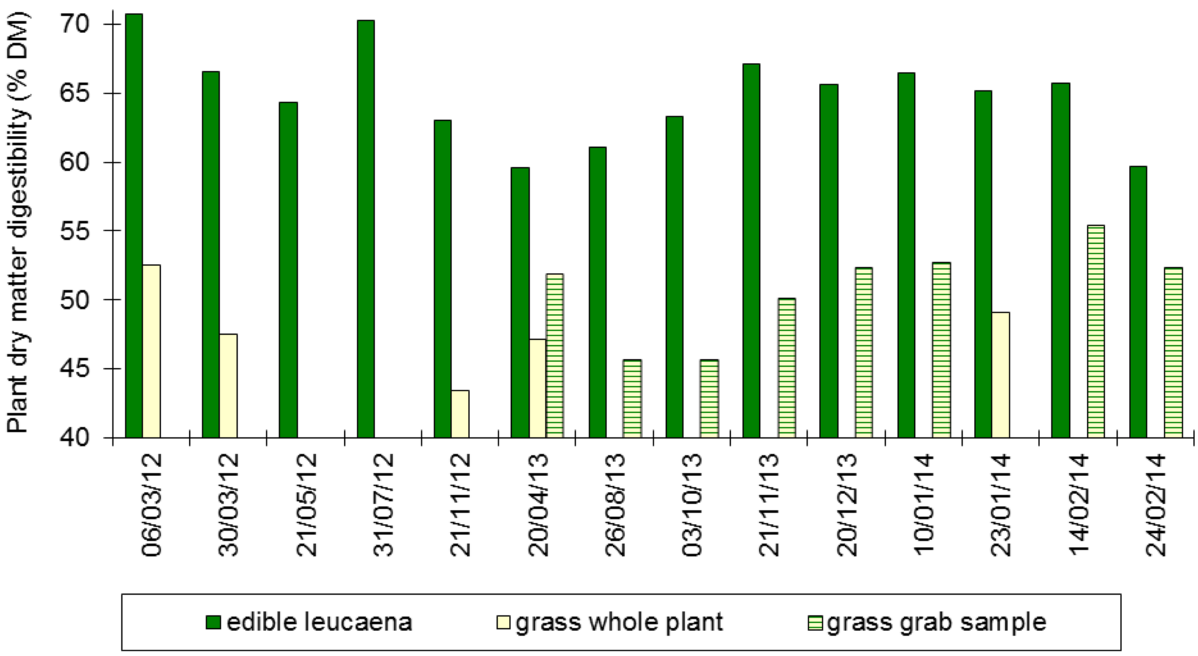

Fig. 127. Dry matter digestibility (%) of edible leucaena (leaf and green stems up to 5 mm in diameter), perennial grass whole plant samples and 'grab' samples of perennial grass during the monitoring period (23/02/12-27/02/14). Samples taken on 20/12/13, 14/02/14 and 24/02/14 were from other leucaena paddocks in the rotation (i.e. not the target paddock) to represent what the cattle had available for consumption at that time.

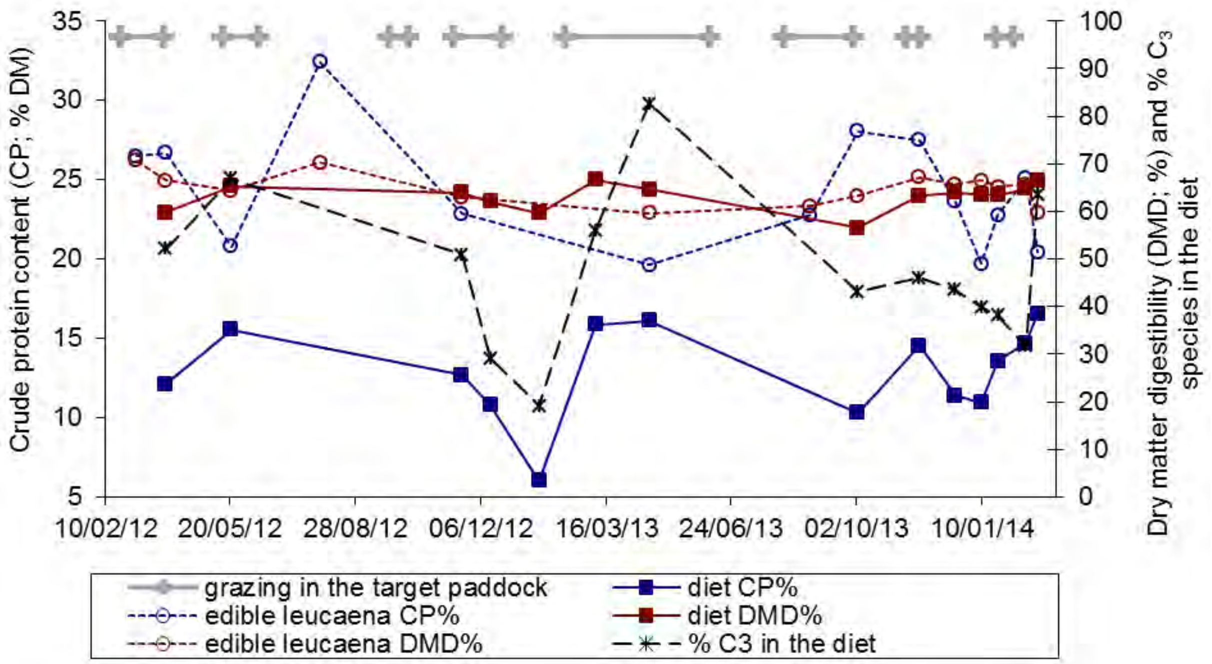

Fig. 128. Diet crude protein (CP) content (% DM) and dry matter digestibility (DMD; %) for grazing cattle predicted from faecal NIRS; measured CP and DMD content of edible leucaena (including stems up to 5 mm in diameter); and the % of the diet as C_3 forage, predicted from $\delta^{13}C$ content in the faeces. Grazing periods in the target paddock shown. Faecal and plant samples were taken from other leucaena paddocks in the rotation to reflect where the cattle were grazing.

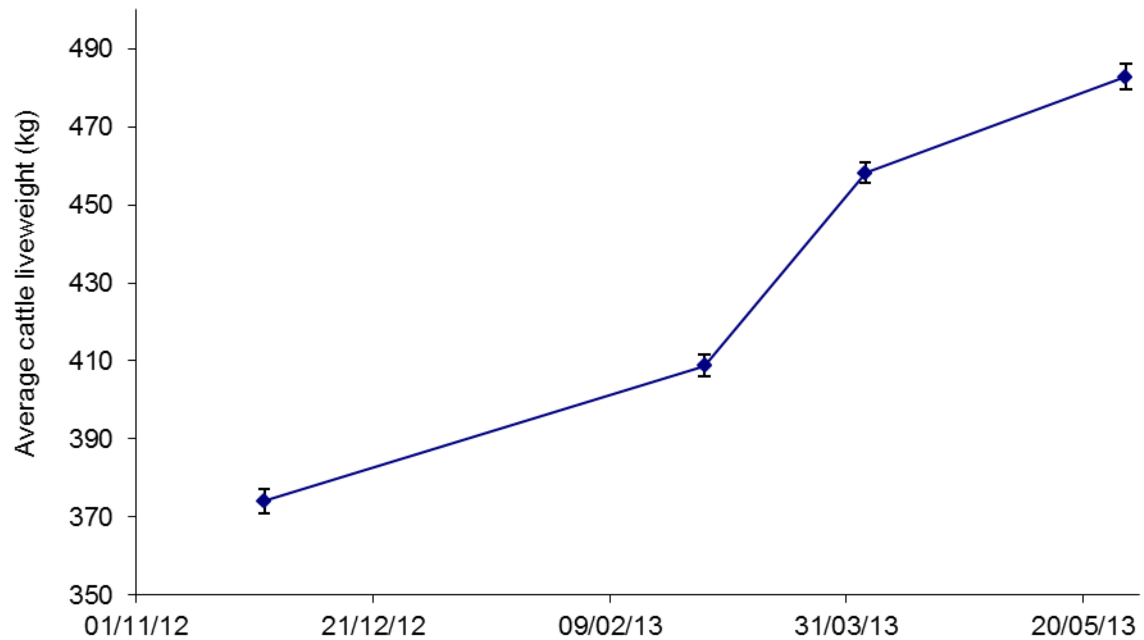

Fig. 129. Average cattle liveweight (kg; mean ± SE) for a subset of 59 Group 3 steers weighed four times over 182 days over the period 28/11/12 to 29/05/13.

Fig. 130. Cattle grazing leucaena-grass paddock, 21/11/12, just prior to the start of the grazing period for Group 3 steers.

Fig. 131. Cattle grazing leucaena-grass paddock, 20/04/13, ca. 1 month prior to the end of the grazing period of Group 3 steers.

The soil in this paddock is black cracking clay typical of the Open Downs soils in the region. Soil depth is relatively deep at 120 cm compared to the typical average for Open Downs soils of 75-90 cm deep. Measured soil P levels were low (11 mg/kg) and are considerably lower than what leucaena typically requires to maximise forage production (15-20 mg/kg; Dalzell *et al.* 2006; Peck *et al.* 2014). This low level would be expected to be a result of the past history of grain and forage cropping in this paddock with no P application except at planting of leucaena in the paddock in 2008.

The annual rainfall totals measured on the property during 2012 and 2013 were 717 and 493 mm, respectively (Fig. 123). The 30-year climate normal mean rainfall measured at the Emerald Post Office (BOM Station 35027) is 653.5 mm (mean of records for period 1961-1990). Hence the annual rainfall measured on property was above the 30-year climate normal in 2012 but below in 2013.

The pasture biomass and diet quality (CP and DMD, and % green in the grass biomass) reflected the seasonal rainfall patterns as well as the grazing history in the paddock. The greatest grass pasture biomass (10,182 kg DM/ha) was measured soon after the start of the monitoring period on 30/03/12 (Fig. 124). The greatest edible leucaena biomass (769 kg DM/ha) was measured on 20/04/13 which also coincided with a peak in grass pasture biomass (5,628 kg DM/ha) and a very high proportion (94%) of the grass pasture biomass assessed as 81-100% green (Fig. 124, Fig. 125). Whilst diet CP concentration ranged from 6.0-16.6%, the CP content of edible leucaena ranged from 19.6-32.4% over the monitoring period (Fig. 128, Fig. 126). Corresponding diet DMD concentrations ranged from 57-67% while the DMD content of edible leucaena ranged from 60-71% (Fig. 128, Fig. 127). The proportion of C_3 species (presumed to be primarily leucaena) in the diet ranged from 19-83%, with the lowest proportion of leucaena coinciding with the period just prior to the seasonal break in early 2013 and the highest proportion of leucaena measured on the 20/04/13 after significant rainfall events.

The total cattle liveweight gain attributed to this paddock was 1.6 times higher for the second 12-month period of monitoring compared to the first (234 cf. 148 kg/ha/annum). This was a result of higher average stocking rate over the second year (0.81 cf. 0.64 AE/ha), a greater number of grazing days per monitoring period (186/363 cf. 140/371), as well as a higher average cattle liveweight gain (weighted average across all mobs) during the second period. There was a wide range in daily liveweight gain measured for different groups of cattle and periods. The lowest daily liveweight gain recorded was 0.31 kg/head/day over 194 days during the 2013 winter and spring period for 18-24 month old steers. Similar low growth rates in the range of 0.38-0.41 were recorded for other groups during winter, spring and early summer grazing periods, prior to the seasonal break. The highest daily liveweight gain figures recorded were 1.53 kg/head/day over 34 days in early autumn 2013 for 17-month steers and 1.14 kg/head/day over 77 days during 2013-14 summer for 14 month old steers. These periods of high growth rate coincided with peaks in grass and leucaena biomass, in the % of leucaena in the diet and in diet quality. Fig. 129 shows the liveweight change over a 182-day period from late November 2012 to end of May 2013 for one of the cattle groups (Group 3) which were weighed multiple times during their grazing period (Fig. 130, Fig. 131).

The gross margin for the total grazing area over the first 12 months of grazing (23/02/12-28/02/13) was $142/ha/annum when calculated using owner rates and $140/ha/annum when calculated using contract rates. The gross margin for the second 12 months of grazing (01/03/13-27/02/14) was $192/ha/annum calculated using owner rates and $191/ha/annum calculated using contract rates. The average gross margin for the total grazing area over the 2 years of monitoring was $167/ha/annum, calculated using owner rates. This is only marginally greater than the gross margin estimated in the constructed scenario for leucaena-grass pastures grown in the Central Queensland Open Downs region ($163/ha/annum), despite only 82% of the total grazing area being planted to leucaena and the number of grazing days in the target paddock being lower (average of 163 vs. 270 days/year). However, the average stocking rate and estimated annual cattle production was higher at this site (average 0.73 vs. 0.44 AE/ha and 191 vs. 140 kg/ha/annum, respectively). In addition, annual, amortised forage costs for this site ($35/ha/annum, owner rates) were lower than that estimated in the constructed scenario ($40/ha/annum) due to ideal establishment conditions. However, the assumed productive life of leucaena was 20 years at this site vs. 30 years in the constructed scenario. Cattle price margin was $0 in the first and the second 12 month period.

3.4.2 Central Queensland Brigalow, Leucaena-grass pasture, January 2012 - April 2013

(S 24.286, E 150.363; near Jambin)

The site was a 97.1 ha paddock with leucaena planted over ca. one half (51.8 ha) and perennial grasses (buffel, green panic, Indian bluegrass and sabi) in the second half (45.2 ha); (Fig. 132). The 51.8 ha leucaena section of the paddock was originally cleared of blackbutt and brigalow timber in the late 1960s and then cropped continually until leucaena was planted in 2001 in twin rows, 1 m apart, on 6 m centres. Grasses were not sown between the leucaena rows, but have naturally colonised since (mainly Indian bluegrass). The leucaena area was initially spelled for 7-8 months after planting and has then been grazed continuously since. The leucaena has never been fertilised or received maintenance chopping. The grass-only section of the paddock was cleared in the 1980s and in the 1990s was blade-ploughed and sown with the perennial grass and legume species: green panic, buffel grass and butterfly pea. However, little to no butterfly pea was present during the monitoring period. The re-growth was cleared in the mid 2000s and the paddock has been continuously grazed except during the periods of timber treatment. This site was located on the same commercial property as the Central Queensland Brigalow Leucaena-grass pasture 2013-14 and Perennial grass pasture 2012-13 sites.

The 97.1 ha trial paddock was grazed continuously with the same 64 steers from 10/01/12 to 25/03/13 when 30 steers were sent to the abattoir. The remaining 34 steers were weighed on 30/04/13 of which 19 steers sent to the abattoir and monitoring finished. A summary of key site details are given in Table 18 and Fig. 132-Fig. 142.

Table 18. Site details. Central Queensland Brigalow, Leucaena-grass pasture 2012-13
For definitions of abbreviations see Glossary of terms and abbreviations

Factor	Details	
Soil characterisation		
Broad land type	Brigalow	
Soil type and characteristics	Brown cracking clay (with melonholes) PAWC: 180 mm Soil depth: 120 cm	
Soil nutrient levels at site establishment (January 2012)		**0–10 cm**
	P (mg/kg)	20
	Organic C (%)	1.2
Forage production		
Average edible leucaena biomass	438 (range: 59-1,212) kg DM/ha	
Average perennial grass presentation yield	2,700 (range: 1,212-5,550) kg DM/ha; major species were the introduced perennial grasses buffel, sabi and green panic.	
Leucaena in the diet	37% (Days 25-477 of grazing period)	
Average edible leucaena quality	23.1% CP, 67% DMD (Day 3-end of grazing period)	
Average diet quality	9.6% CP, 44% DMD (Days 25-477 of grazing period)	

Factor	Details
Grazing management and animal production	
Comments	The paddock was grazed continuously for 476 days (10/01/12–30/04/13). In total, 64 steers grazed the paddock for the first 440 days, after which 30 steers were removed and 34 steers grazed the paddock for the final 36 days. Urea lick (250 kg; Rumevite® SSS weaner lick with rumensin) was fed during Jan-Feb 2013 prior to rain. During this same period 1 round bale of buffel grass hay (250-300 kg) was also fed per day for 34 days. An initial 30 steers were killed at Teys Beenleigh abattoir on 26/03/13. A further 19 steers were killed at Teys Rockhampton abattoir on 03/05/13.
Cattle type monitored for weight gain	Steers; 12-16 months old at entry; Brahmans, 100% *B. indicus*
Animal health treatments	Novartis AG Cypafly and Virbac Taktic® EC on 01/01/12. Cypafly re-treatment on 16/02/13. Cattle were not given the leucaena rumen fluid inoculum.
Total monitoring period	10/01/12–30/04/13 (476 days)
Grazing days over which LW was measured	476 (10/01/12–30/04/13)
Proportion of the total area planted to leucaena	53%
SR (Leucaena area only)	1.22 AE/ha (1 AE : 0.82 ha)
SR (total grazing area)	0.65 AE/ha (1 AE : 1.5 ha)
Number of cattle in weight gain dataset	57-62 for first 438 days, 19 for final 38 days
Average entry LW (± SE)	370 (± 3.60) kg (*n* = 61)
First 90 days of grazing (10/01/12–09/04/12)	
Average LWG (± SE)	0.93 (± 0.017) kg/head/day (*n* = 59)
Following 116 days of grazing (09/04/12–03/08/12)	
Average LWG (± SE)	0.52 (± 0.013) kg/head/day (*n* = 60)
Following 197 days of grazing (03/08/12–16/02/13)	
Average LWG (± SE)	-0.07 (± 0.008) kg/head/day (*n* = 57)
Following 35 days of grazing (16/02/13–23/03/13)	
Average LWG (± SE)	1.30 (± 0.044) kg/head/day (*n* = 57)
Final 38 days of grazing for 2nd slaughter mob only (23/03/13–30/04/13)	
Average LWG (± SE)	1.18 (± 0.046) kg/head/day (*n* = 19)
Average LWG over first 438 days of grazing: 10/01/12-23/03/13 (± SE)	0.39 (± 0.008) kg/head/day (*n* = 54)
Total annual LWG – 1st 12 months	86 kg/ha/annum
Total LWG – 476 days	129 kg/ha per 476 days
First slaughter group (26/03/13)	(*n* = 30)
Average carcase weight (± SE)	288 (± 3.0) kg
Average carcase dentition (± SE)	5 (± 0.2)
Average carcase fat depth (± SE)	11 (± 0.5) mm
Second slaughter group (03/05/13)	(*n* = 19)
Average carcase weight (± SE)	301 (± 4.1) kg
Average carcase dentition (± SE)	5 (± 0.2)
Average carcase fat depth (± SE)	11 (± 0.9) mm

Factor	Details	
Economic performance		
	Leucaena area only ($/ha per 476 days)	**Total grazing area ($/ha per 476 days)**
Gross margin - owner rates	**169**	**90**
Forage costs	47	25
Gross margin - contract rates	**158**	**85**
Forage costs	58	31
CONSTRUCTED SCENARIO	**($/ha/annum)**	**($/ha/annum)**
Gross margin - owner rates	**169**	**169**
Forage costs	42	42
Gross margin - contract rates	**165**	**165**
Forage costs	46	46

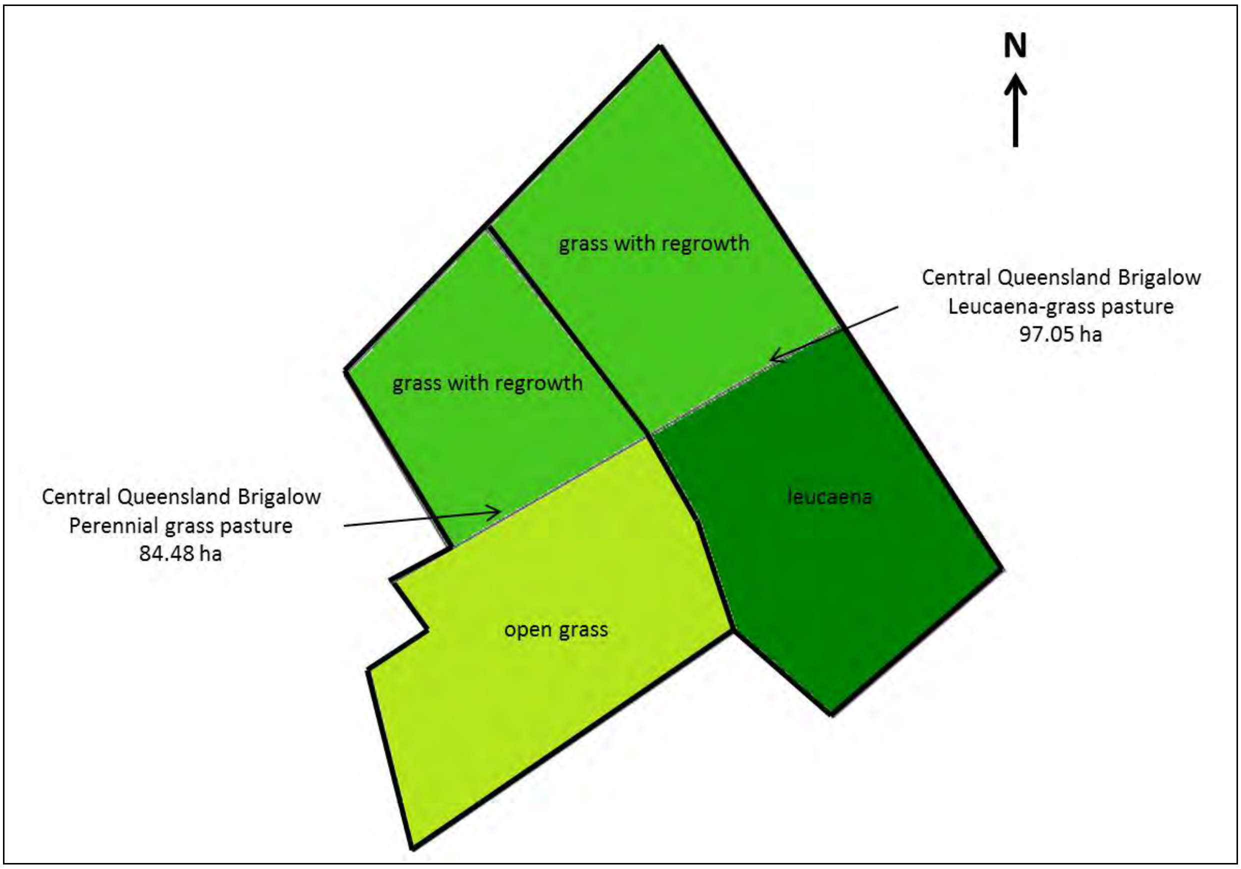

Fig. 132. Paddock layout for Central Queensland Brigalow, Leucaena-grass pasture and the adjacent site representing Central Queensland Brigalow, Perennial grass pasture.

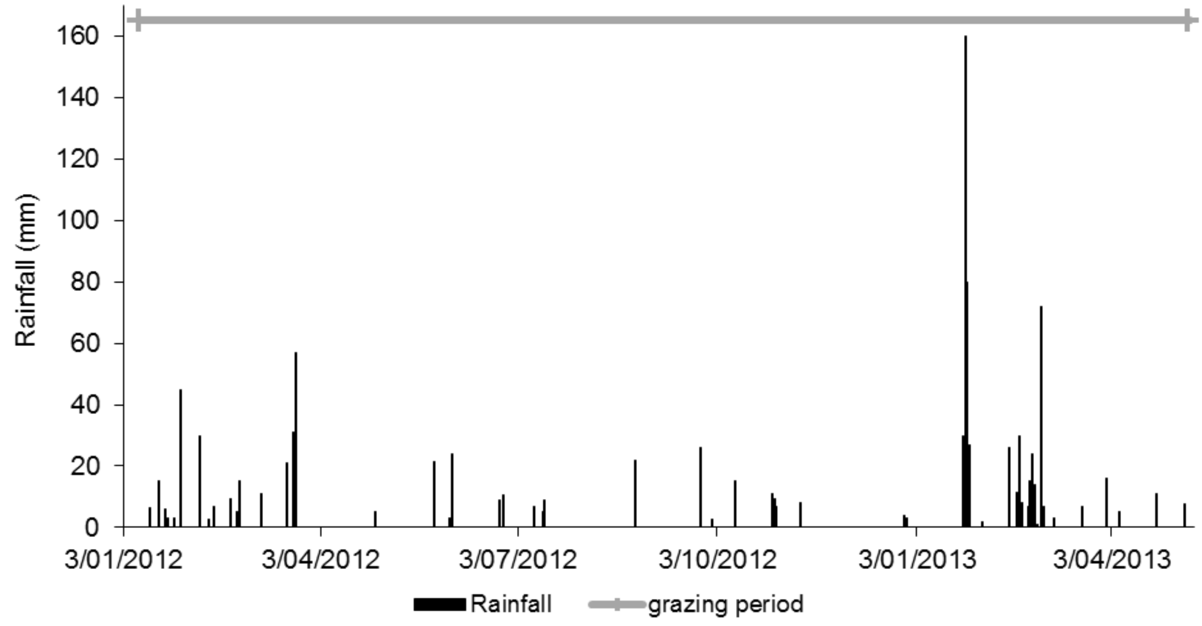

Fig. 133. Daily rainfall (mm) over the period (10/01/12–30/04/13). Measured on property, 1.2 km from the trial paddock. Grazing period shown.

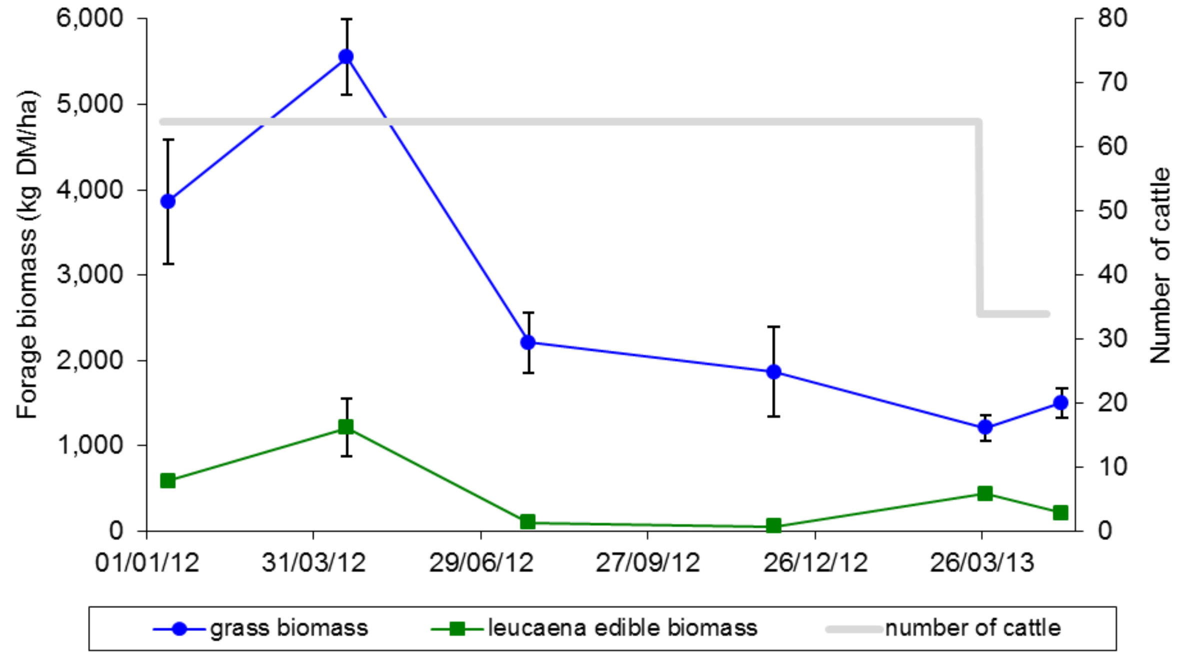

Fig. 134. Grass biomass (kg DM/ha; mean ± SE) over the whole grazing area and biomass of edible leucaena (kg DM/ha; mean ± SE), including green stems up to 5 mm in diameter, in the paddock during the monitoring period (10/01/12–30/04/13). Cattle numbers during the monitoring period shown.

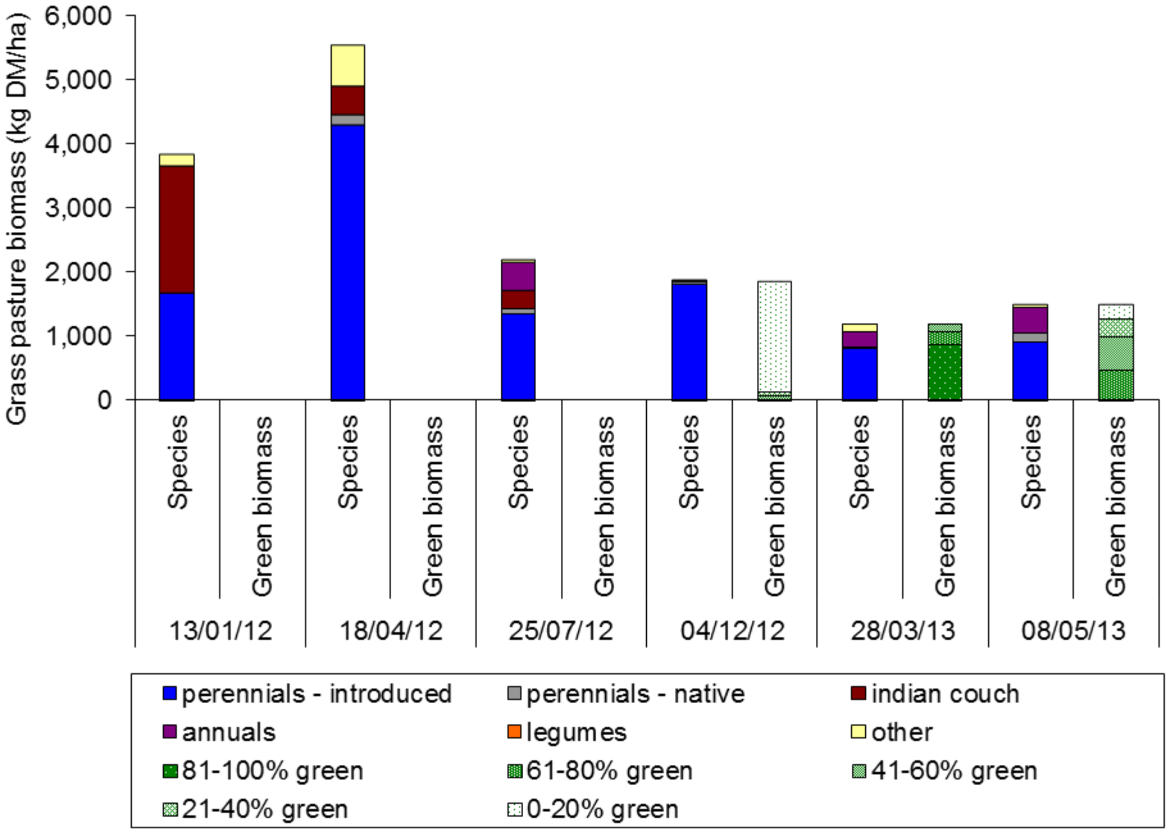

Fig. 135. Perennial pasture species composition (Species) and proportion of green material in the pasture (Green biomass) shown as a proportion of total pasture biomass (kg DM/ha). Assessments were made over the whole grazing area. Introduced perennial grasses consisted of primarily buffel, sabi and green panic. Native perennial grasses were primarily Queensland bluegrass. Green biomass was only assessed from the 04/12/12 sampling onwards.

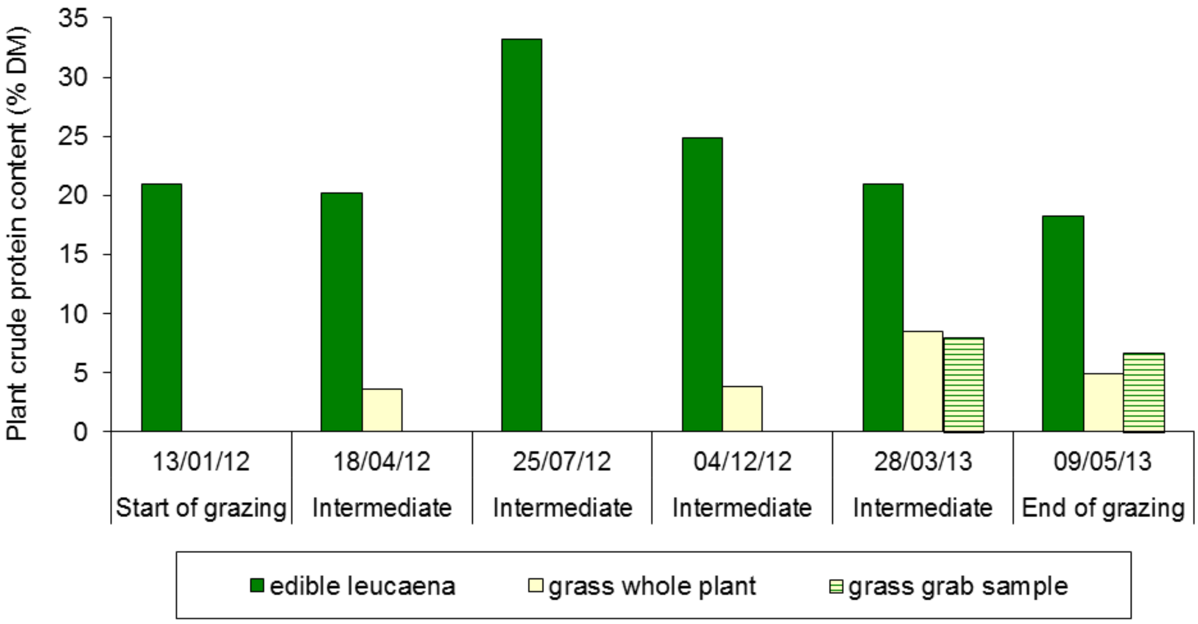

Fig. 136. Crude protein content (% DM) of edible leucaena (leaf and green stems up to 5 mm in diameter), perennial grass whole plant samples and 'grab' samples of perennial grass in the paddock during the monitoring period (10/01/12–30/04/13).

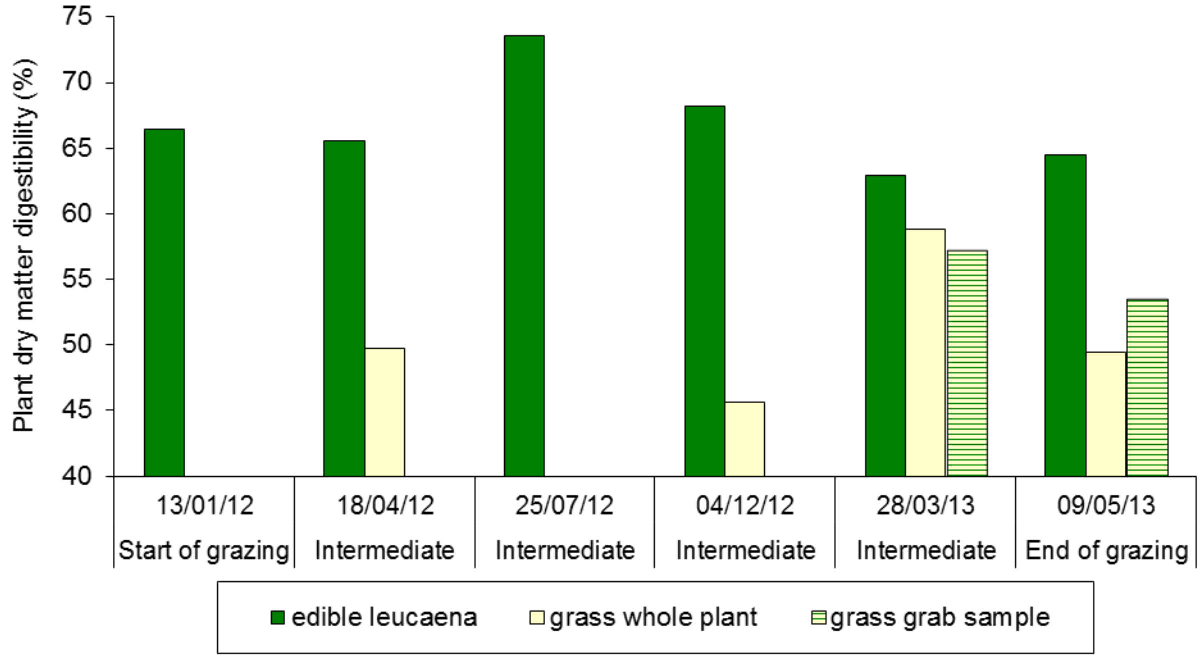

Fig. 137. Dry matter digestibility (%) of of edible leucaena (leaf and green stems up to 5 mm in diameter), perennial grass whole plant samples and 'grab' samples of perennial grass in the paddock during the monitoring period (10/01/12–30/04/13).

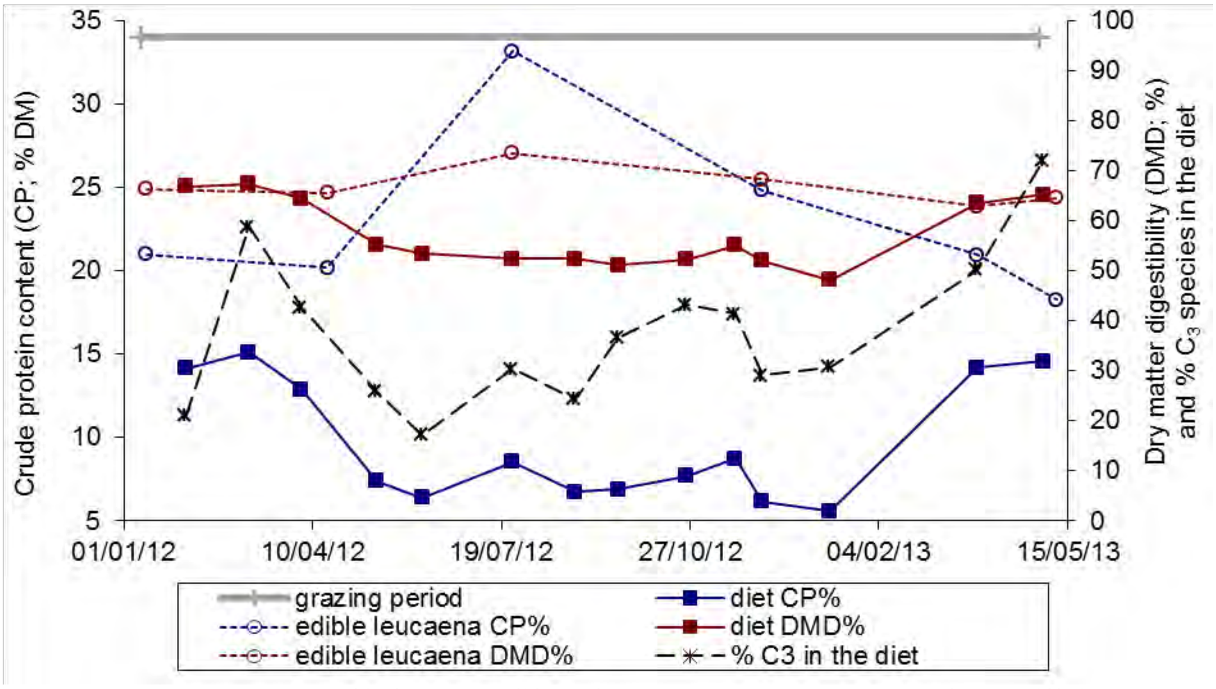

Fig. 138. Diet crude protein (CP) content (% DM) and dry matter digestibility (DMD; %) for grazing cattle predicted from faecal NIRS; measured CP and DMD content of edible leucaena (including stems up to 5 mm in diameter); and the % of the diet as C_3 forage, predicted from $\delta^{13}C$ content in the faeces. Grazing period shown.

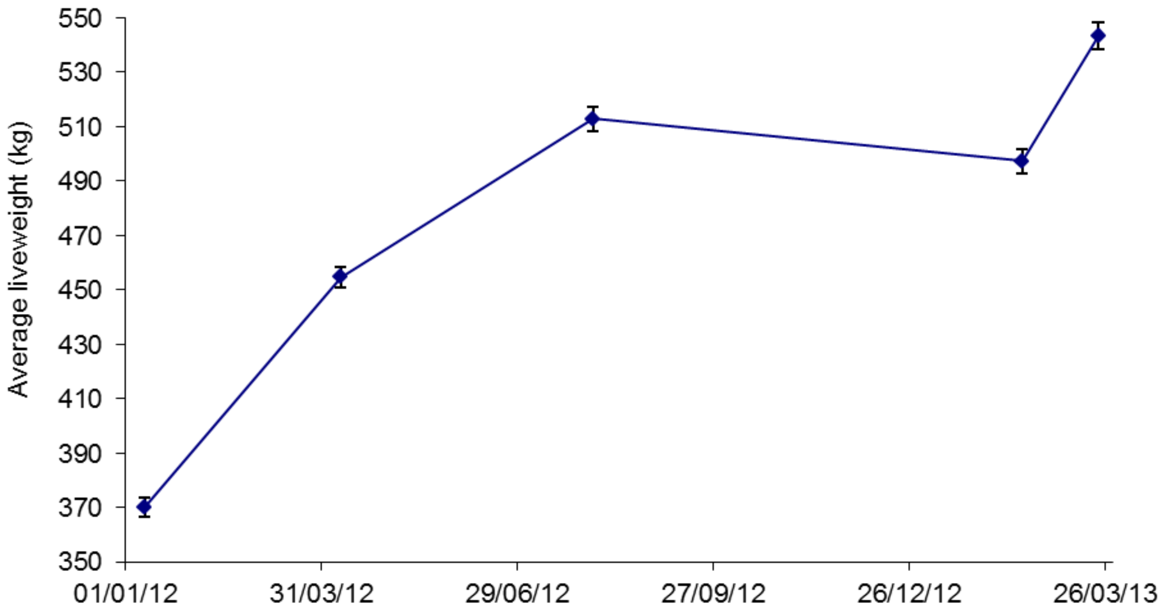

Fig. 139. Average cattle liveweight (kg; mean ± SE) for the first 438 days of grazing (10/01/12–23/03/13) until the first group was removed for slaughter.

Fig. 140. Cattle on leucaena-grass paddock, 18/04/12; at maximum biomass of leucaena and grass forage.

Fig. 141. Leucaena-grass pasture, 04/12/12; at minimum biomass of leucaena and grass.

Fig. 142. Cattle on leucaena-grass pasture, 28/03/13; just after first slaughter date and removal of 30 steers (47% of total cattle numbers).

The soil type in this paddock was typical of the Brigalow land type with good to high water-holding capacity and good fertility (20 mg/kg P and 1.2% organic C in the top 0-10 cm). The presence of green panic in the paddock also indicates that fertility is still relatively high. Standing brigalow suckers were present in the grass-only area of the paddock which is also typical of perennial grass paddocks on this land type. This soil type would be suitable for annual forage cropping apart from the physical limitation presented by melonholes. The leucaena section of the paddock was originally used for dryland cropping prior to sowing to leucaena and thus the fertility of this area, in terms of N and P concentrations, would be expected to be lower than the grass-only area of the paddock which has never been cropped. Separate biomass and species data was kept on four out of six sampling occasions for the grass component of the leucaena area and the grass-only area of the paddock. This data indicated that, compared to the grass-only area, the grass pasture within the leucaena rows had almost 3 times lower biomass on average and contained less perennial grass species, and more annual grasses and Indian bluegrass. However, in addition to the fertility limitations, perennial grasses had not been sown between the leucaena rows. It is also likely that the due to the farming history, and resultant soil nutrient removal, the productivity of leucaena would have been lower than would be expected if the leucaena had been planted on the non-farmed area of the paddock. However, leucaena is commonly planted in old cropping country due to the suitability of the soil type and tilth and the absence of machinery impediments such as melonholes and fallen timber.

The annual rainfall during the 2012 year, measured on property was 470 mm which was below the 30-year climate normal mean of 666.5 mm (records for period 1961–1990); (Fig. 133). Conversely, the total rainfall during the last 4 months of grazing (January to April 2013) was almost double the 30-year climate normal for that period (557 vs. 285.3 mm, respectively). The pasture biomass measured in the grazed paddock reflected the seasonal rainfall patterns with the biomass peaking in late April 2012 at 5,550 kg DM/ha for grass and 1,212 kg DM/ha for edible leucaena (Fig. 134 and Fig. 140). From late July 2012 until the end of the grazing period in early May 2013, very low biomass levels were measured in the paddock; ≤2,200 kg DM/ha for grass and ≤440 kg DM/ha for edible leucaena (Fig. 134 and Fig. 141). Despite the significant rainfall event in late January 2013 the measured biomass of grass and leucaena increased only marginally due to the high stocking rate relative to pasture availability (1 AE : 1.5 ha). The proportion of the pasture biomass which was assessed as 'green' also reflected the rainfall pattern, as expected (Fig. 135). A total of 93% of the biomass was assessed as being 0–20% green on 04/12/12 and 73% of the biomass was assessed as being 81-100% green on 28/03/13 after the significant rainfall event of late January. The dominant pasture species in the paddock were the introduced perennial grasses buffel, sabi and green panic, although some Indian bluegrass (an increaser species) and native perennial grasses (largely Queensland bluegrass) were present.

Despite the relatively low levels of edible leucaena biomass available over the majority of the grazing period, the proportion of C_3 species, assumed to be mainly leucaena, in the diet averaged 37% over the grazing period (range 17-72%; Fig. 138). Diet CP concentrations, and to a lesser extent diet DMD, appeared closely related to the proportion of leucaena in the diet. Analysis of edible leucaena components (leaf and stem material up to 5 mm in diameter) showed that leucaena CP concentrations remained high over widely varying seasonal conditions (range 18.4–33.2% CP; Fig. 136). Edible leucaena DMD varied between 63-74% over the same period (Fig. 137). On the two occasions that 'grab' samples of perennial grass were taken (to imitate likely selection of plant material by cattle), the CP content of the edible leucaena material was 2.7 times greater than for the grab samples of perennial grass. The corresponding DMD content of edible leucaena was 5.7 and 11 units greater than the 'grab' samples of perennial grass. Estimates of diet CP content from faecal NIRS showed that concentrations largely remained above 6% (range 5.6–15.1%). Estimated diet DMD from faecal NIRS ranged from 48-67%.

The cattle liveweight gain over the 476-day period of grazing reflect the rainfall and pasture availability and quality, with growth rates initially 0.93 kg/head/day over the first 90 days of grazing (January to April), and then slowing to 0.52 kg /head/day over the following 116 days of grazing as pasture quantity and quality decreased (Fig. 139). During the 197 days of grazing over the largely dry period, from August 2012 to February 2013, average daily gain was -0.07 kg/head/day. After the significant rainfall events in early 2013, very high growth rates were recorded: 1.30 kg/head/day for the entire group over 35 days in February-March, and 1.18 kg/head/day for the final slaughter group, over 38 days of grazing in March-April 2013 (Fig. 142). These high growth rates reflected the improved quality of the pasture although biomass was still low (<2,000 kg DM/ha grass and <450 kg DM/ha edible leucaena). It is likely that compensatory gain effects were contributing to these high growth rates over the final period of grazing.

The cattle had been bought on to the property and had not been inoculated with the leucaena rumen-fluid inoculum after purchase. It is not known whether the probable absence of the mimosine-degrading rumen bacterium caused any sub-clinical effects on cattle growth rate. The estimated proportion of leucaena in the diet (average of 37% over the grazing period) was in the range shown to cause adverse effects on liveweight gain (Jones and Hegarty 1984) and research has shown that sub-clinical mimosine-induced depressions in cattle growth rates can occur in the absence of visible signs of leucaena toxicity (Quirk *et al.* 1988).

The overall average liveweight gain over the 438 days of grazing prior to removal of the first sale group of cattle was 0.39 kg/head/day, which is less than the annual, long-term average steer liveweight gain for cattle grazing perennial grass pasture as assumed in the constructed scenario for the Central Queensland Brigalow region (0.46 kg/head/day). This result reflects the drought conditions for much of 2012 and generally low biomass of both grass and edible leucaena. The stocking rate on this paddock was higher than that assumed in the constructed scenario for leucaena grown in the Central Queensland Brigalow region (0.65 vs. 0.44 AE/ha). Furthermore, the paddock was continuously stocked cf. the 270-day grazing period per year assumed in the constructed scenario. The beef production per hectare from this site over the first 12 months of monitoring (86 kg/ha/annum) was similar to that from the adjacent Central Queensland Brigalow, Perennial grass pasture site also monitored on this property (85 kg/ha/annum), but was 61% of the assumed long-term average beef production assumed in the constructed scenario for leucaena-grass pastures grown in the Central Queensland Brigalow region (140 kg/ha/year). Compared to the Central Queensland Brigalow, Perennial grass pasture site monitored on this property, average grass pasture biomass in the leucaena-grass paddock was lower due to the relatively poorer grass biomass between the leucaena rows. Furthermore, the edible biomass of leucaena averaged only 438 kg DM/ha throughout the grazing period (Fig. 134). Thus, it appears that the similar total beef production from this site compared to the Central Queensland Brigalow, Perennial grass pasture site on this property was a result of the similar overall biomass and forage energy provided.

The gross margin calculated for the 476-day grazing period was only $90/ha of the total grazing area when calculated using owner rates, and $85/ha when calculated using contract rates. This value is just over half the gross margin for a 365-day period estimated for the constructed scenario for leucaena forage sown over 100% of the grazing area (compared to 53% of the grazing area at this site). Furthermore, the gross margin from this leucaena paddock was 68% of that calculated for the grass-only paddock monitored on the same property. This result was due to the similar beef production per hectare during the same grazing period but the added forage costs of leucaena (amortised development costs). The amortised cost of planting and maintaining forage at this site was $47/ha/476 days as compared to the assumed value of $42/ha/365 days in the constructed scenario (both figures calculated using owner rates). The assumed productive life of the leucaena at this site was 20 years vs. 30 years in the constructed scenario. The price margin for these bought steers was negative at -$0.16/kg liveweight. As not all steers were sold at the end of the grazing period, the gross margin calculated here was not actually realised by the producer but does demonstrate the value added to the steers by grazing leucaena.

3.4.3 Central Queensland Brigalow, Leucaena-grass pasture, April 2013 – April 2014

(S 24.315, E 150.427; near Jambin)

The site was a 100.1 ha paddock with leucaena planted over 66.4% of the area (66.5 ha) and introduced perennial grasses (primarily sabi and green panic) present in the inter-rows and remaining 33.6 ha. Two waterways divided the paddock into three sections, of which the two larger were planted to Cunningham leucaena. The grass-only area of the paddock contained one of the waterways as well as mature trees. The 66.5 ha planted to leucaena had been farmed for grain crop production until 2005 when leucaena was planted in twin rows, 1 m apart, on 6 m centres. Grasses were sown between the leucaena rows twice but there was very poor establishment so most of the grass present has naturalised from surrounding areas. The leucaena area was initially spelled for 6-7 months after planting and has then been grazed almost continuously since with only short periods of spelling when the paddock is likely to be flooded. The leucaena has never been fertilised but received maintenance chopping in 2012. In 2013 the paddock was partially flooded. In February/March 2014 approximately 15 ha of the grass-only area of the paddock was stick-raked for pasture rejuvenation. This site was located on the same commercial property as the Central Queensland Brigalow Leucaena-grass pasture 2012-13 and Perennial grass pasture 2012-13 sites. Prior to the start of grazing the paddock had been spelled for 10 weeks, during which time there had been flood water over it for ca. 10 days. During the period of monitoring, there were three periods of spelling, forming a total of 13% of the total period, including an initial period of 20 days prior to first grazing. During the period of monitoring, two groups of cattle grazed the paddock: steers (Group 1) during the 2013 autumn to spring period and heifers (Group 2) during the 2013-14 summer and 2014 autumn. Assessments of leucaena and grass biomass were only conducted in the larger of the two sections planted to leucaena, forming approximately 75% of total leucaena area. As the leucaena and grass biomass was less affected by flooding in the section that was monitored, the overall biomass of the paddock is overestimated by the figures presented here. A summary of key site details are given in Table 19 and Fig. 143-Fig. 151.

Table 19. Site details. Central Queensland Brigalow, Leucaena-grass pasture 2013-14
For definitions of abbreviations see Glossary of terms and abbreviations

<table>
<tr><th>Factor</th><th colspan="2">Details</th></tr>
<tr><td colspan="3">Soil characterisation</td></tr>
<tr><td>Broad land type</td><td colspan="2">Alluvial</td></tr>
<tr><td>Soil type and characteristics</td><td colspan="2">Deep loam alluvial
PAWC: 220 mm
Soil depth: ≥150 cm</td></tr>
<tr><td rowspan="3">Soil nutrient levels at site establishment
(May 2013)</td><td></td><td>0–10 cm</td></tr>
<tr><td>P (mg/kg)</td><td>110</td></tr>
<tr><td>Organic C (%)</td><td>1.6</td></tr>
<tr><td colspan="3">Forage production</td></tr>
<tr><td>Average edible leucaena biomass</td><td colspan="2">744 (range: 54-1,922) kg DM/ha</td></tr>
<tr><td>Average perennial grass presentation yield</td><td colspan="2">2,746 (range: 988-5,429) kg DM/ha (Day 243-366 of monitoring period); major species were the introduced perennial grasses sabi and green panic.</td></tr>
<tr><td>Leucaena in the diet</td><td colspan="2">61% (Days 32-362 of monitoring period)</td></tr>
<tr><td>Average edible leucaena quality</td><td colspan="2">22.9% CP, 61% DMD (Days 32-362 of monitoring period)</td></tr>
<tr><td>Average diet quality</td><td colspan="2">12.9% CP, 63% DMD (Days 32-362 of monitoring period)</td></tr>
</table>

Factor	Details
Grazing management and animal production	
Comments	Grazing history: • Spelled: 08/04/13-28/04/13 (20 days) • Group 1 s teers: 29/ 04/13-14/07/13 (76 days; 168 steers, 16-18 months at entry) • Group 1 steers: 15/07/13-30/08/13 (46 days; 65 steers, 19-21 months at entry) • Spelled: 31/08/13-17/09/13 (17 days) • Group 1 steers: 18/09/13-30/11/13 (73 days; 48 steers, 21-23 months at entry) • Spelled: 01/12/13-11/12/13 (10 days) • Group 2 he ifers: 12/ 12/13-08/04/14 (117 days; 85 heifers, 16-18 months at entry); 4 round bales of buffel grass hay (250-300 kg) were fed at the start of grazing, 200 L of molasses mix provided in late 2013). A total of 82 of the Group 2 hei fers were killed at Teys Rockhampton abattoir on 11/04/14.
Cattle type monitored for weight gain	Steers and heifers; ca. 50% *B. indicus*; the steers and half the heifers were purchased.
Animal health treatments	Group 2 he ifers received Novartis Acatak® and F lycam Pty Ltd Agressor™ for tick and buffalo control, respectively on 12/12/13. Steers were given the rumen fluid inoculum; heifers had exposure to carrier animals.
Total monitoring period	08/04/13-08/04/14 (365 days)
Proportion of the total area planted to leucaena	66%
Average SR (leucaena area only)	1.31 AE/ha (1 AE : 0.76 ha)
Average SR (total grazing area)	0.87 AE/ha (1 AE : 1.15 ha)
Group 1 steers - (heaviest, exiting), 16-18 months, 2013 Autumn-Winter	
Grazing days over which LW was measured	76 (29/04/13-14/07/13)
Number of cattle in weight gain dataset	101
Average entry LW (± SE)	491 (± 5.5) kg
Average exit LW (± SE)	532 (± 5.8)
Average LWG (± SE)	0.55 (± 0.019) kg/head/day
Group 1 steers - (lightest), 16-18 months, 2013 Autumn-Winter	
Grazing days over which LW was measured	124 (29/04/13-31/08/13)
Number of cattle in weight gain dataset	62
Average entry LW (± SE)	443 (± 6.5) kg
Average exit LW (± SE)	486 (± 6.6)
Average LWG (± SE)	0.35 (± 0.013) kg/head/day
Group 1 steers - (sub-group of original mob), 21-23 months, 2013 Spring	
Grazing days over which LW was measured	75 (16/09/13-30/11/13)
Number of cattle in weight gain dataset	46
Average entry LW (± SE)	541 (± 6.5) kg
Average exit LW (± SE)	563 (± 6.3)
Average LWG (± SE)	0.29 (± 0.033) kg/head/day

Factor	Details	
Group 2 heifers – 16-18 months, 2013/14 Summer to 2014 early Autumn		
Grazing days over which LW was measured	121 (08/12/13-08/04/14)	
Number of cattle in weight gain dataset	81	
Average entry LW (± SE)	440 (± 4.9) kg	
Average exit LW (± SE)	554 (± 5.5)	
Average LWG (± SE)	0.94 (± 0.018) kg/head/day	
Total LWG – 365 days	175 kg/ha/annum	
Group 2 heifer slaughter data (11/04/14)	(*n* = 81)	
Average carcase weight (± SE)	285 (± 3.1) kg	
Average carcase dentition (± SE)	2.3 (± 0.15)	
Average carcase fat depth (± SE)	15 (± 0.5) mm	
Economic performance		
	12-month period (08/04/13-08/04/14), ($/ha/annum)	
	Leucaena area only	**Total grazing area**
Gross margin - owner rates	**458**	**304**
Forage costs	35	24
Gross margin - contract rates	**449**	**299**
Forage costs	44	29
CONSTRUCTED SCENARIO		
Gross margin - owner rates	**169**	**169**
Forage costs	42	42
Gross margin - contract rates	**165**	**165**
Forage costs	46	46

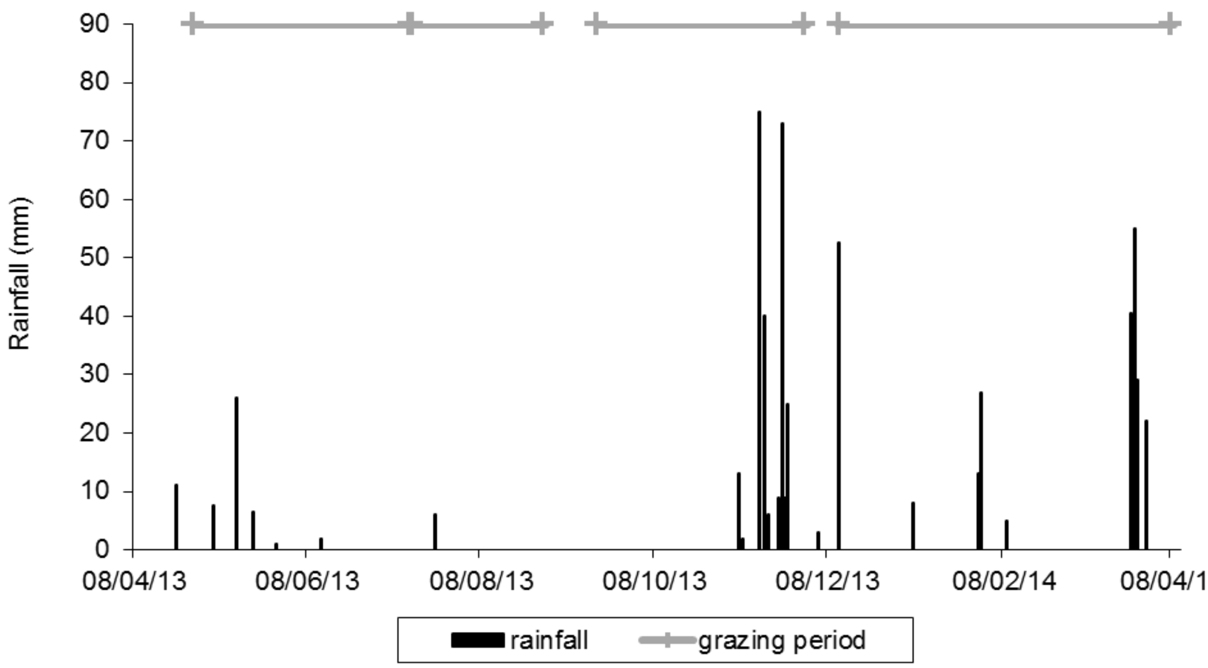

Fig. 143. Daily rainfall (mm) over the period (08/04/13-08/04/14). Measured on property, 6.5 km from the trial paddock. Grazing periods shown.

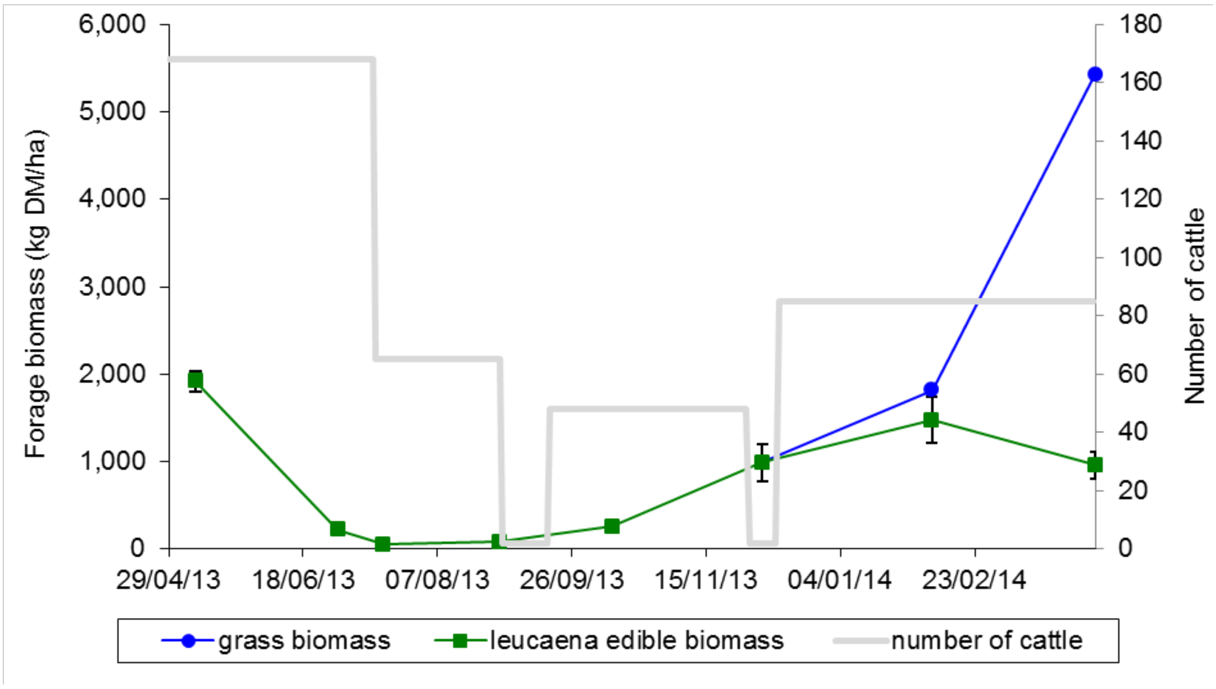

Fig. 144. Grass biomass (kg DM/ha; mean ± SE) and biomass of edible leucaena (kg DM/ha; mean ± SE), including green stems up to 5 mm in diameter in the paddock, both assessed across 75% of the leucaena area (the least flood affected) during the monitoring period (29/04/13-08/04/14). Cattle numbers during the monitoring period shown. Grass biomass only monitored from 06/12/13.

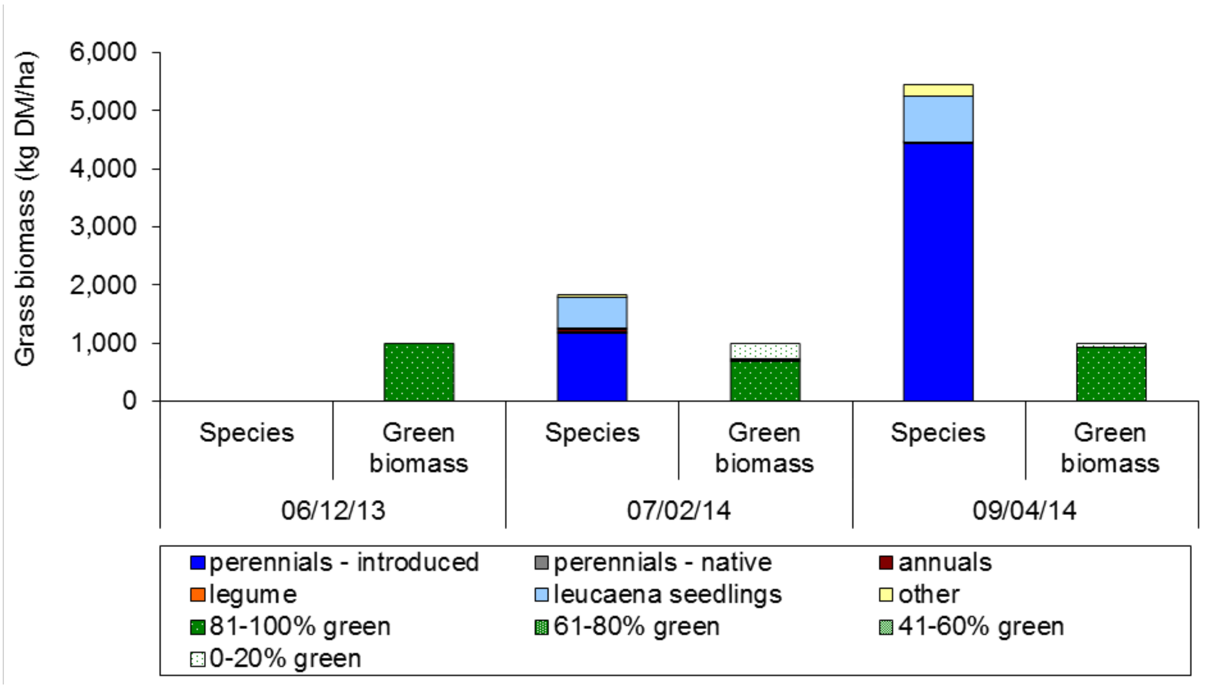

Fig. 145. Perennial pasture species composition (Species) and proportion of green material in the pasture (Green biomass) shown as a proportion of total pasture biomass (kg DM/ha). Introduced perennial grasses consisted of primarily sabi and green panic.

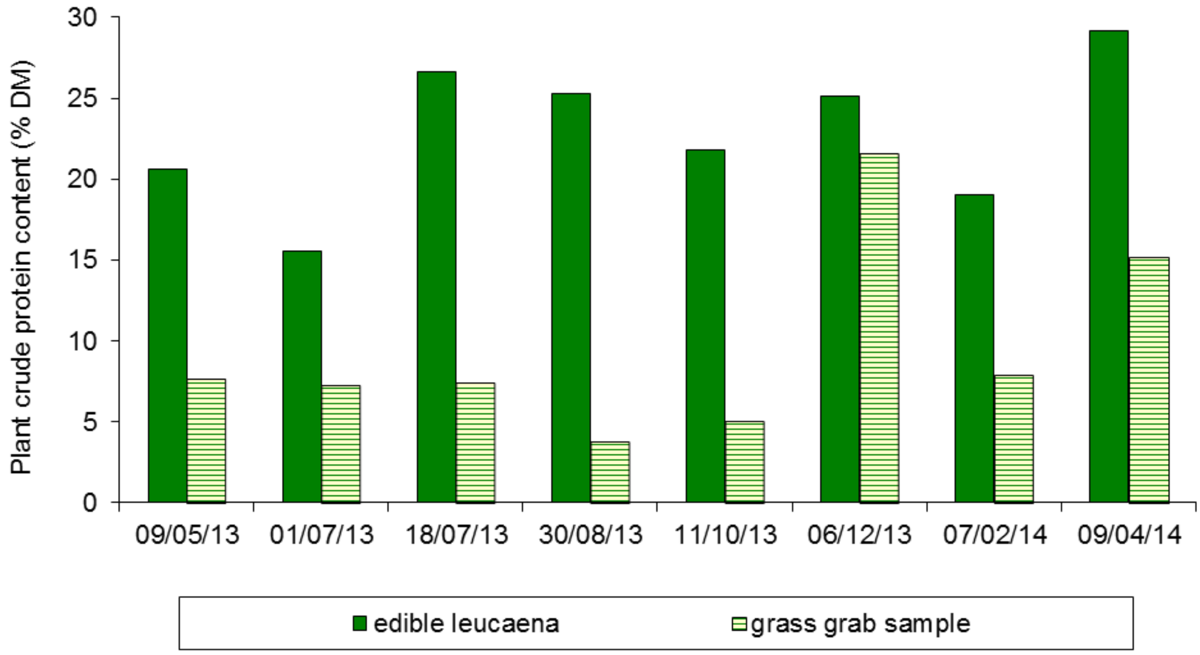

Fig. 146. Crude protein content (% DM) of edible leucaena (leaf and green stems up to 5 mm in diameter) and 'grab' samples of perennial grass in the paddock during the monitoring period (08/04/13-08/04/14).

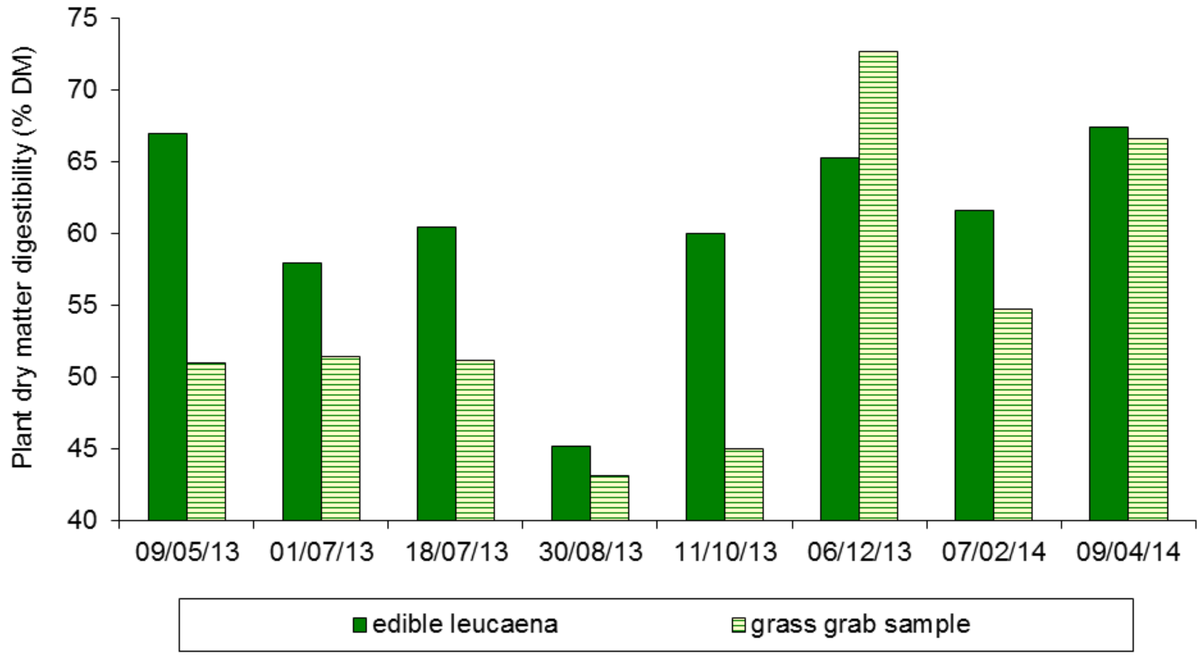

Fig. 147. Dry matter digestibility (%) of edible leucaena (leaf and green stems up to 5 mm in diameter) and 'grab' samples of perennial grass in the paddock during the monitoring period (08/04/13-08/04/14).

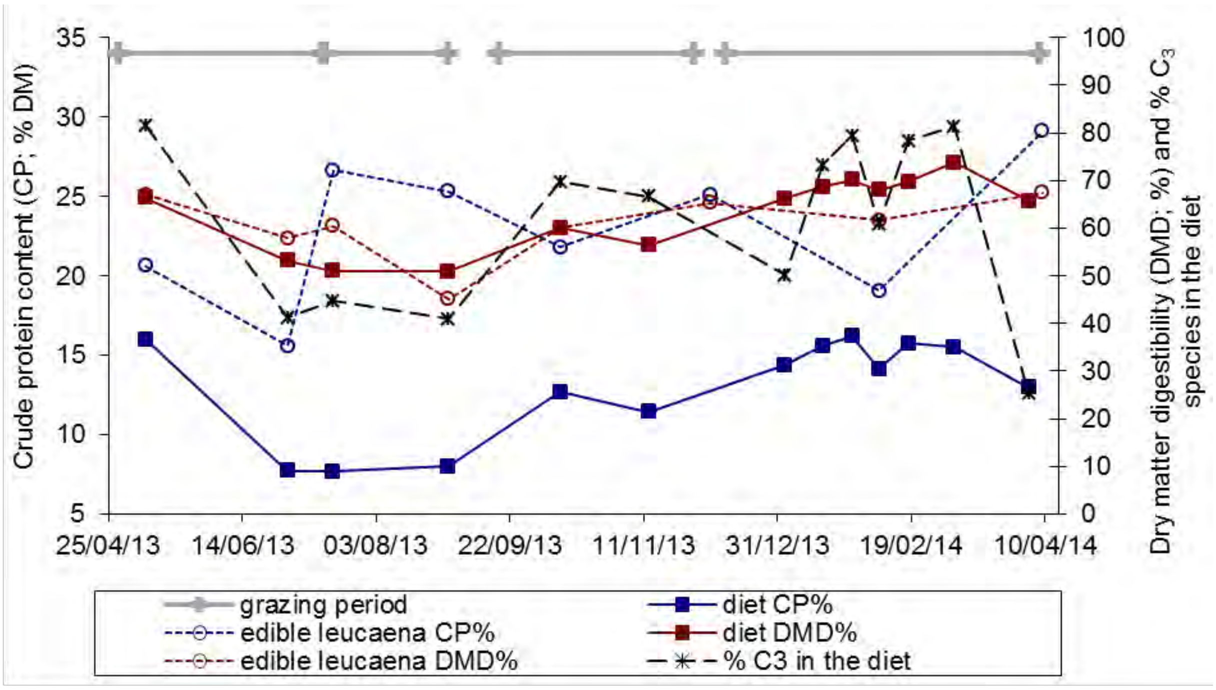

Fig. 148. Diet crude protein (CP) content (% DM) and dry matter digestibility (DMD; %) for grazing cattle predicted from faecal NIRS; measured CP and DMD content of edible leucaena (including stems up to 5 mm in diameter); and the % of the diet as C_3 forage, predicted from $\delta^{13}C$ content in the faeces. Grazing period shown.

Fig. 149. Leucaena-grass paddock, 09/05/13; 10 days after the start of the first grazing period for Group 1 steers.

Fig. 150. Cattle grazing leucaena-grass pasture, 01/07/13; 63 days after the start of the first grazing period for Group 1 steers.

Fig. 151. Leucaena-grass pasture, 06/12/13; 6 days prior to commencement of grazing period for Group 2 heifers.

The soil type in this paddock was a typical loam alluvial soil for this district with good fertility and high water holding capacity, ideal for growing leucaena or other forage or grain crops. Although the area planted to leucaena had been previously grain cropped for many years the fertility was still high at 110 mg/kg P and 1.6% organic C.

The annual rainfall during the 365-day period of monitoring (08/04/13-08/04/14), measured on property, was 567 mm which was below the 30-year climate normal mean of 666.5 mm (records for period 1961–1990); (Fig. 143). The pasture biomass reflected the seasonal rainfall patterns as well as the stocking rates in the paddock (Fig. 144). The greatest edible leucaena biomass (1,922 kg DM/ha) was measured on 09/05/13, at the start of the first grazing period (Fig. 149). Edible leucaena also reached a peak (1,475 kg DM/ha) on 07/02/14 after significant rainfall events in early 2014. Grass pasture biomass was only monitored from 06/12/13, with the greatest biomass from this time measured on 09/04/14 at the end of the monitoring period. Very low edible leucaena biomass levels were measured in the paddock during the 2013 dry season, over the period from 01/07/13 to 11/10/13 (Fig. 150). The proportion of the pasture biomass which was assessed as ‘green’ also reflected the rainfall pattern, as expected (Fig. 145). The proportion of the grass pasture biomass assessed as being 81-100% green, averaged over the three sampling occasions from 06/12/13, was 87%. The dominant pasture species in the paddock were the introduced perennial grasses sabi and green panic.

The proportion of C_3 species, assumed to be mainly leucaena, in the diet averaged 61% over the monitoring period (range 25-82%; Fig. 148). Despite the relatively low levels of edible leucaena biomass (≤ 255 kg DM/ha) over the period from 01/07/13 to 11/10/13, the proportion of leucaena in the diet remained in the range 41-70%. This was likely due to grass pasture biomass also being low during this time with the first grass biomass assessment on 06/12/13, after significant rainfall events, only 988 kg DM/ha. The lowest proportion of leucaena in the diet (25%) was measured at the end of monitoring period, coinciding with the peak in grass pasture biomass of 5,429 kg DM/ha.

Diet CP and DMD concentrations were closely related to the proportion of leucaena in the diet. Analysis of edible leucaena components (leaf and stem material up to 5 mm in diameter) showed that leucaena CP concentrations remained high over widely varying seasonal conditions (range 15.6–29.1% CP; Fig. 146). Edible leucaena DMD varied between 45-67% over the same period (Fig. 147). The ‘grab’ samples of perennial grass, taken to imitate likely selection of plant material by cattle, indicated that the CP content of the edible leucaena material was on average 2.4 times that of the edible components of perennial grass. The corresponding DMD content of edible leucaena was 6.1 units greater than the ‘grab’ samples of perennial grass. Estimates of diet CP content from faecal NIRS showed that concentrations remained above 6% (range 7.7–16.2%). Estimated diet DMD from faecal NIRS ranged from 51-74%.

The cattle liveweight gain over the monitoring period reflected the rainfall and pasture availability and quality, with steer growth rates initially 0.55 kg/head/day over 76 days in autumn-winter 2013 and 0.35 kg/head/day for a sub-group monitored over a longer period of 124 days to late winter. The lowest growth rates were measured for steers grazing over the 2013 spring period prior to the seasonal break: 0.29 kg/head/day for 75 days. The greatest growth rates were recorded for heifers grazing in the 2013/14 summer (Fig. 151) to early autumn 2014: 0.94 kg/head/day over 121 days. The total cattle liveweight gain attributed to this paddock over the 365 days of monitoring was greater than that estimated for the constructed scenario for the Central Queensland Brigalow region: 175 vs. 140 kg/ha/annum. This was a result of a higher average stocking rate (0.87 AE/ha/annum days vs. 0.44 AE/ha/annum) as well as greater days of grazing during the period of monitoring 318 vs. 270 days.

The gross margin for the 365-day period was $304/ha of the total grazing area when calculated using owner rates and $299/ha of the total grazing area when calculated using contract rates. This gross margin was the greatest of all leucaena data sets monitored in the project and 1.8 times the gross margin estimated for the constructed scenario for leucaena forage sown over 100% of the grazing area (compared to 66% at this site). The amortised cost of planting and maintaining forage at this site was $35/ha/annum (owner rates, per forage area only), as compared to $42/ha/annum for the constructed scenario. The assumed productive life of the leucaena at this site was 20 years vs. 30 years in the constructed scenario. The average cattle price margin for these, mainly purchased, cattle was $0.10/kg liveweight. As not all cattle were sold at the end of the grazing period, the gross margin calculated here was not actually realised by the producer but does demonstrate the value added to the cattle by grazing leucaena.

3.4.4 South Queensland Brigalow, Leucaena-grass pasture February 2012 - June 2013

(S 25.944, E 149.987; near Wandoan)

The site was a 101.2 ha paddock which had been planted with Tarramba leucaena seed on 04/12/07 at a rate of 2.5 kg/ha in twin rows, 1 m apart, on 6 m centres. Biloela buffel grass and silk sorghum seed was planted in the inter-rows with a roller drum seeder in December 2008 (2.5 and 1 kg/ha, respectively). The paddock was spelled for 2 months in early 2009, prior to introducing cattle. Prior to planting leucaena the paddock had been farmed for many years with cereal crops such as wheat and oats. The paddock was originally cleared of timber for farming in the 1970's. The leucaena has never been fertilised or received maintenance chopping. This leucaena paddock is used in rotation with a neighbouring leucaena paddock, with approximately 200 head of cattle rotated between the two paddocks every 4-6 weeks during summer. Generally, approximately 75 weaner steers graze the paddock from May/June until the break of the season when additional steers are added and the rotation begins. The paddock was monitored from 25/02/12-10/06/13 (471 days). A summary of key site details are given in Table 20 and Fig. 152-Fig. 159.

Table 20. Site details. South Queensland Brigalow, Leucaena-grass pasture 2012-13
For definitions of abbreviations see Glossary of terms and abbreviations

Factor	Details	
Soil characterisation		
Broad land type	Brigalow/Belah	
Soil type and characteristics	Cracking clay PAWC: 160 mm Soil depth: 120 cm	
Soil nutrient levels at site establishment (March 2012)		**0–10 cm**
	P (mg/kg)	15
	Organic C (%)	0.89
Forage production		
Average edible leucaena biomass	444 (range: 88-794) kg DM/ha	
Average perennial grass presentation yield	3,149 (range: 1,930-5,289) kg DM/ha. Major species were the introduced perennial grasses buffel and sabi (72 and 18% of the biomass, respectively), and the native perennial grass Queensland bluegrass (8% of the biomass).	
leucaena in the diet	67% (Days 9-451 of monitoring period)	
Average edible leucaena quality	18.8% CP, 60% DMD (Days 9-451 of monitoring period)	
Average diet quality	14.7% CP, 63% DMD (Days 9-451 of monitoring period)	

Factor	Details
Grazing management and animal production	
Comments	The paddock was monitored over 25/02/12-10/06/13. In total, 192 steers grazed the paddock for the first 30 days (25/02/12-26/03/12); 129 of these steers were monitored for weight gain (Group 1). For the following 30 days (26/03/12-25/04/12), 175 of the original group were returned to the paddock and given access to a grain ration (ca. 8 kg/head/day); these steers were not monitored for weight gain. From 01/05/12-27/12/12, 75 weaner steers grazed the paddock but were not monitored for weight gain. From 18/02/13-12/05/13, 200 steers were rotated between this paddock and an adjacent paddock (4-6 week rotation); 188 of these steers were monitored for weight gain (Group 2). From the 12/05/13, 188 of the previous steers were returned to the trial paddock which was also grazed in conjunction with 2 other similar sized leucaena paddocks (i.e. grazing pressure was reduced by 1/3) until 111 steers were sent to slaughter on 03/06/13 and the remaining 77 sent to slaughter on 10/06/13. Final exit liveweights were not taken in June for Group 2.
Cattle type monitored for weight gain	Steers; predominantly Charolais x Santa Gertrudis, ca. 20% *B. indicus*
Animal health treatments	Groups 1 and 2: 2 x 5-in-1, 2 x Dectomax®, 1 x B12 injection, 1 x Barricade S for lice. Group 1: 3 x 100-day HGP. Group 2: 2 x 100-day HGP. Group 1: 20% received leucaena rumen fluid inoculum.
Total monitoring period	25/02/12–10/06/13 (470 days)
Total grazing days in target paddock during the 1st 12-month period (25/02/12-17/02/13; 358 days)	300 days
Total grazing days in target paddock during the 2nd summer period of 112 days (18/02/13-10/06/13)	51 days
Proportion of the total area planted to leucaena	100%
Average SR over 1st 12 months	0.82 AE/ha (1 AE : 1.22 ha)
Average SR over 2nd summer	2.48 AE/ha (1 AE : 0.40 ha)
Group 1 – steers (18-20 months), end Feb to end March 2012	
Grazing days over which LW was measured	30
Number of cattle in weight gain dataset	129
Average entry LW (± SE)	590 (± 2.65) kg
Average exit LW (± SE)	639 (± 3.23) kg
Average LWG (± SE)	1.52 (± 0.047) kg/head/day

Factor	Details
Group 2 – steers (17-19 months), mid Feb to Mid May 2013	
Grazing days over which LW was measured	83
Number of cattle in weight gain dataset	188
Average entry LW (± SE)	578 (± 1.75) kg
Average exit LW (± SE)	680 (± 2.35) kg
Average LWG (± SE)	1.23 (± 0.019) kg/head/day
Total annual LWG – 1st 12 months	**306 kg/ha/annum** Note: this value is an estimate as cattle were monitored for weight gain in only 1 out of 3 grazing periods; also includes weight gain from grain feeding 8 kg/head/day for 175 head fed for 30 days in 2012
Total LWG – 2nd 112-day summer period	**108 kg/ha per 112 days** Note: this value is an estimate as cattle were monitored for weight gain in only 1 out of 2 periods of grazing although carcase weights were available for the final group and grazing period, enabling back-calculation of liveweight gain
Economic performance	
	First 358 days (25/02/12-17/02/13), ($/ha/annum)
Gross margin - owner rates	**193**
Forage costs	17
Cost of grain feeding	125
Gross margin - contract rates	**188**
Forage costs	21
CONSTRUCTED SCENARIO	
Gross margin - owner rates	**107**
Forage costs	**42**
Gross margin - contract rates	**103**
Forage costs	45

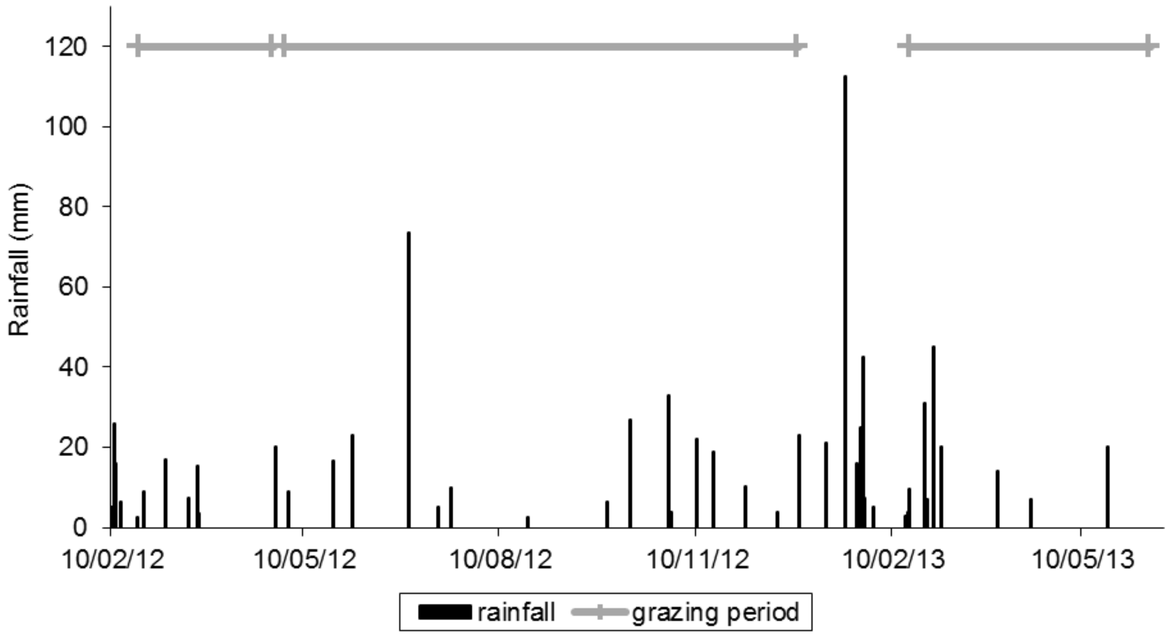

Fig. 152. Daily rainfall (mm) over the period (01/01/12–10/06/13). Measured on property ca. 2 km from the trial paddock. Grazing periods shown.

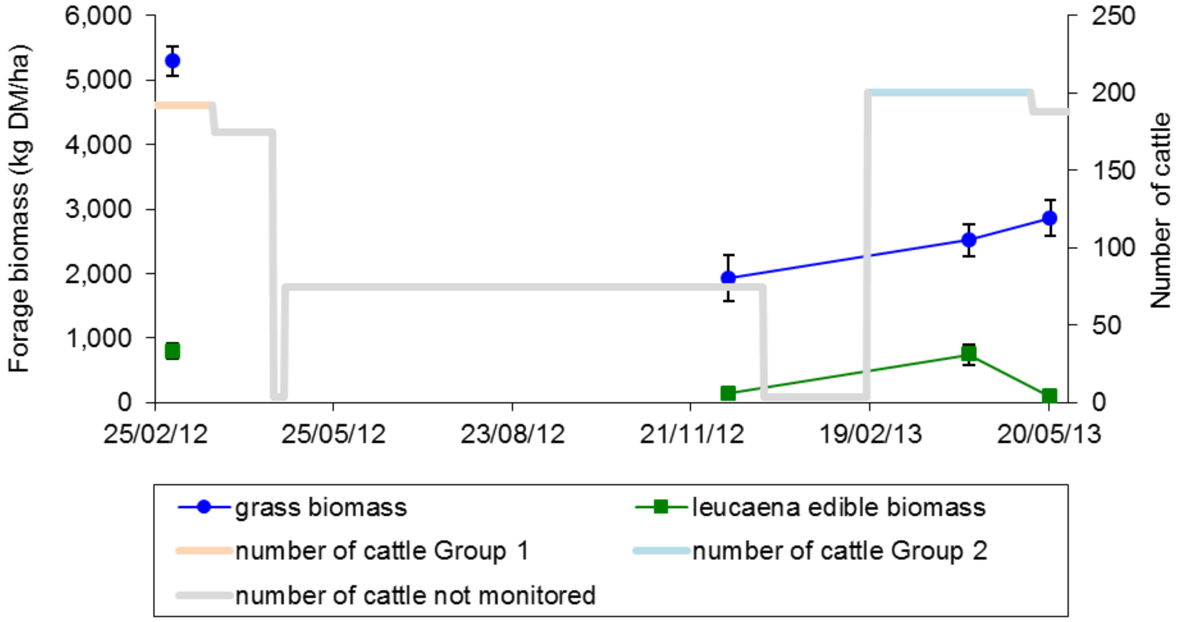

Fig. 153. Grass biomass (kg DM/ha; mean ± SE) and biomass of edible leucaena (kg DM/ha; mean ± SE), including green stems up t o 5 mm in diameter, in the paddock during the grazing period (25/02/12-10/06/13). Cattle numbers during the monitoring period also shown.

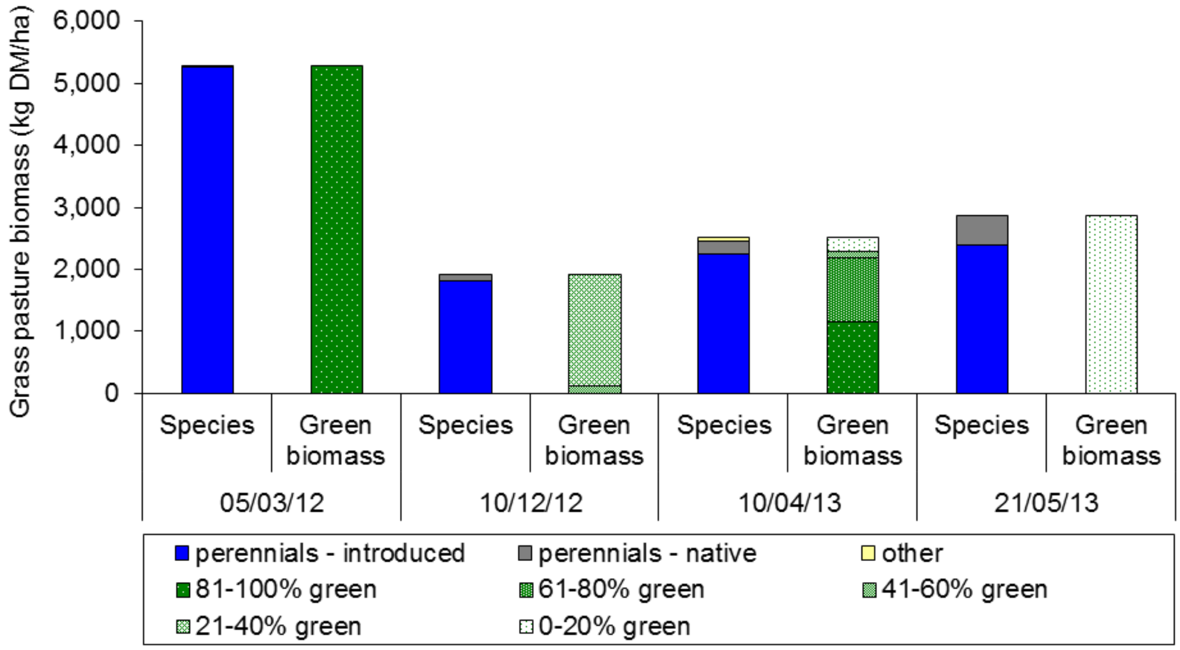

Fig. 154. Perennial grass pasture composition (Species) and proportion of green material in the pasture (Green biomass) shown as a proportion of total pasture biomass (kg DM/ha). Introduced perennial grasses consisted of primarily of buffel and sabi (72 and 18% of the biomass, respectively). Native perennial grasses were primarily Queensland bluegrass (8% of the biomass).

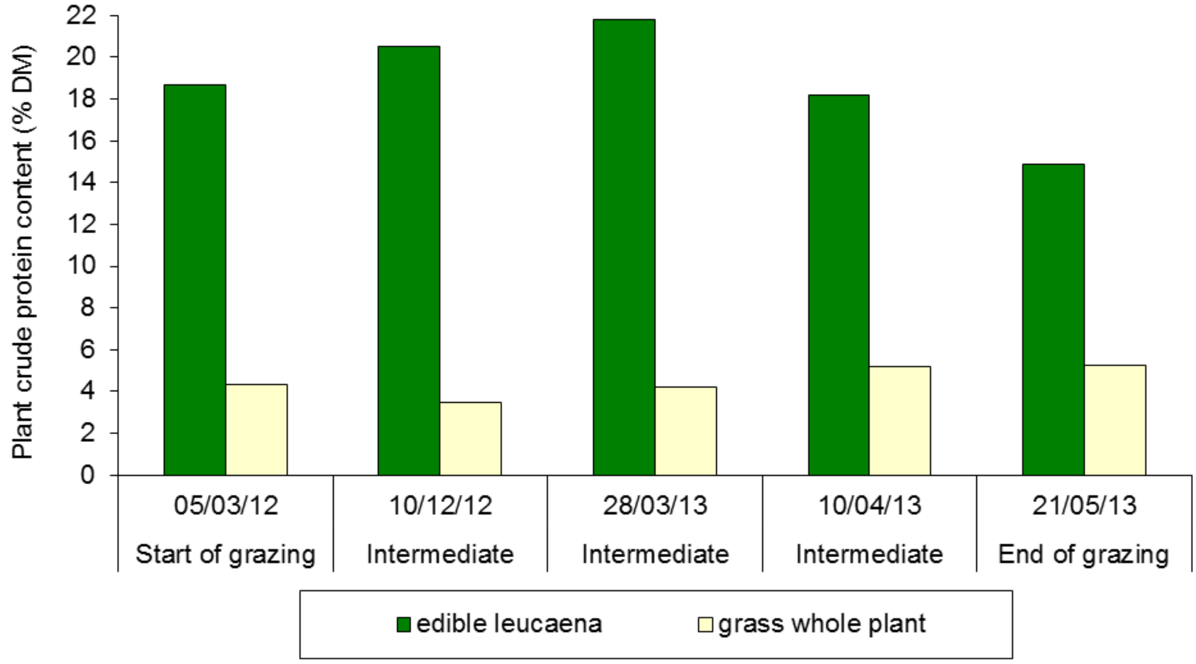

Fig. 155. Crude protein content (% DM) of edible leucaena (leaf and green stems up to 5 mm in diameter), perennial grass whole plant samples in the paddock during the monitoring period (25/02/12–10/06/13).

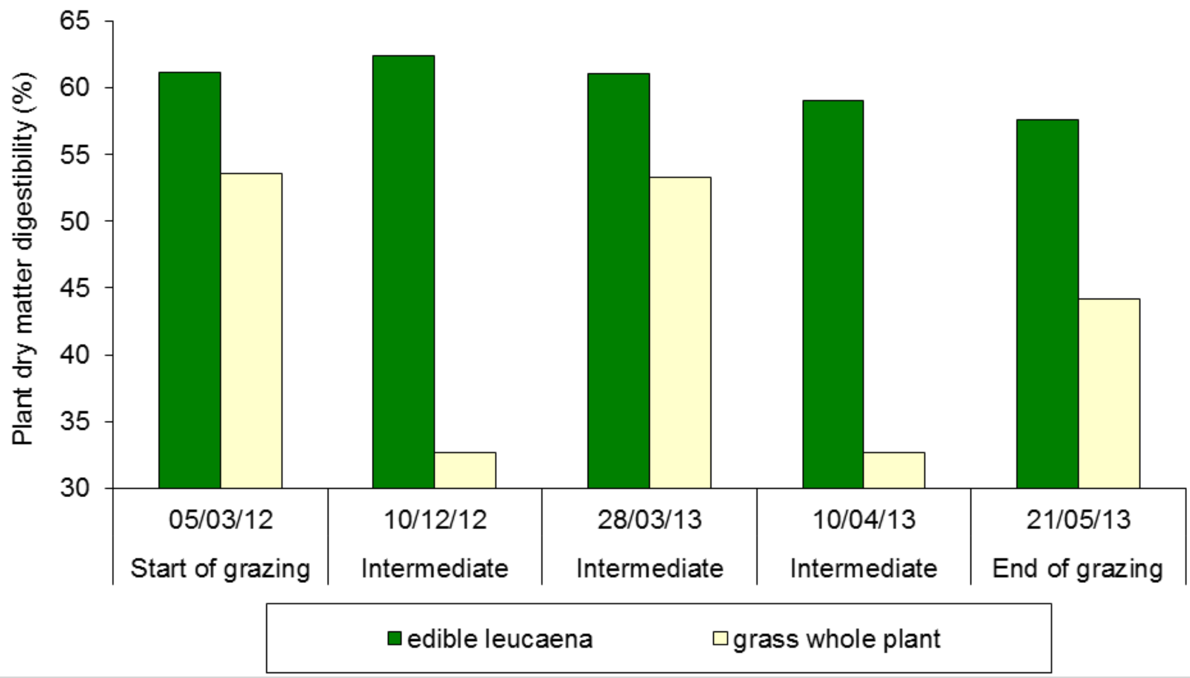

Fig. 156. Dry matter digestibility (%) of edible leucaena (leaf and green stems up to 5 mm in diameter), perennial grass whole plant samples in the paddock during the monitoring period (25/02/12–10/06/13).

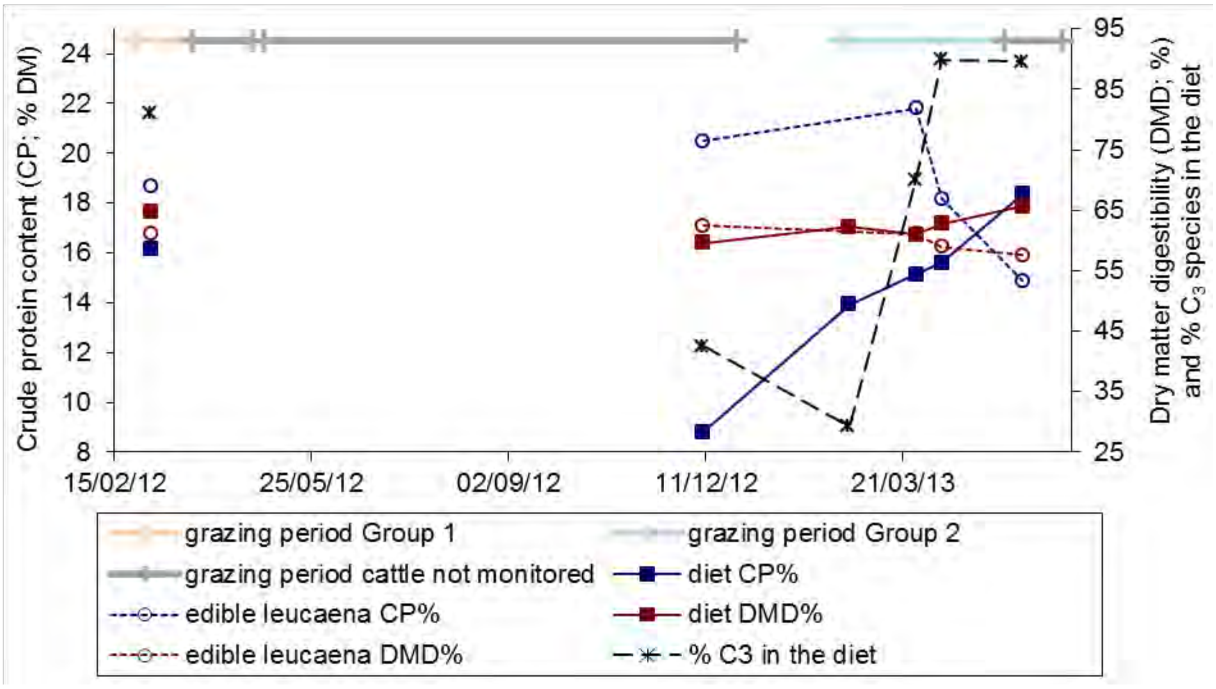

Fig. 157. Diet crude protein (CP) content (% DM) and dry matter digestibility (DMD; %) for grazing cattle predicted from faecal NIRS; measured CP and DMD content of edible leucaena (including stems up to 5 mm in diameter); and the % of the diet as C_3 forage, predicted from $\delta^{13}C$ content in the faeces. Grazing periods shown.

Fig. 158. Cattle grazing leucaena-grass pasture, 05/03/12; during the Group 1 s teers monitoring period.

Fig. 159. Cattle grazing leucaena-grass pasture, 22/02/13; during the Group 2 s teers monitoring period.

The soil type in this paddock is a cracking clay, typical of the soil type in the district. The paddock was utilised for dryland grain crops prior to sowing Leucaena-grass pasture, in line with the high water holding capacity and fertility status. However, the soil analyses provide evidence that many years of grain cropping has depleted essential nutrients, such as P, to an extent that some fertiliser might be needed into the future to maintain maximum potential leucaena production.

The annual rainfall during the 2012 season, measured on property approximately 2 km from the leucaena paddock, was 538 mm which was 80% of the 30-year climate normal mean measured at the Taroom Post Office (BOM Station 35070) of 673.5 mm (records for period 1961 to 1990); (Fig. 152). The total rainfall measured on-property during the last 5 months of grazing (January to May 2013) was 399 mm which was greater than the 30-year climate normal for that period (311.7 mm; measured at Taroom Post Office).

The pasture biomass and diet quality (CP and DMD) reflected the seasonal rainfall patterns with the total forage biomass (edible leucaena and grass biomass) being at its lowest on 10/12/12 (Fig. 153, Fig. 154 and Fig. 157). After the significant rainfall events in January 2013, leucaena and grass biomass increased, as did the % of the perennial grass biomass assessed as green and the diet CP and DMD. Whilst diet CP concentration ranged from 8.8-18.4%, the CP content of edible leucaena ranged from 14.9-21.8% over the monitoring period (Fig. 155). Corresponding diet DMD concentrations ranged from 60-66% while the DMD content of edible leucaena ranged from 58-62% (Fig. 156). The proportion of C_3 species (presumed to be primarily leucaena) in the diet ranged from 29-90%, with the lowest proportion of leucaena coinciding with the period just after the seasonal break in 2013.

The liveweight gain measured for the two groups of cattle monitored after the break of season in early 2012 and 2013 was high: 1.52 kg/head/day over 30 days in early 2012 (Group 1; Fig. 158) and 1.23 kg/head/day over 84 days in early 2013 (Group 2; Fig. 159). These periods of measurement coincided with the highest leucaena biomass and diet quality measured in the paddock. Leucaena edible biomass was 794 kg DM/ha on 05/03/12, 9 days after Group 1 entered the paddock, and 747 kg DM/ha on 18/02/13, 60% of the way through Group 2's grazing period. Diet CP predicted from faecal NIRS analysis during these periods was 16.1% on 05/03/12 for Group 1 cattle and averaged 14.9% during the grazing period of Group 2 cattle. Predicted diet DMD ranged from 60-66% during these two grazing periods. The estimated proportion of leucaena in the diet during the grazing periods of Group 1 and 2 cattle was generally high (>76% of the diet) except on the 22/02/13 shortly after the seasonal break, when cattle were estimated to be consuming only 29% of the diet as leucaena, although diet CP and DMD were still high at 13.9 and 62%, respectively. Although measurements of forage quality were not taken on this date, it is expected that the perennial grass quality would also be at its peak in quality and % green biomass at this time, after the significant rain during January.

The gross margin for the first 358-day period of grazing (25/02/12-17/02/13) was \$193/ha/annum when calculated using owner rates and \$188/ha/annum when calculated using contract rates. These values are higher than that estimated in the constructed scenario for the South Queensland Brigalow region (\$107/ha/annum, owner rates), The number of grazing days and estimated annual cattle production were higher at this site (300 vs. 240 days and 306 vs 112 kg/ha/annum, respectively). In addition, annual, amortised forage costs for this site (\$17/ha/annum, owner rates) were 40% of that estimated in the constructed scenario (\$42/ha/annum). However, at this site there was an added cost of grain feeding of the third group of 175 steers for 30 days. The assumed productive life of the leucaena at this site was 30 years as was the case for the constructed scenario. The average cattle price margin (weighted on animal numbers) for the three groups of steers was -\$0.01/kg liveweight. Gross margins could not be calculated for the second summer period of 112 days, due to insufficient information.

3.5 Butterfly pea (*Clitoria ternatea*) + grass species

3.5.1 Central Queensland Open Downs, Butterfly pea-grass pasture March 2012 – March 2014

(S 23.325 E 148.294; near Emerald)

The site was a 209 ha paddock planted to butterfly pea and perennial grasses including Rhodes, buffel, and bambatsi panic over the period 2004-2006. Prior to 2004 the paddock had been used for organic grain cropping. A total of 90 ha was planted to butterfly pea (11.5 kg/ha) and a perennial grass mix (4 kg/ha) on 01/12/04 and an additional 119 ha planted to butterfly pea (8 kg/ha) on 09/11/05. Additional grass seed including buffel, Rhodes and bambatsi panic was aerially sown (4 kg/ha) over 135 ha on 05/12/06. Phosphorus was added with the second planting of butterfly pea in 2005 at the rate of 3.3 kg P/ha over 119 ha. This site was located on the same commercial property as the Central Queensland Open Downs Oats 2013, Lablab 2011-12, Leucaena-grass 2012-14 and Perennial grass 2011-14 sites.

This paddock was monitored from March 2012 to March 2014. The period of monitoring has been divided into two sub-periods: 1st 12-month period (06/03/12-06/03/13) and 2nd 12-month period (07/03/13-06/03/14). During the total 730-days of monitoring, seven groups of cattle grazed the paddock, each followed by a period of spelling (range 16-85 days, average 54 days). The paddock received six periods of spelling, totalling 325 days, or 45% of the total monitoring period. A summary of key site details are given in Table 21 and Fig. 160-Fig. 170.

Table 21. Site details. Central Queensland Open Downs, Butterfly pea-grass pasture 2012-14
For definitions of abbreviations see Glossary of terms and abbreviations

Factor	Details
Soil characterisation	
Broad land type	Heavy clay alluvial
Soil type and characteristics	Black cracking clay (Vertosol) PAWC: 240 mm Soil depth: 120 cm
Forage production	
Average butterfly pea presentation yield in the paddock	228 (range: 0-845) kg DM/ha
Average perennial grass presentation yield in the paddock	5,118 (range: 3,822-6,687) kg DM/ha. Major species: introduced perennial grasses consisting of primarily Rhodes (41%) and buffel (35%); and native perennial grasses consisting primarily of Queensland bluegrass (10%).
Average butterfly pea presentation yield in the exclosure	324 (range: 0-846) kg DM/ha
Average perennial grass presentation yield in the exclosure	4,131 (range: 1,017-7,981) kg DM/ha. Note the exclosure was mown on 06/08/12 and 03/10/13.
C_3 species (non-grass) in the diet	7.0% (Days 76-727 of monitoring period)
Average diet quality	8.2% CP, 59% DMD (Days 76-727 of monitoring period)

Factor	Details
Grazing management and animal production	
Comments	<u>Grazing history in target paddock</u> 1st 12 months (06/03/12-07/05/13): • Group 1a: 06/03/12-30/05/12 (85 days); 29 steers, 20-24 months at entry • Group 1b: 08/05/13-30/05/13 (22 days); 154 steers; 18-20 months at entry • Spelled: 31/05/12-06/08/12 (67 days) • Group 2: 07/08/12-10/10/12 (64 days); 63 steers, 20-24 months at entry • Spelled: 11/10/12-12/11/12 (32 days) • Group 3: 13/11/12-10/12/12 (27 days); 440 heifers, 13-14 months at entry • Spelled: 11/12/12-06/03/13 (85 days) 2nd 12 months (07/03/13-13/03/13): • Spelled: 07/03/13-13/03/13 (6 days) • Group 4: 14/03/13-20/05/13 (67 days); 408 steers; 18 months at entry; came off poor quality feed near Boulia; the heaviest 145 of this group exited to the feedlot • Spelled: 21/05/13-07/08/13 (78 days) • Group 5: 08/08/13-18/09/13 (41 days); 597 steers; 10-24 months at entry • Spelled: 19/09/13-30/10/13 (41 days) • Group 6: 31/10/13-29/11/13 (29 days); 383 steers; 7-12 months at entry • Spelled: 30/11/13-16/12/13 (16 days) • Group 7: 17/12/13-06/03/14 (79 days); 360 steers; 9-14 months at entry; additional 285-ha butterfly pea-grass paddock also open
Cattle type monitored for weight gain	All cattle either NAPCO Kynuna or Alexandria Composite; ca. 13-38% *B. indicus*
Animal health treatments	Coopers® Amitik cattle dip and spray to Groups 2, 6 and 7 upon entry to paddock to Groups 5 and 7 upon exit. G roup 4: trivalent (3-germ) tick-fever vaccine, Virbac Cydectin. Group 5 were given an Elanco Compudose® 400 HGP implant when they arrived on the property in May-July 20113 (ca. 1-3 months prior to entry to the paddock). Any groups grazing in the paddock between early June to end November were given dry season urea lick.
Total monitoring period	06/03/12-06/03/14 (730 days)
Proportion of the total area planted to butterfly pea	100%

Factor	Details	
Grazing management and animal production		
Average SR – 1st 12 months	0.29 AE/ha (1 AE : 3.5 ha)	
Average SR – 2nd 12 months	1.09 AE/ha (1 AE : 0.9 ha)	
Group 1a – 20-24 month-old steers, autumn 2012		
Grazing days over which LW was measured	85 (06/03/12-30/05/12)	
Number of cattle in weight gain data set	29	
Average entry LW (± SE)	480 (± 3.2) kg	
Average exit LW (± SE)	538 (± 5.2) kg	
Average LWG (± SE)	0.68 (± 0.035) kg/head/day	
Group 4 – 18 month-old steers, autumn 2013		
Grazing days over which LW was measured	67 (14/03/13-20/05/13)	
Number of cattle in weight gain dataset	145	
Average entry LW (± SE)	377 (± 1.9) kg	
Average exit LW (± SE)	457 (± 2.4) kg	
Average LWG (± SE)	1.18 (± 0.022) kg/head/day	
Group 5 – 10-24 month-old steers 2013 late winter to early spring (initial 38 days of grazing were in an adjacent butterfly pea-grass paddock to the trial paddock)		
Grazing days over which LW was measured	79 (01/07/13-18/09/13)	
Number of cattle in weight gain dataset	71	
Average entry LW (± SE)	344 (± 3.2) kg	
Average exit LW (± SE)	343 (± 3.5) kg	
Average LWG (± SE)	-0.01 (± 0.027) kg/head/day	
Group 7 – 9-14 month-old steers 2013/14 summer		
Grazing days over which LW was measured	79 (17/12/13-06/03/14)	
Number of cattle in weight gain dataset	320	
Average entry LW (± SE)	220 (± 1.6) kg	
Average exit LW (± SE)	302 (± 1.7) kg	
Average LWG (± SE)	1.04 (± 0.0.008) kg/head/day	
Total annual LWG – 1st 12 months	50 kg/ha/annum (06/03/12-06/03/13)	
Total annual LWG – 2nd 12 months	245 kg/ha/annum (07/03/13-06/03/14)	
Economic performance		
	1st 12 months (06/03/12-06/03/13), ($/ha/annum)	**2nd 12 months (07/03/13-06/03/14), ($/ha/annum)**
Gross margin - owner rates (total grazing area)	**17**	**379**
Forage costs (forage area only)	21	21
Gross margin - contract rates (total grazing area)	**15**	**377**
Forage costs (forage area only)	23	23
CONSTRUCTED SCENARIO		
Gross margin - owner rates	**110**	**110**
Forage costs	**58**	**58**
Gross margin - contract rates	**84**	**84**
Forage costs	83	83

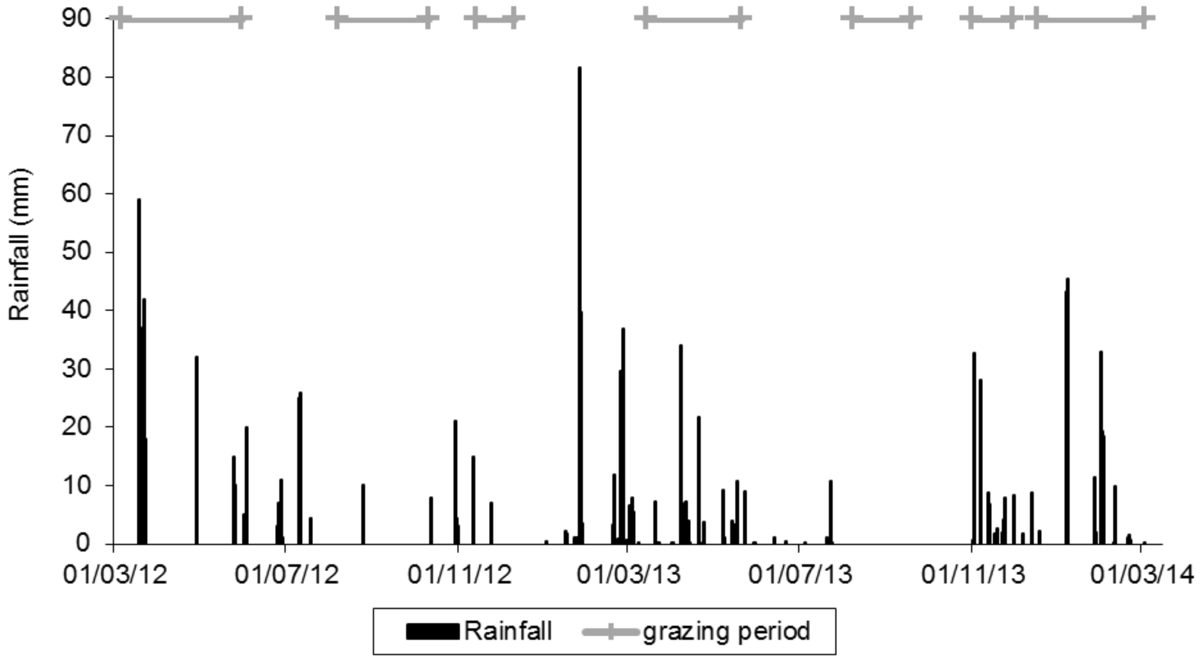

Fig. 160. Daily rainfall (mm) over the monitoring period (06/03/12-06/03/14). Measured on property ca. 6.9 km from the paddock (06/03/12-31/12/12) and with an on-site weather station (01/01/13-06/03/14). Grazing periods shown.

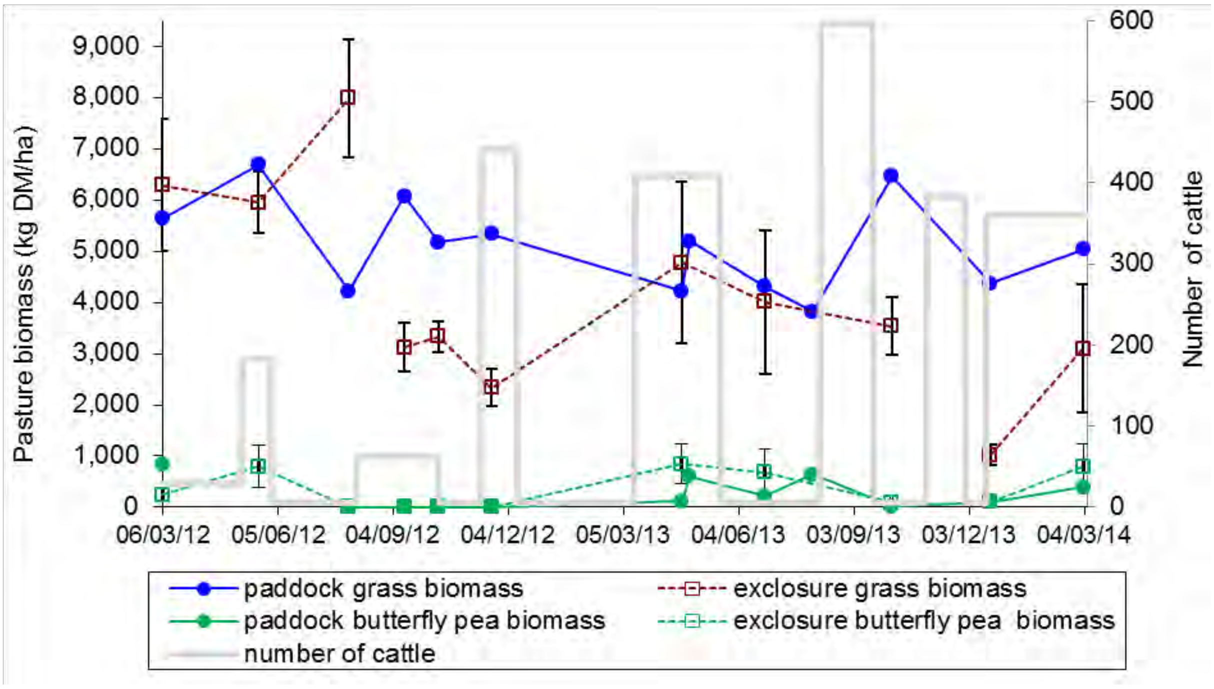

Fig. 161. Grass and butterfly pea biomass (kg DM/ha) in the paddock and the exclosure, and cattle numbers during the monitoring period (06/03/12-06/03/14**).** Exclosure was mown to 10 cm on 06/08/12 and to 5 cm on 03/10/13. Paddock grass biomass on 21/05/12 includes any butterfly pea present in the pasture as no species composition data was collected on this date.

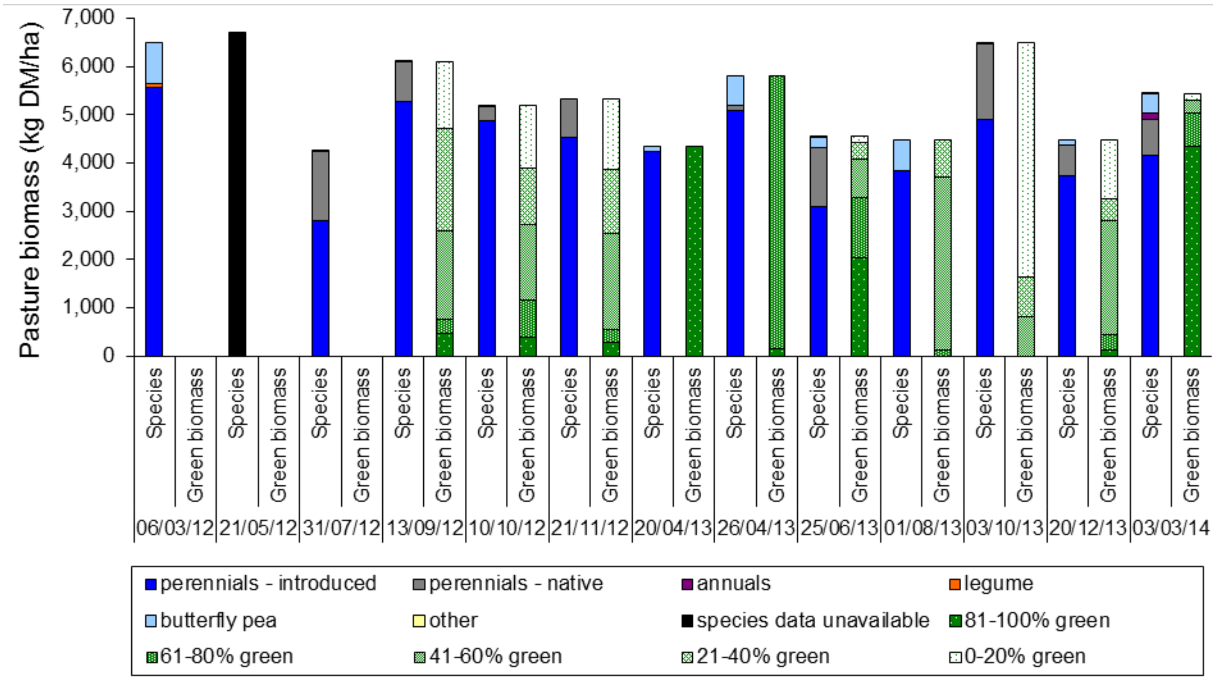

Fig. 162. Perennial pasture composition (Species) and proportion of green material in the pasture (Green biomass) shown as a proportion of total pasture biomass (kg DM/ha). Introduced perennial grasses consisted of primarily Rhodes (average 41% of the biomass) and buffel (average 35% of the biomass average). Native perennial grasses consisted primarily of Queensland bluegrass (average 10% of the biomass). Green biomass was only assessed from the 13/09/12 sampling onwards.

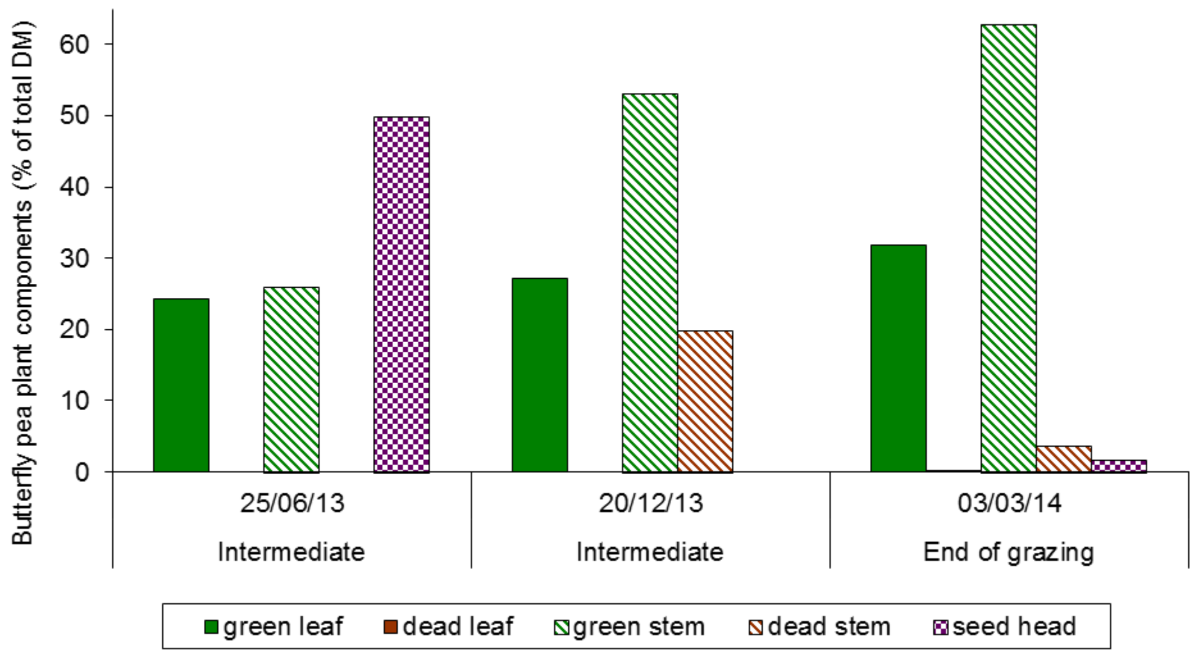

Fig. 163. Butterfly pea component composition (% of total butterfly pea DM) in the paddock during the 2nd 12 months of the monitoring period (06/03/12-06/03/14).

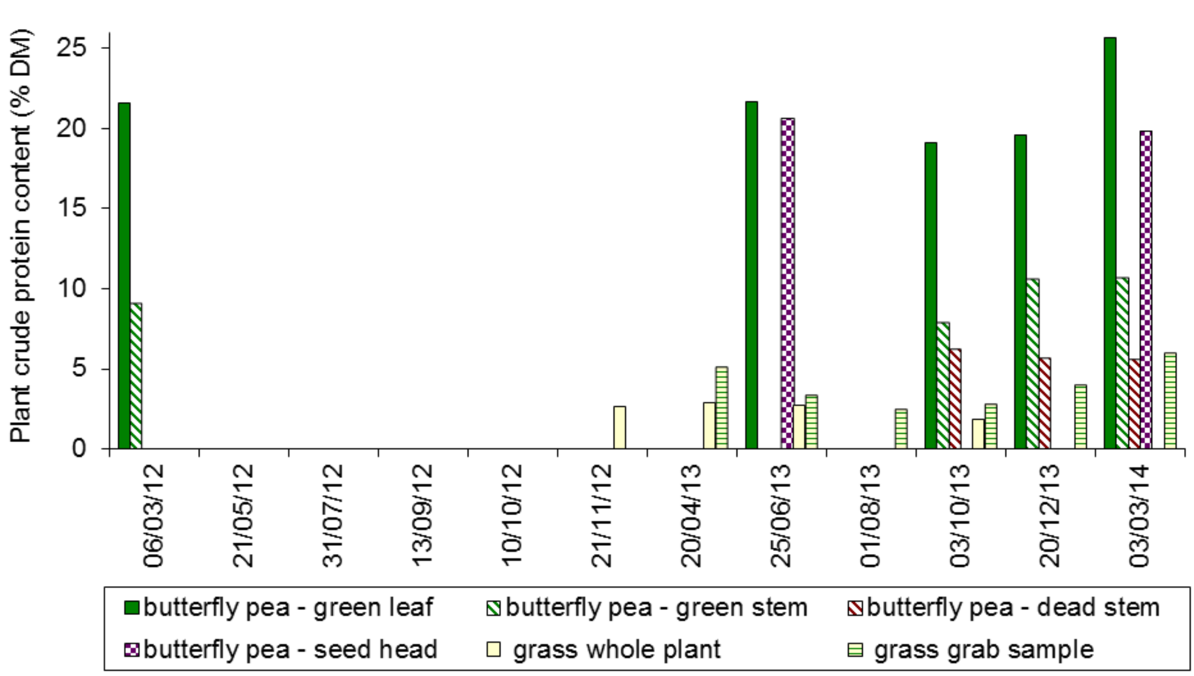

Fig. 164. Crude protein content (% DM) of butterfly pea plant components, perennial grass whole plant samples and 'grab' samples of perennial grass during the monitoring period (06/03/12-06/03/14).

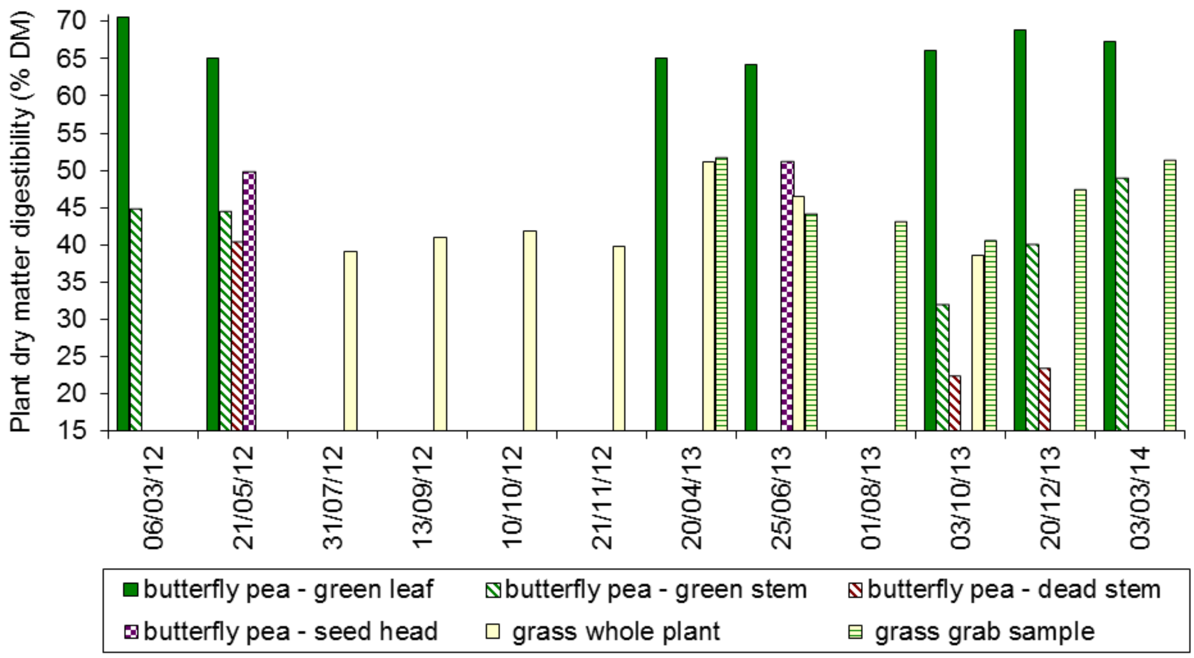

Fig. 165. Dry matter digestibility (%) of butterfly pea plant components, perennial grass whole plant samples and 'grab' samples of perennial grass during the monitoring period (06/03/12-06/03/14).

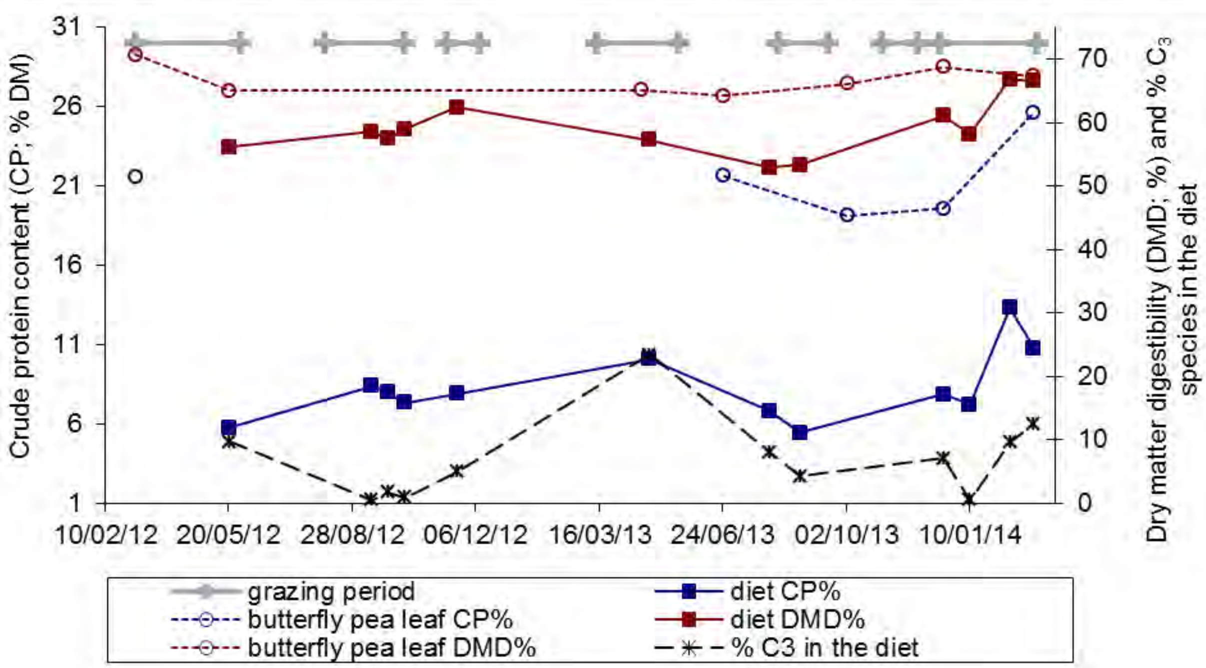

Fig. 166. Diet crude protein (CP) content (% DM) and dry matter digestibility (DMD; %) for grazing cattle predicted from faecal NIRS; measured CP and DMD content of butterfly pea green leaf; and the % of the diet as C_3 forage, predicted from $\delta^{13}C$ content in the faeces. Grazing periods in the target paddock shown.

Fig. 167. Group 1a steers grazing butterfly pea-grass paddock, 21/05/12.

Fig. 168. Butterfly pea plants evident in the butterfly pea-grass paddock, 20/04/13, during the grazing period of Group 4 steers.

Fig. 169. Group 5 steers grazing in the butterfly pea-grass paddock, 26/08/13.

Fig. 170. Butterfly pea plants evident in the butterfly pea-grass paddock, 03/03/14, 3 days prior to the end of the grazing period of Group 7 steers.

The soil in this paddock is black cracking clay typical of a heavy clay alluvial soil in this region. This butterfly pea-grass pasture was monitored towards the end of the expected benefit period of the butterfly pea (ca. 10 years; DPI&F 2005) as the paddock was planted to butterfly pea 7-8 years prior to the start of the monitoring period. During the 2-year period of monitoring the pasture contained only 4.6 (± 1.56) % butterfly pea biomass on average (range: 0-14.5% of the pasture biomass). A decline in butterfly pea proportion in the pasture over the years following sowing is expected due to selective grazing by cattle and poor ability of butterfly pea to compete with strong perennial grass pastures (DPI&F 2005). However, the benefits to the perennial grass component of the pasture, of significant additional nitrogen fixation earlier in the life of the butterfly pea pasture, would be expected to be still significant.

The proportion of introduced perennial grass species in the pasture biomass was estimated to be 83% average over the monitoring period whilst the proportion of native species was 12% of the biomass. This is in contrast to the perennial grass-only pasture also monitored on this property (Central Queensland Open Downs, Perennial grass pasture, 2011-14) which although also planted to perennial grass pastures in 2004, consisted of 54% Queensland bluegrass during the period of monitoring. It is possible that legume inclusion, in the form of butterfly pea, has enabled the maintenance of the higher-N demand, introduced perennial grasses for a longer period at the current site. However it is also likely that the inherently more fertile and deeper alluvial soil at the current site (Heavy clay alluvial land type), compared to the perennial grass paddock (Open Downs land type) would have contributed to the maintenance of the introduced perennial grasses in the pasture.

The annual rainfall totals measured on the property during 2012 and 2013 were 717 and 493 mm, respectively (Fig. 160). The 30-year climate normal mean rainfall measured at the

Emerald Post Office (BOM Station 35027) is 653.5 mm (mean of records for period 1961-1990). Hence the annual rainfall measured on property was above the 30-year climate normal in 2012 but below in 2013.

The pasture biomass and diet quality (CP and DMD, and % green in the grass biomass) reflected the seasonal rainfall patterns as well as the grazing history in the paddock (Fig. 161, Fig. 162, Fig. 163, and Fig. 166). The greatest grass pasture biomass (6,687 kg DM/ha) was measured towards the start of the monitoring period on 21/05/12. The greatest butterfly pea biomass in the paddock (845 kg DM/ha) was measured on 06/03/12 at the start of the monitoring period. Over the 2-year monitoring period, the average grass pasture biomass in the grazed paddock was 5,118 kg DM/ha and the butterfly pea biomass was 228 kg DM/ha.

Whilst diet CP concentration ranged from 5.5-13.3%, the CP content of butterfly pea green leaf ranged from 19.1-25.6% over the monitoring period (Fig. 164). Corresponding diet DMD concentrations ranged from 53-57% while the DMD content of butterfly pea leaf ranged from 64-71% (Fig. 165). The proportion of C_3 species in the diet (presumed to be primarily butterfly pea) ranged from 0.5-23.4%, with the average over the entire monitoring period being 7.0%. Native legumes were also present in the paddock but formed only 0.11% of the biomass, on average. It is of interest that the proportion of C_3 species in the diet of cattle grazing the butterfly pea paddock was similar to that for cattle grazing the perennial grass-only paddock on this same property (7.0% cf. 11.6%, respectively). This is probably due to the current levels of legume in both paddocks being similar: 4.7 cf. 3.3% for the butterfly pea-grass and perennial grass-only pastures, respectively.

It is also notable that whilst the butterfly pea biomass in the paddock was within the range of the edible leucaena biomass in the leucaena-grass paddock also assessed on this property (Central Queensland Open Downs, leucaena-grass pasture, 2012-14), the proportion of C_3 species (assumed to be primarily butterfly pea and leucaena, respectively) in the diet of cattle grazing the butterfly pea-grass paddock was much lower: 7.0% cf. 47%, respectively. It is likely that the total butterfly pea biomass produced (cf. the presentation yield) was less that the total edible leucaena biomass produced. Furthermore, not all the butterfly pea biomass would have been edible, as stem material was included as part of this biomass total.

There was a wide range in daily liveweight gain measured for different groups of cattle and periods. While a growth rate of 0.68 kg/head day was recorded for 10-24 month old steers over 85 days during the 2012 autumn (Fig. 167), a much higher growth rate of 1.18 kg/head/day was recorded for 18 month old steers over 67 days during the 2013 autumn (Fig. 168). A similar high growth rate of 1.04 kg/head/day was recorded for 9-14 month old steers over 79 days during the 2013-14 summer (Fig. 170). The lowest daily liveweight gain recorded was -0.01 kg/head/day over 79 days during the 2013 late winter and early spring period for 10-24 month old steers (Fig. 169). The periods of high growth rate coincided with peaks in grass and butterfly pea biomass, in the % of butterfly pea in the diet and in diet quality.

The total cattle liveweight gain attributed to this paddock was 5 times higher for the 2nd 12-month period of monitoring compared to the 1st (50 cf. 245 kg/ha/annum). This was a result of a much higher average stocking rate over the second year (1.09 cf. 0.29 AE/ha), a greater number of grazing days per monitoring period (223/364 cf. 181/365), as well as a higher average cattle liveweight gain (weighted average across all mobs) during the second period. Despite the very high grazing pressure over the 2nd 12-month period of monitoring, the perennial grass pasture yield at the end of the monitoring period (5,035 kg DM/ha) was close to the average for that paddock over the two years of monitoring (5,118 kg DM/ha), indicating that the rainfall events and pasture growth had been adequate to support the numbers of grazing cattle and the total beef production in the second year.

The total beef production, averaged over two, 12-month periods, from the three perennial pasture paddocks monitored on the same property in the Central Queensland Open Downs region were: 191 kg/ha/annum (leucaena-grass 2012-14); 148 kg/ha/annum (butterfly pea-grass 2012-14) and 36 kg/ha/annum (perennial grass 2011-13). These results are a product of stocking rate, total grazing days and daily liveweight gain. Whilst it is likely that these production levels are strongly influenced by the components of the pasture (i.e. by legume composition), it is also likely that the inherently higher quality alluvial soil at the butterfly pea pasture site is providing some benefit in production as compared to the perennial grass pasture site.

The gross margin for the total grazing area over the first 12 months of grazing (06/03/12-06/03/13) was $17/ha/annum when calculated using owner rates and $15/ha/annum when calculated using contract rates. The gross margin for the second 12 months of grazing (07/03/13-06/03/14) was more than 22 times higher than for the first 12 months: $379/ha/annum calculated using owner rates and $377/ha/annum calculated using contract rates. This much higher result in the second 12 month period was partially a result of 5 times greater beef production and also due to the greater cattle price margin in the second year: $0.16 vs. $0.05/kg LW. The average gross margin for the total grazing area over the 2 years of monitoring was $198/ha/annum, calculated using owner rates. This value is 1.8 times greater than the gross margin estimated in the constructed scenario for the Central Queensland Open Downs region ($110/ha/annum). This result would be partially a product of a higher average annual cattle production at this site (average 148 vs. 128 kg/ha/annum, respectively). In addition, annual, amortised forage costs for this site ($21/ha/annum, owner rates) were lower than that estimated in the constructed scenario ($58/ha/annum). The lower forage costs at this site are largely a result of the forage costs being amortised over 10 years rather than 5 years as in the constructed scenario.

3.5.2 Central Queensland Brigalow, Butterfly pea-grass pasture June 2012 – June 2013

(S 24.555 E 149.935; near Moura)

The site was a 44 ha paddock with 28 ha planted to butterfly pea (10.7 kg/ha) in February 2001. Perennial grasses were not planted but have naturalised from surrounding paddocks and consisted of primarily Queensland bluegrass during the period of monitoring. Phosphorus fertiliser was not applied at planting of butterfly pea. The producer advised that the initial establishment of butterfly pea was poor and that the paddock had been dominated by grass until after the paddock had been flooded for around 15 days in January 2011. The producer has aimed to maintain the butterfly pea component of the pasture by spelling to allow the plants to seed each season, prior to grazing. The paddock had been initially cleared in the 1950s or 60s. It is unknown when the paddock was first cultivated. From 1988 to 2000 the paddock had been used for forage sorghum cropping when seasons permitted.

This paddock was monitored from June 2012 to June 2013: 28/05/12-07/06/13. During the 375-day period, 1 group of maiden heifers grazed the paddock. The paddock was spelled for 236 days from 24/07/12-17/03/13 during which time the heifers grazed a buffel and native pasture paddock containing some Seca stylo. They were mated in October and were due to calve about 6 weeks after the last weight measurement was taken on 07/06/13 when they exited the trial paddock. Seven out of the total group of 47 heifers were not in calf when pregnancy-tested on the 07/06/13. Weights and weight gain data are presented separately for the pregnant and non-pregnant heifers. A summary of key site details are given in Table 22 and Fig. 171-Fig. 180.

Table 22. Site details. Central Queensland Brigalow, Butterfly pea-grass pasture 2012-13
For definitions of abbreviations see Glossary of terms and abbreviations

Factor	Details	
Soil characterisation		
Broad land type	Heavy clay alluvial	
Soil type and characteristics	Black cracking clay (Vertosol) PAWC: 240 mm Soil depth: 120 cm	
Soil nutrient levels (March 2013)		**0–10 cm**
	P (mg/kg)	59
	Organic C (%)	2.1
Forage production		
Average butterfly pea presentation yield in the paddock	1,138 (range: 190-2,368) kg DM/ha (27% of total pasture biomass on average)	
Average perennial grass presentation yield in the paddock	3,480 (range 1,228-4,758) kg DM/ha. Major species: native perennial grasses consisting primarily of Queensland bluegrass (35% of total pasture biomass).	
Average butterfly pea presentation yield in the exclosure	1,829 (range: 1241-2417) kg DM/ha	
Average perennial grass presentation yield in the exclosure	3,500 (range: 3,492-3,509) kg DM/ha. Note the exclosure was mown on 31/08/12 prior to initial exclosure sampling.	
C_3 species (non-grass) in the diet	51% (Days 302 and 325 of monitoring period)	
Average diet quality	12.7% CP, 58% DMD (Days 302 and 325 of monitoring period)	

Factor	Details	
Grazing management and animal production		
Comments	<u>Grazing history over the 375-day period</u> • Group 1: 28/05/12-02/06/12 (6 days); 28 heifers, 20 months at entry • Group 1: 03/06/12-23/07/12 (50 days); 47 heifers 20 months at entry • Spelled: 24/07/12-17/03/13 (236 days) • Group 1: 18/03/13-07/06/13 (81 days); 47 heifers, 30 months at entry, 40 heifers pregnant from October and due to calve ca. 6 weeks after end of monitoring period.	
Cattle type monitored for weight gain	Maiden heifers; grey Brahmans; ca. 100% *B. indicus*	
Animal health treatments	None	
Total monitoring period	28/05/12-07/06/13 (375 days)	
Proportion of the total area planted to butterfly pea	64%	
Average SR – 375 days	0.36 AE/ha (1 AE : 2.8 ha)	
	Pregnant from Oct 2012	**Not pregnant**
June 2012		
Grazing days over which LW was measured	28 (03/06/12-01/07/12)	
Number of cattle in weight gain dataset	40	7
Average entry LW (± SE)	309 (± 5.2) kg	255 (± 13.5) kg
Average exit LW (± SE)	331 (± 6.2) kg	269 (± 16.8) kg
Average LWG (± SE)	0.78 (± 0.073) kg/head/day	0.53 (± 0.144) kg/head/day
July 2012		
Grazing days over which LW was measured	22 (01/07/12- 23/07/12)	
Number of cattle in weight gain dataset	40	7
Average entry LW (± SE)	331 (± 6.2) kg	269 (± 16.8) kg
Average exit LW (± SE)	337 (± 6.2) kg	273 (± 16.4) kg
Average LWG (± SE)	0.28 (± 0.050) kg/head/day	0.18 (± 0.056) kg/head/day
Mid-March to early-April 2013		
Grazing days over which LW was measured	24 (18/03/13-11/04/13)	
Number of cattle in weight gain dataset	35	7
Average entry LW (± SE)	441 (± 7.4) kg	374 (± 14.0) kg
Average exit LW (± SE)	463 (± 8.2) kg	393 (± 15.5) kg
Average LWG (± SE)	0.92 (± 0.072) kg/head/day	0.80 (± 0.123) kg/head/day
Early-April to early-May 2013		
Grazing days over which LW was measured	30 (11/04/13-11/05/13)	
Number of cattle in weight gain dataset	35	7
Average entry LW (± SE)	463 (± 8.2) kg	393 (± 15.5) kg
Average exit LW (± SE)	502 (± 8.7) kg	426 (± 14.1) kg
Average LWG (± SE)	1.28 (± 0.049) kg/head/day	1.10 (± 0.090) kg/head/day
Early-May to early-June 2013		
Grazing days over which LW was measured	27 (11/05/13-07/06/13)	
Number of cattle in weight gain dataset	35	7
Average entry LW (± SE)	502 (± 8.7) kg	426 (± 14.1) kg
Average exit LW (± SE)	495 (± 8.6) kg	414 (± 14.6) kg
Average LWG (± SE)	-0.26 (± 0.059) kg/head/day	-0.43 (± 0.066) kg/head/day
Total annual LWG – 375 days	80 kg/ha/annum (28/05/12-07/06/13)	

Economic performance	
	(28/05/12-07/06/13), ($/ha per 375 days)
Gross margin - owner rates (total grazing area)	**34**
Forage costs (forage area only)	21
Gross margin - contract rates (total grazing area)	**28**
Forage costs (forage area only)	31
CONSTRUCTED SCENARIO	
Gross margin – owner rates	**98**
Forage costs	58
Gross margin - contract rates	**73**
Forage costs	83

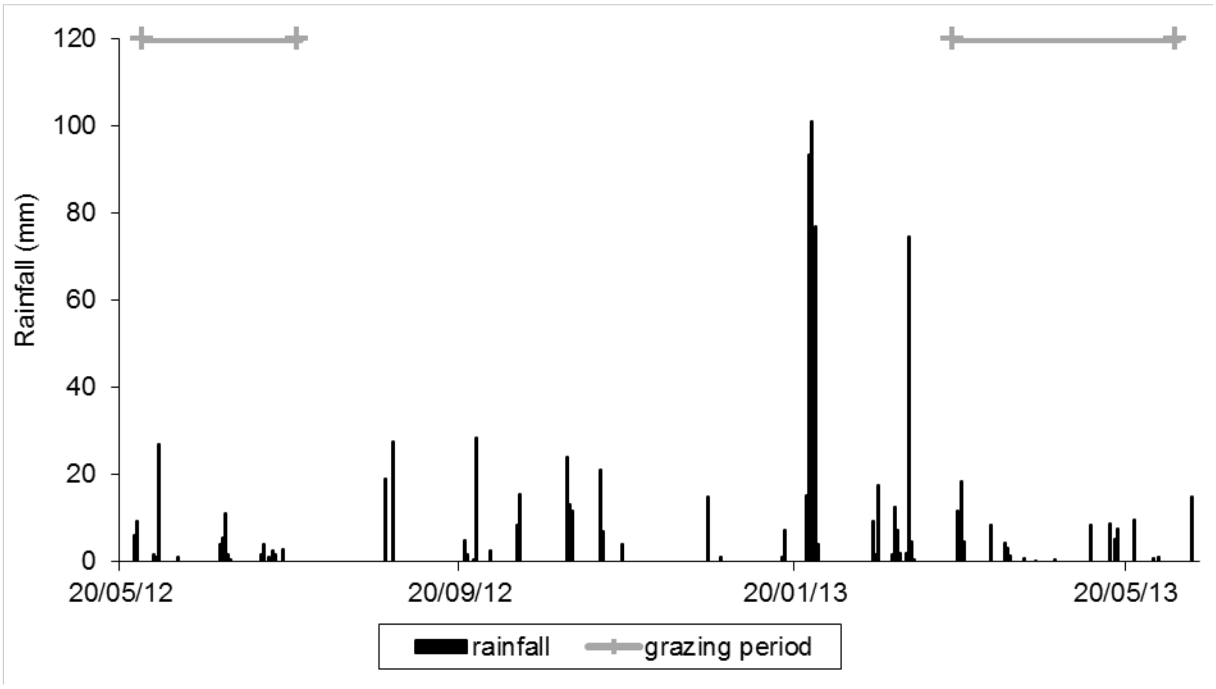

Fig. 171. Daily rainfall (mm) over the monitoring period (28/05/12-07/06/13). Measured at Moura Post Office (BOM Station 39071). Grazing periods shown.

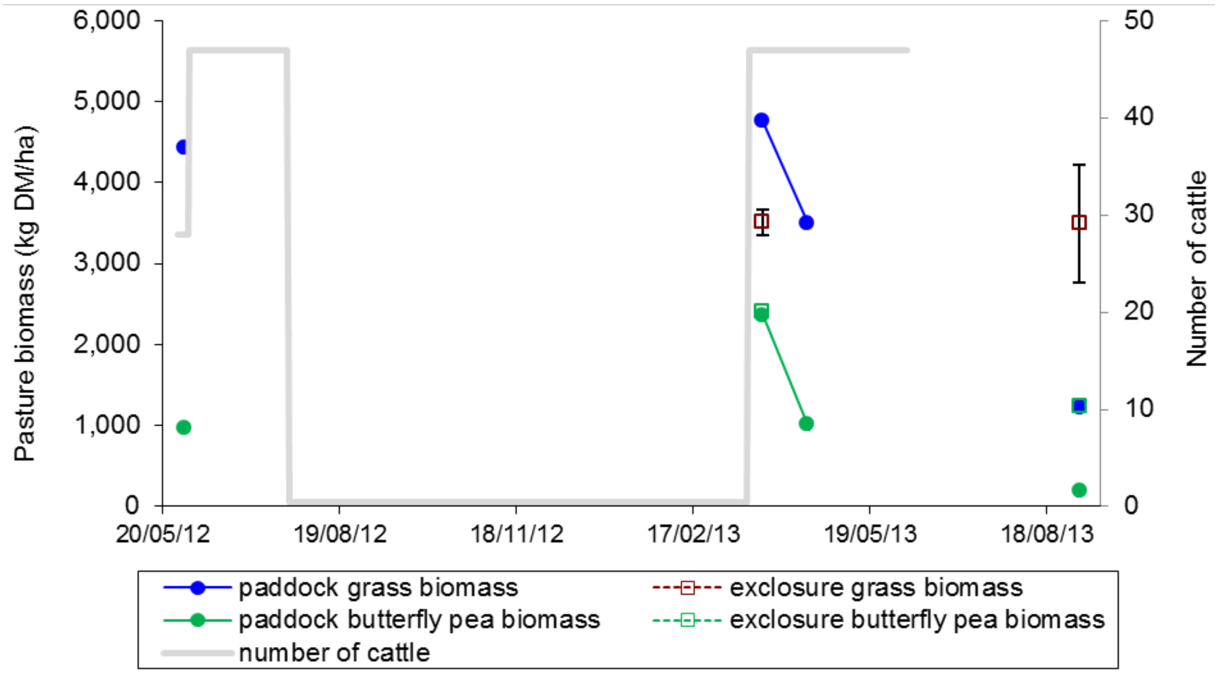

Fig. 172. Grass and butterfly pea biomass (kg DM/ha) in the paddock and the exclosure, and cattle numbers during the monitoring period (28/05/12-07/06/13). Exclosure was mown to 10 cm on 31/08/12, prior to first exclosure sampling. The final pasture assessment was conducted 89 days after the cattle had exited the paddock. However, this was during the winter period and dry season although 30 mm of rain fell during this period.

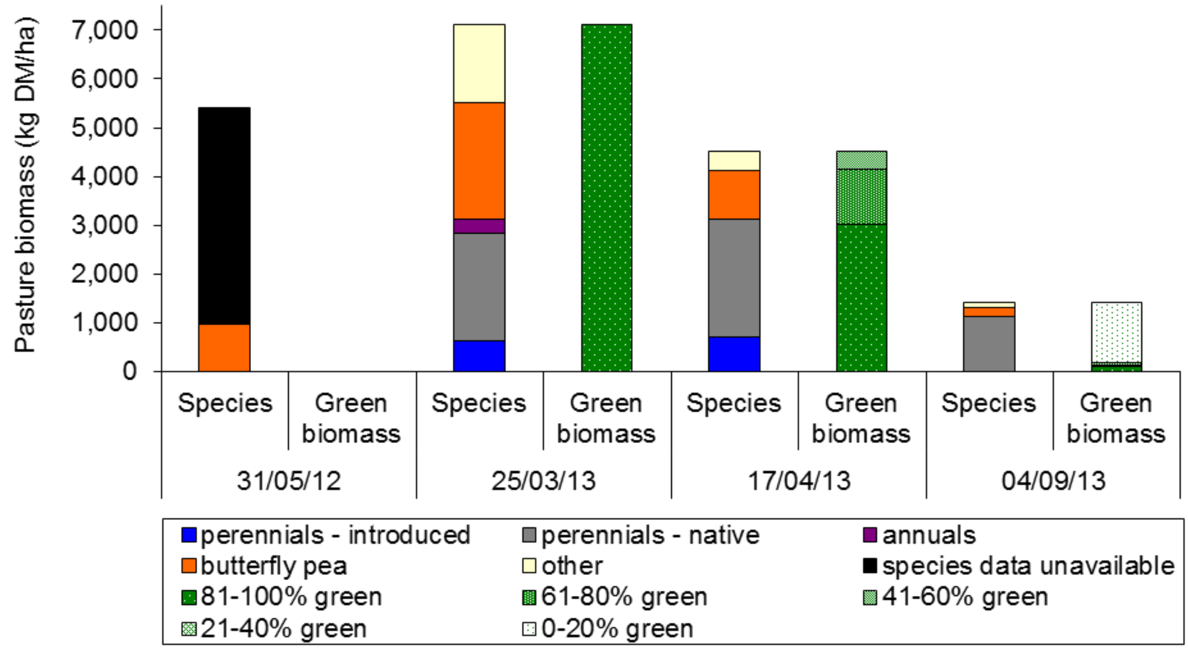

Fig. 173. Perennial pasture composition (Species) and proportion of green material in the pasture (Green biomass) shown as a proportion of total pasture biomass (kg DM/ha). Butterfly pea averaged 27% of the biomass. Native perennial grasses averaged 44% of the biomass and consisted of primarily Queensland bluegrass (average 35% of the biomass). Introduced perennial grasses consisted of buffel, green panic, sabi, (average 10% of the biomass). Other species were nut grass and weeds. Green biomass was only assessed from the 25/03/13 sampling onwards.

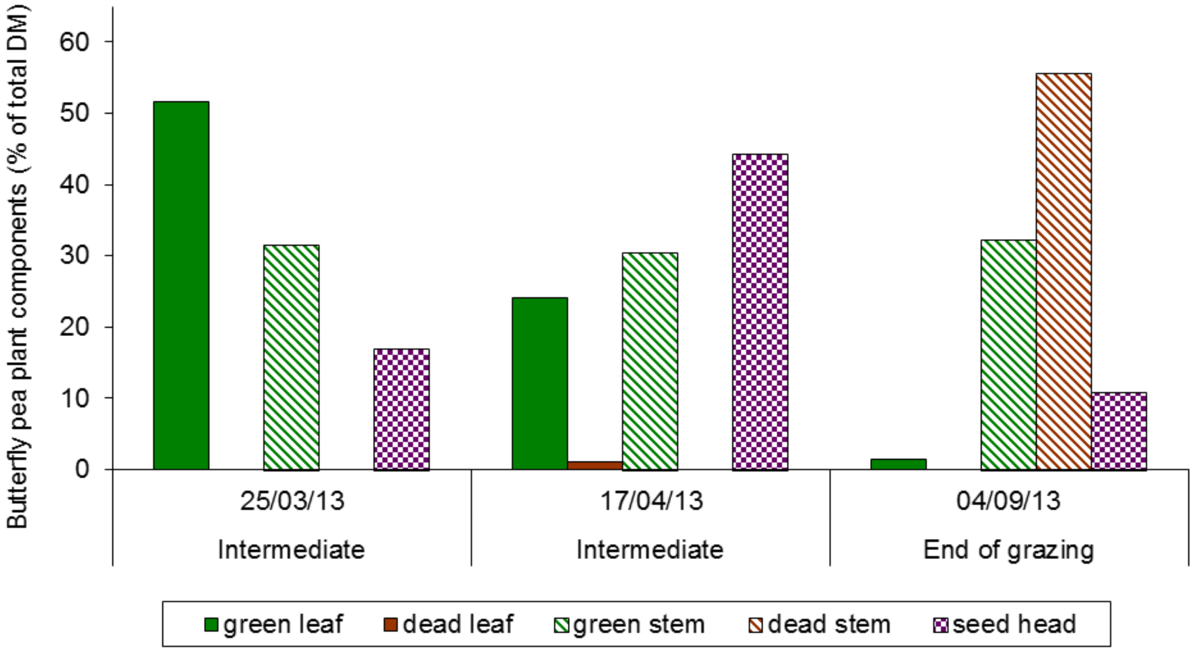

Fig. 174. Butterfly pea component composition (% of total butterfly pea DM) in the paddock during the 2nd grazing period within the monitoring period (28/05/12-07/06/13). The final pasture sample was conducted 89 days after the cattle had exited the paddock. However, this was during the winter period and dry season although 30 mm of rain fell during this period.

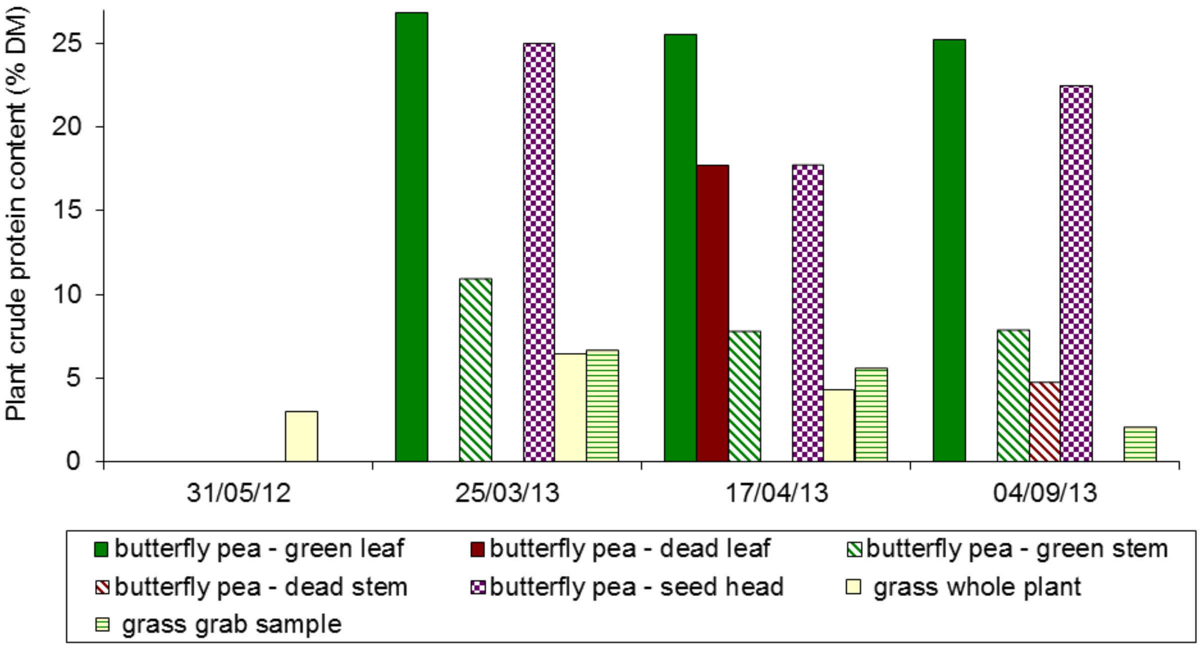

Fig. 175. Crude protein content (% DM) of butterfly pea plant components, perennial grass whole plant samples and 'grab' samples of perennial grass during the monitoring period (28/05/12-07/06/13). The final pasture sample was conducted 89 days after the cattle had exited the paddock. However, this was during the winter period and dry season although 30 mm of rain fell during this period.

Fig. 176. Dry matter digestibility (%) of butterfly pea plant components, perennial grass whole plant samples and 'grab' samples of perennial grass during the monitoring period (28/05/12-07/06/13). The final pasture sample was conducted 89 days after the cattle had exited the paddock. However, this was during the winter period and dry season although 30 mm of rain fell during this period.

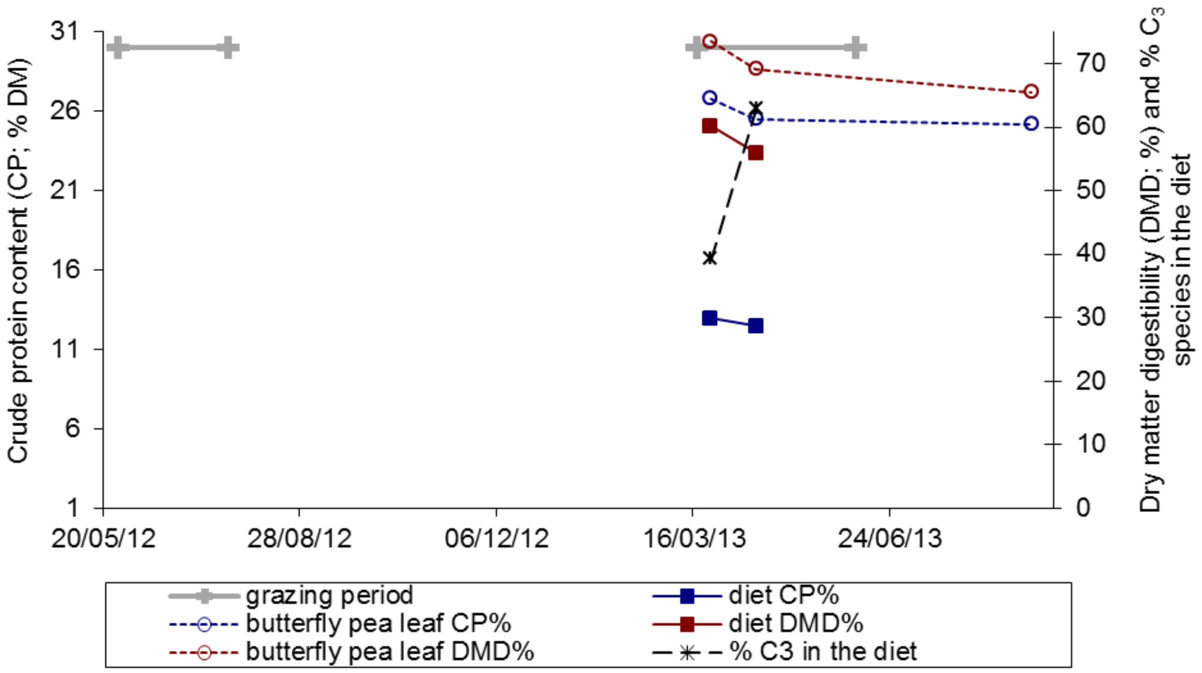

Fig. 177. Diet crude protein (CP) content (% DM) and dry matter digestibility (DMD; %) for grazing cattle predicted from faecal NIRS; measured CP and DMD content of butterfly pea green leaf; and the % of the diet as C3 forage, predicted from δ13C content in the faeces. Grazing periods in the target paddock shown. The final pasture sample was conducted 89 days after the cattle had exited the paddock. However, this was during the winter period and dry season although 30 mm of rain fell during this period.

Fig. 178. Pregnant heifers grazing butterfly pea-grass paddock during the 3rd period of monitoring, 25/03/13.

Fig. 179. Butterfly pea plants evident in the butterfly pea-grass paddock, 25/03/13, during the 3rd period of monitoring of heifers.

Fig. 180. Pregnant heifers grazing the butterfly pea-grass paddock during the 4th period of monitoring, 18/04/13.

The soil in this paddock is black cracking clay typical of a heavy clay alluvial soil in this region. Soil P and organic C levels are high and considered to be adequate for maintenance of legumes such as butterfly pea (Peck *et a*l. 2014). As the paddock was planted to butterfly pea ca. 11 years prior to the start of the monitoring period, this butterfly pea-grass pasture was monitored towards the end of the expected benefit period of the butterfly pea (ca. 10 years; DPI&F 2005). At the start of the first grazing period, the pasture biomass contained 18% butterfly pea and during the second grazing period the pasture contained 27% butterfly pea biomass on average (range: 13-33% of the pasture biomass). These levels are higher than those measured in a butterfly pea-grass pasture of similar age and planted on similar soil type, in the Open Downs region (Central Queensland Open Downs, butterfly pea-grass 2012-14). It is likely that the flooding of the paddock for 18 days in early January 2011 gave the butterfly pea a selective advantage over the perennial grasses (Cook *et al.* 2005; DPI&F 2005), as a dramatic increase in the butterfly pea component of the pasture was observed by the producer after this event. In addition, the management strategy of spelling the pasture during each summer seeding period would be expected to assist in the maintenance of the butterfly pea component in the pasture (DPI&F 2005). The average proportion of native perennial grass species in the pasture biomass was 44% and consisted of primarily Queensland bluegrass (35% of the total biomass on average). Introduced perennial grass species in the pasture biomass were 10% on average over the monitoring period and consisted of buffel, green panic and sabi grass.

The rainfall total measured at Moura Post Office (BOM Station 39071) over the 375-day period of monitoring (28/05/12-07/06/13) was 802 mm (Fig. 171). The 30-year climate normal mean rainfall measured at the same BOM Station is 696 mm. Hence rainfall received during the period of monitoring was above the 30-year climate normal. This was largely the result of the significant rainfall in late January 2013: 291 mm over 5 days.

The pasture biomass and diet quality (CP and DMD, and % green in the grass biomass) reflected the seasonal rainfall patterns as well as the grazing history in the paddock (Fig. 172, Fig. 173, Fig. 174 and Fig. 175). The greatest grass pasture biomass (4,758 kg DM/ha) was measured on the 25/03/13, 7 days after the start of the second period of grazing and after the significant rainfall events in January and early March, during the period of spelling. The greatest butterfly pea biomass in the paddock (2,368 kg DM/ha) was measured on the same date. In addition, on the 25/03/13, the 100% of the pasture biomass was assessed as being 81-100% green. Over the 375-day monitoring period, the average grass pasture biomass in the grazed paddock was 3,480 kg DM/ha and the butterfly pea biomass was 1,138 kg DM/ha.

Unfortunately, only two faecal samples were obtained for analysis of diet quality and proportion of C_3 species in the diet. These samples were obtained on day 302 and 325 of the monitoring period and during the second period of grazing of the heifers, after summer spelling and the significant rainfall events of January and early March. These samples indicated a high quality diet with average diet CP concentration of 12.7% and DMD of 58%. The high diet quality is consistent with the high proportion of C_3 species (assumed to be primarily butterfly pea) in the diet during this period (average 51%) and resulted in high average growth rates of pregnant heifers during this period 0.92 kg/head/day (18/03/13-11/04/13; Fig. 178 and Fig. 179) and 1.28 kg/head/day (11/04/13-11/05/13; Fig. 180). The CP content of butterfly pea green leaf ranged from 25.2-26.8% over the two periods of grazing (Fig. 175). The DMD content of butterfly pea leaf ranged from 66-74% (Fig. 176).

There was a wide range in daily liveweight gain measured for maiden heifers over the varying seasonal conditions. An average growth rate of 0.78 kg/head/day was measured over 28 days in early winter 2012, when there was still significant green material in the pasture but this had decreased to 0.28 kg/head/day over 22 days by mid-winter 2012. Both pregnant and non-pregnant heifers lost weight (-0.26 and -0.43 kg/head/day, respectively) over 27 days in late autumn/early winter 2013 when the pasture had frosted and dried off. The highest growth rates were recorded during the autumn of 2013 (0.92 and 1.28 kg/head/day over 18/03/13-11/04/13 and 11/04/13-11/05/13 measurement periods, respectively) and when the pasture biomass and % of green material and butterfly pea was at its peak after summer spelling and significant rainfall events in January and early March.

The seven heifers which did not fall pregnant after mating during the monitoring period had lower weight gain on average than the 40 heifers which did fall pregnant, even in the two periods of monitoring prior to mating in October 2012, suggesting lower genetic potential for growth. The daily weight gain of the seven heifers which did not fall pregnant was 68% and 64% of that of the heifers which did fall pregnant, in the two monitoring periods prior to joining, respectively, and 85-87% of the pregnant heifers from ca. day 156-210 of gestation. From day 210-237 of gestation of the pregnant heifers, the non-pregnant heifers lost 0.17 kg/head/day more weight than those that were pregnant. Of the seven heifers which did not conceive during the mating period in October 2012, six had lower initial liveweight than the average of the pregnant heifers (<309 kg on 03/06/12). At the start of the monitoring period (03/06/12) the average liveweight of the seven heifers which did not conceive was 83% of the average liveweight of the 40 heifers which did conceive and this weight difference was maintained to the end of the monitoring period. It is likely that the six lightest of the seven heifers which did not conceive had not reached puberty by mating as their average weight was only 260 kg on the 23/07/12, 2.5 months prior to joining. Very low growth rates would have been expected over the August-October period on buffel grass pastures and hence it is likely that the liveweight of the six heifers was <334 kg which is the mean weight at which puberty is likely to occur in Brahman heifers (Johnston *et al.* 2009).

The total cattle liveweight gain attributed to this paddock for the 375 days of monitoring in 2012-13 was 80 kg/ha. This value is almost double the cattle production measured over a similar time period (06/03/12-06/03/13) from a butterfly pea-grass pasture of similar age and planted on similar soils in the Open Downs region (Central Queensland Open Downs, butterfly pea-grass pasture, 2012-14; 44 kg/ha/annum) but 3 times less than that measured from the same Open Downs region paddock in the following 12 months (07/03/13-06/03/14; 242 kg/ha/annum). Despite the butterfly pea-grass pasture being ca. 11 years old, cf. the scenario of re-planting the butterfly pea every 5 years in the constructed scenarios for each region, the total cattle production was still 74% of that estimated for the constructed scenario for butterfly pea-grass pastures in the Central Queensland Brigalow region (108 kg/ha/annum). The lower total beef production at the current site was a result of a lower average stocking rate over the 375 or 365 days (0.36 cf. 0.55 AE/ha for the current site and constructed scenario, respectively) and a lower number of grazing days per monitoring period (138/375 cf. 250/365). The average cattle liveweight gain (average across all periods of measurement) was similar: 0.57 cf. 0.60 kg/head/day, for the current site and constructed scenario, respectively.

The gross margin for the total grazing area over the 375-day period of monitoring (28/05/12-07/06/13) was $34/ha/annum when calculated using owner rates and $28/ha/annum when calculated using contract rates. This is less than the gross margin estimated in the constructed scenario for the Central Queensland Brigalow region ($98/ha/annum, owner rates) which is in line with a the lower average stocking rate, number of grazing days and total beef production at the current site than for the constructed scenario. However, annual, amortised forage costs for this site ($21/ha/annum, owner rates) were lower than that estimated in the constructed scenario ($58/ha/annum, owner rates). Forage costs were amortised over 10 years for the current site rather than 5 years as in the constructed Scenario due to the high proportion of butterfly pea still present in the pasture. The cattle price margin was negative at -$0.40/kg liveweight.

3.6 Perennial grass pasture

3.6.1 Central Queensland Open Downs, Perennial grass pasture December 2011 – February 2014

(S 23.302, E 148.498; near Emerald).

The site was a 1,022.5 ha paddock. The paddock had previously been cropped with wheat but in 2003 was prepared, with cultivation and chemical applications, for aerial seeding in March 2004 with introduced grasses (3.5 kg/ha) including Gayndah and Biloela buffel, Bisset creeping bluegrass, Bambatsi panic, Katambora Rhodes grass and silk/sugardrip sorghum. During the monitoring period for this project the grass paddock contained a mixture of native and introduced grasses (primarily Queensland bluegrass and buffel, respectively). This site was located on the same commercial property as the Central Queensland Open Downs Oats 2013, Lablab 2011-12, Butterfly pea-grass 2012-14 and Leucaena-grass 2012-14 sites.

The paddock was monitored from December 2011 to February 2014. The period of monitoring has been divided into three periods: 1st 12-month period (22/12/11-21/12/12), 2nd 12-month period (22/12/12-16/12/13) and final 57-days (17/12/13-12/02/14). During the 1st 12-month monitoring period the paddock was grazed for 75 days over the summer period from 22/12/11–06/03/12. The paddock was spelled for 162 days over the dry season from 07/03/12–15/08/12 and then grazed for 82 days from 16/08/12–06/11/12 before being spelled again for the final 45 days of the 1st period. During the 2nd 12-month monitoring period the paddock was spelled for initial 165 days and t hen grazed for 193 days from 06/06/13-16/12/13. The paddock was grazed for the final 57 day s of monitoring. A summary of key site details are given in Table 23 and Fig. 181-Fig. 188.

Table 23. Site details. Central Queensland Open Downs, Perennial grass pasture 2011-14
For definitions of abbreviations see Glossary of terms and abbreviations

Factor	Details	
Soil characterisation		
Broad land type	Open Downs	
Soil type and characteristics	Black cracking clay (Vertosol) PAWC: 180 mm Soil depth: 90 cm	
Soil nutrient levels at site establishment (November 2011)		**0–10 cm**
	Nitrate N (mg/kg)	1.0
	Nitrate N total (kg/ha)	1.15
	P (mg/kg)	7
	Organic C (%)	0.98
	Cl (mg/kg)	19
Forage production		
Average perennial grass presentation yield in the paddock	4,170 (range: 1,777-5,682 kg DM/ha). Major species: Queensland bluegrass (49%) and buffel grass (21%).	
Average perennial grass presentation yield in the exclosure	3,427 (range 93-7,433 kg DM/ha); Note the exclosure was mown on 06/08/12 and 03/10/13.	
C_3 species (non-grass) in the diet	11.6% (Days 267-784 of grazing period)	
Average diet quality	6.7% CP, 57.3% DMD (Days 267-784 of grazing period)	

Factor	Details
Grazing management and animal production	
Comments	Grazing history: 1st 12 months (22/12/11-21/12/12): • Group 1a: 22/12/11-06/03/12; 29 steers, 20-24 months at entry • Group 1b: 27/01/12-06/03/12; 382 steers, 21-25 months at entry • Group 1c: 16/08/12–06/11/12; 700 steers, 7-10 month-old at entry. 2nd 12 months (22/12/12-16/12/13) and final 57 days (17/12/13-12/02/14): • Group 2a: 06/06/13-12/02/14; 506 steers, 5-12 months old at entry • Group 2b: 17/12/13-12/02/14; 20 steers, 11-16 months old at entry
Cattle type monitored for weight gain	All cattle either NAPCO Kynuna or Alexandria Composite; ca. 13-38% *B. indicus*
Animal health treatments	Groups 1a and 1b: Coopers® Amitik cattle dip and spray in Dec 2011; Group 1c: de-horn, castrate, trivalent (3-germ) tick-fever vaccine, 5-in-1 and Virbac Cydectin on 03/08/12; dry season urea lick in Aug 2012 (250 g/head/day); Group 2a and 2b: de-horn, castrate, trivalent (3-germ) tick-fever vaccine, 5-in-1, Virbac Cydectin, Elanco Compudose® 400, and Vitamin B12 injection to 25% on 04/06/13.
Total monitoring period	22/12/11–12/02/14 (783 days)
Average SR – 1st 12 months	0.17 AE/ha (1 AE : 5.9 ha)
Average SR – 2nd 12 months	0.15 AE/ha (1 AE : 6.5 ha)
Average SR – final 57 days	0.35 AE/ha (1 AE : 2.8 ha)
Group 1a – steers 2011/12 summer	
Grazing days over which LW was measured	75 (22/12/11–06/03/12)
Number of cattle in weight gain dataset	29
Average entry LW (± SE)	426 (± 2.8) kg
Average exit LW (± SE)	480 (± 3.2) kg
Average LWG (± SE)	0.73 (± 0.044) kg/head/day
Group 2a – steers 2013 winter to 2014 summer (400-d HGP)	
Grazing days over which LW was measured	251 (06/06/13–12/02/14)
Number of cattle in weight gain dataset	412
Average entry LW (± SE)	176 (± 1.1) kg
Average exit LW (± SE)	283 (± 1.6) kg
Average LWG (± SE)	0.43 (± 0.005) kg/head/day
Total annual LWG – 1st 12 months	31 kg/ha/annum (22/12/11-21/12/12)
Total annual LWG – 2nd 12 months	41 kg/ha/annum (22/12/12-16/12/13)
Total LWG – final 57 days	13 kg/ha per 57 days (17/12/13-12/02/14)

Factor	Details	
Economic performance		
	1st 12 months (22/12/11-21/12/12), ($/ha/annum)	**2nd 12 months (22/12/12-16/12/13), ($/ha/annum)**
Gross margin	**25**	**51**
Forage costs	0	0
CONSTRUCTED SCENARIO		
Gross margin	**27**	**27**
Forage costs	0	0

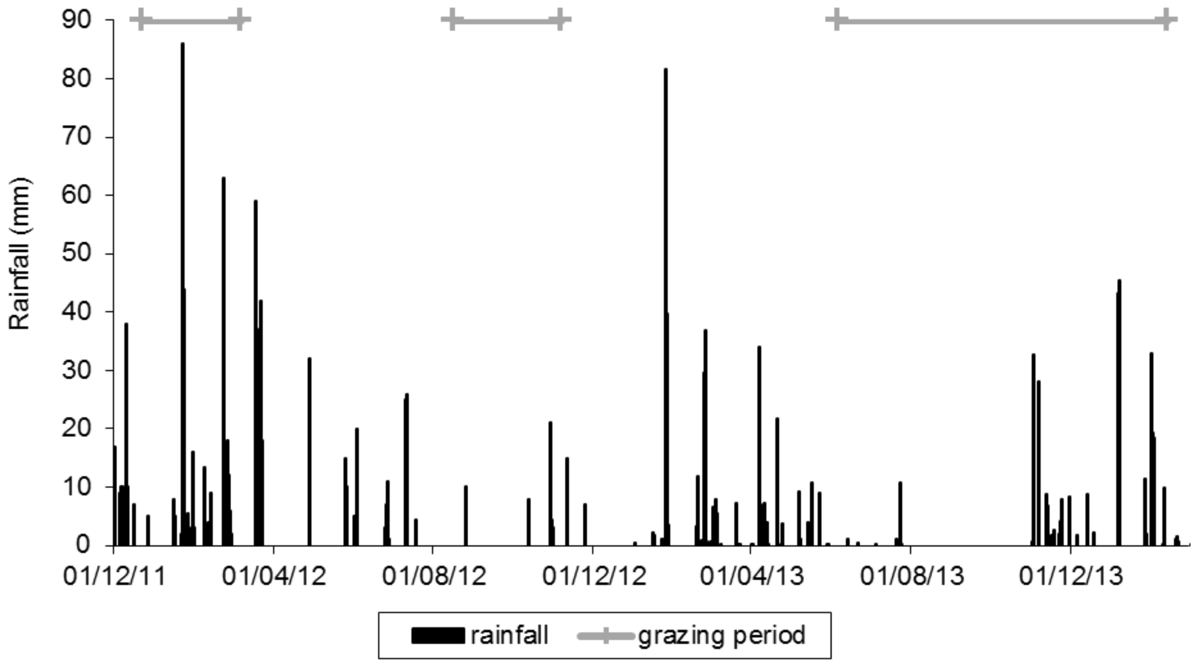

Fig. 181. Daily rainfall (mm) over the monitoring period (22/12/11–12/02/14). Measured on property ca. 2.7 km from the paddock (22/12/11-31/12/12) and with an on-site weather station in the neighbouring butterfly pea paddock ca. 6.3 km from the paddock (01/01/13-12/02/14). G razing periods shown.

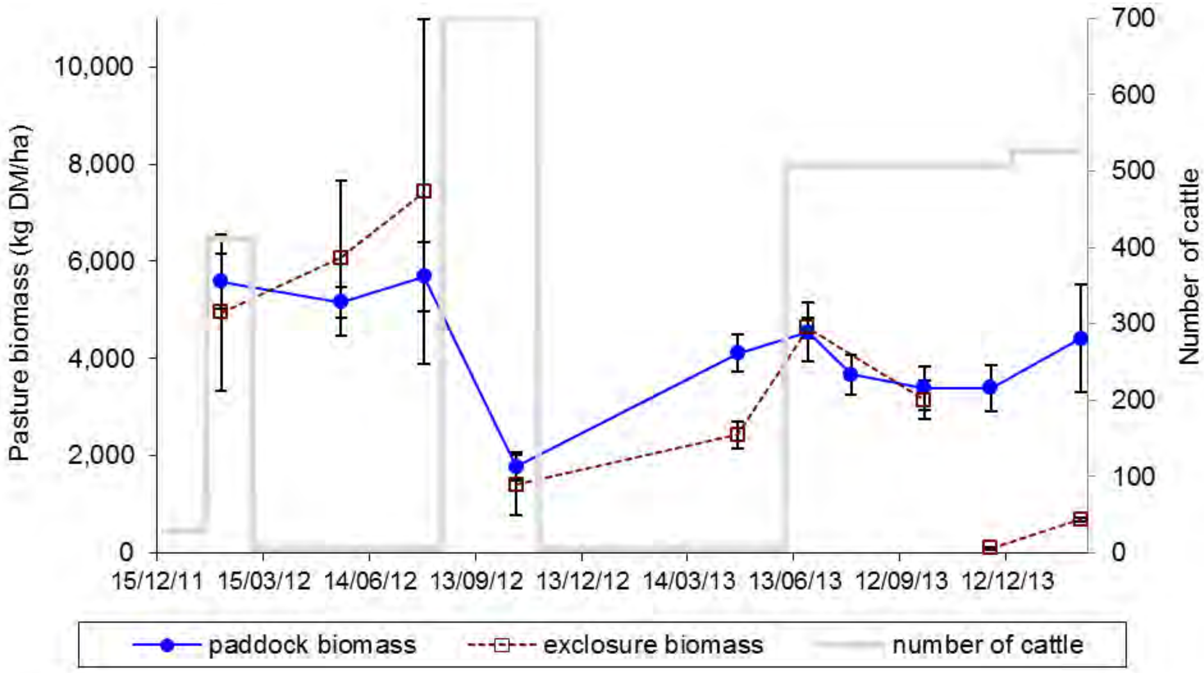

Fig. 182. Pasture biomass (kg DM/ha; mean ± SE) in the paddock and the exclosure, and cattle numbers during the monitoring period (22/12/11-12/02/14). Exclosure was mown to 10 cm on 06/08/12 and to 5 cm on 03/10/13.

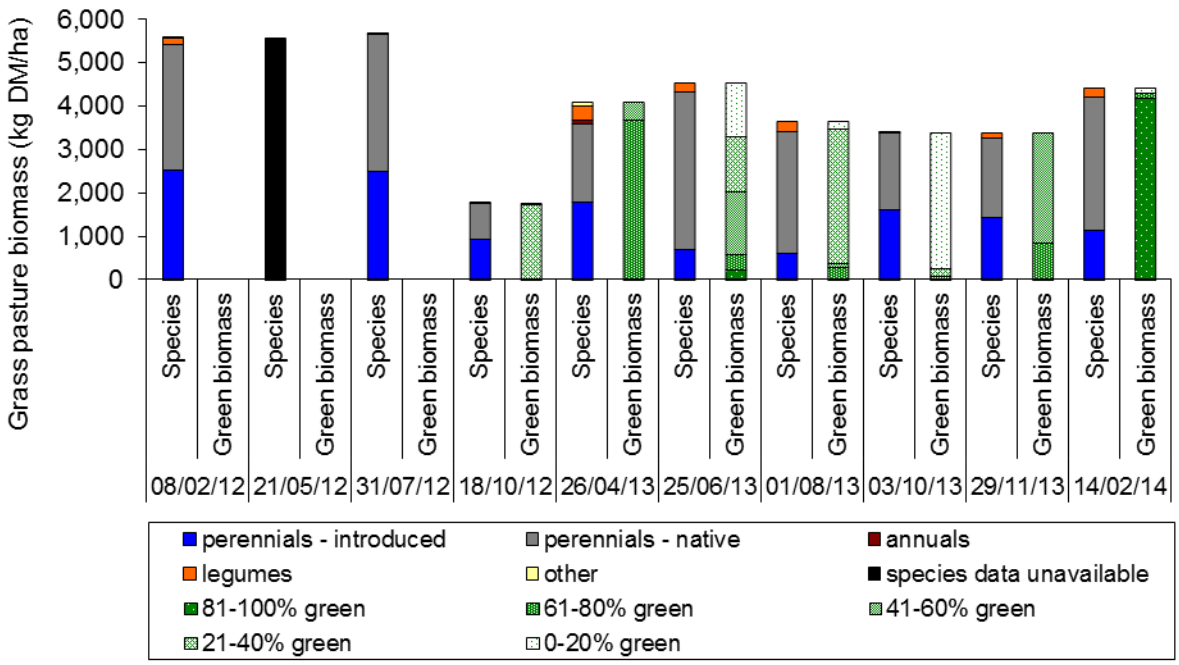

Fig. 183. Perennial pasture species composition (Species) and proportion of green material in the pasture (Green biomass) shown as a proportion of total pasture biomass (kg DM/ha). Native perennial grass was primarily Queensland bluegrass, introduced perennial grass was primarily buffel and legumes were native species and butterfly pea.

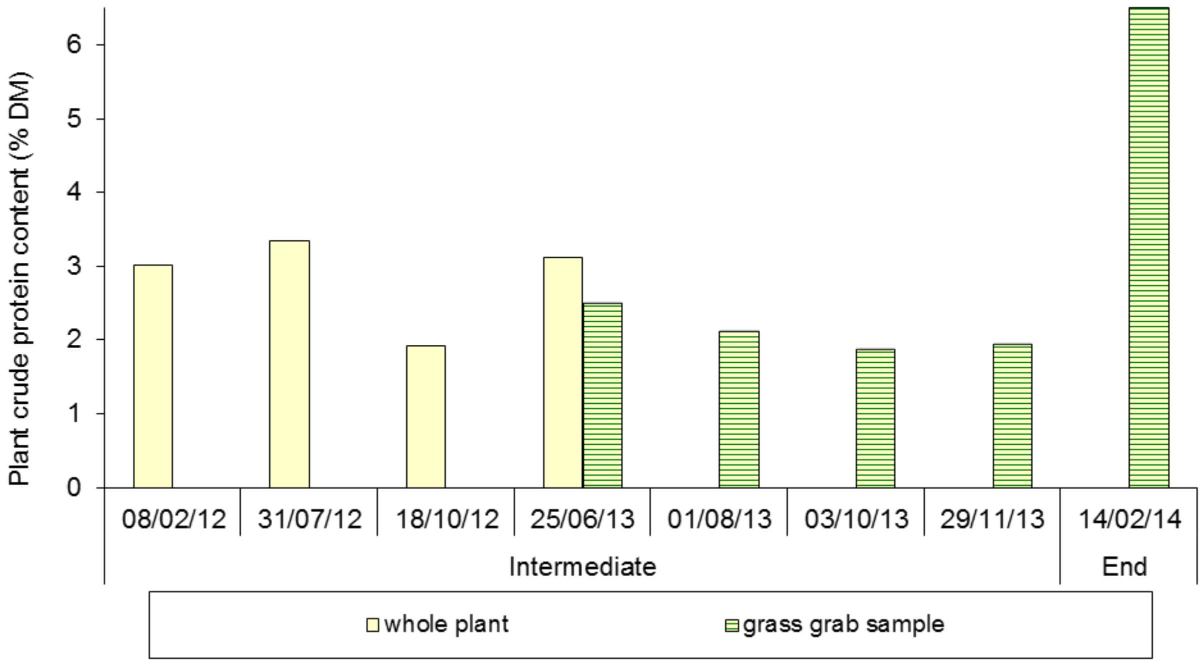

Fig. 184. Crude protein content (% DM) of whole plant samples (mainly perennial grass but included any legumes in the quadrat) and perennial grass grab samples in the paddock during the monitoring period (22/12/11-12/02/14). Start of grazing data was not available (cattle weight gain was monitored from 22/12/11).

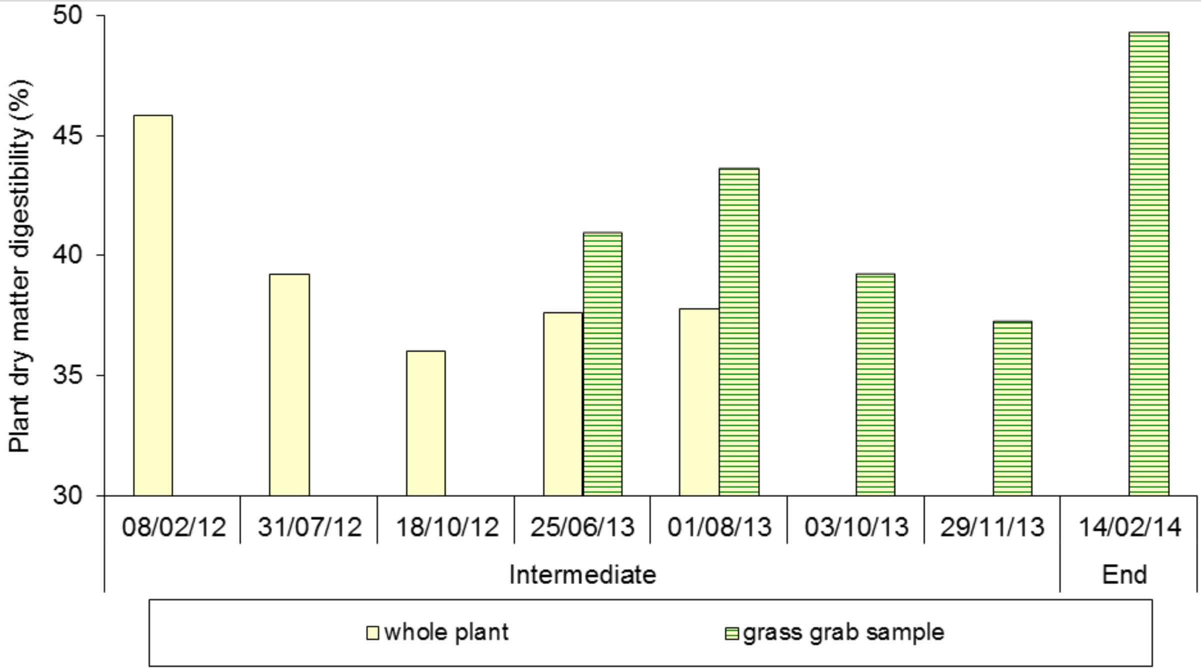

Fig. 185. Dry matter digestibility (%) of whole plant samples (mainly perennial grass but included any legumes in the quadrat) and perennial grass grab samples in the paddock during the monitoring period (22/12/11-12/02/14). Start of grazing data was not available (cattle weight gain was monitored from 22/12/11).

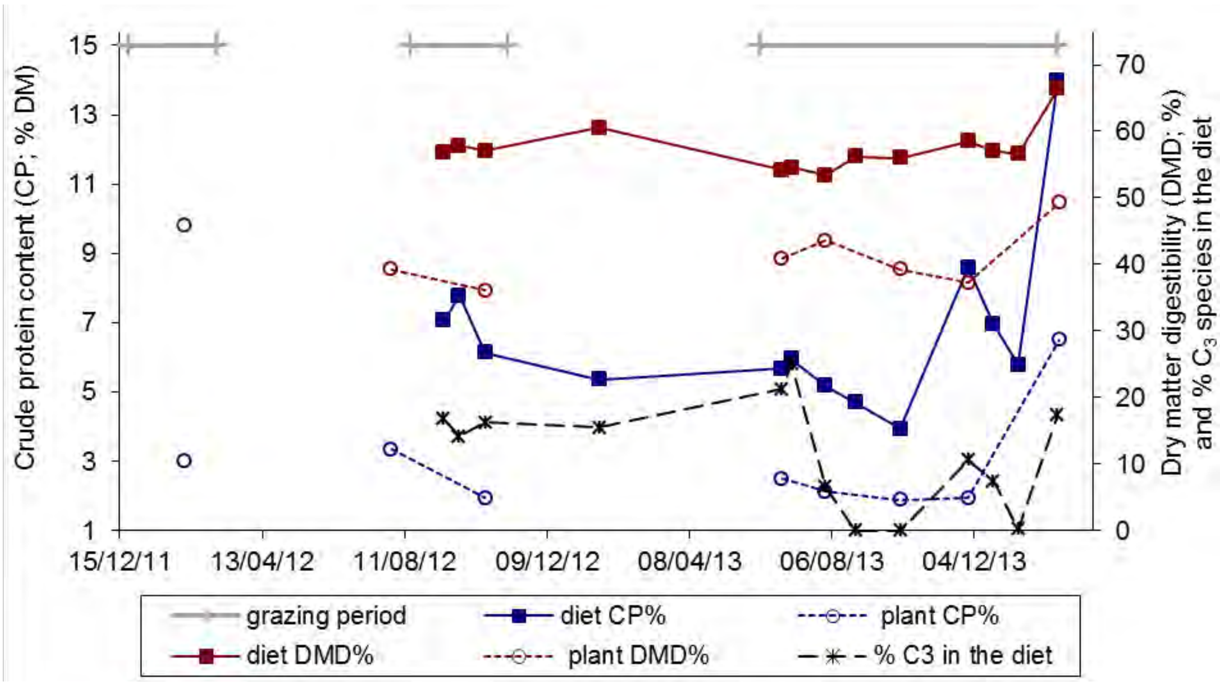

Fig. 186. Diet crude protein (CP) content (% DM) and dry matter digestibility (DMD; %) for grazing cattle predicted from faecal NIRS; measured CP and DMD content of perennial grass plant samples in the paddock (whole plant samples up to 18/10/12, grass grab samples from 25/06/13); and the % of the diet as C3 forage, predicted from δ13C content in the faeces. Grazing periods shown.

Fig. 187. Group 2a steers (5-12 months of age) in the trial paddock 19 da ys after commencing grazing, 25/06/13.

Fig. 188. Perennial grass pasture at the end of the 251-day grazing period of Group 2a steers, 14/02/14.

This paddock was typical of an Open Downs soil type and as it has been used for grain cropping in the past, would be suitable for forage cropping. The soil nutrient levels measured in the paddock at site establishment reflect the paddock history of cropping prior to 2004 with very low soil P and low organic C concentrations in the top 10 cm (7 mg/kg and 0.98%, respectively) being less than what would be expected for non-farmed Open Downs country. The soil P concentration of 7 mg/kg is considered marginal for cattle production (Jackson *et al.* 2012) and also below the level required by legumes suitable for this clay soil such as desmanthus or butterfly pea (Peck *et al.* 2014). As the paddock was initially planted to sown pasture species but now consists of 53% native species, primarily Queensland bluegrass (48% of the pasture DM), the pasture can be classified as 'run-down' and would benefit from legume inclusion.

The annual rainfall totals measured on the property during 2012 and 2013 were 717 and 493 mm, respectively (Fig. 181). The 30-year climate normal mean rainfall measured at the Emerald Post Office (BOM Station 35027) is 653.5 mm (mean of records for period 1961-1990). Hence the annual rainfall measured on property was above the 30-year climate normal in 2012 but below in 2013. The pasture biomass in the grazed paddock reflected the seasonal rainfall patterns and the number of cattle in the paddock (Fig. 182). The highest biomass levels measured in the paddock were during 2012: 5,581 kg DM/ha on 08/02/12 during the grazing period of Group 1a and 1b steers, and 5,682 kg DM/ha on 31/07/12 at the end of the 162-day period of spelling and just prior to the commencement of the grazing period for Group 1c steers. The pasture biomass reached its lowest level at the end of the grazing period of the Group 1c steers: 1,777 kg DM/ha on 18/10/12 but recovered during the 210-day period of spelling to reach 4,539 kg DM/ha on 25/06/13 at the start of the grazing period for Group 2a steers (Fig. 187). During the 251-day grazing period of Group 2a steers, the biomass declined to 3,388 kg DM/ha on 03/13/13, before increasing to 4,409 kg DM/ha on 14/02/14, after summer rainfall (Fig. 188).

The proportion of the pasture which was assessed as 'green' also reflected the rainfall pattern and grazing pressure, as expected (Fig. 183). Assessments of 'greenness' were made on seven occasions, during the latter period of monitoring. The pasture was 'greenest' on the final pasture assessment made on 14/02/14, with 95% of the biomass being assessed as 81-100% green. The dominant species in the paddock was the native perennial grass, Queensland bluegrass (54% of the biomass). The next greatest contributors to the biomass were the introduced perennial grass species, buffel (21%), silk sorghum (8%) and Rhodes grass (5%).

Although analysis of whole plant and perennial grass 'grab' samples showed CP concentrations to be generally very low at ≤3.3% of DM (except for a concentration of 6.5% measured on 14/02/14), the cattle were generally able to select a higher quality diet (Fig. 184 and Fig. 186). Estimates of diet quality from faecal NIRS showed diet CP levels to have ranged from 3.9-14.0%, with an average of 6.7%. As well as diet selection, dry season urea lick fed to Group 1 steers on 22/08/14 would have also increased faecal NIRS estimates of diet CP above CP levels in the plant samples at this time. Over the same period as for CP measurements, estimated diet DMD ranged from 53-66% compared to a range of 36-49% for whole plant or perennial grass grab samples (Fig. 185 and Fig. 186). The predicted concentration of CP in the diet of the cattle grazing this paddock was generally aligned to the proportion of C_3 species in the diet. Delta C analysis showed that cattle were consuming between 0-25% of their diet as C_3 species (average 11.6%).

During the 1st 12 months of monitoring (22/12/11-21/12/12), the paddock was spelled for 207 out of 365 days. The group of cattle monitored for weight gain were recorded over the 2011-12 summer period (22/12/11-06/03/12) and had an average daily weight gain of 0.73 kg/head/day over this 75-day period. This daily weight gain is very similar to that expected, as a long term average, for the Central Queensland Open Downs region over the summer period (December-February): 0.77 kg/head/day (Bowen *et al.* 2010). The average liveweight gain of 5-12 month-old steers grazing the paddock for 251 days from winter 2013 to summer 2014 (06/06/13-12/02/14) was 0.43 kg/head/day. This figure is also very close to that expected for the Central Queensland Open Downs region over the 9-month period from June to February (0.41 kg/head/day; Bowen *et al.* 2010).

The estimated total beef production over the 1st and the 2nd 12 months of monitoring (31 and 41 kg/ha/annum, respectively) were greater than the assumed figure of 25 kg/ha/year in the constructed scenario for the Open Downs region. The average stocking rate in the paddock over the 1st and 2nd 12 months of monitoring (0.17 and 0.15 AE/ha, respectively) were very similar to that assumed in the constructed scenario for the Open Downs region: 0.17 AE/ha. It should be noted that some assumptions had to be made in order to estimate the total beef production during the 1st 12 months of monitoring as Group 1c (700 steers grazing the paddock for 82 days) were not monitored for weight gain.

The gross margin calculated for the 1st 12-month period of monitoring was $25/ha/annum, which was very similar to the value estimated for the constructed scenario for the Central Queensland Open Downs region ($27/ha/annum). The gross margin for the 2nd 12-month period of monitoring was almost double this value, however, at $51/ha/annum. The greater gross margin for the 2nd 12-month period, compared to the 1st 12-month period, was the combined result of the greater beef production during this period and a greater cattle price margin of $0.18 cf. $0.11/kg liveweight.

3.6.2 Central Queensland Brigalow, Perennial grass pasture January 2012 – April 2013

(S 24.286, E 150.363; near Jambin)

The site was an 84.5 ha paddock. The paddock was originally cleared of blackbutt and brigalow timber in the 1980s and then in the 1990s was blade-ploughed and sown with the perennial grass and legume species: green panic, buffel grass and butterfly pea. Re-growth was cleared in the mid 2000s. The paddock had been continuously grazed except during the periods of timber treatment. During the period of monitoring, this paddock was dominated by introduced perennial grasses buffel, sabi and green panic with very little to no butterfly pea present. Approximately half of the paddock area contained dense timber regrowth consisting mostly of brigalow (see Fig. 132 in the section summarising results for Central Queensland Brigalow, Leucaena-grass pasture, January 2012 - April 2013). This site was located on the same commercial property as the Central Queensland Brigalow, Leucaena-grass pasture 2012-13 and Leucaena-grass pasture 2013-14 sites. The paddock was grazed continuously with the same 52 head of cattle from 10/01/12–30/04/13. A summary of key site details are given in Table 24 and Fig. 189-Fig. 197.

Table 24. Site details. Central Queensland Brigalow, Perennial grass pasture 2012-13
For definitions of abbreviations see Glossary of terms and abbreviations

Factor	Details	
Soil characterisation		
Broad land type	Brigalow	
Soil type and characteristics	Brown cracking clay (with melonholes) PAWC: 180 mm Soil depth: 120 cm	
Soil nutrient levels at site establishment		**0–10 cm**
	P (mg/kg)	28
	Organic C (%)	1.3
Forage production		
Average perennial grass presentation yield in the paddock	4,285 (range: 1,936-9,716) kg DM/ha. Major species: were the introduced perennial grasses buffel, sabi and green panic (31%, 24% and 21% of the biomass, respectively).	
Average perennial grass presentation yield in the exclosure	3,890 (range: 1,618-5,397) kg DM/ha. Note: the exclosure was mown on 27/08/12.	
C_3 species (non-grass) in the diet	9% (Days 25-444 of grazing period)	
Average diet quality	6.9% CP, 54% DMD (Days 25-444 of grazing period)	

Factor	Details
Grazing management and animal production	
Comments	The paddock was grazed continuously by 52 steers for 476 from 10/01/12–30/04/13. An additional steer commenced grazing but died during the first 6 months of the grazing period. A total of 200 kg of urea lick (Rumevite® SSS weaner lick with rumensin) was fed during Jan-Feb 2013 prior to rain. During this same period, 1 round bale of buffel grass hay (250-300 kg) was also fed per day for 34 days. A total of 42 of the steers were killed at Teys Rockhampton abattoir on 03/05/13.
Cattle type monitored for weight gain	Steers; 12-16 months old at entry; Brahmans, 100% *B. indicus*
Animal health treatments	Novartis AG Cypafly and Virbac Taktic® EC on 01/01/12 prior to entry to the paddock and Cypafly re-treatment on 16/02/13.
Total monitoring period	10/01/12–30/04/13 (476 days)
Grazing days over which LW was measured	476 (10/01/12–30/04/13)
SR	0.64 AE/ha (1 AE : 1.6 ha)
Number of cattle in weight gain dataset	53, but only 42 with both start and finish weights
Average entry LW (± SE)	356 (± 4.1)kg (*n* = 52)
Average exit LW (± SE)	583 (± 5.0) kg (*n* = 43)
Average LWG (± SE)	0.47 (± 0.009) kg/head/day (*n* = 42)
First 90 days of grazing (10/01/12–09/04/12)	
Average LWG (± SE)	0.81 (± 0.022) kg/head/day (*n* = 49)
Following 115 days of grazing (09/04/12–02/08/12)	
Average LWG (± SE)	0.49 (± 0.014) kg/head/day (*n* = 50)
Following 197 days of grazing (02/08/12–15/02/13)	
Average LWG (± SE)	0.06 (± 0.010) kg/head/day (*n* = 48)
Following 37 days of grazing (15/02/13–24/03/13)	
Average LWG (± SE)	1.13 (± 0.038) kg/head/day (*n* = 47)
Final 37 days of grazing (24/03/13–30/04/13)	
Average LWG (± SE)	1.13 (± 0.033) kg/head/day (*n* = 43)
Total annual LWG – 1st 12 months	85 kg/ha/annum
Total LWG – 476 days	138 kg/ha per 476 days
Number of cattle in carcase dataset	42
Average carcase weight (± SE)	296 (± 2.79) kg
Average carcase dentition (± SE)	5 (± 0.2)
Average carcase fat depth (± SE)	13 (± 0.7) mm

Economic performance

	Total grazing area ($/ha/ annum)	Total period: 476 days ($/ha)	If sold prior to compensatory gain: 402 days ($/ha)	If sold at onset of dry period in August 2012: 205 days ($/ha)
Gross margin		**132**	**44**	**42**
Forage costs		0	0	0
CONSTRUCTED SCENARIO				
Gross margin	**56**			
Forage costs	0			

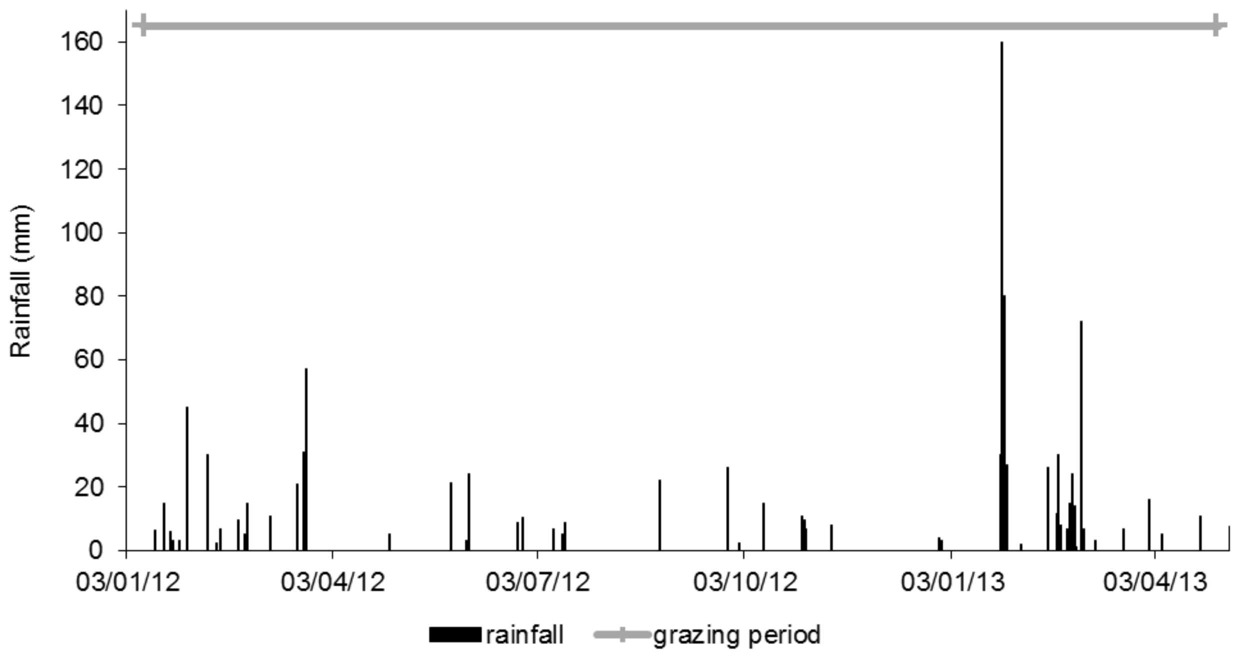

Fig. 189. Daily rainfall (mm) over the period (10/01/12–30/04/13). Measured on property, 1.3 km from the trial paddock. Grazing period shown.

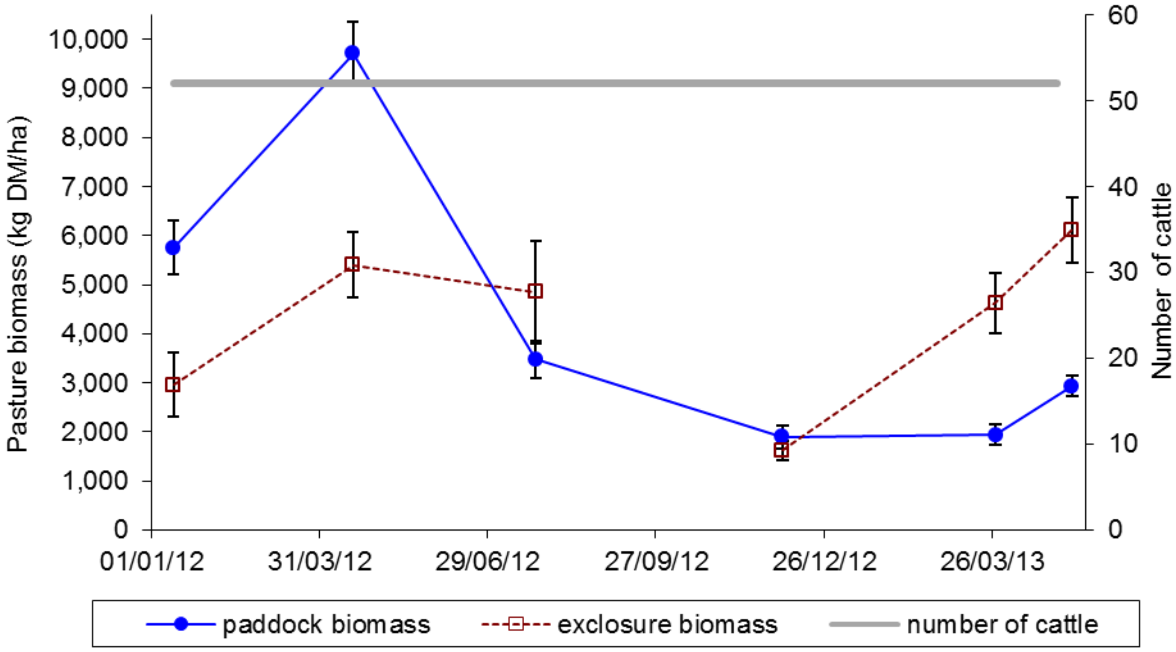

Fig. 190. Pasture biomass (kg DM/ha; mean ± SE) in the paddock and the exclosure, and number of cattle, during the monitoring period (10/01/12–30/04/13). Exclosure was mown to 10 cm on 27/08/12.

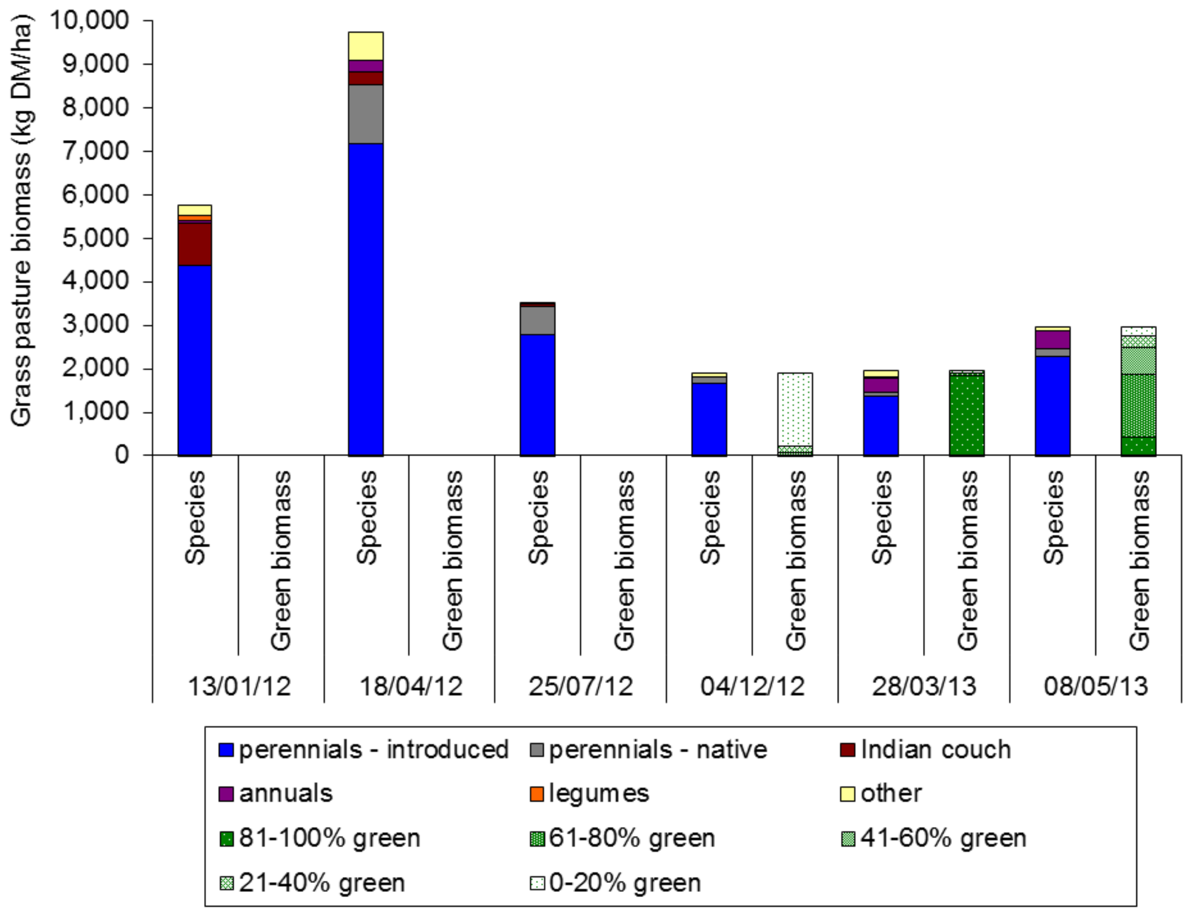

Fig. 191. Perennial pasture species composition (Species) and proportion of green material in the pasture (Green biomass) shown as a proportion of total pasture biomass (kg DM/ha). Introduced perennial grasses consisted of primarily buffel, sabi and green panic (31%, 24% and 21% of the biomass respectively). Native perennial grasses were primarily Queensland bluegrass (6.4% of the biomass). Green biomass was only assessed from the 04/12/12 sampling onwards.

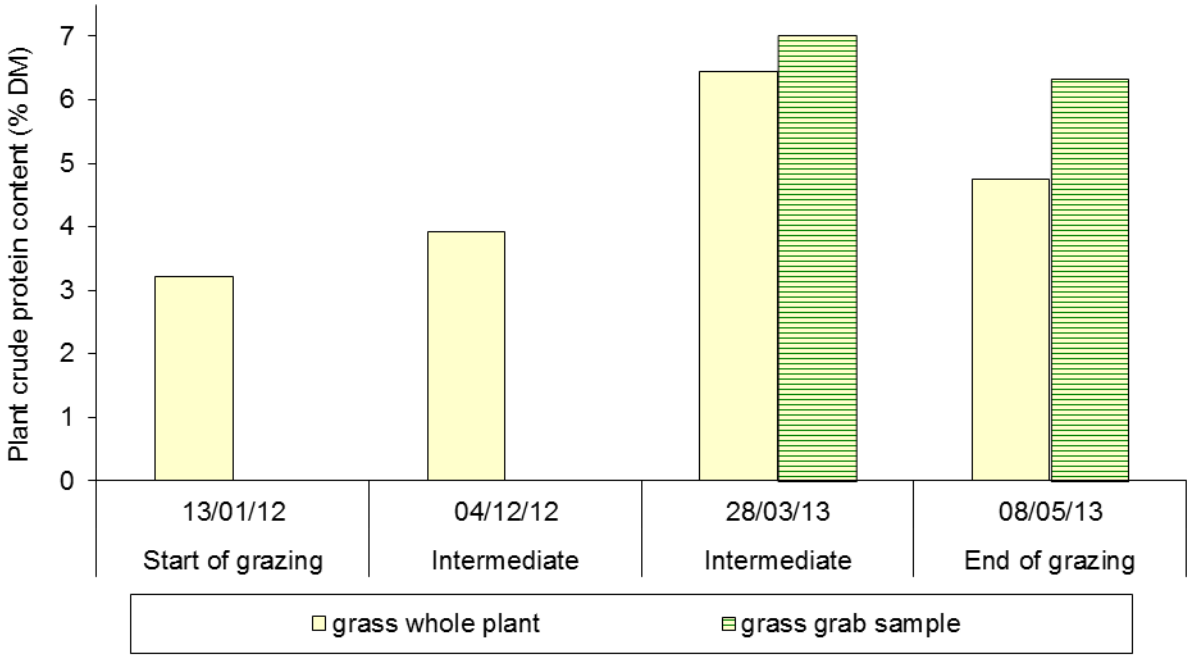

Fig. 192. Crude protein content (% DM) of perennial grass whole plant and grab samples in the paddock during the monitoring period (10/01/12–30/04/13).

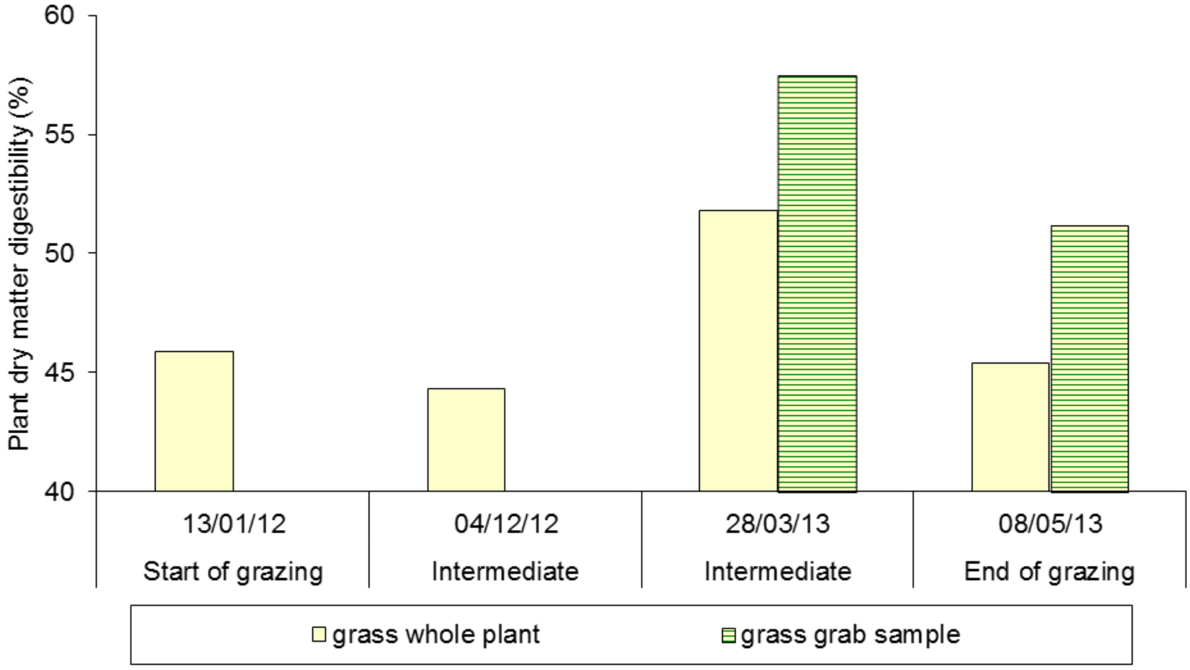

Fig. 193. Dry matter digestibility (%) of perennial grass whole plant and grab samples in the paddock during the monitoring period (10/01/12–30/04/13).

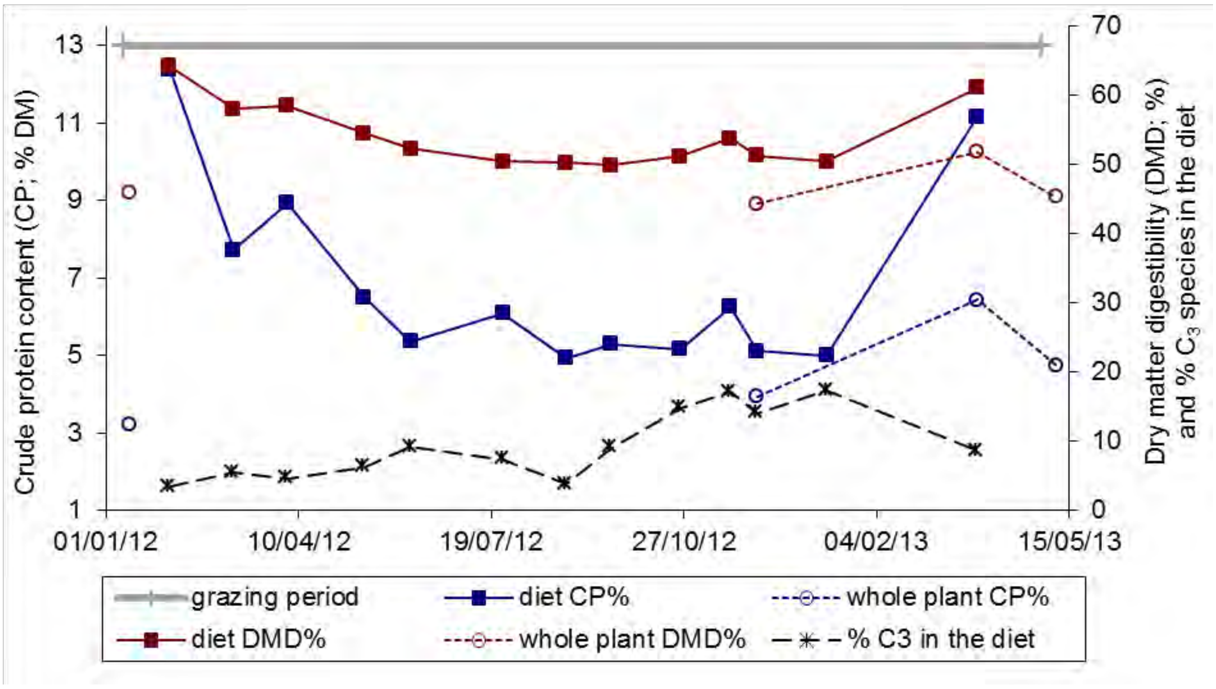

Fig. 194. Diet crude protein (CP) content (% DM) and dry matter digestibility (DMD; %) for grazing cattle predicted from faecal NIRS; measured CP and DMD content of perennial grass whole plant samples in the paddock; and the % of the diet as C_3 forage, predicted from $\delta^{13}C$ content in the faeces. Grazing period shown.

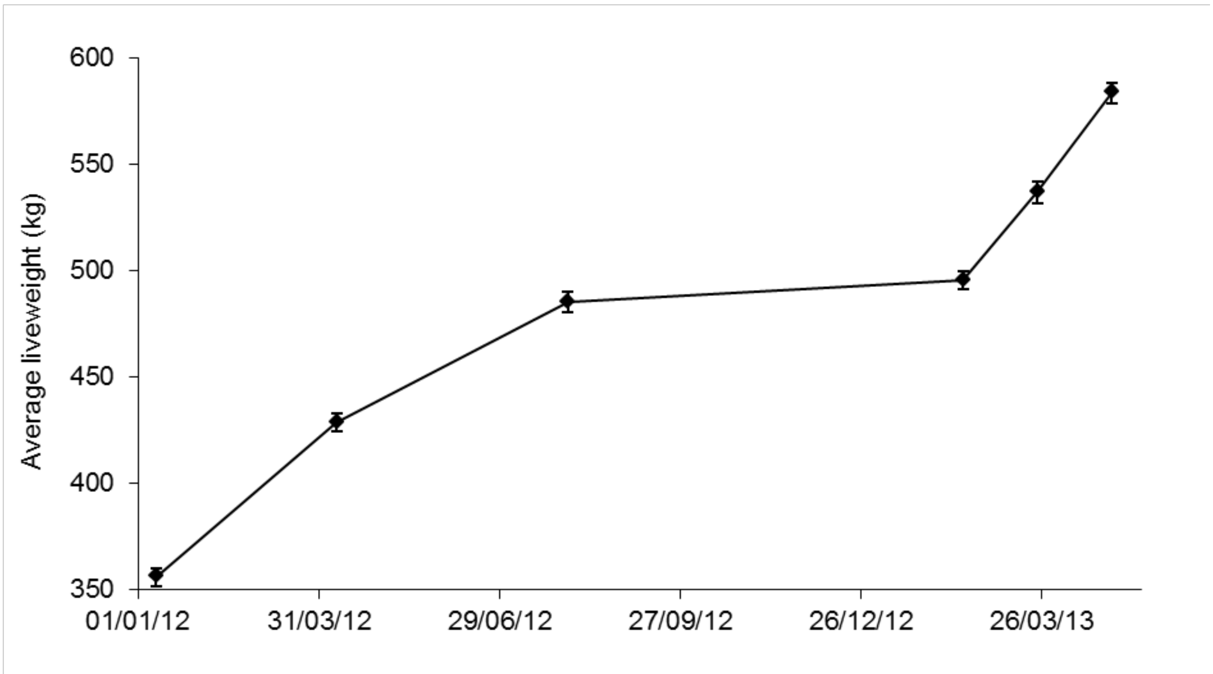

Fig. 195. Average cattle liveweight (kg; mean ± SE) over the grazing period (10/01/12–30/04/13).

Fig. 196. Perennial grass pasture, 28/03/13; fenced exclosure in background.

Fig. 197. Cattle on the trial paddock, 20/11/12.

The soil type in this paddock is typical of the Central Queensland Brigalow land type, having good to high water-holding capacity and good fertility (P and organic C). This paddock would be suitable for forage cropping other than the physical limitation of melonholes. The annual rainfall during the 2012 season, measured on property was 470 mm which was below the 30-year climate normal mean of 666.5 mm (records for period 1961–1990); (Fig. 189). Conversely, the total rainfall during the last 4 months of grazing (January to April 2013) was almost double the 30-year climate normal for that period (557 vs. 285.3 mm, respectively). The pasture biomass measured in the grazed paddock reflected the seasonal rainfall patterns with the biomass peaking in April 2012 at 9,716 kg DM/ha and then decreasing to very low levels of <2,000 kg DM/ha by the end of the 2012 (Fig. 190 and Fig. 197). These low pasture levels were maintained until the significant rainfall event in late January 2013 when biomass began to increase in the both the exclosure and the paddock (Fig. 196), although more slowly in the paddock due to the relatively high stocking rate of 1 AE : 1.6 ha. The proportion of the pasture biomass which was assessed as 'green' also reflected the rainfall pattern, as expected (Fig. 191). A total of 90% of the biomass was assessed as being 0–20% green on 04/12/12 and 94% of the biomass was assessed as being 81-100% green on 28/03/13, after the significant rainfall event in late January 2013. The dominant pasture species in the paddock were the introduced perennial grasses buffel, sabi and green panic, although some Indian bluegrass (an increaser species) and native perennial grasses (largely Queensland bluegrass) were present.

Although whole plant analysis of perennial grass showed CP levels to be generally very low at <5% of DM on three out of the four sampling occasions (Fig. 192), the steers would have been selecting a markedly higher quality diet, where possible. On the two occasions that grab samples of perennial pasture were taken (late March and early May 2013), to simulate likely selection by grazing cattle, the CP levels were greater than that in the whole plant samples, as expected, and were >6%. Similarly, the DMD content of grab samples of perennial grass exceeded the low levels measured for whole plant samples (44-52%; Fig. 193). Estimates of diet quality from faecal NIRS showed diet CP levels to have been initially 12.4% in February 2012, decreasing to levels ≤6.5% by mid May 2012 and staying at these low levels until January 2013 (Fig. 194). Over the same period, estimated diet DMD decreased from 64.2% in February 2012, to low levels, ≤52.5%, from mid May 2012 until January 2013. Delta C analysis showed that cattle were consuming between 3-17% of the diet as C_3 species (average 11 ± 1.6 (SE))%, with the proportion increasing towards the end of the grazing period (from October 2012).

The cattle liveweight gain over the 476-day period of grazing reflects the rainfall and pasture availability and quality, with growth rates initially 0.81 kg/head/day over the first 90 days of grazing (January to April), and then slowing to 0.49 kg /head/day over the following 115 days of grazing as pasture quantity and quality decreased (Fig. 195). During the 197 days of grazing over the largely dry period, from August 2012 to February 2013, average daily gain was only 0.06 kg/head/day. After the significant rainfall events in early 2013, very high growth rates were recorded: 1.13 kg/head/day over the final 74 days of grazing, reflecting the improved quality of the pasture although biomass was still low (< 3,000 kg DM/ha until the end of grazing). It is likely that compensatory gain effects were contributing to these high growth rates over the final period of grazing.

The overall average liveweight gain over the 476-day grazing period was 0.47 kg/head/day which is similar to the annual, long-term average steer liveweight gain assumed in the constructed scenario for the Central Queensland Brigalow region (0.46 kg/head/day). However, when the average liveweight gain for steers in this paddock is estimated for the 365-day period of 2012, the figure is lower at 0.38 kg/head/day, which is not surprising, given the drought conditions for much of the 2012 year. However, the stocking rate at this site was considerably higher than those assumed in the constructed scenario for Central Queensland Brigalow region (1 AE : 1.6 ha vs. 1 AE : 3 ha). The relatively high stocking rate at this site also explains the high beef production per hectare: 85 kg/ha/annum for the first 12 month period, and 138 kg/ha over the total 476 days. These values exceed that assumed as the long-term average in the constructed scenario for Central Queensland Brigalow region (57 kg/ha/annum).

Direct comparison of the gross margins calculated for this paddock with those for the constructed scenario is problematic as gross margins could not sensibly be calculated for a 12-month period. The gross margin for the 476-day period ($132/ha) was higher than that estimated for a 12-month period in the constructed scenario ($56/ha). The gross margin calculated for the entire feeding period of 476 days was 3 times greater than that expected if the cattle had been sold in early August after pasture quality and quantity became limiting (after 205 day s of grazing) or if the cattle had been s old just prior to the rainfall and compensatory gain effect (after 405 days of grazing). This economic benefit of holding cattle over the dry period was seen despite the additional cost of feeding some hay as a supplement during this dry period. However, the effect on pasture sustainability of very high stocking rates used long-term, along with the high economic risk of holding finishing cattle over an extended dry period, should be considered. The price margin on these bought steers was negative at -$0.24/kg liveweight. As not all steers were sold at the end of the grazing period, the gross margin calculated here was not actually realised by the producer but does demonstrate the value added to the steers by grazing the perennial grass paddock.

3.6.3 South Queensland Brigalow, Perennial grass pasture July 2011 – March 2014

(S 25.954, E 149.598; near Taroom).

The site was a 304.6 ha paddock which was originally cleared of standing brigalow timber in 1978 and burnt in 1979. The paddock was re-pulled to control brigalow regrowth in 1999 and again in 2009. In 2009 the paddock was also stick-raked and the timber heaps burnt. Approximately 30 ha was blade ploughed in 2009 and again in 2013. Buffel grass was not deliberately introduced to the trial paddock but naturalised from surrounding paddocks over time. During the period of monitoring, the grass paddock contained primarily buffel grass with minor amounts of Queensland bluegrass and native legume. Brigalow suckers were present throughout the paddock. The period of monitoring has been divided into three periods: 1st 12-month period, 2nd 12-month period and final 8.4 months. During the 1st 12-month period the paddock was grazed from 06/07/11-28/11/11, spelled for the following 68 days and then grazed from 04/02/12-04/07/12. The paddock was spelled for the entire 2nd 12-month period. This 12-month spell was not typical of the producer’s normal spelling schedule for this paddock which is typically 3 months from February to April, every 2nd year. During the final 8.4 months of monitoring the paddock was grazed from 04/07/13-24/11/13, spelled for 50 days and then grazed from 14/01/14-17/03/14. Access to an additional 162 ha, adjacent buffel grass paddock was provided for 31 days from 25/10/13-24/11/13. Monitoring ceased from the 17/03/14 although cattle were still grazing the paddock. A summary of key site details are given in Table 25 and Fig. 198-Fig. 205.

Table 25. Site details. South Queensland Brigalow, Perennial grass pasture 2011-2014
For definitions of abbreviations see Glossary of terms and abbreviations

Factor	Details		
Soil characterisation			
Broad land type	Brigalow		
Soil type and characteristics	Brown cracking clay PAWC: 160 mm Soil depth: 120 cm		
Soil nutrient levels at site establishment (March 2011)		**0–10 cm**	**10–90 cm**
	Nitrate N (mg/kg)	2.6	1.0
	Nitrate N total (kg/ha)	14.8	
	P (mg/kg)	22	n/a
	Organic C (%)	2.5	n/a
	Cl (mg/kg)	35	760
Forage production			
Average perennial grass presentation yield in the paddock	2,764 (range: 1,294-3,922 kg DM/ha). Major species: was the introduced perennial grass buffel (97%).		
Average perennial grass presentation yield in the exclosure	2,755 (range: 935-3,996 kg DM/ha. Note: the exclosure was mown on 10/02/12, 05/09/12 and 28/10/13.		
C_3 species (non-grass) in the diet	8% (Days 22-986) of grazing period)		
Average diet quality	6.1% CP, 54% DMD (Days 22-986 of grazing period)		

Factor	Details
Grazing management and animal production	
Comments	Grazing history: 1st 12 months (06/07/11-04/07/12): • Group 1: 06/07/11 or 15/07/11-30/09/11; 552 heifers, 6-11 months at entry • Group 2: 01/10/11-28/11/11; 287 heifers, 9-14 months at entry (these heifers were all subset of Group 1) • Group 3: 04/02/12-04/07/12; 365 steers, 12-17 months at entry 2nd 12 months (05/07/12-03/07/13): • Spelled 3rd 12 months (04/07/13-17/03/14): • Group 4: 04/07/13-25/11/13; 559 steers progressively removed in 3 gr oups during the period, 8 months at entry, steers relocated from western mulga country • Group 5: 29/07/13-25/11/13; 129 steers progressively removed in 3 gr oups during the period, 9 months at entry • Group 6: 14/01/14-17/03/13; 151 steers, 14 months at entry
Cattle type monitored for weight gain	All ca. 25% *B. indicus* content
Animal health treatments	Groups 1 and 2 received 5-in-1 and Dectomax® in July 2011; Group 3 received Novartis AG Cypafly and Synovex® S in January 2012; Group 4 and 5 received 5-in-1 and Dectomax® in June 2013; and Group 6 steers received Elanco® Demize pour-on for cattle and Compudose 100 in January 2014.
Total monitoring period	06/07/11-17/03/14 (985 days)
Average SR – 1st 12 months	0.87 AE/ha (1 AE : 1.2 ha)
Average SR – 2nd 12 months	0.00 AE/ha
Average SR – final 8.4 months	0.55 AE/ha (1 AE : 1.8 ha)
Group 1 – heifers (6-11 months) early Jul to end Sep 2011	
Grazing days over which LW was measured	86 or 77 (06/07/11 or 15/07/11-30/09/11)
Number of cattle in weight gain dataset	418 (298 for 86 days and 120 for 77 days)
Average entry LW (± SE)	197 (± 2.2) kg
Average exit LW (± SE)	225 (± 2.1) kg
Average LWG (± SE)	0.34 (± 0.007) kg/head/day
Group 2 – heifers (9-14 months) early Oct to end Nov 2011	
Grazing days over which LW was measured	58 (01/10/11-28/11/11)
Number of cattle in weight gain dataset	261
Average entry LW (± SE)	253 (± 2.5) kg
Average exit LW (± SE)	284 (± 2.4) kg
Average LWG (± SE)	0.53 (± 0.011) kg/head/day
Group 3 - steers (12-17 months) early Feb to early Jul 2012	
Grazing days over which LW was measured	151 (04/02/12-04/07/12)
Number of cattle in weight gain dataset	326
Average entry LW (± SE)	413 (± 2.1) kg
Average exit LW (± SE)	488 (± 2.2) kg
Average LWG (± SE)	0.49 (± 0.008) kg/head/day

Factor	Details		
Grazing management and animal production			
Group 4 – steers (8 months) early Jul to mid Oct 2013			
Grazing days over which LW was measured	105 (04/07/13-17/10/13)		
Number of cattle in weight gain dataset	175		
Average entry LW (± SE)	201 (± 2.9) kg		
Average exit LW (± SE)	223 (± 3.0) kg		
Average LWG (± SE)	0.21 (± 0.007) kg/head/day		
Group 5 – steers (9 months) end Jul to mid Oct 2013			
Grazing days over which LW was measured	80 (29/07/13-17/10/13)		
Number of cattle in weight gain dataset	33		
Average entry LW (± SE)	224 (± 7.1) kg		
Average exit LW (± SE)	231 (± 6.9) kg		
Average LWG (± SE)	0.08 (± 0.013) kg/head/day		
Group 6 – steers (14 months) mid Jan to mid Mar 2014			
Grazing days over which LW was measured	62 (14/01/14-17/03/14)		
Number of cattle in weight gain dataset	150		
Average entry LW (± SE)	303 (± 3.3) kg		
Average exit LW (± SE)	362 (± 3.5) kg		
Average LWG (± SE)	0.96 (± 0.017) kg/head/day		
Total annual LWG – 1st 12 months	169 kg/ha/annum (06/07/11-04/07/12)		
Total annual LWG – 2nd 12 months	0 kg/ha/annum (05/07/12-04/07/13; spelled)		
Total LWG – final 8.4 months (256 days)	64 kg/ha per 256 days		
Economic performance			
	1st 12 months (06/07/11-04/07/12), ($/ha/annum)	**2nd 12 months (05/07/12-03/07/13), ($/ha/annum)**	**Final 8.4 months (04/07/13-17/03/14), ($/ha/8.4 months)**
Gross margin	**285**	**-5**	**-12**
Forage costs	5	5	5
CONSTRUCTED SCENARIO			
Gross margin	**49**	**49**	
Forage costs	0	0	

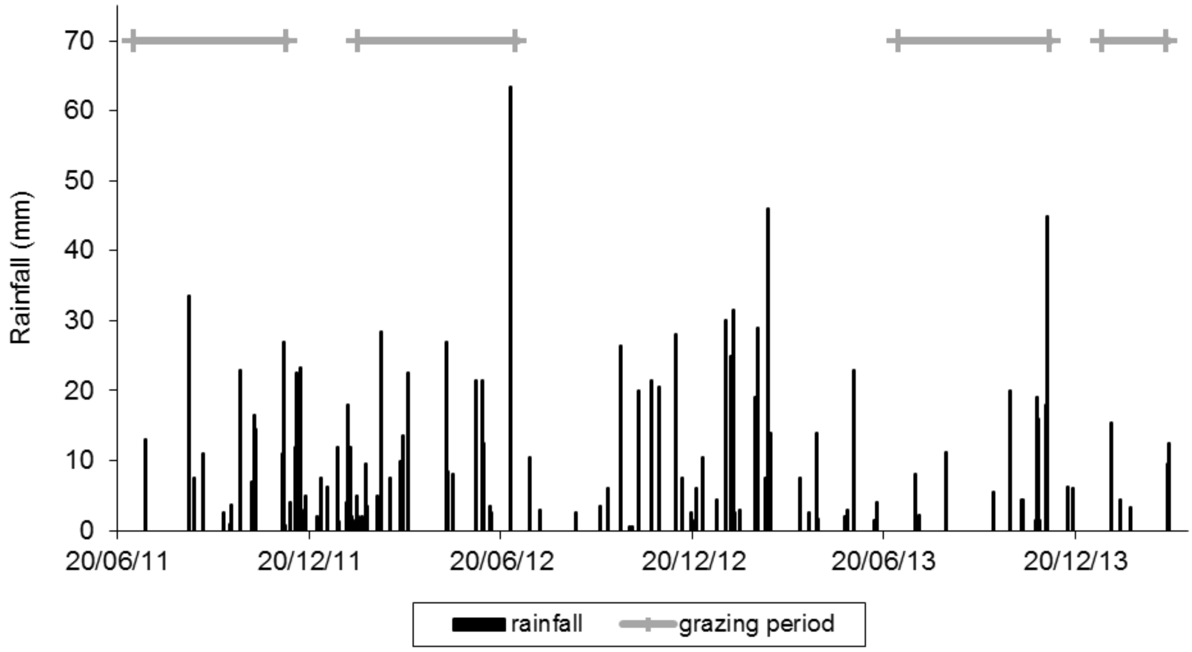

Fig. 198. Daily rainfall (mm) over the monitoring period (06/07/11–17/03/14). Measured on property, 4.8 km from the trial paddock. Grazing periods shown.

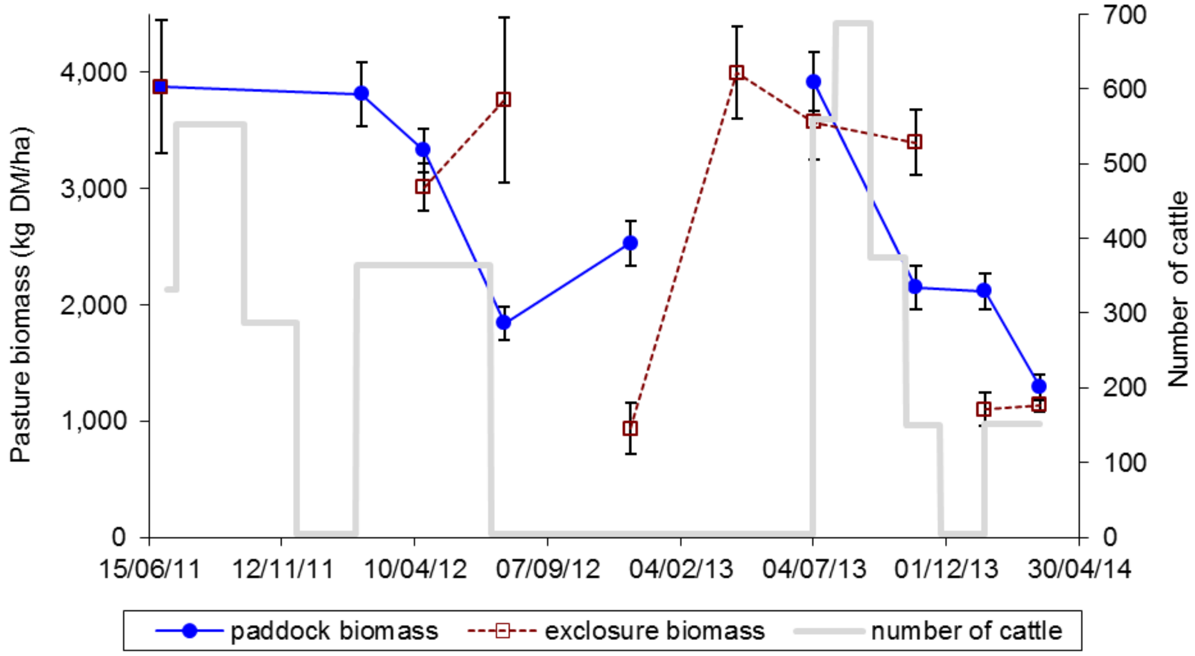

Fig. 199. Pasture biomass (kg DM/ha; mean ± SE) in the paddock and the exclosure, and number of cattle, during the monitoring period (06/07/11–17/03/14). Exclosure was mown to 10 cm on 10/02/12, 05/09/12 and 28/10/13. Cattle had access to an additional, adjacent paddock of 162 ha for 31 days from 25/10/13-24/11/13**.**

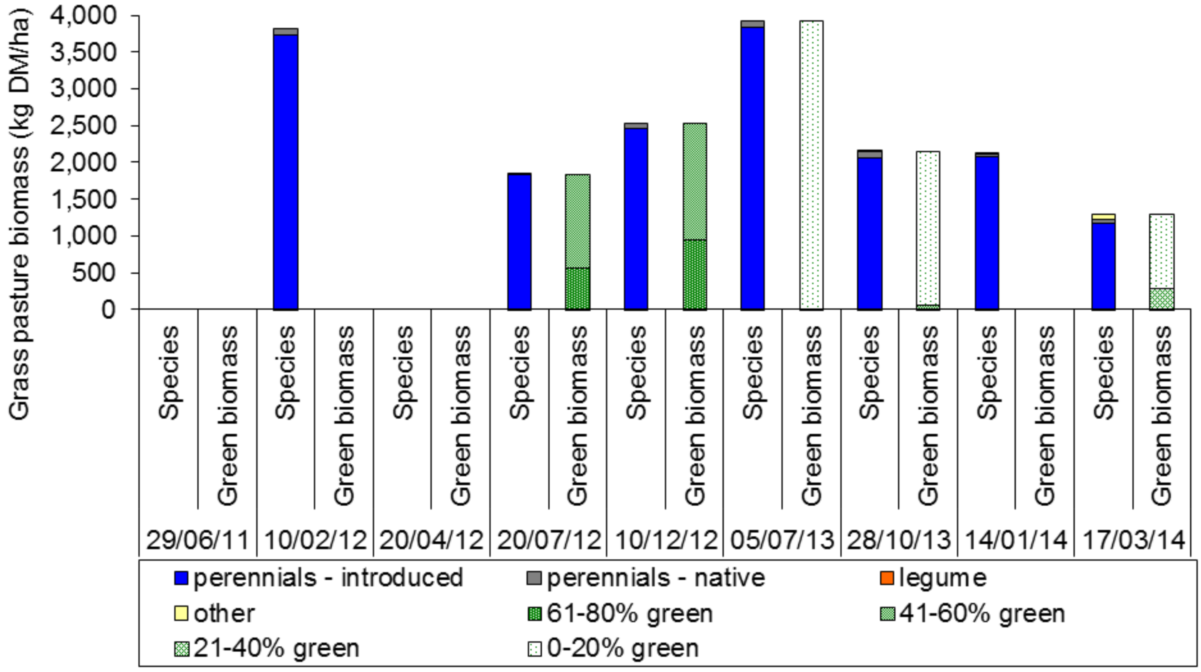

Fig. 200. Perennial pasture species composition (Species) and proportion of green material in the pasture (Green biomass) shown as a proportion of total pasture biomass (kg DM/ha). Introduced perennial grass was buffel, native perennial grass was Queensland bluegrass and legumes were native species. Green biomass was not assessed on all occasions.

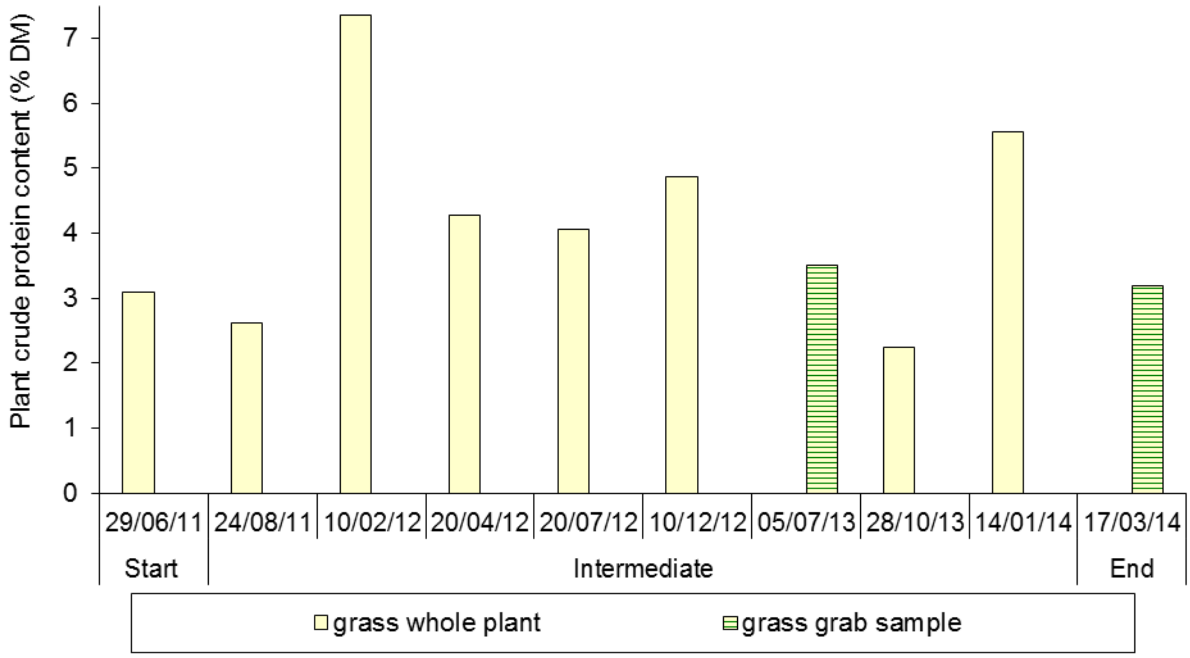

Fig. 201. Crude protein content (% DM) of perennial grass whole plant and grab samples in the paddock during the monitoring period (06/07/11–17/03/14).

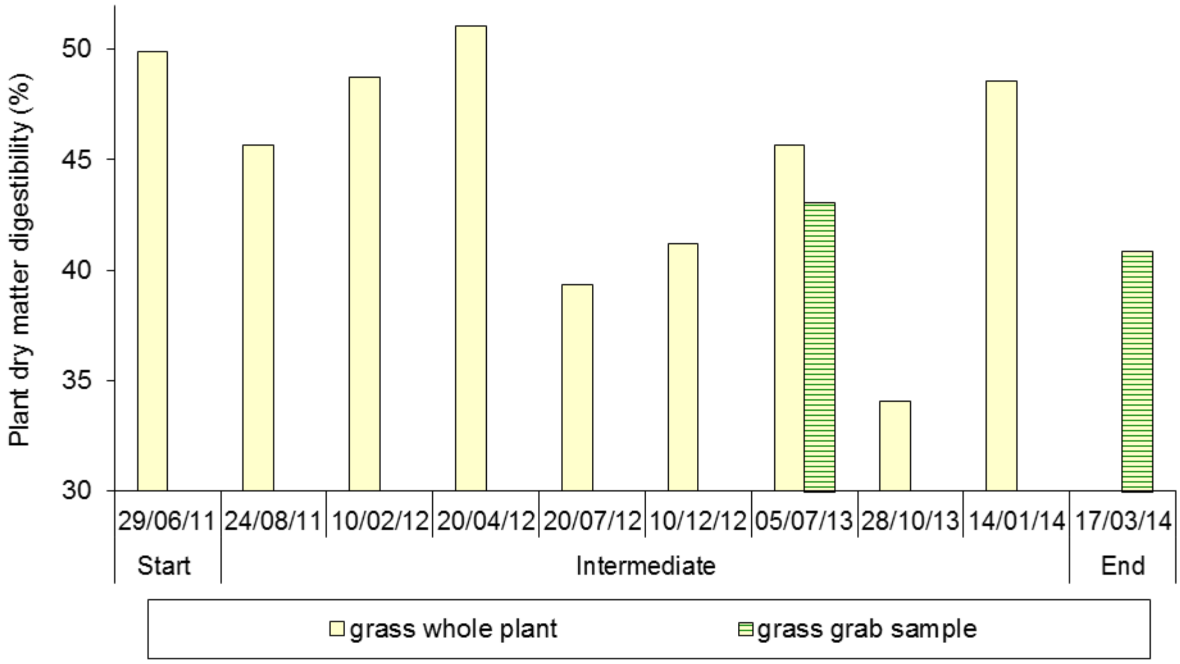

Fig. 202. Dry matter digestibility (%) of perennial grass whole plant and grab samples in the paddock during the monitoring period (06/07/11–17/03/14).

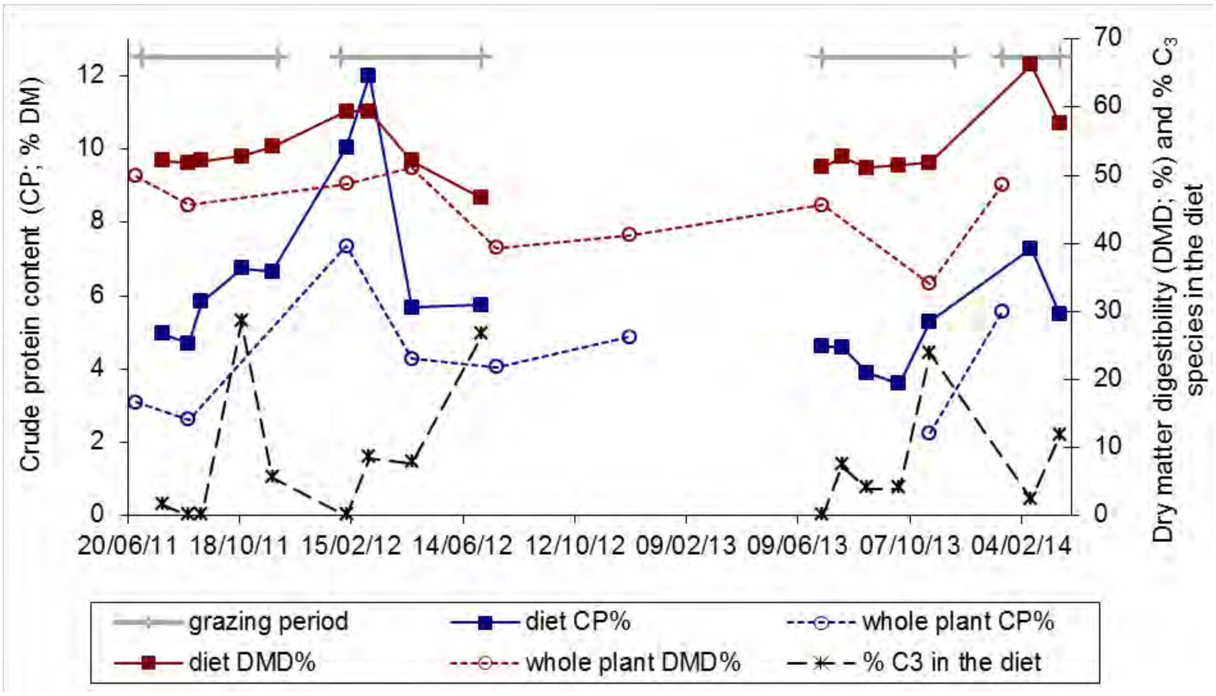

Fig. 203. Diet crude protein (CP) content (% DM) and dry matter digestibility (DMD; %) for grazing cattle predicted from faecal NIRS; measured CP and DMD content of perennial grass whole plant samples in the paddock; and the % of the diet as C_3 forage, predicted from $\delta^{13}C$ content in the faeces. Grazing periods shown.

Fig. 204. Perennial grass pasture, 29/06/11.

Fig. 205. Group 3 steers (12-17 months of age) in the trial paddock, 10/02/12.

This paddock was typical of the Brigalow cracking clay soil type. The organic C and P concentrations were high and at levels able to support legume inclusion in the future. Chloride levels were elevated in the subsoil which is typical of this soil type and could potentially restrict root depth, water extraction and therefore plant growth. The annual rainfall totals measured on the property during 2011, 2012 and 2013 were 690, 513 and 472 mm, respectively (Fig. 198). The 30-year climate normal mean rainfall measured at the Taroom Post Office (BOM Station 35070) is 674.5 mm (records for period 1961-1990). Hence the annual rainfall measured on property was above the 30-year climate normal in 2011, but below in 2012 and 2013. For the 75 days of monitoring in 2014 (to 17/03/14) the rainfall total measured on property was 33 mm. The pasture biomass in the grazed paddock reflected the seasonal rainfall patterns and the number of cattle in the paddock (Fig. 199). The highest biomass levels in the paddock were measured at the start of the 1st 12 months of monitoring (29/06/11; 3,876 kg DM/ha; Fig. 204) and at the start of final 8.4 months of monitoring (05/07/13; 3,992 kg DM/ha) which commenced after 12 months of spelling. The lowest biomass measurements were recorded at the end of the 1st 12 months of monitoring (20/07/12; 1,842 kg DM/ha) and the end of the final 8.4 months of monitoring (17/03/14; 1,294 kg DM/ha).

The proportion of the pasture which was assessed as 'green' also reflected the rainfall pattern and grazing pressure, as expected (Fig. 200). Assessments of 'greenness' were only made on five occasions. The pasture was 'greenest' during the 2nd 12-month period of monitoring, during which the paddock was spelled, with 69% and 62% of the biomass being assessed as 41-60% green on the 20/0712 and 10/12/12, respectively. The dominant species in the paddock was the introduced perennial grass buffel (97% of the biomass).

Although whole plant analysis showed CP concentrations to be generally very low at <5.6% of DM (except for a concentration of 7.4% measured on the 10/02/12); the cattle were generally able to select a higher quality diet (Fig. 201 and Fig. 203). This is evident in the estimates of diet quality from faecal NIRS which showed diet CP levels to have ranged from 3.6-12.0% with an average of 6.1%. Over the same period, estimated diet DMD ranged from 47-66% compared to a range of whole plant DMD of 34-51% (Fig. 202 and Fig. 203). Estimates of diet CP and DMD closely followed the trend of whole plant sample concentrations of these components. Delta C analysis showed that cattle were consuming between 0-28% of the diet as C_3 species (average 8 ± 2.4 (SE) %). In contrast to results for Central Queensland Open Downs perennial grass pasture, the peak concentrations of dietary CP and DMD were associated with very low concentrations of C_3 species in the diet.

The average daily gain of the six heifer and steer groups were generally within the range of the long-term seasonal averages expected for the South Queensland Brigalow region (range: 0.22 kg/head/day over winter to 0.77 kg/head/day over summer; annual, long-term average liveweight gain of 0.44 kg/head/day; Bowen *et al.* 2010). The exception was the final group of cattle monitored (Group 6; weaner steers) which gained 0.96 kg/head/day over 62 days from mid-January to mid-March. The grazing period for Group 6 coincided with a peak in estimated diet CP and DMD concentrations, with the diet DMD of 66% on 14/02/14 being the highest recorded during the entire monitoring period of 985 days.

The overall average total liveweight gain over the 1st 12 months of monitoring was 169 kg/ha/annum which is 3.2 times the long-term average steer liveweight gain assumed in the constructed scenario for the South Queensland Brigalow region (53 kg/ha/annum). The average stocking rate in the paddock over this period was 2.6 times that assumed in the constructed scenario (0.87 vs. 0.33 AE/ha, respectively). However, when the spelling of the paddock for the entire following 12-month period is considered, the average stocking rate and total liveweight gain over the 2-year period are closer to what was assumed for the constructed scenario: 0.44 AE/ha and 84.5 kg/ha/annum. During the final 8.4-month period of monitoring the average stocking rate was higher than the assumed long-term average stocking rate in the constructed scenario: 0.55 vs. 0.33 AE/ha and total liveweight gain also correspondingly higher: 64 kg/ha per 256 days cf. 53 kg/ha/annum.

The gross margin calculated for the first 12-month period of monitoring was $285/ha which is 5.8 times the value calculated for the constructed senario ($49/ha/annum). As well as the very high stocking rates and associated beef production during this period, the average cattle price margin was high at $0.13/kg liveweight. The costs of blade ploughing were accounted for by assuming that the entire paddock would be blade ploughed every 20 years, thus the annual 'forage cost' is the total cost divided by 20, resulting in an annual forage cost, calculated using owner rates, of $5/ha/annum attributed to this paddock. When the gross margins for the first and second 12 month periods of monitoring are averaged, the figure of $140/ha/annum is still 2.9 times the gross margin calculated for the constructed scenario. However, in contrast to these high values, the gross margin for the final 8.4 months of monitoring was -$12/ha per 256 days. Although the stocking rate and beef production figures were higher for this 8.4 month period than the annual figures assumed in the constructed scenario (0.55 AE/ha and 64 kg/ha, respectively) the cattle price margin was only $0.01/kg liveweight, which was insufficient to cover the costs of cattle treatment, freight and selling costs.

4 Results and discussion for farm economic case studies

Although a great deal of production and economic data was produced during the development of the case study strategies, this detail cannot be presented here for privacy reasons. Also, just reporting the relative improvement in economic criterion could be confusing. For example a relative improvement in net profit of 400% could represent an absolute shift in net profit from $1 to $4. This is not much when an investment of millions of dollars is involved and profit margins are minimal. For these reasons the qualitative value of the change, and some of the insights provided by the case studies into the economics of forages, are discussed.

Case study 1
The case study looked at a breeding and fattening enterprise that focussed on using annual forages and improved pastures to produce finished slaughter cattle suitable for direct sale to abattoirs. The base model indicated a high proportion of the sale steers and cull heifers would gain access to winter forages twice before sale. The "without forages" scenario converted the herd to the production of steers and heifers from improved pastures only. The profitability of the enterprise was either slightly improved or slightly lowered by the change depending upon the price scenarios chosen for the feed-on stock, suggesting that the use of annual forages was not significantly improving the profitability of the enterprise and most likely increasing its riskiness. Grain cropping was not considered an option although it had been undertaken in the past.

Case Study 2
The case study also looked at a breeding and fattening enterprise that focussed on using annual forages and native pastures to produce finished slaughter cattle suitable for direct sale to abattoirs. The base model indicated a high proportion of the sale steers and cull heifers would gain access to winter and summer forages twice before sale. The "without forages" scenario converted the herd to the production of weaner/yearling steers and cull heifers from generally improved pastures only. The area of land previously used for forages was mostly converted to cash crop production although some was retained to finish a few cull cows. The conversion to grain was considered viable as cash cropping was already an established practice on part of the property. The profitability of the enterprise was significantly improved by the change. The use of annual forages was significantly reducing the profitability of the enterprise without reducing its riskiness.

Case Study 3
The case study looked at a breeding and fattening enterprise that focussed on using annual summer forages, improved and native pastures to produce finished slaughter cattle suitable for direct sale to abattoirs. The base model indicated only sale steers would gain access to summer forages once before sale. The "without forages" scenario converted the herd to the sale of lighter, but finished steers, from improved pastures only. The area of land previously used for forages was mostly converted to summer crop production. The conversion to grain was considered viable as cash cropping was already established practice. The profitability of the enterprise was improved by the change to summer grain production.

Case Study 4
The case study looked at a breeding and fattening enterprise coupled with a turnover enterprise focussed on using perennial legumes, improved and native pastures to produce finished slaughter cattle suitable for direct sale to abattoirs. The base model indicated sale steers, cull heifers and some cull cows would gain access to perennial legume forage at least once before sale. The "without forages" scenario removed the perennial legume and converted the herd to the sale of fewer and lighter stock from improved pastures only. The area of land previously used for sown perennial legume forages was converted to improved

pasture without perennial legumes. The conversion to improved pasture was considered viable as improved grass pastures were already established over significant areas of the property of a similar soil type. The business was considerably less productive with the change and the profitability of the enterprise was significantly reduced by the change to beef production from improved grass pastures only. Grain cropping was not an option.

Case Study 5

The case study looked at a steer turnover enterprise focussed on using perennial legumes, annual legumes, improved and native pastures to produce feed-on steers with some spending the majority of their grazing period on high quality sown forages. The base model indicated turnover steers would gain access to the high quality forage for significant periods prior to sale. The “without forages” scenario removed the high quality forages and converted the herd to the sale of fewer steers at the same finished weight from improved perennial grass pastures only. The area of land previously used for high quality forages was converted to improved perennial grass pasture. The conversion to improved pasture was considered viable as improved grass pastures were already established over significant areas of the property of a similar soil type. The business was considerably less productive with the change, and the profitability of the enterprise was significantly reduced by the change to beef production from improved grass pastures only. Grain cropping was not considered to be an option.

The insights into the profitability of forages provided by the case studies can be summarised as follows:

- Under current market and cost conditions:
    - Perennial legume-grass pastures have a significant economic advantage over perennial grass pasture and annual forages.
    - However, high-output perennial legume-grass forages are not as profitable as grain cropping, when grain cropping is a feasible alternative.
    - The effect of annual forages on farm profitability can be marginal, and the increase in business risk significant, requiring a careful assessment of the role of annual forages in improving overall profitability.
    - Where high-output annual forages are currently grown successfully and grain crops are a realistic option, it is most likely that grain crops will provide substantially greater economic returns than the alternative annual forage crop.
    - Where grain crops are not an alternative and grass pasture is the alternative option under consideration, annual forages are a high cost option with high timeliness requirements that may only add value to the beef enterprise if the opportunity cost of plant and unpaid labour are excluded.

5 General discussion

5.1 Co-operator sites

5.1.1 Drawing inferences from the co-operator site data sets

While the 24 commercial forage sites monitored in this project give an insight into current industry practices and the associated profitability of high-quality forages, caution needs to be exercised in extrapolating the performance documented at these sites to the rest of the industry. It is likely that the sites monitored in this project are biased towards the higher fertility soils that are still in use for forage cropping throughout the Fitzroy River catchment and towards the more progressive and open-minded producers. Furthermore, it is recognised that the data from the individual forage sites are influenced by the complex combination of management decisions, prevailing weather and market factors at the time. Part of the challenge in collecting data from producer co-operator sites was that there was little influence or control over the management of the site and the project team simply documented what occurred. Despite this, we believe that this project gives valuable insights into forage use in the Fitzroy River catchment and has allowed recommendations to be made on management and economic decisions in relation to forage use.

Difficulty was experienced in engaging producer co-operators for this study. We believe this was partially a reflection of the declining number of producers growing forage crops, probably due to the marginal profitability of the exercise, as demonstrated in this report, as well as the declining soil fertility and thus likely contraction of forage cropping activities to the more fertile soils in the region. Even once producers were located who were intending to plant a forage crop, very few who were approached by the project team were willing to provide sufficient records and data, particularly with regard to cattle weight gain, to be involved in the project. Many producers contacted by the project team indicated that they were not interested in measuring cattle performance on forages in the first instance, or in the profitability of their forage crop/s. However, the interest from producers that was generated at our project field days held in April 2014, and the subsequent enquiries that we have received, contradicts this inference to a large extent. Perhaps people want to know the answers without having to undertake the extra work required to be involved in a project such as this.

5.1.2 Forage production

Key data for forage yield and quality, as well as animal production and economic performance, is summarised for each forage type in Table 26. When average forage yield and quality data is compared across forage types (Table 27) some broad trends are evident.

5.1.2.1 Forage yield

As expected, forage sorghum crops produced the greatest biomass with the average peak biomass in the un-grazed exclosure across four sites being 19,307 kg DM/ha (range 9,573-35,598 kg DM/ha). Three of the four sites with exclosures had peak biomass yields in the range 14,800-35,598 kg DM/ha. These yields are at the upper end of biomass yields measured as cumulative growth from plant biomass cuts in south-west Queensland (range 6,800-22,200 kg DM/ha; Bell *et al.* 2012) and the Darling Downs region of southern Queensland (range 3,050-14,410 kg DM/ha; Chataway *et al.* 2011b). Our values are also high relative to the Sugargraze forage sorghum yields measured in Pacific Seeds forage variety trials in south east Queensland: 9,900 and 11,600 kg DM/ha (Stuart 2002). The very high yield of 35,598 kg DM/ha in the ungrazed exclosure for the Central Queensland Brigalow 2011-12 crop, was unexpected although associated with a high seeding rate (5.5 kg/ha), high planting soil moisture (110 mm) and in-crop rainfall (502 mm) and fertiliser application of 49 kg N/ha. However, a similar yield of 33,000 kg DM/ha was obtained from an irrigated late flowering sweet sorghum hybrid grown near Trangie, near New South Wales (Muldoon 1985). The regrowth crop of forage sorghum monitored in the South Queensland Brigalow region in 2012-13 produced a peak biomass (also the starting biomass) of only 2,069 kg DM/ha in the grazed paddock, which was only ca. 12.5% of the starting biomass of the original crop grazed the previous season. This lower yield is typical of return crops due to a reduced ability to tiller (Muldoon 1985) as well as lower plant population and vigour, which is in turn caused by trampling and plant death as well as reduced N supply.

The average peak biomass in the exclosure for oats crops was approximately half that for forage sorghum: 8,184 DM/ha (Table 27). Although there were variable levels of base soil N and N fertiliser application at our sites, this finding is in line with the finding of Chataway *et al.* (2011b), that biomass production from oats was approximately half that for forage sorghum, for forages grown in the central Darling Downs area of southern Queensland. Two of the eight oats crops monitored at our co-operator sites over 2011 to 2013 had peak biomass in the exclosure which was considered very high: 12,010 kg DM/ha for the Central Queensland Open Downs 2013 crop and 16,456 kg DM/ha for the Central Queensland Brigalow 2012 crop. Pacific Seeds oats variety trials near Roma in south west Queensland and in the Lockyer Valley in south east Queensland measured total cumulative dry matter yield in the range of 5,700 to 9,800 kg DM/ha (Stuart 2002). Furthermore, the oats yields in published reports fall within the range 1,100-7,700 kg DM/ha for south west Queensland (Bell *et al.* 2012) and 810-7,380 kg DM/ha for the Darling Downs area of southern Queensland (Chataway *et al.* 2011a). However, as for forage sorghum, the research group at Trangie, New South Wales (Muldoon 1986) reported high yields for irrigated oats, in the range of 16,000-20,000 kg DM/ha.

The average peak biomass in the exclosure for lablab forage was similar to that for oats, and approximately half that for forage sorghum: 9,637 kg DM/ha (Table 27). However, there were only two data sets for lablab crops, and at one, peak biomass was possibly missed due to sampling in the exclosure only occurring the start and end of grazing. The peak biomass at the second site was reliable and was 14,248 kg DM/ha (Central Queensland Brigalow 2012-13). As for forage sorghum and oats yields measured at our co-operator sites in the Fitzroy River catchment, the peak lablab biomass at our site in the Central Queensland Brigalow region in 2012-13 was greater than published values which include an average of 4,400 kg DM/ha at Emerald in Central Queensland (Armstrong *et al.* 1999) and a range of 2,100-8,600 kg DM/ha for crops grown in south west Queensland (Singh *et al.* 2009; Bell *et al.* 2012) and south east Queensland (Clem 2004; Chataway *et al.* 2011b).

Perennial grass presentation yield, averaged over the duration of monitoring, ranged from 2,186-5,620 kg DM/ha across the 13 individual data sets for perennial sites. The biomass measurements for grass growing with the perennial legumes, leucaena or butterfly pea, were in the same order as for the perennial grass-only sites. Edible leucaena biomass measurements (including stems up to 5 mm in diameter) were in same order as for biomass measurements for the whole butterfly pea plant: 417 and 528 kg DM/ha, respectively (average presentation yield across sites). The average butterfly pea biomass over the duration of monitoring for three data sets ranged from 143-1,138 kg DM/ha. As expected, these presentation yields of butterfly pea yields from our mixed legume-grass pastures, which were towards the end of the expected useful life of butterfly pea (ca. 10 years; DPI&F 2005), were lower than what is considered possible for total annual biomass production in butterfly pea-only pastures with high rainfall and deep fertile soils: 3,500-5,000 kg DM/ha or with medium rainfall and moderate to good soils: 1,300-2,800 kg DM/ha (DPI&F 2005). The butterfly pea presentation yields measured at our sites were also generally below values for total yield measured over the 5 years post establishment for mixed butterfly pea-grass pastures by Clem (2004): 1,009-3,903 kg DM/ha. The average presentation yields of edible leucaena for our five data sets (range: 196-744 kg DM/ha) are in the range of published edible biomass yields for pre-grazing or un-grazed leucaena grown in Queensland (Bray *et al.* 1988; Clem *et al.* 1993; Jones *et al.* 1998).

The growth performance of all forages monitored at the co-operator sites over the years 2011-2014 reflect the seasonal (rainfall) conditions during this period. Annual rainfall for the years 2011, 2012 and 2013 ranged from below to above the 30-year climate normal mean rainfall (mean of records for period 1961-1990) for locations across the Fitzroy River catchment (BOM 2014). However, the very high yielding annual crops were associated with very high levels of in-crop rainfall and, in some cases, high levels of soil moisture at planting. For example, 502 mm in-crop rainfall was measured for the high yielding 2011-12 forage sorghum crop in the Central Queensland Brigalow region and 328 mm in-crop rainfall was measured for the 2012-13 lablab crop in the Central Queensland Brigalow region. Rainfall in the Fitzroy River catchment of Queensland is inherently highly variable and there is a need to extrapolate measured data collected over short time periods into the longer term climatic context to reflect the full range of seasonal conditions likely to be encountered. Computer simulation models such as APSIM (The Agricultural Production Systems Simulator; McCown *et al.* 1996; Keating *et al.* 2003) have potential to facilitate this. For example, using 108 years of historical climate data, the APSIM 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 (Bowen *et al.* 2010). Data from our study was used to test the outputs from annual forage and perennial grass biomass models within APSIM as detailed in Appendix 2 of this report and showed that further work is required before the annual forage models can be used reliably, particularly for grazed systems. The data from our measured field sites could be used to improve the annual forage crop models but additional data sets are also likely to be required.

5.1.2.2 Forage and diet quality

Analysis of plant components showed that sown, high quality forages, particularly the green leaf, generally contained high concentrations of CP and DMD, which were considerably greater than for dry season perennial grass pasture. At the start of grazing, green leaf quality parameters for oats ranged from 4.5-21.4% CP and 76-83% DMD; for forage sorghum, from 11.4-14.3% CP and 64-68% DMD; and for lablab, from 18.0-26.5% CP and 72-77% DMD. Quality parameters for edible leucaena (leaves and stems ≤5 mm thickness), averaged over the grazing period ranged from 18.3-25.9% CP and 59-67% DMD, and for butterfly pea green leaf averaged over the grazing period ranged from 21.5-25.8% CP and 67-69% DMD. Lower than expected plant CP concentrations were measured for some cereal crops, particularly oats, and reflect the low base N levels in the soil and lack of N fertiliser application. The most extreme example of this was the very low plant CP levels measured at the South Queensland Brigalow Oats 2011 site where green leaf CP was around 4.5% DM, even at the start of grazing. It is likely that low forage and diet CP were limiting cattle performance at some oats sites, such as the South Queensland Brigalow Oats 2011 site.

Generally, predictions of diet CP and DMD over the grazing period were closely aligned with the proportion of high quality sown forage in the diet for C_3 species (oats, lablab, leucaena and butterfly pea), which could be detected through faecal $\delta^{13}C$ analysis (see graphs showing diet quality in the summary for each individual forage site in Section 3). Oats forage, provided in association with varying amounts of perennial grass, resulted in the greatest average diet quality in terms of CP and DMD (12.3% DM and 63%, respectively), closely followed by leucaena-grass forage sites (CP 12.0% DM and DMD 59%) and lablab forage sites which were also associated with perennial grass (CP 11.5% DM, DMD 59%). Perennial grass sites resulted in the lowest average diet CP and DMD of all forage types (6.6% DM and 55%, respectively); (Table 26 and Table 27).

Although the area of additional perennial grass provided in conjunction with the annual forages ranged from 17-87% of the total grazing area, faecal $\delta^{13}C$ analysis for cattle grazing oats and lablab crops indicated that cattle were mainly consuming the annual forage crop which generally formed 63-89% of the diet (average value over the total grazing period). Over an annual grazing cycle on leucaena-grass pastures, leucaena comprised 37-62% of the diet, which is line with the findings of Dixon and Coates (2008), Petty (1997) and Galgal (2002) which indicated that leucaena usually comprised 35-60% of the diet selected in leucaena-grass pastures. In the study of Dixon and Coates (2008), the average diet quality for cattle grazing leucaena-grass pastures in southern Queensland (12.4% CP and 62 % DMD) was slightly better than the average measured at commercial sites in our study. Although the proportion of butterfly pea in the pasture was as low as 4.6% of the biomass (on average) at one of the two sites (average of 25% of the biomass at the second site), cattle on average consumed a higher quality diet, in terms of CP and DMD, than for perennial grass sites: 9.7% CP and 59% DMD.

Diet quality was estimated by faecal NIRS technology which relies on representative calibration sets for paired diet and faecal data. The calibration sets for the high quality forage types monitored in our study are not as extensive as those for tropical, perennial grasses (Coates 2004). However, investigations by D. Coates (*pers. comm*) indicated that faecal NIRS predictions of diet CP and DMD at our sites were reliable. Hence there is no obvious explanation for the apparent anomaly at some of our oats sites where predicted diet CP concentrations were up to 2.7 times greater than wet chemistry analysis of green oats leaf. Analysis for faecal $\delta^{13}C$ indicated that the average proportion of C_3 species in the diet was as low as 63% at some oats and thus that cattle were consuming plant material other than oats. The dry season perennial grass (C_4 species) available in association with the oats was generally very low in CP but it is possible that cattle were also selecting some high quality forbs (C_3 species) also present in the perennial grass areas that may have contributed to the higher CP concentration in the diet of cattle than in the green oats leaf.

5.1.2.3 Total grazing days

Leucaena-grass forage resulted in the greatest average total grazing days per annum of all annual and perennial forage types: 284 days/annum (Table 27). All annual forage crop species were grazed for greater than 100 days/annum, on average. The total grazing days on oats forage were generally much greater than the values assumed as typical in the constructed scenarios (76-90 days), ranging from 91-158 days. This was possibly because of the generally much lower stocking rates over the total grazing area than assumed as representative in the constructed scenarios (1.8-2.3 AE/ha), ranging from 0.6-1.5 AE/ha. The primary reason that the stocking rates over the whole grazing area were lower at the co-operator oats sites was that there was often a considerable area of perennial grass provided in conjunction with the oats forage, ranging from 17-87% of the total grazing area. In addition, grain was sometimes provided towards the end of the grazing period on oats to extend the grazing period (Central Queensland Brigalow 2012 and 2013 oats sites).

5.1.2.4 Soil fertility and fertiliser application practices

At all sites key soil fertility attributes applicable to the forage grown were measured at planting, or at site initiation for the perennial forages. However, due to access, timing and equipment difficulties, not all fertility attributes were collected at all sites. Generally, nitrate N was the key measured nutrient at all cereal forage sites, whereas for the annual legume lablab, and perennial legume-grass sites, P was the key parameter.

While soil nitrate N levels were not measured at all sites sown to either oats or forage sorghum, levels measured after N fertiliser application (where applied) were generally low and in most cases below crop requirements to maximise both forage quantity and quality (Stuart 2002). The exception were Central Queensland Open Downs Oats 2013 and Central Queensland Brigalow Oats 2011 sites, where soil nitrate N levels after fertilising were

118 kg/ha and 134 kg/ha, respectively. The lowest soil nitrate N level was measured at the South Queensland Brigalow Oats 2011 site: 42 kg/ha. While this crop produced a moderate forage yield (5,704 kg DM/ha in the exclosure), forage quality and resulting animal diet quality was low (CP content of green leaf at the start of grazing was only 4.5% on a DM basis). This contributed to the lowest total liveweight gain per hectare when expressed per planted forage area only: 92 kg/ha/annum. However, paradoxically, this site produced the highest gross margin per total grazing area of all the oats sites monitored, signifying the complex nature of forage profitability, with a range of factors influencing the overall economic outcome.

The dynamics of soil N in annual forage systems is complex, and it is difficult to measure the complete supply of N that the plant accesses throughout its development. Our standard procedure was to measure soil nitrate N level at sowing, as this was an easily obtainable measure of N supply. However the crop accesses additional soil N while growing, and this N is supplied by soil microbial activity from the soil organic matter pools. Therefore in summer when temperatures are hotter and rainfall is higher, N supply from organic matter mineralisation is higher (ca. 35 kg/ha) than what occurs in winter (ca. 7 kg/ha); (Cox 2009). While these amounts are low and are not sufficient to make up for any short fall in fertiliser, if fertiliser was needed, the total N supply to the crop is higher than we were able to measure. This, however, doesn't explain the very high dry matter yield measured at one of the forage sorghum sites (Central Queensland Brigalow 2011-12), where total measured Nitrate N supply was 90 kg/ha, after N fertiliser application of 40 kg/ha, but over 35 t DM/ha was produced (in the exclosure).

Soil N dynamics under a perennial grass pasture are also complex, and at any given time, soil N levels are low as the pasture immediately utilises N as soon as it is available. Furthermore, as pastures age, soil available N is tied up into unavailable forms, a phenomenon called pasture rundown. After clearing, initial soil nitrate N levels can be as high as 300 kg/ha, but this available N is quickly converted into organic forms (organic material) after pasture is sown and produces high amounts of dry matter (Peck *et al.* 2011). Studies have shown a similar dynamic with P, where large amounts of plant available P are released after clearing, to be also converted into organic, unavailable forms as the pasture grows over time (C Thornton *pers. comm.*).

Generally, soil P levels were moderate (15–25 mg/kg; Colwell bicarbonate extraction), and while reliable relationship data is not available for some forage types, these levels are considered to be adequate to maximise forage and animal growth given the rainfall (Peck *et al.* 2014; McIvor 1984; Jackson *et al.* 2012). However at three sites (Central Queensland Brigalow Oats 2011; Central Queensland Open Downs Leucaena-grass pasture, and Central Queensland Open Downs Perennial grass pasture), measured P levels were at or below 11 mg/kg. These levels are considered low, and reflect the soil type (Open Downs for two of the sites), long term grain cropping and limited to no P fertiliser application history. We estimate that forage production would have been restricted by the lack of soil P at these sites, and at one site (perennial grass pasture) the level could have also negatively impacted animal production (Jackson *et al.* 2012). Despite the low P levels, P fertiliser wasn't applied at these sites. This is most likely due to the co-operators not knowing the magnitude of P deficiency, and possibly not realising the importance of soil P levels to maximise plant and animal growth, particularly when utilising high quality forages. Conversely, three sites (Central Queensland Brigalow Forage sorghum 2012-13, Central Queensland Brigalow Leucaena-grass pasture 2013-14 (Paddock 2), and Central Queensland Brigalow Butterfly pea-grass pasture) recorded very high levels of soil P: 59–130 mg/kg. These levels are common in some central Queensland alluvial soils (Gillespie *et al.* 1991; Thwaites and Maher 1993) and are more than adequate to meet the needs of high output forages.

Despite low N and P soil levels across many sites, the majority of forages monitored were not fertilised. This was also highlighted in a recent review of N and P responses of oats and forage sorghum, and was presumed due to the lack of dry matter response data (Lawrence *et al.* 2014). This review also highlighted the paucity of animal response data from research studies into fertilised annual forages, especially with P fertiliser application. As discussed in Section 5.1.4, there are a range of issues that influence the profitability of sown forages. Controlled experiments in the Fitzroy River catchment are required to obtain plant and animal response data, which in turn can be analysed into economic outcomes for graziers to consider when determining if and what fertiliser to apply to their chosen forage.

5.1.2.5 Stocking rates on perennial grass-only pastures

The two co-operator sites where perennial grass pastures were monitored on family–owned beef enterprises had stocking rates that were generally higher than considered optimal for long-term sustainability and productivity. At the Central Queensland Brigalow site the trial paddock was stocked at twice the stocking rate deemed appropriate in the constructed scenario for buffel grass pastures, for the 476 days of the study (i.e. 0.64 cf. 0.33 AE/ha). At the South Queensland Brigalow site, on buffel pasture showing signs of N run-down, cattle were stocked at 0.44 AE/ha, averaged over the first 2 years (0.87 AE/ha in Year 1 and de-stocked in Year 2). Total beef production per hectare at these sites was correspondingly greater than that estimated for the constructed scenarios (Table 26). Although it is dangerous to draw general conclusions about industry practices from only two examples, this data supports more widespread industry observations and monitoring of stocking rates and land condition (Tothill and Gillies 1992; Beutel *et al.* 2009; McLean *et al.* 2014). Furthermore, it is the observation of the project team that this scenario appears to by typical of many perennial pastures across the Fitzroy River catchment. It is possible that financial pressures on commercial producers are leading them to increase stocking rates above the long-term sustainable carrying capacity for their land type and region. This inference is supported by the McLean *et al.* (2014) who concluded that increasing average stocking rates across northern Australia over 12 years from 2001-2012 may be an attempt to overcome low profitability. In association with the high stocking rates used on the commercial properties monitored in the Central and South Queensland Brigalow regions, both pastures were showing signs of nitrogen rundown which would be further exacerbating financial pressures through reducing productivity and returns over time (Peck *et al.* 2011). The perennial grass site monitored in the Central Queensland Open Downs region in this project was part of a bigger company conglomeration and was managed conservatively with annual stocking rates very similar to that estimated in the constructed scenario (Table 26).

5.1.3 Animal production

5.1.3.1 Total liveweight gain

On average, sown annual and perennial forages resulted in greater beef output compared to that from perennial grass pasture, in terms of kg/ha/annum (Table 27). Leucaena-grass sites produced the greatest average total beef production of all forage types: 198 kg/ha/annum, which was 2.6 times greater than the average annual beef production from perennial grass pasture (76 kg/ha/annum). Furthermore, there appeared to be less variability between sites and years in total beef production from leucaena-grass pasture compared to perennial grass and butterfly pea-grass pastures: coefficient of variation (CV) was 36% for leucaena-grass, 84% for butterfly pea-grass and 97% for perennial grass. Butterfly pea-grass sites ranked second for total beef production (125 kg/ha/annum, average across sites). The average total beef production for the three types of annual forage crop was within the range: 93-108 kg/ha/annum.

Forage sorghum, despite producing twice as much forage biomass as the other annual forages, oats and lablab, on average resulted in similar total beef production. This was due to poor utilisation of forage sorghum biomass in many instances as well as a lower quality diet and hence lower individual animal production from forage sorghum. However, in general terms, across our annual forage data sets the greater the forage biomass produced the greater the output of beef. The data for annual forage sites shows a correlation between peak forage biomass in the un-grazed exclosure (an indication of total forage production) and beef production (r = 0.81; one forage sorghum outlier excluded). The outlier was the Central Queensland Brigalow 2011-12 Forage sorghum crop which produced a large biomass, not through continual regrowth but by being allowed to grow past the optimum grazing time and become mature. This resulted in a large body of mature feed (30,197 kg DM/ha at start of grazing,) with low palatability and digestibility, which was poorly utilised.

As reviewed previously (Bowen *et al.* 2014) there are only a limited number of data sets reporting measured cattle weight gains for high quality forages grown under central Queensland conditions, with which to compare the results from this study. However, in our previous review (Bowen *et al.* 2014) we drew on expert opinion, as well as assessment of the measured data sets, to provide a general indication of expected animal performance from forages within three regions within the Fitzroy River catchment. These values are given in Table 26 for the constructed scenarios developed for each forage and region combination.

Total beef production per hectare, from the total grazing area, for the annual forage crops monitored in this project was generally less than that calculated in the constructed scenarios, and in the review of Bowen *et al.* (2010), as what would be expected based on best-practice management (Table 26 and Table 27). This was the combined result of generally conservative stocking rates, provision of associated perennial grass which reduced the productivity of the total grazing area, and, in some cases, lower individual cattle liveweight gain than estimated for the constructed scenarios. While the stocking rates were generally considered low, especially for oats crops, when expressed per area of sown forage only, this was amplified when stocking rates were expressed per total grazing area. The additional perennial grass areas (ranging from 17-87% of the total grazing area, across annual forage sites) contributed to the lower stocking rates expressed per total grazing area and would be also expected to result in lower individual animal gain in cases where animals were selecting significant proportions of perennial grass in the diet with correspondingly lower forage quality and total biomass than for the annual forage crop. Conservative stocking rates, and provision of additional grass pasture areas in association with forage crops, may be seen by producers as strategies to alleviate the risks due to inherently variable rainfall and thus year-to-year variability in forage biomass production during the grazing period.

The measured values for total beef production at our co-operator sites for leucaena-grass (198 kg/ha/annum, average) and perennial grass-only (76 kg/ha/annum, average) pastures were in the range of values suggested as representative of commercial steer performance in Queensland by Shelton and Dalzell (2007): 167-200 kg/ha/annum for buffel-leucaena pastures and 47-96 kg/ha/annum for introduced perennial grass pastures. However, the average leucaena-grass beef production exceeded our estimates of annual production for the constructed scenarios: 140 kg/ha/annum for Central Queensland scenarios, and 112 kg/ha/annum for the South Queensland Brigalow scenario (Table 26). As discussed above (Section 5.1.2.5), total beef production from perennial grass co-operator sites tended to be greater than values estimated as long-term averages for our constructed scenarios: 25 kg/ha/annum for the Central Queensland Open Downs region, 57 kg/ha/annum for the Central Queensland Brigalow region, and 53 kg/ha/annum for the South Queensland Brigalow region. The higher beef production values at the Central and South Queensland Brigalow co-operator sites were associated with much higher stocking rates than those considered to be long-term, sustainable levels.

Butterfly pea-grass pastures resulted in total beef production 49 kg/ha/annum greater, on average, than for perennial grass-only pastures, at our co-operator sites (Table 27).

Although the proportion of butterfly pea in the pasture was as low as 4.6% of the biomass (on average) at one of the two sites (average of 25% of the biomass at the second site), cattle on average consumed a higher quality diet, in terms of CP and DMD, and had access to a greater total forage biomass yield at the butterfly pea-grass sites. The greater forage and animal production, compared to the perennial grass pastures sites, may have been partially a result of the inherently more fertile and deeper alluvial soils on which the butterfly pea-grass pastures were growing. However, Clem (2004) measured a benefit in beef production of 31 kg/ha from butterfly pea-grass pastures as compared to grass only pastures, monitored over 4 years after establishment at Brian Pastures Research Station, near Gayndah. A similar magnitude of difference between pasture systems was reported by Hill *et al.* (2009) for the same pastures once they had been established for 5 years.

5.1.3.2 Grazing management practices

Observations at the co-operator sites indicated that grazing management practices may in some cases be limiting productivity and profitability of annual forage crops in the Fitzroy River catchment, particularly for forage sorghum crops. It is well known that forage sorghum crops are difficult to manage to optimise forage quality, and therefore animal production, because the quality of the feed declines rapidly as the crop matures (Bowen *et al.* 2010). At three of the four forage sorghum co-operator sites (not considering the one re-growth crop) grazing commenced too late when the crops were already quite mature. In addition, at two of the sites stocking rates were very low which allowed the crop to continue maturing. The most extreme example of this scenario is the Central Queensland Brigalow Forage Sorghum 2011-12 crop where grazing commenced just prior to head emergence at 30,197 kg DM/ha of forage sorghum and a height of 316 cm, which was estimated to be about 6 weeks later than ideal for optimising forage quality. Despite the large forage biomass produced in this paddock only 53 kg/ha of beef was produced due to poor utilisation. One forage sorghum site (Central Queensland Brigalow 2012-13) was managed according what we would consider best-practice grazing management: grazing commenced at the optimal time during vegetative growth, stocking rate was adequate to maintain the vegetative state for as long as possible, and rotational grazing was used cf. continuous grazing which used at all other annual forage crop sites monitored. A correspondingly very high beef production was estimated: 253 kg/ha.

The opposite grazing management scenario can also occur, particularly with forage oats. Grazing too early, and with a high stocking rate, while the crop is still developing can decrease crop yields and hence total cattle production below the potential for that crop. This occurred with the Central Queensland Brigalow Oats 2011 crop.

5.1.3.3 Inoculation of cattle grazing leucaena forages

At one of the four leucaena-grass co-operator sites monitored in this project, cattle were not inoculated with the *in vitro Synergistes jonesii* rumen fluid inoculum or exposed to carrier cattle. It is not known how typical this is of producers in the Fitzroy River catchment although a state-wide survey by Dalzell *et al.* (2012) found that 37% of producers had either never inoculated their cattle or had used inappropriate procedures. The lack of exposure to the appropriate rumen fluid micro-organisms may be causing sub-clinical mimosine and dihydroxypyridine (DHP) toxicity which will reduce cattle growth rates although clinical signs of toxicity are absent (Quirk *et al.* 1988).

5.1.3.4 Effects of HGP use

HGPs were not commonly used in cattle grazing the high quality forages monitored in this project. It is generally accepted that HGPs can increase growth rates of cattle by 10–30% and feed conversion efficiency by 5–15% (Hunter 2010). The increased growth rates can have a significant benefit, enabling the weight-for-age specifications of the target market to be met, particularly when cattle are grazing perennial grass-only pastures. However, cattle treated with HGPs are excluded from the European Union market. In addition, under some circumstances HGP treatment can make it more difficult to achieve the grading specifications required to achieve maximum price per kg carcass weight. Cattle treated with HGPs will receive a lower MSA grading score due to the penalty in the MSA grading system for HGP treatment as well as the higher ossification score that HGP treated cattle have (Anon. 2007; Hunter 2010; McLennan 2014). HGPs can also increase carcass leanness by 5–8% (Hunter 2010) and thus may not be beneficial when late maturing genotypes are used to produce beef for markets requiring substantial fat levels at light carcass weights. McLennan (2014) demonstrated that the use of HGPs in cattle with high growth rates, such as when grazing high quality forages, was highly profitable, despite virtually rendering the cattle ineligible for MSA compliance. There was often insufficient information available from the producer co-operators in this project on cattle price data and target markets to accurately discern the reasons for the lack of use of HGPs and whether this could be decreasing potential profits.

5.1.3.5 Monitoring cattle weight gain on high quality forages

Many producers contacted in the process of engaging co-operators for this project commented that they do not usually monitor weight gain of cattle on forages. Those producers that do monitor weight gain generally only weigh at the start and end of a grazing period. This can lead to cattle gaining either more or less weight than anticipated resulting in less than optimal timing of sale and marketing and is likely to be one reason that a proportion of cattle from all annual forage crop co-operator sites were retained on-property at the end of the grazing period. An example of this scenario is the Central Queensland Brigalow Lablab crop 2012-13 where cattle gains were greater than anticipated by the producer (1.22 kg/day for the first 90 days of grazing) and cattle became heavier than optimal for the intended feedlot entry market resulting in a negative cattle price margin of -$0.20/kg liveweight. For this crop, a total of 33% of the original mob intended for feedlot entry were retained on property at the end of the grazing period due to not meeting specifications for either the feedlot or abattoir. Additionally, a further 44 weaner cattle were grazed on the forage for the final 38 days of the grazing period and were also retained on-property. In situations such as these where cattle return to perennial grass pastures, the liveweight advantage due to the forage may be eroded over time, resulting in reduced, or negative, profitability of the forage crop.

5.1.3.6 Effects of compensatory growth

Compensatory growth can be defined as the greater than expected weight gain in animals following an extended period of slow growth or weight loss due to restricted nutrition. This phenomenon is well recognised (McLennan 1997). The age at which restriction to growth occurs, and the severity and duration of the restriction, have been identified as the major factors contributing to compensatory growth (Ryan 1990). The ‘higher than expected’ rates of growth are likely to be caused primarily by an above-average feed intake (Thornton *et al.* 1979; Graham and Searle 1979). There is also evidence of an increase in the gross efficiency of conversion of feed to body gain due to a greater proportion of the liveweight gain being stored as protein and water (Oddy and Sainz 2002) as well as a reduced maintenance requirement carried over for some time after the period of under-nutrition (CSIRO 2007). However, sound equations or principles upon which to predict the extent and period of compensatory growth have remained elusive with reports showing it can vary from 0-100% (Winks 1984). Currently, the Australian animal growth model, GrazFeed (CSIRO 2014), only has the capacity to predict the effects of compensatory growth of severely restricted animals, i.e. cattle which are at a lower weight than the maximum they have reached previously in their lives. This creates major difficulties in predicting growth rates for cattle typically grown and finished in Queensland pasture production systems as it can be surmised that most young cattle grown on tropical perennial pastures would have received some degree of ‘nutritional restriction’ during their lifetime, even if not severe, where they would have received inadequate nutrition to grow to their genetic potential. The poor ability of the GrazFeed model to predict the liveweight gains measured at our co-operator sites (reported in Appendix 2) is likely to be partially a result of the inability to adequately capture compensatory gain effects.

The role of compensatory growth in the economic returns measured at our co-operator sites is likely to be twofold. Where forages are fed to stock immediately prior to them reaching slaughter weights, the benefits of any compensatory growth are likely to be fully captured and are likely to magnify the returns to the forage. Where forages are fed to stock not immediately going to slaughter and it is likely that compensatory growth will be a factor in the later development of those livestock, it is highly likely that the reported value added for such livestock is more than the benefits likely to accrue from that forage in the final production value of those livestock. That is, benefits of the forage need to be maintained to the point of slaughter (when compared to a group of similar livestock that do not receive the same forage input) to be counted as benefits.

5.1.3.7 Relative efficiency of growth of younger vs. older cattle

The relative ages of cattle grazing forages across our co-operator sites should be considered when comparing the daily liveweight gain data reported in the individual site summaries in Section 3 and summarised in Table 26. As cattle age, relatively more fat and less protein is deposited (CSIRO 2007). Due to the association of water with lean tissue deposition, energy used exclusively for protein synthesis results in 5-6 times greater empty body weight gain than when it is used exclusively for fat deposition (CSIRO 2007). Thus, it is generally expected that young cattle with their higher protein deposition and composition would be more efficient in conversion of units of energy to growth, or liveweight gain, than older animals.

5.1.4 Economic performance

5.1.4.1 Forage gross margins

Gross margins are the first step in determining the effect of sown forages on whole farm profitability. They show whether the activity itself makes a profit or loss, at the paddock level. As anticipated, there was a wide range in profitability of annual and perennial forage options in the Fitzroy River catchment, both within and across forage types (Table 26 and Table 27). Profitability was the combined result of forage and beef production (kg/ha), forage costs and cattle price margin. These factors were, in turn, influenced by management, seasonal and market factors. However, there was no statistical correlation of the major variables of forage biomass, total beef production, forage costs, or cattle price margin, with forage gross margin. Hence there was no one overriding factor that could be identified as determining the profitability of forages. This demonstrates the importance of optimising all contributing factors in order to maximise profitability of sown forage systems.

As shown in Table 27, leucaena-grass forage produced the highest average gross margin ($184/ha/annum, averaged across all sites and years). The other perennial legume-grass pasture studied, butterfly pea-grass, produced the second highest average gross margin: $143/ha/annum. Oats forage produced a higher average gross margin than perennial grass pasture. However, forage sorghum and lablab resulted in lower average gross margins than for perennial grass. These means should be interpreted in light of the fact that differences were not able to be tested statistically and that the range in gross margin values was very high for most forage types.

Sown perennial legume-grass forages and oats forage sites were more profitable on average (in terms of gross margin per total grazing area) than that calculated for the constructed scenarios (Table 27 and Table 28). This was despite the majority of sown forage sites, especially annual forage sites, having a considerable area of perennial grass provided as part of the total grazing area, as compared to the constructed scenarios where only oats and lablab forage had additional areas of perennial grass which contributed to 10%

of the total grazing area. One contributing factor to the generally higher gross margins for the co-operator sites appears to be lower forage costs, on average, than that estimated in constructed scenarios. This, in turn, was a result of no, or less, fertiliser application and less chemical and machinery applications than assumed in the constructed scenarios. In some cases, very good cattle price margins caused the higher than anticipated gross margins.

Forage sorghum sites, on average, resulted in a lower gross margin than for the constructed scenarios, despite also having lower average forage costs. A contributing factor to this result is likely to be a lower total beef production per hectare at the co-operator sites (average 108 kg/ha) compared to that estimated in the constructed scenarios (average 178 kg/ha), which was in turn a result of poor grazing management and poor utilisation of forage biomass as discussed above. There were only two lablab co-operator sites and one of these had a considerable area of additional perennial grass (57% of the total grazing area), hence it is difficult to make general comparisons with the constructed scenarios. However, when comparing the Central Queensland Brigalow Lablab 2012-13 site with the constructed scenario for Central Queensland Brigalow, the gross margin was lower, despite similar total beef production and lower forage costs, due to the negative cattle price margin of -$0.14/kg LW. This site provides a good example of how all contributing factors must be optimal for a good gross margin to be achieved.

Each gross margin was calculated using the relevant market price for the livestock at the time they entered the forage and at the time they left the forage. As highlighted above, this means that the gross margins calculated for each co-operator site not only reflect the production circumstances of the forage but also the market circumstances prevailing over the production period of each of the forages. Fig. 206 shows the variation in store steer prices at Roma and Gracemere over the life of the project. It can be seen that the variability over any time period is significant and that the middle period of the project is dominated by a marked fall in prices followed by a moderate recovery. These market influences must be incorporated into any consideration of the gross margins calculated at co-operator sites and are detailed in the individual results and discussion for each site in Section 3.

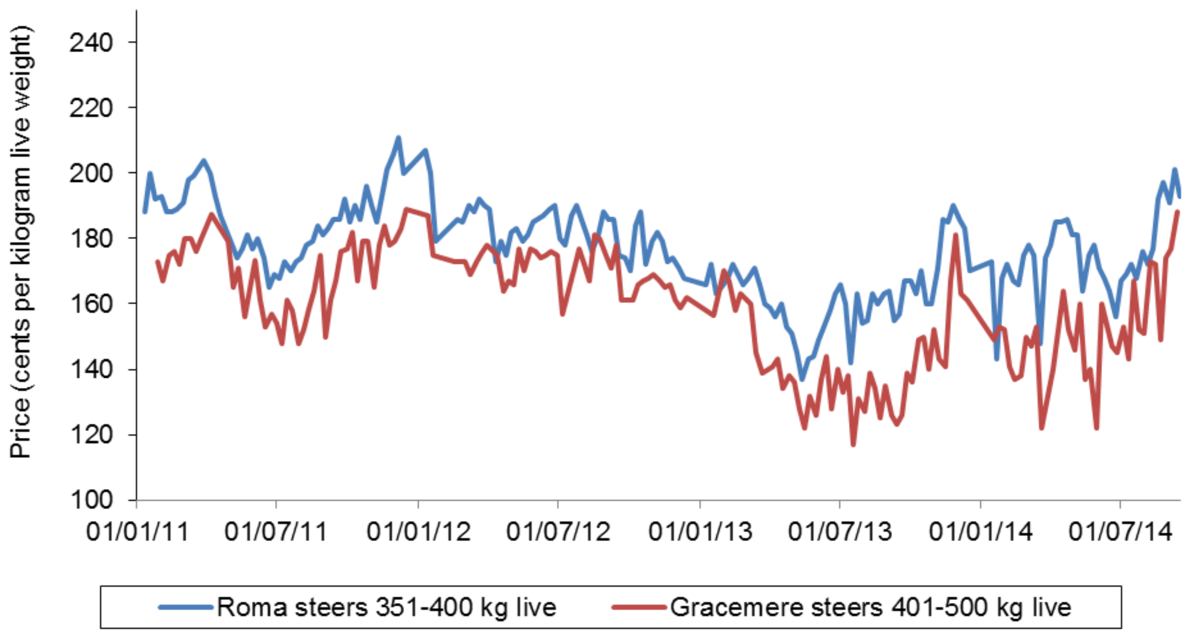

Fig. 206. Variation in the market price of store steers at Roma and Gracemere saleyards over the period of data collection from co-operator sites.

A significant proportion of cattle grazing annual forage crops were not sold directly to market but were returned to perennial grass pastures after grazing the crop. This was either because the forage was being used to spell perennial pastures (particularly for forage sorghum crops), because weaners or younger cattle were fed, or because a proportion of the mob did not attain desired finishing weights or fat cover. Thus, the gross margins calculated for many of our forage sites were not actually attained as <100% of cattle grazing the crop were sold upon exiting the paddock. In these situations, the whole farm case studies give the most accurate indication of the value of the forages to the beef enterprise. Particularly for oats crops, where cattle graze perennial pastures in the following summer season, it is highly likely that compensatory gain effects would erode most of the liveweight advantage provided by forage oats and thus make the activity unprofitable.

It is important to remember that the paddock gross margins are only the first step in determining the effect of sown forages on farm profitability. To determine the value of the sown forage system to the whole farm or business, a more complete economic analysis is required to consider the business operation with and without forages and to compare the net profit generated by alternative operating systems. Furthermore, adjustments are required to account for changes in unpaid labour, herd structure and capital that would be likely to occur as a result of changes to the overall production system. The five whole farm case studies conducted with producer co-operators give an insight into the effects of sown forages on whole farm profitability in the Fitzroy River catchment.

5.1.4.2 Farm case studies

The case studies were conducted to examine the value of the sown forages to the business, relative to other alternatives which could also be undertaken such as grazing perennial grass pasture or growing a grain crop. The major conclusion from this work was that although annual forages often produced better gross margins than perennial grass pastures at the paddock level, the inclusion of the costs not covered in the gross margin analysis in the farm level case study reduced the difference to the point where the additional expenses of annual forages were not covered by the additional income generated. Furthermore, compared to perennial grass pastures, perennial legume-grass pastures improved farm profit due to the relatively larger increase in total beef production, and relatively lower annual (amortised) forage costs, than for annual forages.

These insights reinforce the findings of previous work undertaken in this region over the past 10-15 years as part of the Central Queensland Sustainable Farming Systems project funded by the Grains Research and Development Corporation (GRDC). That is, grain cropping is generally more profitable than grazed forages. If a successful forage crop can be grown then it is more than likely that a successful, and more profitable, grain crop can be grown in its place. Where good quality cropping soils are available and grain cropping is not an option, it appears most likely that perennial forages will add more profit to the farm business than annual forages. Although these insights have proven to be robust over a number of case studies that does not mean they will hold true for all circumstances. It is still necessary for each manager, who is considering a change to their farm operations, to appropriately consider the impact on farm profit, risk and cash flow of implementing that change under their circumstances.

In a recent report by Hunt *et al.* (2013) and paper by Bell *et al.* (2014), the authors have proposed a system of mosaics of irrigated forages in pasture beef systems across northern Australia to overcome seasonal feed gaps and increase overall stocking rate and productivity. The associated economic analysis showed large benefits from relatively small additional feed supply at key times of the year. Forage production of annual forages was modelled using APSIM. In light of the poor ability of the APSIM model to simulate un-grazed forage sorghum and lablab yields, or grazed yields of any annual forage, in our study of 14 field sites (Appendix 2) as well as the marginal impact on business profitability that we have demonstrated in this report for dryland annual forage cropping in central Queensland, we recommend caution in the use of APSIM predictions of forage yield in modelling exercises to produce gross margins with a view to estimating the economic value of forages. This approach would potentially compound two errors. Firstly, the output of APSIM appears unlikely to appropriately model the production of annual forages under grazed conditions in central or north Queensland. Secondly, the use of gross margin analysis to indicate the profitability of irrigated (or dryland) annual forages without recognition of the opportunity costs incurred will not provide an appropriate estimate of the economic value of the forages. Monjardino *et al.* (2014) apply an appropriate method of estimating the economic value of irrigated annual forages to north Queensland beef producers and find them to be a very poor investment. Although the results of our case studies do not show the same dramatic and negative impact on profitability as that shown by Monjardino *et al.* (2014) for irrigated annual forages in north Queensland, annual forages in central Queensland appear unlikely to make a positive contribution to profit when the alternatives are appropriately considered.

5.2 Constructed scenarios

The production and economic results from the co-operator sites were subject to the vagaries of the climate during the measurement period, as well as to market fluctuations, and the individual management decisions of the co-operators. The constructed scenarios add value by allowing comparisons of forage performance over a longer time-frame, hence taking out variation due to seasonal and market fluctuations. In addition, standard management practices, based on what was deemed ‘best-practice’, were assumed.

The gross margin analyses for the constructed scenarios (data presented in Table 26 and Table 28) corroborated the results from the co-operator sites (Table 26 and Table 27) in showing that a leucaena-grass pasture provided the highest gross margins when compared to other key perennial legume–grass and annual forage options. However, it is generally accepted that there is a lag time of 3–7 years after planting before the cash flow from leucaena–grass systems break-even when compared to the costs of establishment (e.g. as demonstrated in Bowen *et al.* 2010). This needs to be taken into account when long-lived perennial legumes are being considered.

The other perennial, legume-grass pasture examined in the constructed scenarios, butterfly pea-grass, also performed well in terms of gross margin, with the average ranking being second out of the six forage options studied (Table 28). This ranking also corroborates that determined for the co-operator sites, for butterfly pea-grass pasture. A useful life of 5 years was assumed in the constructed scenarios for butterfly pea. However under conditions where butterfly pea is grown on good quality soils with optimal grazing management, butterfly pea may contribute to a more productive pasture for a longer period. This will correspondingly decrease annual, amortised forage costs and hence increase butterfly pea gross margins. In a mixed forage and grain cropping system the flexibility offered by butterfly pea, compared to leucaena, may add to its usefulness as it can be easily removed to allow the recommencement of annual grain cropping. However, its ability to deplete soil water and be a weed could potentially depress grain yields in the initial phase of the cropping cycle (DPI&F 2005).

In the scenarios for Central Queensland Brigalow and Central Queensland Open Downs sites forage sorghum produced the highest gross margins calculated using owner rates, of the annual forages, and these were much greater than gross margins for the perennial grass pastures (Table 26). However, forage sorghum produced a negative gross margin after interest for the South Queensland Brigalow site, in part due to the lower production expected in this region. As discussed above, the management of grazing is critical to achieving the estimated returns for forage sorghum at any location. It is also important to identify the price risk inherent in purchasing a large number of mature steers suitable to meet the optimal grazing needs of forage sorghum. A small change in the margin between the purchase price and selling price can dramatically impact on the profitability of the forage. Oats and lablab also produced higher gross margins calculated using owner rates than for the perennial grass pasture in each region, except for lablab in South Queensland Brigalow (Table 26).

When considering constructed scenario gross margins calculated using owner rates, the average ranking across regions for forages was the same as for the co-operator sites (Table 28 and Table 27, respectively), except for perennial grass pasture which ranked sixth for the constructed scenarios but fourth for the co-operator sites, ahead of forage sorghum and lablab. The difference in ranking appeared largely due to the tendency towards higher stocking rates, and hence beef production per hectare, at the perennial grass co-operator sites compared to the values assumed as sustainable long-term values in the constructed scenarios.

The gross margins calculated using contract rates for planting and maintaining forages (Table 28) showed that paying a contractor to plant and maintain forages was considerably more expensive than just counting the direct costs incurred using owned machinery. Including more of the indirect costs of machinery ownership in the gross margin calculation possibly reveals more about the long term profitability of forages than the gross margins that only include the variable costs. The use of contract rates to calculate the gross margins had a relatively bigger effect on the gross margins of annual forages, which required annual re-planting, than on the longer-lived perennial-legume grass pastures which had an assumed life in these scenarios of 5 years for butterfly pea and 30 years for leucaena. Forage costs were on average 1.5 times more expensive when using contract rates as compared to owner rates for annual forages compared to 1.4 times for butterfly pea-grass and 1.1 times for leucaena-grass pastures. This resulted in annual forages being more marginal for profitability when contract rates were used, with the average gross margins across the three regions being negative for all three annual forage types. The marginal profitability of the annual forages when contract rates are used to calculate gross margins adds further weight to the conclusions from the whole farm economic case studies indicating that annual forages generally only add value to the beef enterprise if the opportunity cost of plant and unpaid labour are excluded. The results for the constructed scenarios for gross margins calculated using contract rates are in line with the previous calculations of net present value (NPV) of forages calculated in Phase 1 of this project (Bowen *et al.* 2010) which also showed the legume-grass forages, and particularly leucaena, to generally produce the highest returns over a 30-year period of investment.

Adding N fertiliser to annual forage crops increased forage costs considerably and, in constructed scenarios, made it unprofitable using contract rates to plant oats and forage sorghum in the Central Queensland Open Downs and South Queensland Brigalow scenarios, compared to Central Queensland Brigalow where N fertiliser was not applied. However, if using owner rates, adding N fertiliser to oats and forage sorghum still resulted in a profitable outcome and a higher gross margin than for perennial grass pasture except for forage sorghum in South Queensland Brigalow. As there is little existing data available indicating the forage and cattle production responses to level of fertiliser application, these gross margin results are based on assumed responses which may be incorrect. As highlighted above, the high cost of fertiliser application and the uncertainty surrounding the associated production responses of both the forage and livestock, are likely to be a major reason for general lack of fertiliser application by commercial producers in the Fitzroy River catchment when growing high quality forages.

Cattle bred by the enterprise have a different opportunity cost as they enter the forage paddock, compared to purchased stock, and this can make a significant difference to the gross margin. Bought steers have transport costs and sale fees added to their starting value and this higher value is also what is used to calculate the opportunity cost of capital for the livestock. Cattle bred by the enterprise have a value at the nearest point of sale and will generally need to have selling costs deducted from that price to identify their value as they enter the forage. A difference of up to $0.10 to $0.15 per kilogram live weight can be allocated to stock entering forages depending upon whether they were purchased to graze the forage or were already owned. All constructed scenario gross margins were calculated on the assumption that cattle going on to all forages were bought in and thus the gross margins are lower than they would be if the cattle were assumed to have been bred on-property.

The results of any gross margin analysis are extremely sensitive to changes in the cattle price, and very sensitive to changes in cattle growth and cost assumptions. 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 price risk associated with the relatively short periods of ownership of generally many more larger and older steers tied up in the use of annual forages tends to make such activities much more risky than the perennial grass pasture.

There was little correlation of total beef production per hectare, or of cattle price margin, with gross margin across all forages and sites. While there was a trend towards lower gross margin with forage costs, the correlation was not strong ($r = 0.67$). These results support the conclusions from the co-operator sites which indicate that the gross margin is the result of a complex interaction of factors with the major variables determining the profitability of forages being the cost of planting, the cattle buying and selling price (price margin), the daily cattle liveweight gain, the stocking rate and number of grazing days on the forage. The results from these constructed scenarios confirm the findings from the co-operator sites which highlight the importance of considering gross margin performance, in addition to agronomic and livestock performance, when comparing forage options.

In this analysis only the scenario of finishing steers has been considered. Other uses of high quality forages include backgrounding or growing out steers prior to the finishing stage and providing high quality feed for special classes of cattle such as weaners or replacement heifers. Assessing the value added by forages in such circumstances is much more problematic than where the livestock are sold immediately for slaughter and the value added is captured. In particular, the influence of compensatory gains in offsetting the value added by feeding forages to young stock needs to be incorporated in any analysis of benefit.

There are some producers who use summer and winter forages, particularly forage sorghum, as part of a plan to either spell grass pastures, fill feed gaps or carry more cattle in total. The economic benefit of such strategies cannot be assessed by looking at the gross margins for the various pastures and forages involved. For these situations it is more appropriate to look at the impact on the profit of the whole farm business and consider the alternative operating systems available at that level.

Table 26. Comparison of key results from the co-operator sites with values calculated for the constructed scenarios
For definitions of abbreviations, see Glossary of terms and abbreviations. Maximum value in each row highlighted yellow where appropriate

Oats	CQOD			CQB				SQB			
	Constructed scenario	2011	2013	Constructed scenario	2011	2012	2013	Constructed scenario	2011	2012	2013
Soil nitrate N (kg/ha; after fertiliser)		50	118		134	n/a	n/a		42	n/a	n/a
N fertiliser (kg N/ha)	40	0	32	0	28	0	55	20	0	0	0
Soil P (mg/kg; 0-10 cm)		15	15		10	n/a	32		16	n/a	36
Fallow weed control method	minimal till	minimal till	cultivation	minimal till	minimal till	zero till	zero till	minimal till	cultivation	zero till	minimal till
% total grazing area as oats forage	90	13	83	90	78	56	36	90	68	68	68
% oats in the diet [day of grazing period]		83 [14-85]	89 [11-74]		64 [23-138]	100 [42]	78 [17-113]		63 [29-86]	72 [17-139]	65 [24-91]
Forage peak biomass (kg DM/ha); paddock (P), exclosure (E)		5,180 (P) >4,939 (E)	5,425 (P) 12,010 (E)		2,278 (P) 6,609 (E)	4,263 (P) 16,456 (E)	4,476 (P) >5,965 (E)		4,723 (P) 5,704 (E)	4,921 (P) >7,182 (E)	5.175 (P) 6,605 (E)
Oats green leaf as % of biomass at start of grazing		74	67		77	65	55		35	n/a	54
Oats green leaf CP at start of grazing (% DM)		13.1	11.4		21.4	14.9	16.3		4.5	6.3 [Day 63]	10.4
Oats green leaf DMD at start of grazing (%)		81	77		80	77	77		83	75 [Day 63]	76
Average diet CP (%) [day of grazing period]		11.3 [14-85]	14.7 [11-74]		13.6 [23-138]	12.2 [42]	14.2 [17-113]		8.4 [29-86]	12.7 [17-139]	11.1 [24-91]
Average diet DMD (%) [day of grazing period]		61 [14-85]	66 [11-74]		66 [23-138]	65 [42]	64 [17-113]		55 [29-86]	62 [17-139]	61 [24-91]
Total grazing period (days)	76	97	92	83	158	110	143	90	91	138	98
SR (forage area only; AE/ha)	2.2	4.6	2.0	2.0	1.9	1.7	2.2	2.5	1.9	1.4	1.3
SR (total grazing area; AE/ha)	2.0	0.6	1.2	1.8	1.5	1.0	0.8	2.3	1.3	1.0	0.9
HGP	none	none	none	none	none	none	none	none	100-d	100-d	100-d
Group 1		2.5 yr-old steers	20-24 mth-old steers		2.5 yr-old steers	3 yr-old steers	2 & 3 yr-old steers		18-24 mth-old steers	18-24 mth-old steers	18-24 mth-old steers
Entry LW (kg)	512	622	383	505	566	518	503	497	523	449	528
Days LW measured over	76	34	full 92	83	82	59	first 50	90	first 63	79	98
Cattle daily LWG (kg/head/day)	1.1	0.70	0.93	1.1	0.47	1.55	1.09	1.1	0.79	1.47	1.15
Group 2		1.5 yr-old steers	20-24 mth-old steers			2 yr-old steers	2 & 3 yr-old steers		18-24 mth-old steers		
Entry LW (kg)		462	454			416	557		520		
Days LW measured over		42	final 34			30	final 46		final 28		
Cattle daily LWG (kg/head/day)		0.95	0.28			1.69	0.70		0.26		
Group 3						2 yr-old spayed heifers					
Entry LW (kg)						361					
Days LW measured over						30					
Cattle daily LWG (kg/head/day)						2.19					
Total LWG (forage area only; kg/ha/annum)	157	282	177	157	113	257 (includes benefit from grain)	228 (includes benefit from grain)	214	92	208	121
Total LWG (total grazing area; kg/ha/annum)	143	38	108	141	89	144 (includes benefit from grain)	81 (includes benefit from grain)	197	63	141	82
Gross margin from total grazing area ($/ha) – owner rates	35	54	131	123	73	144	177	85	197	157	118
Gross margin from forage area only ($/ha) – owner rates	39	403	214	137	93	256	497	95	290	231	173
Forage costs for forage area only ($/ha) – owner rates	200	193	158	144	164	102	175	178	93	109	94

Forage sorghum	CQOD		CQB			SQB		
	Constructed scenario	**2012-13**	**Constructed scenario**	**2011-12**	**2012-13**	**Constructed scenario**	**2011-12**	**2012-13 Return crop**
Soil nitrate N (kg/ha; after fertiliser)		n/a		90	64		81	
N fertiliser (kg N/ha)	40	0	0	49	40	20	0	0
Soil P (mg/kg; 0-10 cm)		16		23	130		17	
Fallow weed control method	minimal till	zero till	minimal till	minimal till	minimal till	minimal till	cultivation	
% of total grazing area as forage sorghum	100	50	100	61	80	100	73	73
Forage peak biomass (kg DM/ha); paddock (P), exclosure (E)		9,573 (P) 9,573 (E)		30,197 (P) >35,598 (E)	2,308 (P) 17,243 (E)		16,604 (P) 14,814 (E)	2,069 (P)
Sorghum green leaf as % of biomass at start of grazing		23		20	57		30	
Sorghum green leaf CP at start of grazing (% DM)		14.3		14.2	13.3		11.4	
Sorghum green leaf DMD at start of grazing (%)		65		68	64		66	
Average diet CP (% DM) [day of grazing period]		7.2 [3-97]		6.6 [11-113]	10.1 [4-113]		10.3 [15-60]	10.0 [5-53]
Average diet DMD (%) [day of grazing period]		52 [3-97]		53 [11-113]	58 [4-113]		57 [15-60]	57 [5-53]
Total grazing period (days)	130	124	120	112	139	130	108	52
SR (forage area only; AE/ha)	3.0	1.7	3.0	2.2	3.3	2.5	3.3	1.6
SR (total grazing area; AE/ha)	3.0	0.9	3.0	1.3	2.6	2.5	2.4	1.2
HGP	none	none	none	none	none	none	none	none
Group 1		2 yr-old steers		2 yr-old steers	1-1.5 yr-old steers		2 yr-old steers	2 yr-old steers
Entry LW (kg)	518	507	524	477	336	525	549	563
Days LW measured over	130	124	120	112	33	130	108	52
Cattle daily LWG (kg/head/day)	0.6	0.43	0.6	0.37	1.1	0.55	0.15	0.70
Group 2				1 yr-old steers			1 yr-old steers	1 yr-old steers
Entry LW (kg)				383			428	397
Days LW measured over				112			108	52
Cattle daily LWG (kg/head/day)				0.30			0.59	1.1
Group 3				1 year-old spayed heifers				
Entry LW (kg)				335				
Days LW measured over				112				
Cattle daily LWG (kg/head/day)				0.23				
Total LWG (forage area only; kg/ha/annum)	199	82	183	87	316	152	192	74
Total LWG (total grazing area; kg/ha/annum)	199	41	183	53	253	152	140	54
Gross margin from total grazing area ($/ha) – owner rates	82	41	159	12	-48	-14	243	22
Gross margin from forage area only ($/ha) – owner rates	82	87	159	20	-60	-14	333	30
Forage costs for forage area only ($/ha) – owner rates	194	24	138	169	144	172	125	16

Lablab	CQOD		CQB		SQB
	Constructed scenario	**2011-12**	**Constructed scenario**	**2012-13**	**Constructed scenario**
Soil nitrate N (kg/ha)		46		n/a	
Soil P (mg/kg; 0-10 cm)		23		15	
Fallow weed control method	minimal till	minimal till	minimal till	zero till	minimal till
% of the total grazing area as lablab forage	90	43 (final 62 d)	90	73	90
% lablab in the diet [day of grazing period]		31 [29]		76 [16-107]	
Forage peak biomass (kg DM/ha); paddock (P), exclosure (E)		5,484 (P) >5,021 (E)		6,543 (P) 14,253 (E)	
Lablab green leaf as % of biomass at start of grazing		32		58	
Lablab green leaf CP at start of grazing (% DM)		26.5		18.0	
Lablab green leaf DMD at start of grazing (%)		77		72	
Average diet CP (% DM) [day of grazing period]		9.9 [29]		13.0 [16-107]	
Average diet DMD (%) [day of grazing period]		58 [29]		59 [16-107]	
Total grazing period (days)	100	103	100	111	90
SR (forage area only; AE/ha)	2.5	1.5	2.5	1.8	2.5
SR (total grazing area; AE/ha)	2.3	0.6	2.3	1.3	2.3
HGP	none	none	none	none	none
Group 1		20-24 month-old steers		18-24 month-old steers	
Entry LW (kg)	516	439	516	410	524
Days LW measured over	100	final 62	100	first 90	90
Cattle daily LWG (kg/head/day)	0.8	0.81	0.8	1.22	0.8
Group 2		20-24 month-old steers		18-24 month-old steers	
Entry LW (kg)		458		421	
Days LW measured over		final 54		111	
Cattle daily LWG (kg/head/day)		0.64		0.98	
Group 3				8-10 month-old steers and heifers	
Entry LW (kg)				249	
Days LW measured over				final 38	
Cattle daily LWG (kg/head/day)				0.65	
Total LWG (forage area only; kg/ha/annum)	171	96	171	212	153
Total LWG (total grazing area; kg/ha/annum)	157	41	157	156	141
Gross margin from total grazing area ($/ha) – owner rates	77	38	105	50	6
Gross margin from forage area only ($/ha) – owner rates	86	89	117	68	7
Forage costs for forage area only ($/ha) – owner rates	**170**	**85**	**170**	**113**	**170**

Leucaena-grass	CQOD			CQB			SQB		
	Constructed scenario	**1st 12 mths (23/02/12-28/02/13)**	**2nd 12 mths (01/03/13-27/02/14)**	**Constructed scenario**	**Pdk 1: 476 d (10/01/12-30/04/13)**	**Pdk 2: 365 d (08/04/13-08/04/14)**	**Constructed scenario**	**1st 12 mths (25/02/12-17/02/13)**	**Final 112 d (18/02/13-10/06/13)**
Soil P (mg/kg; 0-10 cm)		11			20	110		15	
Average (and range) of edible leucaena biomass (kg DM/ha in forage area)		236 (97-666)	196 (17-172)		438 (59-1,212)	744 (54-1,922)		470 (145-794)	417 (88-747)
Average (and range) of grass biomass (kg DM/ha)		5,620 (2,894-10,182)	4,369 (2,776-5,623)		2,700 (1,212-5,550)	2,746 (988-5,429)		3,610 (1,930-5,289)	2,689 (2,515-2,862)
% of the total grazing area planted to leucaena	100	82	82	100	53	66	100	100	100
% leucaena in the diet [day of grazing period]		44 [37-335]	49 [8-361]		37 [25-477]	61 [11-341]		62 [9-289]	70 [4-92]
Average edible leucaena CP (% DM)		25.9	23.3		23.1	22.9		19.6	18.3
Average edible leucaena DMD (%)		67	64		67	61		62	59
Average diet CP (% DM) [day of grazing period]		11.4 [37-335]	13.8 [8-361]		9.6 [25-477]	12.9 [11-341]		12.5 [9-289]	15.8 [4-92]
Average diet DMD (%) [day of grazing period]		62 [37-335]	64 [8-361]		44 [25-477]	63 [11-341]		62 [9-289]	63 [4-92]
Total monitoring period (days)	365	371	363	365	476	365	365	358	112
Days of grazing per period in target pdk	270	140	186	270	476	318	240	300	51
Average SR (total grazing area; AE/ha/365 d or total monitoring period)	0.44	0.64	0.81	0.44	0.65	0.87	0.36	0.82	2.48
HGP	None	400-d as weaners	400-d as weaners	none	none	none	none	100-d	100-d
Group 1		Spring-Summer	Early Autumn		Jan-Apr	May-Jul		End Feb-end Mar	Mid Feb-mid May
Entry LW (kg)	353	426	414	353	370	491	380	590	578
Days LW measured over	270	78	94	270	90	76	240	30	84
Cattle daily LWG (kg/head/day)	0.9	0.38	1.53	0.9	0.93	0.55	0.9	1.52	1.23
Group 2		Summer	Mid-late Autumn		Apr-Aug	May-Aug			
Entry LW (kg)		409	462			443			
Days LW measured over		93	55		116	124			
Cattle daily LWG (kg/head/day)		0.40	0.49		0.52	0.35			
Group 3			Winter-Spring		Aug-Feb	Sep-Nov			
Entry LW (kg)			364			541			
Days LW measured over			194		197	75			
Cattle daily LWG (kg/head/day)			0.31		-0.07	0.29			
Group 4			Winter-Spring		Feb-Mar	Heifers, Dec-Apr			
Entry LW (kg)			356			440			
Days LW measured over			141		35	121			
Cattle daily LWG (kg/head/day)			0.41		1.30	0.94			
Group 5			Summer		Mar-Apr				
Entry LW (kg)			336						
Days LW measured over			77		38				
Cattle daily LWG (kg/head/day)			1.14		1.18				
Total LWG (total grazing area; kg/ha/annum)	140	148	234	140	86 -1st 12 mths 129 - per 476 d	175	112	306 (includes benefit from grain)	108 – per 112 d
Gross margin from total grazing area ($/ha/annum) – owner rates	163	142	192	169	90 – per 476 d	304	107	193	n/a
Forage costs for forage area only ($/ha/annum) – owner rates	40	35	35	42	47 – per 476 d	35	42	17	n/a

Butterfly pea-grass	CQOD			CQB		SQB
	Constructed scenario	1st 12 mths (06/03/12-06/03/13)	2nd 12 mths (07/03/13-06/03/14)	Constructed scenario	375 days (28/05/12-07/06/13)	Constructed scenario
Soil P (mg/kg; 0-10 cm)		n/a			59	
Average (and range) of butterfly pea biomass – paddock (kg DM/ha)		143 (0-845)	302 (19-648)		1,138 (190-2,368)	
Average (and range) of butterfly pea biomass – exclosure (kg DM/ha)		174 (0-798)	505 (92-846)		1,829 (1,241-2,417)	
Average (and range) of grass biomass – paddock (kg DM/ha)		5,519 (4,223-6,687)	4,775 (3,822-6,464)		3,480 (1,228-4,758)	
Average (and range) of grass biomass – exclosure (kg DM/ha)		4,835 (2,333-7,981)	3,287 (1,017-4,777)		3,500 (3.492-3,509)	
% of the total grazing area planted to butterfly pea	100	100	100	100	64	100
% C_3 species (non-grass) in the diet [day of grazing period]		3.6 [77-261]	9.4 [51-362]		51 [302 & 325]	
Average diet CP (% DM) [day of grazing period]		7.5 [77-261]	8.8 [51-362]		12.7 [302 & 325]	
Average diet DMD (%) [day of grazing period]		59 [77-261]	59 [51-362]		58 [302 & 325]	
Total monitoring period (days)	365	365	364	365	375	365
Days of grazing per period	270	181	223	250	139	240
Average SR (total grazing area; AE/ha/365 d or total monitoring period)	0.59	0.29	1.09	0.55	0.36	0.53
HGP	none	none	2nd group, 400-d	none	none	none
Group 1		Autumn	Autumn		Early winter, heifers	
Entry LW (kg)	421	480	377	446	309	452
Days LW measured over	270	85	67	250	28	240
Cattle daily LWG (kg/head/day)	0.65	0.68	1.18	0.6	0.78	0.6
Group 2			Winter-early Spring		Mid winter, heifers	
Entry LW (kg)			344		331	
Days LW measured over			79		22	
Cattle daily LWG (kg/head/day)			-0.01		0.28	
Group 3			Summer		Early autumn, pregnant heifers	
Entry LW (kg)			220		441	
Days LW measured over			79		24	
Cattle daily LWG (kg/head/day)			1.04		0.92	
Group 4					Mid autumn, pregnant heifers	
Entry LW (kg)					463	
Days LW measured over					30	
Cattle daily LWG (kg/head/day)					1.28	
Group 5					Late autumn-early winter, pregnant heifers	
Entry LW (kg)					502	
Days LW measured over					27	
Cattle daily LWG (kg/head/day)					-0.26	
Total LWG (total grazing area; kg/ha/annum)	128	50	245	108	80	103
Gross margin from total grazing area ($/ha) – owner rates	110	17	379	98	34	59
Forage costs for forage area only ($/ha) – owner rates	**58**	**21**	**21**	**58**	**21**	**59**

Perennial grass	**CQOD**				**CQB**		**SQB**			
	Constructed scenario	**1st 12 mths (22/12/11-21/12/12)**	**2nd 12 mths (22/12/12-16/12/13)**	**Final 57 d (17/12/13-12/02/14)**	**Constructed scenario**	**476 d (10/01/12-30/04/13)**	**Constructed scenario**	**1st 12 mths 06/07/11-04/07/12**	**2nd 12 mths 05/07/12-03/07/13**	**Final 8.4 mths 04/07/13-17/03/14**
Soil nitrate N (kg/ha)		n/a				n/a		14.8		
Soil P (mg/kg; 0-10 cm)		7				28		22		
Average (and range) of pasture biomass – paddock (kg DM/ha)		4,549 (1,777-5,682)	3,819 (3,388-4,539)	4,409		4,285 (1,936-9,716)		3,673 (3,328-3,876)	2,186 (1,842-2,530)	2,371 (1,294-3,922)
Average (and range) of pasture biomass - exclosure (kg DM/ha)		6,146 (4,943-7,433)	2,904 (1,397-4,637)	93		3,890 (1,618-5,397)		3,444 (3,012-3,876)	2,893 (935-3,996)	2,303 (1,099-3,574)
% C_3 species (non-grass) in the diet [day of grazing period]		16 [267-302]	11 [32-343]	8 [4-58]		9 [25-444]		9 [22-365]		8 [2-257]
Average diet CP (% DM) [day of grazing period]		7.0 [267-302]	5.6 [32-343]	8.9 [4-58]		6.9 [25-444]		6.9 [22-365]		5.0 [2-257]
Average diet DMD (%) [day of grazing period]		57 [267-302]	57 [32-343]	60 [4-58]		54 [25-444]		53 [22-365]		55 [2-257]
Total monitoring period (days)	1,006	365	359	57	891	476	870	364	365	256
Days of grazing per period	1,006	157	193	57	891	476	870	296	0	206
Average SR (total grazing area; AE/ha)	0.17	0.17	0.15	0.35	0.33	0.64	0.33	0.87	0	0.55
HGP	none	none	400-d		none	none	none	Final group: 70-d		Final group: 100-d
Group 1		Summer, 20-24 mth-old steers				12-16 mth-old steers		Early Jul-end Sep, 6-11 mth-old heifers		Early Jul-mid Oct, 8 mth-old steers
Entry LW (kg)	213	426			213	356	240	197		201
Days LW measured over	1,006	75			891	476	870	86 or 77		105
Cattle daily LWG (kg/head/day)	0.38	0.73			0.43	0.47	0.41	0.34		0.21
Group 2			Early Winter-early Summer, 5-12 mth-old steers					Early Oct-end Nov, 9-14 mth-old heifers		End Jul-mid Oct, 9 mth-old steers
Entry LW (kg)			176					253		224
Days LW measured over			251					58		80
Cattle daily LWG (kg/head/day)			0.43					0.53		0.08
Group 3								Early Feb-early Jul, 12-17 mth-old steers		Mid Jan-mid Mar, 14 mth-old steers
Entry LW (kg)								413		303
Days LW measured over								151		62
Cattle daily LWG (kg/head/day)								0.49		0.96
Total LWG (total grazing area; kg/ha/annum)	25	31	41	13 – per 57 days	57	85 -1st 12 mths 138 - per 476 d	53	169	0	64 – per 256 d
Gross margin from total grazing area ($/ha/annum) – owner rates	27	25	51	n/a	56	132 - per 476 d	49	285	-5	-12 – per 256 d

Note: assumptions had to be made for some sites, across all forage types, to calculate the total annual LWG, where some groups of cattle grazing the paddock were not weighed. Only those groups with measured LWG have daily LWG figures presented in this table.

Table 27. Co-operator sites: summary by forage type of key forage, animal and economic performance data
For definitions of abbreviations, see Glossary of terms and abbreviations. Values are the average (and range), across data sets, for each forage type. Maximum value in each row highlighted yellow

	Annual forages			Perennial forages		
	Oats	Forage sorghum	Lablab	Leucaena-grass	Butterfly pea-grass	Perennial grass
Number of data sets (full 12-month periods for perennials)	8	5	2	5	3	5
Peak biomass in the un-grazed exclosures (kg DM/ha)[A]	8,184 (4,939-16,456)	19,307 (9,573-35,598)	9,637 (5,021-14,253)	n/a	n/a	n/a
Forage biomass measurements in the grazed paddocks (kg DM/ha)[B]	4,555 (2,278-5,425)	12,150 (2,069-30,197)	6,014 (5,484-6,543)	*Leucaena*: 417 (196-744) *Grass*: 3,809 (2,700-5,620)	*Butterfly pea*: 528 (143-1,138) *Grass*: 4,591 (3,480-5,519)	3,702 (2,186-4,549)
Total grazing days per annum or total period	116 (91-158)	107 (52-139)	107 (103-111)	284 (140-476)	181 (139-223)	224 (0-476)
Diet CP (% DM)	12.3 (8.4-14.7)	8.8 (6.6-10.3)	11.5 (9.9-13.0)	12.0 (9.6-13.8)	9.7 (7.5-12.7)	6.6 (5.6-7.0)
Diet DMD (%)	63 (55-66)	55 (52-58)	59 (58-59)	59 (44-64)	59 (58-59)	55 (53-57)
Total LWG (kg/ha per annum or total grazing period) per total grazing area	93 (38-144)	108 (41-253)	99 (41-156)	198 (129-306)	125 (50-245)	76 (0-169)
Forage costs ($/ha per annum) per forage area only; owner rates[C]	136 (93-193)	96 (16-169)	99 (85-113)	34 (17-47)	21 (21-21)	2 (0-5)
Gross margin ($/ha per annum or total grazing period) per total grazing area; owner rates	131 (54-197)	54 (-48-243)	44 (38-50)	184 (90-304)	143 (34-379)	98 (-5-285)

[A]These figures are the maximum biomass measured in fenced (non-grazed) exclosure sites and are an indication of the total biomass grown during the grazing period.
[B]These figures are the peak biomass measured in the paddock for annuals, and the average biomass measured in the grazed paddock over the duration of monitoring for perennials. They do not indicate the total biomass grown during that period due to being the net result of what was grown and what was consumed by grazing livestock. Figures for leucaena biomass represent only the edible material (i.e. leaves and stems up to 5 mm in diameter).
[C]Annual forage costs for perennials were calculated by amortising establishment and maintenance costs (determining an average annual cost over the life of the forage).

Table 28. Constructed scenarios: comparison of the effect of using owner rates or contract rates on forage costs and gross margins
For definitions of abbreviations, see Glossary of terms and abbreviations. Values are the average (and range), across three regions, for each forage type. Maximum value in each row highlighted yellow

	Annual forages			Perennial forages		
	Oats	Forage sorghum	Lablab	Leucaena-grass	Butterfly pea-grass	Perennial grass
	Forage costs per forage area only ($/ha)					
Owner rates	174 (144-200)	168 (138-194)	170 (170-170)	41 (40-42)	58 (58-58)	0 (0-0)
Contract rates	266 (223-298)	260 (217-292)	248 (248-248)	45 (44-46)	83 (83-83)	0 (0-0)
	Gross margin per total grazing area ($/ha)					
Owner rates	81 (35-123)	76 (-14-159)	63 (6-105)	146 (107-169)	89 (59-110)	44 (27-56)
Contract rates	-2 (-54-52)	-16 (-113-80)	-8 (-65-34)	142 (103-165)	64 (34-84)	44 (27-56)

6 Conclusions

This report brings together, for the first time, data sets for forage and associated animal production, as well as gross margins, for commercial beef enterprises in Queensland. Farm case studies with commercial producers, as well as constructed scenarios where variables could be held constant, provided further insights into the profitability of sown forages. The key conclusions about the performance and value of forages in the Fitzroy River catchment are given below.

6.1 Co-operator sites

6.1.1 Forage production

- Forage sorghum crops produced the greatest biomass of all forage types: 19,307 kg DM/ha average across sites, for the un-grazed exclosure. On average, oats and lablab forage crops produced a similar peak biomass in the exclosure, which was approximately half that for forage sorghum: 8,184 and 9,637 kg DM/ha, respectively.
- Edible leucaena (leaves and stems up to 5 mm in diameter) presentation yield, averaged over the period of monitoring, was in same order as for the total butterfly pea presentation yield: 417 and 528 kg DM/ha, respectively.
- Perennial grass presentation yield, averaged over the duration of monitoring, ranged from 2,186-5,620 kg DM/ha across the 13 individual data sets for perennial sites. The biomass measurements for grass growing with the perennial legumes, leucaena or butterfly pea, were in the same order as for the perennial grass-only sites.
- Oats forage, provided in association with varying amounts of perennial grass, resulted in the greatest average diet quality in terms of CP and DMD (12.3% DM and 63%, respectively), closely followed by leucaena-grass forage sites (CP 12.0% DM and DMD 59%) and lablab forage sites which were also associated with perennial grass (CP 11.5% DM, DMD 59%). Perennial grass sites resulted in the lowest average diet CP and DMD of all forage types (6.6% DM and 55%, respectively).
- Leucaena-grass forage resulted in the greatest average total grazing days per annum of all annual and perennial forage types: 284 days/annum. All three annual forage crop types were grazed for greater than 100 days/annum, on average.
- Of the sites monitored, soil fertility was generally low and fertiliser application was not common practice. It is likely that both soil N and P fertility may be limiting production of many annual forage crops in the Fitzroy River catchment. Phosphorus fertility may be limiting production of perennial legume-grass pastures.
- Very high stocking rates were used by commercial producers on some perennial grass-only paddocks in some years. Some of these pastures were showing signs of nitrogen rundown, in terms of pasture composition and yield, and would benefit from legume inclusion. The observations of the project team are that this scenario appears to be typical of many perennial grass pastures across the Fitzroy River catchment.

6.1.2 Animal production

- On average, sown annual, and perennial legume-grass, forages resulted in greater beef output compared to that from perennial grass pasture, in terms of kg/ha/annum.
- Leucaena-grass sites produced the greatest average total beef production of all forage types: 198 kg/ha/annum, which was 2.6 times greater than the average annual beef production from perennial grass pasture (76 kg/ha/annum). Furthermore, there appeared to be less variability between sites and years in total beef production from leucaena-grass pastures compared to perennial grass and butterfly pea-grass pastures.
- Butterfly pea-grass sites ranked second for total beef production (125 kg/ha/annum).
- The average total beef production for the three types of annual forage crop was within the range 93-108 kg/ha/annum.
- Forage sorghum, despite producing twice as much forage biomass as the other annual forages, oats and lablab, on average resulted in similar total beef production. This was due to poor utilisation of forage sorghum biomass in many instances as well as a lower quality diet and hence lower individual animal production from forage sorghum.
- Observations at the co-operator sites indicated that grazing management practices may in some cases be limiting productivity and profitability of annual forage crops in the Fitzroy River catchment, particularly for forage sorghum crops which are difficult to manage to optimise forage quality and therefore animal production. Commonly, grazing commenced once the forage sorghum crops were already mature, and at several sites, stocking rates were too low to prevent the crop maturing.
- Some producers are not inoculating cattle grazing leucaena-grass pastures with the rumen fluid inoculum, or using carrier cattle. This may be causing sub-clinical mimosine and dihydroxypyridine toxicity which will reduce cattle growth rates.
- HGPs were not commonly used in cattle grazing the high quality forages monitored in this project. There was often insufficient information available from the co-operators on cattle price data and target markets to accurately discern the reasons for the lack of use of HGPs and whether this could be decreasing potential profits.
- Monitoring of cattle weight gain during grazing periods on high quality forages may allow more optimal timing of sale. Many producers contacted in the process of engaging co-operators for this project commented that they do not usually monitor weight gain of cattle on forages. Those producers that do monitor weight gain generally only weigh at the start and end of a grazing period.
- A significant proportion of cattle grazing annual forage crops in this project were not sold directly to market but were returned to perennial grass pastures after grazing the crop. This was either because: the forage was being used to spell pastures (particularly for forage sorghum crops), weaners or younger cattle were fed, or a proportion of the mob did not attain desired finishing weights or fat cover. In these cases, the gross margins calculated, were not actually realised by the producers, as although the cattle were valued upon exiting the forage, they were not actually sold. For these cases, the true economic benefit of feeding the annual forage crops would have to be determined on an individual basis by examining the effect on the profit of the whole farm business. However, it is clear that where cattle graze wet season perennial pastures in the summer season after grazing a forage oats crop it is highly likely that compensatory gain effects would erode most of the liveweight advantage provided by forage oats. This would likely make the venture unprofitable when considered in the context of overall farm profitability.

6.1.3 Economic performance

Gross margins

Gross margins are the first step in determining the effect of sown forages on farm profit. They show whether the forage activity itself makes a profit or loss, at the paddock level. A total of 24 annual and perennial forage sites were monitored on 12 producer co-operator properties in the Fitzroy River catchment over the period 2011 to 2014.

- There was a wide range in profitability of annual and perennial forage options both within and across forage types.
- Profitability was the combined result of forage and beef production (kg/ha), forage costs, and cattle price margin (sale price less purchase price). These factors were, in turn, influenced by management, seasonal and market factors.
- There was no single, over-riding factor that determined the profitability of forage systems. This confirms the importance of optimising all contributing factors in order to maximise profitability of sown forage systems.
- Leucaena-grass sites had the highest average gross margin ($184/ha/annum) averaged across all sites and years.
- Butterfly pea-grass produced the second highest average gross margin: $143/ha/annum.
- Oats forage produced a higher average gross margin ($131/ha/annum) than perennial grass pasture ($98/ha/annum).
- Forage sorghum and lablab resulted in lower average gross margins than for perennial grass pasture ($54 and $44/ha/annum, respectively).

Farm case studies

Farm economic case studies were conducted to examine the value of the sown forage systems to the ‘whole farm’ or business, relative to other alternatives which could also be undertaken such as grazing perennial grass pasture or growing a grain crop. These analyses compared the net profit generated by alternative systems and accounted for changes in such factors as unpaid labour and capital that would be likely to occur. The insights into the profitability of forages, provided by five case studies conducted with producers in the Fitzroy River catchment, can be summarised as follows:

- Under current market and cost conditions:
  - Perennial legume-grass pastures have a significant economic advantage over perennial grass pasture and annual forages.
  - However, high-output perennial legume-grass forages are not as profitable as grain cropping, when grain cropping is a feasible alternative.
  - The effect of annual forages on farm profitability can be marginal, and the increase in business risk significant, requiring a careful assessment of the role of annual forages in improving overall profitability.
  - Where high-output annual forages are currently grown successfully and grain crops are a realistic option, it is most likely that grain crops will provide substantially greater economic returns than the alternative annual forage crop.
  - Where grain crops are not an alternative and grass pasture is the alternative option under consideration, annual forages are a high cost option with high timeliness requirements that may only add value to the beef enterprise if the opportunity cost of plant and unpaid labour are excluded.

6.2 Constructed scenarios

Example gross margin analyses were conducted for constructed scenarios based on the same three regions and six forage types monitored on the co-operator sites. These scenarios allowed the performance of forages to be modelled over a longer time-frame, hence taking out the variation due to seasonal and market fluctuations. In addition, standard management practices, based on what was deemed best-practice, were assumed.

- These results support the conclusions from the co-operator sites which indicate that forage gross margins are the result of a complex interaction of factors with the major variables determining the profitability of forages being the:
  - daily cattle liveweight gain, stocking rate, and number of grazing days on the forage, the combined result of which is total beef production per hectare;
  - cost of planting;
  - cattle buying and selling price (cattle price margin).
- As for the co-operator sites, leucaena-grass pasture produced the highest gross margins when compared to other key perennial legume-grass and annual forage options.
- Butterfly pea grass also performed well with the average ranking for gross margin being second out of the six forage options studied.
- Forage sorghum produced the highest gross margins of the annual forages, calculated using owner rates, for Central Queensland Brigalow and Central Queensland Open Downs sites. These results assume a high utilisation of forage sorghum biomass, which was shown at the co-operator sites to be difficult to achieve. Forage sorghum produced a negative gross margin for the South Queensland Brigalow site, in part due to the lower production expected in this area.
- Oats and lablab also produced higher gross margins, calculated using owner rates, than for the perennial grass pasture in each region, except for lablab in South Queensland Brigalow.
- When contract rates rather than owner rates were used to calculate gross margins, forage costs were on average 1.5 times more expensive for the annual forages, 1.4 times more expensive for butterfly pea-grass and 1.1 times more expensive for leucaena-grass pastures. This resulted in annual forages being more marginal for profitability when contract rates were used, with the average gross margins across the three regions being negative for all three annual forage types.
- The marginal profitability of the annual forages when contract rates were used is in line with the conclusions from the whole farm economic analyses which indicate that growing annual forages may not provide the most profitable enterprise.

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9 Addendum – assumptions for the constructed gross margin scenarios

A description of each of the constructed scenarios for gross margin analysis sites and the general assumptions used in the gross margin analysis are detailed in Table 29-Table 31. In particular, the following points should be remembered when perusing the tables and considering the results of the gross margin analysis:

- Cattle production from each of the forage types was assessed by comparing the scenario of steers finished to the same target weight (596 kg liveweight; 310 kg carcass weight).
- The grazing days, stocking rate and daily liveweight gain for each forage at each site were based on an assessment of measured values in both unpublished and published reports and the considered judgments of experienced beef research and extension staff.
- These values are based on the assumption that forages are grown and grazed using best-practice agronomic management and represent the expected long-term average performance over both good and bad rainfall years.
- The gross margin analyses were conducted using the assumption that the same market conditions occur across all forages in each region and the results compare the economic performance of the forages based on the defined set of market assumptions.
    - Livestock purchase prices were taken from long-term averages at the Gracemere (Central Queensland Open Downs and Central Queensland Brigalow) or Roma (South Queensland Brigalow) saleyards.
    - The livestock purchase 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.

All terms and abbreviations used in the tables are given at the start of this report.

Table 29. Constructed scenario for Central Queensland Open Downs (Emerald-Capella area): description and assumptions for gross margin analysis

Factor	Description
General description and assumptions	
Broad land type	Open Downs
Soil type and characteristics	Black vertosol-Orion PAWC: 150 mm Soil depth: 75 cm 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%)
Place of cattle purchase	Gracemere saleyards
Place of cattle sale	Rockhampton meatworks
Perennial grass pasture	
Pasture characteristics	Native pasture, primarily Queensland bluegrass
Stocking rate	0.17 AE/ha (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 1st Dec for three months; 318 days from joining to mean calving date; mean calving weight: 35 kg, LWG from birth to weaning: 0.9 kg/head/day; wean on 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)	 139 kg/head/year (0.38 kg/head/day) 0.77 kg/head/day 0.34 kg/head/day 0.11 kg/head/day 0.34 kg/head/day
Calculated grazing days from weaning to turn-off	1006
Age at turn-off	40 months
Animal health treatments	5-in-1 x 1 (booster at weaning)
Forage oats	
Sowing window	1 April – 1 June
Sowing rate	40 kg/ha
Fertiliser	40 kg N/ha applied pre-plant with air-seeder
Fallow weed control	Amicide 625 0.75 L/ha x 2, Glyphosate 450 CT 1.5 L/ha x 2; chisel plough x 1, scarifier x 1
In-crop weed control	MCPA LVE 1 L/ha x 1 application
Planter	Air-seeder, twin bin, spear points and presswheels
% of the paddock sown to forage	90% of total grazing area
Grazing days on forage	76
Starting cattle weight (kg)	512
LWG (kg/head/day)	1.1
Stocking rate	2.0 AE/ha
Animal health treatments	5-in-1 x 1

Factor	Description
Forage sorghum	
Sowing window	1 September – 31 January
Sowing rate	4 kg/ha
Fertiliser	40 kg N/ha applied pre-plant with air-seeder
Fallow weed control	Amicide 625 0.75 L/ha x 2, Glyphosate 450 CT 1.5 L/ha x 2; chisel plough x 1, scarifier x 1
In-crop weed control	Atrazine 3 L/ha x 1 application post-plant, pre-emerge
Planter	Air-seeder, twin bin, spear points with presswheels
Grazing days on forage	130
Starting cattle weight (kg)	518
LWG (kg/head/day)	0.6
Stocking rate	3.0 AE/ha
Animal health treatments	5-in-1 x 1
Lablab	
Sowing window	1 September – 31 January
Sowing rate	25 kg/ha
Fallow weed control In-crop weed control	Amicide 625 0.75 L/ha x 2, Glyphosate 450 CT 1.5 L/ha x 2; chisel plough x 1, scarifier x 1 Spinnaker 100 g/ha x 1 application post-plant, pre-emerge
Planter	Air-seeder, twin bin, spear points with presswheels
% of the paddock sown to forage	90% of total grazing area
Grazing days on forage	100
Starting cattle weight (kg)	516
LWG (kg/head/day)	0.8
Stocking rate	2.3 AE/ha
Animal health treatments	5-in-1 x 1
Leucaena–grass	
Assumed life of the forage	30 years
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
Sowing rate	2.5 kg/ha leucaena; 4 kg/ha tropical grass species
Fertiliser and maintenance	At sowing: 60 kg MAP/ha; maintenance (every 10 years): 100 kg MAP/ha, mechanical cutting
Fallow weed control	Amicide 625 0.50 L/ha x 3, Roundup CT 1.5 L/ha x 3, chisel plough x 1
In-crop weed control	Spinnaker 140 g/ha x 1 and Roundup 1.5 L/ha x 1 application over ½ the area post-plant, pre-emerge
Leucaena planter	Leucaena planter (precision row crop planter)
Grass planter	Drum seeder (at the same time as planting leucaena)
Grazing days on forage	270
Starting cattle weight (kg)	353
LWG (kg/head/day)	0.9
Stocking rate over 365 days	0.44 AE/ha
Animal health treatments	5-in-1 x 1; inoculate 10% of the herd at the rate of 100 mL leucaena rumen fluid inoculum/steer

Factor	Description
Butterfly pea–grass	
Assumed life of the forage	5 years
Adjustment to account for time-lag in production after planting	In the year of planting the grazing days were halved but SR and LWG kept constant
Sowing window	15 December – 15 March
Sowing rate	10 kg/ha Milgarra; 2 kg/ha tropical grass species
Fallow weed control	Amicide 625 0.50 L/ha x 3, Roundup CT 1.5 L/ha x 3; Chisel plough x 2, scarifier x 1
In-crop weed control	Spinnaker 150 g/ha x 1 application post-plant, pre-emerge
Butterfly pea planter	Air–seeder, twin bin, spear points with presswheels
Grass planter	Drum seeder (grass planted 12 months later)
Grazing days on forage	270
Starting cattle weight (kg)	421
LWG (kg/head/day)	0.65
Stocking rate over 365 days	0.59 AE/ha
Animal health treatments	5-in-1 x 1

Table 30. Constructed scenario for Central Queensland Brigalow (Biloela-Rolleston area): description and assumptions for gross margin analysis

Factor	Description
General description and assumptions	
Broad land type	Brigalow
Soil type and characteristics	Grey vertosol PAWC: 137 mm Soil depth: 150 cm 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%)
Place of cattle purchase	Gracemere saleyards
Place of cattle sale	Biloela meatworks
Baseline pasture	
Pasture characteristics	Buffel grass (older pastures), minimal tree regrowth
Stocking rate	0.33 AE/ha (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 D ec for 3 months; 318 days from joining to mean calving date; mean calving weight: 35 kg, LWG from birth to weaning: 0.9 kg/head/day; wean on 1 May at 6.5 months and 213 kg
Long-term, steer LWG: Annual Summer (D-J-F) Autumn (M-A-M) Winter (J-J-A) Spring (S-O-N)	 157 kg/head/year (0.43 kg/head/day) 0.84 kg/head/day 0.38 kg/head/day 0.24 kg/head/day 0.38 kg/head/day
Calculated grazing days from weaning to turn-off	891
Age at turn-off	36 months
Animal health treatments	5-in-1 x 1 (booster at weaning)
Forage oats	
Sowing window	1 April – 1 June
Sowing rate	40 kg/ha
Fertiliser	0 kg N/ha
Fallow weed control	Amicide 625 0.75 L/ha x 2, Glyphosate 450 CT 1.5 L/ha x 2; chisel plough x 1, scarifier x 1
In-crop weed control	MCPA LVE 1 L/ha x 1 application
Planter	Air-seeder, twin bin, spear points and presswheels
% of the paddock sown to forage	90% of total grazing area
Grazing days on forage	83
Starting cattle weight (kg)	505
LWG (kg/head/day)	1.1
Stocking rate (total area)	1.8 AE/ha
Animal health treatments	5-in-1 x 1

Factor	Description
Forage sorghum	
Sowing window	1 September – 31 January
Sowing rate	4 kg/ha
Fertiliser	0 kg N/ha
Fallow weed control	Amicide 625 0.75 L/ha x 2, Glyphosate 450 CT 1.5 L/ha x 2; chisel plough x 1, scarifier x 1
In-crop weed control	Atrazine 3 L/ha x 1 application post-plant, pre-emerge
Planter	Air-seeder, twin bin, spear points with presswheels
Grazing days on forage	120
Starting cattle weight (kg)	524
LWG (kg/head/day)	0.6
Stocking rate	3.0 AE/ha
Animal health treatments	5-in-1 x 1
Lablab	
Sowing window	1 September – 31 January
Sowing rate	25 kg/ha
Fallow weed control	Amicide 625 0.75 L/ha x 2, Glyphosate 450 CT 1.5 L/ha x 2; chisel plough x 1, scarifier x 1
In-crop weed control	Spinnaker 100 g/ha x 1 application post-plant, pre-emerge
Planter	Air-seeder, twin bin, spear points with presswheels
% of the paddock sown to forage	90% of total grazing area
Grazing days on forage	100
Starting cattle weight (kg)	516
LWG (kg/head/day)	0.8
Stocking rate	2.3 AE/ha
Animal health treatments	5-in-1 x 1
Leucaena–grass	
Assumed life of the forage	30 years
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
Sowing rate	2.5 kg/ha Leucaena; 4 kg/ha tropical grass species
Fertiliser and maintenance	At sowing: 60 kg MAP/ha; maintenance (every 10 years): 100 kg MAP/ha, mechanical cutting
Fallow weed control	Amicide 625 0.50 L/ha x 3, Roundup CT 1.5 L/ha x 3; chisel plough x 1
In-crop weed control	Spinnaker 140 g/ha x 1 and Roundup 1.5 L/ha x 1 application over ½ the area post-plant, pre-emerge
Leucaena planter	Leucaena planter (precision row crop planter)
Grass planter	Drum seeder (at the same time as planting leucaena)
Grazing days on forage	270
Starting cattle weight (kg)	353
LWG (kg/head/day)	0.9
Stocking rate over 365 days	0.44 AE/ha
Animal health treatments	5-in-1 x 1; inoculate 10% of the herd at the rate of 100 mL leucaena rumen fluid inoculum/steer

Factor	Description
Butterfly pea–grass	
Assumed life of the forage	5 years
Adjustment to account for time-lag in production after planting	In the year of planting the grazing days were halved but SR and LWG kept constant
Sowing window	15 December – 28 February
Sowing rate	10 kg/ha Milgarra; 2 kg/ha tropical grass species
Fallow weed control	Amicide 625 0.50 L/ha x 3, Roundup CT 1.5 L/ha x 3; chisel plough x 2, scarifier x 1
In-crop weed control	Spinnaker 150 g/ha x 1 application post-plant, pre-emerge
Butterfly pea planter	Air–seeder, twin bin, spear points with presswheels
Grass planter	Drum seeder (grass planted 12 months later)
Grazing days on forage	250
Starting cattle weight (kg)	446
LWG (kg/head/day)	0.6
Stocking rate over 365 days	0.55 AE/ha
Animal health treatments	5-in-1 x 1

Table 31. Constructed scenario for South Queensland Brigalow (Taroom–Wandoan area): description and assumptions for gross margin analysis

Factor	Description
General description and assumptions	
Broad land type	Brigalow
Soil type and characteristics	Grey vertosol PAWC: 162 mm Soil depth: 150 cm 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 Central Queensland Brigalow)
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%).
Place of cattle purchase	Roma saleyards
Place of cattle sale	Dinmore
Baseline pasture	
Pasture characteristics	Buffel grass (older pastures); minimal tree regrowth
Stocking rate	0.33 AE/ha (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 N ov for 3 months; 318 days from joining to mean calving date; mean calving weight: 35 kg, LWG from birth to weaning: 0.9 kg/head/day; wean on 1 May at 7.5 months and 240 kg
Long-term steer LWG: Annual Summer (D-J-F) Autumn (M-A-M) Winter (J-J-A) Spring (S-O-N)	149 kg/head/year (0.41 kg/head/day) 0.77 kg/head/day 0.34 kg/head/day 0.22 kg/head/day 0.42 kg/head/day
Calculated grazing days from weaning to turn-off	870
Age at turn-off	36 months
Animal health treatments	5-in-1 x 1 (booster at weaning)
Forage oats	
Sowing window	1 April – 1 June
Sowing rate	40 kg/ha
Fertiliser	20 kg N/ha applied at planting
Fallow weed control	Amicide 625 0.75 L/ha x 2, Glyphosate 450 CT 1.5 L/ha x 2; chisel plough x 1, scarifier x 1
In-crop weed control	MCPA LVE 1 L/ha x 1 application
Planter	Air-seeder, twin bin, spear points and presswheels
% of the paddock sown to forage	90% of total grazing area
Grazing days on forage	90
Starting cattle weight (kg)	497
LWG (kg/head/day)	1.1
Stocking rate	2.3 AE/ha
Animal health treatments	5-in-1 x 1

Factor	Description
Forage sorghum	
Sowing window	20 October – 31 January
Sowing rate	4 kg/ha
Fertiliser	20 kg N/ha applied at planting
Fallow weed control	Amicide 625 0.75 L/ha x 2, glyphosate 450 CT 1.5 L/ha x 2; chisel plough x 1, scarifier x 1
In-crop weed control	Atrazine 3 L/ha x 1 application post-plant, pre-emerge
Planter	Air-seeder, twin bin, spear points with presswheels
Grazing days on forage	130
Starting cattle weight (kg)	525
LWG (kg/head/day)	0.55
Stocking rate	2.5 AE/ha
Animal health treatments	5-in-1 x 1
Lablab	
Sowing window	15 October – 31 January
Sowing rate	25 kg/ha
Fallow weed control	Amicide 625 0.75 L/ha x 2, glyphosate 450 CT 1.5 L/ha x 2, chisel plough x 1; scarifier x 1
In-crop weed control	Spinnaker 100 g/ha x 1 application post-plant, pre-emerge
Planter	Air-seeder, twin bin, spear points with presswheels
% of the paddock sown to forage	90% of total grazing area
Grazing days on forage	90
Starting cattle weight (kg)	524
LWG (kg/head/day)	0.8
Stocking rate	2.3 AE/ha
Animal health treatments	5-in-1 x 1
Leucaena–grass	
Assumed life of the orage	30 years
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
Sowing rate	2.5 kg/ha leucaena; 4 kg/ha tropical grass species
Fertiliser and maintenance	At sowing: 60 kg MAP/ha; maintenance (every 10 years): 100 kg MAP/ha, mechanical cutting
Fallow weed control	Amicide 625 0.5 L/ha x 3, Roundup CT 1.5 L/ha x 3; chisel plough x 1
In-crop weed control	Spinnaker 140 g/ha x 1 and Roundup 1.5 L/ha x 1 over ½ the area post-plant, pre-emerge
Leucaena planter	Leucaena planter (precision row crop planter)
Grass planter	Drum seeder (at the same time as planting leucaena)
Grazing days on forage	240
Starting cattle weight (kg)	380
LWG (kg/head/day)	0.9
Stocking rate over 365 days	0.36 AE/ha
Animal health treatments	5-in-1 x 1; inoculate 10% of the herd at the rate of 100 mL leucaena rumen fluid inoculum/steer

Factor	Description
Butterfly pea–grass	
Assumed life of forage	5 years
Adjustment to account for time-lag in production after planting	In the year of planting the grazing days were halved but SR and LWG kept constant
Sowing window	15 December – 15 February
Sowing rate	10 kg/ha Milgarra; 2 kg/ha tropical grass species
Fallow weed control	Amicide 625 0.5 L/ha x 3, Roundup CT 1.5 L/ha x 3; chisel plough x 2 scarifier x 1
In-crop weed control	Spinnaker 150 g/ha x 1 application post-plant, pre-emerge
Butterfly pea planter	Air–seeder, twin bin, spear points with presswheels
Grass planter	Drum seeder (grass planted 12 months later)
Grazing days on forage	240
Starting cattle weight (kg)	452
LWG (kg/head/day)	0.6
Stocking rate over 365 days	0.53 AE/ha
Animal health treatments	5-in-1 x 1

final report
appendix 2

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High-output forage systems for meeting beef markets – Phase 2

Appendix 2:

Evaluation of forage and animal modelling capabilities for forages grown in the Fitzroy River catchment

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

Table of contents

1 General 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 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. This was the premise for undertaking the work outlined in this Appendix. The objective was to use appropriate forage and animal models to develop a DST that could be used, in conjunction with the associated best-practice guide and gross margin spreadsheet calculators, to investigate 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 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 predictive models or tools 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 Department of Agriculture and Fisheries (DAF), 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 DSTs 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; McCown *et al.* 1996; Keating *et al.* 2003), and extended through the DAF, CQSFS project and by grain industry consultants. There are currently no such tools or models being successfully applied to predict cattle performance, and to support adoption of improved management practices, in tropical pasture or forage grazing systems.

The objective of this aspect of the project was to test and evaluate approaches for incorporating forage and animal production modelling simulation capabilities within the APSIM modelling framework (McCown *et al.* 1996; Keating *et al.* 2003) with the objective of using the most appropriate approach to develop a simple DST. There were two components to this work. The first involved validating APSIM model predictions of forage biomass yield against data collected from the commercial co-operator field sites detailed in Appendix 1 of the Final Report. The second involved testing three approaches to predicting liveweight gain from forages, using the data collected at the co-operator sites.

2 Evaluation of APSIM model predictions of forage biomass against field data from commercial beef properties

The APSIM modelling framework (The Agricultural Production Systems Simulator; McCown *et al.* 1996; Keating *et al.* 2003) was evaluated for predictions of forage biomass yield against data collected from 17 field sites on commercial beef properties in the Fitzroy River catchment. These field sites and the associated data sets are detailed in Appendix 1 of this report. Modelling was completed for 14 annual forage data sets and three perennial grass data sets where measured data was available to compare pasture biomass and, for the annual forages, also components such as green leaf, green stem, dead leaf, dead stem and seed head. This modelling exercise is the first time that the APSIM model has been tested against measured experimental data for forage biomass, for forages and perennial grasses grown in northern Australia.

2.1 Methodology

APSIM was used for simulating the annual forage cropping systems of oats, sorghum and lablab. APSIM is a modular modelling framework that was developed to simulate biophysical process in grain cropping systems. APSIM has numerous modules which include a diverse range of crops, pastures and trees, soil processes including water balance, erosion and a full range of management controls. A complete description of the APSIM model can be found in Keating *et al.* (2003). A version of the GRASP pasture model (Littleboy and McKeon 1997; McKeon *et al*. 2000) that is incorporated within the APSIM framework was used for modelling perennial grass production. GRASP is a deterministic, one-dimensional model of perennial pastures, calibrated for native pastures and buffel grass, in semi-arid and tropical grasslands (Rickert *et al.* 2000).

The models require inputs of (a) daily climate data, (b) soil and hydrologic parameters, and (c) crop and grazing management parameters. The daily climate data required were daily rainfall, minimum and maximum temperatures, radiation, evaporation and vapour pressure. Daily rainfall, minimum and maximum temperature, were measured at the majority of the field sites using an on-site weather station (Hastings Tinytag Data Logger). If an on-site weather station was not available, rainfall data was obtained from property records, if deemed reliable. Where this was not available, the closest Bureau of Meteorology (BOM) climate station was used for rainfall and temperate data, as well as radiation, evaporation and vapour pressure for all sites. The BOM data was obtained from the national climate database SILO (Jeffrey *et al.* 2001).

Soil and water balance model parameters were either measured at the field sites, as described in Appendix 1, or obtained from other sites in the region according to similarity of soil characteristics. The main soil parameters required for each soil layer were:

- bulk density
- air dry moisture content
- lower limit moisture content (also referred to as wilting point)
- drained upper limit moisture content (also referred to as field capacity)
- saturated moisture content (equal to or slightly less than total porosity)
- infiltration rate at saturation in the subsoil.

Planting, tillage, fertilisation and grazing management were replicated in APSIM according to records for each field site (details in Appendix 1). Soil nitrogen and moisture content was set to what was measured, or estimated, before planting for annual forage crops, or at commencement of monitoring for perennial grasses. As each grazed field site had a fenced exclosure, the models were able to be evaluated for prediction of both ungrazed and grazed biomass.

2.2 Results and discussion

A comparison of measured and predicted forage biomass over time, for both un-grazed and grazed forage, is presented in the following figures for the 17 data sets.

2.2.1 Oats

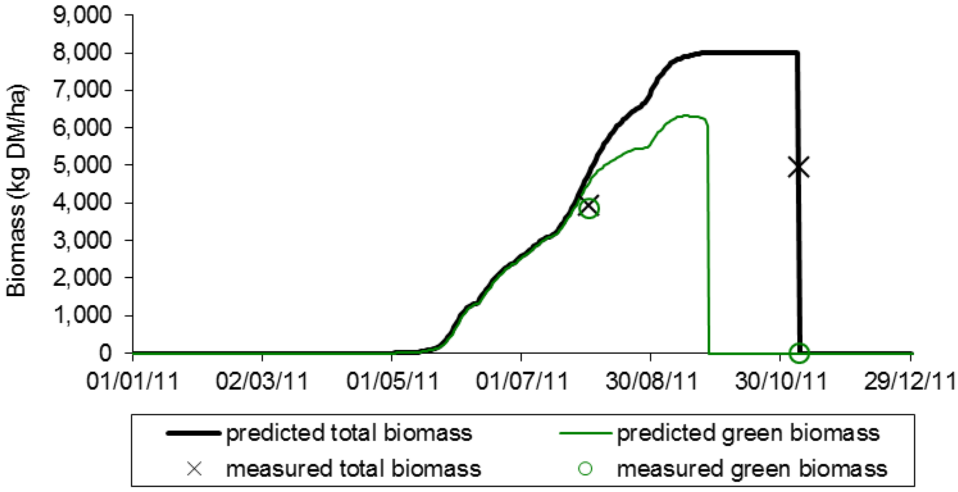

Fig. 1. Predicted total and green biomass over time in the un-grazed exclosure for oats forage grown in the Central Queensland Open Downs region in 2011. Measured data points are also shown for total and green biomass.

Key points from Fig. 1:

- good prediction of measured points
- peak biomass was not captured with paddock measurements, precluding a comparison with model output.

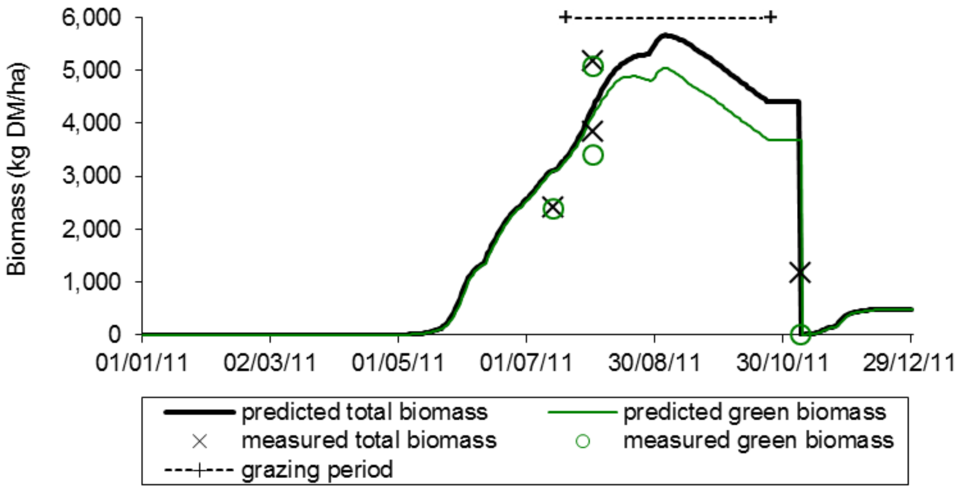

Fig. 2. Predicted total and green biomass over time in the grazed paddock for oats forage grown in the Central Queensland Open Downs region in 2011. Measured data points are also shown for total and green biomass. Grazing period shown.

Key points from Fig. 2:

- good prediction of measured points
- peak biomass was not captured with paddock measurements, precluding a comparison with model output.

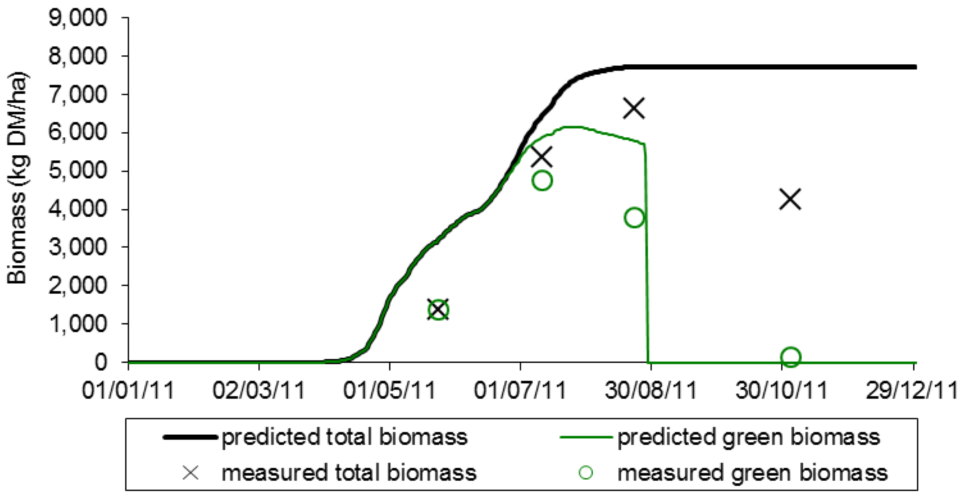

Fig. 3. Predicted total and green biomass over time in the un-grazed exclosure for oats forage grown in the Central Queensland Brigalow region in 2011. Measured data points are also shown for total and green biomass.

Key points from Fig. 3:

- predicted forage development was faster than measured
- reasonable prediction of measured points
- reasonable prediction of peak biomass
- measured biomass decreased after peak, likely due to detachment and loss of plant parts and mature grain as the plants senesced.

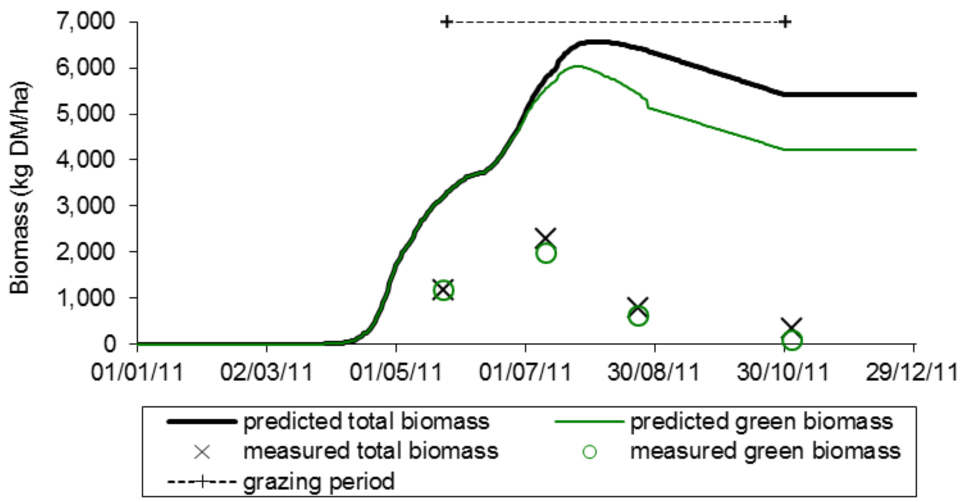

Fig. 4. Predicted total and green biomass over time in the grazed paddock for oats forage grown in the Central Queensland Brigalow region in 2011. Measured data points are also shown for total and green biomass. Grazing period shown.

Key points from Fig. 4:

- poor prediction of measured points, with all points considerably over-predicted
- peak biomass considerably over-predicted
- it is possible that an improvement in predicted effects of grazing may occur if the simulated crop emerged later as this may change the dynamics of forage consumption by the livestock so that they remove more leaf and hence slow growth more quickly in the grazed crop
- this crop was grazed heavily with grazing commencing at 2.5 AE/ha and an initial biomass of only 1,177 kg DM/ha, when the crop was still developing. This resulted in

very low biomass in the paddock for the entire grazing period (maximum biomass in the paddock only 2,278 kg DM/ha). Even with this relatively extreme example of high stocking rate, the model predicted only a small reduction in total forage biomass production in the grazed paddock compared to the ungrazed exclosure: 7,696 vs. 7,718 kg DM/ha, respectively.

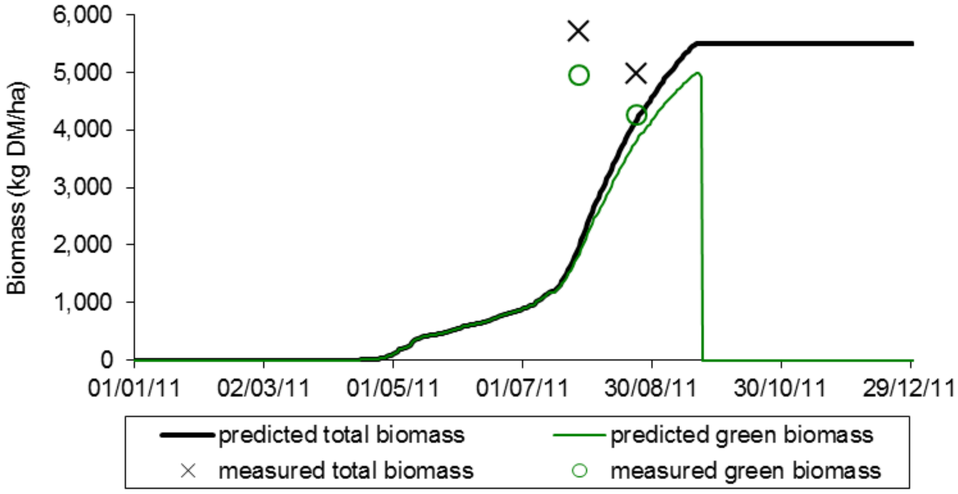

Fig. 5. Predicted total and green biomass over time in the un-grazed exclosure for oats forage grown in the South Queensland Brigalow region in 2011. Measured data points are also shown for total and green biomass.

Key points from Fig. 5:

- modelled initial forage growth was later than measured
- reasonable prediction of measured points
- reasonable prediction of peak biomass
- it was thought likely that the low planting soil nitrate N level (42 kg/ha) was reducing simulated early growth of the crop more than that observed. However, when the crop was modelled with higher soil N this did not improve the simulated timing of growth. The simulation was also re-run with full soil moisture profiles which, similarly, resulted in no improvement in simulated timing of growth.

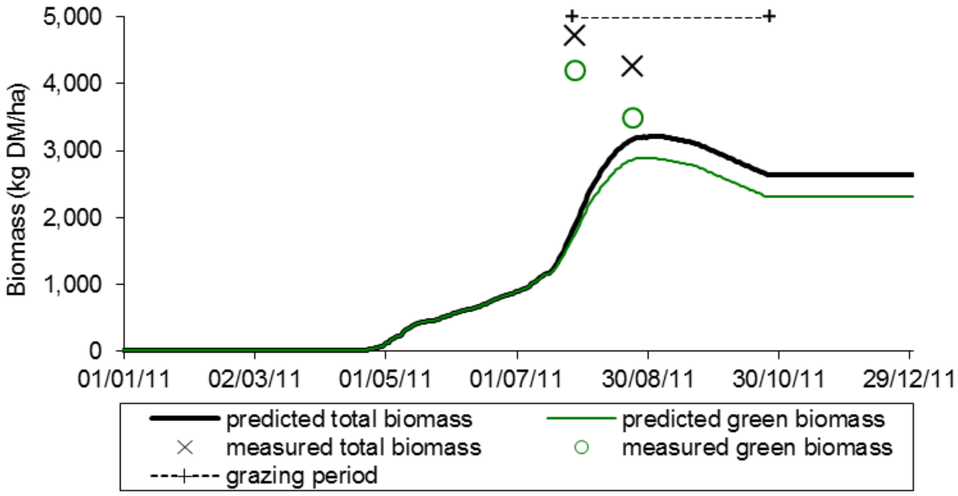

Fig. 6. Predicted total and green biomass over time in the grazed paddock for oats forage grown in the South Queensland Brigalow region in 2011. Measured data points are also shown for total and green biomass. Grazing period shown.

Key points from Fig. 6:

- poor prediction of measured points, with biomass under-predicted
- peak biomass under-predicted
- the delayed timing of crop growth may be contributing to the under-prediction of observed yields as the simulated crop biomass at start of grazing is lower than the observed yields, and hence removal of leaf area by grazing should result in a more dramatic effect of plant growth than what actually occurred.

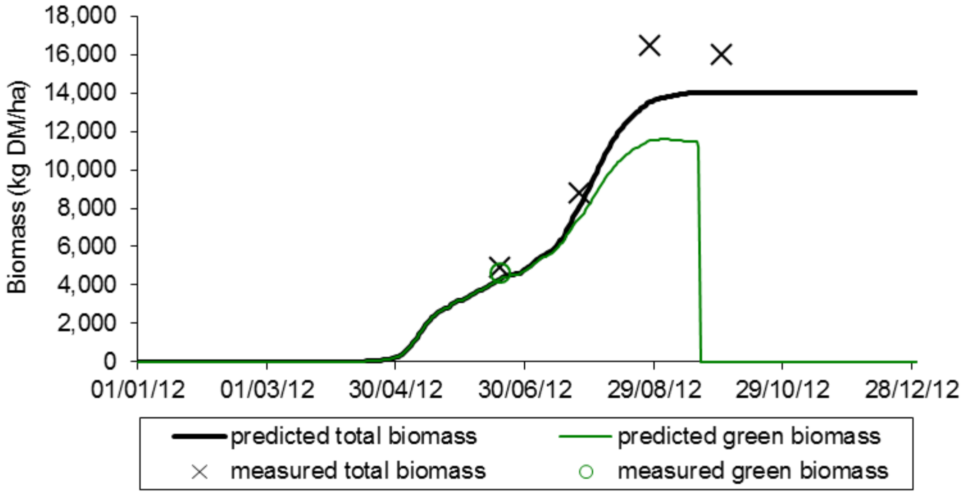

Fig. 7. Predicted total and green biomass over time in the un-grazed exclosure for oats forage grown in the Central Queensland Brigalow region in 2012. Measured data points are also shown for total and green biomass.

Key points from Fig. 7:

- good prediction of measured points mid-way through forage development
- prediction of peak biomass was slightly lower than measured.

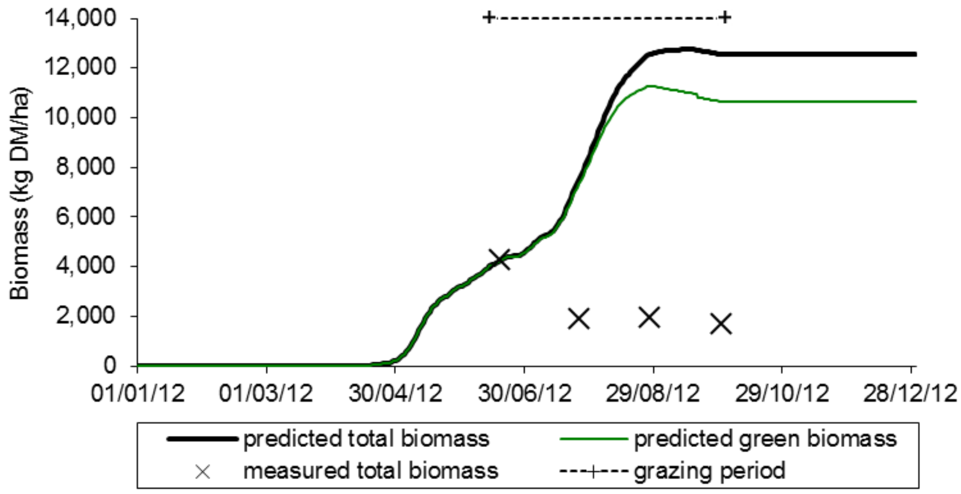

Fig. 8. Predicted total and green biomass over time in the grazed paddock for oats forage grown in the Central Queensland Brigalow region in 2012. Measured data points are also shown for total and green biomass. Grazing period shown.

Key points from Fig. 8:

- poor prediction of measured points after introduction of cattle, with all points considerably over-predicted.

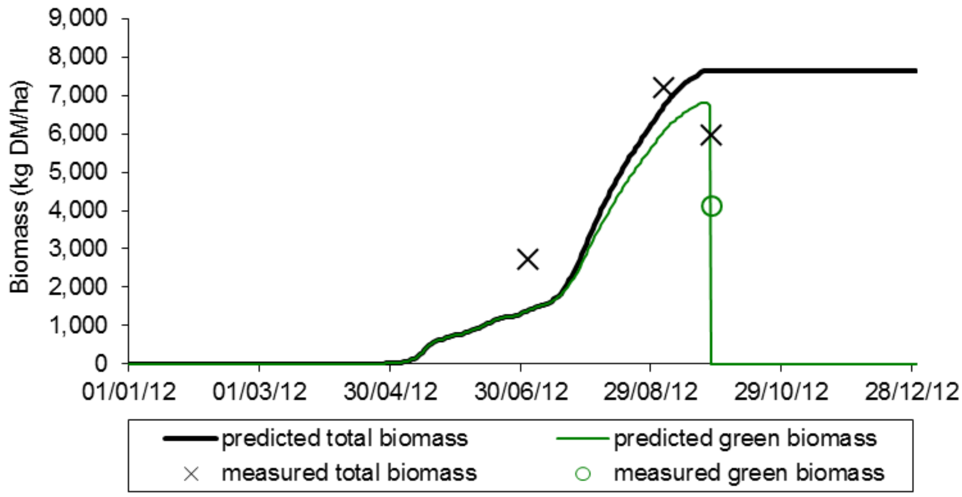

Fig. 9. Predicted total and green biomass over time in the un-grazed exclosure for oats forage grown in the South Queensland Brigalow region in 2012. Measured data points are also shown for total and green biomass.

Key points from Fig. 9:

- timing of emergence and early crop growth was slightly delayed, similar to the South Queensland Brigalow region oats crop in 2011 (the same paddock was used)
- reasonable prediction of measured points
- good prediction of peak biomass
- measured biomass decreased after peak, likely due to detachment and loss of plant parts and mature grain as the plants senesced.

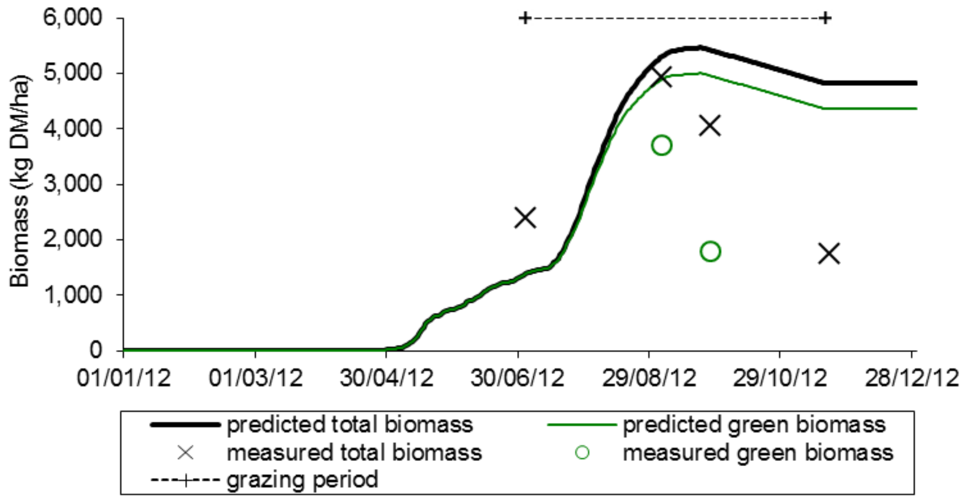

Fig. 10. Predicted total and green biomass over time in the grazed paddock for oats forage grown in the South Queensland Brigalow region in 2012. Measured data points are also shown for total and green biomass. Grazing period shown.

Key points from Fig. 10:

- peak biomass, which was half-way through the grazing period, was well predicted
- observed biomass in the latter half of the grazing period was considerably over-predicted
- it is worth noting here that the stocking rate for the first half of the grazing period was twice that in the second half, although an average for the entire period was used as the model input.

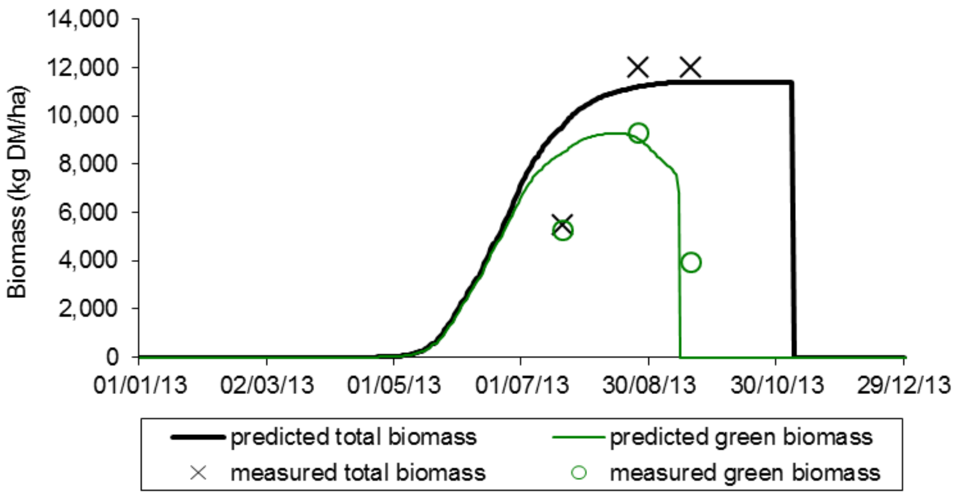

Fig. 11. Predicted total and green biomass over time in the un-grazed exclosure for oats forage grown in the Central Queensland Open Downs region in 2013. Measured data points are also shown for total and green biomass.

Key points from Fig. 11:

- predicted forage emergence, and early development, was faster than measured
- reasonable prediction of measured points
- reasonable prediction of peak biomass.

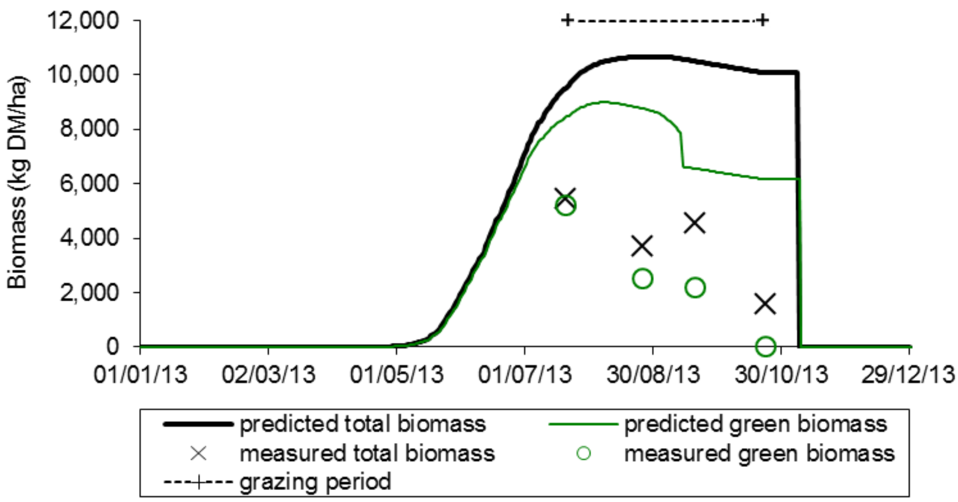

Fig. 12. Predicted total and green biomass over time in the grazed paddock for oats forage grown in the Central Queensland Open Downs region in 2013. Measured data points are also shown for total and green biomass. Grazing period shown.

Key points from Fig. 12:

- poor prediction of measured points, with all points considerably over-predicted
- peak biomass considerably over-predicted
- it is possible that an improvement in the predicted effects of grazing may occur if the simulated crop emerged later as this may change the dynamics of forage consumption by the livestock so that they remove more leaf and hence slow growth more quickly in the grazed crop.

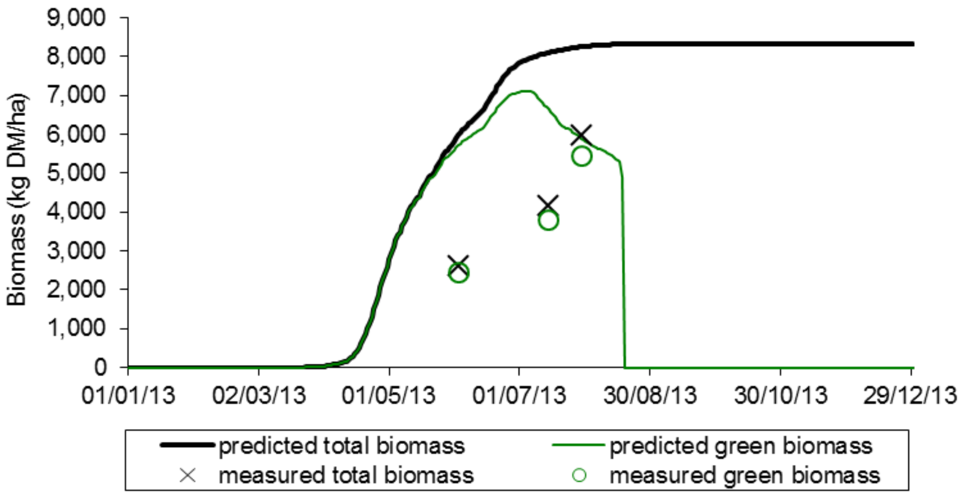

Fig. 13. Predicted total and green biomass over time in the un-grazed exclosure for oats forage grown in the Central Queensland Brigalow region in 2013. Measured data points are also shown for total and green biomass.

Key points from Fig. 13:
- predicted forage emergence was earlier, and early development faster, than measured
- poor prediction of measured points, with all points considerably over-predicted
- peak biomass considerably over-predicted.

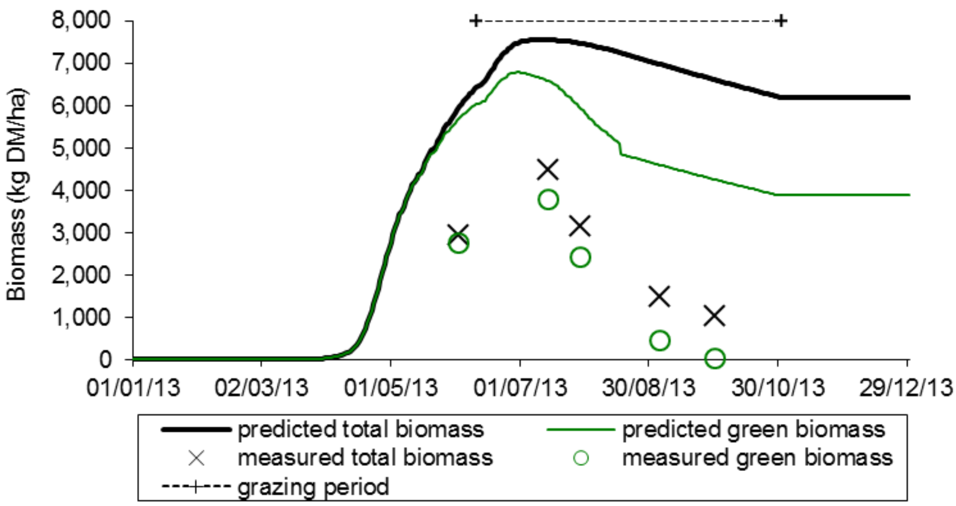

Fig. 14. Predicted total and green biomass over time in the grazed paddock for oats forage grown in the Central Queensland Open Brigalow region in 2013. Measured data points are also shown for total and green biomass. Grazing period shown.

Key points from Fig. 14:
- poor prediction of measured points, with all points considerably over-predicted
- peak biomass considerably over-predicted
- it is possible that an improvement in predicted effects of grazing may occur if the simulated crop emerged later as this may change the dynamics of forage consumption by the livestock so that they remove more leaf and hence slow growth more quickly in the grazed crop.

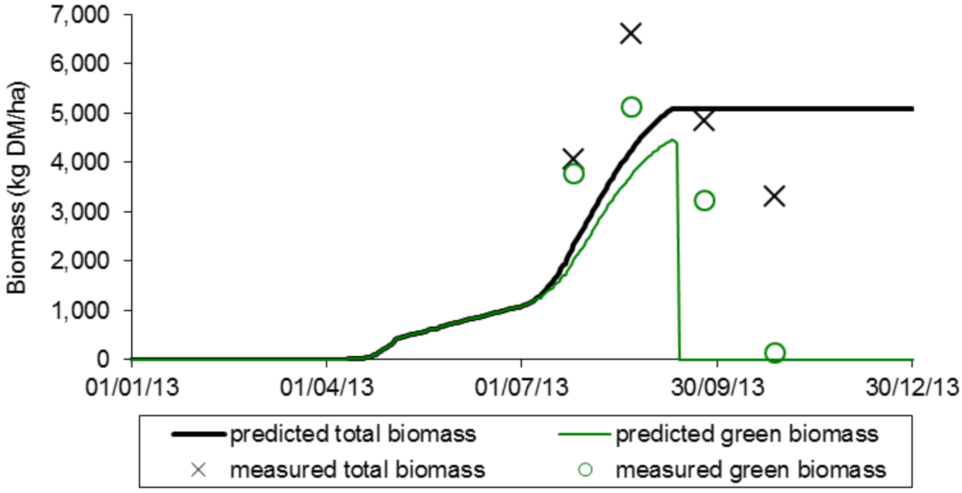

Fig. 15. Predicted total and green biomass over time in the un-grazed exclosure for oats forage grown in the South Queensland Brigalow region in 2013. Measured data points are also shown for total and green biomass.

Key points from Fig. 15:
- timing of emergence and early crop growth was slightly delayed, similar to the South Queensland Brigalow region oats crops in 2011 and 2012 (the same paddock was used)
- poor prediction of peak biomass (under-predicted), however, measured biomass was probably over-estimated at this site due to the high weed presence resulting in difficulty in locating forage rows and possible operator bias towards areas with lower weed density
- measured biomass decreased after peak, likely due to detachment and loss of plant parts and mature grain as the plants senesced.

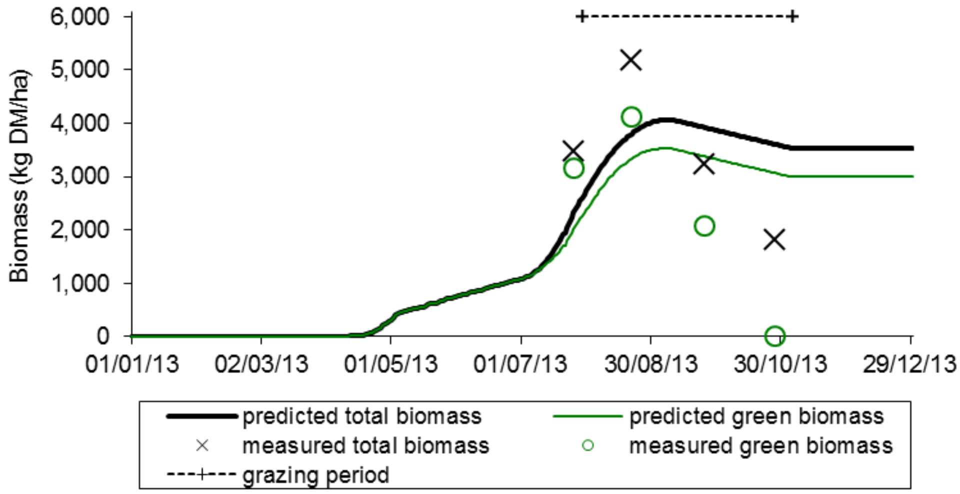

Fig. 16. Predicted total and green biomass over time in the grazed paddock for oats forage grown in the South Queensland Brigalow region in 2013. Measured data points are also shown for total and green biomass. Grazing period shown.

Key points from Fig. 16:
- poor prediction of measured points, with biomass under-predicted in the early part of the grazing period and over predicted in the latter part
- peak biomass under-predicted
- the delayed timing of crop growth may be contributing to the under-prediction of observed yields in the early part of the grazing period as the simulated crop biomass at start of

grazing is lower than the observed yields, and hence removal of leaf area by grazing should result in a more dramatic effect on plant growth than what actually occurred.

2.2.2 Forage sorghum

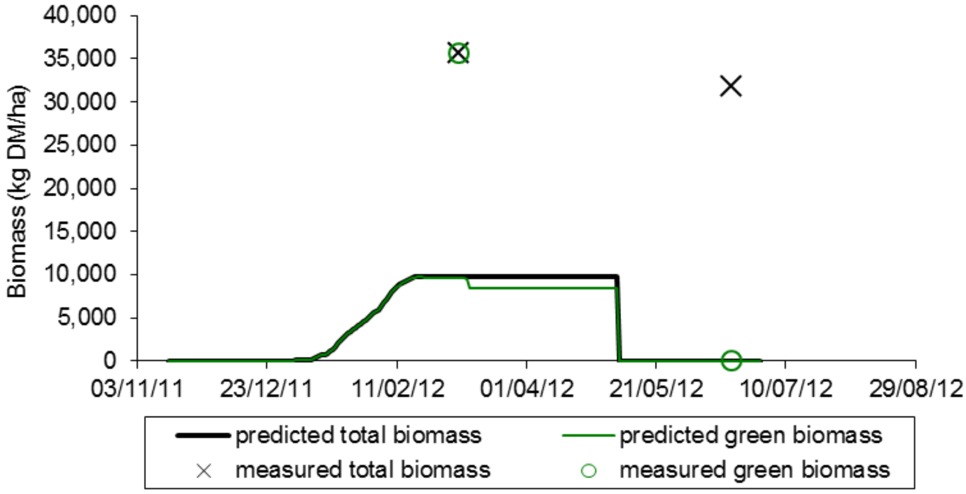

Fig. 17. Predicted total and green biomass over time in the un-grazed exclosure for forage sorghum grown in the Central Queensland Brigalow region in 2011-12. Measured data points are also shown for total and green biomass.

Key points from Fig. 17:

- the model considerably under-predicted biomass at the two measured points
- manipulation of APSIM model inputs showed that it was not possible for the model to simulate such high yields. However, we have confidence in the methodology used to determine biomass yields in the paddock
- although the observed maximum biomass yields were greater than reports for forage sorghum crops grown in south-west Queensland and the Darling Downs region of southern Queensland (13,000-16,000 kg DM/ha; Chataway *et al.* 2011; Bell *et al.* 2012), they were in the range of maximum biomass yields for a forage sorghum crops grown at Trangie, New South Wales (31,000-33,000 kg DM/ha; Muldoon 1985).

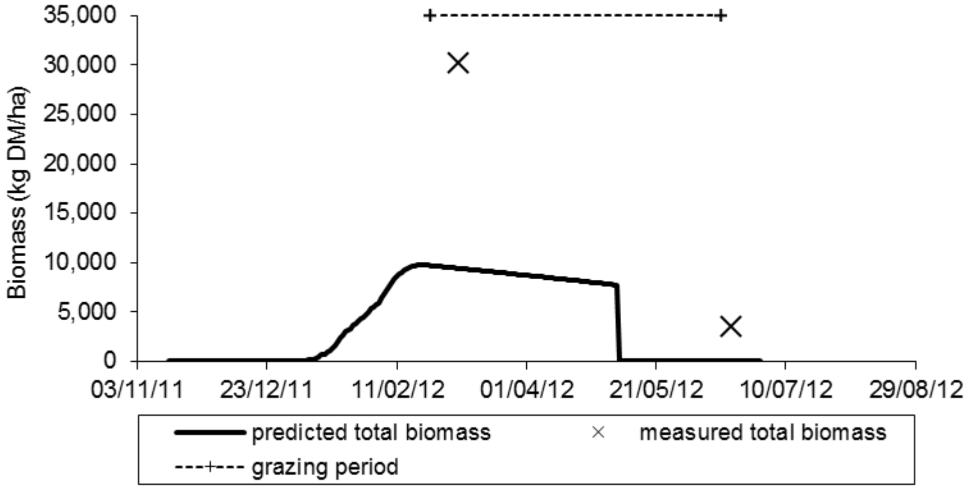

Fig. 18. Predicted total biomass over time in the grazed paddock for forage sorghum grown in the Central Queensland Brigalow region in 2011-12. Measured data points are also shown for total biomass. Grazing period shown.

Key points from Fig. 18:
- poor prediction of measured points, with starting biomass, in particular, considerably under-predicted.

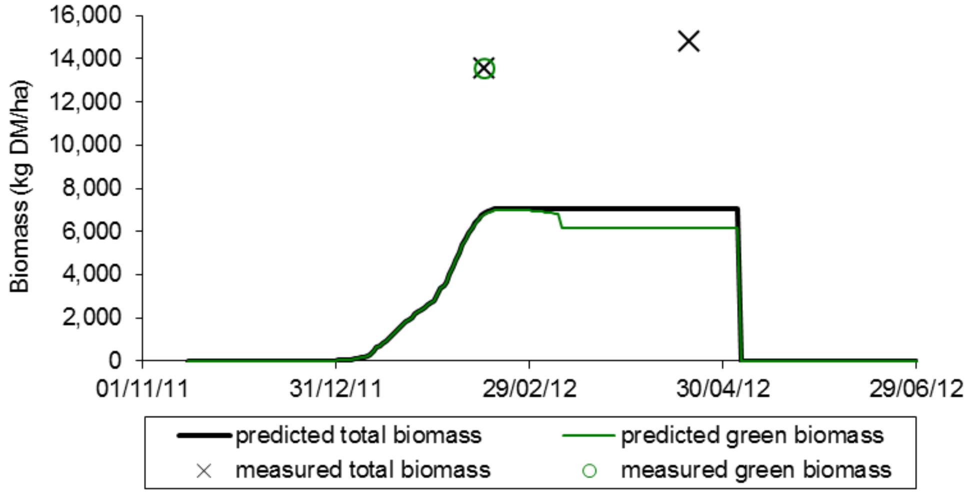

Fig. 19. Predicted total and green biomass over time in the un-grazed exclosure for forage sorghum grown in the South Queensland Brigalow region in 2011-12. Measured data points are also shown for total and green biomass.

Key points from Fig. 19:
- the model considerably under-predicted biomass at the two measured points.

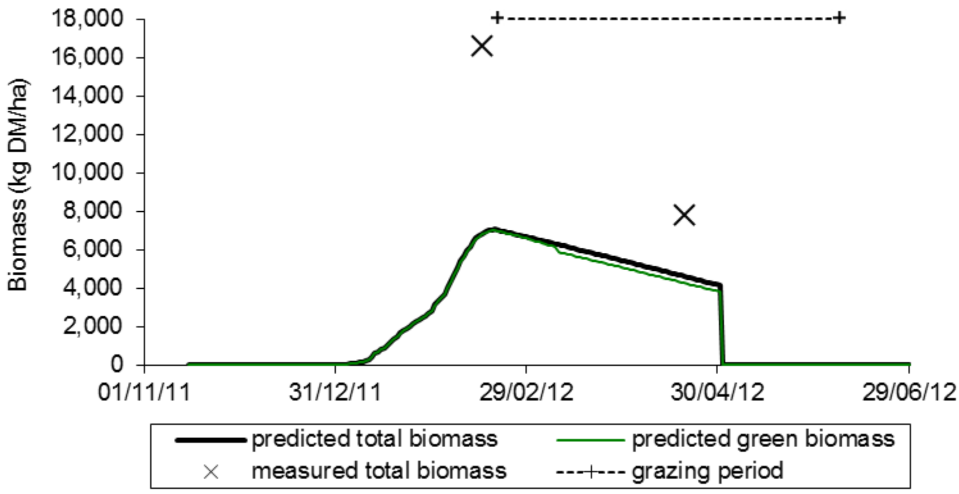

Fig. 20. Predicted total and green biomass over time in the grazed paddock for forage sorghum grown in the South Queensland Brigalow region in 2011-12. Measured data points are also shown for total biomass. Grazing period shown.

Key points from Fig. 20:
- poor prediction of measured points, with starting biomass, in particular, considerably under-predicted.

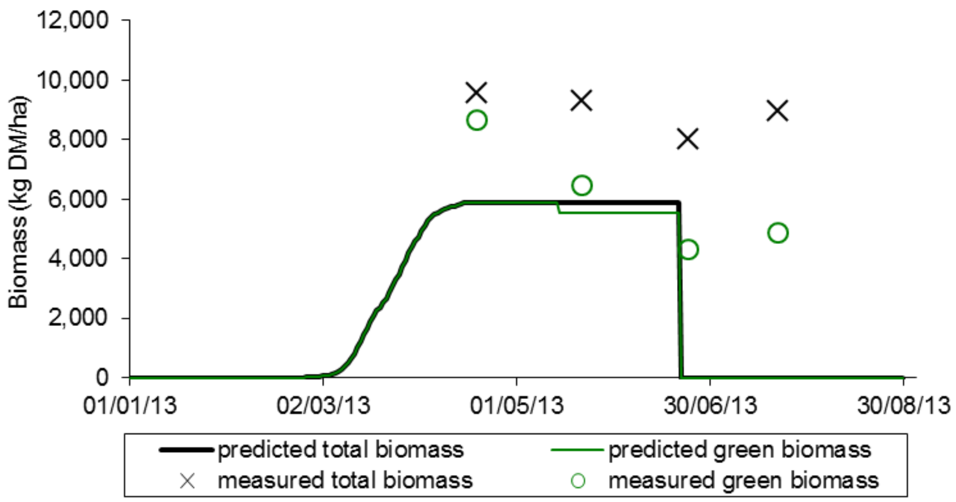

Fig. 21. Predicted total and green biomass over time in the un-grazed exclosure for forage sorghum grown in the Central Queensland Open Downs region in 2012-13. Measured data points are also shown for total and green biomass.

Key points from Fig. 21:

- the model under-predicted total biomass at all measured points
- the model ended crop growth earlier than that observed in the paddock, on 21/06/13.

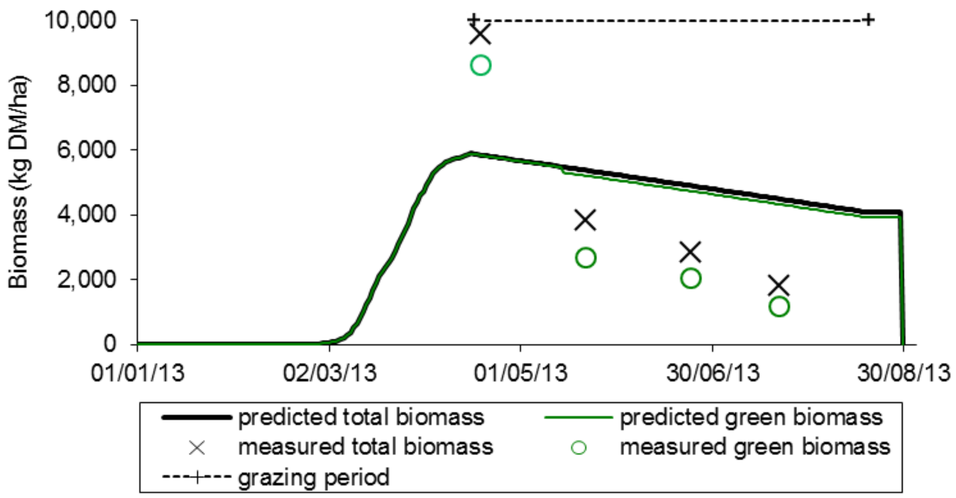

Fig. 22. Predicted total and green biomass over time in the grazed paddock for forage sorghum grown in the Central Queensland Open Downs region in 2012-13. Measured data points are also shown for total and green biomass. Grazing period shown.

Key points from Fig. 22:

- starting biomass, which was also peak biomass, was considerably under-predicted
- observed biomass during the grazing period was over-predicted
- Note that the model ended the crop on 21/06/13, prior to the actual end of the grazing period. However, the grazing period was manually over-ridden in the model to match the observed period.

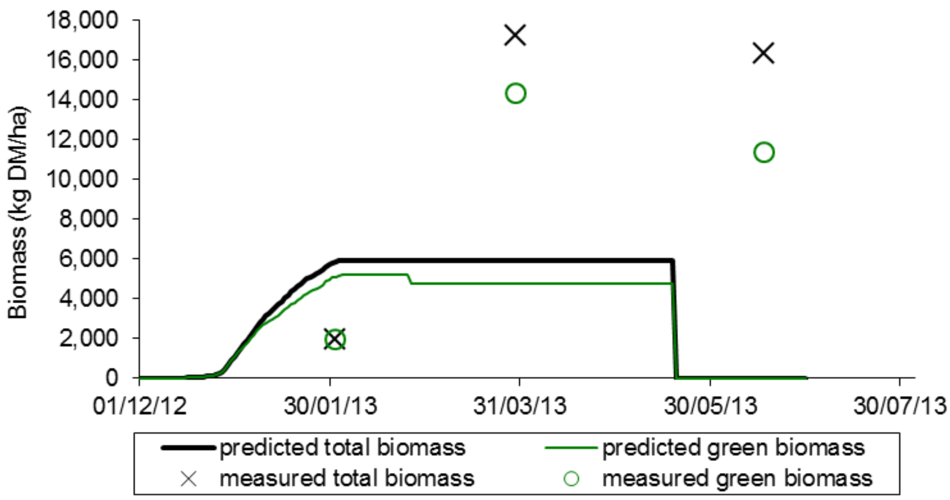

Fig. 23. Predicted total and green biomass over time in the un-grazed exclosure for forage sorghum grown in the Central Queensland Brigalow region in 2012-13. Measured data points are also shown for total and green biomass.

Key points from Fig. 23:

- peak biomass was considerably under-predicted
- the model over-predicted early biomass due to timing of emergence and early growth being earlier than observed
- the model ended crop growth earlier than that observed in the paddock, on 19/05/13.

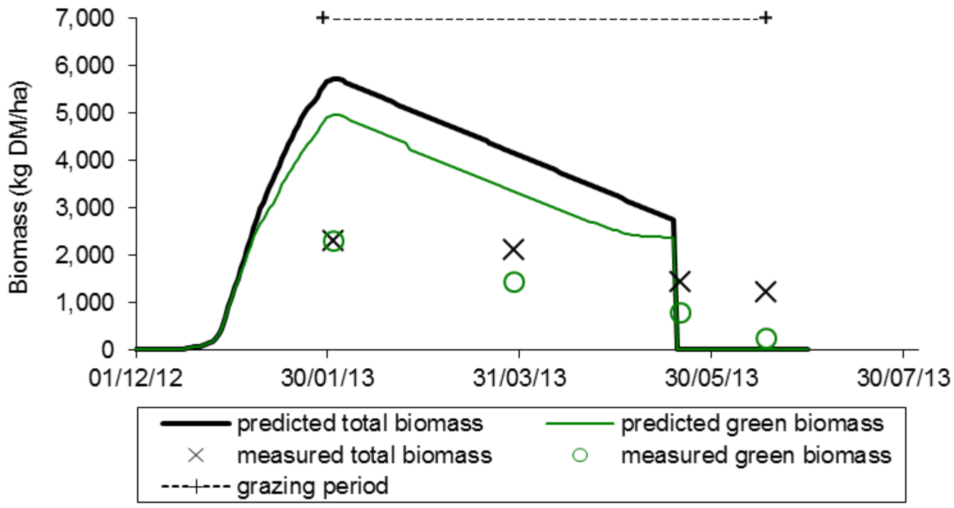

Fig. 24. Predicted total and green biomass over time in the grazed paddock for forage sorghum grown in the Central Queensland Brigalow region in 2012-13. Measured data points are also shown for total and green biomass. Grazing period shown.

Key points from Fig. 24:

- the model over-predicted observed biomass at all points except for the end of the grazing period. This last point was under-predicted as the model had ended the crop earlier than observed, on 20/05/13.

2.2.3 Lablab

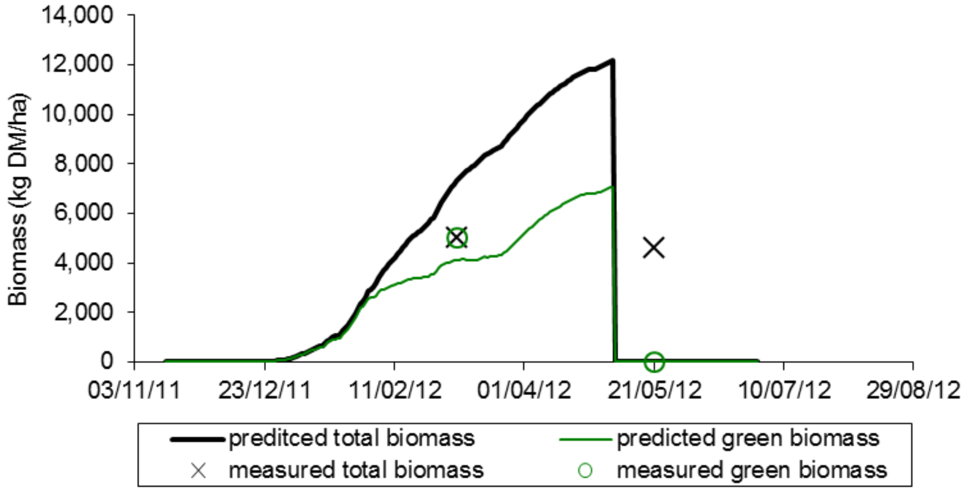

Fig. 25. Predicted total and green biomass over time in the un-grazed exclosure for lablab forage in the Central Queensland Open Downs region in 2011-12. Measured data points are also shown for total and green biomass.

Key points from Fig. 25:

- reasonable prediction of measured points
- peak biomass was not captured with paddock measurements, precluding a comparison with model output.

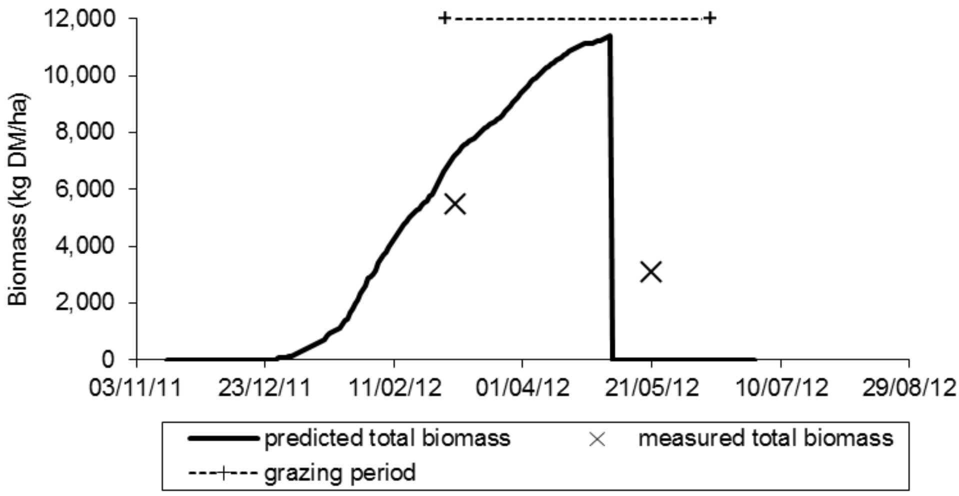

Fig. 26. Predicted total biomass over time in the grazed paddock for lablab forage sorghum grown in the Central Queensland Open Downs region in 2011-12. Measured data points are also shown for total biomass. Grazing period shown.

Key points from Fig. 26:

- reasonable prediction of measured points
- peak biomass was not captured with paddock measurements, precluding a comparison with model output.

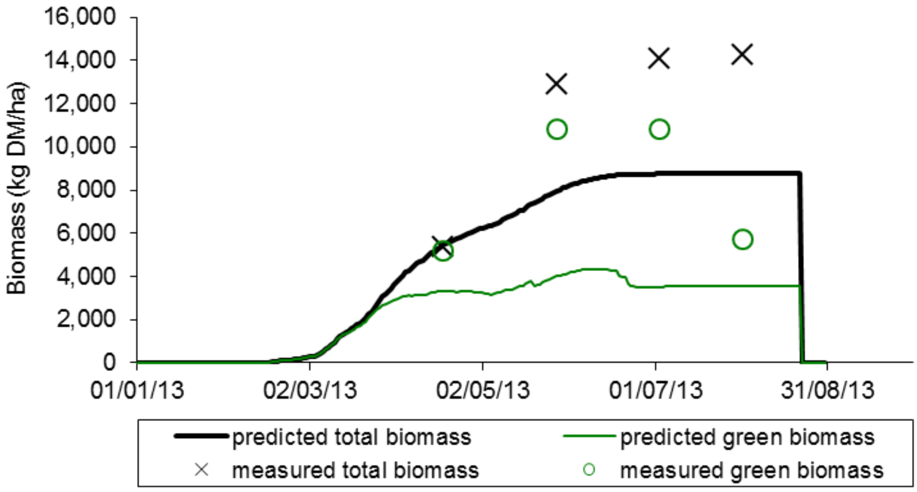

Fig. 27. Predicted total and green biomass over time in the un-grazed exclosure for lablab forage in the Central Queensland Brigalow region in 2012-13. Measured data points are also shown for total and green biomass.

Key points from Fig. 27:

- total biomass was predicted well early in the growing period
- peak biomass and biomass later in the growing season was under-predicted.

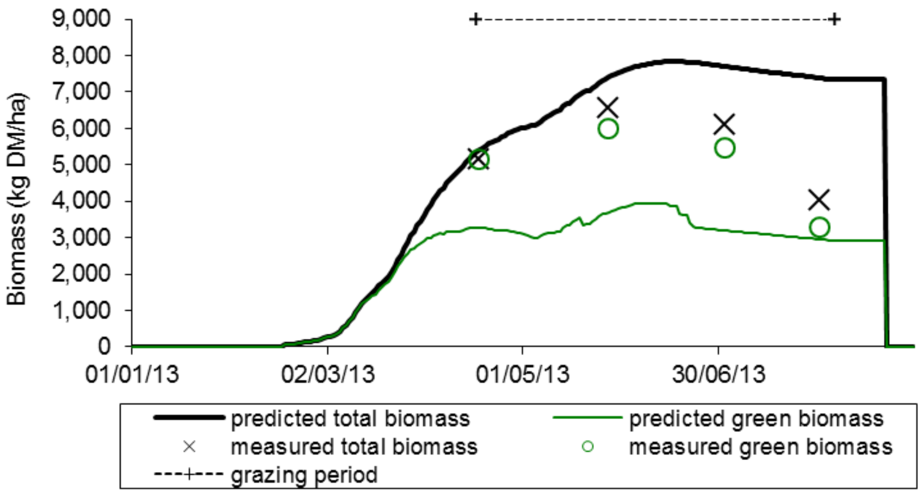

Fig. 28. Predicted total and green biomass over time in the grazed paddock for lablab forage in the Central Queensland Brigalow region in 2012-13. Measured data points are also shown for total and green biomass. Grazing period shown.

Key points from Fig. 28:

- total biomass was predicted well prior to grazing
- peak biomass and biomass later in the growing season was over-predicted.

2.2.4 Perennial grass pasture

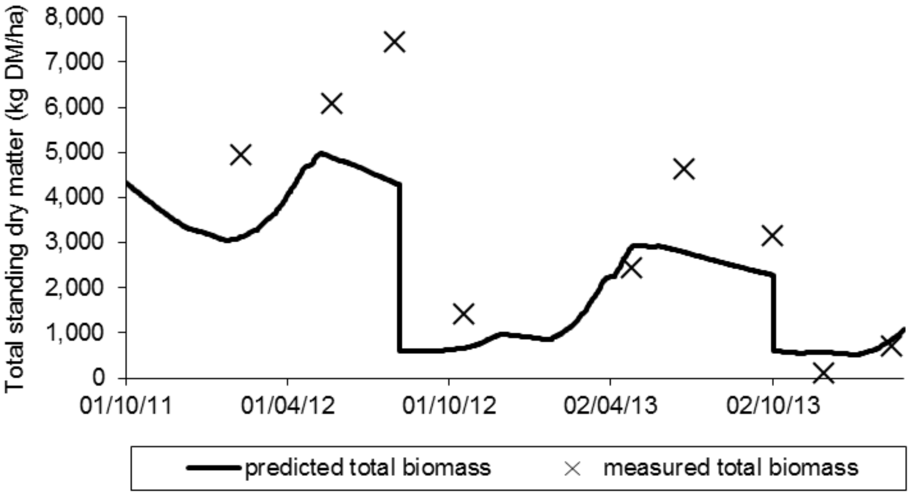

Fig. 29. Predicted and measured biomass over time in the un-grazed exclosure for perennial grass pasture in the Central Queensland Open Downs region over 2011-2014.

Key points from Fig. 29:

- the trend in standing biomass over seasons was predicted by the model
- peak biomass yields were under-predicted.

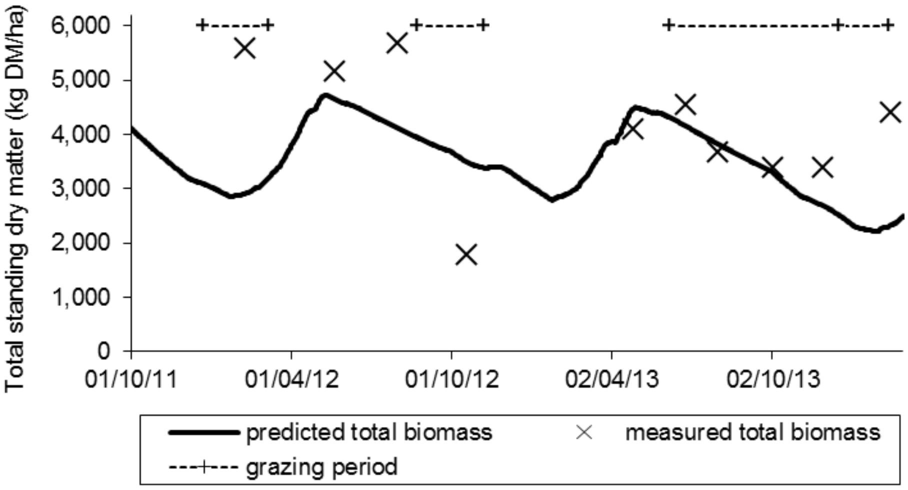

Fig. 30. Predicted and measured biomass over time in the grazed paddock for perennial grass pasture in the Central Queensland Open Downs region over 2011-2014.

Key points from Fig. 30:

- the trend in standing biomass over seasons was predicted by the model
- peak biomass yields were under-predicted
- the very low standing biomass predicted at the end of the second grazing period was over-predicted.

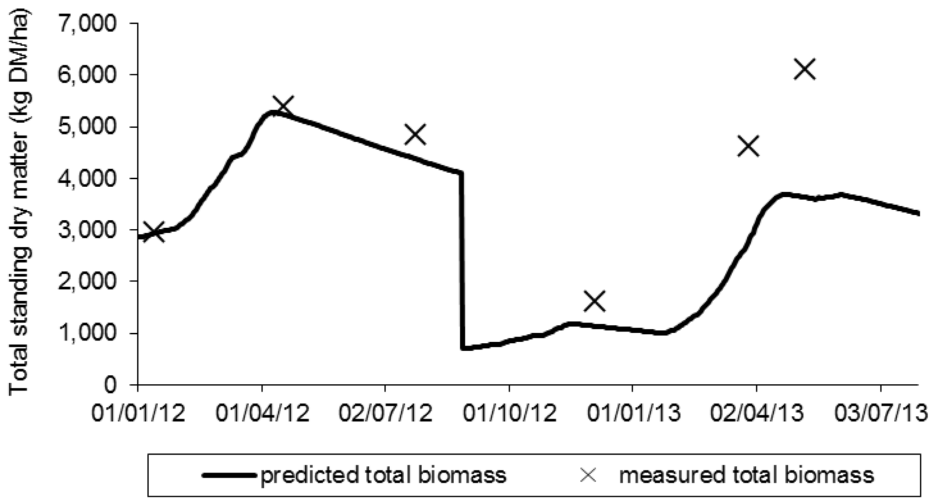

Fig. 31. Predicted and measured biomass over time in the un-grazed exclosure for perennial grass pasture in the Central Queensland Brigalow region over 2012-2013.

Key points from Fig. 31:

- the trend in standing biomass over seasons was predicted by the model
- model predictions were close to measured data for most points except the final two measurements towards the end of the grazing period
- peak biomass yields in 2013 were under-predicted.

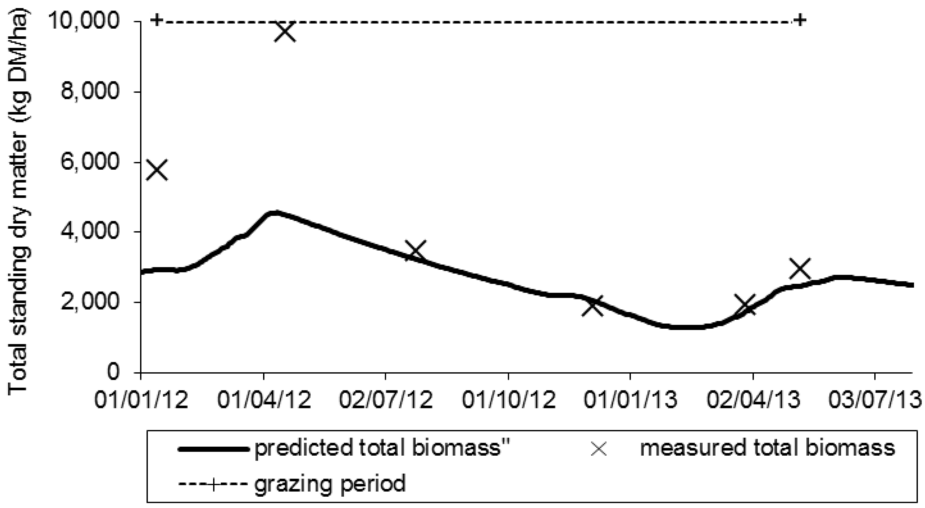

Fig. 32. Predicted and measured biomass over time in the grazed paddock for perennial grass pasture in the Central Queensland Brigalow region over 2012-2013.

Key points from Fig. 32:

- the trend in standing biomass over seasons was predicted by the model
- model predictions were close to measured data for most points except the initial two measurements at the start of the grazing period
- peak biomass measurements in 2012 were under-predicted.

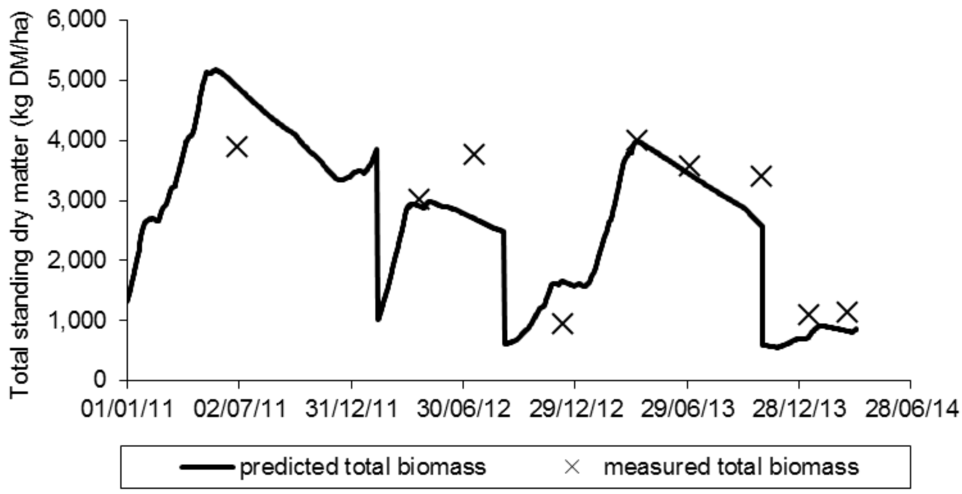

Fig. 33. Predicted and measured biomass over time in the un-grazed exclosure for perennial grass pasture in the South Queensland Brigalow region over 2011-2014.

Key points from Fig. 33:

- the trend in standing biomass over seasons was predicted by the model
- model predictions were close to measured data for most points over the 3-year period.

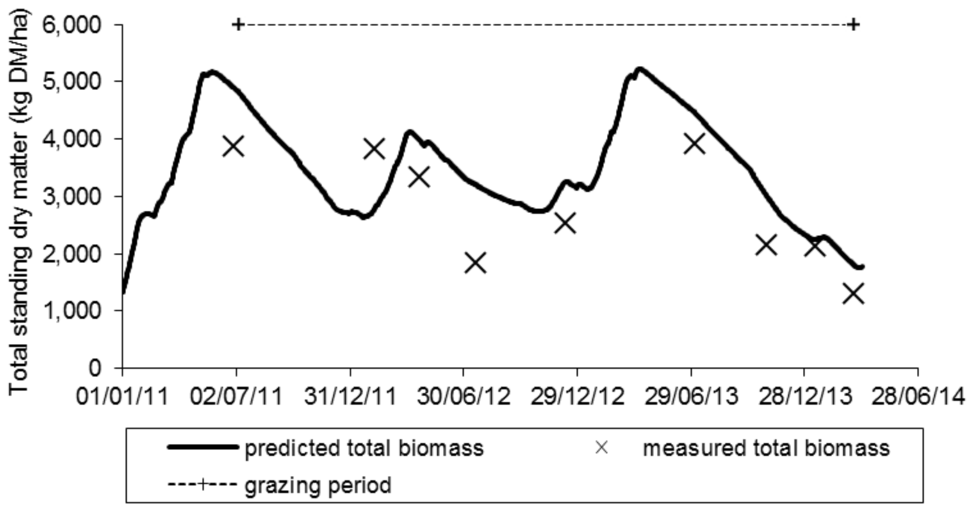

Fig. 34. Predicted and measured biomass over time in the grazed paddock for perennial grass pasture in the South Queensland Brigalow region over 2011-2014.

Key points from Fig. 34:

- the trend in standing biomass over seasons was predicted by the model
- model predictions were close to measured data for most points over the 3-year period.

2.2.5 Simulation of un-grazed forage biomass

The annual forage growth models in APSIM have not been as widely used or tested as the grain crop models, and results from our testing has been variable.

2.2.5.1 Oats

In broad terms, the APSIM model predicted un-grazed oats biomass satisfactorily:

- six out of eight oats sites were considered to have reasonable prediction of measured biomass over time
- five out of seven oats sites with measured data for peak biomass data were considered to have reasonable prediction of peak biomass. For these five sites the total APSIM simulated un-grazed biomass, as a % of measured peak yield in the exclosure, ranged from 85 to 117% (i.e. modelled results were within approximately 15% of the measured yields). In this comparison, the measured peak biomass in the exclosure was used as the best indication of total (accumulative) biomass growth.

The model did not accurately predict the correct timing of plant emergence and early growth of oats in six out of eight sites, with varying degrees of difference to observed data:

- plant growth was delayed in three out of eight oats sites. These three sites were sequential oats crops, in the same paddock, in the South Queensland Brigalow. This site had very low soil nitrate N and it is possible that the model was over-predicting the negative effect of this, on early plant growth. Although, when 2011 crop was modelled with higher soil N this did not improve the simulated timing of growth
- emergence and plant growth was too early for three out of eight oats sites.

This inaccuracy in timing of plant emergence has implications for the simulated dynamics of forage selection and consumption by grazing cattle, resulting in possible inaccuracies in simulated effects of grazing on forage growth.

2.2.5.2 Forage sorghum

The APSIM model considerably under-predicted forage sorghum biomass for the four data-sets available:

- the total APSIM simulated un-grazed biomass, as a % of peak yield in the exclosure, averaged 43 ± (7.9)%; range: 27-62%
- emergence and early plant growth was too early for at least one of the four sites.

The forage sorghum model in APSIM has been developed from a more limited pool of data sets than for the oats model. The poor agreement of simulated, un-grazed forage sorghum growth with observed data indicates a need to improve the model to provide more reliable results.

2.2.5.3 Lablab

Only one out of the two lablab sites had a data set with sufficient measured points for good comparison with the modelled output. At this site the model under-predicted forage biomass:

- total APSIM simulated un-grazed biomass, as a % of peak yield in the exclosure was 61%.

The lablab model in APSIM has been developed from a more limited pool of data sets than for the oats model. The poor agreement of simulated, ung-grazed lablab growth with observed data indicates a need to improve the model to provide more reliable results.

2.2.5.4 Perennial grass
The GRASP model has been well tested in Queensland with a good understanding of parameter values from approximately 100 sites across northern Australia including sown grasses such as buffel (Day *et al.,* 1997). This was evident in the generally very good prediction of standing biomass in un-grazed paddock exclosures at three sites across the Fitzroy River catchment. The trend in standing biomass over seasons was well predicted by the model. There was some evidence of under-prediction of peak biomass yields at two of the sites.

2.2.6 Simulation of forage biomass in the grazed paddock

2.2.6.1 Oats
The APSIM model was not able to adequately predict the effects of grazing on oats biomass:

- observed biomass over time was under-predicted for one out of eight sites
- observed biomass over time was considerably over-predicted for six out of eight sites
- it is evident that the reduction in APSIM simulated forage biomass growth in grazed paddocks is inadequate to accurately represent the effects of consumption and trampling.

2.2.6.2 Forage sorghum
The APSIM model was not able to adequately predict the forage sorghum biomass in grazed paddocks:

- observed biomass during the grazing period of cattle was under-predicted for two out of four sites and over-predicted for the remaining two sites.

This poor agreement of simulated biomass with observed in the grazed paddock was not unexpected considering the poor agreement of simulated with observed un-grazed biomass. Although un-grazed forage sorghum biomass was under-predicted for all sites, the biomass in grazed paddocks was over-predicted for two of the forage sorghum, similar to the general trend for the grazed oats simulations.

2.2.6.3 Lablab
At the one site with sufficient data points to adequately compare simulated with measured lablab biomass in the grazed paddock, the observed biomass during the grazing period was over-predicted. As for the forage sorghum simulations, the poor agreement of simulated with observed biomass in the grazed paddock was not unexpected given the poor agreement of simulated with observed un-grazed biomass.

2.2.6.4 General discussion of APSIM grazing simulations for annual forages
The APSIM annual forage models have only a rudimentary equation to alter forage biomass production due to grazing. This equation is a simple relationship between an estimate of the amount of leaf mass consumed and the reduction in leaf area available to intercept radiation. It does not attempt to account for diet selection. Most importantly, there is currently no equation to attempt to account for effects of trampling on forage growth.

There were two aspects of these datasets that may have contributed to differences between simulated and observed data sets. Firstly, an average stocking rate over the entire grazing period was used rather than altering the stocking rate over time, as usually occurred at the commercial forage sites that were monitored. It is possible that using the actual stocking rate over time, rather than an average, may change the dynamics of forage selection by livestock and the feedback mechanism on modelled forage growth. However, this aspect was examined for Central Queensland Brigalow Oats 2011, with five different stocking rates over time used as inputs to the model, and resulted in little improvement in the agreement between modelled and measured biomass. Another complication in comparisons of the measured data sets with modelled output for these grazed sites is that, generally, considerable areas of perennial grass pasture were provided in conjunction with the forage area, for example, ranging from 17 to 87% of the total grazing area for oats sites. Despite this, cattle were generally primarily consuming the sown forage, for example, the average component of the diet as C_3 plants, assumed to be oats, over the entire grazing period ranged from 63-89%. The stocking rate figures used as model inputs were those expressed per the area of planted forage only, rather than the total grazing area. Thus the grazing pressure on the forage area only was actually lower than that used as the model input. Despite an over-estimated stocking rate being used as a model input, the effects of grazing were still generally under-predicted for the annual forage crops (i.e. the biomass over time in grazed paddocks was over-predicted) compared to the observed data points. This further substantiates the conclusion that APSIM annual forage model is unable to adequately account for the effects of grazing, including both effects of consumption and trampling, on biomass growth.

In most cases, there was very little reduction in simulated total biomass yield (i.e. total yield over the entire grazing period) for the grazed paddock when compared to the un-grazed exclosure:

- oats
  - grazed total biomass prediction as a % of un-grazed total biomass prediction ranged from 94-100% for five out of the eight oats sites
  - grazed total biomass prediction as a % of un-grazed total biomass prediction ranged from 72-88% for three out of eight of the oats sites.
- forage sorghum
  - grazed total biomass prediction was the same as un-grazed total biomass prediction for all four forage sorghum sites.
- lablab
  - grazed total biomass prediction was the same as the un-grazed total biomass prediction for both lablab sites.

It is has been well documented that the net effect of grazing on the cumulative growth of plants can be negative, zero, or positive, depending on the availability of leaf area, meristems, stored nutrients, and soil resources, and on the frequency and intensity of defoliation (Noy-Meir 1993). Hence, the effects of grazing on total biomass yields in the monitored forage paddocks could have fallen anywhere within this range, dependant on the above variables. However, as the observed biomass yields at points in time over the grazing period were over-predicted for six out of eight oats sites, two out of four forage sorghum sites and one out of two lablab sites, it follows that the total biomass yields in the grazed paddock were also over-predicted for these sites. As it was not possible to measure total biomass growth in the grazed paddock, due to the inability to quantify consumption and trampling effects, this over-prediction cannot be quantified.

2.2.6.5 Perennial grass

Similar to GRASP predictions of un-grazed biomass for perennial grasses, there was generally very good prediction of standing biomass in grazed paddocks at three sites across the Fitzroy River catchment. The trend in standing biomass over seasons was well predicted by the model. There was some evidence of under-prediction of peak biomass yields at two of the sites and over-prediction of minimum biomass yields at two of the sites.

3 Evaluation of the GrazFeed model for predictions of cattle liveweight gain against field data from commercial beef properties

3.1 Methodology

An investigation was conducted into the accuracy of liveweight gain predictions for the measured data sets reported in Appendix 1, by the GrazFeed decision support tool, Tropical version 5.0.5 (CSIRO 2014,) which is based on the Australian feeding standards (CSIRO 2007) and the animal biology model described in Freer *et al. (*2012). GrazFeed predicts the intake of energy and protein from the pasture by grazing animals and estimates the use of the diet for maintenance and production. The Tropical version of Grazfeed allows the user to enter faecal near infrared reflectance spectroscopy (NIRS) –derived estimates of diet crude protein (CP) and dry matter digestibility (DMD) directly, rather than diet selection being estimated by the model from the presentation of green and dead biomass and estimates of the digestibility of these components. In addition to the ability to input diet quality parameters directly, there are several important modifications within the Tropical version to better represent the forage species and cattle breeds used in Northern Australia:

1. The relationship between digestibility and intake for C_4 grasses (tropical species) is different to that for the C_3 grasses (temperate species) and is based on the work of McLennan (1997) which indicated that intakes were greater for C_4 species than C_3 species at the same digestibility.
2. *Bos indicus* cattle differ from *B. taurus* cattle in three respects (a) their maintenance energy and protein requirements are lower; (b) their ability to recycle nitrogen is greater when rumen degradable protein (RDP) is lower than the required level, resulting in a reduced effect of RDP deficiency on intake; and (c) the composition of weight gain is assumed to be similar to European breeds rather than British breeds, with *B. indicus* and *B. taurus* crossbreds having intermediate values.

A total of 26 data sets for grazed annual forages were used to test the GrazFeed model. These data sets were discrete periods of liveweight gain measured for groups of cattle grazing either oats (14 data sets), sorghum (nine data sets) or lablab (three data sets) forage, and are detailed in Appendix 1. Representative faecal NIRS-derived estimates of diet DMD and CP were used as the key inputs of forage quality. As far as we are aware, this is the first time the GrazFeed model has been tested against measured data for grazed, high quality, temperate and tropical forages in northern Australia.

3.2 Results and discussion

Daily cattle liveweight gain was under-predicted for 25 out of 26 data sets (Fig. 35). The under-prediction was most extreme for cattle grazing forage oats where the average under-prediction for 14 data sets was 0.9 kg/head/day (range: 0.2-1.9 kg/head/day under-prediction). Furthermore, a negative liveweight gain was predicted for five of the data sets when measured liveweight gains ranged from 0.26-0.95 kg/head/day for these five data sets. The average under-prediction of daily cattle liveweight gain for the nine forage sorghum data sets was 0.4 kg/head/day (range: 0-0.8 kg/head/day under-prediction). A negative liveweight gain was predicted for four of the nine forage sorghum data sets when measured liveweight gains ranged from 0.23-0.43 kg/head/day for these four data sets. The average under-prediction of daily cattle liveweight gain for the three lablab data sets was 0.3 kg/head/day (range: 0.2-0.3 kg/head/day under-prediction).

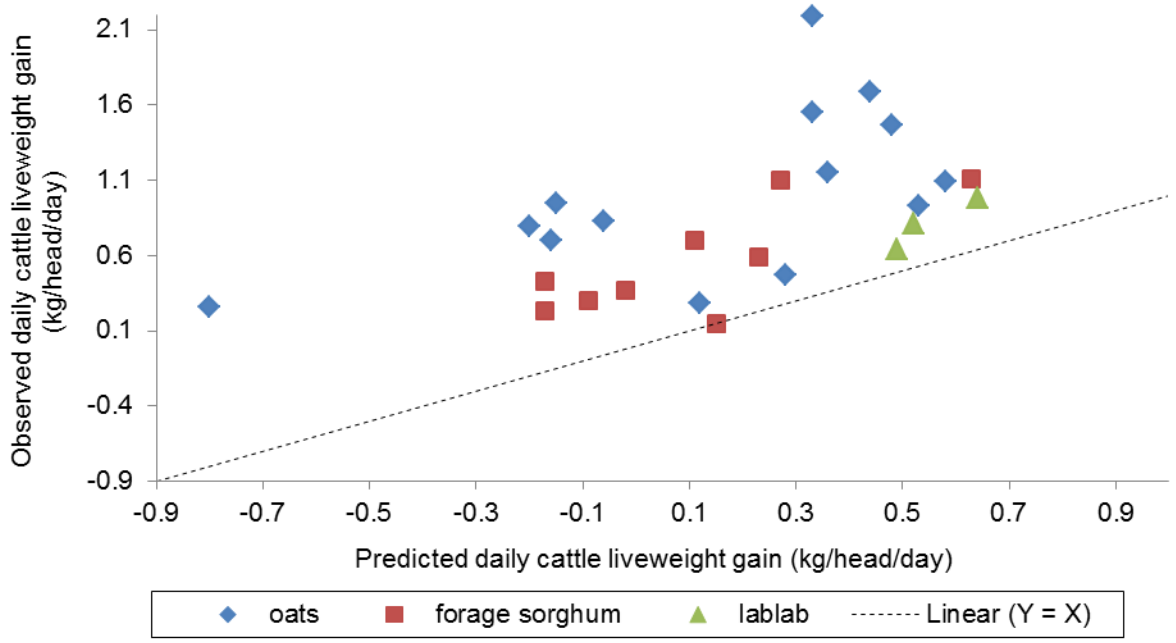

Fig. 35. Relationship between the observed daily liveweight gain (kg/head/day) and the daily cattle liveweight gain (kg/head/day) predicted with Tropical Grazfeed version 5.0.5, for cattle grazing high quality sown forages and with access to varying amounts of perennial grass pasture.

Our results support the findings of others, including Thompson (1996), Bolam (1998), McLennan (1997), McLennan and Poppi (2005), Dove *et al.* (2010) and McLennan (2014), who have also shown that the existing models based on the Australian feeding standards are generally poor at predicting the performance of cattle consuming tropical forages, primarily due to difficulties in accurately predicting the intake of forage. The Australian feeding standards (CSIRO 2007), similar to the ruminant feeding standards of countries (e.g. NRC 2000), have been developed on temperate forage systems and usually with *B. taurus* cattle. Dove *et al.* (2010) have shown that GrazFeed accurately predicts the liveweight gains of sheep and cattle under grazing conditions for temperate pastures. However researchers, including most recently McLennan and Poppi (2005) and McLennan (2014) have shown that the Australian feeding standards and GrazFeed consistently under-predict the liveweight gain of cattle consuming tropical forages, or conversely, over-estimate intake for a given liveweight change. The authors concluded that the underlying equations used in the feeding standards and model to predict energy utilisation for cattle growth were sound. However, the algorithms relating DMD to intake were not appropriate for tropical forages.

The premise of our study was that GrazFeed may be able to reliably predict the growth rates of cattle grazing the temperate (C_3) forage, oats, and the high quality sown tropical forage crops, sorghum and lablab, especially in light of the recent modifications including:

- ability to input faecal NIRS-estimated diet DMD and CP rather than have the model estimate these parameters;
- improved algorithm relating DMD to intake; and
- modifications to the parameters for *B. indicus* cattle.

However, even for the data sets for high quality tropical and temperate forages reported in this study, the GrazFeed model over-predicted liveweight gain, as has been consistently reported for lower quality tropical, forages (e.g. McLennan and Poppi (2005) and McLennan (2014)). In fact, the predicted results for temperate forage, oats, had the largest deviation from observed values. The Grazfeed program predicts lower intakes, in relation to a given DMD, for temperate feeds and this could explain the more exacerbated under-prediction of liveweight gain for oats relative to forage sorghum. It appears likely that the same DMD-intake algorithm may be appropriate for both C_3 and C_4 forages grown in tropical or subtropical environments. The effect of higher growth temperatures on reducing DMD has been well documented with Wilson (1982) suggesting that temperature influences could lead to at least 5-10 percentage units difference in DMD between species grown in tropical versus temperate climates. As reviewed by this author, in addition to the higher growth temperatures accelerating the maturation processes, the potential DMD of newly formed tissue is lower for plants grown at higher temperatures due to less accumulation of soluble carbohydrates and a decrease in cell wall digestibility. It is possible that the DMD-intake algorithm required to accurately predict liveweight gain for cattle in the tropics should be related to the latitude of forage growth rather than to the forage species.

As the diet DMD input parameters in this study were obtained from faecal NIRS, there is a possibility that this may be a source of error as the calibration sets for the high quality forage types grazed in this study are not as extensive as those for tropical, perennial grasses (Coates 2004). The reference values used to develop the faecal NIRS calibration equation for predicting diet DMD in grazing cattle were derived from a relationship developed between dry matter intake and estimated *in vivo* DMD derived from pepsin-cellulase *in vitro* analysis Coates (2004). When NIRS-predicted diet DMD for the forages in this study were used to predict intake using the Coates (2004) equation, the result was similar to that obtained using the simple Minson and McDonald (1987) equation which estimates intake based on the liveweight and growth rate of the animal. Both sets of intake predictions exceeded the intake predictions of GrazFeed, for example, by an average of 2.2 kg/day for the oats data sets (D Coates *pers. comm.*). These calculations add further weight to the conclusion that the algorithm in GrazFeed for predicting intake from DMD is still inaccurate for tropical forages and also for temperate forages grown in subtropical/tropical environments.

In addition to the algorithm relating diet DMD to intake, there are several other limitations to the GrazFeed model which were evident for our data sets.

1. There is difficulty in selecting an appropriate ‘standard reference weight’ (SRW) for the cattle which is a major input in the model, having a significant effect on the liveweight gain prediction. For our data sets, where cattle were *B. indicus* and *B. taurus* crossbreds, SRW was kept constant at 550 kg for a female (corresponding to 660 kg for a castrate). This value was selected based on what was deemed most representative of typical steers in central Queensland. However, the corresponding female SRW of 550 kg (calculated from the feeding standards (CSIRO 2007)) was deemed high, and 480 kg considered to be more reasonable. It is possible that females grown out under central Queensland conditions may not reach their genetic potential for frame score, resulting in a different relationship between female and male SRW for our conditions. Regardless, if we were to alter the SRW, it would be to reduce it below what was used, and this further exacerbates the under-prediction of liveweight gain by GrazFeed.
2. There is no mechanism in the model for predicting effects of compensatory growth for cattle where they are above their ‘normal’ weight for age. Especially in our oats data sets where cattle grazed low quality perennial grass pastures prior to grazing the forage, we would expect some level of compensatory gain. However, the model only applies compensation effects when the animals are currently at a lower weight than that achieved earlier in their life (i.e. when cattle have lost weight rather than just growing a reduced rate).
3. There is no mechanism in the model to account for the effects of hormonal growth promotant (HGP) use. For our data sets, where HGPs had been used, we followed the recommendations in SCA (1990) that SRW be increased by 10%.
4. There is currently no breed option with GrazFeed for Brahman x European breed cattle. This type of *B. indicus* crossbred is widely produced within the Fitzroy River catchment

area. The ‘British x Brahman’ option was used for our datasets for all *B. indicus* crossbred cattle.

It is concluded that there is currently no confidence in the use of GrazFeed or the Australian feeding standards in northern Australia, even when high quality forages, and temperate forages such as oats, are fed. Hence, the GrazFeed animal biology model was deemed unsuitable for use in a DST designed for cattle grazing high quality forages in the Fitzroy River catchment.

4 Evaluation of the GRASP daily liveweight gain model for predictions of cattle liveweight gain against field data from commercial beef properties

4.1 Methodology

The simple GRASP daily liveweight gain model (Littleboy and McKeon 1997; McKeon *et al.* 2000), called 'GRAZ' in the APSIM modelling platform, was used to predict cattle production for each of the 17 field sites. GRAZ is a simple potential growth model based that limits animal growth by feed deficit. Forage biomass is not used as an input and predicted cattle growth rates are based on expected growth rates specified by the modeller and reduced if feed deficits arise during the grazing period.

4.2 Results and discussion

The model was configured to predict a final cattle liveweight at the end of the grazing period from an assumed starting liveweight of steers of 450 kg. When the predicted final cattle liveweight was compared to the calculated finishing weight (based on a starting liveweight of 450 kg and the known average daily liveweight gain), the agreement was good: average 100% (predicted as a % of calculated). However, given that this result relies on the user specifying the expected cattle growth rates in the first instance, the good agreement of modelled with measured growth rates is not surprising. Furthermore, this approach to predicting cattle production does not use the simulated forage biomass as an input and thus does not produce an estimate of total liveweight gain per hectare. For these reasons, this modelling approach to predicting cattle production was deemed unsuitable for use in our decision support tool.

5 Evaluation of a simple forage utilisation equation for predictions of cattle liveweight gain against field data from commercial beef properties

5.1 Methodology

A simple forage utilisation equation was used to estimate total paddock liveweight gain (LWG) for each of the 14 annual forage data sets:

Total paddock LWG (kg/ha) = [total biomass (kg/ha) – residual (kg/ha)] x biomass utilisation x efficiency of feed utilisation

where:

- total biomass is the APSIM-estimated total biomass grown in the grazed paddock
- residual is the paddock biomass below which no utilisation can occur. The mean of measured paddock residuals for each forage species was used.
- biomass utilisation is the proportion of the biomass that can be consumed by the animal after losses due to trampling, soiling, unpalatability and other wastage is accounted for
- efficiency of feed utilisation is a measure of the amount of cattle liveweight gain per unit of plant material consumed (i.e. kg LWG per kg of feed DM consumed) as given in Minson and McDonald (1987). The table below gives an example of efficiency values for four different starting cattle weights. However, the efficiency values were adjusted for within 10 kg of the starting weight for each cattle group.

The following table summarises the parameters used for each forage type:

Table 1. Parameters used in the simple forage utilisation equation to estimate paddock liveweight gain

	Annual forages		
	Oats	Forage sorghum	Lablab
Residual (kg DM/ha)	1200	2200	3500
Biomass utilisation	0.4	0.3	0.4
Efficiency of feed utilisation (examples for several entry liveweights of cattle)			
400 kg	0.119	0.078	0.099
450 kg	0.110	0.071	0.092
500 kg	0.103	0.067	0.085
520 kg	0.100	0.065	0.083

It was not sensible to conduct this validation exercise for the perennial pastures due to the large number of cattle groups, each with different specifications, entering and exiting the commercially run paddocks over the monitored period, which was for up to 3 years.

5.3 Results and discussion

5.3.1 Oats

The agreement of predicted total liveweight gain (kg/ha), with measured, was variable:

- four out of eight oats sites had predicted paddock liveweight gain within approximately 15% of that measured (range across all 8 sites for predicted liveweight gain as a % of measured liveweight gain was 92-276%)
- seven out of eight sites over-predicted liveweight gain.

The general over-prediction of liveweight gain for cattle grazing oats sites was not unexpected due to the over-prediction of biomass yield in the grazed paddock.

5.3.2 Forage sorghum

The agreement of predicted total liveweight gain (kg/ha), with measured, was poor, which was expected due to the poor ability of the model to predict forage sorghum biomass growth in the first instance and the poor ability to predict the effects of grazing on biomass growth:

- the predicted paddock liveweight gain as a % of measured liveweight gain ranged from 32-190%.

5.3.3 Lablab

The agreement of total liveweight gain (kg/ha), with measured, varied for the two sites:

- the predicted paddock liveweight gain as a % of measured liveweight gain for one lablab site was 321%
- the predicted paddock liveweight gain as a % of measured liveweight gain for the 2nd lablab site was 88%, i.e. within 15%.

The comparison of estimated total liveweight gain with measured data from the annual forage sites is complicated by the complex nature of the co-operator sites, where varying amounts of perennial grass areas were provided in conjunction with forage, supplementary grain was sometimes provided, different groups of cattle entered and exited during the grazing period, and liveweight gain by some groups of cattle was not measured and had to be estimated. Furthermore, the APSIM-predicted biomass yields in the grazed paddock were generally over-predicted. In light of these limitations, the variable agreement of modelled with predicted total liveweight gain was not surprising. However, in light of the limitations of the GrazFeed and the GRASP daily liveweight gain models for our circumstances and purpose, the simple forage utilisation equation was deemed to be the most appropriate approach for estimating cattle production within a simple DST.

6 Conclusions

The conclusions from the evaluation of forage and animal modelling capabilities for forages grown in the Fitzroy River catchment can be summarised as follows:

- the APSIM forage growth model for oats predicted measured biomass at field sites satisfactorily
- APSIM forage growth models for forage sorghum and lablab require modification, as biomass production is currently under-predicted
- the simulated effect of grazing on biomass growth needs improving for all annual forage models in APSIM as the models are currently considerably under-predicting the effects of grazing in reducing biomass production
- the GRASP model predicted biomass of perennial grass pastures, in un-grazed and grazed areas, satisfactorily
- the GrazFeed model was unable to accurately predict cattle liveweight gain from grazed forage paddocks, including the temperate forage, oats
- the GRASP daily liveweight gain model was considered unsuitable for use in a decision support tool comparing annual forage crops due to not using biomass production as an input and requiring user-estimated liveweight gain as an input
- the simple forage utilisation equation was deemed the most appropriate approach for estimating cattle production, although the accuracy of total liveweight gain (kg/ha) predictions are currently limited by inaccuracies in simulating the effect of grazing on annual forages within APSIM
- in light of the poor ability of forage models within APSIM to predict annual forage crop biomass production from grazed forages, a DST developed using this output should be treated as a prototype, providing a framework which can be built upon and improved as further data sets become available and as improvements to the underlying plant growth and grazing functions are made.

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