final report

NATURAL RESOURCE MANAGEMENT

Project code: B.NBP.0353

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Date published: October 2011

ISBN: 9781741916355

PUBLISHED BY
Meat & Livestock Australia Limited
Locked Bag 991
NORTH SYDNEY NSW 2059

Volume I - Investigating Intensive Grazing Systems in Northern Australia

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

Abstract

Beef producers face increasing environmental and financial pressures to remain productive and viable. Many are considering using more intensive grazing systems to achieve their goals but are unsure of the costs and benefits of alternative systems. This research project was developed to provide information on different intensities of grazing systems in northern Australia. Nine properties were selected, with each operating paddocks under at least 2 of the broad system types of interest – continuous, rotational and cell. Properties were located in both north and south Queensland and on either brigalow or eucalypt country. Paddocks within each of the grazing systems on each property were monitored for pasture attributes, soil surface condition, grazing days harvested, and diet quality of cattle between 2006 and 2009. The intensive systems on each property had been in place for up to 10 years prior to the project starting.

During the four-years of measurement, there were initially two or more years at each site of well below average rainfall followed by up to two average rainfall years. There was little or no impact of grazing system on pasture attributes or soil surface condition. Trends in pasture condition and growth were dominated by seasonal conditions, with pastures in all systems responding well to the better rainfall conditions towards the end of the project. Diet quality (measured by NIRS) was generally lower in the more intensive systems, especially during the growing season. There was no consistent difference in grazing days per ha due to grazing system.

The different grazing systems within a property were not managed independently of each other but tended to be operated as an integrated management system. This meant cattle could spend time within different systems within the one 12-month period, especially during dry years. In combination with differences in animal classes between systems at some sites, this precluded attempts to directly assess the impact of grazing system on individual animal productivity.

The integrated management of paddocks across systems on each property suggests that key management principles, such as matching stocking rate to carrying capacity, were applied to all paddocks on a property to a similar extent. This helps explain lack of impact of grazing system per se and supports the extensive evidence base that indicates stocking rate management, and not grazing system, is the major driver of pasture and animal productivity.

Executive summary

Beef producers face increasing environmental and financial pressures to remain productive and viable. While past cases of deteriorating condition of grazing land have been clearly linked to poor management of stocking rate, there has been increasing interest and investment in intensive grazing systems, especially cell grazing, which provide greater control of the location, duration, intensity and timing of grazing. Part of the attraction of such systems is their perceived potential to increase stocking rates, improve land condition, and enhance animal performance due to factors such as improved spatial distribution of grazing, long spell periods, and maintaining pasture in a vegetative state.

While interest in more intensive grazing systems has grown, there are mixed views, and a lack of positive experimental evidence, over their benefits and their suitability for different environments, levels of property infrastructure, management capacities and lifestyle preferences. The management and infrastructure requirements of grazing systems can be viewed as a continuum from low-input continuous grazing, through rotational systems, to intensive 'cell' systems.

This research project assessed the impacts of more intensive grazing systems on (a) the condition and trend of grazing land, (b) paddock carrying capacities and (c) diet quality of cattle. It measured the inputs and outcomes from different systems with the objective of providing producers with additional evidence on which to assess their merits.

Nine properties were selected, with each operating paddocks under at least two of the broad system types of interest – continuous, rotational and cell. The intensive systems had been in place for between 2 and 10 years prior to the project starting. Properties were located in both north and south Queensland, and on both brigalow and eucalypt land types. From 2006 to 2009, a sub-set of paddocks from each intensive system was monitored for pasture and animal performance including analysis of grazing records. A total of 74 paddocks (54 cell, 13 rotation and seven continuous), across 21 grazing systems (eight cells, six rotational and seven continuous), were monitored for the 4-year period.

At all sites, the project period covered two below-average rainfall years followed by two average to above-average years. The property owners made all management decisions and conducted all management operations as part of their normal property operations. Consequently, the stocking of paddocks in each system on a property varied with seasonal conditions and other management factors.

Impacts of more intensive grazing systems

There were no significant or consistent impacts of grazing system on soil surface condition, pasture attributes (yield, botanical composition, litter cover) or land condition rating. There were small but consistent impacts of grazing system on (1) pasture species diversity, with least diversity in cell paddocks and (2) the spatial variability of defoliation, with least variability under cell grazing. There was a trend, significant in one year, for cell paddocks to have more spatially uniform groundcover. All paddocks improved in condition during the latter two years of average to above-average rainfall, but the degree of improvement was not affected by grazing system.

Historical analysis (previous 20 years) of trends in annual groundcover (Landsat data using VegMachine software) was done for each monitored paddock at each site. Groundcover levels and trends followed trends in annual rainfall with no influence of grazing system.

Grazing system had no affect on the grazing days per ha per year imposed on paddocks, except for some instances of lower grazing days from rotational systems due, in part, to extraneous factors. Overall, there were similar numbers of stock days per hectare per year for paddocks

within the Cell (119) and Continuous systems (115). On average, cell and continuous paddocks were grazed somewhat above the objectively assessed values for long-term carrying capacity.

Grazing system affected diet quality as estimated via faecal NIRS. More intensive systems generally had lower diet quality. Over all sites and seasons, the continuous system had 1-2% higher crude protein and digestibility than the cells, with diet estimates for the rotation system consistently between those for continuous and cell systems. These differences were largest from samples collected during the growing season and least with samples collected during the dry season.

A grazing system intensity index (GSI) with a scale from 0 to 100 was calculated from three factors: capital costs, operating costs and management inputs. The values for the different systems at the nine sites ranged from 21 to 96. The average GSI for the systems was: cells 79 (range 63-96), rotations 61 (range 45-84) and continuous 26 (range 21-31). However, following on from the results above, GSI was generally unrelated to pasture and animal performance.

A spreadsheet (Excel®) template, based on partial budgeting, was developed for assessing the costs and benefits of investing in more intensive grazing systems. This tool helps assessment of the likely impact on profit, as well as estimating how much additional production is required to ‘break even’, and how long it might take before any increased profit will recoup the capital outlays that are involved.

Implications for industry

The intensity of the grazing system had no consistent effect on soil surface condition, pastures or carrying capacity when compared to less intensive systems on the same property. This confirms other studies that have consistently shown stocking rate management to be the major driver of pasture and animal productivity rather than grazing system per se. In this project, each of the systems within a property appeared to be equally well managed with respect to stocking rate and monitoring of soil, pasture and stock. In addition, operation of each system varied considerably over the four years as managers reacted to changing circumstances, and livestock were often grazed across different systems within a year, especially during drier times. This would reinforce the extent to which all systems on a property were equally well managed.

This research has described how grazing management has been intensified on each of the nine properties and quantified the effects of these grazing systems on their pastures and cattle. This information can be used by other producers to develop grazing practices that will suit their resources, finances and lifestyles, with an understanding of the inputs required and what outcomes they may expect.

While this study found that grazing system or method was relatively unimportant, this does not diminish the importance of improved grazing management for the beef cattle industry in northern Australia. Research in northern Australia has consistently shown that major opportunities for improved land condition and productivity are based around:

- better spatial distribution of grazing pressure (through location and number of water points, sub-divisional fencing);
- better matching of stocking rate with carrying capacity; and
- targeted use of wet season spelling.

Implementing a more intensive grazing system is one way of achieving these benefits but the results from this project indicate that simpler and less expensive management systems will achieve similar outcomes, eg, through modification of continuous grazing systems with rotational wet season spelling and with more active management of stocking rate around the long-term carrying capacity.

Acknowledgments

We thank the nine property owners, managers and their staff for cooperation, support and interest during the project, for sharing their records, experience and knowledge, and also for their generous hospitality which made the field work all the more enjoyable. We thank producers who recognised the need for this work, those who participated in the advisory group and others who contributed to developing the project, especially during the site selection process, and to the continuing discussions on their grazing management and on the project results as they emerged.

We thank Meat and Livestock Australia (MLA), the Department of Employment, Economic Development and Innovation (DEEDI) (formerly Department of Primary Industries and Fisheries, Queensland) and CSIRO for contributing finance and facilities to the project team. Staff from these organisations also provided valuable guidance during the project. We acknowledge the Queensland Department of Natural Resources and Water (now DERM) for providing data for property imagery, regional ecosystem mapping and satellite ground cover data. We thank the many DEEDI and CSIRO staff for their interest and participation in field work and results throughout the project. The assistance and dedication of David Coates for the NIRS analysis, Simone Grounds (mapping), Chris Holloway (VegMachine) and Christina Playford (NIRS statistics) are especially acknowledged. We also thank the families of project staff for their understanding and support during the multiple field recording trips.

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1 Background

1.1 Introduction

Grazing management practices of commercial beef producers across northern Australia have been evolving, associated with a number of factors including the search for new ways to improve economic and environmental outcomes. There has been increased awareness that lack of attention to grazing management in the past, when cattle condition and prices drove grazing decisions, has not delivered the best economic and environmental outcomes. Tothill and Gillies (1992) reported pasture condition across the northern half of Australia, based largely on expert opinion, and found that only 42% of Queensland grazing lands were in good condition.

Consequently, there has been increasing interest in, and adoption of, more deliberate and judicious grazing management integrating additional fencing and water points, better management of stocking rate, and wet season spelling. In northern Australia, most grazing is based on continuous or near-continuous stocking of paddocks and most research has been targeted at the impact that the overall level of stocking and the use of wet season spelling have on pasture and animal production (e.g., Ash et al. 2001; Ash et al. 1997; Burrows et al. 2010). This research has shown that stocking at or around the long-term carrying capacity, adjusting grazing pressure in relation to seasonal or annual forage supply, and wet season spelling are the key practices for improving pasture and animal productivity.

However, there has also been significant interest in the potential benefits of more intensive systems. These usually involve rotational grazing of some sort and, in the most intensive versions, typically involve the movement of a single mob of cattle around a large number of paddocks. Systems such as cell grazing have been promoted widely (e.g. McCosker 2000) and have been adopted by some producers. This has attracted interest from other producers but many are unsure of the costs and benefits of such systems and whether they are suited to their environment, climate, property infrastructure, management capacity and desired lifestyle.

Cell grazing and other rotational systems were first evaluated and promoted in South Africa and the USA, where there has been longer and more intense interest in the need for greater intervention and control of grazing. In both countries, some form of rotational grazing is commonly seen as being a minimum requirement for a more deliberate and planned approach to grazing management. Consequently most studies of grazing systems, including cell grazing, have occurred in these countries. Interestingly, these studies do not generally support the claimed benefits of cell systems over less-intensive grazing methods. For example, Briske *et al.* (2008) recently reviewed the results of world-wide research on cell and other rotational grazing systems and found there was no evidence of superior plant and animal production from such systems compared to well-managed continuous grazing. Be that as it may, strong belief is maintained in the value of more intensive systems by some producers and grazing consultants, e.g., Flynn (2008) recently elaborated on some of the cell grazing principles promoted by Allan Savory, one of the original promoters of high density grazing systems in Southern Africa.

Despite the lack of experimental evidence of superior performance from these intensive forms of grazing management, the growing curiosity amongst producers in northern Australia motivated this evaluation of various grazing systems already operating on commercial enterprises. The research measured the inputs and outcomes from these systems with a view to providing producers with additional evidence on which to assess their merits relative to other approaches to grazing management.

This report outlines the results from a 4-year study of 21 grazing systems on nine beef properties located across Queensland.

1.2 Grazing methods

There are four main components that drive successful grazing management and these were identified some 50 years ago:

1. Number of animals
2. Kind and class of animals
3. Spatial distribution of animals
4. Temporal distribution of animals

The overall number of animals is the broadest and most important driver of animal performance, profitability and sustainability and over the last two decades considerable effort has been directed towards developing sustainable carrying capacities and utilisation rates for grazing enterprises. More recently, attention has shifted to the spatial and temporal distribution of grazing pressure and this has led to considerable interest amongst producers in different grazing methods or systems (i.e. methods of controlling the location and timing of grazing that often incorporate a period of planned pasture spelling or rest and often emphasise intra-annual adjustment of grazing pressure in relation to forage supply). Such systems can be seen as covering a range of management and infrastructure intensity, from:

- the traditional practice of continuous grazing in relatively large paddocks and with relatively little intra-annual or inter-annual adjustment of stocking rates and where such changes are reactive rather than planned,
- through ‘continuous’ grazing systems in smaller, well-watered paddocks and with some form of intra-annual stocking rate adjustment where appropriate, and regular wet season spelling,
- to systems of rotational grazing that involve a few paddocks, and incorporate frequent periods of wet-season resting where the rest period is relatively short compared to grazing period, and resting is planned proactively,
- to increasing system intensity, such as cell or time-control grazing systems with large numbers of paddocks, short grazing periods and long rest periods.

Producers are unsure of the costs and benefits of various systems and whether they are suited to their environment, climate, property infrastructure and management capacity. Questions include, what will the benefits be for me? What aspect of the management system confer benefits? Does cell grazing work everywhere? If not, what are the limits to successful use? Is it possible to achieve the benefits of sound grazing management with other approaches and grazing methods?

There are many possible goals for adopting a grazing system but for this project they are considered to be:

- improved financial performance due to increased production and/or lower costs;
- improved environmental performance due to better and more productive pastures, improved soil health, and reduced off-site impacts; and
- long-term sustainability of grazing properties and the people they support.

1.3 Research project development

The challenge in designing the project to answer producers’ questions was to:

- Identify the key questions to be addressed,
- Have a scientifically sound and rigorous approach, and
- Obtain credible and robust results that are commercially relevant.

Comparisons of grazing systems can be somewhat self-defeating in that they imply there is a unique treatment called ‘continuous stocking’ that can be compared with another unique treatment called ‘cell grazing’, or the ‘Merrill’ system, or the ‘Hornay’ rest rotation system.

However it is clear that any given grazing method, such as continuous stocking, does not explicitly indicate either the approach to managing grazing pressure, the distribution of watering points or the fencing lay-out i.e., there can be more variation caused by the differences in management of a given grazing method than between different grazing methods *per se*. Valid comparisons therefore need to ensure that other interacting factors (stocking rate, distance to water etc) are controlled and that different systems be evaluated across a range of values in key factors such as stocking rate.

Comparison of grazing systems, be it on research stations or commercial properties, is therefore resource-hungry, difficult to design, somewhat time and location specific, and often limited in the questions it can address. It must also be long-term to have any real value. Given these factors, this project was designed to rely on data obtained from commercial properties with existing management systems. Such an approach has advantages in terms of producer input and operation at a scale of commercial interest, but also has limits related to experimental design. Given the resources available, the chosen approach appeared to be the best compromise between the experimental integrity (but site specificity, limited treatments, and large cost) of a replicated, long-term grazing trial and the appeal (but lack of ability to establish cause and effect) of anecdotal case studies.

The project development advisory team chose three broad systems to compare: continuous grazing which may include some resting and adjustment of stocking rate over time, rotational grazing with more frequent and longer rest periods, and more intensive cell grazing systems. The research approach was to monitor and compare established grazing systems within and across commercial enterprises. On each of the nine properties used in the study, data was collected on biophysical (animal, pasture, soil), financial and management inputs and outputs for 2 or 3 different grazing systems.

1.3.1 Project development and research approach

1.3.1.1 Phase 1. Project scoping and establishment (October 2004 - May 2005)

1. Advisory group

An advisory group of five beef producers from across Queensland and staff from MLA, QDPIF and CSIRO was formed to guide the development of the project.

2. Regional framework

For the outputs of the project to have relevance across a wide area of northern Australia it was important to include regions, and properties in each region, that allowed extrapolation to other properties and regions. Initially, two criteria were used to select regions: growing season length and soil fertility, which reflect the production potential and resilience of the properties. The environmental framework included areas with:

- (i) Long growing season and relatively high soil fertility e.g. brigalow in southern Queensland
- (ii) Long growing season and low soil fertility e.g. eucalypt country in southern Queensland
- (iii) Short growing season and relatively high soil fertility e.g. northern brigalow/gidgee
- (iv) Short growing season and low soil fertility e.g. northern speargrass (eucalypt country), Gulf country.

We selected nine properties from over 100 investigated across these four regions. The matrix was high and low fertility (brigalow and eucalypt vegetation communities) in both north and south Queensland.

3. Research locations

To reduce confounding of grazing system impacts with differences in management style and capacity, selected properties had one owner or manager running at least two established grazing systems. By telephone interviews and property inspections, we identified nine properties with two or three established grazing systems, owners keen and able to collaborate, an appropriate fit to the regional environmental framework, suitable location in relation to DPI&F project staff, no need for any extra facilities, and obtained their in-principle agreement to participate.

4. Data collection and analysis

The team developed and tested suitable methods of data collection and analysis at a paddock scale on extensive beef properties by:

- Undertaking a review of measures and measurement techniques appropriate for the project objectives and the scale of the test paddocks.
- Acquiring advice on statistical design and sampling strategies, and
- Field testing the methodologies, as well as training staff.

5. Review of Phase 1 by MLA and project partners.

After developing the research methodology and selecting suitable co-operators, a decision was reached to proceed to full project implementation.

1.3.1.2 Philosophy behind the methodology

1.3.1.2.1 Grazing Systems

The project results were aimed at providing producers with an improved information base on which to make decisions regarding the importance and use of different grazing systems or methods. The challenge for the project was to use as scientifically sound and rigorous an approach as possible given the constraints of having two or three systems within each property with some level of inherent variation, no within site system replication, and no control over day to day management.

It was therefore important to recognise and communicate to producers the statistical limitations of the approach. Unreplicated comparisons on a property are easy to take at face value and, hence, to read meaning where there may be none. It was only from considering the combined data sets across sites that some degree of careful inference would be possible.

1.3.1.2.2 Sites

All research was conducted on grazing properties under commercial conditions managed by the owners/managers. Details of the properties are given in Chapter 3.2. The project did not seek to alter or influence management but obtained records of what the managers did within each grazing system in use.

1.3.1.3 Procedures and measurements

Baseline information. The starting conditions at each site were recorded. This included the following aspects: people (visions, motivations and goals), land (property history, pasture communities, current condition), livestock (types, numbers and breeds), level of monitoring, and capital and operating finance.

Description of grazing systems. The grazing systems at each site were defined. This included information on breeds, numbers and classes of animals, changes to numbers, periods of rest and grazing, supplementation programs, record keeping, labour and infrastructure requirements. There were 2-3 systems monitored on each of the nine properties.

Field measurements. Details are given in Chapter 3 Methodology

Pasture modelling. The pasture growth model GRASP was used to relate the growing seasons experienced during the trial period to longer term climate records.

Decision making information. The project was interested in the decision making processes used in determining and conducting the various grazing systems successfully. A written survey assessment of producers at an annual national BeefPlan group meeting was used to describe producers' attitudes to, and reasons for, their grazing systems. This was to help our understanding of the management, as shown by the actions/behaviour of what was actually done and the responses in the physical (pasture and soil ecology, and cattle performance) measurements we were recording. The survey methods were based on current social science practices, including qualitative analysis.

A MS Access database was established to maintain and manipulate the data for presentation.

Details of these methodologies and associated data analyses are reported briefly in the Methodology (Chapter 3) and in detail in the Appendix (Chapter 9).

1.3.1.4 Phase 2. Full project implementation (July 2005 - June 2009)

The second project phase involved the collection of data from the nine properties and the analysis and synthesis of the results.

1.3.1.4.1 Experimental properties

Each property had two or three established grazing systems, with a total of 21 systems monitored.

1.3.1.4.2 Monitor paddock selection

(a) On each property we identified paddocks with similar characteristics (soil type, pasture, tree cover, topography, etc) in each grazing system. Where possible, we selected paddocks to monitor with similar areas within a system, a similar distribution of water points and the same land type patterns. Established paddocks within systems were selected to avoid requiring additional fencing or water points.

(b) All animal management and movements were conducted by the property staff. Although it is desirable for grazing pressure to be similar for all grazing methods at any one property in any one year, management decisions meant this did not always occur.

(c) At each property we selected 5-11 paddocks within a cell system, 2-3 paddocks within a rotational system and one continuously-grazed paddock.

(d) Grazing information was provided by the owners from their grazing records. Such data as numbers of animals, changes to numbers, periods of rest and grazing, etc for each paddock were collected. Some properties maintained records on grazing charts (RCS type charts) and others used varying charts, notebooks or directly to computer Excel files.

(e) There were 7 continuous, 13 rotational and 54 cell paddocks, making a total of 74 monitor paddocks selected on the nine properties.

(f) The project staff conducted pasture measurements within the selected monitor paddocks only. We did not monitor each system as a whole, nor did we attempt to assess the whole property.

1.3.1.4.3 Sampling and monitoring strategy

A sampling strategy that was statistically sound and recognised variation in land types within the experimental areas was developed. Pastures and soil surface conditions were monitored at set locations on a grid across each paddock and locations were identified by a GPS.

1.3.1.4.4 Measurements

1. Pasture – annual (end of wet season) estimates of yield, botanical composition, species frequency, cover and degree of utilisation were recorded using the Botanal methodology at the end of summer in 2006, 2007 and 2009. There were 62 individual pasture species (selected as potential ecological indicators) and six species groups for additional unidentified species.

2. Landscape health – annual estimates of land condition (by ABCD method), soil health (infiltration, nutrient cycling, stability) by Landscape Functional Analysis (LFA), ground cover, basal area of perennial grasses, landscape leakiness (surrogate for erosion and sediment movement at paddock scale). The LFA methodology was modified to match the Botanal approach using 0.25 m^2 quadrats on a fixed point grid across all paddocks.

3. Animal performance – paddock grazing use [measured in terms of number of animal equivalents (livestock units) (AE) by times (dates and number of days) of grazing)]; liveweight and reproduction (where possible); grazing distribution (by evenness of pasture utilisation); and diet quality through approximately monthly NIRS sampling. Systems were grazed by either growing cattle, mainly steers, or breeding animals with progeny and bulls.

4. Herd management information on a grazing method and property basis for enterprise economic analyses.

5. Finances – capital costs, operating costs (including labour) and returns.

6. Management – input into the system including why and how decisions are made, extra labour provided, record keeping, satisfaction rating with the systems.

7. Data analysis – results from the above data sets were used to describe the performance of the grazing systems on each property and to infer possible causes for any differences between grazing methods within and between properties. Individual property data was also used to develop and allocate a Grazing System Intensity index (GSI) to each of the 21 systems monitored. This index can be used to compare systems operating on any property.

8. Models (GRASP, ENTERPRISE) were used to relate the actual growing seasons to long-term values and predict the likely variability in pasture and economic performance.

1.3.1.5 Synthesis

A synthesis of the results from individual paddocks, systems, properties and across system and property comparisons has been used to gain an understanding of the implications of the results for northern Australia, and develop guidelines for producers to use to assess the value of different systems for their situations.

2 Project objectives

1. Assess the impacts of more intensive grazing systems on the condition and trend of grazing land.

2. Quantify the costs of more intensive systems and derive an intensity index which reflects these costs, the relative number and size of paddocks, and the management input.

3. Record the carrying capacities of different grazing systems.

4. Evaluate the likely financial implications of investing in more intensive grazing systems through break-even analysis.

5. Identify the key findings for producers, the basis for these, their practical implications and benefits, their geographic relevance, risks in their application, and any remaining uncertainties.

3 Methodology

A summary of the sites, pastures, soil surface conditions and animal measurement methodologies are presented below. Full details of these field procedures, data recording and data analysis methodologies are reported in the Appendix (Chapter 9) and the references are listed in the Bibliography (Chapter 8).

3.1 Procedures and measurements

Methods were devised to monitor pastures, land condition and carrying capacity, soil health, animal grazing and production, diet quality and financial inputs and returns. In some cases, new techniques and modified recording systems were developed for on-property monitoring and data analysis. The individual methodologies are briefly described below. Modelling of pastures and financial implications was also conducted to extrapolate beyond the 4-year (2006-2009) recording period of the project.

3.2 Data collection and management procedures

The nine sites (

Table 3.2.1) and 21 grazing systems, were selected across Queensland to satisfy our selection criteria of regional location and vegetation/soil fertility type. There were five sites in the northern half of Queensland and four sites in the southern half. Of these sites, five were eucalypt community sites and four were brigalow sites. One brigalow site (Banyula at Condamine) also had a cell system established on eucalypt country. These properties were chosen after extensive telephone interviews followed by property inspections of potential sites. Only properties with multiple planned grazing systems already established were considered in the selection process. All sites were well managed by experienced owner operators or on-site managers, all with good local knowledge and some formal training in pasture management.

Paddocks within systems were chosen from study of aerial photographs and on-ground survey to find paddocks across the different systems with similar land types, features and stages of development, especially in regard to distribution of water points and any tree clearing or associated regrowth control.

There is limited capacity to statistically compare systems at any one site. While there was no system replication at any site, there were multiple paddocks in the rotation and cell systems at all sites, and repeating the measurements over four years and at multiple sites, permitted some statistical analysis across sites from which the impacts of grazing systems have been inferred.

3.2.1 Site locations

The locations and nearest towns of the nine sites are shown in Figure 3.2.1. The locations of some other major grazing studies in Queensland are also included.

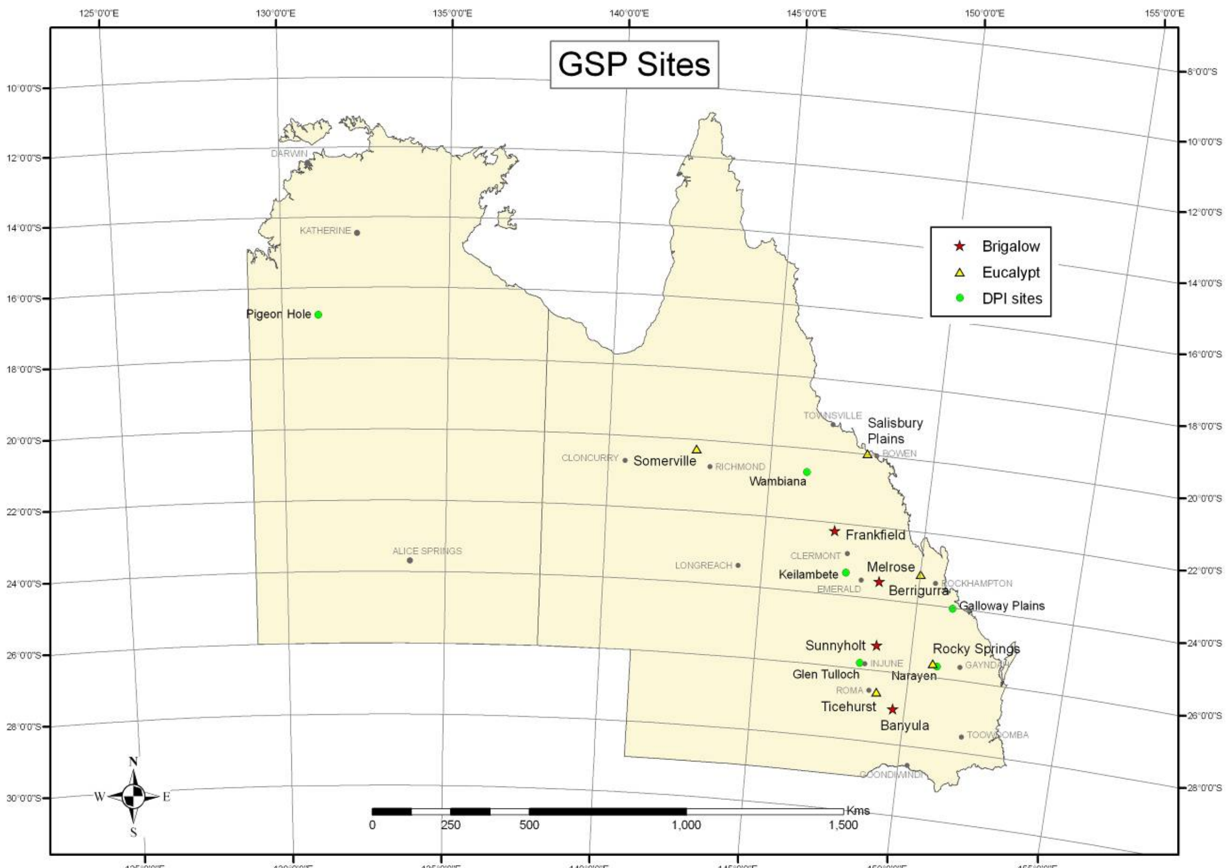


Figure 3.2.1. Map of Queensland showing location of nine sites (brigalow or eucalypt), other grazing research sites and nearest main towns.

Paddock boundary, vegetation/land type, air photo and Spot-5 satellite maps were prepared for each property showing the selected monitor paddocks and pasture types to be sampled. The example below (Figure 3.2.2) shows the Berrigurra monitoring paddocks overlaying a Spot-5 satellite image. There were 74 paddocks selected for monitoring at the nine sites.

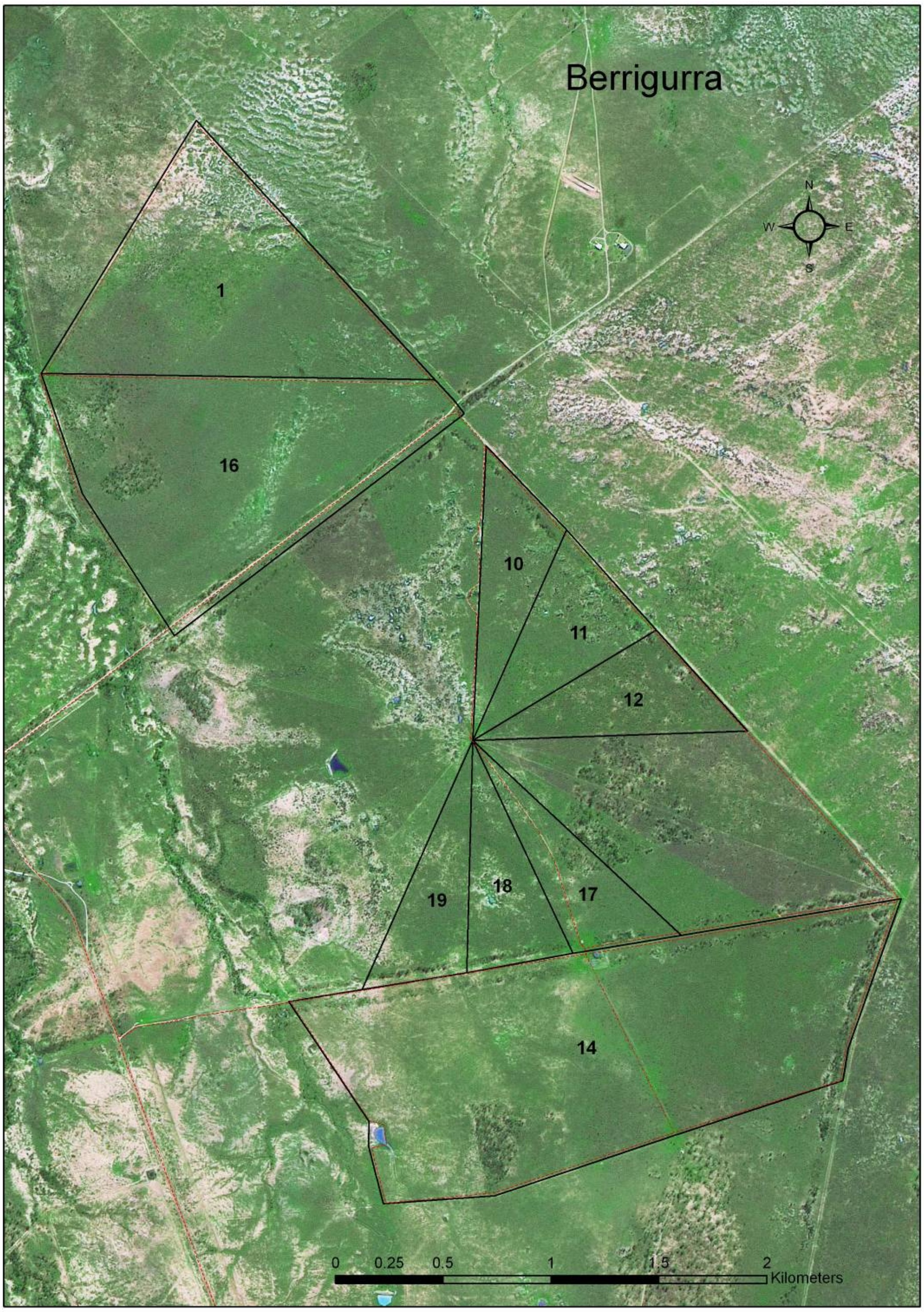


Figure 3.2.2. Spot-5 image map of Berrigurra showing the location of the six cell (nos. 10, 11, 12, 17, 18, 19), two rotation (1 and 16) and one continuous (14) paddock monitored during the project.

The number of paddocks monitored at the sites ranged from three to eleven (

Table 3.2.1).

Table 3.2.1. Nine properties, grazing systems and number of monitored paddocks within each system.

Property	Number of monitor paddocks			
	Continuous	Rotation	Cell	Total Paddocks
Banyula	1		10	11
Berrigurra	1	2	6	9
Frankfield	1	2	8	11
Melrose	1	2	5	8
Rocky Springs	1	2		3
Salisbury	1		9	10
Somerville		3	6	9
Sunnyholt	1		5	6
Ticehurst		2	5	7
Total paddocks	**7**	**13**	**54**	**74**

3.2.2 Sites and paddocks

The site combinations of three grazing systems (eight cell, six rotation, seven continuous), two vegetation communities (four brigalow, five eucalypt) and two regions (five north, four south) for the nine sites are shown in Table 3.2.2. The main parameters measured were analysed for main effects and interactions between these three factors across, within and between sites.

Table 3.2.2. Vegetation type, region and grazing systems at nine experimental sites.

Site/Property	Vegetation	Region	Grazing system		
Banyula	Brigalow	South	Cell		Continuous
Berrigurra	Brigalow	North	Cell	Rotation	Continuous
Frankfield	Brigalow	North	Cell	Rotation	Continuous
Melrose	Eucalypt	North	Cell	Rotation	Continuous
Rocky Springs	Eucalypt	South		Rotation	Continuous
Salisbury Plains	Eucalypt	North	Cell		Continuous
Somerville	Eucalypt	North	Cell	Rotation	
Sunnyholt	Brigalow	South	Cell		Continuous
Ticehurst	Eucalypt	South	Cell	Rotation	

The region, location, vegetation community of the grazing systems and paddocks with individual paddock areas (

Table 3.2.3) shows the range of the sites and the grazing systems monitored. The paddock botanal identification codes are shown in square brackets.

Table 3.2.3. Primary site property location, grazing system, identification of monitored paddock and paddock areas.

Region	Property Town	Vegetation	Grazing system No. Paddocks	Paddock name [Botanal Id. No.]	Area (ha)
South	**Banyula**	Brigalow	Cell (Clay) (5)	Amberley 1 [11]	19.1
	Condamine			Amberley 10 [10]	21.6
				Mascot 2 [2]	23.3
				Mascot 3 [13]	21.3
				Mascot 6 [16]	25.0
		Eucalyptus	Cell (Loam) (5)	Eagle Farm 1 [1]	54.9
				Eagle Farm 3 [3]	43.3
				Eagle Farm 7 [7]	26.7
				Richmond 4 [4]	27.9
				Richmond 6 [6]	19.6
			Continuous (1)	Bankstown [8]	607.7
North	**Berrigurra**	Brigalow	Cell (6)	EA10 [10]	26.6
	Emerald			EA11 [11]	30.5
				EA12 [12]	30.7
				EA17 [17]	26.7
				EA18 [18]	26.3
				EA19 [19]	26.0
			Rotation (2)	Middle [1]	107.9
				16 [16]	133.2
			Continuous (1)	14 [14]	228.1
North	**Frankfield**	Brigalow	Cell (8)	A1 [31]	119.0
	Clermont			A7 [7]	163.9
				A8 [8]	172.0
				A9 [9]	116.0
				B11 [11]	148.3
				B12 [12]	142.7
				B17 [17]	133.0
				B18 [18]	143.3
			Rotation (2)	Road [1]	941.9
				Carrington's [2]	876.5
			Continuous (1)	Mitchell [3]	1304.2
North	**Melrose**	Eucalypt	Cell (5)	Marys 7 [7]	40.2
	Rockhampton			Marys 16 [16]	27.0
				Marys 17 [17]	48.3
				Marys 20 [20]	44.8
				Marys 22 [22]	44.1
			Rotation (2)	Dam [52]	211.7
				Alston [53]	110.0
			Continuous (1)	Green Gully [51]	561.0
South	**Rocky Springs**	Eucalypt	Rotation (2)	Telegraph [2]	446.9
	Mundubbera			Stud [3]	319.4
			Continuous (1)	No. 1 Cows [1]	246.8

Region	Property Town	Vegetation	Grazing system No. Paddocks	Paddock name [Botanal Id. No.]	Area (ha)
North	**Salisbury Plains**	Eucalypt	Cell (9)	C1-1 [1]	35.4
	Bowen			C1-2 [2]	11.0
				C1-8 [8]	39.8
				C2-11 [11]	22.7
				C2-12 [12]	10.1
				C2-13 [13]	6.0
				C2-14 [14]	12.5
				C4-25 [25]	23.8
				C4-26 [26]	31.7
			Continuous (1)	Wilmington [20]	800.8
North	**Somerville**	Eucalypt	Cell (6)	Spinifex Ridge 1 [1]	86.7
	Richmond			Spinifex Ridge 2 [2]	112.6
				Spinifex Ridge 3 [3]	72.3
				Top Bullock 5 [5]	90.7
				Top Bullock 6 [6]	124.6
				Top Bullock 7 [7]	99.0
			Rotation (3)	East Rustlers [8]	721.8
				West Rustlers [9]	1257.6
				Trivalore [10]	448.3
South	**Sunnyholt**	Brigalow	Cell (5)	Homestead 2 [2]	93.6
	Injune			Mill 3 [3]	100.0
				Mill 4 [4]	88.8
				Pines 1 [1]	93.7
				Walangra 8 [8]	67.5
			Continuous (1)	Homestead 1 [9]	109.9
South	**Ticehurst**	Eucalypt	Cell (5)	K3 [3]	25.8
	Surat			K5 [4]	20.3
				O5 [5]	26.1
				S5 [6]	24.4
				S7 [7]	27.3
			Rotation (2)	Y1 [1]	48.0
				X1 [2]	38.0

The grazing systems, number of paddocks and paddock areas at each site (

Table 3.2.4) show there was one continuous paddock monitored, two to three rotation paddocks and/or five to ten cell paddocks at any site. The grazing system areas ranged from 86-2428 ha and total area monitored at the sites ranged from 210-2461 ha.

Table 3.2.4. Grazing systems, number of paddocks and total monitored areas at nine sites.

Property	Grazing system	No. paddocks	GS area (ha)	Total monitored area on property (ha)
Banyula	Cell	10	283	891
	Continuous	1	608	
Berrigurra	Cell	6	167	636
	Rotation	2	241	
	Continuous	1	228	
Frankfield	Cell	8	1138	4261
	Rotation	2	1818	
	Continuous	1	1304	
Melrose	Cell	5	204	1087
	Rotation	2	322	
	Continuous	1	561	
Rocky Springs	Rotation	2	766	1013
	Continuous	1	247	
Salisbury Plains	Cell	9	193	994
	Continuous	1	801	
Somerville	Cell	6	586	3013
	Rotation	3	2428	
Sunnyholt	Cell	5	444	554
	Continuous	1	110	
Ticehurst	Cell	5	124	210
	Rotation	2	86	
Total		**74**		**12659**

There was a total area of 12659 ha monitored in the 74 paddocks with average paddock areas of 58 ha in the cells (total 3139 ha), 412 ha in the rotation (total 5771 ha) and 625 ha in the continuous (total 3749 ha) grazing system paddocks.

3.2.3 Baseline information

At the start of the project the conditions at each site were recorded. The following issues were discussed with the owners – people (visions, goals, motivations, objectives and attitudes towards their grazing systems, labour), land and resources (property and paddock histories, capital works, current condition), livestock (types and breeds, management inputs, enterprise types), level of monitoring and finances.

3.2.4 Description of grazing systems and management

Descriptions of the grazing systems included: number of paddocks within systems, animals, stock classes, changes to numbers, rate of paddock movements, periods of rest and grazing, labour requirements, infrastructure, and development plans.

The management practices of the owners/managers were recorded during the project e.g. level of record keeping, monitoring, active decision-making, forward planning, and grazing chart or recording system used.

3.2.5 Field measurements

The following data measurements were made during the project. The main pasture and soil surface condition parameters were recorded in autumn of 2006, 2007 and 2009.

3.2.5.1 Climate data

Daily rainfall records were collected from the property homesteads and from gauges nearest the monitored paddocks. The long-term climate records used for modelling pasture growth potential and for calculating long-term carrying capacity were obtained from the Bureau of Meteorology, the Department of Natural Resources (DERM) Long Paddock site and from Rainman.

3.2.5.2 Pastures

(a) Pasture characteristics including biomass, cover and species composition, frequency and individual species contribution to total pasture yield, were recorded by visual estimation in 0.25m^2 quadrats at pre-determined points on a fixed grid across each monitored paddock by the Botanal method (Tothill et al. 1992). There were three sampling occasions in autumn of 2006, 2007 and 2009 at approximately 8000 sampling locations located by GPS along 360 transects across the 74 monitor paddocks. Sampling density was around three points per ha in smaller paddocks (e.g. <100 ha) and less than one point per 2 ha in the larger paddocks (>1000 ha). There were 61 individual pasture species, selected as potential ecological indicators, recorded and seven species groups for minor or unidentified species.

(b) Ground cover was measured as total cover, litter cover and LFA cover (the latter is longer-term cover, excluding transient cover such as litter and dung) in each quadrat sampled for the Botanal measurements. Tree and shrub cover was also recorded at the same quadrat locations.

(c) Historical groundcover trends (1986/87-2008) for each monitored paddock were derived using VegMachine software (Karfs et al. 2004) and satellite imagery to estimate bare ground in late winter or spring in each year (from the bare ground index calculated by the Queensland Department of Environment and Resource Management (DERM)).

(d) Utilisation of pastures was recorded in every pasture composition quadrat on a 4-point scale (1 = >70% consumed, 2 = 31-70 %, 3 = 6-30%, 4 = 0-5%).

3.2.5.3 Land condition

(a) An initial assessment of the soil surface condition in every paddock was made by the Landscape Function Analysis (LFA) method (Tongway and Hindley 2004) using 5-20 transects each of 50 m per paddock. These 487 transects, located by GPS and compass bearing, were subsequently used as the annual photo sites.

(b) Soil surface characteristics, using the LFA parameters and definitions (Tongway and Hindley 2004), were also recorded in each Botanal quadrat. These parameters were used to calculate indices of infiltration, surface stability and nutrient cycling.

(c) Annual estimates of whole paddock land condition by the ‘ABCD’ category using the GLM method (definitions are reported in Appendix 9.5).

(d) The PatchKey method (Corfield et al. 2006) using both Botanal and LFA parameters, was used to quantify land condition with a LC1-LC4 scoring system for each quadrat to produce a paddock average. These LC1-4 classes are similar to and are used to represent the ‘ABCD’ classes respectively.

(e) Land types within each paddock (74) were mapped and the condition of each land type was assessed, its average pasture growth estimated by GRASP (Littleboy et al. 1997), appropriate safe utilisation levels applied, and the whole paddock long-term carrying capacity (LTCC) was determined by the sum of each land type after the method of Johnston et al. (1996). This LTCC was compared with the actual annual grazing imposed during the project.

(f) Fixed photographic points (5-20 per paddock, total 487) were recorded at least annually, using the GRASS Check 'landscape' procedure from the uphill point of the original LFA transect lines.

3.2.5.4 Cattle

(a) Paddock grazing information. The producers' grazing charts or equivalent records were sourced to calculate animal numbers, classes, condition scores, grazing dates and number of grazing days. Adult Equivalents (AEs) were derived from records of animal numbers, classes, and, where available, liveweights. Homestead rainfall over the 12 months prior to each grazing event was used to calculate stock days grazing per ha per 100 mm rainfall (SDH/100mm).

(b) Individual performance data for different grazing systems was difficult to obtain. Recording of individual animal performance within grazing systems on these properties was not a routine practice. Limited data were available for some sites. In any case, due to cattle movements between systems throughout the year, performance measures for a specified time period could not be confidently allocated to a particular system. In addition, breeders were grazed in the systems at some sites. Where pregnancy or weaning rates were available, they were not always linked to one particular grazing system.

(c) The diet quality (crude protein (%), digestibility (%)), faecal N, and proportion of non-grass in the diet (%) of cattle in each grazing system on each property were estimated by NIRS analysis of fresh dung samples (Coates 1999; Coates and Dixon 2008) collected at approximately monthly intervals throughout the project. One bulked fresh cattle faecal sample (minimum 10 sub-samples) was collected from each grazing system by the property owners for each analysis. The dry matter digestibility to crude protein ratio was calculated for each sample. The properties were provided with a NIRS sampling and recording kit and instructed in its use. This included instructions on condition scoring required for our NIRS field data collection sheets (FDCS) which were completed with each sample to assist in interpretation of the results. At two sites, additional samples were taken from rotation and cell paddocks on clay soil at Banyula, and from leucaena with buffel grass cell paddocks at Sunnyholt.

(d) A grazing system intensity index (GSI) on a continuous scale from 1 to 100 was developed to rate the relative intensity of the 21 systems in the project. This index incorporates capital costs, operating costs and management inputs (see Appendix 9.13).

3.2.5.5 Economics

(a) The owner's objectives in establishing each grazing system were used as the starting point for assessing the economic performance of each system. Both the capital and operating costs were used, along with producer perceptions of benefits, to assess how well the development of the more intensive grazing systems was apparently meeting property goals.

(b) A break-even calculator for estimating the costs of changing a grazing system, and an Excel spreadsheet calculator for estimating the return on the investment in this grazing system change, were developed. The cost and benefit data used for applying these calculators in practice are necessarily provided by the producers who are considering making a change to their production system. The data in the example in this report has been based on the application of a herd economic model that was calibrated with production and financial data sourced from a case study property near Rockhampton.

3.2.5.6 Producer perceptions

(a) To capture producers' ideas and perceptions of their grazing systems, why they chose their systems and what they perceived to be the benefits and disadvantages of their current practices, producers from across northern Australia were surveyed at an annual BeefPlan review meeting (Hall and Hall 2008). These written results were distilled into a series of themes including: cattle, pastures, management, labour and lifestyle.

3.2.5.7 Data analysis

Broadly three methods of data analysis were performed on each parameter set: (a) detailed statistical analysis of three main factors; grazing system, vegetation community and region, by REML (Patterson & Thompson 1971), (b) across year time trends analysed by regression analysis, and (c) within paddock spatial variability analysed by SADIE (Perry 1995; Perry et al. 1999). The analyses are briefly described here with details are in the Appendix.

(a) All pasture, LFA, grazing and diet quality data sets were statistically analysed to compare three grazing systems, two vegetation communities (eucalypt Vs brigalow) and two regions (north Vs south Queensland) using the method of residual maximum likelihood (REML). The REML programme was chosen because it provides efficient estimates of treatment effects in unbalanced designs with more than one source of error. The REML algorithm estimates the treatment effects and variance components in a linear mixed model: a linear model with both fixed and random effects. It can analyse unbalanced data sets and account for more than one source of variation in the data, providing an estimate of the variance components associated with the random terms in the model.

(b) Data trends with time for the various grazing systems at each site were assessed by regression analysis of 14 parameters measured in 2006, 2007 and 2009. The values for each parameter at each site were standardised by dividing them by the mean value over the three sample times i.e. if the values were 40, 50 and 60 then the mean is 50 and the standardised values are 0.8, 1.0 and 1.2. These standardised values were then regressed on years (1, 2 and 4). Based on the "b" values from the regressions, the responses were divided into three groups:

$b > 0.10$	+	(positive change)
$b = -0.10$ to 0.10	0	(no change)
$b < -0.10$	-	(negative change)

The trends for each of the 14 parameters were assessed as "Improving", "No change" or "Deteriorating" (Table 3.2.5).

Table 3.2.5. Trend responses definitions for regression 'b' values for 14 data parameters over four years with three sampling times, 2006, 2007 and 2009.

Measurement / parameter	Regression 'b' value range		
	b>0.100	b=-0.100 to 0.100	b<-0.100
Pasture performance			
Yield	Improving	No change	Deteriorating
Sown grass (%)	Improving	No change	Deteriorating
Native perennial grass (%)	Improving	No change	Deteriorating
Utilisation	Deteriorating	No change	Improving
Diversity			
Species per quadrat	Improving	No change	Deteriorating
Species for 90% yield	Improving	No change	Deteriorating
Contribution of dominant species	Deteriorating	No change	Improving
Land condition			
Woody regrowth	Deteriorating	No change	Improving
Ground cover	Improving	No change	Deteriorating
Litter cover	Improving	No change	Deteriorating
LFA stability	Improving	No change	Deteriorating
LFA infiltration	Improving	No change	Deteriorating
LFA Nutrient cycling	Improving	No change	Deteriorating
PatchKey class	Deteriorating	No change	Improving

These improving/no change/deteriorating assessments were applied to each site-grazing system combination.

(c) Within paddock spatial variability in pasture and soil surface condition parameters (recorded by the botanal and LFA methods) was analysed by the SADIE program to measure individual paddock uniformity and then compare the number of uniform versus non-uniform paddocks between grazing systems at each site.

4 Results and discussion

4.1 Summary for pasture and land condition

There was no significant effect of grazing system on pasture yield, proportion of sown grass or native perennial grass, woody regrowth or litter. Differences in pasture yield across systems, sites and years were primarily driven by variation in year-to-year rainfall. By autumn of 2009, after one or two improved rainfall seasons at all sites, there were much higher pasture yields, ground cover and litter cover in all pastures compared to those measured in the autumns of 2006 and 2007.

The very strong dominance of buffel grass at the five brigalow sites meant there was limited scope for change in composition with grazing treatment, but even at the sites where native pastures were dominant, grazing system had little impact on botanical composition over the four-year monitoring period.

There were only small apparent differences in pasture diversity among grazing systems with some evidence that the cell systems were slightly less diverse than rotational and continuous systems. There were no significant differences for the number of grass species that contributed 90% of total yield; there were small differences in the number of species per quadrat with the rotation pastures being highest and the cell pastures significantly lower in 2007 (P=0.074); and the dominant grass species contributed a greater proportion of the pasture in the cells than in other systems, significantly so in 2006 (P<0.05).

As one would expect, differences in diversity across systems, sites and years were primarily driven by country type, with brigalow sites being buffel-dominated and therefore inherently less diverse.

While the differences were small, the continuous paddocks appeared to have more variable spatial utilisation than other systems. The log-linear modelling showed a significant relationship (P=0.062) between grazing system and pasture utilisation was evident only in 2006, with rotation and cell paddocks having a greater percentage of paddock area in the lower utilisation classes (utilisation classes 3 and 4) than continuously grazed paddocks.

Differences in other aspects of pasture and land condition (ground cover; LFA; condition rating; spatial variation in yield, litter and other vegetation characteristics) between systems were small and inconsistent.

The bottom line from all these measurements and analyses is that there were few significant effects of grazing system on pasture attributes or land condition. The details of the analysis of pasture and land condition data is presented in the following sections.

4.2 Pastures

The pasture-related data sets were analysed for the three factors of Grazing System (GS), Vegetation community (V) and Region (R).

Comparisons were only made between grazing systems on similar land types. Thus at Banyula, the cell-loam paddocks were compared with similar country in the cleared area in the continuous paddock; at Frankfield the cell paddocks that were sampled in 2006 and were not subsequently blade-ploughed were compared with the rotation and continuous systems (two of the cell paddocks recorded 2006 were blade ploughed in 2007); and at Salisbury Plains the cell system was compared with the sandy-loam portion of the continuous paddock. Results from other systems and/or land types (e.g. cell-clay at Banyula, continuous-clay at Salisbury Plains) are given in the individual property reports (Appendix 9.1).

The treatment impacts have been assessed in two ways: firstly, their impact on the grazing system (overall paddock means via REML analysis), and secondly their impact on spatial variability or variation across each paddock (via SADIE analysis). The REML analysis adjusts for the unbalanced nature of the data and accounts for the fact that not all systems occurred at all sites. The adjusted means are compared and presented.

4.2.1 Parameter means

Apart from utilisation rate and the PATCHKEY land condition classes where the analyses were based on the proportion of quadrats in different classes, the analyses were based on the mean values for individual paddocks.

4.2.2 Pasture yield

There were no significant effects of grazing system, vegetation type or their interaction on pasture yields. However, yields were higher at the northern sites in 2007 and 2009 and tended to be higher at the brigalow sites (
Table 4.2.1.).

Table 4.2.1. Effect of grazing system, vegetation type and region on pasture yield (kg/ha) in 2006, 2007 and 2009*.

Treatment	**Pasture yield (kg/ha)**					
	2006		**2007**		**2009**	
Syst/Vegn/Region	Mean	Transf.	Mean	Transf.	Mean	Transf.
Grazing system (GS)		ns		ns		ns
Cell	2480	7.82	1730	7.46	3810	8.25
Rotation	2370	7.77	1490	7.31	4040	8.30
Continuous	1990	7.60	1780	7.49	3630	8.20
Av. s.e.d.		0.14		0.18		0.08
Vegetation type (V)		ns		ns		ns
Brigalow	2480	7.82	1710	7.45	4220	8.35
Eucalypt	2080	7.64	1610	7.39	3470	8.15
s.e.d.		0.27		0.14		0.12
Region (R)		ns		P<0.05		P<0.01
North	2190	7.69	1970*a*	7.58	4850*a*	8.49
South	2350	7.76	1410*b*	7.25	3010*b*	8.01
s.e.d.		0.26		0.15		0.12
GSxV interaction		ns		ns		ns

* The statistical analyses were performed on log-transformed data and the back-transformed means are presented. Means followed by different letters are significantly different (P=0.10).

4.2.3 Botanical composition

Palatable, productive, perennial grasses (3P's), either native species or buffel, dominated the pastures at all sites. There were only small proportions of annual grasses, native legumes, forbs and sedges at all sites and no consistent differences between grazing systems.

Only Melrose and Salisbury Plains had more than trace quantities of exotic legumes. At Melrose, the proportion of exotic legume (*Stylosanthes* cultivars) was lower in the cells (1.3%) than the rotation (8.0%) and continuous (5.7%) systems. At Salisbury Plains, there was little difference between the two systems in any year (overall means of 17.1% in the cells and 18.1% in the continuous paddock).

Only results for sown grasses and native perennial grasses are considered in detail.

4.2.3.1 Proportion of sown grass

The main effects for grazing system and region and the grazing system by vegetation community (GSxV) interaction were not significant in any year. As expected, the brigalow sites with a high proportion of clay soils had higher proportions of sown grass (predominantly buffel) than the eucalypt sites (Table 4.2.2).

Table 4.2.2. Effect of grazing system, vegetation type and region on the percentage of sown grass in 2006, 2007 and 2009*.

Treatment	Sown grass (%)					
	2006		2007		2009	
Syst/Vegn/Region	Mean	Transf.	Mean	Transf.	Mean	Transf.
Grazing system (GS)		ns		ns		ns
Cell	77	1.07	76	1.06	78	1.09
Rotation	71	1.00	76	1.06	77	1.07
Continuous	68	0.97	70	1.00	73	1.03
Av. s.e.d.		0.06				0.07
Vegetation type (V)		*P*=0.071		ns		ns
Brigalow	95	1.36	95	1.34	95	1.35
Eucalypt	39	0.67	45	0.73	49	0.78
s.e.d.		0.31		0.32		0.36
Region (R)		ns		ns		ns
North	58	0.86	60	0.89	67	0.96
South	84	1.16	86	1.19	85	1.17
s.e.d.		0.30		0.31		0.35
GSxV interaction		ns		ns		ns

*The statistical analyses were performed on arcsine-transformed data and the back-transformed means are presented.

4.2.3.2 Proportion of native perennial grass

The main effects for grazing system (GS) and region (R) and the GSxV interaction were not significant in any year. As expected, the eucalypt sites had higher proportions of native perennial grass than the brigalow sites (Table 4.2.3).

Table 4.2.3. Effect of grazing system, vegetation type and region on the percentage of native perennial grass in 2006, 2007 and 2009*.

Treatment	Native perennial grass (%)					
	2006		2007		2009	
Syst/Vegn/Region	Mean	Transf.	Mean	Transf.	Mean	Transf.
Grazing system (GS)		ns		ns		ns
Cell	15	0.40	18	0.44	15	0.40
Rotation	14	0.38	14	0.39	14	0.39
Continuous	20	0.46	24	0.51	19	0.45
Av. s.e.d.		0.06		0.07		0.08
Vegetation type (V)		ns		*P*=0.099		ns
Brigalow	2	0.13	2	0.15	4	0.19
Eucalypt	42	0.70	45	0.74	36	0.64
s.e.d.		0.33		0.30		0.35
Region (R)		ns		ns		ns
North	21	0.48	29	0.56	21	0.48
South	12	0.35	10	0.32	12	0.35
s.e.d.		0.32		0.29		0.34
GSxV interaction		ns		ns		ns

*The statistical analyses were performed on arcsine-transformed data and the back-transformed means are presented.

4.2.3.3 Pasture diversity

In this project we did not attempt to record all species, only a set of 61 indicator species in seven species groups across the nine sites. Bearing this in mind, the cell systems appeared to be slightly less diverse than the rotation and continuous systems for all three diversity measures (fewer species per quadrat, fewer species to produce 90% of total yield and a greater contribution by the dominant species). These differences were statistically significant for the number of species per quadrat in 2007 and the contribution of the dominant species in 2006 (Table 4.2.4).

The GSxV interaction was significant in 2007 for the number of species to produce 90% of total yield and contribution by the dominant species (

Table 4.2.5). In both cases there were no differences between grazing systems at the brigalow sites, but at the eucalypt sites the cell systems were less diverse than the rotation and continuous systems.

The eucalypt sites were more diverse than the brigalow sites for all measures in all years reflecting the strong dominance (% contribution to total dry matter yield) of buffel grass at the brigalow sites (Table 4.2.6). Overall, the northern sites were more diverse than the southern sites but the differences were not always significant. Plant species diversity in eucalypt communities can be high with 175 herbaceous and 60 woody species recorded for a grazed Eucalypt woodland paddock in southern Queensland (Silcock et al. 1996). Manipulating grazing pressure, tree competition and burning can all influence the pasture composition of this *Aristida-Bothriochloa* pasture community (Hall and Douglas 2005; Silcock et al. 2005).

Table 4.2.4. Effect of grazing system, vegetation type and region on the number of species per 0.25m^2 quadrat in 2006, 2007 and 2009*.

Treatment		**No. species per quadrat**	
Syst/Vegn/Region	**2006**	**2007**	**2009**
Grazing system (GS)	ns	*P*=0.074	ns
Cell	1.8	1.6*a*	2.0
Rotation	1.9	1.9*b*	2.1
Continuous	1.8	1.8*ab*	2.0
Av. s.e.d.	0.1	0.1	0.1
Vegetation type (V)	*P*=0.051	*P*=0.090	*P*=0.095
Brigalow	1.4*b*	1.3*b*	1.3*b*
Eucalypt	2.3*a*	2.2*a*	2.8*a*
s.e.d.	0.4	0.4	0.7
Region (R)	ns	ns	ns
North	2.1	2.1	2.3
South	1.5	1.4	1.8
s.e.d.	0.4	0.4	0.7
GSxV interaction	ns	ns	ns

* Means followed by different letters are significantly different (*P*=0.10).

Table 4.2.5. Effect of grazing system, vegetation type and region on the number of species to contribute 90% of the total yield in 2006, 2007 and 2009*.

Treatment	**No. species contributing 90% of yield**					
	2006		**2007**		**2009**	
Syst/Vegn/Region	Mean	Transf.	Mean	Transf.	Mean	Transf.
Grazing system (GS)		ns		ns		ns
Cell	2.2	1.15	2.4	1.22	2.6	1.27
Rotation	3.0	1.38	3.7	1.56	3.1	1.40
Continuous	3.6	1.52	3.7	1.55	3.6	1.52
Av. s.e.d.		0.19		0.21		0.25
Vegetation type (V)		*P*<0.05		*P*<0.05		*P*=0.054
Brigalow	1.2*b*	0.79	1.5*b*	0.93	1.2*b*	0.78
Eucalypt	5.7*a*	1.91	6.0*a*	1.95	6.5*a*	2.02
s.e.d.		0.32		0.36		0.49
Region (R)		*P*<0.05		*P*=0.086		ns
North	4.8*a*	1.76	5.0*a*	1.80	4.6	1.72
South	1.6*b*	0.94	2.0*b*	1.08	1.9	1.07
s.e.d.		0.31		0.35		0.47
GSxV interaction		ns		*P*<0.05		ns

* The statistical analyses were performed on log-transformed data and the back-transformed means are presented. Means followed by different letters are significantly different (*P*=0.10).

Table 4.2.6. Effect of grazing system, vegetation type and region on the contribution (% of total dry matter yield) by the dominant species# in 2006, 2007 and 2009*.

Treatment	**Dominant species contribution (%)**					
	2006		**2007**		**2009**	
Syst/Vegn/Region	Mean	Transf.	Mean	Transf.	Mean	Transf.
Grazing system (GS)		*P*<0.01		ns		ns
Cell	84*a*	1.16	83	1.15	83	1.14
Rotation	75*b*	1.04	75	1.05	76	1.06
Continuous	76*ab*	1.06	76	1.06	76	1.06
Av. s.e.d.		0.05		0.07		0.07
Vegetation type (V)		*P*<0.05		*P*<0.05		*P*=0.086
Brigalow	95*a*	1.36	94*a*	1.33	95*a*	1.36
Eucalypt	54*b*	0.82	56*b*	0.85	53*b*	0.82
s.e.d.		0.18		0.18		0.25
Region (R)		*P*=0.081		*P*=0.096		ns
North	62*b*	0.91	62*b*	0.91	63	0.91
South	91*a*	1.27	91*a*	1.26	91	1.26
s.e.d.		0.17		0.18		0.24
GSxV interaction		ns		*P*=0.091		ns

[#] The dominant species was the species contributing the highest proportion of dry matter yield in each quadrat.

* The statistical analyses were performed on arcsine-transformed data and the back-transformed means are presented. Means followed by different letters are significantly different (*P*=0.10).

4.2.4 Pasture utilisation

Grazing system (Figure 4.2.1), vegetation type and region had little impact on the proportion of quadrats in each utilisation category in all three years. In 2007 a GSxV interaction was evident (P<0.01) for utilisation class 3 (6-30%) with a greater proportion of rotational paddocks in utilisation class 3 than continuous paddocks which, in turn, had a greater proportion in class 3 than cell paddocks (45% vs 27% vs 8%) at the brigalow sites. There was no effect of grazing system at the eucalypt sites (average approximately 24%). The only other significant differences were for grazing system effects in utilisation class 2 (31-70%) in 2006 (values from 0 to 8%) and in utilisation class 1 (>70%) in 2009 (values 0 and 1%) for vegetation type in utilisation class 2 in 2009 (values 2 to 9%).

The rotation and cell systems had a greater percentage of paddocks in the lowest utilisation class (class 4) than continuously grazed paddocks in autumn of each year.

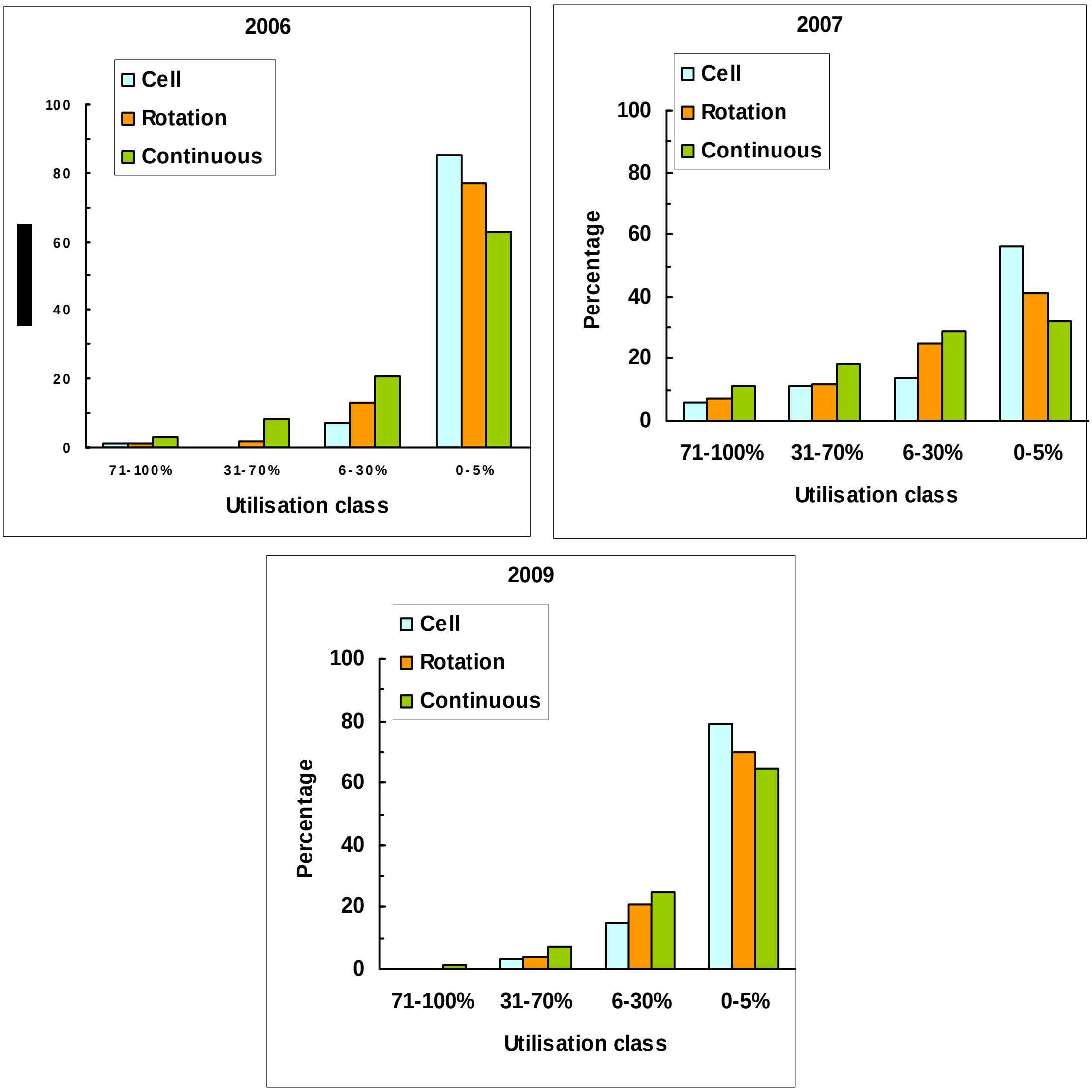


Figure 4.2.1 The influence of grazing system on the percentage of quadrats in four pasture utilisation classes in autumn.

4.2.5 Woody regrowth

There were no significant differences between grazing systems in woody regrowth (Table 4.2.7). There were, however, significant effects between vegetation types, with more regrowth measured at the brigalow sites in 2009. The GSxV interaction was significant at the brigalow sites where the systems ranked cell>continuous>rotation for regrowth cover. There were no differences between systems at the eucalypt sites.

Table 4.2.7. Effect of grazing system, vegetation type and region on woody regrowth (per cent cover) in 2006, 2007 and 2009*.

Treatment	**Woody regrowth (% cover)**					
	2006		**2007**		**2009**	
Syst/Vegn/Region	Mean	Transf.	Mean	Transf.	Mean	Transf.
Grazing system (GS)		ns		ns		ns
Cell	1.1	0.10	1.0	0.10	1.4	0.12
Rotation	0.7	0.08	0.8	0.09	0.8	0.09
Continuous	1.3	0.11	1.3	0.12	0.9	0.10
Av. s.e.d.		0.02		0.01		0.03
Vegetation type (V)		ns		ns		$P<0.05$
Brigalow	0.9	0.10	1.1	0.11	1.7*a*	0.13
Eucalypt	1.1	0.10	0.9	0.10	0.5*b*	0.07
s.e.d.		0.04		0.04		0.02
Region (R)		ns		ns		ns
North	1.2	0.11	1.0	0.10	0.9	0.10
South	0.9	0.09	1.1	0.10	1.1	0.11
s.e.d.		0.04		0.04		0.02
GSxV interaction		ns		ns		$P<0.05$

*The statistical analyses were performed on arcsine-transformed data and the back-transformed means are presented. Means followed by different letters are significantly different ($P=0.10$).

4.2.6 Ground cover

4.2.6.1 Total ground cover

Differences in ground cover between grazing systems were small, but the rotation systems had higher cover levels in 2009, possibly influenced by their lower level of grazing during this year. Cover levels were higher at the eucalypt sites, significantly so in 2009, and they were also higher at the northern sites in 2009 after above-average summer rainfall (but not in earlier years) (

Table 4.2.8).

Table 4.2.8. Effect of grazing system, vegetation type and region on total ground cover (%) in 2006, 2007 and 2009*.

Treatment	Total ground cover (%)					
	2006		2007		2009	
Syst/Vegn/Region	Mean	Transf.	Mean	Transf.	Mean	Transf.
Grazing system (GS)		ns		ns		*P*=0.092
Cell	58	0.86	54	0.83	72*b*	1.01
Rotation	63	0.92	53	0.82	77*a*	1.07
Continuous	59	0.87	52	0.80	70*b*	0.99
Av. s.e.d.		0.05		0.05		0.03
Vegetation type (V)		ns		ns		*P*=0.056
Brigalow	58	0.87	52	0.80	65*b*	0.94
Eucalypt	61	0.90	55	0.83	80*a*	1.11
s.e.d.		0.09		0.10		0.07
Region (R)		ns		ns		*P*<0.05
North	56	0.85	57	0.85	81*a*	1.12
South	63	0.92	50	0.78	63*b*	0.92
s.e.d.		0.08		0.09		0.07
GSxV interaction		ns		ns		ns

* The statistical analyses were performed on arcsine-transformed data and the back-transformed means are presented. Means followed by different letters are significantly different (P=0.10).

4.2.6.2 Litter cover

The main effects of grazing system, vegetation type and region were not significant for litter cover in any year (Table 4.2.9). The GSxV interaction was significant in 2007 when there were no differences between grazing systems at the eucalypt sites, but the rotation systems had more litter cover than the cell and continuous systems at the brigalow sites.

Table 4.2.9. Effect of grazing system, vegetation type and region on litter cover (%) in 2006, 2007 and 2009*.

Treatment	Litter cover (%)					
	2006		2007		2009	
Syst/Vegn/Region	Mean	Transf.	Mean	Transf.	Mean	Transf.
Grazing system (GS)		ns		ns		ns
Cell	16	0.41	19	0.46	28	0.56
Rotation	19	0.45	19	0.46	28	0.55
Continuous	18	0.44	16	0.42	22	0.48
Av. s.e.d.		0.03		0.03		0.03
Vegetation type (V)		ns		ns		ns
Brigalow	18	0.44	18	0.43	19	0.45
Eucalypt	18	0.43	19	0.45	33	0.61
s.e.d.		0.02		0.05		0.09
Region (R)		ns		ns		ns
North	18	0.44	19	0.45	32	0.60
South	18	0.43	18	0.44	20	0.46
s.e.d.		0.02		0.05		0.09
GSxV interaction		ns		*P*=0.055		ns

* The statistical analyses were performed on arcsine-transformed data and the back-transformed means are presented. Means followed by different letters are significantly different (*P*=0.10).

4.2.7 Historical cover trends

VegMachine was use to identify the historical ground cover of the 74 monitor paddocks over the period 1987 to 2008. Many of the paddocks were not yet built for some of this period but the shape files of the paddocks that we monitored were used to identify the areas on each property and produce an annual cover index, based on the bare ground index (BGI) from Landsat satellite imagery in late winter-spring each year. These indices were graphed and related to the average of the whole property and of the surrounding catchment or sub-region, as well as to annual rainfall and paddock development. Management operations that may have impacted on ground cover were included to explain within and between year paddock fluctuations in the cover index (reverse of the bare ground index).

The example from the Ticehurst paddocks shows a clear correlation between groundcover and annual rainfall in the 1988 to 2000 period with somewhat less variable cover during more recent years (Figure 4.2.2).

The changes in paddock cover were sufficiently sensitive to show past management effects such as timber-pulling, reduced cattle numbers, cropping of some paddocks, cutting cypress pine trees and also pasture cover decline in droughts and its recovery after good rainfall years. In the rotation monitor paddock TY1, there was a sharp cover decline in 2007 following stick-raking the paddock and poor summer rainfall. The paddock-scale VegMachine method was sufficiently sensitive to demonstrate this low cover. There was a sharp rise in the cover index in all paddocks in 2008 following the higher rainfall summer, with negligible differences between paddocks or systems.

The cover index for the whole of the property was usually lower than the monitor paddocks for the whole period, which can be explained by the inclusion of bare ground in late winter in the cultivation paddocks. Even including this cultivation influence, the average cover index of the whole property was usually higher than the average of the surrounding sub-catchment, indicating the pastures on Ticehurst were managed to maintain above average ground cover throughout the 22-year period. This VegMachine cover index approach was used for the nine monitor properties and details are reported in the individual property reports in Appendix 9.1.

The VegMachine cover analysis of the other eight properties showed similar general trends as those for Ticehurst, with a strong influence of annual rainfall and little if any influence of grazing system either prior to, or during, the experimental period.

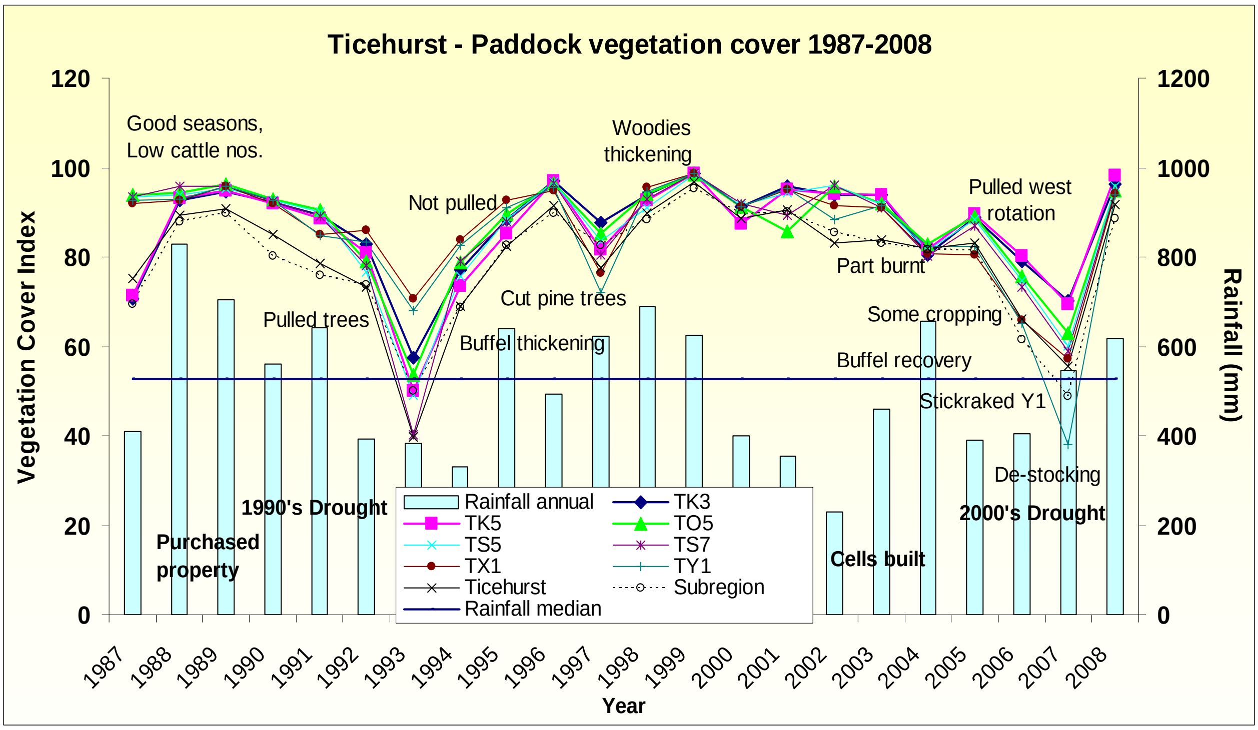


Figure 4.2.2. VegMachine time series cover index and annual rainfall for paddocks, whole property and catchment sub-region at Ticehurst from 1987 to 2008.

4.2.8 Impacts of grazing system on land condition

4.2.8.1 LFA indices

There were no significant differences between grazing systems for the Infiltration index or Nutrient Cycling index in any year. For the Stability index, values were lowest in the continuous system in all years, significantly so in 2009 (P=0.078) (Table 4.2.10). This may reflect more variable land types and grazing patterns in the larger paddocks of the continuous system than in the other two systems.

The eucalypt sites had higher values for the Stability index in all years, significantly so ($P<0.05$) in 2009. The GSxV interaction was significant in 2007 for the Infiltration index when there was no difference between systems for eucalypt sites, but the rotation systems had a higher value (43.9) than the continuous (38.3) and cell (38.1) systems at the brigalow sites.

The region (north vs. south Queensland) had no consistent effect on any index.

Table 4.2.10. Effect of grazing system, vegetation type and region on the mean values of three LFA indices in 2006, 2007 and 2009*.

Treatment		**Stability Index**			**Infiltration Index**			**Nutrient Cycling Index**		
		2006	**2007**	**2009**	**2006**	**2007**	**2009**	**2006**	**2007**	**2009**
Grazing system (GS)		ns	ns	*P*=0.078	ns	ns	ns	ns	ns	ns
	Cell	60.3	59.1	64.7*a*	36.1	39.0	40.8	27.9	31.0	34.7
	Rotation	60.9	58.8	64.7*a*	37.7	40.1	41.9	29.5	31.8	35.6
	Continuous	59.6	56.9	62.7*b*	37.5	39.1	40.0	28.7	30.8	32.8
	Av. s.e.d.	0.8	1.3	0.9	1.2	1.6	1.3	0.9	1.3	1.5
Vegetation type (V)		ns	ns	*P*<0.05	ns	ns	ns	ns	ns	ns
	Brigalow	58.6	56.3	60.3b	37.0	39.3	38.5	29.3	31.1	32.2
	Eucalypt	62.0	60.2	67.8a	37.1	39.4	43.3	28.1	31.3	36.5
	s.e.d.	4.3	4.4	2.9	1.5	1.8	2.5	0.9	2.2	2.8
Region (R)		ns	ns	ns	ns	ns	ns	ns	ns	ns
	North	58.8	58.6	66.1	37.8	39.7	42.9	28.6	31.4	36.4
	South	61.7	58.0	62.0	36.4	39.1	38.8	28.8	30.9	32.3
	s.e.d.	4.0	4.2	2.8	1.4	1.8	2.4	0.9	2.1	2.7
GSxV interaction		ns	ns	ns	ns	*P*<0.05	ns	ns	ns	ns

* Means followed by different letters are significantly different (*P*=0.10).

4.2.8.2 PATCHKEY land condition

The PATCHKEY analysis allocates quadrats, based on several of the Botanal parameters, to four land condition classes where LC1 is good condition (equivalent to A in the 'ABCD' framework) to LC4 which is very poor condition (equivalent to D).

Grazing System, Vegetation type and Region had no impact (P>0.10) on the proportion of a paddock in land condition categories in 2007 and 2009. At the first paddock recording in 2006, there was a greater (P=0.101) proportion of the area of cell and rotationally grazed paddocks in LC1, and a lower proportion in LC3, than in continuously grazed paddocks (Figure 4.8.2). In 2006, the brigalow sites had a greater (P<0.05) proportion in LC1 and a lower proportion in LC3 compared with the eucalypt sites.

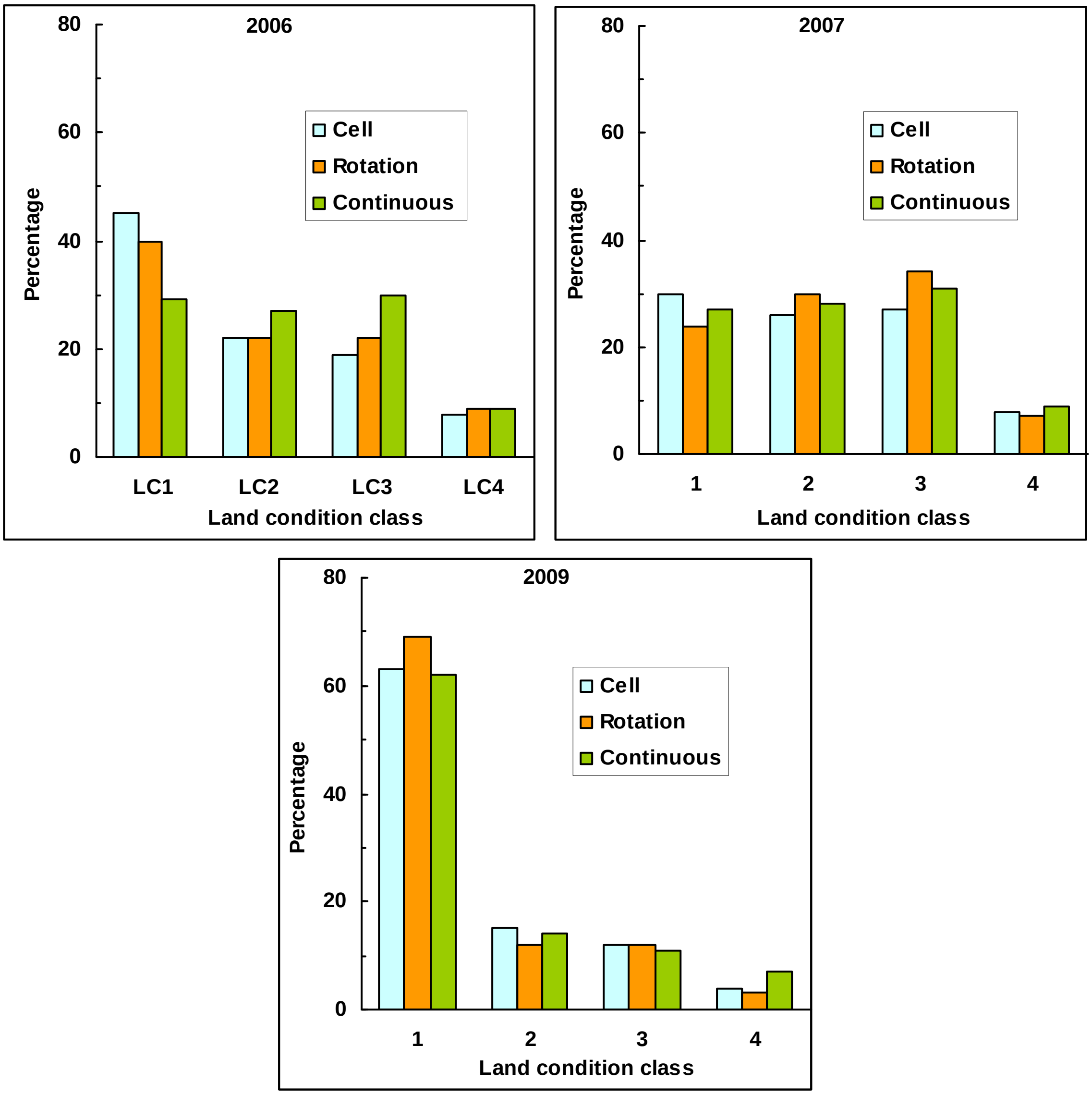


Figure 4.2.3 The influence of grazing system on the percentage of quadrats in four land condition classes in 2006, 2007 and 2009.

Log-linear modelling revealed no relationship (P>0.10) between Grazing System and land condition classes or between Region and land condition classes across the three years of data. A relationship between Vegetation and land condition classes was evident (P<0.10) in all years primarily with a greater proportion of Brigalow paddocks in LC1 and a lesser proportion in LC3 compared with Eucalypt paddocks. All systems had greater than 60% in good condition (LC1) and negligible areas in poor condition (LC4) in 2009 after two higher rainfall seasons. Seasonal conditions, and not grazing system, drove the measured trend in land condition at each of the nine sites. The importance of above average rainfall years in accelerating improvements in pasture condition is well known and the mechanism is primarily via increased grass basal area (Orr et al. 2005).

4.2.9 Summary of statistical analyses of Botanal/LFA parameter means

A summary of statistical analysis for the 14 main Botanal/LFA parameters between grazing systems, vegetation communities and regions shows there were only 28 significant responses ($P<0.10$) from the possible 142 parameter combinations (7 significant for systems, 14 for vegetation and 7 for region). This further illustrates how any ecological differences due to grazing system were generally small and inconsistent. The probabilities associated with the significant differences for these parameters are summarised in Appendix 9.5.

4.3 Pasture and land condition trends between grazing systems over time

Sites where there were different directional trends between grazing systems for particular pasture attributes are shown in

Table 4.3.1 (Imp = Improving; No = No change; Det = Deteriorating). There were relatively few contrasts in pasture trends between systems within sites and none of any consistency. Where contrasts occurred, it was usually a static trend versus an improving one. The only negative trend of any note was for woody regrowth at some brigalow sites and again this was unrelated to grazing system. The major influence on trends was the rainfall pattern, with a positive trend due to higher rainfall during the second half of the 4-year measurement period.

Table 4.3.1. Sites within which there was a contrasting directional trend between grazing systems in an attribute of pasture or land condition.

Measurement / parameter	Site	Grazing system		
		Cell	Rotat.	Cont.
Pasture performance				
Yield	Banyula	No		Imp
	Rocky Springs		Imp	No
	Sunnyholt	Imp		No
Sown grass (%)	No sites			
Native perennial grass (%)	Banyula	Det		No
	Frankfield	Imp	Imp	No
	Sunnyholt	Imp		No
Utilisation	Berrigurra	No	No	Imp
Diversity				
Species per quadrat	No sites			
Species for 90% yield	Frankfield	No	Det	No
	Melrose	No	Det	No
Contribution of dominant species	Melrose	Imp	No	No
	Rocky Springs		Imp	No
	Salisbury Plains	No		Imp
Land condition				
Woody regrowth	Banyula	No		Det
	Berrigurra	Det	No	No
	Frankfield	Det	Det	No
	Melrose	No	No	Imp
Ground cover	Berrigurra	No	No	Imp
	Frankfield	Imp	No	No
Litter cover	Berrigurra	Det	No	No
	Frankfield	Imp	No	No
	Rocky Springs		Imp	No
	Sunnyholt	Imp		No
LFA stability	No sites			
LFA infiltration	No sites			
LFA Nutrient cycling	Frankfield	Imp	No	No
	Melrose	No	Imp	Imp
PatchKey class	Berrigurra	No	No	Imp
	Frankfield	No	Imp	Imp

4.4 Spatial variability across paddocks

Spatial variability of the pasture, soil condition and utilisation measures within all paddocks were investigated to determine if there were differences due to the grazing system. The SADIE analysis method determines if the variation between sampling points on the paddock grid was random or if there was clustering (or aggregation) due to grazing or some other factor. Considerations in interpreting the analyses are reported in Appendix 9.9.

4.4.1 Pasture yield variability

The statistical models were not able to predict the means for pasture yield in 2006 and 2007 (the models did not converge) so systems could not be compared. However, the analysis was valid in 2009 and neither grazing system nor region had any significant effect on the degree of spatial randomness (the reverse of spatial clustering) in yield across paddocks. Between communities, pasture yield was more often ‘uniform’ (not clustered) (P=0.096) at the brigalow sites (47% of paddocks were spatially uniform) relative to the eucalypt sites (24% of paddocks were spatially ‘uniform’) (Table 4.4.1).

Table 4.4.1. Percentage of paddocks with spatially 'uniform' patterns of pasture yield in 2006, 2007 and 2009. (Back-transformed means are presented as percentages* and total number of paddocks).

Treatment		**Uniform paddocks for pasture yield (%)** (number of paddocks with no significant clustering pattern, expressed as a percentage of the total number of paddocks within each grouping)								
		2006			**2007**			**2009**		
Syst/Vegn/Region		**% Pdk**	**Sig.**	**No. Pdk**	**% Pdk**	**Sig.**	**No. Pdk**	**% Pdk**	**Sig.**	**No. Pdk**
Grazing system (GS)			NA			NA			ns	
	Cell	54		40	45		50	49	-0.04	52
	Rotation	45		11	54		13	29	-0.90	13
	Continuous	67		8	0		9	28	-0.96	9
	Av. s.e.d.								0.99	
	Total Pdks			**59**			**72**			**74**
Vegetation type (V)			NA			NA			*P*=0.096	
	Brigalow			15			27	47*a*	-0.13	29
	Eucalypt			44			45	24*b*	-1.14	45
	s.e.d.								0.60	
Region (R)			NA			NA			ns	
	North			36			45	41	-0.35	47
	South			23			27	29	-0.92	27
	s.e.d.								0.62	

* Means followed by different letters are significantly different (*P*=0.10); ns = P>0.10; NA = analysis not available due to model not converging (results are presented as the means from the original data).

4.4.2 Pasture utilisation variability

**The cell pastures had the most spatially 'uniform' (non-clustered) patterns of utilisation. There was less variation (SADIE analysis) in pasture utilisation across cell paddocks in all years, and significantly so in 2006 and 2009. The influence of vegetation type varied between years but there was more clustering at the brigalow sites than at the eucalypt sites in 2009 (
Table 4.4.2).**

Table 4.4.2. Percentage of uniform paddocks for pasture utilisation in 2006, 2007 and 2009*.

Treatment	**Spatial uniformity of paddocks for utilisation** (number of paddocks with no significant clustering pattern, expressed as a percentage of the total number of paddocks within each grouping)					
	2006		**2007**		**2009**	
Syst/Vegn/Region	Mean	Transf.	Mean	Transf.	Mean	Transf.
Grazing system (GS)		*P*<0.01		ns		*P*=0.081
Cell	87*a*	1.86	45	-0.21	64*a*	0.59
Rotation	26*b*	-1.03	25	-1.10	26*b*	-1.03
Continuous	35*b*	-0.63	31	-0.81	26*b*	-1.06
Av. s.e.d.		1.17		0.95		1.02
Vegetation type (V)		ns		ns		*P*=0.077
Brigalow	66	0.67	45	-0.21	25*b*	-1.08
Eucalypt	37	-0.54	23	-1.21	52*a*	0.08
s.e.d.		1.71		0.72		0.64
Region (R)		ns		ns		ns
North	56	0.26	28	-0.94	31	-0.81
South	47	-0.13	38	-0.48	45	-0.19
s.e.d.		1.52		0.73		0.65

* Back-transformed means are presented as percentages. Means followed by different letters are significantly different (*P*=0.10); ns = P>0.10.

4.4.3 Ground cover variability

4.4.3.1 Total ground cover

The cell pastures appeared to have more uniform ground cover than those under continuous grazing, and this effect was statistically significant for the 2006 data. Paddock uniformity of the rotation system was intermediate (Table 4.4.3). The average total ground cover (52-72%) was similar for the three systems over the three years of measurement (

Table 4.2.8).

Table 4.4.3. Percentage of uniform paddocks for total ground cover in 2006, 2007 and 2009*.

Treatment	**Spatial 'uniformity' of paddocks for total ground cover (%)** (number of paddocks with no significant clustering pattern, expressed as a percentage of the total number of paddocks within each grouping)					
	2006		**2007**		**2009**	
Syst/Vegn/Region	Mean	Transf.	Mean	Transf.	Mean	Transf.
Grazing system (GS)		*P*=0.062		ns		NA
Cell	76*a*	1.15	44	-0.24	56	0.23
Rotation	53*ab*	0.13	13	-1.90	63	0.52
Continuous	18*b*	-1.52	43	-0.29	0	-15.81
Av. s.e.d.		1.10		0.97		
Vegetation type (V)		ns		ns		NA
Brigalow	60	0.40	31	-0.82		
Eucalypt	36	-0.56	31	-0.80		
s.e.d.		0.77		0.66		
Region (R)		ns		ns		NA
North	48	-0.09	37	-0.52		
South	48	-0.07	25	-1.10		
s.e.d.		0.63		0.68		

* Back-transformed means are presented as percentages. Means followed by different letters are significantly different (*P*=0.10); ns = P>0.10; NA = analysis not available due to model not converging (results are presented as the means from the original data).

4.4.3.2 Litter cover

There were no significant effects for within paddock variation in litter cover due to systems, vegetation type or regions in any year (analysis is shown in Appendix 9.9).

4.4.3.3 Tree/shrub cover

There were no significant or consistent effects on within paddock variation in tree/shrub cover due to systems, vegetation type or region (Appendix 9.9).

4.4.4 Pasture performance between sites

There was no consistent pattern of changes in pasture measures between sites over the four years of monitoring. Some small differences in one or other parameter occurred at most sites at some time but these were likely idiosyncratic responses and not suggestive of any coherent impact of grazing system over time.

4.4.5 LFA Indices variability

There were no significant or consistent effects on variation (uniformity) in the LFA indices for Stability, Infiltration or Nutrient cycling across paddocks over the three years 2006, 2007 and 2009 (analyses and results are shown in Appendix 9.9).

Summary of statistical analyses – spatial variability

For eight Botanal/LFA parameters measured in 2006, 2007 and 2009, and analysed by grazing system, vegetation communities and region, there were five significant differences (P<0.10) from a possible 63 combinations. Pasture utilisation was the only parameter with consistent differences due to grazing system over the four-year sampling period, with significant differences at 2 of 3 the sampling times. The trend was for cell pastures to be more uniformly utilised than either rotation or continuous pastures. A summary of analysis and probability levels is shown in Appendix 9.9.

4.5 Summary of Cattle performance

There were no statistically significant differences in the level of grazing (stock days per ha per year) between grazing systems at five of the project sites, but there were at Frankfield, Rocky Springs, Somerville and Ticehurst due to lower values for the rotation paddocks at these sites. The average grazing received by rotational pastures over all sites (92 SDH) was 81% of that in the cell or continuous systems (average 114 SDH), which is in line with the proportional difference in estimated long-term carrying capacities (LTCCs) between the rotation paddocks and the average of the cell and continuous system paddocks. The carrying capacity of rotation paddocks at these sites was reduced due to additional periods of destocking, opening of multiple paddocks as part of drought management, and/or woody regrowth control. Overall, there was similar grazing pressure (in stock days per hectare per year) for the Cell (113 SDH) and Continuous systems (115 SDH). On average, the three systems were grazed at 37% above their assessed LTCCs. There was, however, significant variability in the ratio values of actual grazing days:LTCC across systems and sites.

The NIRS analyses showed that, overall, cattle on continuous pastures had higher diet quality (crude protein, faecal nitrogen and digestibility) than those grazing cell pastures, with those on rotation pastures being intermediate. The influence of grazing system on diet quality varied with growing conditions. Diet quality was generally low and with little difference between grazing systems during dry times (GI<0.2) but, when good growing conditions (GI>0.5) improved diet quality overall, grazing system had a significant impact.

The detailed measurements and analysis of the grazing data are presented in the following sections.

4.6 Cattle grazing

4.6.1 Grazing pressure (grazing chart data)

There were two main measures of the grazing pressure imposed on the systems at each of the nine sites. They were stock days per ha (SDH) and stock days per ha per 100mm of rain over the previous 12 months from each grazing event (SDH/100mm).

Grazing pressure, measured as average annual SDH and SDH/100mm rainfall for the three systems at the nine sites, shows that the cell and continuous pastures received similar grazing pressure on average during the project period, while the rotation pastures were more lightly grazed (

Table 4.6.1).

Table 4.6.1. Grazing system averages for the two measures of grazing pressure over the project period (2005-09).

Grazing pressure	System grazing pressure		
	Cell	Rotation*	Continuous
SDH	113	92	115
SDH /100mm	20	16	20

* The lower grazing pressure on rotation pastures is due, in part, to destocking following woody regrowth control at one site and drought management strategies at two sites.

Four of the nine sites, Frankfield, Rocky Springs, Somerville and Ticehurst, had significant grazing pressure differences between grazing systems. There were no significant differences between systems at the other five sites.

There were significant between-year differences in the three grazing pressure measures at all sites except at Berrigurra (no difference between either measure) and at Rocky Springs (significant only in SDH/100mm). The between year differences were exacerbated by the initial drought years at the start of the project and the above-average rainfall years at some sites in the last two years of monitoring.

The grazing system-by-year interaction was significant at five of the nine sites for the two grazing pressure measures. At Banyula, this significance level was less than P=0.09 for both measures, while at Frankfield, Melrose, Somerville and Ticehurst, the significance level was P<0.05. There was a significant (at least P<0.10) system-by-year interaction for average annual stocking rate at the nine sites. The transformed and back transformed means and significant main effects and interactions from the statistical analysis are shown in the Appendices.

Over the four years for the 21 systems monitored, there was relatively good correlation between the actual annual grazing pressure (in SDH) and the estimated LTCC for 16 systems, but not for five, which were all grazed at higher rates than the estimated LTCC (Figure 4.6.1). The five outliers were the cell systems at Salisbury Plains and Sunnyholt, the rotation system at Frankfield, and the continuous systems at Frankfield and Sunnyholt.

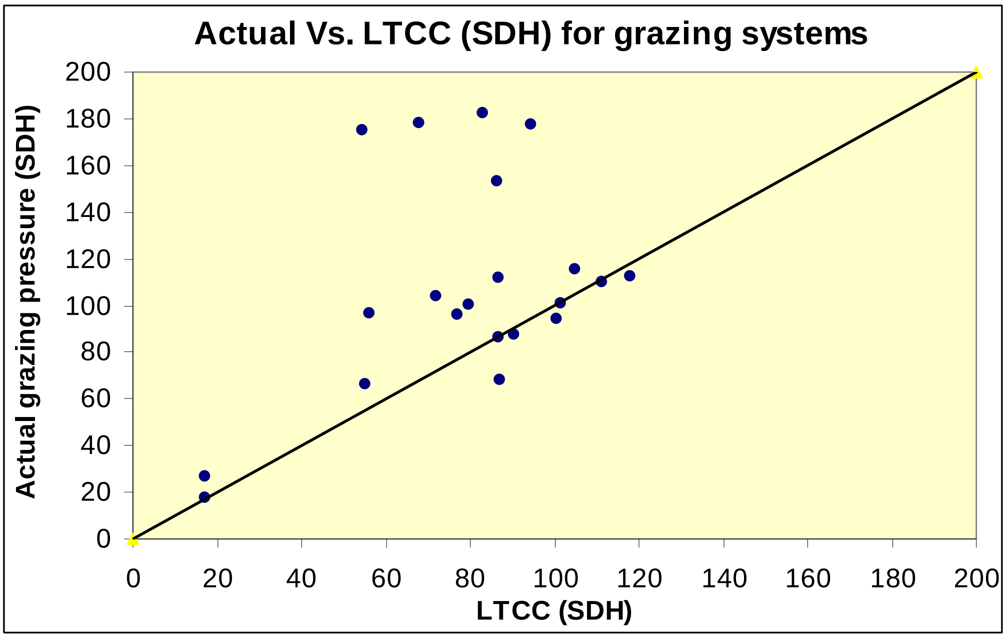


Figure 4.6.1. Actual average annual grazing pressure related to LTCC in SDH for 21 grazing systems.

The wide range of grazing pressures on different land types is shown by an analysis of average annual (2005-06 to 2008-09) grazing pressure of all systems at the nine sites. The site averages (over four years) for the two grazing pressure parameters show a range from 24 to 174 SDH and 5 to 31 SDH/100 mm rainfall (Table 4.6.2). The average over all sites showed no difference between the cell and continuous systems. The highest rates were in cleared country, one was on buffel grass pastures on the more fertile brigalow soils in southern Queensland and the other on light textured soils supporting a eucalypt community in the north which received relatively high rainfall. The lowest grazing pressure was on sandy soils supporting a mixed treed community in a low rainfall environment of north-west Queensland.

Table 4.6.2. Annual average grazing system SDH and site means of grazing pressure parameters SDH and SDH/100 mm rainfall between 2005 and 2009*.

Grazing	**Av. Annual SDH by system and site and Av. SDH/100mm by site**									
System	**Ban**	**Ber**	**Fra**	**Mel**	**Roc**	**Sal**	**Som**	**Sun**	**Tic**	**Site Av.**
Cell	112	101	97	110		182	27	178	96	119
Rotation		116	175	112	68		17		66	89
Continuous	104	100	178	87	94	87		153		115
Av. SDH	111	104	122	107	77	173	24	174	88	113
Av. SDH/100 mm	22	21	21	17	15	23	5	31	18	20

* Grazing system with highest SDH is highlighted in yellow.

4.6.2 Long term carrying capacity

Long-term carrying capacity (LTCC) for each site (based on the monitor paddocks) was compared with the stocking rates in use during the project. Differences between actual grazing imposed (from records) and the estimated LTCC for the monitored pastures are shown for systems (Table 4.6.3) and sites (Table 4.6.4). At Frankfield, the rotation and continuous systems were more heavily grazed than the cells; at Somerville and Ticehurst the cells were grazed more heavily than the rotation paddocks. At the latter site the rotation was grazed lightly after stick-raking one paddock and both rotation monitor paddocks were lightly grazed after destocking due to drought and had not been grazed by the recording time in the following autumn. The monitor cell paddocks had been grazed by this time. There were no consistent differences in actual grazing pressure applied between regions or vegetation types.

On average the LTCC of the rotation paddocks was lower than the other two systems.

Table 4.6.3. Average annual difference between actual grazing pressure and LTCC (AE/100ha) for grazing systems between 2005 and 2009 at all sites.

Site	Grazing System	LTCC and actual grazing (AE/100ha)			
		LTCC	Graz charts Actual	Difference % relative to LTCC	Actual Vs. LTCC
Banyula	Cell	32	28	-13	Under
	Continuous	20	29	47	Over
Berrigurra	Cell	28	18	-35	Under
	Rotation	29	22	-23	Under
	Continuous	22	20	-8	Under
Frankfield	Cell	15	18	17	Over
	Rotation	15	33	122	Over
	Continuous	19	48	158	Over
Melrose	Cell	31	29	-5	Under
	Rotation	24	24	1	Over
	Continuous	24	23	-3	Under
Rocky Springs	Rotation	24	18	-25	Under
	Continuous	28	25	-9	Under
Salisbury Plains	Cell	23	28	23	Over
	Continuous	25	23	-7	Under
Somerville	Cell	5	5	7	Over
	Rotation	5	2	-57	Under
Sunnyholt	Cell	26	28	8	Over
	Continuous	24	33	40	Over
Ticehurst	Cell	21	20	-5	Under
	Rotation	15	3	-80	Under
Av. all sites	Cell	23	22	-2	Under
(GS averages)	Rotation	19	17	-8	Under
	Continuous	23	29	27	Over

Five properties were grazed above the estimated LTCC and four properties were below the LTCC, although at seven sites these differences were relatively small.

Table 4.6.4. Difference between property average LTCC and annual average grazing pressure (AE/100ha) between 2005 and 2009. The relative difference between actual and LTCC is shown in brackets.

Site	Site Av.*LTCC and actual grazing (AE/100ha) / difference (%)			
	LTCC AE/100ha	Actual AE/100ha	Difference relative to LTCC %	Actual Vs. LTCC
Banyula	24	28	18	Over
Berrigurra	26	19	-27	Under
Frankfield	16	21	30	Over
Melrose	25	26	4	Over
Rocky Springs	25	20	-19	Under
Salisbury Plains	24	27	11	Over
Somerville	5	3	-36	Under
Sunnyholt	25	29	14	Over
Ticehurst	19	7	-62	Under
Av. all sites	**17**	**20**	**18**	Over

*Average LTCC calculated from total monitor paddock area and total AE carrying capacity (not as an average of paddocks within a system).

There were properties and pasture types (buffel dominant or native pasture) in both regions with average grazing (2005-06 to 2008-09) both under and over the estimated LTCC. Buffel grass pastures were grazed both under and over the estimated LTCC, while two of the four native pasture sites were grazed above the estimated LTCC.

In both regions, pastures where the average annual grazing was below the estimated LTCC had rainfall over the project period that was lower than average. All sites where grazing was above the estimated LTCC had rainfall over the project period that was above average except for one buffel pasture site on brigalow soil in southern Queensland.

Over the four years of monitoring, approximately 60% of cell and continuous paddocks were grazed at higher rates than the estimated LTCC, while 70% of rotation paddocks were grazed below the LTCC. Over all sites, the inherent carrying capacity of the land in the three systems was marginally lower in the rotation system paddocks. At two sites, the rotation paddocks had interrupted management due to the drought and timber treatment.

The process of assessing LTCC, based on land types, GRASP-derived pasture growth, safe utilisation values, and adjusting for distance to water, provided some additional insights into the land resource, level of development and potential productivity of each site. The level of fencing and water development was good with less than 1-2 km between water points in most paddocks, so LTCC was not limited by this factor. Paddocks with more fertile brigalow soil types were sown to improved pastures, mainly buffel grass, which offers less potential for further improvement in LTCC. Eight of the nine sites were predominantly cleared of trees, with one site (Somerville) retaining the native woodlands. A majority of the monitored areas on all the sites were in very good or good (A or B) land condition. There was some potential for improvement in LTCC by improving land condition in parts of paddocks and even across whole paddocks, mainly by managing woody regrowth, and in some paddocks by reducing the area of scalds and other bare areas.

4.6.3 Diet quality (NIRS)

The system means over all sites (Table 4.6.5) showed a significantly higher diet quality for cattle grazing continuous pastures than for those grazing cell pastures with respect to crude protein, faecal nitrogen and digestibility. Diet quality for cattle on rotation pastures was consistently between the values for cattle on cell and continuous pastures, but was not significantly ($P > 0.05$) higher than the cell pastures. As expected, the diet quality in the growing months was higher ($P<0.001$) than the dry (winter) months for all parameters. There was also a significant difference between years, with the highest quality in 2007 and the lowest in the following good rainfall year 2008. This poor quality in 2008 was reflected in poor liveweight performance in that year as commented on specifically by owners of four of the sites, and by anecdotal evidence from other properties in other regions across southern Queensland. The only significant interactions were between the grazing systems and seasons for crude protein and faecal nitrogen. NIRS monitoring of up to 150 properties across northern Australia also found that cattle in continuous and rotational grazing systems had a higher average diet quality than cattle in cell systems (Jackson et al. 2009).

The diet quality deficiency between years and seasons is clear with 2005 having the highest DMD:CP ratio (8.4), which is within the range where cattle are expected to respond to urea supplements (ratio >8-10) (Dixon 2007).

The ranges of quality values for site-system combinations were: crude protein 6.67 to 9.47%, faecal nitrogen 1.27 to 1.63% and digestibility 53.7 to 58.5%. Non-grass in diets ranged from 10 to 35% and liveweight gain predictions ranged from 0.4 to 0.9 kg/head/day (

Table 4.6.6).

Table 4.6.5. Mean NIRS diet quality and significant differences between systems, seasons and years from all samples (n=565) at nine sites.

Main effects	**NIRS parameter**											
(No. samples)	**Crude Protein (%)**		**Faecal N (%)**		**Digestibility (%)**		**Non-Grass (%)**		**LWG (kg/day)**		**DMD/CP ratio**	
Grazing System	**		**		*		P=0.079		P=0.096		P=0.070	
Cell (214)	7.39	b	1.39	b	55.4	b	16.0		0.59		7.9	
Rotation (156)	7.72	b	1.42	b	55.6	b	19.8		0.62		7.6	
Continuous (195)	8.55	a	1.53	a	56.9	a	19.1		0.69		7.2	
sed (av.) (565)	0.30		0.04		0.5		1.7		0.04		0.3	
Season	***		***		***		***		***		***	
Growing (251)	8.85	a	1.54	a	57.8	a	16.7	b	0.78	a	6.9	b
Winter (314)	6.92	b	1.35	b	54.1	b	19.9	a	0.49	b	8.2	a
sed (av.)	0.19		0.02		0.4		0.8		0.03		0.1	
Year	***		***		*		***		***		***	
2005 (70)	6.96	d	1.35	c	56.7	a	18.0	b	0.59	bc	8.4	a
2006 (161)	8.31	ab	1.48	ab	55.8	ab	22.4	a	0.67	b	7.2	c
2007 (153)	8.95	a	1.53	a	56.4	a	21.5	a	0.82	a	6.7	d
2008 (146)	7.53	cd	1.45	b	55.1	b	18.5	b	0.57	c	7.9	b
2009 (35)	7.66	bc	1.43	b	55.7	ab	11.0	c	0.52	c	7.6	bc
sed (av.)	0.33		0.04		0.6		1.3		0.05		0.2	
GS * Season	P=0.054		P=0.091		ns		ns		ns		ns	
GS * Yr	ns		ns		ns		ns		ns		ns	
Season * Year	ns		*		ns		*		*		*	
GS * Season * Yr	ns		ns		ns		ns		ns		ns	

Table 4.6.6. Mean NIRS diet quality results at nine sites (n=565).

Property	Grazing System	No. Samples	NIRS parameter: Crude Protein %	Faecal N %	Digestibility %	Non-Grass %	LWG kg/day	DMD/CP ratio
Banyula	Cell-loam	16	8.52	1.57	56.9	19.9	0.82	7.4
Banyula	Continuous	16	8.69	1.59	56.4	24.8	0.70	7.4
Berrigurra	Cell	35	7.48	1.48	54.7	11.9	0.67	7.6
Berrigurra	Rotation	40	7.69	1.45	55.2	16.8	0.70	7.5
Berrigurra	Continuous	29	9.21	1.62	57.1	9.9	0.88	6.6
Frankfield	Cell	24	7.02	1.27	55.2	12.0	0.57	8.2
Frankfield	Rotation	32	7.84	1.34	55.0	13.3	0.61	7.5
Frankfield	Continuous	23	8.01	1.38	55.5	13.9	0.62	7.3
Melrose	Cell	32	6.67	1.32	53.7	15.0	0.47	8.4
Melrose	Rotation	31	7.51	1.38	55.1	22.9	0.58	7.6
Melrose	Continuous	29	8.37	1.54	56.5	22.1	0.68	7.0
Rocky Springs	Rotation	29	7.70	1.44	54.3	22.8	0.55	7.5
Rocky Springs	Continuous	29	8.01	1.44	54.4	22.2	0.59	7.2
Salisbury Plains	Cell	25	7.00	1.30	54.0	24.2	0.38	8.0
Salisbury Plains	Continuous	30	9.49	1.63	58.5	34.7	0.70	6.5
Somerville	Cell	24	6.67	1.34	55.0	22.7	0.54	8.8
Somerville	Rotation	10	7.50	1.49	55.2	29.6	0.60	7.7
Sunnyholt	Cell	39	8.79	1.48	57.6	15.2	0.87	7.0
Sunnyholt	Continuous	39	9.03	1.62	58.3	13.9	0.89	7.1
Ticehurst	Cell	18	7.93	1.44	55.9	20.4	0.68	7.6
Ticehurst	Rotation	15	8.49	1.44	56.7	24.4	0.74	7.5
Average		565	**7.98**	**1.46**	**55.7**	**19.7**	**0.66**	**7.5**

At the three sites where there were three grazing systems, a comparison of systems when all were sampled on the same day shows that there was a trend for both protein and digestibility to increase in the diet as the system intensity decreased. At all sites, over 20 to 28 sampling times, the cells had lower values (1-2% lower crude protein and digestibility) than the continuous systems (Table 4.6.7.). Quality differences were significant at Berrigurra and Melrose, but not at Frankfield where sampling times excluded the main wet season (when pasture quality would have been highest and differences between systems greatest).

Table 4.6.7. Diet quality at Berrigurra, Frankfield and Melrose when the three systems were sampled on the same day.

Site	**No.**	**NIRS parameter**					
Grazing System		**Crude Protein (%)**	**Faecal N (%)**	**Digesti-bility (%)**	**Non-Grass (%)**	**LWG prediction (kg/day)**	**DMD/CP ratio**
Berrigurra		*	*	ns	*	P=0.075	ns
Cell	25	7.6 b	1.48 b	55	10 b	0.69	7.7
Rotation	25	7.3 b	1.43 b	55	15 a	0.73	7.7
Continuous	25	9.3 a	1.63 a	57	10 b	0.91	6.6
sed (av.)		0.7	0.07	1	2	0.10	0.8
Frankfield		ns	ns	ns	ns	ns	ns
Cell	20	6.6	1.22	54	13	0.44	8.4
Rotation	20	7.6	1.30	55	12	0.57	7.5
Continuous	20	7.4	1.31	55	10	0.51	7.7
sed (av.)		0.9	0.06	1	5	0.19	0.8
Melrose		**	***	*	**	*	*
Cell	28	6.8 b	1.34 b	54 b	16 b	0.49 b	8.2 a
Rotation	28	7.6 ab	1.38 b	55 ab	23 a	0.60 ab	7.5 ab
Continuous	28	8.3 a	1.53 a	56 a	22 a	0.68 a	7.0 b
sed (av.)		0.4	0.05	1	2	0.07	0.4

At individual sites, the differences in diet quality parameters between grazing systems were not always consistent. For example, Berrigurra, Melrose, Salisbury Plains and Sunnyholt had differences between systems for only some quality parameters. There was a significant system response in all parameters on the native pastures at Melrose.

The statistically significant differences between diet quality parameters for grazing systems, seasons, years and their interactions at the nine sites (Table 4.6.8) show the variation between sites. Season and year differences were most consistent, with Melrose, Berrigurra, Salisbury Plains and Sunnyholt having the most frequent instances of differences in diet quality.

Table 4.6.8. Significant NIRS diet quality parameters and interactions for all samples at nine sites*.

NIRS parameter Syst/Season/Year	**Banyula**	**Berrigurra**	**Frankfield**	**Melrose**	**Rocky Springs**	**Salisbury Plains**	**Somerville**	**Sunnyholt**	**Ticehurst**
Crude Protein %	Statistical significance								
Grazing System	ns	**	ns	***	ns	***	ns	ns	ns
Season	**	***	ns	**	***	**	ns	*	*
Year	ns	*	**	***	***	ns	ns	***	**
GrazSys*Season	ns	ns	ns	ns	ns	ns	ns	ns	ns
GrazSys*Year	ns	ns	ns	ns	ns	ns	ns	ns	ns
Season*Year	ns	ns	ns	ns	P=0.088	ns	ns	ns	**
GrazSys*Season*Year	ns	ns	ns	ns	ns	ns	-	ns	-
Faecal N %									
Grazing System	ns	**	ns	ns	ns	***	ns	ns	ns
Season	*	***	*	**	***	***	ns	*	*
Year	ns	ns	*	*	***	ns	ns	***	*
GrazSys*Season	ns	ns	ns	ns	ns	ns	ns	ns	ns
GrazSys*Year	ns	ns	ns	ns	ns	ns	ns	ns	ns
Season*Year	ns	ns	*	ns	ns	ns	P=0.095	ns	***
GrazSys*Season*Year	ns	ns	ns	ns	ns	ns	-	ns	-
Digestibility %									
Grazing System	ns	P=0.093	ns	**	ns	***	ns	ns	ns
Season	**	***	**	**	***	*	ns	*	**
Year	ns	*	ns	ns	ns	ns	ns	**	ns
GrazSys*Season	ns	ns	ns	ns	ns	ns	ns	ns	ns
GrazSys*Year	ns	ns	ns	ns	ns	ns	ns	ns	ns
Season*Year	ns	ns	*	ns	ns	ns	P=0.092	ns	P=0.062
GrazSys*Season*Year	ns	ns	ns	ns	ns	ns	-	ns	-

	Banyula	Berrigurra	Frankfield	Melrose	Rocky Springs	Salisbury Plains	Somerville	Sunnyholt	Ticehurst
Non-Grass %					Statistical significance				
Grazing System	ns	***	ns	***	ns	ns	*	ns	ns
Season	ns	P=0.074	*	P=0.086	ns	***	ns	P=0.060	ns
Year	**	***	***	ns	**	ns	*	***	ns
GrazSys*Season	ns	ns	ns	ns	ns	P=0.099	ns	ns	ns
GrazSys*Year	ns	ns	ns	ns	ns	ns	ns	ns	ns
Season*Year	ns	ns	ns	ns	ns	ns	ns	***	ns
GrazSys*Season*Year	ns	ns	*	ns	ns	*	-	ns	-
LWG kg/day									
Grazing System	ns	**	ns	**	ns	*	ns	ns	ns
Season	***	***	**	**	***	**	ns	P=0.082	**
Year	*	**	***	**	***	ns	ns	**	*
GrazSys*Season	ns	ns	ns	ns	ns	ns	ns	ns	ns
GrazSys*Year	ns	ns	ns	ns	ns	ns	ns	ns	ns
Season*Year	ns	*	ns	*	*	ns	P=0.083	ns	*
GrazSys*Season*Year	ns	ns	ns	ns	ns	ns	-	ns	-
DMD/CP ratio									
Grazing System	ns	**	ns	***	ns	ns	ns	ns	ns
Season	**	***	ns	*	***	*	ns	*	*
Year	ns	**	***	***	***	ns	ns	**	ns
GrazSys*Season	ns	ns	ns	ns	ns	ns	ns	ns	ns
GrazSys*Year	ns	ns	ns	ns	ns	ns	ns	ns	ns
Season*Year	P=0.087	ns	ns	ns	P=0.050	ns	ns	ns	*
GrazSys*Season*Year	ns	ns	ns	ns	ns	ns	-	ns	-

* excludes Banyula clay cell paddocks.

An analysis of the diet quality parameters and the pasture growth index interactions shows the effect of grazing system occurred primarily in the growing season and not in the dry season (Table 4.6.9). There was no difference in crude protein between the systems when the GI was <0.2 (range in CP of 6.6% to 7.2%). However, above this GI level, the continuous system had higher CP than the rotation, which was higher than the cells. Effects of grazing system on faecal nitrogen were similar to those for crude protein. The order for digestibility was similar, with a range from 53% (rotation GI<0.2) to 59% (continuous GI>0.5). The mean values and significant differences between systems, growth index classes and the system by GI interaction are shown in Appendix 9.12.

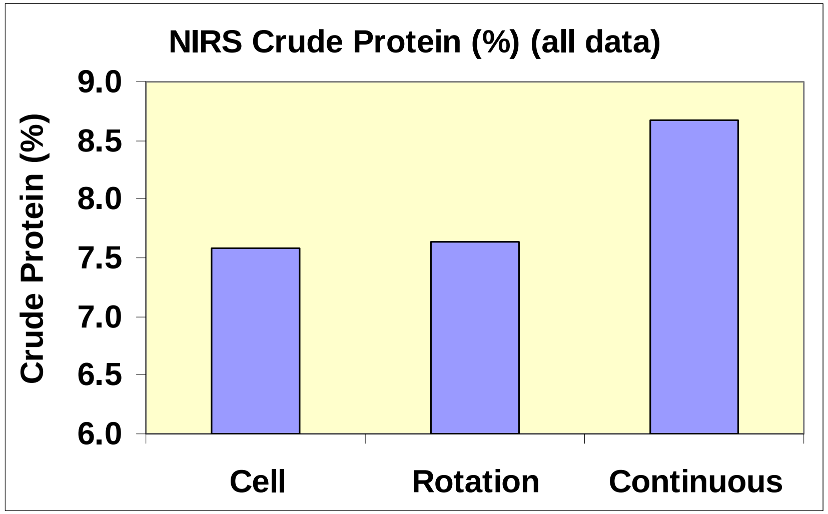
Table 4.6.9. Mean NIRS results for paired samples (497 total) for three growth index classes and three grazing systems between 2005 and 2009 (non-transformed data).

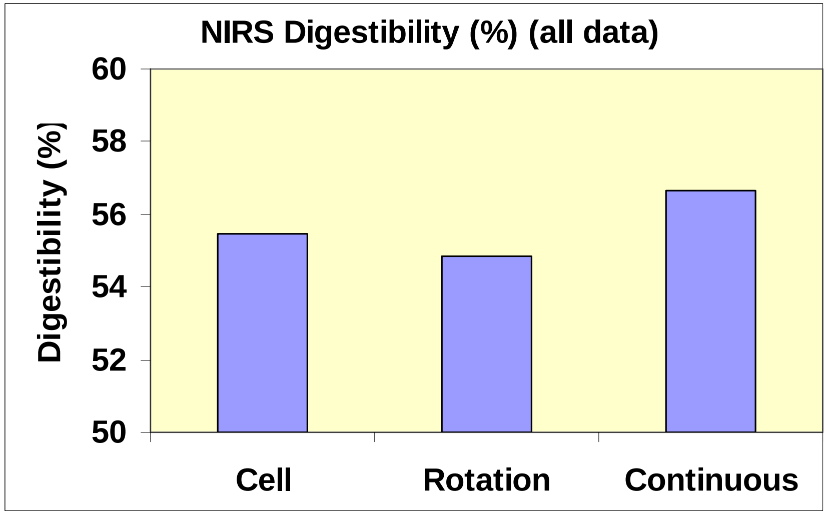
NIRS parameter	GS NIRS diet quality parameter by GI class			
GI Class	Cell	Rotation	Continuous	Average
Crude Protein %				
<0.2	6.85	6.58	7.15	6.88
0.2-0.5	7.74	8.22	9.34	8.46
>0.5	8.31	8.33	9.94	8.92
Mean	**7.50**	**7.64**	**8.66**	**7.96**
Digestibility %				
<0.2	54	53	54	54
0.2-0.5	56	56	58	57
>0.5	57	56	59	57
Mean	**55**	**55**	**57**	**56**
Faecal N %				
<0.2	1.33	1.31	1.39	1.35
0.2-0.5	1.40	1.47	1.59	1.49
>0.5	1.49	1.47	1.69	1.56
Mean	**1.40**	**1.41**	**1.54**	**1.45**
Predicted LWG kg/day				
<0.2	0.47	0.38	0.49	0.45
0.2-0.5	0.69	0.73	0.84	0.75
>0.5	0.79	0.79	0.95	0.85
Mean	**0.62**	**0.61**	**0.74**	**0.66**
DMD/CP ratio				
<0.2	8.3	8.3	8.0	8.2
0.2-0.5	7.5	7.2	6.5	7.1
>0.5	7.3	7.1	6.2	6.8
Mean	**7.8**	**7.6**	**7.0**	**7.4**

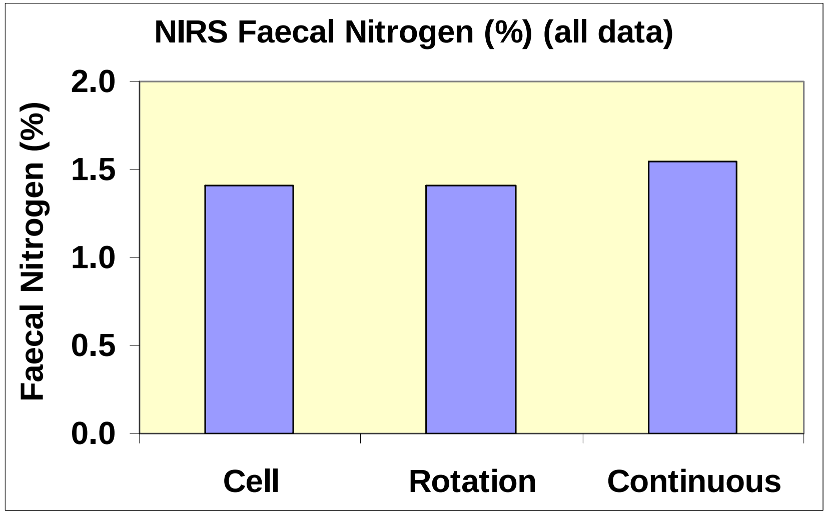
A summary of the statistical analyses of systems and growth index classes over all properties shows the strong main effects of grazing system and GI, and an interaction for crude protein and faecal N%.

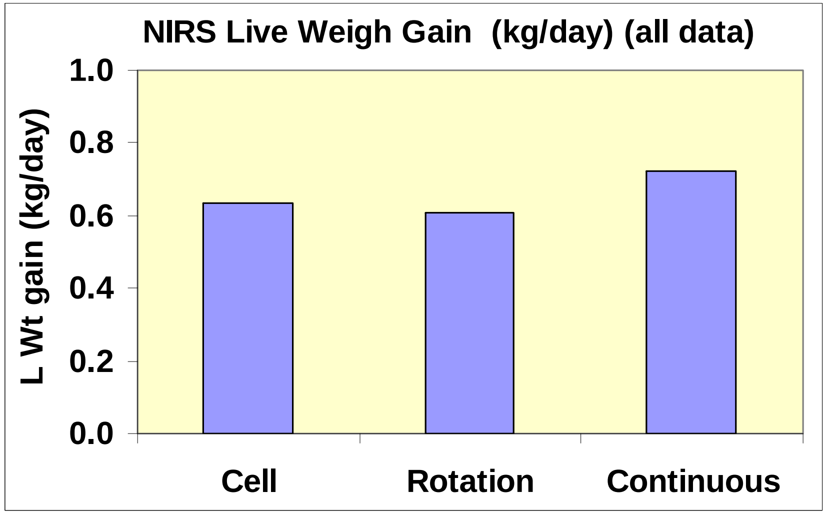
The superiority of NIRS-derived diet quality parameters, especially dietary crude protein, for cattle from the continuous systems over that of cattle from cells is illustrated in Figure 4.6.2; the trend for the rotation systems was to be in between these systems but more similar in diet quality to the cells. Generally the south region and the brigalow vegetation communities had the higher diet quality values, as was expected. These differences between north and south regions and between the eucalypt and brigalow vegetation communities are shown in Appendix 9.12.

Markets for better finished cattle will influence the types of systems developed, as the nutrition from the less intense systems is superior under some circumstances to the more intensive ones. When there is a small price margin between store and finished condition, per hectare production will have increased influence on profitability. There was no evidence of any differences in either calculated LTCC or grazing pressures imposed between the different systems, so production per ha may well have been slightly higher from less intensive systems due to the higher diet quality.


NIRS Crude Protein (%) (all data)
Crude Protein (%)
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Cell
Rotation
Continuous


NIRS Digestibility (%) (all data)
Digestibility (%)
60
58
56
54
52
50
Cell
Rotation
Continuous


NIRS Faecal Nitrogen (%) (all data)
Faecal Nitrogen (%)
2.0
1.5
1.0
0.5
0.0
Cell
Rotation
Continuous


NIRS Live Weigh Gain (kg/day) (all data)
L Wt gain (kg/day)
1.0
0.8
0.6
0.4
0.2
0.0
Cell
Rotation
Continuous

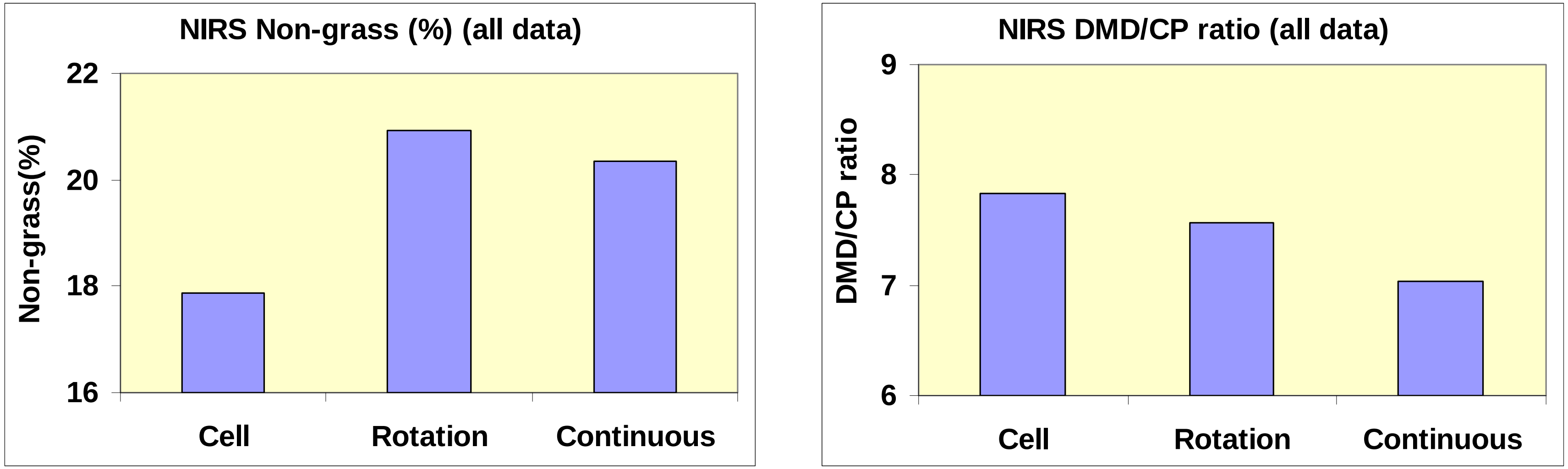


Figure 4.6.2 Mean NIRS results for grazing systems across nine sites and 565 samples.

4.7 Grazing system intensity index

The calculations of the grazing systems intensity index (GSI) from the three factors: capital costs (CI), operating costs (OI) and management inputs (MI), for the 22 grazing systems (Banyula cell clay and cell loam are separated) at the nine properties (Table 4.7.1) shows a range of 21 to 96. The average GSI for the systems was: cells 79 (range 63-96), rotation 61 (range 45-84) and continuous 26 (range 21-31). The average of all systems was 57. The details of calculating each index are shown in Appendix 9.13.

Table 4.7.1. Values of the GSI for the 22 grazing systems on the nine properties.

Property	Grazing system	GSI
Banyula	Cell (Clay)	78
	Cell (Loam)	77
	Continuous	22
Berrigurra	Cell	63
	Rotation	52
	Continuous	21
Frankfield	Cell	75
	Rotation	59
	Continuous	29
Melrose	Cell	73
	Rotation	53
	Continuous	24
Rocky Springs	Rotation	45
	Continuous	31
Salisbury Plains	Cell	72
	Continuous	26
Somerville	Cell	91
	Rotation	73
Sunnyholt	Cell	82
	Continuous	26
Ticehurst	Cell	96
	Rotation	84

4.7.1 Grazing System Intensity index relationships across sites

The values of the various pasture, soil surface and cattle measurements (e.g. yield, ground cover, utilisation, NIRS results, etc) in the systems at the sites was related to their GSI value to determine if there were meaningful relationships. This is illustrated for average ground cover over all land types and environments within each system (Figure 4.7.1) where there was no clear relationship. Most measurements generated similar scattered figures showing that other factors (e.g. growing season, soil fertility, stocking rate), were more important in determining the measured values than the system GSI.

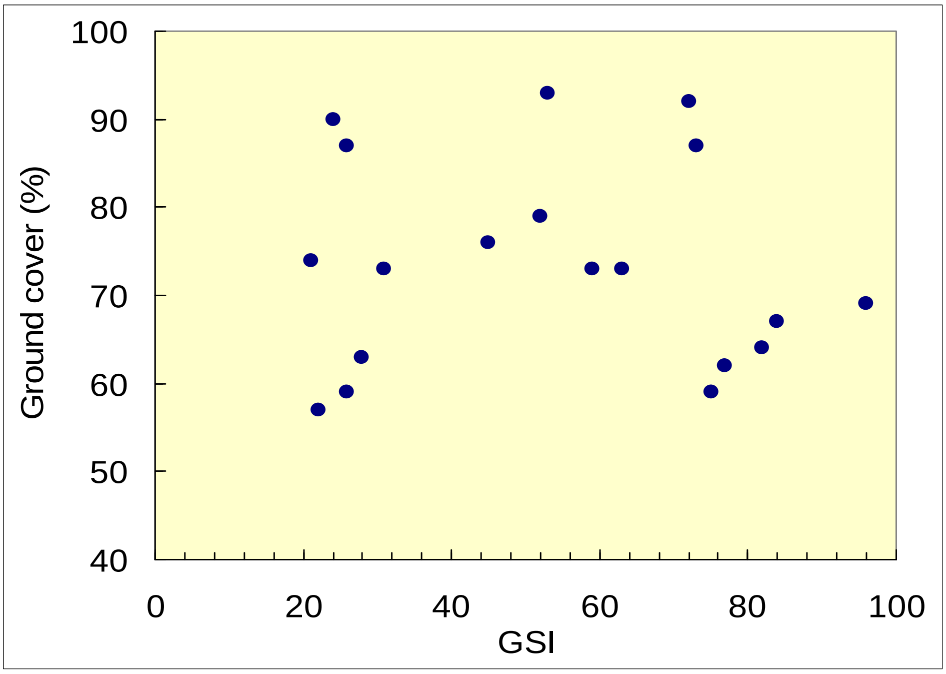


Figure 4.7.1. Relationship between grazing system Intensity (GSI) index and ground cover in 2009.

Some measurements showed a relationship with GSI, e.g. NIRS-derived estimates of crude protein in the diet (Figure 4.7.2) where there is a decline in crude protein as GSI increased. However, this figure disguises the different relationships that occur at each site (Figure 4.7.3). There were strong relationships between GSI and average crude protein at only some sites.

The two sites with the least relationship between GSI and crude protein (Banyula and Sunnyholt) were buffel pastures in southern Queensland. The strongest relationships were at native pasture sites (Salisbury Plains, Melrose, Somerville) as well as on the buffel pasture at Berrigurra.

Given the lack of a relationship with GSI for most ecological measurements, and the variations in the relationships between sites, attempts to relate the performance of different systems to GSI were not pursued.

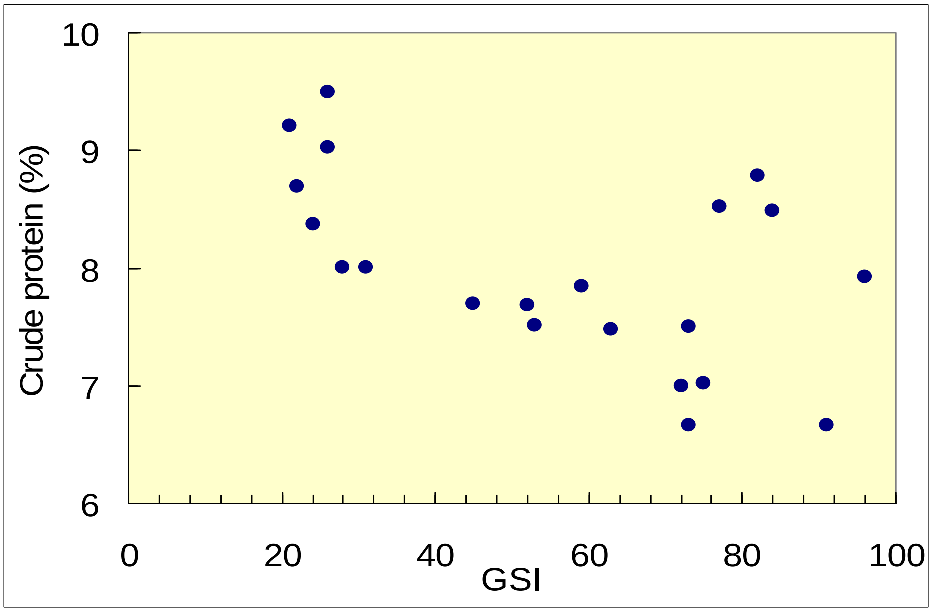


Figure 4.7.2. Relationship between grazing system Intensity (GSI) index and average estimated crude protein in the diet (mean of all values) for 21 grazing systems over four years.

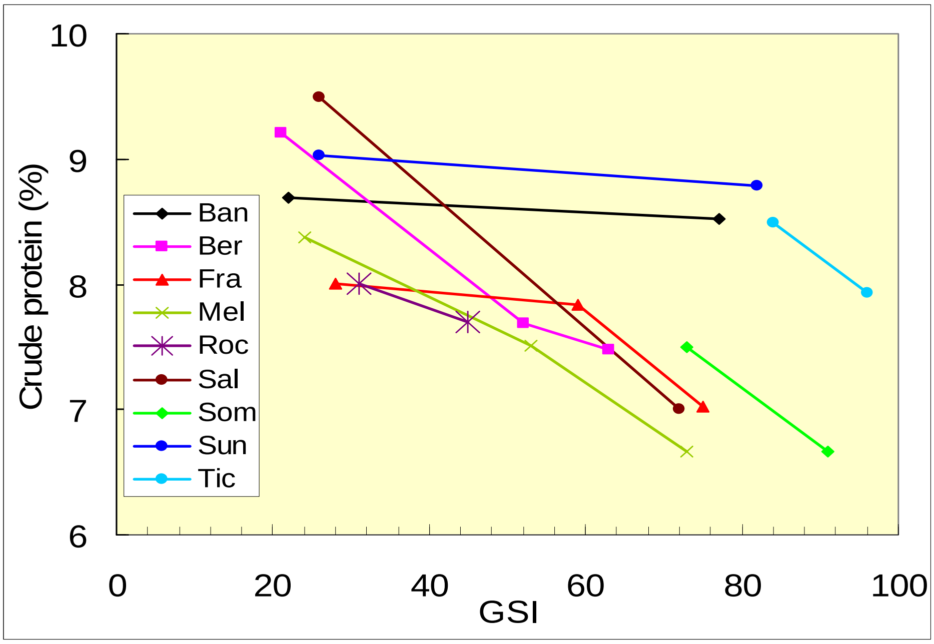


Figure 4.7.3. Relationship between grazing system Intensity (GSI) index and estimated crude protein in the diet at individual sites over four years.

4.8 Economic analysis

4.8.1 Using a particle budgeting approach to evaluating impacts of a change in grazing system

4.8.1.1 Introduction

Many producers seeking to improve the performance of their enterprise for a wide range of reasons. This may include a need to keep on top of cost-price pressures by raising productivity per animal and per ha and/or responding to concerns that their existing pastures are deteriorating under their current management practices. These concerns were expressed by most of the owners of the case study enterprises in this project. The typical response of these producers was to plan and execute changes to the present grazing system. Their main focus was how cattle and pastures are interactively managed in order to cost-effectively increase turnoff while maintaining the capacity of pastures to support that activity into the future.

A key consideration for deciding whether or not to progress with a plan to modify or replace the existing grazing system is to determine the costs and benefits of a new system. Even where the motivation to change the present system is not being driven directly by an economic imperative, for example as part of a pasture rehabilitation plan, it should remain of interest to identify the economic consequences of making the change.

This section we report on development of a relatively simple technique based on partial budgeting. The technique can also be used to identify how the projected outcome will be influenced by changes in key factors such as animal production, price and costs, including capital outlays. A simple template is provided that can be used by individual producers and their advisors to apply the technique to their own circumstances.

Caveats
Before progressing, however, it is important to state clearly that this can only provide producers with a preliminary guide to the potential worth of a proposed change in their grazing systems.

Some changes, such as installing sophisticated cell grazing systems, or subdivision of large paddocks into smaller units with or without timber management and pasture development, will require major capital outlays and substantial changes to the way that herd and general property management practices are conducted. They may also involve complex financing and taxation accounting arrangements which will impinge on both the final design and financial outlook for the changes. There ultimately is no substitute for careful planning and searching for sound technical and financial advice to guide such developments. Nevertheless, the simple appraisal technique can help screen possible options for further scrutiny and serve as a reliable 'back of the envelope' support aid.

A second caveat is that the analysis can only be as good as the estimates of both costs and benefits. For the case study described further below, the costs of the additional fencing and water points was relatively easy to derive. In terms of benefits, the analysis was conducted assuming the producer's anticipated increase in carrying capacity was actually achieved. This assumption was used so that the analysis could be illustrated and its value for decision-making discussed. The specifics of this case study analysis are, therefore, not to be taken as a general guide to the likely merits of investing in intensive systems.

Definitions and theoretical considerations:
To provide some background to the profit concepts that underpin the appraisal techniques the following definition of *profit* is provided. Some simple models of how the components of profit might interact to influence economic outcomes are presented in a following section (cost-volume-profit) and also in Appendix 9.14.

Profit
Profit can be represented in the following 3-variable equation:

Net Profit = total revenue - total variable costs - total fixed costs

NP= TR –TVC - TFC

Where, TR is the gross revenue from livestock sales, TVC is the sum of all the production costs that vary generally with the number of stock carried or sold, and TFC is the fixed or overhead costs which have to be met but do not directly change with livestock numbers or turnoff levels.

The simple profit equation is often expressed as:

Net Profit = total gross margin – total fixed costs

NP = TGM - TFC

Where TGM = TR – TVC, and where for cases in which the fixed costs are not expected to change significantly the change in profitability from a course of action can be simplified to just comparing the effect on gross margins.

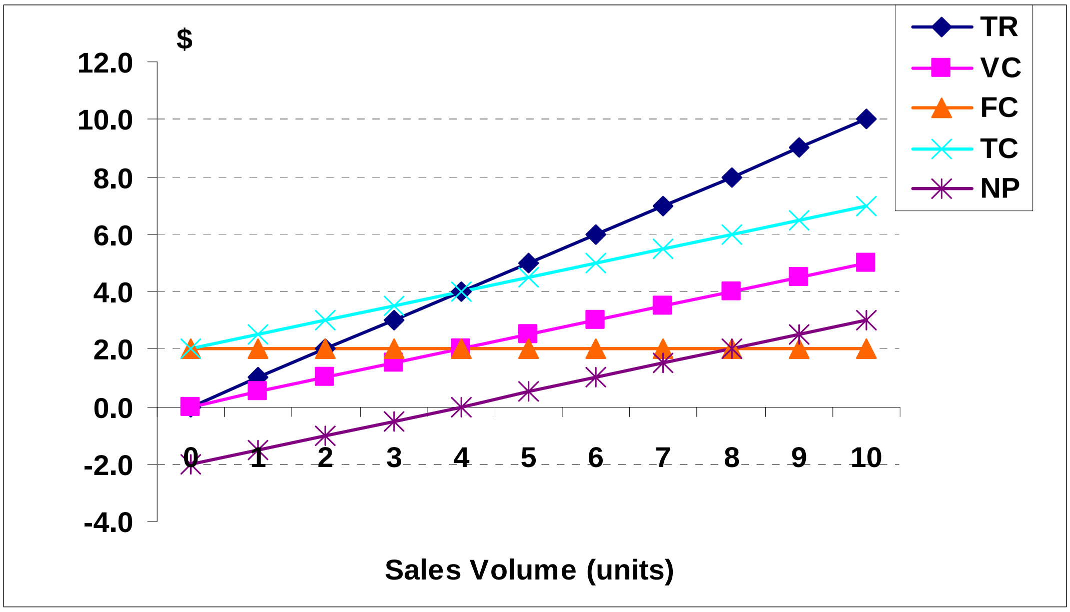
Break-even
Beef producers who are thinking of committing serious funds to changing their grazing systems will usually be keen to know more than just whether the change might return an enhanced profit. They will also be interested in knowing how much additional production will be required to 'break even' and how long it might take before any increased profit will recoup the capital outlays that are involved. Two simple techniques for addressing these concerns are *cost-volume-profit analysis* and comparisons of the changes in *additional profit* for a given additional level of investment.

(a) Cost-volume-profit

Cost-volume-profit analysis (CVP) can be used to identify the minimum profitable level of production and is a simple manipulation of the 3 variable profit formula discussed before, viz.

NP = 0, when TR = TVC+TFC

The inter-relationship between total revenue, total variable costs, total fixed costs and break-even production levels is illustrated in a hypothetical example in Figure 4.8.1.



Note: Break-Even sales volume = 4 units

Figure 4.8.1. Cost-Volume-Profit Relationship.

In this hypothetical illustration, under prevailing product prices and input costs, for any sales volume less than 4 units, total costs (TC) exceed total revenue (TR) and net profit (NP) is negative. When sales volumes exceed 4 units TR exceeds TC and NP is positive. The Break-Even volume directly decreases with increasing unit prices (P), and increases with increasing variable costs (VC) and fixed costs (FC). This simple figure illustrates an important principle concerning the profitability of any production enterprise - that break-even levels of production depend on the unique relationship that exists at the time between prices, variable costs and fixed costs of the particular beef enterprise under review. Nevertheless, a particular enterprise will be more profitable at any given production or sales volume if it can extract higher prices for its output, produce at lower variable costs or contain its fixed costs - which for most beef enterprises will be heavily influenced by animal turnoff age and quality, feed costs, permanent labour and depreciation charges made against plant and fixed infrastructure. These relationships are illustrated for a case study beef enterprise in Appendix 9.14.3.

(b) Marginal profit and Marginal investment

Beyond deciding whether production can break-even, it is important to determine whether the new system can generate enough additional (marginal) profit to cover the additional (marginal) investment in fixed infrastructure and any associated operating costs. Marginal net profit (MNP) is the difference between the profit earned by the new production system and the original system, and marginal investment (MI) is the capital outlay required to establish the new system once a steady state of operation has been reached.

An example of MNP and MI are shown in Figure 4.8.2 for a hypothetical grazing enterprise that is considering a new grazing system that should increase the carrying capacity above the present grazing system. Both MNP and MI increase with increasing stock numbers as, in the absence of significant increases in fixed costs, total revenues increase and the marginal investment includes both the additional livestock and infrastructure required to support the new grazing system.

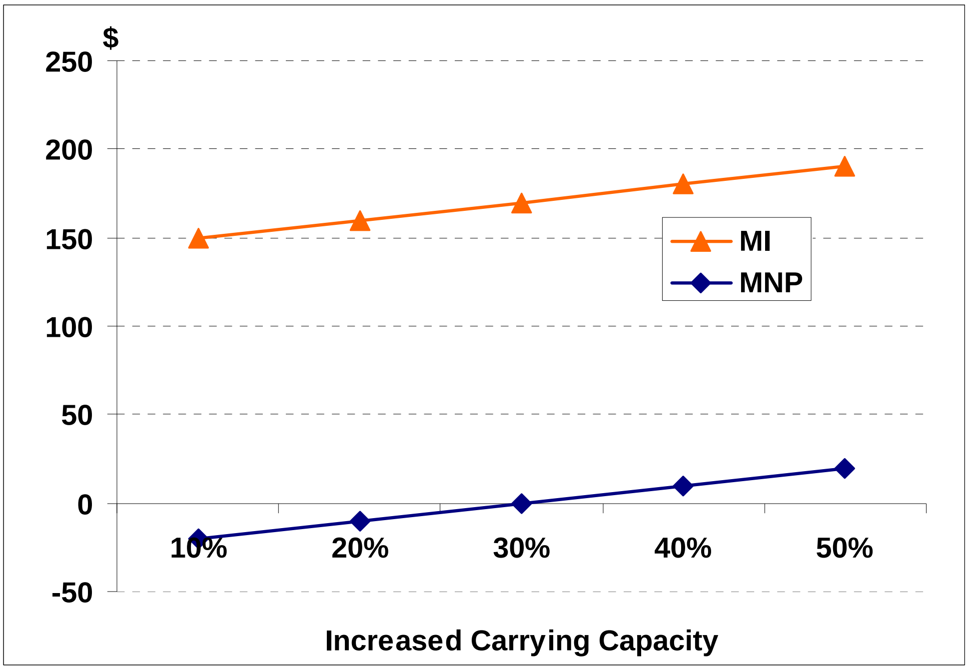


Figure 4.8.2. MNP and MI for a hypothetical new grazing system.

Because MI represents a capital stock with an expected life that can span many years it can not be directly compared to MNP which is an annual flow of funds. The two measures can really only be compared in terms of how many years it may take to recoup the capital outlays involved - the ‘break-even’ period. This comparison can be made by employing amortisation factors to convert the total MI outlay to a series of equal annual payments for an appropriate discount rate and time period that reflects the producers’ risk and time preferences[1]. A ‘break-even’ period can then be estimated as the point at which the MNP just exceeds an amortised annual equivalent of the MI outlay for any particular combination of discount rates and amortisation periods - illustrated in Figure 4.8.3 for an MI ranging between $150K and $190K (equal to MI illustrated in Figure 4.8.2) reduced to an annuity over periods of 10 years or 20 years at discount rates of 0% and 5%.

[1] Amortisation methods and calculation formulae are discussed in Chisholm and Dillon (1971). *Discounting and Other Interest Rate Procedures in Farm Management,* Guidebook 2, UNE, Armidale. They are easily accommodated using spreadsheet models.

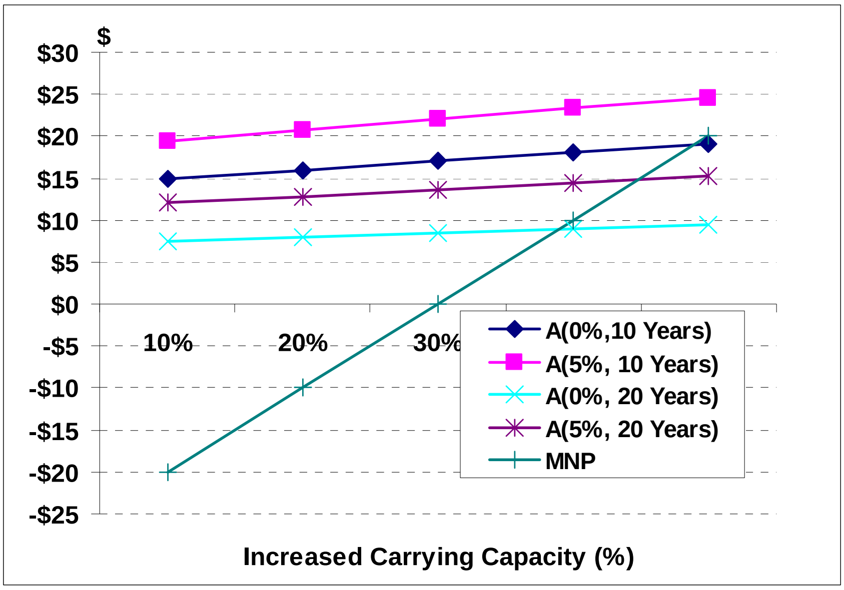


Figure 4.8.3. Break-even relationship between amortised values of MI and MNP.

MI increases directly with the size of the capital sum and the *discount* rate used to calculate the annuity, and decreases with increasing time periods over which the capital outlay is to be recovered. In the example illustrated in Figure 4.8.2 the MNP will only `break-even' for increases in stock numbers in excess of 40% and only if the annuity value of MI is based either on no discounting or seeking to recover the capital outlay over the longer period of 20 years.

Partial budgets
A final technique for assessing the potential worth of a change to a new grazing system involves calculation of partial budgets. Partial budgeting examines the net changes to both revenues and costs that arise as a direct consequence of the proposed change within the overall grazing management plan; and only those sources of revenues and costs that are likely to change need to be identified and estimated as shown in Table 4.8.1.

Table 4.8.1. General structure of a partial budget related to changing a grazing system.

Partial budget general structure	
Favourable (gains from the proposed change)	**Unfavourable (losses from the proposed change)**
A. Additional revenue	C. Additional costs
B. Reduced costs	D. Reduced revenue (including foregone revenue)
Total gain (A+B)	*Total loss* (C+D)
E. *Net monetary gain* (A+B) - (C+D)	
F. Capital required to implement the change	G. Capital released from present activities
H. *Net capital investment required* (F-G)	
I. Return on net additional capital invested % (E/H) x 100	

Note: Items E and H are, respectively, MNP and MI as used before.

4.8.1.2 Applying the profit and break-even concepts to a beef business

The 'theory' section has introduced the general idea of 'break-even' analysis for production enterprises using both the simple accounting concept of cost-volume-profit analysis and comparisons of MNP and amortised values of MI.

The CVP based 'break-even' analysis is not easily applied to beef enterprises which are based on mixed breeding and finishing herds as these do not have a single measure of production or sales volume against which the break-even level of profit can be assessed. The production and revenue measures in the profit equation are typically comprised of mixed stock classes of varying ages and condition at sale and husbandry and marketing costs vary as much according to the age, class and sex structure of the herd as to the total numbers carried or sold. However, aggregate revenue and costs values can be included in measures of MNP and MI for a given beef enterprise structure and potential change of grazing systems. Also like cost-volume-profit analysis, insights based on MNP-based 'break-even' analysis can be provided for the effect of changes in some important parameters that link to the TR, VC and FC components of the profit equations that were discussed in the earlier sections. This is illustrated with a case study from the Fitzroy region of Queensland.

An Example - Rockhampton Cell Grazing Case Study
The case study enterprise is located near Rockhampton, comprising a total area of 8,000 ha with a permanent labour force of two full time adult labour equivalents. The enterprise traditionally carried a total herd of 1630 adult equivalents (AE) centred on a breeding herd of 700 breeders and finishing steers to north Asian market specifications at approximately 30-36 months. Under present input and output costs and prices the estimated profit for the enterprise includes a total gross margin (TGM) of ~$337K and, after fixed costs (FC) of $108K, a net profit (NP) of ~$229K. This net profit represents a return of ~ 2.8% on a total capital investment in land, plant and equipment, infrastructure and livestock of ~$6.9million.

A new grazing system is proposed that will include an intensive cell system with 28 cells centred on eight cell centres and nine watering points, and eight larger rotation paddocks centred on eight existing watering points. New fencing will include 37km of single wire electric fence and 4 km of double wire electric fence. Water to the cells and rotation paddocks will be supplied through 13km of 63mm polythene pipelines utilising two pumps and seven polythene tanks. Site treatment, fencing and pipe-laying tasks will be undertaken using the owners' labour and station plant and machinery. The estimated cost of installing the new system is ~$138K excluding any additional livestock carried once the system is operating. The owners' objective is to run an additional 90 breeders giving a total herd of 1840 AE with no change in the individual animal performance, and the same labour force. The augmented breeding herd is estimated to generate a TGM of ~$379K and, after overhead costs of $122K (allowing for depreciation of new infrastructure), a NP of ~$257K. This upgraded NP represents a return of ~3.1% on the total capital investment of ~$7.2million including the additional livestock.

A partial budget framework for the proposed change in grazing system is presented in

Table 4.8.2. The expanded herd size is projected to generate additional livestock sales revenue of ~$59K largely from the sale of additional steers and cull breeders. Production and marketing costs associated with carrying the increased number of animals are projected to increase by ~$17K and overhead costs will increase by $14K mainly attributed to depreciation on the additional infrastructure required to support the new grazing system. Because the enterprise is expanding with no redundant production activities directly resulting from the changing grazing system, there is no reduction in revenue or saving in costs from redundant or displaced activities.

Table 4.8.2. Rockhampton Case Study - Partial budget associated with establishing a new grazing system.

New grazing system partial budget			
Favourable (gains from the proposed change)		**Unfavourable (losses from the proposed change)**	
A. Additional revenue:		C. Additional costs:	
Livestock sales:		Livestock purchases:	
31 Steers	$33,364	1 Bull	$5,000
28 Cull breeders	$24,860		
1 Bull	$800	Husbandry expenses:	$10,665
		Marketing expenses:	$899
Total:	$59,024	Overhead costs:	$14,000
		Total	$30,564
B. Reduced costs:		D. Reduced revenue (including foregone revenue)	
Nil		Nil	
Total gain (A+B):		*Total loss* (C+D):	
	$59,024 + $0 = $59,024		$30,564 + $0 = $30,564
E. *Net monetary gain* (A+B) - (C+D):			
	$59,024 - $30,564 = $28,460		
F. Capital required to implement the change:		G. Capital released from present activities:	
Fencing	$30,338	Nil	
Water supplies	$103,620		
Livestock	$145,933		
Training	$2,000		
Design consultancy	$2,000		
Total:	$283,891		
H. Net capital investment required (F-G):			
	$283,931 - $0 = $283,891		
I. Return on net additional capital invested % (E/H) x 100:			
	$28,460/$283,891 X 100 = 10.0%		

The investment in the new grazing system, assuming the anticipated production benefits are actually realised, appears to be economically viable - the increased annual profit (MNP) of

~$28.5K (item E) is a return of ~10% on the additional investment (MI) in infrastructure and livestock of ~$284K (item F) which could be fully recovered in less than 8.5 years[2].

A direct annual comparison can be made between the MNP and MI estimates if MI is converted to an annual value using an appropriate discount rate and recovery period. Equivalent annuity values for the estimated MI of ~$284K are presented in Table 4.8.3 for three discount rates (nil, 5%, 10%) and two recovery periods (5 years, 10 years).

Table 4.8.3. Rockhampton Case Study - Annuity values for a Marginal Investment of $284K calculated for nil, 5% and 10% discount rates and 10 and 20 year recovery periods.

Discount rate	Recovery period (years)	
	10	**20**
Nil	$28,400	$14,200
5%	$36,770	$22,785
10%	$46,210	$33,351

When the MNP of ~$28.5K is compared with the annuity values, it is evident that the MI of ~$284K is more attractive when either low discount rates are used or the owners are prepared to wait for a longer period to recover the investment. For the example, the annuity for MI is less than the MNP at nil discount rate and either a 10 year or 20 year recovery rate, which is consistent with the projected break-even period of 8.5 years when MNP and MI are directly compared. However, for discount rates of either 5% or 10% (in the example) the required recovery sums exceed the MNP for the 10 year recovery period, and for the 10% rate even when the recovery period is doubled to 20 years.

These values have been based on a single set of values for turnoff, prices, variable costs, overhead costs and labour. The effects on the projected MNP values for changes to these parameters are considered in Appendix 9.14.3.

Rockhampton Case Study Summary
Some central conclusions can be drawn from this case study analysis of the investment in the new grazing system, including the eight sensitivity testing scenarios canvassed in Appendix 9.14.3.

Foremost, given the estimated productivity of this case study enterprise, and the prevailing input and output price regime, the MI of ~$284K in the necessary infrastructure and livestock appears to be recoverable (break-even), as long as the objective of increasing stock numbers can be met and the owners are not placing a high time premium on recovering the capital investment (i.e. MNP exceeds the annuity values of MI for nil discount rates or recovery periods extended beyond 10 years). The sensitivity testing of several critical assumptions (Appendix 9.14.3) highlights some opportunities for improving the prospective value of the investment in the new grazing system - essentially taking action to increase the gross margin on sales through seeking means to further raise herd performance (B%, LWG), exploit increased price premiums or by reducing either variable or fixed costs especially through reductions in permanent labour committed to operating the new system.

4.8.2 A template for estimating MNP, MI and break-even points

In order to conduct the assessment of the prospective profitability of a proposed change in a grazing system on the Rockhampton case study, and the sensitivity of the projected results to variation in a range of key variables (Appendix 9.14.3), the two central building blocks of

[2] Note: This recovery rate does not account for financing charges on the investment in infrastructure or livestock or tax implications (+/-) on the additional income or investment.

marginal net profit (MNP) and *marginal investment* (MI) were first estimated. These same primary steps should be followed by beef producers who are contemplating a change to their own grazing system – whether it involves just a modification of the existing grazing system or a complete replacement with an entirely new grazing system.

The simplest method for estimating these two measures is to follow the simple guide for constructing a partial budget for the system change as summarised in Table 4.8.1, and illustrated for the Rockhampton case study example in

Table 4.8.2. The MNP and MI can also be directly estimated by calculating and measuring the differences between the net profit and total capital investment of the existing enterprise and that associated with the enterprise that incorporates the revised grazing system. However, using partial budgets is recommended for three reasons – 1. The method is reasonably simple; 2. It only focuses on changes that are associated with implementing and operating the new system; and 3. The steps involved in constructing the partial budget provides a checklist of considerations that should also help to ensure that important revenue, cost or capital items are not overlooked in the planning process.

A simple Excel® spreadsheet template has been developed to standardise the preparation of a simple partial budget for a grazing system modification or replacement. It follows the basic logic of partial budgeting to summarise and compare the 'favourable' and 'unfavourable' changes to beef enterprise revenues and costs that are likely to result from implementation of the proposed changes to the grazing system. The net result of these changes (MNP) is then compared to the scale of the additional investment required to undertake the grazing system change (MI) allowing also for any recovery of capital through the sale of any redundant assets. A quick comparison of the results for any potential option will indicate whether there is considerable scope for improvement in profitability of the enterprise, or if the present grazing system is already performing reasonably well.

An important caveat is that estimating the return to the extra investment in a grazing system change using the template is really just the first step in making a decision on whether or not to proceed with a specific plan. The results will give producers a rough guide to the scale and nature of benefits that a change in grazing systems might provide. However, a definitive answer to the ultimate value will also need to include additional considerations of designing and operating the new system; taxation and financing implications and the time taken get the new system operating well. These are serious considerations that often require specialist skills and advice which are beyond the scope of the simple template. Nevertheless, the simple partial budget generated by the template can give an indication of whether the proposed change is worth further consideration or not and where the main strengths and weaknesses lie.

Template Structure
The template has three sections – Section (A) is used to prepare an estimate of the *Marginal Net Profit* (MNP) associated with the proposed grazing system change. Section (B) is used to prepare an estimate of the *Marginal Investment* (MI) required to design and commission the proposed grazing system change. Finally, Section (C) is used to estimate the potential percentage rate of return on the marginal investment in the proposed grazing system change. These three sections are structured as follows. A worked example using the Rockhampton Case Study from the previous section is also provided as a guide.

Section (A) - Marginal Net Profit (MNP)
This section of the template is comprised of five sub-sections that generate estimates of the net profit of the existing grazing system and the alternative grazing system under consideration.

Subsection **(1) Returns** identifies revenue from stock sales for each of the stock classes run on the property under both the existing and alternative grazing systems. The numbers of animals sold in each class and the total sales values are recorded for both that existing grazing system and the alternative systems in separate columns and the template automatically calculates the difference.

(1) Returns:	**Existing system**		**New system**		**Difference**	
Stock sales	**No.**	**Value**	**No.**	**Value**	**No.**	**Value**
Steers	239	$257,224	270	$290,588	31	$33,364
CFA Cows	24	$21,504	27	$24,192	3	$2,688

Cull breeders	188	$168,448	212	$189,952	24	$21,504
Heifers (cull)	9	$6,014	10	$6,683	1	$668
Cull bulls	6	$4,800	7	$5,600	1	$800
Total:	466	$457,990	526	$517,014	60	$59,024

For the Rockhampton case study under the existing grazing system centred on 700 breeders there are 466 animals sold to generate gross sales revenue of $457,990. Under the proposed new system involving cell and rotational grazing and an additional 90 breeders there are 526 animals sold for a gross value of $517,014. The net gain in total revenue per annum is estimated to be $59,024. In this example, the owners saw the gain to come from running additional animals and did not expect the productivity of individual animals to increase over the present system. If the new system is designed to increase per animal productivity or value per head, this gain should also be included in the projection of sales revenue.

Subsection **(2) Costs** is broken into four categories including purchases of stock by stock class, livestock material expenses (e.g. fodder, supplements, animal health etc), labour expenses for mustering, handling stock and managing infrastructure, and marketing expenses (e.g. stock cartage, transaction levies, commission, yard dues, scale fees, etc). These are input separately for both the existing and alternative grazing systems.

	Existing system		**New system**		**Difference**	
2.1 Stock purchases	**No.**	**Value**	**No.**	**Value**	**No.**	**Value**
Steers						$0
Breeders						$0
Heifers						$0
Calves						$0
Bulls	6	$30,000	7	$35,000	1	$5,000
Total:	6	$30,000	7	$35,000	1	$5,000

The increased breeding herd on the Rockhampton case study required the annual purchase of one additional bull for $5,000. The difference in purchase costs for the two systems in sub-table 2.1 reflects this additional cost.

	Existing system		**New system**		**Difference**	
2.2 Livestock Xs	**No.**	**Value.**	**No.**	**Value**	**No.**	**Value**
Steers	481	$28,364	543	$32,021	62	$3,656
Breeders	700	$47,775	790	$53,918	90	$6,143
Heifers	0	$0	0	$0	0	$0
Calves	503	$5,201	567	$5,863	64	$662
Bulls	25	$1,708	28	$1,912	3	$205
Total:	1709	$83,048	1928	$93,713	219	$10,665

The increased size of the Rockhampton case study herd as a result of carrying an additional 90 breeders is reflected in both an expansion of animals and total cost of livestock expenses in sub-table 2.2. The increase in livestock expenses is estimated to be $10,665 per annum.

	Existing system	**New system**	**Difference**
2.3 Labour Xs	**Value**	**Value**	**Value**
Mustering	$1,200	$1,200	$0
Managing stock			$0
Managing infrastructure			$0

Total:	$1,200	$1,200	$0

The Rockhampton case study is operated by two permanent unpaid labour units comprising a father and son partnership with some casual labour employed for stock operations and maintenance. The owners felt that the additional stock could be managed from within the existing labour resources and no additional labour expense is recorded in sub-table 2.3.

2.4 Marketing Xs	**Existing system Value**	**New system Value**	**Difference Value**
Cartage (out)	$3,709	$4,189	$480
Cartage (in)	$231	$269	$38
Transaction levy	$2,330	$2,630	$300
Commission	$541	$614	$73
Yard dues, scale fees etc	$64	$71	$7
Total:	$6,875	$7,773	$899

The increased size of the Rockhampton case study herd as a result of carrying an additional 90 breeders is reflected in both an increase in the number of animals turned off each year and the total cost of livestock marketing expenses in sub-table 2.4. The increase in livestock marketing expenses is estimated to be $899 per annum.

Subsection **(3) Total Gross Margin** (TGM) is the difference in total revenue and total direct costs as defined in the earlier section (*Definitions and theoretical considerations*). This profit measure is automatically calculated by the template using the return and costs values included in subsections (1) and (2).

	Existing system	**New system**	**Difference**
(3) Total Gross Margin	$336,868	$379,327	$42,460

Based on the revenue and direct cost estimates, the projected increase in the TGM for the Rockhampton case study following an increase in the breeding herd by 90 breeders is $42,460.

Subsection **(4) Fixed Costs** captures estimates of the fixed costs associated with the beef enterprise operating under the existing grazing and also under the alternative grazing system under consideration. For many enterprises, especially where the new grazing system does not represent a radical restructuring of the operations or installation of new infrastructure, there may not be a large change in fixed costs. It is quite important when completing this sub-section of the template to seriously consider how the fixed cost structure of the beef enterprise might be affected by the proposed change in grazing system – especially where increases in permanent labour, vehicles or extensive changes to plant and infrastructure are involved.

(4) Fixed costs	**Existing system Value**	**New system Value**	**Difference Value**
Repairs and maintenance	$6,500	$6,500	$0
General insurance	$4,000	$4,000	$0
Administration	$2,500	$2,500	$0
Rates, levies, agistment	$5,500	$5,500	$0
Fuel and oil	$6,000	$6,000	$0
Electricity and gas	$3,500	$3,500	$0

Depreciation	$45,000	$59,000	$14,000
Fertiliser and seed	$2,500	$2,500	$0
Wages and salaries	$30,000	$30,000	$0
Other	$2,500	$2,500	$0
Total:	$108,000	$122,000	$14,000

As noted, the owners of the Rockhampton case study felt that the additional stock could be managed from within the existing labour resources on the property with little impact on the fixed costs of the enterprise, other than an increase in depreciation on the infrastructure required to operate the proposed change to a cell and rotational grazing system. This is captured in an increase in deprecation of $14,000 in subsection (4).

Subsection **(5) Net Profit** (NP) is calculated as the difference in *total revenue* and *total direct and fixed costs*, or simply as the difference between TGM and fixed costs as defined in the earlier section (*Definitions and theoretical considerations*). This net profit measure is automatically calculated by the template using the return and costs values included in subsections (1) to (4).

	Existing system	**New system**	**Difference**
(5) Net profit	$228,868	$257,327	$28,460

Based on the revenue and cost estimates, the projected increase in the NP for the Rockhampton case study following an increase in the breeding herd by 90 breeders is $28,460.
Subsections **(6) to (10)** are the core elements of the partial budget that is derived within the template and each are automatically calculated by the template from the summary output from the preceding subsections **(1) to (5)**.

Subsection **(6) Increased revenue** provides a summary estimate of the increased revenue from all sources attributed to the change in grazing system – for example an increase in sales or sales values of any particular class of stock.

(6) Increased revenue	$59,024

For the Rockhampton case study this was attributed to the increased turnoff valued at $59,024.

Subsection **(7) Reduced revenue** provides a summary estimate of any reductions in revenue from all sources attributed to the change in grazing system – for example a decrease in sales of any particular class of stock which may no longer be relevant to the new grazing system such as when sales store weaners are replaced by finished steers.

(7) Reduced revenue	$0

In the case of the Rockhampton case study there is no projected reduction in the sales or sales value of any of the stock classes as a result of the proposed change in grazing system.

Subsection **(8) Additional costs** provides a summary estimate of any projected increases in either direct or overhead costs associated with the change in grazing systems.

(8) Additional costs	$30,564

The summary measure for the Rockhampton case study of $30,564 is comprised of the increase in direct costs - subsection **(2) -** of $16,564 as a result of increased livestock, labour and marketing expenses and increased fixed costs - subsection **(4)** – resulting from the increased allowance for deprecation on new infrastructure of $14,000.

Subsection **(9) Reduced costs** provides a summary estimate of any projected decrease in either direct or overhead costs associated with the change in grazing systems. This might occur, for example, when direct expenses are avoided for a particular class of stock no longer carried on the property, where labour savings might be available under the new grazing system or where depreciation is avoided on redundant plant and infrastructure that might be disposed of with the new grazing system.

(9) Reduced costs	$0

In the case of the Rockhampton case study there is no projected reduction in either the direct or fixed costs as a result of the proposed change in grazing system.

Subsection **(10) Marginal Net Profit** (MNP) is the central summary profit measure provided by the template. It summarises the net change in profit when all of the favourable impacts (increased revenue, reduced costs) and unfavourable impacts (reduced revenue, increased costs) associated with the proposed change in grazing system have been tallied and compared.

(10) Marginal Net Profit = [(6)+(9) - (7)+(8)]	$28,460

For the Rockhampton case study, the estimate of MNP of $28,460 is provided by the template.

Section (B) - Marginal Investment (MI)

The second major section of the template is comprised of nine sub-sections that generate estimates of the additional investment in livestock and infrastructure that will be associated with the change from the existing grazing system and the alternative grazing system under consideration.

Subsection **(11) Livestock on hand** records the number of animals in each of the different classes of stock that make up the herd under both the existing and alternative grazing systems. It also places a capital value on those animals based on average weights and prevailing market prices. The template automatically calculates the difference to estimate the net change in capital invested in livestock on the property as a result of the proposed change in grazing system.

(11) Livestock on hand Animal class	Existing system No.	 Value	New system No.	 Value	Difference No.	 Value
Steers	481	$421,276	543	$475,829	62	$54,554
Breeders	700	$470,400	790	$531,447	90	$61,047
Heifers	0	$0	0	$0	0	$0
Calves	503	$221,221	567	$249,664	64	$28,443
Bulls	25	$14,700	28	$16,590	3	$1,890
Total:	1709	$1,127,597	1928	$1,273,530	219	$145,933

The total herd carried under the existing grazing system centred on 700 breeders for the Rockhampton case study and included 1709 animals valued at $1,127,597. The projected herd based on the alternative grazing system with 790 breeders included 1928 animals valued at $1,273,530, representing an additional investment in livestock carried of $145,933.

Subsection **(12) Fencing** records the capital investment in any new fencing that is specifically associated with the proposed change in grazing system. It records a description of the type of fencing used, lengths involved and additional fixtures including gates and any costs associated with erecting the fences and delivery of materials etc.

(12) Fencing

Fence type	km fenced	$/km	no. gates	$/gate	$/labour	$/delivery	Total
Cells	34	$595					$20,128
Rotation	14	$730					$10,210
							$0
						Total	$30,338

The proposed change to the grazing system on the Rockhampton case study involved establishing 28 intensive cells based on eight cell centres and nine water points, and eight larger rotational grazing paddocks centred on eight existing water points. This involves 34 km of new fencing for the cell paddocks valued at $20,128 and 14 km of new fencing for the rotation paddocks values at $10,210. As this fencing was to be established at a contract rate including delivery, erection, gates, etc, only the cost per kilometre is recorded for this example.

Subsection **(13) Water supplies** is broken into four categories including establishment of piping, troughs, pumps/mills and tanks. Each category can be itemised to include separate values for each item including fittings, installation and delivery or simply estimated as a fully installed value inclusive of fittings, labour and delivery, etc.

13.1 Water piping

Description	km pipe	$km	no. fittings	$/fitting set	$/labour	$/delivery	Total
Cells	8	$5,650	1	$2,850			$48,050
Rotation	5	$5,650	1	$1,500			$29,750
							$0
						Total	$77,800

Establishment of the cells and rotation paddocks on the Rockhampton case study involves laying 13 km of 63 mm polythene pipe valued at $77,800 including delivery, installation and fittings.

13.2 Troughs							
Description	no. troughs	$/trough	no. fittings	$/fitting set	$/labour	$/delivery	Total
Cells	9	$610					$5,490
Rotation	7	$610					$4,270
							$0
						Total	$9,760

The proposed cell and rotational grazing paddocks on the Rockhampton case study involves the installation of nine concrete stock troughs in the new cell paddocks and seven concrete stock troughs in the rotation paddocks. The estimated cost of purchase, delivery and installation of these troughs is $9,760.

13.3 Pumps / mills etc								
Description	no. pumps	$ /pumps	no. fittings	$/fitting set	$ /labour	$ /connect	$ /delivery	Total
Cells	1	$2,500						$2,500
Rotation	1	$2,500						$2,500
								$0
							Total	$5,000

Water is pumped from existing water points on the Rockhampton case study property to tanks in both the new cell paddocks and rotational grazing paddocks. This involves the installation of two new pumps valued at $5,000 including delivery, installation and fittings.

13.4 Tanks							
Description	no. tanks	$/tank	no. fittings	$/fitting set	$/labour	$/delivery	Total
Cells	2	$3,000	2	680			$7360
Rotation	1	$3,000	1	700			$3,700
							$0
						Total	$11,060

The proposed cell and rotational grazing system on the Rockhampton case study utilises seven polythene tanks for holding and distributing water to the individual cells and paddocks. The change required three additional tanks estimated to cost $11,060 delivered and installed.

Subsection **(14) Tree planting** allows for changes to grazing systems that may include the planting, establishment and protection of trees and shrubs for shade, shelter or forages as in the case of leucaena or saltbush. The template includes descriptions of the plantings by type, numbers of plants involved, unit costs, tree guards, other planting materials, labour and other costs associated with planting, establishing and protecting the trees. Fencing to protect tree plantings is best included in subsection (11) Fencing.

(14) Tree planting

Note: fencing as part of a tree planting/protection exercise is included in item (11) above

Description	no. trees	$ /tree	no. guards	$ /guard	$ /materials	$ /labour	$ /delivery	Total
								$0
								$0
								$0
								$0
							Total	$0

The proposed change of grazing systems on the Rockhampton case study does not involve any tree planting activities. The cells in subsection (14) are blank returning a zero value for this category of investment outlays.

Subsection **(15) Fire Management** allows for changes to grazing systems that include the use of prescribed burning as part of the proposed pasture management system. The template includes categories for constructing fire-breaks, fire crew labour, fuel and plant operation including plant and tanker hire to conduct the burns. Sub-items of costs include lengths of fire breaks, cost per kilometre for fire break establishment and maintenance, labour materials and any other costs (e.g. permits, etc).

(15) Fire management

Description	km /breaks	$/km	$ /labour	$ /materials	$ /other	Total
Fire-breaking						$0
Fire crews						$0
Fuel						$0
Plant						$0
					Total	$0

The proposed change of grazing systems on the Rockhampton case study does not involve any prescribed fire activities. The cells in subsection (15) are blank returning a zero value for this category of investment outlays. Subsection **(16) Pasture development** allows for changes to grazing systems that include the establishment of new pastures or the rehabilitation of existing pastures. The template includes a description of each type of development and categories for areas treated, number of operations (e.g. cultivation, seeding, weed control, etc), cost per treated or developed hectare, materials used, labour and other cost items.

(16) Pasture development

Description	Area (ha)	No. ops	$/ha	$ /materials	$ /labour	$ /other	Total
							$0
							$0
							$0
							$0
						Total	$0

The proposed change of grazing systems on the Rockhampton case study does not involve any specific pasture development or rehabilitation activities. The cells in subsection (16) are blank returning a zero value for this category of investment outlays.

Subsection **(17) Disposal of redundant assets** recognises the fact that some proposed changes to new grazing systems may actually make some assets that are used by the existing grazing system redundant. For example, livestock handling equipment, vehicles or plant that were used for specific activities that will no longer be used can be disposed of, thereby reducing the total capital outlay associated with implementing the change in grazing systems. In some cases where particular classes of animals are no longer kept as part of the grazing system, for example when the change involves replacing a breeding activity with a purchase and finishing activity, this category will include the initial liquidation of that class of stock from the herd.

(17) Disposal of redundant assets

Description	Total
Total	$0

The proposed change of grazing systems on the Rockhampton case study does not involve the disposal of any redundant assets. The cells in subsection (17) are blank returning a zero value for this category of investment outlays.

Subsection **(18) System design, training etc** allows for the cost of designing the proposed grazing system and any training associated with operating the new systems once it has been implemented. For example, it is common for producers who either are considering making changes in their grazing systems or have committed to making such changes to incur substantial costs in searching out options, inspecting other properties with such systems, or undertaking formal training in the concepts and practices underpinning the proposed changes. This is particularly common, for example, when the proposed change includes a commitment to cell grazing practices.

(18) System design, training etc

Description	Total
Cell grazing course	$2,000
Design consultancy	$2,000
Total	$4,000

Prior to deciding to establish the cell grazing and rotation grazing systems on their property, one of the operators of the Rockhampton case study undertook a dedicated cell grazing course costing $2,000. While the ultimate design of the proposed system was determined by the operators themselves, they were partly informed by a simple design consultancy from a Rockhampton based advisory service that also cost $2,000.

Subsection **(19) Net (marginal) investment** is the central summary capital investment measure provided by the template. It summarises the net value of the capital committed to implementing an alternative grazing system drawing on each of the investment categories in detailed in Subsections **(11) to (18)**. The summary values are automatically calculated by the template from the summary output from the preceding subsections.

(19) Net (marginal) investment

Livestock (11)	$145,933
Fencing (12)	$34,338
Water Supplies (13)	$103,620
Tree planting (14)	$0
Fire Management (15)	$0
Pasture development (16)	$0
Disposal of redundant assets (17)	0
System design, training etc (18)	0
Total (marginal) investment (19)	$283,891

The augmentation of the present grazing system on the Rockhampton case study with the proposed cell and rotational grazing paddocks is estimated to involve a net capital investment of $283,891. This is approximately equally comprised of additional livestock in the herd inventory and additional water and fencing infrastructure associated with construction of the cells and subdivision of the rotational grazing paddocks.

Section (C) - Return on Marginal Investment (%)
The third section of the template simply brings together the summarised Marginal Net Profit and Marginal Investment measures from Sections (A) and (B) to provide a simple estimate of the rate of return the MNP would represent for a MI of that magnitude.

Marginal Net Profit (10)	$28,460
Total (marginal) investment (19)	$283,891
Return on MI (20) = (10)/(19) X 100	10.0%

For the Rockhampton case study the estimated MNP of $28,460 represents a rate of return on the estimated MI of $283, 891 of ~10%.

Note: These projections of potential profitability are necessarily dependant on the assumptions and sources of data that are used to populate the template. Under different assumptions, for example stock numbers carried, livestock prices, potential weight gain, extent and cost of infrastructure, labour demands, etc, the estimates of MNP and MI will naturally vary. It is desirable that producers utilise the best available advice or data possible when exploring their options. Various sensitivity testing procedures can be employed when using the template to consider the implications of changes to many of the key parameters. As noted before, estimating the MNP and MI for a potential change in grazing systems is really just an initial step in the process of making judgments about the feasibility of such changes. Producers seriously considering making changes are advised to also measure the performance of their existing enterprises in more detail, along with that of the proposed change - canvassing ideas and data from other producers with experience in establishing and managing the new grazing systems is obviously desirable as is further considering the full financial implications of establishing the new system with appropriate taxation and finance specialists.

5 Success in achieving objectives

5.1 Achievements

The project has successfully achieved its five objectives which were revised after the mid-project review following recording at all sites in 2006 and 2007.

Meeting the specific objectives:

1. Assess the impacts of more intensive grazing systems on the condition and trend of grazing land.
Two or three pre-existing grazing systems (continuous, rotational, cell) were evaluated on nine properties over four years, and data collected on pasture and soil condition, stocking rates imposed, and diet quality. Time series analysis of ground-cover trends over the past 20-years did not suggest any major differences in historical pasture condition between system areas within a property. The long-term carrying capacity (LTCC) of each monitored paddock was calculated (see Objective 3 below) to assess inherent differences in site potential within and across properties.

Based on inspection of data from each site, and on statistical analysis of data from all sites, grazing system per se did not have significant or consistent impacts on the condition and trend of pasture. This is consistent with many past and current studies which show that continuous stocking and rotational grazing can either sustain, improve or reduce pasture condition depending primarily on how stocking rate is managed. The lack of evidence of impacts of grazing system on pasture condition most likely infers that stocking rates of all systems were equally well managed relative to annual pasture production in each system, which was the intention of the owners of all sites.

2. Quantify the costs of more intensive systems and derive an intensity index which reflects these costs, the relative number and size of paddocks, and the management input.
The estimated replacement capital cost of the grazing systems on the nine sites, including fencing, water, labour and planning costs, was used to quantify the value of investing in changing to a more intensive system. These costs are reported in the individual property reports in Appendix 9.1. The actual annual financial records of the properties were not accessed to produce these analyses. On all properties the grazing systems are integrated rather than operating independently and it was not possible to quantify changes in operating costs in most cases.

A grazing system intensity index (GSI) was developed taking into account the three main inputs required to operate any grazing system. They were:

(1) capital costs - mainly fencing and water infrastructure costs but it could include other capital such as more yards if a herd size increase warranted this expenditure;
(2) operating costs - labour for moving animals between paddocks and for mustering, plus infrastructure maintenance; and
(3) management inputs - decisions on moving cattle between paddocks, adjusting animal numbers to match expected feed supply, monitoring, feed budgeting, forward herd planning and record keeping.

Definitions were developed for each of these three components of the index which have values between 0 and 100 (most intensive). The three components are given equal weighting and the average value taken to estimate the GSI which ranges in value from 15 for a low input, single paddock, continuous grazing system to 100 for an intensively-managed, well-recorded, multiple paddock system. The range of GSI values for the 21 grazing systems monitored in the project was from a continuous system with a GSI of 21, to an intensive cell system, where cattle were moved daily during periods of rapid pasture growth, with a GSI of 96. This GSI system is designed to rank any form of grazing system and can be used to compare system inputs on different properties. A table of the GSI values for the grazing systems at the nine sites is shown in the Results section and the detailed calculations are shown in the Appendix 9.13.

There was, however, no relationship between GSI and the pasture and animal performance of the systems evaluated in this project.

3. Record the carrying capacities of different grazing systems.
The long-term carrying capacity (LTCC) of each monitored paddock was calculated via the GLM workshop method, to assess inherent differences in site potential within and across properties and to compare these values with the actual grazing imposed during the four-year study period. Over the four years of monitoring, average annual grazing was at or above the estimated LTCC for six properties (four in north Queensland and two in the south), and below the estimated LTCC for the other three (one in the north and two in the south).

There were no statistically significant differences in the level of grazing (stock days per ha per year) between grazing systems at five of the project sites, but there were at Frankfield, Rocky

Springs, Somerville and Ticehurst due to lower values for the rotation paddocks at these sites. The average grazing of the rotational pastures over all sites (92 SDH) was 81% of that in the cell or continuous systems (average 114 SDH), which is in line with the proportional difference in calculated long-term carrying capacities (LTCCs) between the rotation paddocks and the average of the cell and continuous system paddocks.

4. Evaluate the likely financial implications of investing in more intensive grazing systems through break-even analysis.
An Excel® spreadsheet-based break-even analysis calculator was developed to provide producers with a tool to help them evaluate the likely financial implications, costs and returns of investing in more intensive grazing systems. The two main measures of marginal net profit (MNP) and marginal investment (MI) are first estimated using a simple partial budget approach to the system change. The rate of return on the marginal investment is calculated to provide guidance to producers in deciding on modifying an existing system or changing to a different system. The details of this calculator are demonstrated in an example from the implementation of an intensive system on one of the monitored properties in central Queensland.

While the costs of more intensive systems are relatively easy to estimate, it can be difficult to estimate the benefits. The worked example in the spreadsheet calculator for the Central Queensland property is based on the producer's expectation of increased carrying capacity (of around 14% in the breeder herd), but the project found there to be no consistent difference in carrying capacity (either potential or realised) between systems on any of the nine properties.

5. Identify the key findings for producers, the basis for these, their practical implications and benefits, their geographic relevance, risks in their application, and any remaining uncertainties.

Pasture condition
Grazing method per se is not the major driver of pasture condition. There were no substantial and consistent differences between grazing methods (continuous, rotation, cell) for the range of pasture and soil surface measurements made during the project. The grazing systems covered a wide range of situations (stocking rates, rest periods, paddock numbers, animal classes, etc.) and had been in place for up to 10 years prior to the experimental period. Also, measurements were made at the range of sites over four years with variable growing conditions. Hence, the conclusions should be robust. The performance of the pastures in this project suggests that the paddocks within each property were equally well managed especially with respect to stocking rate, which has been frequently identified as the main driver of pasture and animal productivity.

Diet quality
Grazing system did affect the diet quality of animals with those grazing in continuous systems having higher quality diets than those grazing cell systems; diet quality of rotational systems was intermediate. The impact of grazing system on diet quality was most evident during the growing season.

Carrying capacity
Grazing system had no affect on the grazing days per ha per year imposed on paddocks, except for some instances of lower grazing days from rotational systems due, in part, to extraneous factors. Overall, there were similar numbers of stock days per hectare per year for paddocks within the cell (119) and continuous systems (115). On average, cell and continuous paddocks were grazed somewhat above the objectively assessed values for long-term carrying capacity.

Flexibility and adaptability
Flexibility and adaptability were common attributes of the properties which hosted the various grazing systems assessed in this project. For example, the stocking of each system on a property, and each paddock within a system, varied greatly over time with variation in seasonal

conditions and other factors. In addition, different grazing systems on a property were not managed independently of each other. This was especially the case during the first 2 years when rainfall was generally well below-average in rainfall. During this time, there were occurrences of multiple paddocks within a system being open at the same time and of stock being moved between systems. This finding is not surprising but made it more difficult to distinguish any key attributes of a particular grazing method from the overall management approach or system applied, as a whole, across each property.

Other observations

It is very likely that implementation of an intensive grazing system is associated with many changes in management philosophy and practices across an enterprise that provide producers with greater control and direction of resources.

Intensive grazing systems, by their nature, demand much closer monitoring of pasture and cattle to ensure timeliness of decisions. This appeared to be a strong inducement for better record keeping and also appeared to encourage a much more deliberate and informed consideration of stocking rate management. However, it appeared that the intensive system itself was not a pre-requisite for improved management.

Having the higher number of smaller paddocks associated with intensive systems should make it easier to implement better pasture management. For example, targeted spelling of areas can be more easily implemented, and with less consequence to grazing pressure on other paddocks. This is, of course, also possible in less intensive systems provided there is an adequate level of paddock subdivision and water point development. Again, the project found that an intensive system is not a pre-requisite for better pasture management.

Extended wet weather can cause problems in cell systems by bogging, pasture damage and possibly compaction, as well as making shifting cattle difficult and sometimes impossible.

In at least some situations, highly intensive grazing systems appeared to facilitate easier management of practices such as supplementation (eg, via water medication) and mustering. Much quieter cattle was a commonly reported benefit of intensive grazing systems. In several cases, however, the labour required to run these systems was seen as a significant constraint.

Experimental approach and strength of inferences

The approach taken in the project had many strengths with respect to scale, producer involvement, and the range in grazing systems covered. However, it also had limitations associated with lack of replication within sites, and with variation in how systems were managed. Hence, inferences must be drawn with some caution.

There appears to be relatively strong evidence for lack of impact of grazing system, per se, on land condition and pasture productivity, and this concurs with previous studies using either replicated trials or on-property assessments (Briske et al. 2008; Dowling et al. 2005). Also, the reduction in diet quality with greater intensity of grazing system was consistent and in agreement with other data (Desiree Jackson, pers com). The lack of effect of grazing system on carrying capacity is, perhaps, somewhat less certain as there was considerable variability in this parameter within and across sites. However, any impact of more intensive grazing on carrying capacity would need to be derived from more even utilisation rather than from improved pasture growth (as pasture condition was unaffected by system).

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

The results from this project are anticipated to have a significant impact on future plans of beef producers across northern Australia in developing their grazing strategies. With current pressures on profitability and labour constraints on extensive properties, understanding the costs and management inputs required for various levels of system intensification will provide the basis of more efficient infrastructure development and grazing management strategies.

Previous MLA research (e.g. NBP.317 Pigeon Hole, NT) has shown that simply increasing the number of water points and reducing paddock sizes can provide significant improvements in profitability for enterprises in environments where paddock sizes remain relatively large (50-500 km^2). Our study operated in regions where, for the most part, paddock sizes are already relatively small (500-2000 ha), and the focus of increased infrastructure investment was for the operation of more 'intensive' grazing systems. These systems require multiple paddocks (6 to 60+) and typically utilise a single mob of cattle, or perhaps two mobs, moving through the paddocks at different rates (days, weeks) which vary with rate of pasture growth and other prompts. These systems also emphasise the use of tools such as grazing charts to help match stocking rate to carrying capacity.

We found a general absence of ecological and production responses from increased levels of intensified grazing management. There were no consistent effects of grazing system on land condition, carrying capacity, or stocking rates imposed.

The industry no doubt has significant opportunity, and need, to improve its grazing management. Simply stocking paddocks based on past expectations or subjective criteria, without objective assessment of carrying capacities (both long-term and short-term) is not sufficient to ensure optimal productivity and acceptable land condition. However, intensive grazing systems are not required to achieve such improvements.

Increased awareness and appreciation of the soil and pasture resource as the basis of a beef business, and the motivation to better manage grazing, arise from association with the training in livestock business management typically associated with promotion of intensive grazing systems. It is therefore very likely that implementation of an intensive grazing system is associated with a whole raft of changes in management philosophy and practices across the enterprise that provide producers with greater control and direction. The associated benefits for enterprise management could well be significant. Be that as it may, implementation of an intensive grazing system per se is not a pre-requisite for improved grazing management.

Results from the project have the potential to save the beef industry significant investment in intensification to levels beyond which the owners cease to gain production and land condition benefits. There are multiple examples across the northern beef industry of over-intensification causing a waste of resources as the systems are subsequently simplified to management levels that are more acceptable to the owners' abilities, resources and lifestyle choices.

7 Conclusions and recommendations

We found that intensity of the grazing system had no consistent effect on soil surface condition, pastures or carrying capacity when compared to less intensive systems on the same property. This confirms other studies that have consistently shown stocking rate management to be the major driver of pasture and animal productivity rather than grazing system per se. In this project, each of the systems within a property appeared to be equally well managed with respect to stocking rate and monitoring of soil, pasture and stock. In addition, operation of each system varied considerably over the four years as managers reacted to changing circumstances, and livestock were often grazed across different systems within a year, especially during drier times. This would reinforce the extent to which all systems on a property were equally well managed.

While this study found that grazing system or method was relatively unimportant, this does not diminish the importance of improved grazing management for the beef cattle industry in northern Australia. Other grazing research has shown that major opportunities for improved land condition and productivity are based around:

- better spatial distribution of grazing pressure (through location and number of water points, sub-divisional fencing);
- better matching of stocking rate with carrying capacity; and
- targeted use of wet season spelling.

Producers seeking improved grazing management to achieve improved land condition and/or increased carrying capacity should therefore objectively assess the current long-term carrying capacity for each paddock and systematically identify the most cost-effective opportunities for improvement. Most of these opportunities will be based around better spatial distribution of grazing pressure, better matching of stocking rate with variation in short-term carrying capacity, and use of wet season spelling. Implementing a more intensive grazing system is one way of addressing these issues, but results from this project strongly suggest that simpler and less expensive management systems will achieve similar outcomes.

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