final report

NATURAL RESOURCE MANAGEMENT

Project code: B.NBP.0353

Prepared by: Trevor J Hall[1]
with assistance from John McIvor[2], Paul Jones[1], Neil MacLeod[2], Cam McDonald[2], David Reid[1], David Smith[1], Kathy Delaney[1]

1. Department of Employment, Economic Development and Innovation
2. Commonwealth Scientific and Industrial Research Organisation

Date published: October 2011

ISBN: 9781741916515

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

Volume III - Investigating Intensive Grazing Systems in Northern Australia Appendix 2

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

Contents

1 APPENDICES ... 4

1.1 Appendix 1 – Property reports – Nine Primary sites ... 4

1.2 Appendix 2 - Initial Project Objectives ... 5

1.3 Appendix 3 - Climate and rainfall ... 6
1.3.1 Records and long-term data ... 6
1.3.2 Southern oscillation index ... 8
1.3.3 Monthly and long-term site rainfall ... 8
1.3.4 Monthly rainfall variability ... 13

1.4 Appendix 4 – Botanal and LFA methodologies ... 14
1.4.1 Pasture and soil surface condition measurements ... 14
1.4.2 Methodology - pastures and soil surface conditions ... 15
1.4.3 General sampling details ... 17

1.5 Appendix 5. Botanal / LFA quadrat data ... 30
1.5.1 Statistical probability of Botanal / LFA parameters ... 30
1.5.2 LFA quadrat data ... 31
1.5.3 Land condition ... 32

1.6 Appendix 6 - VegMachine Cover estimates ... 36
1.6.1 VegMachine Methodology ... 36
1.6.2 DERM pasture and cover reports ... 37
1.6.3 References ... 42

1.7 Appendix 7 - Fixed-point photograph record ... 42

1.8 Appendix 8 - Pasture modelling ... 43
1.8.1 Growing seasons ... 43
1.8.2 GRASP modelling ... 44

1.9 Appendix 9 - Spatial analyses - pasture and soil surface data ... 46
1.9.1 Paddock and system uniformity results ... 47
1.9.2 Standard deviation between Botanal/LFA means ... 50

1.10 Appendix 10 - Grazing pressure – grazing records ... 54
1.10.1 Statistical analysis of impacts from grazing records ... 59

1.11 Appendix 11 – Long-term carrying capacity (LTCC) ... 67
1.11.1 Introduction ... 67
1.11.2 Landtype Carrying Capacity Calculations ... 68
1.11.3 References ... 72

1.12 Appendix 12 - Diet quality (NIRS) ... 74
1.12.1 Faecal sample collection ... 74
1.12.2 NIRS analysis of GSP samples 2005-2009 ... 74
1.12.3 Results presentation ... 74
1.12.4 References ... 74
1.12.5 NIRS statistical analysis ... 74

1.13 Appendix 13 - Grazing system intensity index ... 89
1.13.1 Capital costs sub-index (CI) ... 89
1.13.2 Operating costs sub-index (OI) ... 90
1.13.3 Management sub-index (MI) ... 92
1.13.4 Calculation of GSI values for hypothetical systems ... 92

1.14 Appendix 14 - Economic analysis 96
1.14.1 Template model........ 96
1.14.2 Break even calculator........ 96
1.14.3 Rockhampton Case Study – Impact on Marginal Net Profit (MNP) from Variation in key parameters. 101

1.15 Appendix 15 – Producer perceptions of systems........ 109

1.16 Appendix 16 - Communications list 110

1.17 Appendix 17 - Publications 115

1.18 Appendix 18 - Project Posters 131

1.19 Appendix 19 - Staff involved in the project 136

1 Appendices

1.1 Appendix 1 – Property reports – Nine Primary sites

Refer Volume II for Appendix 1.

1.2 Appendix 2 - Initial Project Objectives

When the project was developed by the Producer Advisory Group, DPIF, CSIRO and MLA, four main objectives were formulated to address the issues and hypotheses identified during the project development phase. The project aimed to determine the advantages and disadvantages, and costs and benefits of grazing systems to assist producers to decide the most appropriate grazing system for their purposes. As the research progressed with the first two years of results, these objectives were re-defined to the five objectives listed in the main report (Chapter 2).

The initial four main objectives considered during the project development phase were:

1. Identify the key principles that define productive and sustainable cell and other grazing systems in northern Australia.

2. Produce a technical compendium (including case studies), which will describe the structure, management and performance aspects of cattle production and associated resource condition of cell and other grazing systems under review in northern Australia.

3. Produce a package containing guidelines and decision aids for producers to use in assessing the potential performance, profitability and sustainability of cell and other grazing management systems.

4. Incorporate the information and guidelines into training and extension references and materials including, for example, the EDGEnetwork Grazing Land Management (GLM) package.

1.3 Appendix 3 - Climate and rainfall

1.3.1 Records and long-term data

The nine sites received varying rainfall during the four-year monitoring period. There was generally a serious drought in the first two years at all sites; in the final two years the north Queensland sites received higher rainfall than average while southern Queensland sites were closer to average. Salisbury Plains received unusually high rainfall from cyclone influences while Melrose received good-pasture growing rainfall in both summer and winter seasons over 2008 and 2009.

Monthly and annual total rainfall with long-term monthly mean rainfall for the nine sites is shown in the individual property reports. Climatic records from the nearest station with near 100 or more years of records (Sources: property records, BOM, RainMan. DERM LongPaddock web site) were used in pasture growth analyses.

A summary of the long-term rainfall at the nine sites is shown in Table 1.3.1.

Table 1.3.1. Long-term annual rainfall (mm) – mean, median, SD, highest/lowest, rain days and no. of years of records for nine sites.

Property	Long-term location	Mean mm	Median mm	Standard deviation mm	Highest on record mm	Lowest on record mm	Mean rain days	No. of years records
Banyula	WARKON	541	525	151	966	251	49	93
Berrigurra	BLACKWATER	573	560	180	1,081	238	48	113
Frankfield	ELGIN DOWNS	572	528	221	1,400	150	37	121
Melrose	WESTWOOD PO	690	674	229	1,436	246	50	123
Rocky Springs	NARAYEN CSIRO	693	676	199	1,377	317	65	124
Salisbury Plains	BOWEN AIRPORT	987	975	412	2,015	215	75	138
Somerville	SAXBY DOWNS	503	470	204	1,227	145	34	112
Sunnyholt	WARRINILLA	710	670	256	1,565	295	49	121
Ticehurst	FROGMOOR	537	517	173	1,022	201	45	91
All Sites Average rainfall		645	622	225	1343	229	50	115

1.3.2 Southern oscillation index

The southern oscillation index for the period from 2000 to 2009 (Figure 1.3.1) shows the extended negative phase in the 2002-03 period, causing a widespread drought prior to commencing project monitoring. There was a brief period of positive index in summer of 2003-04, but another negative phase drought period at the start of the project in late 2005. The serious drought of 2006-07 occurred during the negative SOI phase. The above average summer rainfall in the final two years of the project occurred during the positive SOI phases.

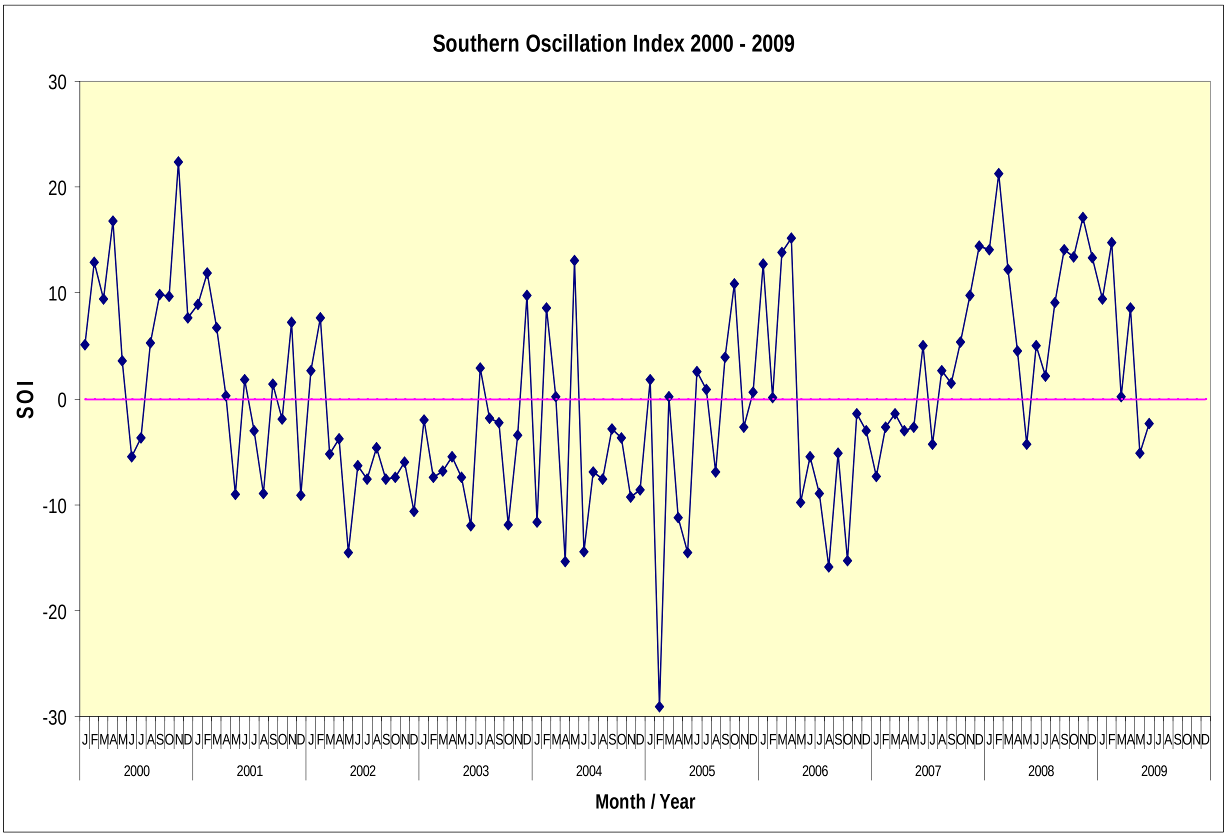


Figure 1.3.1. Southern oscillation index 2000-2009.

1.3.3 Monthly and long-term site rainfall

The total monthly rainfall received at each site compared with the long-term mean monthly rainfall from July 2005 to June 2009 is shown for the nine sites in following figures (Figures 9.3.2 to 9.3.10). The abnormally dry periods experienced at all sites with some well above average rainfall months and site variability can be seen.

Banyula

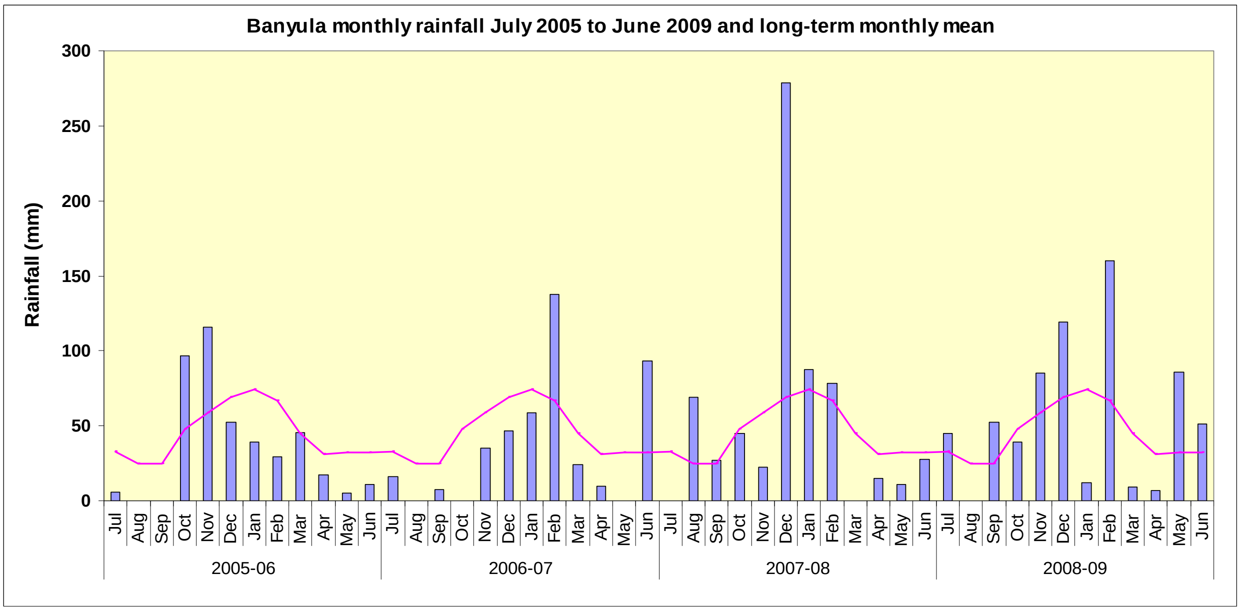


Figure 1.3.2. Banyula monthly rainfall and long-term mean July 2005 to June 2009 and long-term monthly mean.

Berrigurra

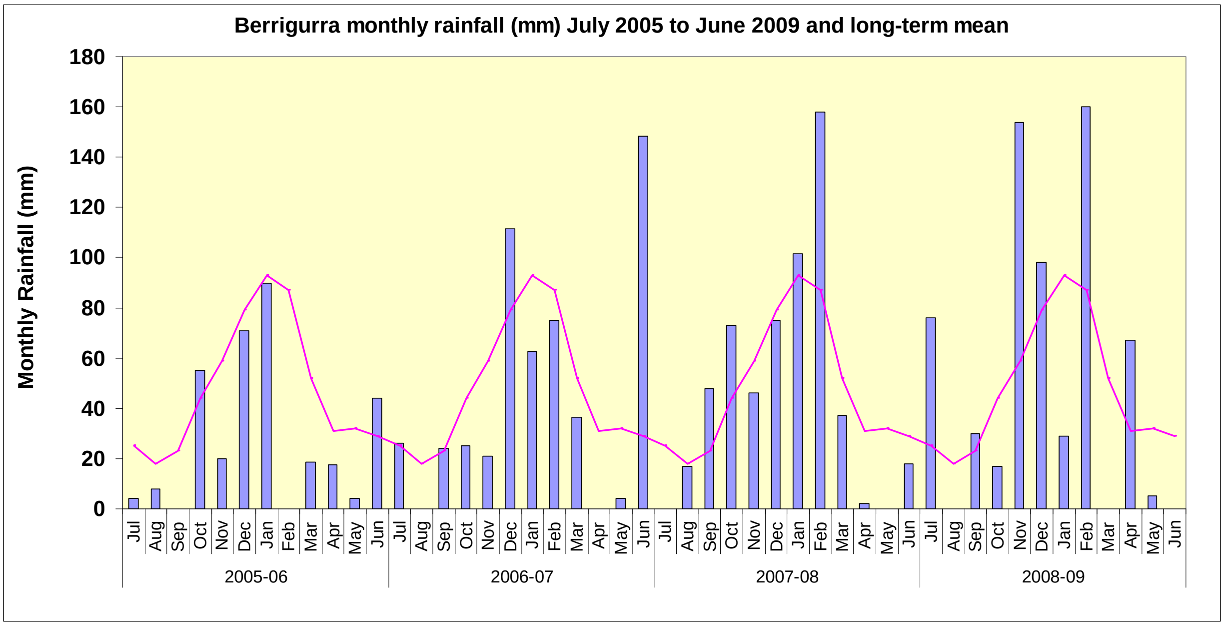


Figure 1.3.3. Berrigurra monthly and long-term mean rainfall (mm) July 2005 to June 2009 and long-term monthly mean.

Frankfield

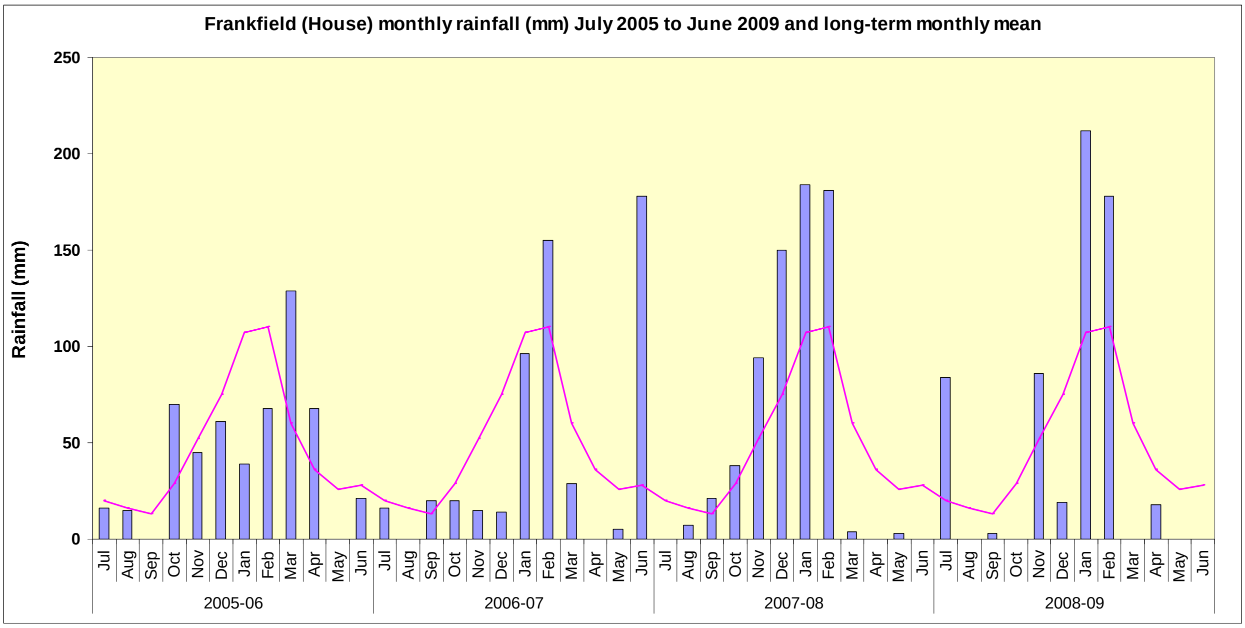


Figure 1.3.4. Frankfield monthly rainfall (mm) July 2005 to June 2009 and long-term monthly mean.

Melrose

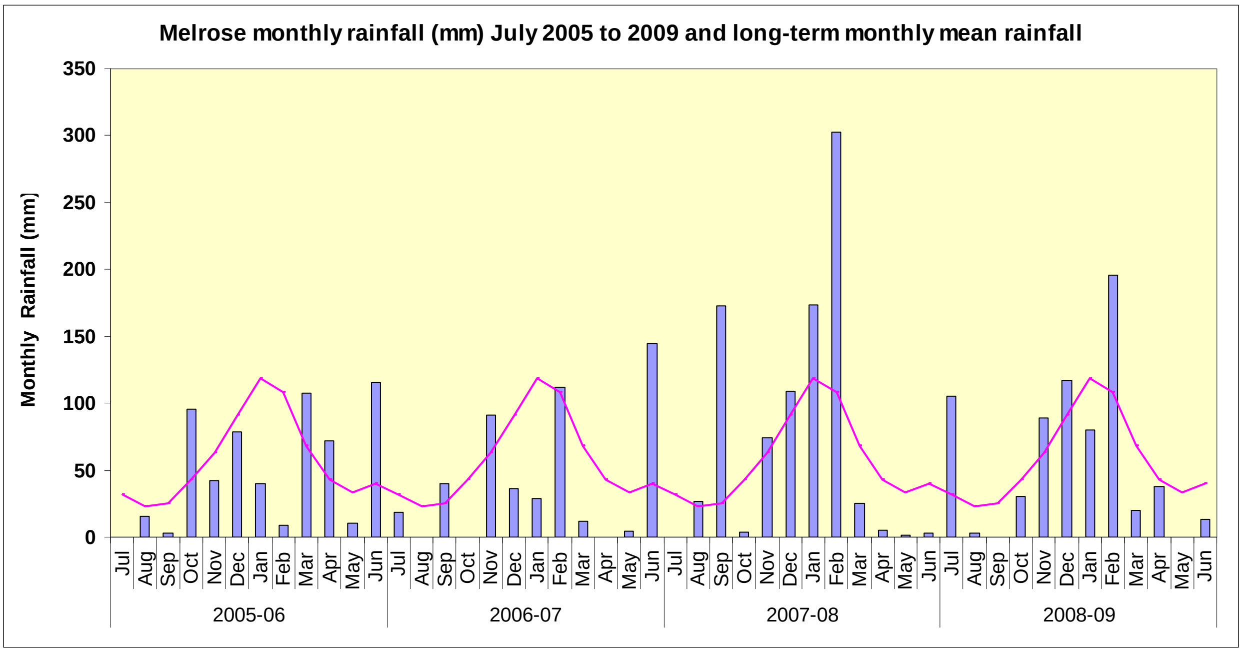


Figure 1.3.5. Melrose monthly rainfall (mm) July 2005 to June 2009 and long-term monthly mean.

Rocky Springs

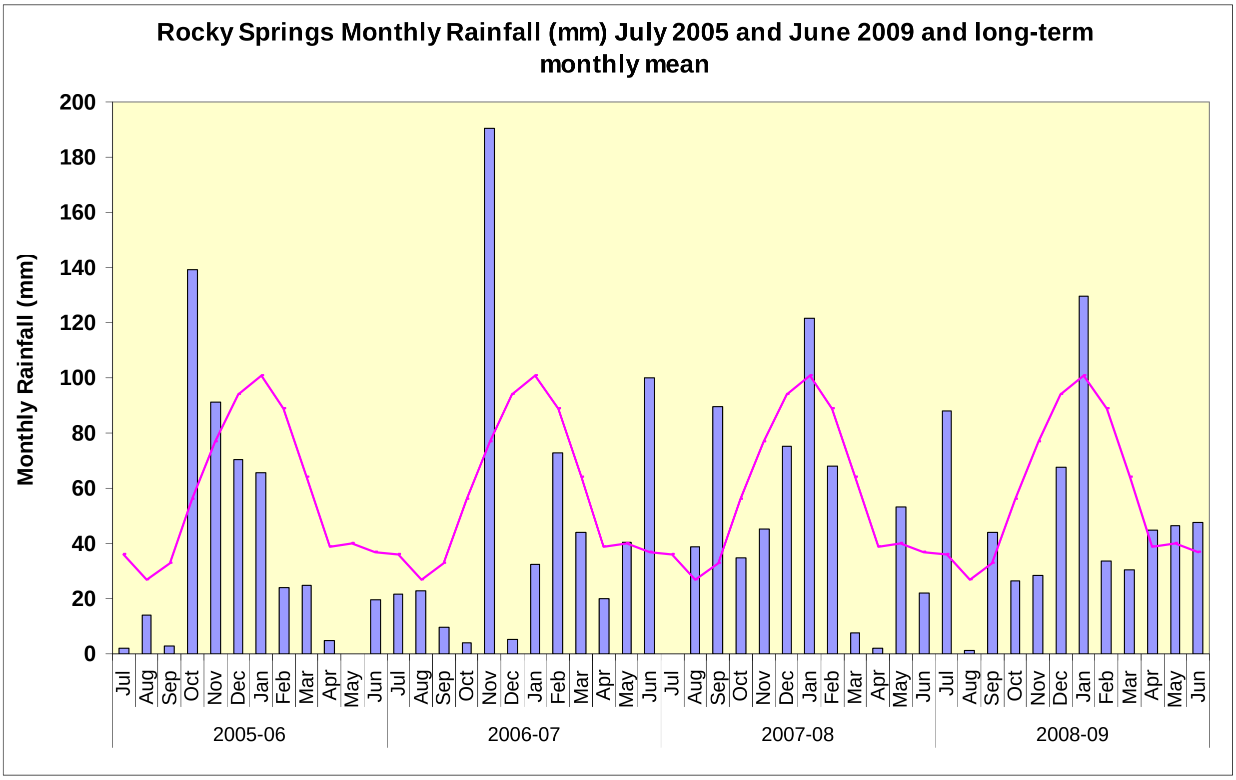


Figure 1.3.6. Rocky Springs monthly rainfall (mm) July 2005 to June 2009 and long-term monthly mean.

Salisbury Plains

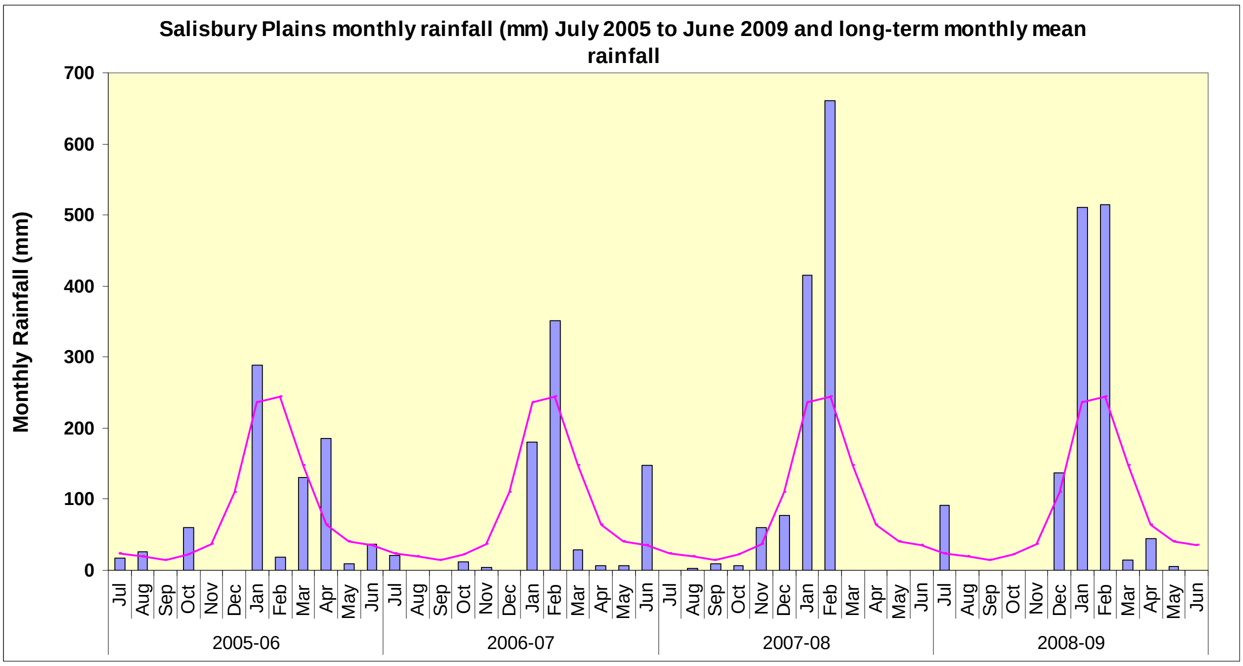


Figure 1.3.7. Salisbury Plains monthly rainfall (mm) July 2005 to June 2009 and long-term monthly mean.

Somerville

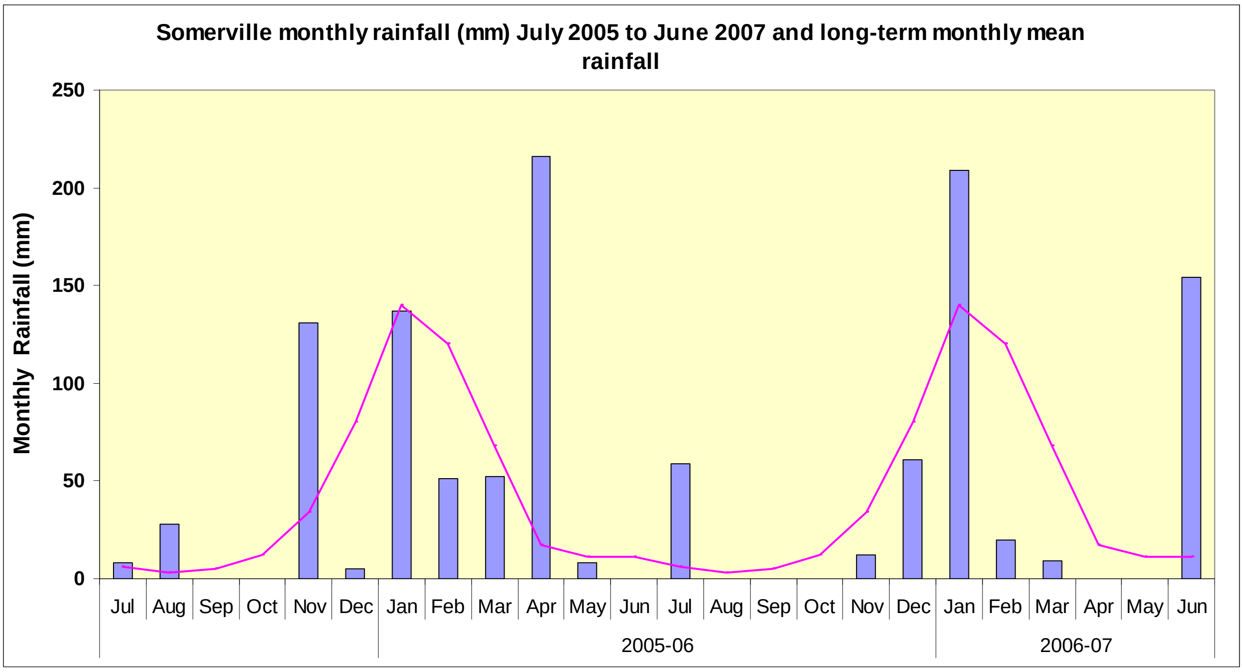


Figure 1.3.8. Somerville monthly rainfall (mm) July 2005 to June 2007 and long-term monthly mean.

Sunnyholt

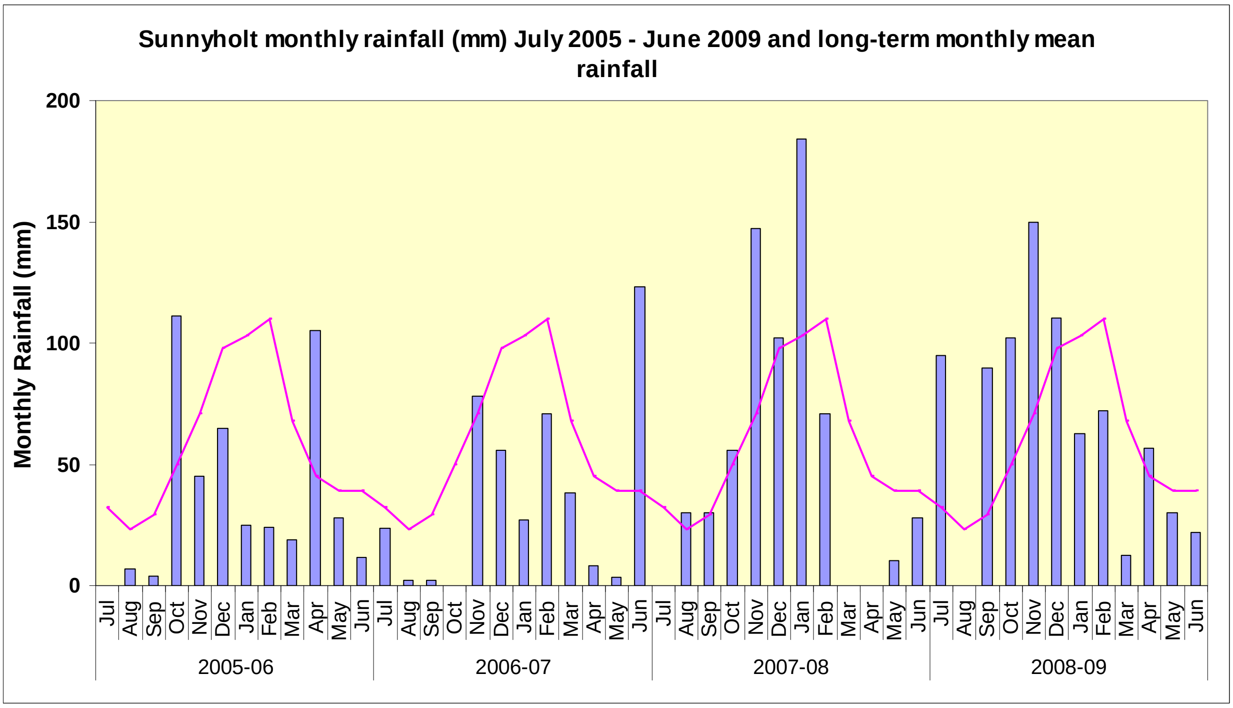


Figure 1.3.9. Sunnyholt monthly rainfall (mm) July 2005 to June 2009 and long-term monthly mean.

Ticehurst

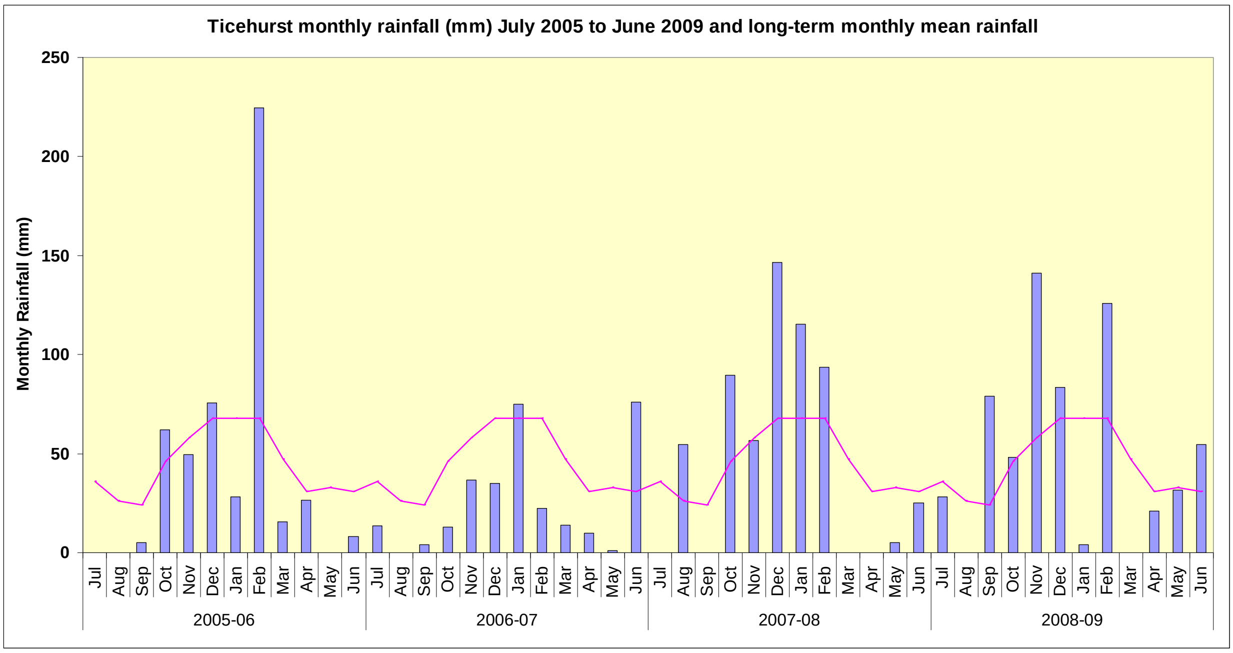


Figure 1.3.10. Ticehurst monthly rainfall (mm) July 2005 to June 2009 and long-term monthly mean.

1.3.4 Monthly rainfall variability

Between years, monthly rainfall was highly variable at all sites throughout the four-year monitoring period. An example of this monthly variability for the four years 2005-06 to 2008-09 for Melrose (Figure 1.3.11) shows a wide range of monthly rainfall throughout the year, in both summer and winter months. For example, the rainfall range in February ranged from 9 to 302 mm compared with the long-term meant of 108 mm and in June the range was 3 to 144 mm, compared with a mean of long-term mean of 40 mm. This site had better than average rainfall for the last two years.

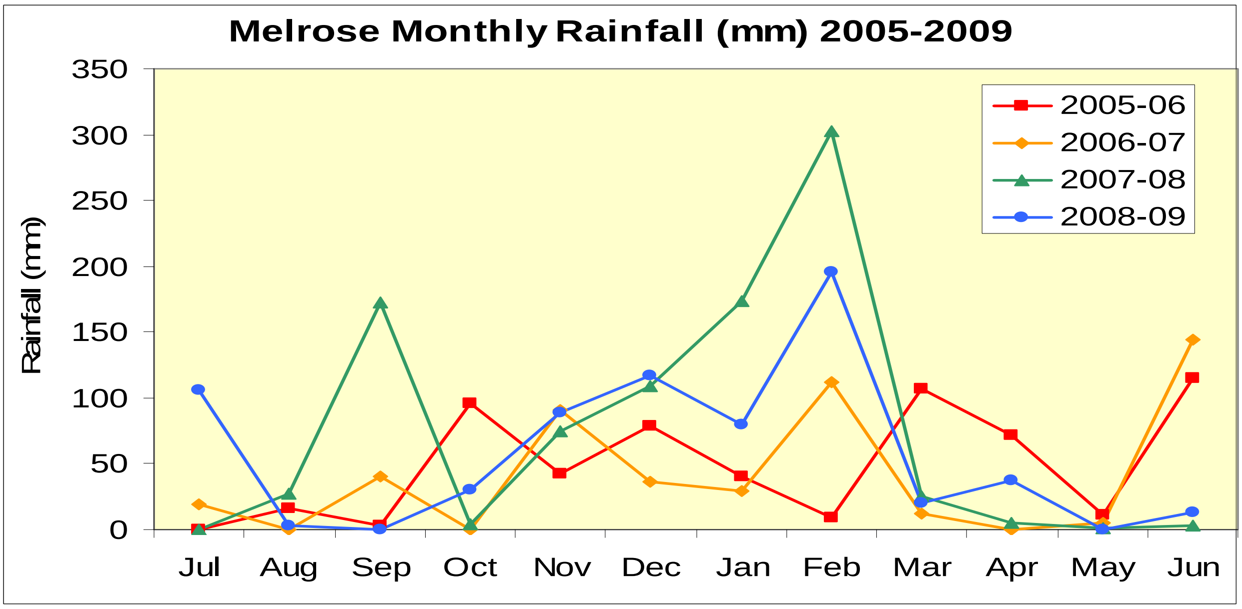


Figure 1.3.11. Melrose monthly rainfall (mm) variability over four years July 2005 to June 2009.

1.4 Appendix 4 – Botanal and LFA methodologies

1.4.1 Pasture and soil surface condition measurements

1.4.1.1 General sampling details

The number of quadrats samples per paddock varied between paddocks, with the following range used as a guide in planning the grid sizes:

Up to 50 ha: 50-120 quadrats
100-200 ha: 100-200 quadrats
Over 200 ha: 200-400 quadrats

The same sampling grid was used each year.

1.4.1.2 Landscape organisation (LFA transects)

The Landscape Function Analysis (LFA) method developed by CSIRO (David Tongway) was used. This is a widely used method for assessing soil condition and can generate indices of stability, infiltration and nutrient cycling. LFA procedure is based on assessing linear transects down slopes to characterise landscape organisation (accumulation patches and resource loss inter-patches) plus ratings on various soil and vegetation indicators in the patches. These parameters are converted to classes and the values are then used to calculate the indices.

Landscape organisation (areas of soil accumulation and loss) were measured along 50 m transects in all monitor paddocks at the start of the project during October-December 2005 and recorded on palmtop computers. The transect length was divided into resource accumulation and loss categories (Table 1.4.1). The grassy patches are the most desirable type accumulation zone and the bare ground is the least desirable form of loss zone. Each category value is calculated as the percentages of the 50 m transect length. The total of accumulation plus total loss = 100%.

Table 1.4.1. LFA transect resource accumulation and loss codes.

Resource allocation	Code No.	Description Pasture/soil/litter
Accumulation	1	Perennial grass patch - accumulation
Accumulation	2	Sparse grass - accumulation
Accumulation	3	Litter complexes
Accumulation	4	Log/log complex/mound obstructions
Accumulation	5	Bare soil - accumulation
Accumulation	6	Cultivated – pasture grasses remaining
Accumulation	7	Cultivated - weeds remaining
Accumulation	8	Grassy and Stable
Accumulation	9	Shrub - accumulation
Accumulation	10	*unallocated*
Loss	11	Sparse grass - loss
Loss	12	Sparse litter - loss
Loss	13	Bare soil - loss
Loss	14	Perennial grass patch - loss
Loss	15	Shrub - loss
Loss	16	*unallocated*

A digital photograph was taken along each transect from the upper-slope end. These fixed sites were re-photographed periodically during the project.

A property example of the location, layout and direction of LFA transects and fixed photograph points is shown for each paddock at Melrose in Figure 1.4.1.

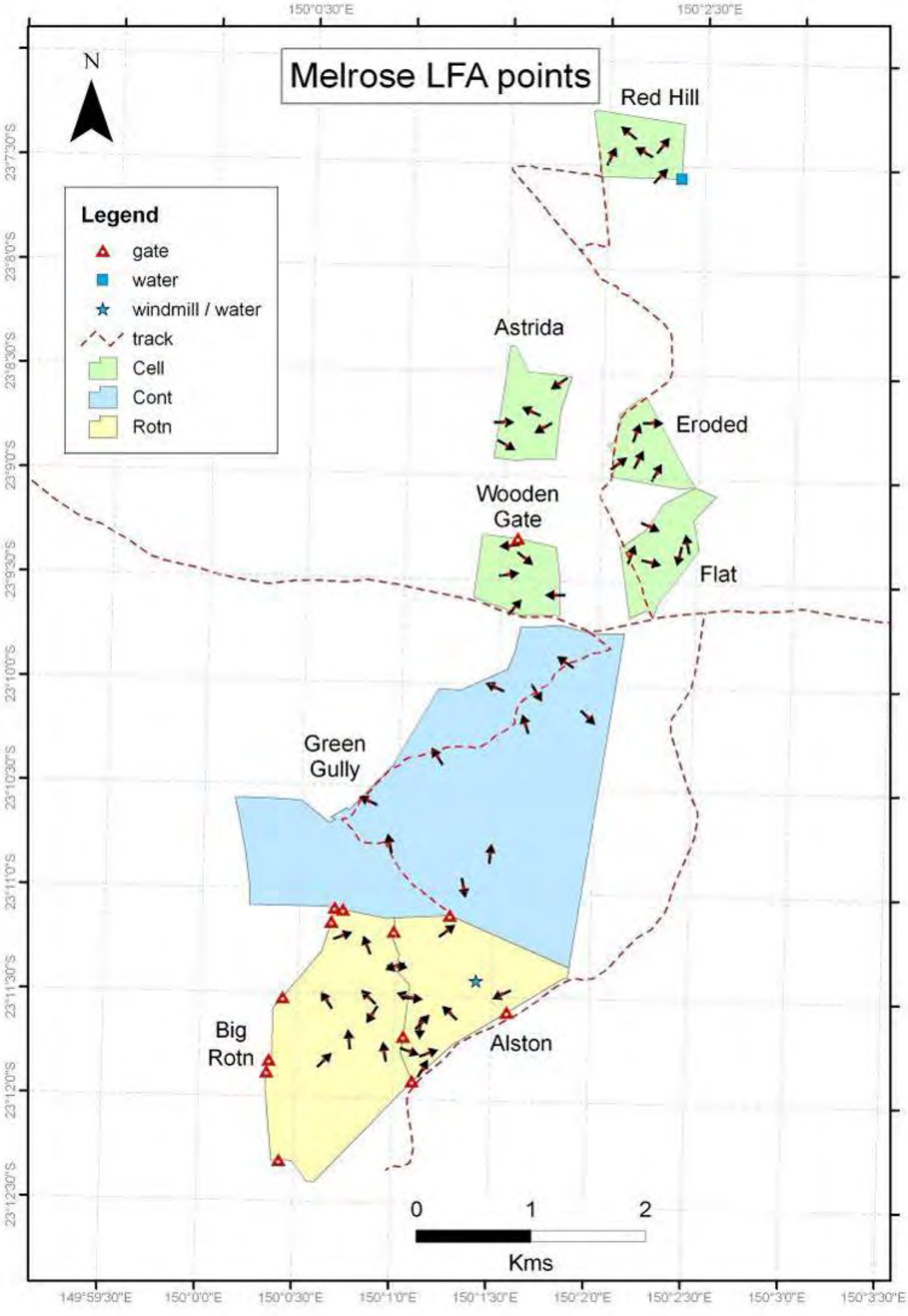


Figure 1.4.1. Layout and direction of LFA transect and fixed photograph sites in eight paddocks of three grazing systems at Melrose.

1.4.2 Methodology - pastures and soil surface conditions

1.4.2.1 Introduction

The following measurements were made at each property:

- Pasture characteristics (Botanal methodology with additional parameters).
- Soil surface condition by Landscape Function Analysis (LFA).

1.4.2.2 Pasture and soil surface measurements

The pasture measurements were recorded on predetermined points on a grid across the 74 paddocks at the nine sites and were located in the field each year by a hand-held GPS. The same points were recorded in 2006, 2007 and 2009. An example of both the paddock scale and property scale is shown for the continuous system paddock (Green Gully) at Melrose and for the five cell and one continuous paddock at Sunnyholt in Figure 1.4.2 and Figure 1.4.3 respectively.

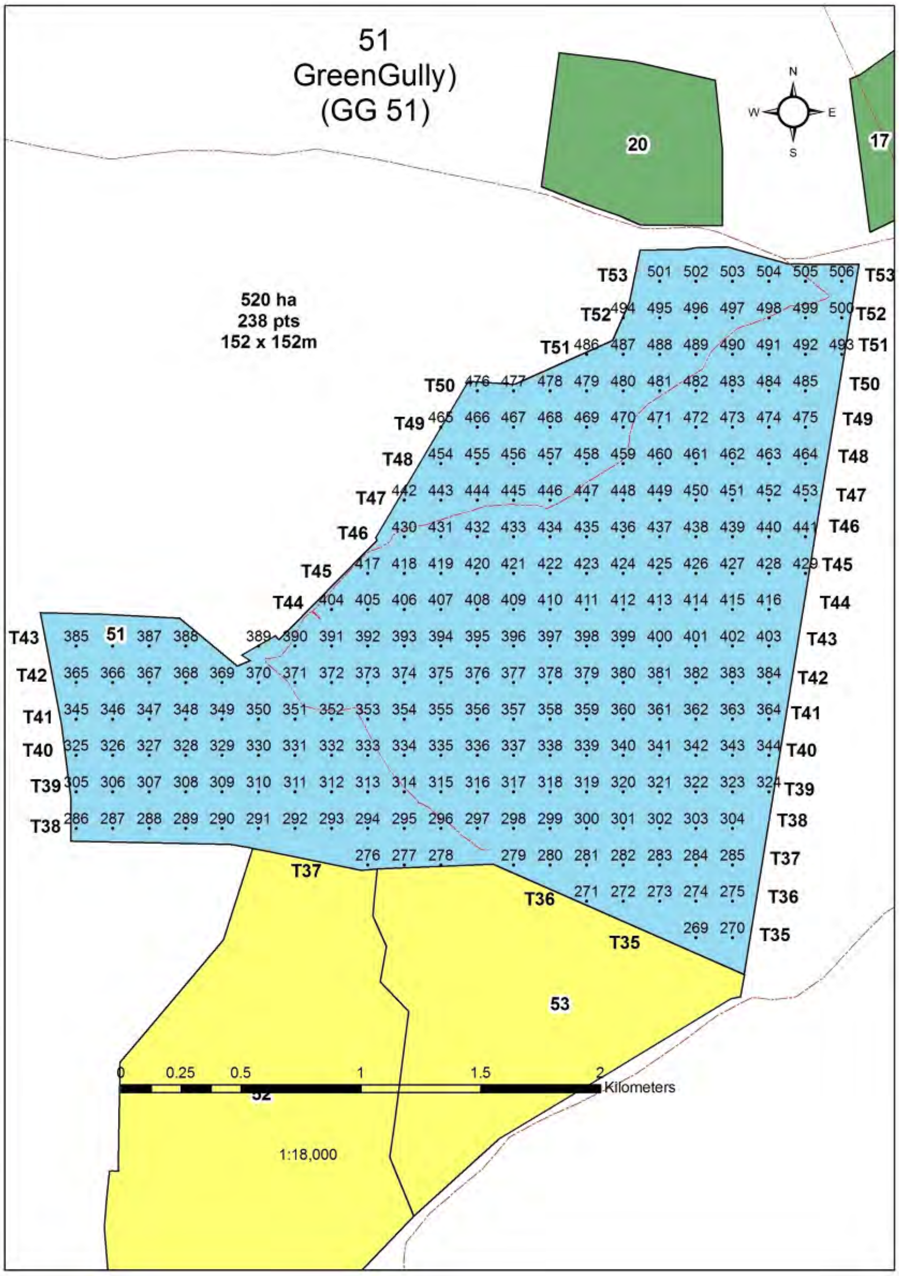


Figure 1.4.2. Botanical and soil surface sampling grid points in Green Gully (no. 51) paddock (continuous grazing system) at Melrose.

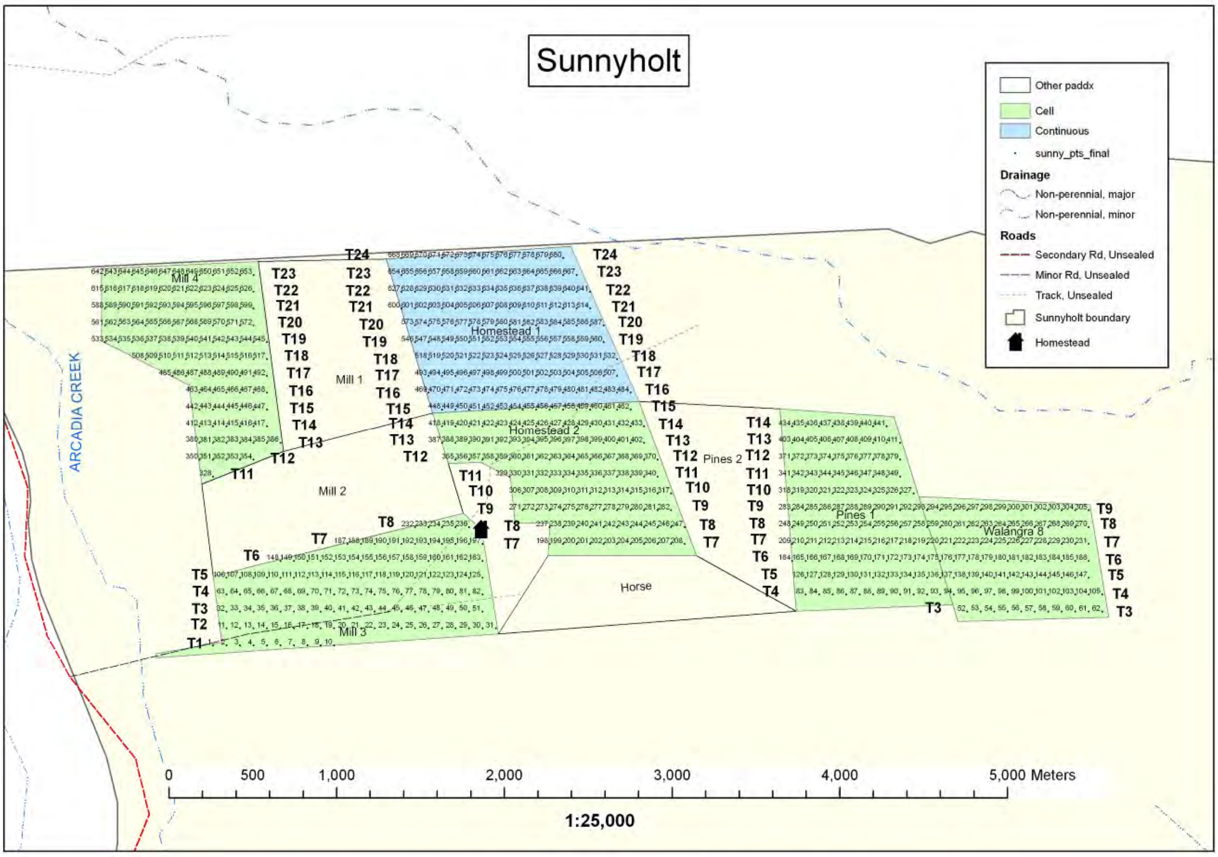


Figure 1.4.3. Botanical and soil surface sampling grid points across six paddocks of two grazing systems at Sunnyholt.

1.4.3 General sampling details

Pasture and soil surface observations were made at pre-determined locations set out on a regular pre-determined sampling grid across each paddock. The position of each quadrat was recorded by GPS and observations made at the same location each year. The number of samples per paddock varied between paddocks.

Quadrat size was 50 x 50cm (0.25m^2).

Pasture and soil surface observations were made at the end of the growing season (March-June) in 2006, 2007 and 2009.

Yield

Pasture presentation yield was rated on a 0 to 100 point scale and standardised with cut quadrats (approximately 13 per site) and converted to kg/ha dry weight.

Botanical composition

The proportion (%) of the pasture biomass contributed by each the five most abundant species in each quadrat was estimated. The individual species recorded across all sites is shown in Table 1.4.2. A photographic identification booklet was prepared showing all species and was used by Botanal recorders in the field to help ensure consistency in species identification between operators and over the three years of recording. This booklet, not included in these Appendices, is available separately. The major, potential indicator species, minor species and others that could not be identified were allocated to one of the following seven functional groups:

1. Native perennial grasses
2. Exotic perennial grasses (sown and naturalised species)
3. Annual grasses
4. Exotic legumes
5. Native legumes
6. Forbs
7. Sedges.

The 61 recorded species were also allocated to the seven species groups for analysis of botanical composition data (Table 1.4.2).

Table 1.4.2. Sixty one pasture species and seven species groups recorded across all sites in 2006, 2007 and 2009.

No.	Genus	Species	Common name
	Native perennial grass		
1	*Aristida*	*calycina*	branched wiregrass
2	*Aristida*	*latifolia*	feathertop
3	*Aristida*	*leptopoda*	white spear
4	*Aristida*	*ramosa*	purple wiregrass
5	*Aristida*	other species	wiregrass
6	*Astrebla*	*elymoides*	hoop Mitchell
7	*Astrebla*	*lappacea*	curly Mitchell
8	*Astrebla*	*squarrosa*	bull Mitchell
9	*Bothriochloa*	*bladhii*	forest bluegrass
10	*Bothriochloa*	*decipiens*	pitted bluegrass
11	*Bothriochloa*	*ewartiana*	desert bluegrass
12	*Chloris*	spp.	windmill
13	*Chrysopogon*	*fallax*	golden beard
14	*Cymbopogon*	spp.	barb wire
15	*Dichanthium*	spp.	Qld blue, Gulf bluegrass
16	*Digitaria*	spp.	blow-away
17	*Enneapogon*	spp.	bottle washer
18	*Enteropogon*	spp.	curly windmill
19	*Eragrostis*	spp.	love
20	*Eriochloa*	spp.	summer grass
21	*Heteropogon*	*contortus*	black spear
22	*Panicum*	spp.	panic
23	*Paspalidium*	spp.	shot
24	*Eulalia*	*aurea*	silky browntop
25	*Sporobolus*	spp.	rats tail; Katoora
26	*Themeda*	*triandra*	kangaroo
27	*Triodia*	spp.	spinifex
28	*Tripogon*	*loliiformis*	5-minute
29	*Aristida*	*pruinosa*	gulf wiregrass
30	Other or unidentified native perennial species		
	Exotic perennial grass		
31	*Cenchrus*	*ciliaris*	buffel
32	*Chloris*	*gayana*	Rhodes

33	*Panicum*	*maximum*	green panic
34	*Urochloa*	*mosambicensis*	sabi
35	*Bothriochloa*	*pertusa*	Indian bluegrass
36	*Melinis*	*repens*	red Natal
37	*Sorghum*	hybrid	silk
40	Other or unidentified exotic species		
	Native legume		
41	*Alysicarpus*	spp.	alysicarpus
42	*Crotalaria*	spp.	rattlepod
43	*Desmodium*	spp.	desmodium
44	*Glycine*	spp.	glycine
45	*Indigofera*	spp.	indigofera
46	*Rhynchosia*	*minima*	rhyncho
47	*Zornia*	spp.	zornia
48	*Neptunia*	spp.	neptunia
50	Other or unidentified native legume species		
	Exotic legume		
51	*Medicago*	spp.	medic
52	*Stylosanthes*	*hamata*	verano, amiga
53	*Stylosanthes*	*scabra*	seca, shrubby stylo
54	*Macroptilium*	spp.	siratro, phasey bean
60	Other or unidentified exotic legume species		
	Annual grass		
61	*Dactyloctenium*	spp.	button grass
62	*Iseilema*	spp.	Flinders grass
63	*Tragus*	*australianus*	small burr grass
64	*Perotis*	*rara*	comet grass
65	*Digitaria*	*ciliaris*	tropical summer grass
66	*Brachyachne*	*convergens*	native couch
67	*Sporobolus*	*caroli*	fairy grass
70	Other or unidentified annual grass species		
	Forbs		
71	*Parthenium*	hysterophorus	parthenium
72	*Sclerolaena*	spp.	burrs, galvanised burr
73	Malvaceae	spp.	sida, flannel
74	*Verbena*	spp.	Mayne's pest
80	Other or unidentified forb species		
	Sedge		
81	*Cyperus*	spp.	nut grass
82	*Fimbristylis*	spp.	sedge
90	Other or unidentified sedge species		

Basal area

The basal area of perennial grasses was estimated as the proportion (%) of ground in the quadrat that was occupied by the base of a perennial grass plant.

Ground cover

Three estimates of ground cover were made.

1. Total ground cover

The proportion (%) of the soil that was covered by herbage and shrubs <0.5m tall, rocks, stones, logs, litter, dung and any other objects that intercept raindrops and protect the soil surface. This value is equivalent to 100% - bare ground.

2. Total organic cover

This was the total ground cover less any cover of rocks and stones. Where there were no rocks or stones the values were the same.

3. Permanent cover (LFA)

Permanent or long-term cover was estimated for calculating the LFA indices. This cover included plants, wooden litter and stones, anything that intercepted rainfall, with the exception of transient cover, such as fine litter and dung.

Utilisation per cent

Pasture utilisation (consumption) in each quadrat was rated in four categories:

1 71-100%
2 31-70%
3 6-30%
4 0-5%

Colonisation and regrowth of woody species

The projected foliage cover of woody species <2m tall was estimated (%) in a 10 m radius circle around each quadrat.

Cattle pads

The number of active cattle pads that crossed the path between successive quadrat locations was recorded.

Soil surface condition

We modified the LFA linear technique to fit with our general pasture data quadrat collection method. The ratings on various soil and vegetation indicators were incorporated with the collection of pasture quadrat data by assessing the soil surface condition in the quadrats used to collect pasture information.

The slake tests were conducted on a land type basis, instead of in each quadrat. The land types were identified and mapped as part of the estimations of carrying capacity, and were based on the Queensland vegetation mapping units.

The methods used to calculate the LFA indices for stability, infiltration and nutrient cycling from the indicators are shown below.

Soil surface assessment

There were 11 surface indicators recorded for LFA.

1. Soil cover

Definition: the projected percentage cover of perennial grasses and shrubs <0.5m tall, rocks, logs and any other relatively immovable and long-lived objects that will intercept raindrops. Litter or dung is not included in soil cover estimates in LFA so this estimate differs from those for total ground cover above. Projected cover was rated in five classes:

Projected cover	Class	Interpretation
Less than 1%	1	No rain-splash protection
1 to 15%	2	Low rain-splash protection
16 to 30%	3	Moderate rain-splash protection
31 to 50%	4	High rain-splash protection
More than 50%	5	Very high rain-splash protection

2. Perennial grass basal area

We estimated basal area as part of the pasture measurements (see above). These estimates were allocated to four LFA basal area classes:

Basal cover	Class	Interpretation
1.0% or less	1	No below ground contribution
1.1 to 2.0%	2	Low below ground contribution
2.1 to 5.0%	3	Moderate below ground contribution
More than 5.0%	4	High below ground contribution

Note. In LFA, shrub and tree cover is also included in this indicator and the class values are higher than we used (<1, 1-10, 10-20 and >20%).

3. Litter cover, origin and degree of decomposition

Litter is detached leaves, stems, twigs, fruit, dung, etc.
Litter cover was assessed in three stages:

a. **Litter cover** was assessed in five classes from 1 (≤10%) to 5 (76-100%):

% cover of litter	Class
10 or less	1
11-25	2
26-50	3
51-75	4
76-100	5

Note. LFA includes a further five classes where litter cover is 100% and of increasing depth with class. These were unlikely to occur in the pastures we were sampling and they were omitted.

2. The **source** of the litter was assessed as:
local (L) = derived from plants growing in very close proximity and showing no signs of transport/deposition by wind or water flows, or
transported (T) = litter has clear signs of being washed or blown to the current location.

The degree of decomposition/incorporation was assessed in four classes as:

c. **Decomposition: nil (N)** – the litter is loosely spread on the surface with few signs of decomposition and incorporation,
slight decomposition (S) – the litter is broken down into small fragments and intimately in contact with soil; some fragments may be partially buried,
moderate decomposition (M) – the litter is in several distinct layers; some fungal attack is visible; the layer next to the soil is somewhat humified; some darkening of the soil to a depth of less than 10 mm, or
extensive decomposition (E) – the litter has at least three layers or stages in decomposition ranging from fresh material on top to 20 mm or more of comprehensively humified (very dark,

with no identifiable fragments) at the soil-litter interface; mineral soil may have significant organic darkening in excess of 10 mm.

4. Cryptogam cover

Cryptogams include algae, fungi, lichens, mosses and liverworts. These plants can exist on stable (i.e. non-shifting) surfaces with access to light, and stabilise and help protect the soil surface. This assessment is not applicable to mobile soils (loose sands and self-mulching clays) or where there is extensive and deep litter cover.

Cryptogam cover was assessed in the following five classes:

Cryptogam cover (%)	Class	Interpretation
Not applicable	0	No stable crust present
Less than 1	1	No contribution
1 to 10	2	Slight contribution
11 to 50	3	Moderate contribution
More than 50	4	Extensive contribution

5. Crust broken-ness

A crust is a physical surface layer that overlies sub-crust material. This assessment measures the degree surface crust materials are broken or loosely attached and available for erosion. Soils with physical crusts in good condition (crusts are smooth and conform to the gentle undulations in the soil surface) yield little soil material in a runoff event. However crusts can become unstable, brittle and easily disturbed by grazing animals and the materials become available for erosion. This assessment is not applicable_to loose sandy soil, self-mulching soils, or when < 25% of the quadrat is crusted.

Crust broken-ness was assessed in the following five classes:

Crust brokenness	Class
No crust present	0
Crust present but extensively broken	1
Crust present but moderately broken	2
Crust present but slightly broken	3
Crust present but intact, smooth	4

6. Erosion type and severity

This indicator assesses the nature and severity of active or current loss of soil material. Forms of erosion include rills and gullies, terracettes, sheeting, scalding, and pedestalling of plants.

a. rills and gullies (R) are channels cut by flowing water (rills are <30 cm deep and gullies are deeper);
b. terracettes (T) are abrupt walls from 1 to 10 cm high, aligned with the local contour;
c. sheeting (Sh) is the progressive removal of very thin layers of soil across extensive areas - characteristically associated with gradational or uniform textured soils; at an advanced stage sheeted surfaces may be covered by layers of gravel or stone left behind after erosion of finer material;
d. scalding (Sc) is the loss of A-horizon material in texture-contrast soils which exposes lower horizons which are typically very hard when dry and have extremely low infiltration rates; scalds are a severe form of erosion and always rate as Class 1;

e. pedestalling of plants (P) results from erosion leaving the butts of plants on a column of soil above the new level of the landscape.

The most severe form of erosion was identified and the site allocated to one of four severity classes (insignificant, slight, moderate and severe) using the guidelines in the following table.

LFA erosion types and severity definitions used in each pasture recording quadrat:

Erosion type	Insignificant (4)	Slight (3)	Moderate (2)	Severe (1)
Rills & gullies	No rills or gullies	Evidence of focussed water flow but there may be no distinct channels	Some incision but rills <10 cm deep; active head-ward cutting	Rills >10 cm deep; active head-ward cutting
Terracettes	No terracettes	Terracettes rare and small (<1 cm) but some evidence of them forming	Terracettes are obvious but <2 cm high	Extensive, deep (>2 cm) terracettes
Sheeting	No evidence of sheeting or current soil loss	Soil surface removed from up to 30% of the quadrat	Soil surface removed from 31-70% of the quadrat	Soil surface removed from more than 70% of the quadrat
Scalding	No scalding			Whole A horizon removed leaving B horizon exposed; large amount of soil lost
Pedestals	No pedestals – plant crowns on or near level with the soil surface	Plant crown above the soil surface around part of its perimeter; braking away tends to occur on the downhill side of clumps	Plants on a soil pedestal above the adjacent soil surface on all sides	Grass on top of pedestal dead or nearly so; pedestal disintegrating

7. Deposited materials

The degree transported materials are deposited was assessed in the following four classes:

Deposited material	Class
Extensive amount of material available > 50% cover several cm deep	1
Moderate amount of material available 21 to 50% cover	2
Slight amount of material available 6 to 20% cover	3
None or small amount of material available 0 to 5% cover	4

8. Surface roughness

Soil surface roughness was assessed for its capacity to capture and retain mobile resources such as water, propagules, topsoil and organic matter in the following six classes:

Surface roughness	Class
<3 mm relief in soil surface Smooth	1
Shallow depressions 3-8 mm relief Low retention	2
Deeper depressions 9-25 mm relief, dense tussock grasslands Moderate retention	3
Deep depressions that have a visible base Large retention	4
Very deep depressions or cracks >100 mm Extensive retention	5

9. Surface nature (resistance to disturbance)

The likely impact of mechanical stress (e.g. trampling) to yield erodible material was assessed in the following five classes.

Definitions and descriptions of the classes describing resistance-to-disturbance nature of the soil surface:

Surface nature	Class	Interpretation
Non-brittle	5	Shows some “springiness” when pressed with finger, typically with A_0 layer; **or** Surface is a self-mulching clay; **or** Surface has no physical crust and is under a dense perennial grass sward
Crust is very hard and brittle	4	Needs a metal implement to break the surface, forming amorphous fragments or powder. The sub-crust is also very hard, coherent and brittle.
Moderately hard	3	Surface has a physical crust and moderately hard, needing a plastic tool to pierce, breaking into amorphous fragments or powder. The sub-crust is coherent.
Easily broken	2	Surface is easily penetrated with finger pressure (to about first knuckle joint). Surface may have a weak physical crust and sub-crust is non-coherent e.g. sandy.
Loose sandy surface	1	Surface is not crusted, easily penetrated by finger pressure to about second knuckle joint. Sub-surface is non-coherent.

10 Slake test

The objective of this test is to assess the stability of natural soil fragments to rapid wetting. An air-dry soil fragment of 1-cm cube size was gently immersed in rainwater (saline water is unsuitable) with the soil crust uppermost and the response observed. There are five classes, with four time-related classes for surfaces surface crusts are present:

Observed behaviour	Class	Interpretation
Not applicable	0	No coherent fragments available e.g. sand
Very unstable	1	Fragment collapses in less than 5 seconds
Unstable	2	Fragment substantially collapses 5-10 seconds; a thin surface crust remains. >50% of the sub-crust material slumps
Moderately stable	3	Surface crust remains intact with some slumping of the sub-crust but less than 50%
Very stable	4	Whole fragment remains intact with no swelling

11. Soil texture

The texture of the surface soil was classified in relation to permeability in four classes:

Texture	Class
Silty clay to heavy clay (Very slow infiltration rate)	1
Sandy clay loam to sand clay (Slow infiltration rate)	2
Sandy loam to silt loam (Moderate infiltration rate)	3
Sandy to clayey sand (High infiltration rate)	4

Note: self mulching, cracking clays were assessed as Class 3 because of their moderate infiltration rate.

Calculation of LFA indices for stability, infiltration and nutrient cycling

The contributions of the various indicators to the three indices are shown below. The sum of the class values for these indicators at a site are expressed as a percentage of the maximum.

Stability Index

Definition: the ability of the soils to withstand erosive forces, and to reform after disturbance (eight indicators):

Stability Indicators	Class range
Crust broken-ness	1-4
Surface resistance	1-5
Slake test	1-4
Erosion type and severity	1-4
Deposited materials	1-4
Cryptogam cover	1-4
Soil cover	1-5
Litter cover*	1-5
Total	**8-35**

*Litter cover alone

Infiltration Index

Definition: how the soil partitions rainfall into soil-water (water available for plants to use), and runoff water which is lost from the local system, and may also transport materials (soil, nutrients and seed) away (six indicators):

Infiltration Indicators	Class range
Perennial grass basal area	1-4
Surface rough-ness	1-5
Slake test	1-4
Litter cover, origin and decomposition†	1-15
Surface resistance*	1-10
Soil texture	1-4
Total	**6-42**

†The full contribution of litter to this index is obtained by multiplying the basic litter cover by the following factors:

(a) both transported (T) and nil (N) incorporation of litter, multiply cover value by **1** (i.e. no change to cover)
(b) for litter of local (L) origin, multiply cover value by **1.5**
(c) for slight (S) incorporation of litter, multiply cover value by **1.3**
(d) for moderate (M) incorporation of litter, multiply cover value by **1.7**
(e) for extensive (E) incorporation of litter, multiply cover value by **2.0**
For example, for a recording of 3LS, the litter score contributing to the index is 3 x 1.5 x 1.5 = 6.75
*Infiltration is slowed by compact soil surfaces (e.g. a scald). To allow for this, the assessed surface resistance to disturbance indicator is reallocated in the following way in calculating the Infiltration Index.

Class 5 → 6.6
Class 4 → 1
Class 3 → 3.3
Class 2 → 6.6
Class 1 → 10

Nutrient cycling index

Definition: how efficiently organic matter is cycled back into the soil (four indicators):

Nutrient Cycling Indicators	Class range
Perennial grass basal area	1-4
Surface rough-ness	1-5
Litter cover, origin and decomposition†	1-15
Cryptogam cover	1-4
Total	**4-28**

†See notes under Infiltration Index for contribution of litter.

A field sheet for recording botanal and LFA parameters is shown in Table 1.4.3.

Table 1.4.3. Field summary recording sheet for Botanal and LFA parameters.

GSP - Botanal and LFA field recording Codes and Species 2009 (Year 4)

	Parameter		Description / Class
	No. quadrats	**0.25m^2**	>1 quadrat / ha; Expt code GSP; Site; Pdk; Transect; Operator
1	**BOTANAL**	**Spp * %**	1. 5 species * % contribution of each
	DMY rating	**0 - 99**	2. DM Yield rating (10 - 50 standards; regression)
2	**UTILISATION**	**1- 4**	1. 71 - 100 % pasture growth consumed (reverse order in '06)
			2. 31 - 70 %
			3. 6 - 30 %
			4. 0 - 5 %
3	**WOODY REGROWTH 1 <3m^2**	**0 - 9**	Regrowth cover between 0 - 0.9% in 10m radius (3.1m^2 = 1%)
4	**WOODY REGROWTH 2 >3m^2**	**0 -99**	Regrowth cover is >1% (>3.1m^2 in 10m radius) - 3m high
5	**GRASS BASAL AREA**	**0 - 20%**	Quadrat frame (no. cm over plant base on two sides = 100cm)
6	**TREE-SHRUB COVER**	**0 - 99%**	Projected cover woody spp >2m, above quad
7	**TOTAL COVER**	**0 - 99%**	Herbage, litter, dung, logs, stones + shrubs <0.5m high
8	**ORGANIC COVER**	**0 - 99%**	Total ground cover (excl stones)
9	**'TONGWAY' LFA COVER**	**0 - 99%**	Total cover, excluding litter / dung (long-term cover, incl stones)
10	**LITTER COVER**	**0 - 99%**	Detached leaves, stems, twigs, fruits, seed, dung
11	**LITTER ORIGIN**	**1 - 2**	1. Local (L)
			2. Transported (T)
12	**LITTER DECOMPOSITION**	**1 - 4**	1. Nil decomposition (N)
			2. Slight decomposition (S)
			3. Moderate decomposition (M)
			4. Extensive decomposition (E)
13	**CRYPTOGAM COVER**	**0 - 4**	0. Not applicable - no stable crust - sand, self mulch, litter
			1. <1% - no contribution
			2. 1 - 10% - slight
			3. 11 - 50% - moderate
			4. > 50% - extensive
14	**CRUST BROKENNESS**	**0 - 4**	0. No crust present
			1. Crust present - extensively broken (available for erosion)
			2. Crust - moderately broken
			3. Crust - slightly broken
			4. Crust - intact, smooth (stable, no material for erosion)
15	**EROSION TYPE**	**1 - 5**	1. Sheeting (Sh)
			2. Rills and Gullies (R)
			3. Terracettes (T)
			4. Scalding (Sc)
			5. Pedestalling of plants (P)

GSP - Botanal and LFA field recording Codes and Species 2009 (Year 4)

	Parameter		Description / Class
16	**EROSION SEVERITY**	**1 - 4**	1. Severe erosion
			2. Moderate
			3. Slight
			4. Insignificant
17	**DEPOSITS**	**1 - 4**	1. >50 % cover, cm deep; Extensive amount
			2. 21 - 50 % cover; Moderate amount available
			3. 6 - 20 % cover; Slight amount available
			4. 0 - 5 % cover; None or small amount available
18	**SURFACE ROUGHNESS**	**1 - 5**	1. Smooth - <3 mm relief in surface (water holding ability)
	(hold water)		2. Low retention - Shallow depressions 3-8 mm
			3. Moderate - depressions, 9-25 mm, tussock grasslands
			4. Large - deep depressions, visible base
			5. Extensive - V. deep depressions or cracks >100 mm
19	**SURFACE HARDNESS**	**1 - 5**	5. Non-brittle; **no crust**, sponginess, self mulching
			4. Crust very hard and brittle; **metal** to break surface
			3. Moderately hard; **plastic** to break
			2. Easily broken; by **finger**
			1. Loose **sandy** surface; not crusted, penetrate finger
20	**SOIL TEXTURE - classes**	**1 - 4**	1. Silty clay to heavy clay; **V. low infiltration**
	(Infiltration)		2. Sandy clay loam to sand clay; **Slow infiltration**
			3. Sandy loam to silt loam ; **Moderate infiltration**
			4. Sandy to clayey sand; **High infiltration**
21	**GPS Point No.**	**1 - 9999**	Waypoint No. on GPS (= quadrat location no.)
22	**PADS COUNT No.**	**0 - 9**	No. active cattle pads (bet. quadrats)
23	**SLAKE test - classes**	**0 - 4**	0. Not applicable - no stable crust, no fragments, sand
			1. Very unstable - collapses <5 secs
			2. Unstable - >50% collapse 5-10 secs
			3. Moderately stable - crust intact, <50% sub-crust slump
			4. Very stable - remains intact, no swelling

1.4.3.1 Statistical analyses

1.4.3.1.1 REML - analysis of mixed models

The method of *residual maximum likelihood* (REML), sometimes also known as *restricted* maximum likelihood analysis of linear mixed models, was selected for our unbalanced experimental design because it provides an estimation of variance components and modelling of covariance structures. Below is a description of the programmes capabilities and suitability for this project.

The REML algorithm estimates the treatment effects and variance components in a linear mixed model: that is, a linear model with both fixed and random effects. Like regression, REML can be used to analyse unbalanced data sets; but, unlike regression, it can 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. You can also model the covariance structures of the random terms.

The REML method has many applications. It can be used to obtain information on sources and sizes of variability in data sets. This can be of interest where the relative size of different sources of variability must be assessed, for example to identify the least reliable stages in an industrial process, or to design more effective experiments.

REML provides efficient estimates of treatment effects in unbalanced designs with more than one source of error. For example, it can be used to provide estimates of treatment effects that combine information from all the strata of an unbalanced design. It can also be used to combine information over similar experiments conducted at different times or in different places. So you can obtain estimates that make use of the information from all the experiments, as well as the separate estimates from each individual experiment. Finally its ability to model correlated error structures can be useful in a wide range of situations, including repeated measurements, spatial data and random coefficient regression.

Fixed and random effects

1. Fixed effects are used to describe treatments imposed in an experiment where it is the effect of those specific choices of treatment that are of interest, and
2. Random effects are generally used to describe the effects of factors where the values present in the experiment represent a random selection of the values in some larger homogeneous population.

It is then possible to make some inference about this population, for example to estimate its variance and to assess the contribution from a factor to the total variation in the data. Predictions of random effects may also be of interest.

REML estimation

The method of residual maximum likelihood (REML) was introduced by Patterson & Thompson (1971). It was developed in order to avoid the biased variance component estimates that are produced by ordinary maximum likelihood estimation: because maximum likelihood estimates of variance components take no account of the degrees of freedom used in estimating treatment effects, they have a downwards bias which increases with the number of fixed effects in the model. This in turn leads to underestimates of standard errors for fixed effects, which may lead to incorrect inferences being drawn from the data. Estimates of variance parameters which take account of the degrees of freedom used in estimating fixed effects, like those generated by ANOVA in balanced data sets, are more desirable.

The REML method splits the data into two parts: treatment contrasts which contain information only on the fixed effects; and error contrasts (that is, all contrasts with zero expectation) which contain information on the variance components. The error contrasts alone are then used to estimate the variance parameters, since they contain all of the information available on the variance parameters.

1.5 Appendix 5. Botanal / LFA quadrat data

1.5.1 Statistical probability of Botanal / LFA parameters

There were no consistent significant differences between Botanal or LFA parameters for factors grazing system, vegetation type or region for the three years of recording. The % dominant species was significant for the three factors in 2006 and total cover was significant in 2009 (Table 9.5.1).

Table 1.5.1. Summary of statistical analysis probability levels for main Botanal/LFA parameters between grazing systems, vegetation communities and regions in 2006, 2007 and 2009.

Factor	Parameter	Botanal / LFA parameter Statistical probability 2006	2007	2009
Grazing system	Yield	P>0.10	P>0.10	P>0.10
	Sown grass	P>0.10	P>0.10	P>0.10
	Native per grass	P>0.10	P>0.10	P>0.10
	Spp/quadrat	P>0.10	P=0.074	P>0.10
	No. spp 90%	P>0.10	P>0.10	P>0.10
	% dominant spp	P<0.05	P>0.10	P>0.10
	Utilisation	P<0.05	P>0.10	P=0.074
	Woody regrowth	P>0.10	P>0.10	P>0.10
	Total cover	P>0.10	P>0.10	P=0.092
	Litter cover	P>0.10	P>0.10	P>0.10
	LFA Stability	P>0.10	P>0.10	0.078
	LFA Infiltration	P>0.10	P>0.10	P>0.10
	LFA Nutrient cycling	P>0.10	P>0.10	P>0.10
	PatchKey	P<0.05	P>0.10	P>0.10
Vegetation	Yield	P>0.10	P>0.10	P>0.10
	Sown grass	P=0.071	P>0.10	P>0.10
	Native per grass	P>0.10	P=0.099	P>0.10
	Spp/quadrat	P=0.051	P=0.090	P=0.095
	No. spp 90%	P>0.10	P>0.10	P=0.054
	% dominant spp	P<0.05	P<0.05	P=0.086
	Utilisation	P>0.10	P>0.10	P=0.072
	Woody regrowth	P>0.10	P>0.10	P<0.05
	Total cover	P>0.10	P>0.10	P=0.056
	Litter cover	P>0.10	P>0.10	P>0.10
	LFA Stability	P>0.10	P>0.10	P<0.05
	LFA Infiltration	P>0.10	P>0.10	P>0.10
	LFA Nutrient cycling	P>0.10	P>0.10	P>0.10
	PatchKey	P<0.05	P>0.10	P>0.10
Region	Yield	P>0.10	P<0.05	P<0.05
	Sown grass	P>0.10	P>0.10	P>0.10
	Native per grass	P>0.10	P>0.10	P>0.10
	Spp/quadrat	P>0.10	P>0.10	P>0.10
	No. spp 90%	P<0.05	P=0.086	P>0.10
	% dominant spp	P=0.081	P=0.096	P>0.10
	Utilisation	P>0.10	P>0.10	P>0.10
	Woody regrowth	P>0.10	P>0.10	P>0.10
	Total cover	P>0.10	P>0.10	P<0.05
	Litter cover	P>0.10	P>0.10	P>0.10
	LFA Stability	P>0.10	P>0.10	P>0.10

	LFA Infiltration	P>0.10	P>0.10	P>0.10
	LFA Nutrient cycling	P>0.10	P>0.10	P>0.10
	PatchKey	P>0.10	P>0.10	P>0.10

1.5.2 LFA quadrat data

1.5.2.1 LFA Indicators statistical analysis

Mean paddock LFA indices of land condition (stability, infiltration and nutrient cycling) from 2006, 2007 and 2009 were analysed by residual maximum likelihood (REML). Models included fixed effects of Grazing System (*Sys*; Cell, Rotation, Continuous), Vegetation (*Veg*; Brigalow, Eucalypt) and Region (*Reg*; South, North) and appropriate interactions and the random effects of Property, System and Paddocks within System. A step-down procedure was used to remove non-significant (P>0.10) two-way interactions with the three-way interaction always removed. Generally, the models reduced to simple main effects models so main effects models were fitted to all variables and predicted means obtained. In the few cases of evidence (P<0.10) of a Grazing *Sys* by *Veg* interaction, the interaction was subsequently included in the model and predicted interaction means obtained.

Standard error of differences (sed's) were presented and, where differences (P<0.10) were observed, approximate lsd's were calculated and used to perform pair-wise comparisons of means. Distributional assumptions for all analyses were assessed by visual inspection of residual and normal probability plots with no major departures being observed.

1.5.2.2 LFA transect data

A summary of the percentage accumulation and run-off in each grazing system (Table 1.5.1), the grazing system mean (Table 1.5.2) and the property mean (Table 1.5.3) from the 50m LFA transects at the start of the project are presented. The mean of the three systems was similar (70-76 % accumulation and 23-30% run-off), however the range of accumulation was from 30 to 100%, both in continuous systems. The average accumulation across all sites was 72% (range 42-97%). The majority of accumulation areas were 'grassy patches' with smaller areas of 'sparse grass' and majority of resource loss areas were 'sparse grass' and to a lesser degree 'bare' areas. (Data for individual transects or resource zones are not presented).

Table 1.5.1. LFA transect accumulation and run-off (%) in 21 grazing systems at nine primary sites.

Property	Grazing System	Mean all transects Accumulation %	Run-off %
Banyula	Cell (Loam)	74.6	25.4
	Continuous	74.6	25.4
Berrigurra	Cell	95.6	4.4
	Rotation	96.1	3.9
	Continuous	100.0	0.0
Frankfield	Cell	44.8	55.2
	Rotation	68.3	31.7
	Continuous	30.4	69.6
Melrose	Cell	48.9	51.1
	Rotation	33.8	66.2
	Continuous	51.5	48.5
Rocky Springs	Rotation	80.9	19.1
	Continuous	97.6	2.6

Salisbury	Cell	92.5	7.5
	Continuous	87.2	12.8
Somerville	Cell	72.0	28.0
	Rotation	96.3	3.7
Sunnyholt	Cell	96.4	3.6
	Continuous	94.8	5.2
Ticehurst	Cell	40.2	59.8
	Rotation	44.4	55.6

Table 1.5.2. LFA transect accumulation and run-off (%) grazing systems mean at nine primary sites.

Grazing System	Accumulation %	Run-off %
Cell	70.6	29.4
Rotation	70.0	30.0
Continuous	76.6	23.4

Table 1.5.3. LFA transect accumulation and run-off (%) means at nine primary sites and overall site mean.

Property	Accumulation %	Run-off %
Banyula	74.6	25.4
Berrigurra	97.2	2.8
Frankfield	47.8	52.2
Melrose	44.7	55.3
Rocky Springs	89.2	10.8
Salisbury	89.9	10.1
Somerville	84.2	15.8
Sunnyholt	95.6	4.4
Ticehurst	42.3	57.7
All Sites	72.4	27.6

1.5.3 Land condition

The land condition in all monitor paddocks was assessed at three scales, from quadrats to whole paddocks:

1**. Quadrat scale**. The Botanal/LFA quadrat data was analysed using a modified PATCHKEY method to allocate individual quadrats to land condition classes LC1-LC4. The species and species group definitions are shown in Table 1.5.4.

The PATCHKEY technique, developed by CSIRO Townsville, provides an objective means of estimating land condition. The technique uses pasture composition, perennial grass basal area and ground cover to allocate land to the four classes (and also to sub-classes). In our analysis a Land Condition Score (LCS) based on a LC1 to LC4 scale was calculated from the pasture and LFA data recorded in each quadrat at the end of the summer growing periods for 2006, 2007 and 2009. The PatchKey system used different definitions of land condition to the ‘ABCD’ method; however, the LC1-LC4 approximates the ‘ABCD’ land condition system scores respectively.

The LCS was calculated from the dominant species group (SG) and basal area of perennial grasses (BA). Using the recordings of species (Table 1.4.2) each quadrat was allocated to an SG on the basis of which species dominated (i.e. has the highest % composition) the quadrat. There were six groups which were dominated by:

1 – 3P grasses (perennial, palatable and productive),
2 – increaser grasses (perennial, lower palatability);
3 - Indian couch/bluegrass (*Bothriochloa pertusa*);
4 - annual grasses;
5 – legumes; and
6 – other species (forbs, sedges) or bare.

The SG was then combined with BA to produce the LCS for the quadrat as follows:

For SG=1; if BA>3, LCS=1, if BA>1.5, LCS=2, else LCS=3
For SG=2; if BA>1.5, LCS=3, else LCS=4
For SG=3; if BA>1.5, LCS=2, else LCS=3
For SG=4; if BA>0, LCS=3, else LCS=4
For SG=5; LCS=3
For SG=6; LCS=4

If it doesn't fit any of these categories, it is set as a missing value.

Table 1.5.4. Herbaceous species recorded and six species groups.

3P grasses		
Astrebla elymoides	*Astrebla lappacea*	*Astrebla squarrosa*
Bothriochloa bladhii	*Bothriochloa ewartiana*	*Chrysopogon fallax*
Cymbopogon spp.	*Dichanthium* spp.	*Digitaria* spp.
Eriochloa spp.	*Heteropogon contortus*	*Panicum* spp.
Eulalia aurea	*Sporobolus* spp.	*Themeda triandra*
Cenchrus ciliaris	*Chloris gayana*	*Panicum maximum*
Urochloa mosambicensis	*Melinis repens*	Other sown perennial grass
Increaser grasses		
Aristida calycina	*Aristida latifolia*	*Aristida leptopoda*
Aristida pruinosa	*Aristida ramosa*	Other *Aristida* spp.
Bothriochloa decipiens	*Chloris* spp.	*Enneapogon* spp.
Enteropogon spp.	*Eragrostis* spp.	*Paspalidium* spp.
Tripogon loliiformis	*Bothriochloa pertusa*	Other native perennial grass
Annual grasses		
Dactyloctenium spp.	*Iseilema* spp.	*Tragus australianus*
Perotis rara	*Digitaria ciliaris*	*Brachyachne convergens*
Sporobolus caroli	Other annual grasses	
Legumes		
Alysicarpus spp.	*Crotalaria* spp.	*Desmodium* spp.
Glycine spp.	*Indigofera* spp.	*Macroptilium* spp.
Medicago spp.	*Neptunia* spp.	*Rhynchosia minima*
Stylosanthes hamata	*Stylosanthes scabra*	*Zornia* spp.

Other native legumes	Other sown legumes	

Other species

Cyperus spp.	*Fimbristylis* spp.	*Parthenium hystophorus*
Sclerolaena spp.	*Malvaceae / Sida* spp.	*Verbena* spp.
Other forbs	Other sedges	

2. Land type scale. The land condition of each land type in each paddock was assessed by the 'ABCD' methodology.

The land types in each paddock at each property were identified from Spot 5 satellite imagery and the Botanal surveying, and then mapped in ArcMap. The land type definitions were from the GLM regional lists. Each land type within each paddock was assessed by the 'ABCD' condition framework in 2006, 2007 and 2009. Numerical values were assigned to the ABCD categories (A = 1; B = 2; C = 3; D = 4) and averages weighted by the area in each condition were calculated for each land type in each grazing system.

3. Paddock scale. The whole paddocks were assessed by the 'ABCD' methodology after pastures and soil surface conditions were recorded.

The two larger scale land condition assessments, based on the 'ABCD' framework, consider that the land condition is the capacity of land to respond to rain and produce useful forage. This technique for measuring land condition at a paddock scale has been developed and is recommended in the STOCKTAKE and GLM packages.

The four land condition (A, B, C, D) definitions used for each land type within each paddock were:

i. "A" condition land has good coverage of perennial grasses dominated by those species considered to be 3P grasses for that land type and ground cover is above 70%. There are few weeds, good soil condition, no erosion and no or early signs of woodland thickening.

ii. "B" condition land is similar to "A" except that there is some decline of 3P grasses, and ground cover is around 40 - 70%. There are some signs of previous erosion and/or current susceptibility to erosion is a concern, and there is some thickening in density of woody plants.

iii. "C" condition land has a general decline of 3P grasses with large amounts of less favoured species and ground cover less than 40%. There are obvious signs of past erosion and/or current susceptibility is high. There is a general thickening in density of woody plants.

iv. "D" condition land has a general lack of any perennial grasses or forbs. There is severe erosion or scalding, resulting in a hostile environment for plant growth. Thickets of woody plants cover most of the area.

1.5.3.1 Diversity measures

Three measures were used to describe the diversity of species in the pastures.

1. **Number of species per quadrat** – the number of species or species groups that were recorded in each quadrat was counted and these values were averaged to provide a diversity estimate for each grazing system at each site.

2. **Number of species that contributed 90% of the pasture yield** – in each grazing system at each site the species was ranked in descending order of their proportion in the pasture and the number of species to contribute 90% of the yield was counted.

3. **Contribution of the dominant species** – the proportion of the total yield contributed by the dominant species was recorded.

1.6 Appendix 6 - VegMachine Cover estimates

1.6.1 VegMachine Methodology

VegMachine analysis is a recent approach to paddock-scale land condition assessment based on a bare ground index (BGI) derived from Landsat satellite time-series data over about the last 21 years. The satellite imagery is analysed producing a bare ground index, which has been reversed to produce a vegetation cover index. This cover includes both the tree layer and the pasture ground layer. It is possible to analyse any differences (statistically) between paddocks to determine if they are in different condition. The VegMachine method and initial applications have been published (e.g. Karfs *et al.* 2004; Beutel *et al.* 2005; Peel *et al.* 2006).

The VegMachine analysis involves collating spatial GSP monitor paddocks (74), the lot plan areas of the whole property, and the neighbourhood catchment data in a GIS, with paddock mapping identified in ArcMap. The paddock shape files for the GSP paddocks were derived from GPS points of all corners and bends, as part of planning the original Botanal recording and for calculating areas, grazing pressures and long-term carrying capacities. The whole property analysis is conducted on total lot plan areas that make up each primary site. Some properties were a single lot plan area, while others are made up of multiple lease areas.

An annual paddock, property and catchment cover index from time-series Landsat data over the last 21 years, 1986-2007, was calculated and graphed. The annual satellite images were taken around August-September when clouds were minimal, and the pasture cover was still near its peak and of a uniform mature colour which helped give a more consistent contrast between dry vegetation ground cover and the bare soil background. Any trees also had their lowest foliage cover in late winter to early spring. Data from the image was used to produce an average bare ground index for each shape file area, e.g. each paddock. We compared the annual vegetation cover index results, using the inverse of the bare ground index, between paddocks, grazing systems and the whole property with the surrounding neighbourhood catchment. The annual rainfall and the owner's knowledge of paddock/property development and management histories were used to describe the changes in paddock/system vegetation cover. Management effects on cover include: clearing, burning, cropping, varying stocking rates and grazing systems. Drought periods were the major climatic influence on cover. In the 2 years of GSP field monitoring, 2006 and 2007, the GSP botanal and LFA paddock data was used to confirm the VegMachine results. Most paddocks had been cleared so the cover could be directly related to the pasture layer. There were sown pastures, predominantly buffel grass, and native perennial grass pastures included in the monitor paddocks.

The Landsat TM bands used in the VegMachine analysis were the same for all sites.

At the GSP sites, we used the methods developed in the NT investigating the separation of seasonal responses from management via an analysis of paddock cover changes over a 21-year range of seasonal cycles. This assessment aimed at determining the effects of different grazing management regimes within the variability arising from seasonal changes.

The long-term rainfall records from the nearest station (from Rainman) with around 100 years of records were chosen for annual rainfall over the 21-year periods, for interpreting the cover analysis, if records were not available from the primary site. These long-term stations were also used for the long-term median rainfall comparison on the VegMachine vegetation cover graphs.

Vegetation cover field measurements in the GSP were only over the two years of available Landsat data (2006 and 2007); however, the VegMachine approach allowed the last 21 years of average paddock cover to be monitored. To assess if any cover differences could be directly related to the grazing system and property management, the surrounding properties with similar landtypes in the same neighbourhood catchments were also analysed where data was accessible. This was aimed at identifying any real management differences within the paddocks and different grazing systems, and helped separate seasonal versus manager impacts.

Over the last 21 years, there have been two significant drought periods affecting the GSP sites. They were from 1992-1994 and from 2001-2004 and continuing beyond at some sites. Comparing the monitor paddocks, whole property and neighbourhood catchment cover over these periods has implications for changes in management, which suggests recent training in grazing land management provided by both private companies and Government may have had an influence on soil cover management. It is between these two drought periods that the more intensive grazing systems have been installed at the sites.

At each site, the VegMachine cover analysis has been reviewed by the property owners and any fluctuations between paddocks have been identified where possible, within the limits of the memory and records of the owners. The cover index is equated to an approximate cover % for discussions with the property owners. On occasions the cover index value is considered higher than the estimated actual pasture vegetation cover %.

The cover levels in the field (means for paddocks and grazing systems) measured at Botanal recording in autumn of 2006 and 2007 for total pasture cover (%), litter only cover (%) and woody cover (%), with the associated dry matter yield (kg/ha), are included in this report. The measured cover can be compared with the annual vegetation cover index (VegMachine) for the years 1987 to 2007 shown in time series graphs. The Landsat cover index included woody cover with the pasture layer; however, most of the GSP paddocks have been cleared of most tree cover, or have a negligible or low percentage tree cover, except for Somerville which is virgin open woodland.

1.6.2 DERM pasture and cover reports

The bare ground image data (Landsat) analysis available from Qld NRW is combined with pasture growth modelling (AussieGrass) and long-term rainfall to produce Pasture and Rainfall Reports and Ground Cover Reports for lot plan areas. These analyses have been created for the whole area of the properties of the GSP, but are not available to the paddock or system scale for a direct comparison with field measured data. The annual pasture cover predictions by AussieGrass modelling for the whole property have been compared with the VegMachine cover analysis and GSP data recorded in the field in 2006 and 2007 for the paddocks and averages of grazing systems. Where available, an image of the average vegetation cover and surrounding properties over the last 5-6 years has been included. The monitor paddocks have been superimposed to show their cover relationship with the surrounding areas.

The DERM Pasture Growth and Rainfall, and Ground Cover reports are from the web site: http://www.longpaddock.qld.gov.au/AboutUs/ResearchProjects/AussieGRASS/ and use the following criteria:

1.6.2.1 Pasture and Rainfall Summary

"The Pasture and Rainfall Summary gives a report, for the location (lot plan) on: 1. Pasture total standing dry matter (TSDM – total green and dead material above ground but not including plant litter); 2. Pasture and litter cover; 3. Rainfall; and 4. Pasture growth. Pasture TSDM, cover and growth are calculated using the Grasp/AussieGrass model."

1.6.2.2 Ground Cover Report

“This report is generated by FORAGE on a request for imagery for Most Recent (closest available – see top left of image for date). The lot plan is highlighted. Areas of the map where there are too many trees or cloud cover for the satellite to see the ground is masked out in green. It there is no image, then there is probably no image available for the chosen location”.

As an example, the Ground Cover Report for Berrigurra states: “The chart is a time series of ground cover, with the mean ground cover from the bare ground index as red dots, and the AussieGrass modelled ground cover as a blue line (monthly output). Possible differences between AussieGrass and the GBI product are caused by inaccuracies in the model and the BGI product, differences between actual stocking rates and the ABS stock numbers used in AussieGrass, and limited resolution of AussieGrass and the available climate data. AussieGrass is using Aussie\Grass landtype Gidgee Brigalow N (4059) y2.43 SI12 (2489) for this point”

Both Pasture and Ground Cover analyses for the main lot plan lease areas covering the GSP grazing system areas of the nine sites was investigated.

The interpretation of these time series cover data outputs should be treated carefully, and we are not making absolute claims such as ‘one system is better than the other’ based on the cover results. The outputs are used to identify major paddock or grazing system differences that have been discussed with the owners to identify if there are known management effects showing up. The linkages with our Botanal on-ground data can be explored over the first two years only. All owners were impressed with the results and could often suggest what was happening with their development and management that may have caused any paddock cover divergence. There were multiple reasons provided, such as: pulling, clearing, blade ploughing, stick raking, buffel spreading, cutting timber, regrowth increasing, over stocked, low cattle numbers, cultivation, crop growing, burning, etc. Some of these development or management issues are highlighted on the time series figures for each property.

The VegMachine cover graphs for the last 21 years for grazing systems and paddocks for the nine sites are shown and discussed separately and can be compared with GSP field data and the NRW modelled outputs.

An example of the DERM modelled pasture and cover output for Banyula is shown below:

1.6.2.3 Banyula

The ground cover index image produced from the average of a series of images over 2003-2007 for Banyula is shown in Figure 9.6.1. This image shows the highly variable cover in Bankstown, from very high to bare areas, relative to the loam and clay soil cell areas. The Cell-loam has maintained a consistent average cover, with some patches of low cover in paddock E7 only. In the Cell-clay paddocks M6 has maintained the highest cover. Because this paddock has gilgais it was not all cultivated and is all buffel grass with the most brigalow regrowth, helping to maintain high vegetation cover. The treed areas of Bankstown are clearly identified (dark green) in the image.

The bare ground image data (Landsat) analysis available from QDERM was combined with pasture growth modelling (Aussie GRASS) and long-term rainfall to produce Pasture and Rainfall Reports and Ground Cover Reports for the whole of Banyula. The results of the modelled pasture standing dry matter (kg/ha), total pasture and litter cover (%), annual rainfall (mm) and annual pasture growth (kg/ha) from 1970 to 2008 (Figure 9.6.1) show the wide annual variation in all parameters and the longer-term cycles reflecting droughts and other periods of above average rainfall.

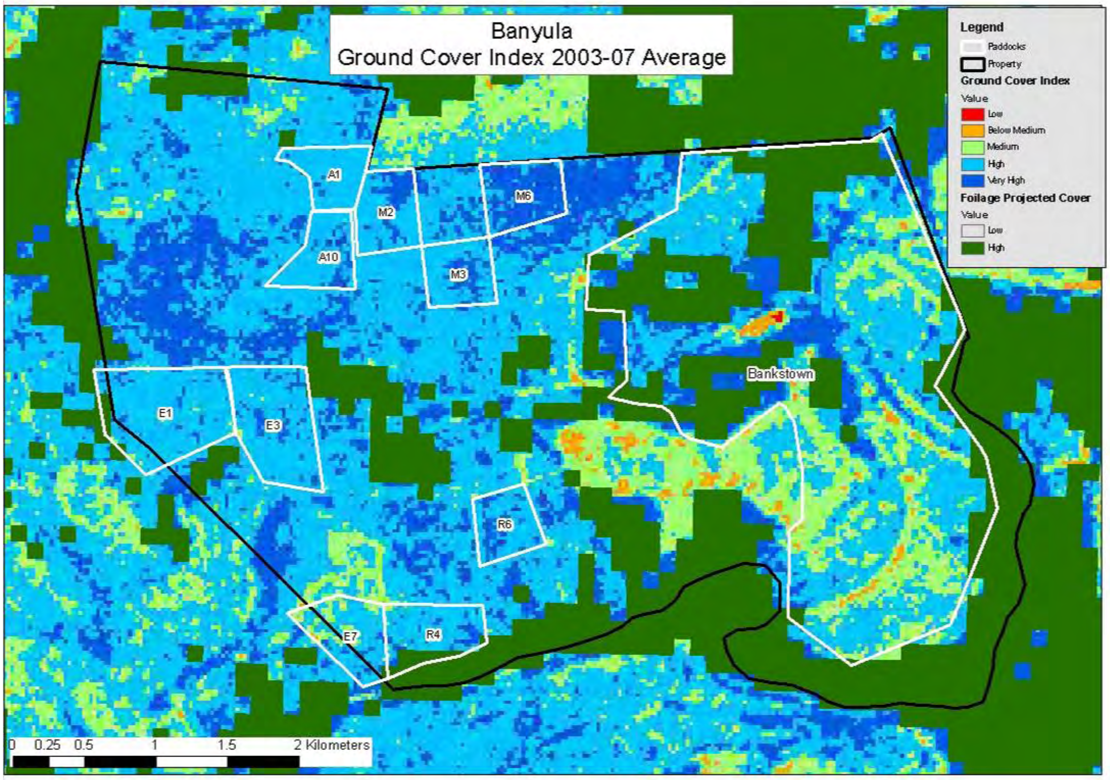


Figure 9.6.1. Average (2003-2007) ground cover index (vegetation cover) image for the Cell-loam and Cell-clay, Bankstown Continuous paddock, the whole Banyula property and surrounding properties.

The pasture yields measured in the GSP monitor paddocks in autumn of 2006 and 2007 are more similar (means over grazing systems of 1430 and 1620 kg/ha respectively for the two years) than the modelled results. This could reflect the grazing management of this property where stock numbers are adjusted periodically throughout the year to reflect the actual pasture production. The DERM models suggest there was a much lower cover in (in winter) 2007 (to 20%) than in 2006, however, such low cover was not recorded in autumn in the monitor paddocks. There is some conflict in the DERM predicted cover and pasture growth in 2007; 4000 kg/ha of pasture growth is predicted with a cover of near 20% and almost negligible standing pasture yield. For these models to be useful on a smaller scale, for example individual paddocks or grazing systems, the outputs need to be more consistently close to field recorded information.

The DERM analysis of pasture production related to rainfall (Figure 9.6.2) shows the wide annual variation in pasture growth rates and rapid responses to summer rain. Average property pasture and litter cover has fluctuated between 20% and 90% since 1970. There is a good correlation between pasture growth and cover, both closely related to rainfall events.

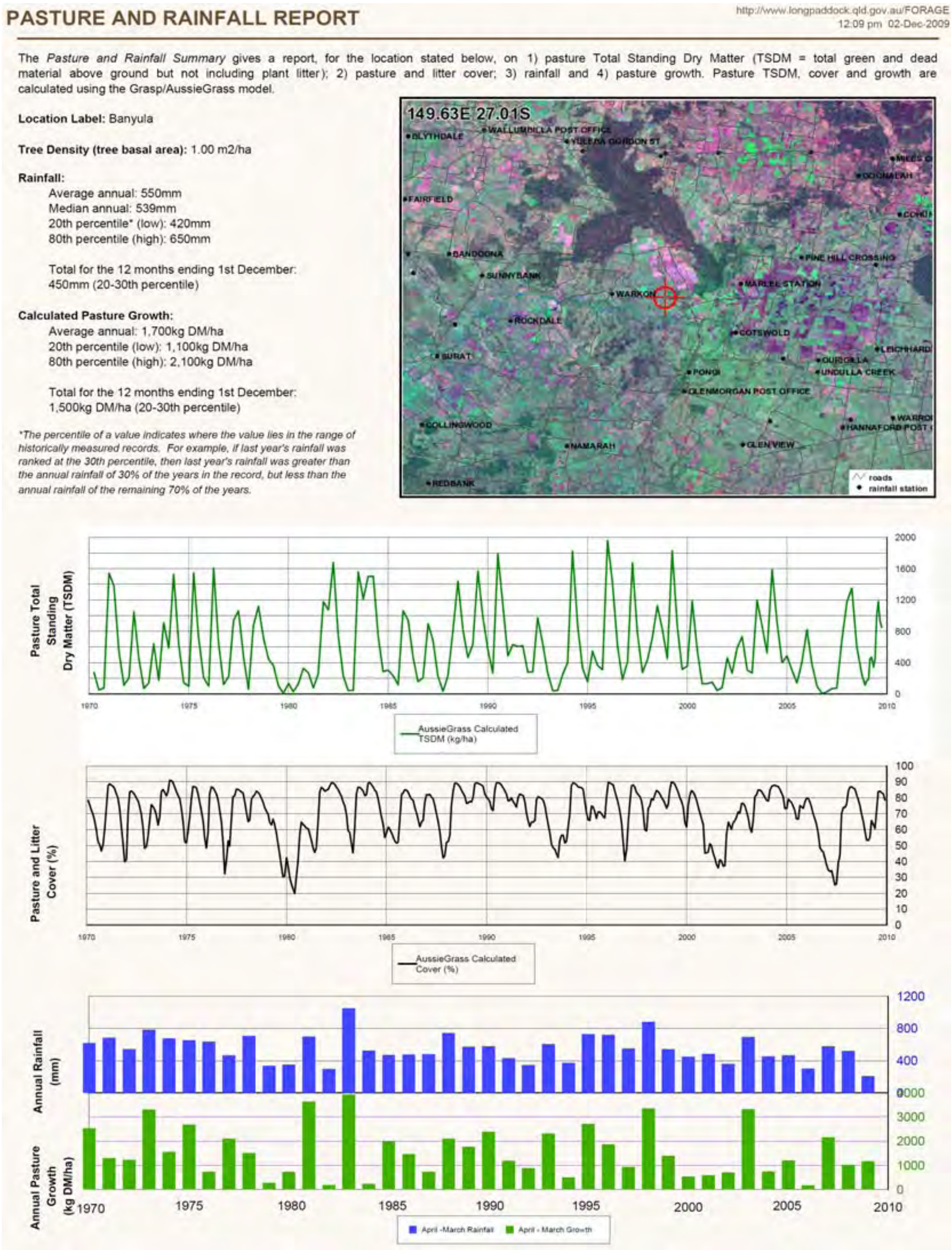


Figure 9.6.2. Modelled pasture standing dry matter (kg/ha), total pasture and litter cover (%), annual rainfall (mm) and annual pasture growth (kg/ha) from 1970 to 2009 at Banyula (DERM data).

The modelled ground cover (%) from AussieGrass compared with Landsat whole property BGI from 1985 to 2009 (Figure 9.6.3) shows good correlations in many periods, with the Landsat BGI suggesting higher cover at other times. For the whole property the BGI method indicates a cover range from 38-95%, while the AussieGrass model suggests cover ranged from 25-90% over this period. The AussieGrass model predicts cover of near 55% in 2006, the same as recorded in the GSP paddocks, declining to about 25% in 2007, which is lower than was recorded in the GSP paddocks (about 48%). The model suggests a sharp increase to about 85% cover in the higher rainfall summer of 2007-08. Cover and yields were not recorded in the GSP paddocks in 2008.

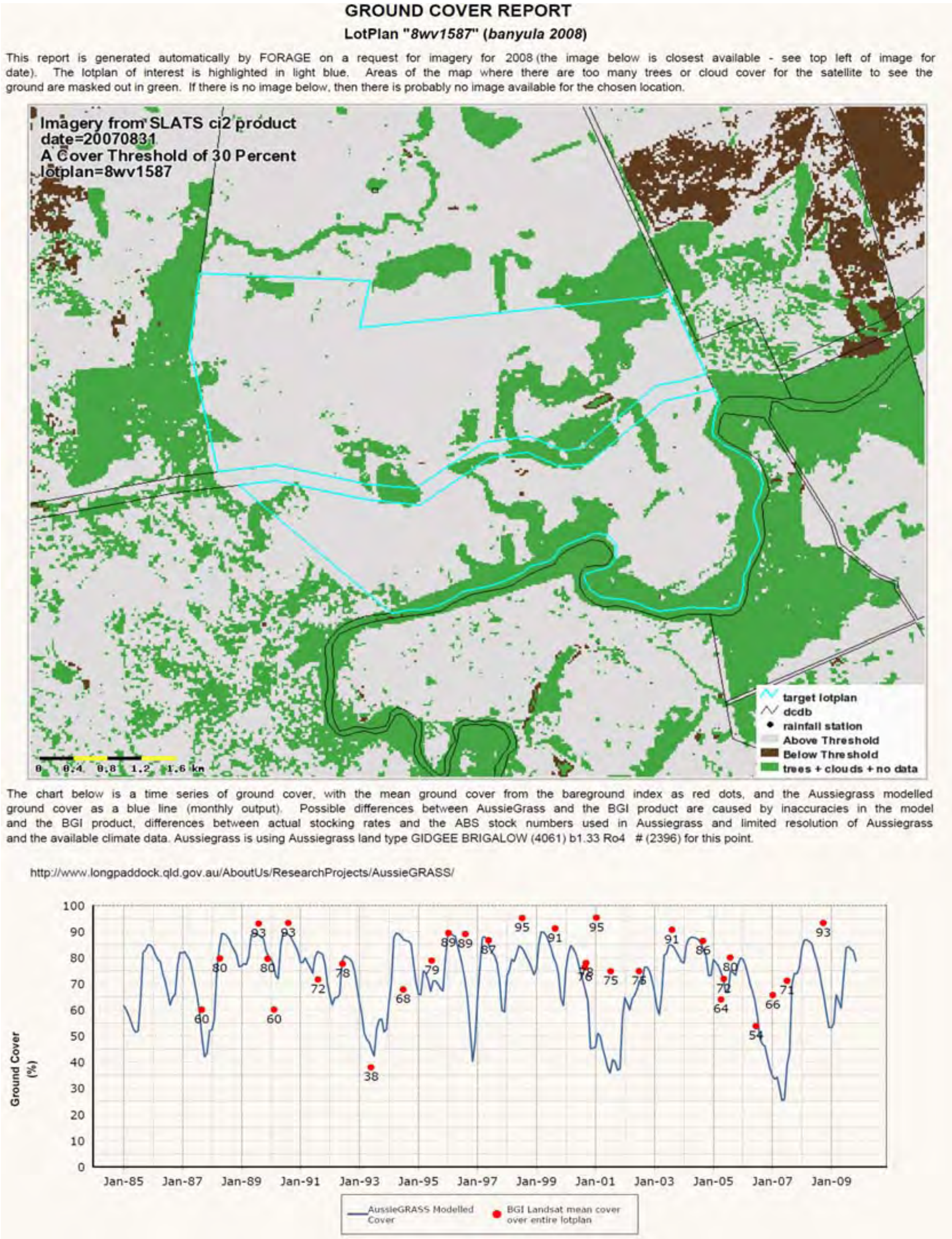


Figure 9.6.3. Modelled ground cover (%) from AussieGrass compared with Landsat whole property BGI from 1985 to 2008 at Banyula (DERM data).

1.6.3 References

Anon 'Rainman StreamFlow' v4.3 CD (Queensland DERM)

Beutel, T.S., Karfs, R.A., Bull, A.L., Peel, L. and Wallace, J.F. (2005). VegMachine - putting pastoralists in the picture. *Agricultural Science*, **17**(3): 18-20.

Karfs, R.A., Applegate, R., Fisher, R., Lynch, D., Mullin, D., Novelly, P., Peel, L., Richardson, K., Thomas, P. and Wallace, J.F. (2000). *Regional land condition and trend assessment in tropical savannas: The Audit Rangeland Implementation Project Final Report.* National Land and Water Resources Audit, Canberra. http://audit.ea.gov.au/ANRA/rangelands/docs/project.htm!

Karfs, R.A. & Trueman, M. (2005). *'Tracking Changes in the Victoria River District Pastoral District, Northern Territory, Australia - 2005'*. Report to the Australian Collaborative Rangeland Information System (ACRIS) Management Committee.

Karfs, R.A., Daly, C., Beutel, T.S., Peel, L. and Wallace, J.F. (2004). VegMachine – delivering monitoring information to Northern Australia's pastoral industry. 12th Australasian Remote Sensing and Photogrammetry Association Conference, Freemantle.

Peel, L.J., Beutel, T.S., Bull, A.L., Karfs, R.A. and Wallace, J.F. (2006). *VegMachine – Extending Integrated Rangeland Monitoring Information to Industry.* Final Report to MLA, Project NBP.315 (June 2006, ISBN 9781741910940).

Tongway, D.J. and Hindley, N.L. (2004). Landscape Function Analysis Manual: Procedures for monitoring and assessing landscapes. CSIRO Sustainable Ecosystems, ver. 3.1, May 2004, CD-Rom.

Wallace, J.F. and Thomas, P. (1999). *Monitoring and summarizing rangeland changes using sequences of Landsat data.* People and Rangelands: Building the Future (Eds. D. Eldridge & D. Freudenberger), pp. 777-778. Proc. VI International Rangeland Congress. Townsville, Australia, July 1999, pp 19-23.

Wallace, J.F., Caccetta, P.A. and Kiiveri, H.T. (2004). Recent developments in analysis of spatial and temporal data for landscape qualities and monitoring. *Austral Ecology* **29**: 100-107.

1.7 Appendix 7 - Fixed-point photograph record

A time series of fixed points photographs from six to twenty sites within each monitor paddock was taken along the original LFA transect lines annually or more frequently. These photographs show the vegetation and soil surface cover changes, and seasonal effects during the project monitoring period. One main site is selected to represent seasonal or annual pasture condition changes in each grazing system at each site and time-series photographs are presented in the nine individual property reports in Appendix 9.1. (Photographs from the other fixed sites within each paddock are not presented here).

1.8 Appendix 8 - Pasture modelling

1.8.1 Growing seasons

In a series of papers published in *Agricultural Systems*, McCown analysed the climatic potential for beef production in northern Australia. He used long-term rainfall records and mean values for temperature and evaporation in simple water balance models to define “green seasons” and “dry seasons” and showed animal growth rates were related to these. These methods have been used and extended in this study for the nine sites.

Daily rainfall, evaporation and maximum and minimum temperatures for the period 1957 to 2006 were extracted from the SILO data base for each property. These were used in the simple water balance model WATBAL to estimate weekly values the “water index”, which is the ratio of actual to potential evapotranspiration and has values between 0 and 1. Weekly “temperature indices” for tropical and temperate pasture species were calculated using the weekly values of mean temperature ([maximum + minimum]/2) taken the temperature records using the relationships shown in
Figure 1.8.1 below. A weekly “growth index” was calculated as the minimum value of the water and temperature indices. For all indices, a value of 0 indicates that factor is totally limiting for growth, and a value of 1 indicates no limit to growth by that factor.

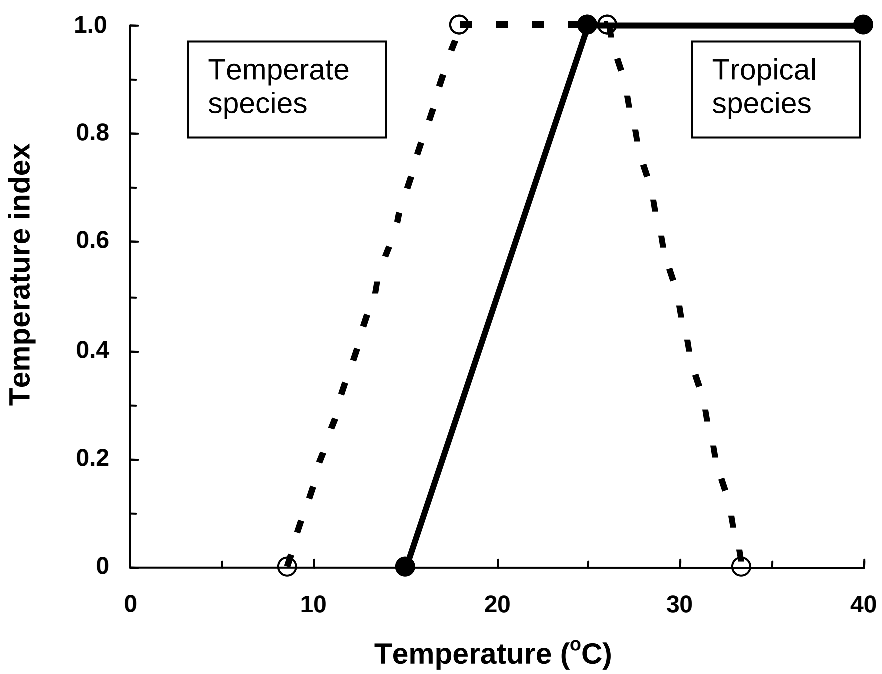


Figure 1.8.1. Temperature indices for tropical and temperate grass species.

McCown defined the start of the green season (Gowk) when liveweight gain commences after the dry season as the first week where 3 of 4 weeks AND 6 of 8 weeks had a growth index of more than 0.1. He defined the end of the green season (Stopwk) as the first of two consecutive weeks when the water index fell below 0.1.

These methods were used to calculate the following for each site:

- Green season – the number of weeks from Gowk to Stopwk.
- Annual growth weeks – the sum of the weekly growth indices for tropical pastures from one Gowk to the next Gowk.

Extra temperate growth weeks: In many years, particularly at the southern sites, there can be a number of weeks where moisture is available (water index >0), but temperature is limiting for tropical species. The sum of the differences in weekly growth indices between tropical and temperate pastures values when the growth index for temperate pastures exceeded the growth index for tropical pastures was calculated as an estimate of the likely boost to pasture growth from temperate species in a pasture. The length of the pasture green season, annual growth period and extra temperate growth weeks, at the nine sites is summarised in Table 1.8.1.

Table 1.8.1. Pasture green season, annual growth weeks and extra temperate growth weeks (50-year mean) for nine sites.

Property	Green season (weeks)	Annual growth (weeks)	Extra temperate growth (weeks)
Banyula	29	12.1	6.5
Berrigurra	29	14.6	3.2
Frankfield	24	13.4	2.5
Melrose	35	18.6	3.8
Rocky Springs	31	15.4	7.4
Salisbury Plains	33	20.3	1.8
Somerville	19	11.1	0.4
Sunnyholt	29	14.1	6.5
Ticehurst	27	11.7	6.5

The longest growing seasons are at the sites near the east coast (Salisbury Plains and Melrose) and Somerville in the north-west has the shortest season – this is true for both the length of the green season and the number of growth weeks for tropical pastures. The most southern sites (Banyula and Ticehurst) have similar numbers of growth weeks for tropical pastures to Somerville, but many more growth weeks with temperate species (6.5 weeks compared to 0.4 weeks). Buffel grass has a greater capacity to respond to this extra green period than the native tropical grasses.

1.8.2 GRASP modelling

The GRASP (GRASs Production) model is a deterministic, point-based model of soil water, grass growth and animal production (McKeon *et al.* 1990, 2000; Littleboy and McKeon 1997). Soil water is simulated from daily inputs of rainfall, temperature, evaporation, vapour pressure and solar radiation. Plant growth is calculated from transpiration, but includes the effects of vapour pressure deficit, temperature, radiation interception, nitrogen availability and grass basal area. The competitive effect of trees is simulated via their effects on water use and nitrogen uptake.

Land types were selected from the GLM lists for each region and the .mrx files for these were used. Daily weather data from 1889 to 2009 was obtained from SILO climate data sets (Jeffrey *et al.* 2001). GRASP was run for the major land types at each of the nine site and some parameters in the .mrx files for these land types were adjusted so the predicted standing dry matter values better matched the pasture yield values determined in the field. The final values used for some GRASP parameters are sown in Table 1.8.2.

Table 1.8.2. Tree basal area and GRASP parameters used for the different sites and land types.

Site	Land type	TBA	ASWC	Max N	Regrowth	TUE	Min N
Banyula							
	Brigalow Belah Scrub (buffel)	0	102	20	3.5	25.4	0.50
	Cypress pine on duplex soils (buffel)	10	75	15	6.0	17.0	0.40
	Poplar Box Flats (buffel)	1	145	20	3.5	17.0	0.40
	Poplar box on duplex soils (buffel)	1	90	20	3.5	16.0	0.50
Berrigurra							
	Brigalow Blackbutt (Emerald)	1	183	25	6.0	20.0	0.68
Frankfield							
	Buffel on scrubs on deep clays	1	102	20	3.5	20.0	0.50
Melrose							
	Blue gum/River red gum flats (R'ton/Marl)	2					
	Silver leaved ironbark on texture contrast soils (Morinish)	1	100	20	3.5	13.5	0.60
Rocky Springs							
	Silver-leafed ironbark on granite	1	76	20	1.0	13.5	0.40
	Narrow-leafed ironbark on granite	5					
Salisbury Plains							
	Bluegrass browntop plains	0	142	20	3.5	25.4	0.42
	Coastal tea tree lowlands (improved)	5	75	15	2.0	13.5	0.50
	Poplar gum dominant woodlands (improved)	1	120	25	6.0	15.0	0.50
Somerville							
	Sandy forest country	3	150	15	5.0	13.5	0.40
Sunnyholt							
	Brigalow with softwood scrub species (buffel)	1					
	Poplar box/ brigalow/ bauhinia (buffel)	1	84	25	6.0	15.0	0.40
Ticehurst							
	Cypress pine on duplex soils (buffel)	0					
	Poplar box / Silver-leaved ironbark (buffel)	0	97	20	7.0	20.0	0.50

Using the rainfall values from 1889 to 2009 the median annual pasture growth was estimated. The annual pasture growth estimates for the different land types for 2006 to 2009 were used to calculate the amount of pasture grown in the different paddocks and grazing systems at each site. The weekly values of the growth index (a value between 0 and 1 where 0 = no growth and 1 = no limit to growth) were calculated to show how growing conditions varied during the experimental period.

1.9 Appendix 9 - Spatial analyses - pasture and soil surface data

Different grazing systems can be considered to lie along a spectrum of increasing management intensity from continuous set-stocking at low stock densities in large paddocks, to cell grazing at high stock densities with large numbers of paddocks and frequent movement of cattle in relatively small paddocks (see Chapter 6 for the development of an index of management intensity). It is hypothesised that, as grazing system intensity increases, spatial uniformity of grazing will increase. This hypothesis has been addressed using a method of spatial analysis by distance indices (SADIE; Perry 1995) to assess the degree of spatial uniformity in pasture and soil surface data of the different grazing systems.

As described in the previous section, pasture and soil surface condition were assessed in 2006, 2007 and 2009 by a combination of Botanal and LFA recording systems based on quadrats (50 x 50 cm) located on a fixed, pre-determined sampling grid was used to assess pasture and soil condition.

Spatial patterns or degree of uniformity across each paddock, in pasture and soil surface attributes were investigated using the method of spatial analysis by distance indices. The SADIE methodology detects and measures the degree of non-randomness in the two-dimensional spatial patterns of populations (Perry 1995). Briefly, SADIE calculates an index based on the total distance of the sample from a completely regular arrangement by comparing the spatial arrangement of the observed sample with arrangements derived from it, such that they are as regularly spaced as possible – a distance to regularity. Although the SADIE methodology was originally developed to assess spatial pattern in count data (Perry *et al.* 1999), and it can validly be extended to other forms of data (Perry, *pers. comm.*).

The spatial pattern of each individual paddock will be influenced by how recently a paddock has been grazed. This is particularly pertinent for paddocks in a cell system as paddocks cover a range from just grazed to having been spelled for some time and are about to be re-grazed.

For each attribute, the data in each paddock were displayed graphically with ‘shade’ plots (see

Figure 1.91 for an example). Each paddock was tested for spatial randomness, or spatial aggregation, using the SADIE methodology. The results were then summarised across paddocks and properties to give the number (or proportion) of paddocks in a grazing system for which there was no evidence (P>0.10) that the data were not spatially uniform. A chi-squared test for contingency tables was then used to statistically compare grazing systems.

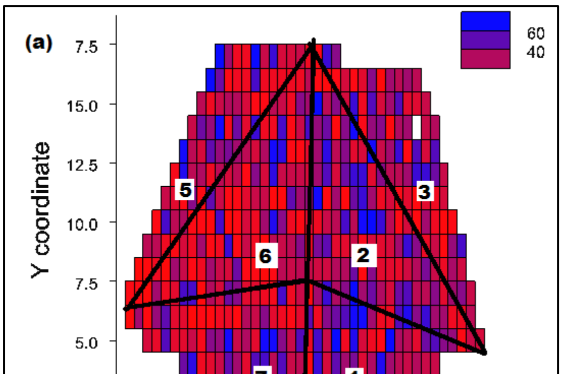


Figure 1.91. Total ground cover (%) in 2007 for the six cell paddocks that were monitored at one site.

When interpreting these results a number of issues need to be considered:

a. the scale of the sampling grid varies among paddocks,

b. only a single scale is used for all measures in a paddock, but different measures may vary at different scales so testing at another scale may show a different result,

c. the data from each small quadrat are used to represent larger areas (sometimes more than 1 ha) under the assumption that the area is similar to the quadrat for that measure. In some cases, there may be as much variation between individual patches within the area as there is between quadrats over the whole paddock, and

d. the analysis is restricted by the limited number of rotation and continuous paddocks monitored.

References

Perry, J.N. (1995). Spatial analysis by distance indices. *Journal of Animal Ecology* **64,** 303-314.

Perry, J.N., Winder, L., Holland, J.M. and Alston, R.D. (1999). Red-blue plots for detecting clusters in count data. *Ecology Letters* **2,**106-113.

1.9.1 Paddock and system uniformity results

1.9.1.1 Litter cover

There were no significant effects on within paddock variation in litter cover between systems, vegetation type or regions in any year (Table 9.9.1).

Table 1.3.1. Percentage of uniform paddocks for litter cover in 2006, 2007 and 2009*.

Treatment	**Uniform paddocks for litter cover (%)**					
	2006		**2007**		**2009**	
Syst/Vegn/Region	Mean	Transf.	Mean	Transf.	Mean	Transf.
Grazing system (GS)		ns		ns		ns
Cell	66	0.68	62	0.50	31	-0.78
Rotation	62	0.48	38	-0.49	11	-2.09
Continuous	54	0.15	59	0.36	45	-0.20
Av. s.e.d.		0.59		0.84		1.17
Vegetation type (V)		ns		ns		ns
Brigalow	71	0.88	52	0.08	37	-0.53

Eucalypt	50	-0.01	54	0.17	18	-1.51
s.e.d.		0.70		0.62		0.68
Region (R)		ns		ns		ns
North	60	0.42	47	-0.13	21	-1.30
South	61	0.46	59	0.37	32	-0.74
s.e.d.		0.92		0.63		0.69

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

1.9.1.2 Tree/shrub cover

Paddock tree/shrub cover uniformity statistical analysis showed no system, vegetation type or region significant differences in number of uniform paddocks, expressed as a percentage of total paddocks within each system, across all sites (Table 9.9.2).

Table 9.9.2. Proportion of uniform paddocks for tree/shrub cover in 2006, 2007 and 2009*.

Treatment	**Uniform paddocks for tree/shrub cover (%)**					
	2006		**2007**		**2009**	
Syst/Vegn/Region	Mean	Transf.	Mean	Transf.	Mean	Transf.
Grazing system (GS)		ns		ns		ns
Cell	78	1.29	87	1.93	77	1.20
Rotation	63	0.55	83	1.58	80	1.38
Continuous	85	1.72	89	2.12	78	1.26
Av. s.e.d.		1.09		1.04		1.05
Vegetation type (V)		ns		ns		ns
Brigalow	79	1.32	78	1.27	81	1.44
Eucalypt	74	1.05	92	2.49	76	1.13
s.e.d.		0.90		1.25		1.36
Region (R)		ns		ns		ns
North	75	1.10	93	2.66	80	1.36
South	78	1.27	75	1.10	77	1.20
s.e.d.		0.78		1.21		1.33

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

1.9.1.3 LFA indices

The proportion of paddocks with uniform LFA Stability index is shown in Table 9.9.3. There were no significant differences between systems, vegetation type or region.

Table 9.9.3. Percentage of uniform paddocks for LFA Stability index in 2006, 2007 and 2009*.

Treatment	**Uniform paddocks for LFA stability index (%)**					
	2006		**2007**		**2009**	
Syst/Vegn/Region	Mean	Transf.	Mean	Transf.	Mean	Transf.
Grazing system (GS)		ns		ns		ns
Cell	62	0.48	54	0.16	35	-0.60
Rotation	45	-0.19	43	-0.30	37	-0.53
Continuous	45	-0.19	73	0.99	56	0.24
Av. s.e.d.		0.94		0.90		0.92

Vegetation type (V)		ns		ns		ns
Brigalow	42	-0.32	62	0.48	44	-0.24
Eucalypt	59	0.38	52	0.09	41	-0.35
s.e.d.		0.80		0.78		0.60
Region (R)		ns		ns		ns
North	42	-0.33	47	-0.13	55	0.20
South	60	0.39	67	0.70	31	-0.80
s.e.d.		0.72		0.77		0.63

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

There were no significant effects on within-paddock variation in the LFA Infiltration index (Table 9.9.4).

Table 9.9.4. Percentage of uniform paddocks for LFA Infiltration index in 2006, 2007 and 2009*.

Treatment	**Uniform paddocks for LFA infiltration index (%)**					
	2006		**2007**		**2009**	
Syst/Vegn/Region	Mean	Transf.	Mean	Transf.	Mean	Transf.
Grazing system (GS)		ns		ns		ns
Cell	56	0.24	46	-0.16	39	-0.44
Rotation	33	-0.71	32	-0.74	41	-0.37
Continuous	16	-1.67	14	-1.78	44	-0.26
Av. s.e.d.		1.08		1.07		0.92
Vegetation type (V)		ns		ns		ns
Brigalow	31	-0.80	34	-0.65	53	0.13
Eucalypt	35	-0.62	24	-1.14	30	-0.84
s.e.d.		0.67		0.56		0.59
Region (R)		ns		ns		ns
North	39	-0.43	30	-0.87	45	-0.19
South	27	-0.99	29	-0.92	37	-0.53
s.e.d.		0.61		0.59		0.62

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

There were no significant effects on within-paddock variation in the LFA Nutrient cycling index (Table 1.95).

Table 1.99.5. Percentage of uniform paddocks for LFA Nutrient cycling index in 2006, 2007 and 2009*.

Treatment	**Uniform paddocks for LFA nutrient cycling index (%)**					
	2006		**2007**		**2009**	
Syst/Vegn/Region	Mean	Transf.	Mean	Transf.	Mean	Transf.
Grazing system (GS)		ns		ns		ns
Cell	66	0.67	61	0.47	47	-0.13
Rotation	74	1.07	42	-0.32	10	-2.16
Continuous	69	0.82	46	-0.16	45	-0.21
Av. s.e.d.		1.00		0.89		1.13
Vegetation type (V)		ns		ns		ns

Brigalow	75	1.09	42	-0.30	38	-0.51
Eucalypt	65	0.62	57	0.30	24	-1.16
s.e.d.		0.72		1.12		0.67
Region (R)		ns		ns		ns
North	79	1.32	56	0.22	27	-1.01
South	59	0.38	44	-0.23	34	-0.65
s.e.d.		0.61		1.08		0.68

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

1.9.2 Standard deviation between Botanal/LFA means

The variation in the standard deviation for the three factors, Grazing System, Vegetation type and Region, for main Botanal/LFA parameters in the three years of monitoring, 2006, 2007 and 2009, show a high degree of similarity between the factors.

The standard deviations for total cover means (Table 1.99.6) show no differences in the first two years of recording and that the brigalow land type had a more variable cover range than the eucalypt communities in 2009. Between regions, the total cover in the south was marginally more variable than the north region only in 2009. There were no differences between the grazing systems.

Table 1.96. Mean values of standard deviations of total cover %.

Treatment	Total cover (%)		
	2006	**2007**	**2009**
Grazing system (GS)			
Cell	27.1	26.6	23.8
Rotation	25.3	24.5	20.9
Continuous	26.0	25.7	23.0
Vegetation type (V)			
Brigalow	27.2	26.1	26.2
Eucalypt	25.3	25.4	18.9
Region (R)			
North	26.5	25.6	21.3
South	25.7	25.8	24.8

The standard deviation for litter cover was the same for grazing systems and regions in all years, but there was marginally higher variation in the eucalypt sites only in 2009 (Table 1.9).

Table 1.97. Mean values of standard deviations of litter cover %.

Treatment	Litter cover (%)		
	2006	**2007**	**2009**
Grazing system (GS)			
Cell	15.6	16.7	20.0
Rotation	17.4	17.9	18.7
Continuous	15.6	15.4	19.4

Vegetation type (V)			
Brigalow	16.2	15.3	16.7
Eucalypt	16.1	17.7	22.4
Region (R)			
North	16.4	16.7	20.2
South	15.6	16.4	18.4

The standard deviation for LFA Stability index was the same for grazing systems in 2006 and 2009, but was marginally higher in the cells in 2007, indicating a greater variation in this year. There were no differences between vegetation type and regions in any year (Table 1.9).

Table 1.99.8. Mean values of standard deviations of LFA Stability index.

Treatment	Stability index		
	2006	**2007**	**2009**
Grazing system (GS)			
Cell	7.55	8.55	7.46
Rotation	6.63	6.36	5.71
Continuous	6.52	6.21	6.38
Vegetation type (V)			
Brigalow	6.89	6.42	6.59
Eucalypt	6.99	7.80	6.62
Region (R)			
North	7.35	7.68	6.75
South	6.28	6.26	6.40

The standard deviation for LFA Infiltration index was the same for grazing systems in 2006 and 2009 but was marginally higher in the cells than in the continuous system in 2007, indicating a greater variation in this year. The eucalypt sites had a greater variation than the brigalow community in every year. There was no difference between regions in any year (Table 1.9.9).

Table 1.9.9. Mean values of standard deviations of LFA Infiltration index.

Treatment	Infiltration index		
	2006	**2007**	**2009**
Grazing system (GS)			
Cell	8.33	9.17	8.16
Rotation	7.79	8.29	7.56
Continuous	7.39	7.36	8.17
Vegetation type (V)			
Brigalow	7.43	7.13	6.95
Eucalypt	8.26	9.29	9.18
Region (R)			
North	8.23	8.46	8.13

South	7.27	8.07	7.83

The standard deviation for LFA Nutrient cycling index was similar for grazing systems, and region in all years, and the eucalypt vegetation type had a marginally higher variation than the brigalow every year (Table 1.910). This may be due the litter component which was also more variable in the eucalypt community.

Table 1.99.10. Mean values of standard deviations of LFA Nutrient cycling index.

Treatment	Nutrient cycling index		
	2006	2007	2009
Grazing system (GS)			
Cell	8.59	8.78	9.07
Rotation	8.56	9.20	8.41
Continuous	8.12	7.88	8.95
Vegetation type (V)			
Brigalow	8.11	7.85	8.16
Eucalypt	8.71	9.28	9.62
Region (R)			
North	9.06	8.75	9.06
South	7.39	8.36	8.56

A summary of statistical analysis (REML) probability levels for spatial variability of eight botanal/LFA parameters is shown in Table 9.9.11. There were six significant differences from a possible 63 combinations.

Table 9.9.11. Summary of statistical analysis probability levels for spatial variability in the main Botanal/LFA parameters between grazing systems, vegetation communities and regions in 2006, 2007and 2009.

Factor	Variability parameter	Spatial variability statistical significance		
		2006	2007	2009
Grazing system	Yield	NA	NA	P>0.10
	Utilisation	P<0.05	P>0.10	P=0.081
	Total cover	P=0.062	P>0.10	NA
	Litter cover	P>0.10	P>0.10	P>0.10
	Tree/shrub cover	P>0.10	P>0.10	P>0.10
	LFA Stability	P>0.10	P>0.10	P>0.10
	LFA Infiltration	P>0.10	P>0.10	P>0.10
	LFA Nutrient cycling	P>0.10	P>0.10	P>0.10
Vegetation	Yield	NA	NA	P=0.096
	Utilisation	P>0.10	P>0.10	P=0.077
	Total cover	P>0.10	P>0.10	NA
	Litter cover	P>0.10	P>0.10	P>0.10
	Tree/shrub cover	P>0.10	P>0.10	P>0.10
	LFA Stability	P>0.10	P>0.10	P>0.10
	LFA Infiltration	P>0.10	P>0.10	P>0.10
	LFA Nutrient cycling	P>0.10	P>0.10	P>0.10

Region	Yield	NA	NA	P>0.10
	Utilisation	P>0.10	P>0.10	P>0.10
	Total cover	P>0.10	P>0.10	NA
	Litter cover	P>0.10	P>0.10	P>0.10
	Tree/shrub cover	P>0.10	P>0.10	P>0.10
	LFA Stability	P>0.10	P>0.10	P>0.10
	LFA Infiltration	P>0.10	P>0.10	P>0.10
	LFA Nutrient cycling	P>0.10	P>0.10	P>0.10

1.10 Appendix 10 - Grazing pressure – grazing records

Cattle movements at the nine sites were recorded in various formats with varying levels of information for routine cattle husbandry and in some instances for pasture management by the owners/managers. There were both breeding and growing cattle run in all grazing systems. Record keeping appeared to be better in the more intense systems. Most cell operators keep records of movements of their cell cattle on large ‘RCS-type’ grazing charts, although there is some direct computer recording into modified grazing chart formats. The low intensity systems have generally less detail and at times incomplete written records. Rotation systems have varying levels of written records and with the recent drought years, multiple paddocks have been grazed together. Multiple paddocks of cell systems were also grazed at the one time on occasions.

Data (numbers and types of animals) were collected directly from the owners or from their written records. All cattle classes were converted to standard Adult Equivalent (AE), using the same convention as a standard Livestock (Large stock) Unit (LSU). Two AE tables, in use by the owners, were used for cattle at maintenance and growing at different daily growth rates. One table was for breeders where one AE is a 450-460 kg dry breeder at maintenance (Table 1.10.1) and a second table for growing cattle and replacement heifers where one AE is a 420 kg steer at maintenance (Table 1.10.2). In this report one AE (dry breeder) was used to calculate long-term carrying capacity of all land types in all paddocks.

The paddock areas were estimated from our paddock corner GPS mapping measurements and ArcMap calculations. This area was used to calculate SDH or AE/ha as used by some producers. The total rainfall over the immediate 12 months prior to each grazing event, including the month of each individual grazing event, was used as the rainfall value to calculate the AE/ha/100mm of rain (SDH/100mm) values. At all sites the homestead rainfall was used as the most reliable measure for all systems on a property, as there may be missing events for some paddock gauges.

All grazing pressure calculations were based on a 12-month year, from 1 July to 30 June the following year. Four years of grazing, 2005-06 to 2008-09 was recorded. When comparing the grazing pressure in the different paddocks and systems the number of stock days per ha over multiple years is required as in any one year, the grazing can be influenced by many factors other than the seasonal pasture growth. Often if a paddock is heavily grazed in one year it will receive lower grazing the following year. Rest periods also may carry over from one year into the next.

Table 1.10.1. Standard AE/LSU table for breeding cattle.

Breeding cattle (cows and calves)			
Liveweight kg	**Dry Cow AE**	**Pregnant AE**	**Cow & Calf AE**
350	0.85	0.86	1.74
360	0.87	0.89	1.78
370	0.89	0.94	1.82
380	0.90	0.99	1.86
390	0.92	1.04	1.90
400	0.94	1.09	1.94
410	0.95	1.11	1.98
420	0.96	1.13	2.02
430	0.97	1.14	2.06
440	0.98	1.16	2.10
450	0.99	1.18	2.14

460	1.00	1.19	2.15
470	1.01	1.19	2.16
480	1.01	1.20	2.18
490	1.02	1.20	2.19
500	1.03	1.21	2.20
510	1.05	1.23	2.24
520	1.07	1.25	2.28
530	1.08	1.26	2.31
540	1.10	1.28	2.35
550	1.12	1.30	2.39
560	1.14	1.32	2.43
570	1.16	1.34	2.47
580	1.17	1.36	2.50
590	1.19	1.38	2.54
600	1.21	1.40	2.58
610	1.23	1.42	2.62
620	1.25	1.44	2.65
630	1.27	1.45	2.69
640	1.29	1.47	2.72
650	1.31	1.49	2.76
660	1.33	1.51	2.80
670	1.35	1.53	2.83
680	1.36	1.55	2.87
690	1.38	1.57	2.90
700	1.40	1.59	2.94
710	1.42	1.61	2.97
720	1.44	1.63	3.01
730	1.45	1.64	3.04
740	1.47	1.66	3.08
750	1.49	1.68	3.11
760	1.51	1.70	3.15
770	1.53	1.72	3.18
780	1.55	1.75	3.22
790	1.57	1.77	3.25
800	1.59	1.79	3.29
850	1.68	1.87	3.49
900	1.78	1.97	3.64

Table 1.10.2. Standard AE/LSU table for growing steers and replacement heifers.

	Growing cattle - Liveweight gain - kg per day					
Liveweight kg	**0 kg/d AE**	**0.25 kg/d AE**	**0.5 kg/d AE**	**0.75 kg/d AE**	**1 kg/d AE**	**1.5 kg/d AE**
200	0.47	0.62	0.76	0.87	0.98	1.19
210	0.51	0.65	0.79	0.90	1.02	1.22
220	0.55	0.69	0.82	0.94	1.05	1.24
230	0.59	0.72	0.86	0.97	1.09	1.27
240	0.63	0.76	0.89	1.01	1.12	1.29
250	0.67	0.80	0.92	1.04	1.16	1.32
260	0.69	0.82	0.95	1.07	1.19	1.35
270	0.71	0.85	0.98	1.10	1.23	1.37

280	0.74	0.87	1.00	1.13	1.26	1.40
290	0.76	0.90	1.03	1.16	1.30	1.42
300	0.78	0.92	1.06	1.20	1.33	1.45
310	0.80	0.95	1.09	1.23	1.37	1.47
320	0.82	0.97	1.12	1.27	1.42	1.50
330	0.84	1.00	1.16	1.31	1.46	1.52
340	0.86	1.02	1.19	1.35	1.51	1.55
350	0.88	1.05	1.22	1.39	1.55	1.57
360	0.90	1.07	1.24	1.41	1.57	1.60
370	0.91	1.09	1.26	1.43	1.59	1.62
380	0.93	1.10	1.28	1.45	1.61	1.65
390	0.94	1.12	1.30	1.47	1.63	1.67
400	0.96	1.14	1.32	1.49	1.65	1.70
410	0.98	1.16	1.34	1.50	1.67	1.73
420	1.00	1.17	1.35	1.52	1.69	1.75
430	1.01	1.19	1.37	1.54	1.71	1.78
440	1.03	1.21	1.38	1.56	1.73	1.80
450	1.05	1.23	1.40	1.58	1.75	1.83
460	1.06	1.24	1.42	1.59	1.77	1.86
470	1.08	1.26	1.43	1.61	1.79	1.88
480	1.09	1.27	1.45	1.63	1.80	1.91
490	1.11	1.29	1.46	1.64	1.82	1.93
500	1.12	1.30	1.48	1.66	1.84	1.96
510	1.13	1.31	1.49	1.67	1.85	1.98
520	1.14	1.32	1.50	1.68	1.86	2.01
530	1.14	1.33	1.52	1.70	1.88	2.03
540	1.15	1.34	1.53	1.71	1.89	2.06
550	1.16	1.35	1.54	1.72	1.90	2.08
560	1.18	1.37	1.56	1.74	1.92	2.12
570	1.20	1.39	1.58	1.76	1.94	2.16
580	1.22	1.41	1.60	1.78	1.96	2.21
590	1.24	1.43	1.62	1.80	1.98	2.25
600	1.26	1.45	1.64	1.82	2.00	2.29
610	1.28	1.47	1.66	1.84	2.02	2.30
620	1.30	1.49	1.68	1.86	2.04	2.31
630	1.32	1.51	1.69	1.88	2.06	2.32
640	1.34	1.53	1.71	1.90	2.08	2.33
650	1.36	1.55	1.73	1.92	2.10	2.34
700	1.46	1.65	1.83	2.02	2.19	2.47
750	1.56	1.75	1.92	2.12	2.29	2.72

There is also an average monthly AE rating for breeding cattle (Table 1.10.3). 'Somerville' was the only site to use this system with an AE rating for different aged breeders and discounting for expected pregnancy stages during the year. The AE for breeding females is based on 3 ratings, for first and second calf heifers and mature cows, then accounting for different feed intakes on a monthly basis as pregnancy and lactation progress. The AE for growing cattle is rated on age, with their liveweight taken into account, and feed intake and growth rate adjusted monthly. Replacement heifers are rated the same as 1 year old growing steers (0.7 AE).

Table 1.10.3. Summarised monthly AE rating for breeding cattle, based on calendar months. (This system is suitable for the reliable and well defined growing season in northern areas).

	Breeding cows				
	Dry Cow	**Pregnant**	**Cow & Calf**	**Av. for Year**	**Working Bulls**
Mature Breeder	1.08	1.26	2.3	1.72	
H2	1.03	1.21	2.2	1.64	
H1	0.9	1.05	1.84	1.39	
January (herd %)		10%	90%		2.3
February			100		2.3
March			100		2.3
April	50%		50		2.3
May	50		50		1.8
June	50		50		1.8
July	100				1.8
August	40	60			1.8
September	20	80			1.8
October		100			1.8
November		40	60		1.8
December		20	80		1.8
Av. weight	**375 kg**	**470 kg**	**525 kg**		

(*Table provided by 'Somerville'*)

The paddock grazing data was recorded in a range of formats. An example from one site (Table 1.10.4) shows a monthly summary of the paddocks identified within the cell, their area, number of graze periods, the total AE's, total stock days grazed, the stockdays/ha (SDH) and the severity of the graze (light, medium or heavy). This comment helps manage the grazing in future cycles and in forward planning feed budgets.

Table 1.10.4. Example of grazing chart data for part of a cell system at one site. This system was developed for direct computer excel® data entry and automatic analysis.

Class **Mar-'07**			**Cattle in East Cells**	
	No.	**Av Weight**	**AU**	**Total AE**
Stock Condition	score 2-4	Drought conditions		
Type of Animals	Breeder herd			
Dry Cows				0
Pregnant Cows	170	450	1.2	204
Lactating Cows	110	450	2	220
Bulls	7		2	14
Small Dry stock				0
Medium Dry stock				0
Large Dry stock				0
				438

Paddock	**Area ha**	**Graze Period** (no. days)	**AE**	**Stock Days**	**SD/ha**	**Graze Type**
P1	21	1	440	440	20.95	medium
P3	51	1.5	440	660	12.94	heavy
P5	96			0		
P7	28	1	440	440	15.71	medium
Q1	23	0.75	440	330	14.35	light
Q3	26	0.75	440	330	12.69	light
Q5	28	0.75	440	330	11.79	light

Q7	34	0.75	440	330	9.71	light
R1	21	0.75	440	330	15.71	light
R3	31	0.75	440	330	10.65	light
R5	26	0.75	440	330	12.69	light
R7	23	0.75	440	330	14.35	light
S1	28	0.75	440	330	11.79	light
S3	28	0.75	440	330	11.79	light
S5	34	0.75	440	330	9.71	light
S7	29	0.75	440	330	11.38	light
O1	35	1	440	440	12.57	medium
O3	23	1	440	440	19.13	medium
O5	37	1	440	440	11.89	medium
O7	26	1	440	440	16.92	medium
N1	17			0		
N3	28			0		
L1	34			0		
H1	23	1.5	440	660	28.70	heavy
H7	18	1	440	440	24.44	medium
J1	21	1.5	440	660	31.43	heavy
J3	28	1.5	440	660	23.57	heavy
J5	26	1.5	440	660	25.38	heavy
J7	29	1.5	440	660	22.76	heavy
K1	28	1.5	440	660	23.57	heavy
K3	28	1.5	440	660	23.57	heavy
K5	28	1.5	440	660	23.57	heavy
K7	28	1.5	440	660	23.57	heavy
G1	96			0		
Total		**31**		**13640**		
Average			**440**		**17.49**	

The usual classes of cattle and number of head or AE run in each grazing system during the project ranged from 30-50 head in the continuous paddock at Sunnyholt to over 1500 steers in the cells at Frankfield, and up to 1500 AE in the cells at Sunnyholt (Table 1.10.5). The numbers and classes of cattle grazed in the systems were not fixed within a year or between years, but fluctuated with seasons, whole property grazing management and marketing needs, which included forward planning from paddock feed budgeting on occasions.

Table 1.10.5. Grazing system and class of grazing stock and usual number of head or AE in monitor paddocks.

Property	Grazing system	Class of cattle	Number of head or AE
Banyula (Condamine)	Cells (Loam & Clay)	Steers/heifers	200-400 (variable)
	Continuous	Steers/heifers	100-500 (variable)
Berrigurra	Cells	Weaner heifers	~ 350 hd
(Blackwater)	Rotation	Steers	~ 600 hd
	Continuous	Breeders + calves	~ 100 hd
Frankfield	Cells	Steers	~ 1500
(Clermont)	Rotation	Breeders + calves	~ 400 (variable)
	Continuous	Breeders + calves	~ 500 (variable)
Melrose	Cells	Breeders + calves	~ 210 hd
(Morinish)	Rotation	Breeders + calves	~ 140 hd
	Continuous	Breeders + calves	~ 90 hd

Rocky Springs	Rotation	Breeders + calves	~120 hd
(Mundubbera)	Continuous	Breeders + calves	~ 40 hd
Salisbury Plains	Cells	Breeders + calves	~ 450 hd
(Bowen)	Continuous	Breeders	40-200 hd (variable)
Somerville	Cells	Breeders	~ 1200 hd
(Richmond)	Rotation	Weaners / growers	~ 1200 hd (variable)
Sunnyholt	Cells	Steers	~ 1500 AE
(Injune)	Continuous	Steers, bulls	~ 30-50 hd
Ticehurst	Cells	Breeders + weaners	~ 250 hd
(Surat)	Rotation	Breeders + weaners	~ 250 hd

1.10.1 Statistical analysis of impacts from grazing records

1.10.1.1 Grazing chart analysis methodology

Paddock grazing data (stock days per ha (SDH), SDH/100 mm rain, Annual stocking rate (SR; ha/AE)) in 2006, 2007 and 2009 calculated from grazing chart records were analysed by residual maximum likelihood (REML). The clay cell paddocks at Banyula were excluded, to have a direct comparison with the loam cells and the loam soil continuous paddock. Further, the blade ploughed paddocks at Frankfield (A7 and B12) were also excluded, because they were cultivated and sown to improved pasture during the monitoring period.

Analyses were initially done separately for each property to compare grazing systems over time. Models included the fixed effects of grazing system (*Sys*; Cell, Rotation, Continuous), time (*Year*; 05/06, 06/07, 07/08. 08/09) and their interaction and the random effects of System, Paddocks within System and Year within Paddocks. If there was evidence ($P<0.10$) of an interaction, predicted means were obtained. The interaction was then removed from the model and the main effects tested and predicted means obtained. Distributional assumptions were assessed by visual inspection of residual and normal probability plots. As there was evidence of non-homogeneity of variance, data were log-transformed prior to analysis. Standard error of differences (seds) were presented and, where differences ($P<0.05$) were observed, approximate least significant differences (lsds) calculated and used to perform pair-wise comparisons of means at the 5% probability level.

Analyses across properties were then performed. Models included fixed effects of Grazing System (*Sys*; Cell, Rotation, Continuous), Vegetation (*Veg*; Brigalow, Eucalypt), Location (*Loc*; South, North) and time (*Year*; 05/06, 06/07, 07/08. 08/09) and interactions and the random effects of Property, System, Paddocks, and Years. A step-down procedure was used to remove non-significant ($P>0.10$) interactions. Finally, main effect means were predicted from a simple main effects model. Distributional assumptions were assessed by visual inspection of residual and normal probability plots. As there was evidence of non-homogeneity of variance, data were log-transformed prior to analysis. Standard error of differences (seds) were presented and, where main effect differences ($P<0.05$) were observed, approximate least significant differences (lsds) calculated and used to perform pair-wise comparisons of main effect means at the 5% probability level.

1.10.1.2 Grazing pressure imposed

Three main measures of grazing pressure imposed on individual paddocks of the systems at each of the nine sites were calculated from grazing charts and paddock records. They were: stock days per ha (SDH) (Table 1.10.6); stock days per ha per 100 mm of rain over the previous 12 months from each grazing event (SDH/100mm) (Table 1.10.7); and a stocking rate measure in ha/head, converted to one AE (ha/AE) (Table 1.10.8). The results of the statistical analysis of the grazing pressure imposed on the systems at the nine sites are shown in the three tables. The data was log-transformed prior to analysis and both the log means and the back-transformed means are shown, with the significant treatment differences.

There were significant between system differences at four of the nine sites, Frankfield, Rocky Springs, Somerville and Ticehurst, in all three measures, and the other five sites had no system difference in any measure.

There were significant between-year differences in the three grazing pressure measures at all sites except at Berrigurra (no difference between any measure) and at Rocky Springs (significant only in SDH/100mm). The grazing system by year interaction was significant at five of the nine sites for the three grazing pressure measures. At Banyula, this significance level was less than P=0.09 for all measures, while at Frankfield, Melrose, Somerville and Ticehurst, this significance level was P<0.05.

Table 1.10.6. Effect of grazing system and year on grazing in stock days per hectare (SDH) at the nine sites*.

System * year	Banyula			Berrigurra			Frankfield			Melrose			Rocky Springs			Salisbury			Somerville			Sunnyholt			Ticehurst		
System (GS)	ns			ns			**			ns			*			ns			*			ns			***		
Cell	4.7	*107*		4.4	*83*		4.4	*80*	b	4.7	*107*		-			5.0	*143*		3.2	*23*	a	5.0	*146*		4.5	*87*	a
Rotation	-			4.6	*96*		5.1	*156*	a	4.6	*99*		4.2	*66*	b	-			2.6	*12*	b	-			3.6	*36*	b
Continuous	4.6	*103*		4.5	*87*		5.2	*175*	a	4.5	*85*		4.5	*92*	a	5.2	*177*		-			4.9	*138*				
Ave sed	0.3			0.3			0.3			0.2			0.1			0.6			0.2			0.3			0.2		
Year (Yr)	*			ns			*			*			ns			*			***			***			***		
2005-2006	4.6	*97*	b	4.4	*78*		5.2	*187*	a	4.3	*76*	b	4.4	*80*		5.4	*229*	a	2.5	*11*	b	4.1	*57*	b	4.4	*83*	a
2006-2007	4.6	*103*	b	4.6	*95*		4.5	*89*	b	4.6	*95*	ab	4.5	*86*		5.0	*142*	b	3.5	*33*	a	5.2	*181*	a	4.5	*90*	a
2007-2008	4.9	*130*	a	4.7	*114*		5.1	*159*	a	4.6	*97*	ab	4.1	*62*		4.7	*110*	bc	2.7	*14*	b	5.2	*185*	a	2.8	*16*	b
2008-2009	4.6	*94*	b	4.3	*73*		4.7	*108*	ab	4.8	*125*	a	4.5	*89*		5.2	*178*	ab	-			5.3	*209*	a	4.4	*82*	a
sed	0.1			0.3			0.3			0.1			0.2			0.2			0.2			0.3			0.3		
GSxYr	*P=0.081*			ns			*			**			ns			ns			***			ns			***		
Cell 2005-06	4.6	*97*	*b*				5.1	*161*	a	4.6	*100*	a							3.0	*20*	b				4.8	*126*	a
Cell 2006-07	4.7	*105*	*ab*				3.8	*42*	b	4.7	*107*	a							3.8	*44*	a				4.6	*99*	a
Cell 2007-08	5.0	*141*	*a*				4.5	*90*	ab	4.6	*100*	a							2.7	*14*	b				3.7	*40*	b
Cell 2008-09	4.5	*92*	*b*				4.2	*68*	ab	4.8	*124*	a							-						4.7	*114*	a
Rot 2005-06	-						4.0	*52*	b	3.9	*46*	c							1.6	*4*	b				4.0	*56*	b
Rot 2006-07	-						5.2	*188*	a	4.6	*102*	b							3.2	*24*	a				4.9	*135*	a
Rot 2007-08	-						5.5	*242*	a	4.8	*120*	ab							3.0	*19*	a				1.3	*3*	c
Rot 2008-09	-						4.8	*120*	ab	5.1	*169*	a							-						4.3	*70*	b
Cont 2005-06	4.7	*104*	*a*				5.0	*150*	a	4.4	*78*	ab							-						-		
Cont 2006-07	4.6	*101*	*a*				5.2	*181*	a	4.3	*70*	b							-						-		
Cont 2007-08	4.6	*95*	*a*				5.5	*232*	a	4.5	*86*	ab							-						-		
Cont 2008-09	4.8	*115*	*a*				5.0	*150*	a	4.7	*112*	a							-						-		
sed wi GS	0.1						0.5			0.2									0.3						0.1		
sed wi Yr	0.3						0.5			0.2									0.3						0.2		

* ns - not significant (P>0.10); * P<0.05; ** P<0.01; *** P<0.001; Data were log-transformed prior to analysis. Back-transformed means are given in italics. Means not followed by a common letter are significantly different (*P*=0.05).

Table 1.10.7. Effect of grazing system and year on stock days per hectare per 100mm rainfall (SDH/100mm) at the nine sites*.

System * year	Banyula			Berrigurra			Frankfield			Melrose			Rocky Springs			Salisbury			Somerville			Sunnyholt			Ticehurst		
System (GS)	ns			ns			*			ns			*			ns			*			ns			*		
Cell	3.1	*21*		2.8	*16*		2.7	*15*	b	2.9	*17*		-			2.9	*18*		1.9	*5*	a	3.3	*26*		2.9	*17*	a
Rotation	-			3.0	*19*		3.3	*26*	a	2.8	*16*		2.6	*12*	b	-			1.3	*3*	b	-			2.5	*11*	b
Continuous	3.1	*21*		2.9	*17*		3.4	*28*	a	2.6	*13*		2.9	*17*	a	3.1	*21*		-			3.2	*24*		-		
Ave sed	0.3			0.4			0.3			0.1			0.1			0.5			0.2			0.3			0.1		
Year (Yr)	***			ns			*			P=0.056			*			***			*			***			***		
2005-2006	3.1	*20*	b	2.9	*17*		3.6	*36*	a	2.7	*14*	ab	2.7	*14*	a	3.7	*40*	a	1.5	*3*	b	2.5	*11*	b	3.0	*20*	ab
2006-2007	3.4	*29*	a	3.3	*25*		2.9	*18*	b	2.9	*17*	a	3.0	*19*	a	3.1	*21*	b	1.9	*6*	a	3.8	*45*	a	3.2	*23*	a
2007-2008	3.1	*22*	b	3.0	*19*		3.1	*21*	ab	2.6	*12*	b	2.4	*10*	b	2.6	*12*	c	1.4	*3*	b	3.4	*29*	a	1.7	*4*	c
2008-2009	2.8	*15*	c	2.4	*10*		2.9	*17*	b	2.9	*17*	a	2.8	*16*	a	2.7	*14*	a	-			3.3	*27*	a	2.8	*16*	b
sed	0.1			0.3			0.3			0.1			0.1			0.2			0.2			0.3			0.1		
GSxYr	P=0.081			ns			**			**			ns			ns			***			ns			*		
Cell 2005-06	3.1	*20*	*ab*				3.5	*34*	a	3.0	*18*	ab							2.0	*6*	a				3.3	*26*	a
Cell 2006-07	3.4	*29*	*a*				2.3	*9*	b	3.0	*20*	a							2.2	*8*	a				3.2	*25*	a
Cell 2007-08	3.2	*23*	*a*				2.6	*13*	a	2.6	*13*	b							1.4	*3*	b				2.0	*6*	b
Cell 2008-09	2.8	*15*	*b*				2.5	*11*	a	2.9	*17*	ab							-						3.0	*20*	a
Rot 2005-06	-						2.4	*10*	b	2.4	*10*	b							0.7	*1*	b				2.7	*13*	b
Rot 2006-07	-						3.7	*38*	a	3.0	*19*	a							1.7	*4*	a				3.3	*27*	a
Rot 2007-08	-						3.5	*31*	a	2.8	*16*	a							1.6	*4*	a				1.3	*3*	c
Rot 2008-09	-						3.0	*19*	ab	3.2	*23*	a							-						2.6	*13*	b
Cont 2005-06	3.1	*21*	*b*				3.3	*26*	a	2.8	*15*	a													-		
Cont 2006-07	3.4	*30*	*a*				3.5	*33*	a	2.6	*12*	ab													-		
Cont 2007-08	2.8	*16*	*b*				3.5	*31*	a	2.3	*9*	b													-		
Cont 2008-09	3.0	*19*	*b*				3.2	*23*	a	2.8	*16*	a													-		
sed wi GS	0.1						0.4			0.2									0.2						0.2		
sed wi Yr	0.3						0.5			0.2									0.2						0.2		

* ns - not significant (P>0.10); * P<0.05; ** P<0.01; *** P<0.001; Data were log-transformed prior to analysis. Back-transformed means given in italics. Means not followed by a common letter are significantly different (*P*=0.05).

Table 1.10.8. Effect of grazing system and year on annual stocking rate (ha/AE) at the nine sites*.

System * year	Banyula	Berrigurra	Frankfield	Melrose	Rocky Springs	Salisbury	Somerville	Sunnyholt	Ticehurst
System (GS)	ns	ns	*	ns	*	ns	*	ns	***
Cell	1.5 *3*	1.7 *5*	1.7 *5* a	1.5 *3*	-	1.3 *3*	2.8 *16* b	1.3 *3*	1.7 *4* b
Rotation	-	1.6 *4*	1.2 *2* ab	1.6 *4*	1.9 *6* a	-	3.5 *31* a	-	2.5 *12* a
Continuous	1.5 *4*	1.7 *4*	1.1 *2* b	1.7 *4*	1.6 *4* b	1.5 *3*	-	1.3 *3*	-
Ave sed	0.2	0.3	0.2	0.1	0.1	0.5	0.2	0.2	0.2
Year (Yr)	*	ns	*	*	ns	*	***	***	***
2005-2006	1.6 *4* a	1.8 *5*	1.1 *2*	1.8 *5* a	1.7 *5*	1.2 *2* c	3.6 *37* a	2.0 *7* a	1.7 *5* b
2006-2007	1.5 *4* a	1.6 *4*	1.7 *4*	1.6 *4* ab	1.7 *4*	1.5 *4* ab	2.5 *11* b	1.1 *2* b	1.7 *4* b
2007-2008	1.3 *3* b	1.5 *3*	1.2 *2*	1.6 *4* b	1.9 *6*	1.7 *4* a	3.3 *27* a	1.1 *2* b	3.3 *25* a
2008-2009	1.6 *4* a	1.8 *5*	1.5 *4*	1.4 *3* b	1.6 *4*	1.3 *3* bc	-	1.0 *2* b	1.7 *5* b
sed	0.1		0.2	0.1	0.1	0.2	0.3	0.2	0.3
GSxYr	P=0.085	ns	*	**	ns	ns	***	ns	***
Cell 2005-06	1.6 *4*		1.2 *2* b	1.5 *4* a			3.0 *18* a		1.4 *3* a
Cell 2006-07	1.5 *3*		2.3 *9* a	1.5 *3* a			2.2 *8* b		1.5 *4* a
Cell 2007-08	1.3 *3*		1.6 *4* ab	1.5 *4* a			3.3 *27* a		2.3 *9* b
Cell 2008-09	1.6 *4*		1.9 *6* ab	1.4 *3* a			-		1.4 *3* a
Rot 2005-06	-		2.1 *7* a	2.2 *8* a			4.6 *103* a		2.0 *7* b
Rot 2006-07	-		1.1 *2* b	1.5 *4* b			2.8 *15* b		1.3 *3* c
Rot 2007-08	-		0.9 *2* b	1.4 *3* bc			3.0 *19* b		5.0 *144* a
Rot 2008-09	-		1.4 *3* ab	1.2 *2* c			-		1.8 *5* b
Cont 2005-06	1.5 *4*		1.2 *2* a	1.7 *5* ab			-		-
Cont 2006-07	1.5 *4*		1.1 *2* a	1.8 *5* a			-		-
Cont 2007-08	1.6 *4*		0.9 *2* a	1.7 *4* ab			-		-
Cont 2008-09	1.4 *3*		1.2 *2* a	1.4 *3* b			-		-
sed wi GS	0.1		0.4	0.1			0.3		0.1
sed wi Yr	0.3		0.4	0.2			0.3		0.2

* ns - not significant (P>0.10); * P<0.05; ** P<0.01; *** P<0.001; Data were log-transformed prior to analysis. Back-transformed means given in italics. Means not followed by a common letter are significantly different (*P*=0.05).

A summary of statistical significance levels of systems, years and system*year interactions for three grazing pressure measures (SDH, SDH/100mm rainfall and ha/AE) at the nine sites is shown in the following three tables (Table 1.10.9, Table 1.10.10, Table 1.10.11).

Table 1.10.9. Effect of grazing system and year on stock days per hectare (SDH) at nine sites.

Grazing System x Year	Statistical significance (SDH)								
	Ban	Ber	Fra	Mel	Roc	Sal	Som	Sun	Tic
System (GS)	P>0.10	P>0.10	P<0.05	P>0.10	P<0.05	P>0.10	P<0.05	P>0.10	P<0.05
Year (Yr)	P<0.05	P>0.10	P<0.05	P<0.05	P>0.10	P<0.05	P<0.05	P<0.05	P<0.05
GSxYr interaction	P<0.10	P>0.10	P<0.05	P<0.05	P>0.10	P>0.10	P<0.05	P>0.10	P<0.05

Table 1.10.10. Effect of grazing system and year on stock days per hectare per 100mm rainfall (SDH/100mm) at nine sites.

Grazing System x Year	Statistical significance (SDH / 100mm rainfall over previous 12 months)								
	Ban	Ber	Fra	Mel	Roc	Sal	Som	Sun	Tic
System (GS)	P>0.10	P>0.10	P<0.05	P>0.10	P<0.05	P>0.10	P<0.05	P>0.10	P<0.05
Year (Yr)	P<0.05	P>0.10	P<0.05	P<0.10	P<0.05	P<0.05	P<0.05	P<0.05	P<0.05
GSxYr interaction	P<0.10	P>0.10	P<0.05	P<0.05	P>0.10	P>0.10	P<0.05	P>0.10	P<0.05

Table 1.10.11. Effect of grazing system and year on annual stocking rate (ha/AE) at nine sites.

Grazing System x Year	Statistical significance (stocking rate ha/AE)								
	Ban	Ber	Fra	Mel	Roc	Sal	Som	Sun	Tic
System (GS)	P>0.10	P>0.10	P<0.05	P>0.10	P<0.05	P>0.10	P<0.05	P>0.10	P<0.05
Year (Yr)	P<0.05	P>0.10	P<0.05	P<0.05	P>0.10	P<0.05	P<0.05	P<0.05	P<0.05
GSxYr interaction	P<0.10	P<0.10	P<0.05	P<0.05	P<0.10	P<0.10	P<0.05	P<0.10	P<0.05

1.10.1.3 Grazing pressure range between systems

The range of grazing pressures imposed on the different grazing systems at the sites shows that grazing was similar in the different systems at most sites with exceptions of Somerville and Ticehurst, where the cells received higher grazing pressures than the rotation systems (Table

1.10.12). The cells at Somerville carried the breeder herd and the rotation paddocks were usually grazed by weaners and growing cattle. Woody regrowth and drought management strategies reduced the grazing in rotation paddocks at Ticehurst. There was a small difference at Frankfield, due to the lighter grazing of the cells, which were not grazed over the main wet season.

Table 1.10.12. Range of average annual grazing pressure (ha/AE) between grazing systems at each site.

Property	Between system grazing pressure range (ha/AE)*
Banyula	0.0
Berrigurra	1.0
Frankfield	3.6
Melrose	0.9
Rocky Springs	1.6
Salisbury Plains	0.7
Somerville	37.1
Sunnyholt	0.6
Ticehurst	35.1

* from grazing chart and property records; regrowth and drought management strategies affected Ticehurst.

1.10.1.4 Grazing pressure compared with LTCC

There were properties and pasture types (buffel grass or native pasture dominant) with average grazing (2005-06 to 2008-09) under and over the estimated LTCC in both regions (Table 1.10.13) and in both vegetation communities (Table 1.10.14).

Table 1.10.13. Properties where annual average grazing pressure (ha/AE) between 2005 and 2009 was under or over estimated LTCC by region and vegetation type.

Region			
North Qld		**South Qld**	
Under LTCC	Over LTCC	Under LTCC	Over LTCC
Berrigurra	Frankfield Melrose Salisbury Somerville	Rocky Springs Ticehurst	Banyula Sunnyholt

Vegetation type (relative fertility)			
Eucalypt		**Brigalow**	
Under LTCC	Over LTCC	Under LTCC	Over LTCC
Rocky Springs Ticehurst Somerville	Banyula* Melrose Salisbury	Berrigurra	Frankfield Sunnyholt

* Only loam soil systems included.

Table 1.10.14. Number of sites and pasture types where annual average grazing pressure (ha/AE) between 2005 and 2009 was under or over estimated LTCC by region and vegetation type.

Region			
North Qld		South Qld	
Under LTCC	Over LTCC	Under LTCC	Over LTCC
1 buffel 1 native pasture	1 buffel 2 native pasture	1 buffel 1 native pasture	2 buffel

Vegetation type (relative fertility)			
Eucalypt		Brigalow	
Under LTCC	Over LTCC	Under LTCC	Over LTCC
1 buffel 3 native pasture	1 buffel 2 native pasture	1 buffel	2 buffel

In both regions, pastures where the average annual grazing was below the estimated LTCC had an average annual rainfall decile at or below 5.0 (Table 1.10.15). All sites where grazing was above the estimated LTCC had an average rainfall decile above 5.0, except at one buffel pasture site on brigalow soil in southern Queensland.

Table 1.10.15. Average annual rainfall decile (four years, 2005-06 to 2008-09) for sites where the annual average grazing pressure (ha/AE) between 2005 and 2009 was under or over estimated LTCC by region and vegetation type.

Region			
North Qld		South Qld	
Under LTCC	Over LTCC	Under LTCC	Over LTCC
4.75	5.25	2.50	6.00
5.33	5.25	4.50	3.50
	5.50		
Av. 5.04	**5.33**	**3.50**	**4.75**

Vegetation / Fertility			
Eucalypt		Brigalow	
Under LTCC	Over LTCC	Under LTCC	Over LTCC
2.50	6.00	4.75	5.25
4.50	5.25		3.50
5.33	5.50		
Av. 4.11	**5.58**	**4.75**	**4.38**

1.11 Appendix 11 – Long-term carrying capacity (LTCC)

1.11.1 Introduction

We calculated long-term carrying capacity (LTCC) of each paddock as a comparison with the actual stocking pressure during the project monitoring period. The long-term carrying capacity is an estimate of a property's ability to sustainably carry cattle with minimal pasture and soil degradation. It apples to a time scale in the order of ten plus years and is calculated from the average pasture growth of the land types on the property. LTCC is expressed in the units hectares per adult equivalent (ha/AE). One AE is a 460 kg dry breeder at maintenance consuming 3560 kg dry feed per year (Table 1.10.1). This is from the same AE tables used by the producers and for calculating grazing pressure in all paddocks throughout this study.

LTCC is intended as a guide for grazing decisions and not as a ceiling for stocking rates. It takes into account good and bad seasons and can be taken as an average long-term stocking rate, e.g. for a period of over 10 years.

The on-property assessments of land type boundaries, tree basal area and land condition can have errors associated with them because of the low intensity of sampling. This needs to be kept in mind when these results are used as a guide in making grazing management decisions at the paddock scale. At the property scale the calculations are considered reliable. The method we used was developed and evaluated at a commercial scale in a range of Queensland land types (Johnston, McKeon and Day 1996; Johnston, Tannock and Beale 1996).

The method for calculating LTCC for a paddock involves the addition of the number of AE that each land type contributes. This does not account for preferential grazing in the short-term. For example, one land type or an area within a paddock may carry all the cattle in a paddock if they prefer to graze those areas. If preferential grazing is occurring, then calculated LTCC may not reflect the actual LTCC of the whole paddock.

The nine properties were inspected and land types, paddocks, permanent watering points, tree density and land condition were mapped by GPS and Spot-5 imagery. This included the contribution by roads, reserves and stock routes which were fenced into the paddocks. Land types were selected from the GLM lists for each region and catchment, and the land condition assessments were based on the definitions of Chilcott *et al.* (2004).

Land types are manageable units of land, readily recognised by landholders as having distinct soil, vegetation, landform and productive capacity. The physical descriptions and identification of the land types were based on land systems (Gunn *et al.* 1967; Speck *et al.* 1968), Regional Ecosystems (Qld EPA 2007), regional GLM definitions, aerial photography and satellite imagery (Spot 5) as well as on-ground knowledge of project staff. The land types were overlain on the monitor paddock boundaries (in ArcMap) and checked for accuracy and their correspondence with our Botanal pasture/soil surveying data and field experience. The land type boundaries were adjusted if necessary.

LTCC was calculated with a safe utilisation level (those recommended by GLM, usually 20-30%) for the land type, pasture growth for a given tree density (m^2/ha tree basal area) discounted for declining land condition, and distance to water on a per km basis. Pasture growth models for each land type were calibrated using the core models in GRASP (McKeon *et al*. 1990; Chilcott *et al*. 2004) for the relevant pasture type, either buffel grass or native pastures. Discounts in grazing activity, and therefore LTCC were applied to account for permanent water point distribution (Table 1.11.1).

The method has evolved from previous work in western Queensland (Johnston, McKeon and Day, 1996), in the Desert Uplands (Jones *et al*. 2006) and a consultancy for Stanwell Energy Corporation (Jones and Sandral 2007).

Table 1.11.1. Discounts in grazing activity with distance (km) to permanent water.

Distance from water zones km	Discount factor
0-1	1
1-2	0.77
2-3	0.62
3-4	0.47
4-5	0.37
5-6	0.28

An Excel[R] spreadsheet was developed to incorporate the outputs from a computer mapping program (ArcMap) to calculate LTCC at a paddock, land type, distance from water, land condition, utilisation rate and property level.

Land condition is the capacity of land to respond to rain and produce useful pasture. The "ABCD" condition framework, a simple paddock scale assessment method was used for all land types within every paddock. These techniques for reporting land condition at a paddock scale have been developed in the program STOCKTAKE and in the regional GLM (Edge*Network*) packages. The land condition (ABCD) was based on the same definitions described in the Land condition assessment section, briefly:

"A" condition land has good coverage of perennial grasses dominated by 3P grasses and > 70% cover.

"B" condition land is similar to "A" except that there is a decline of 3P grasses, and ground cover is around 40 – 70%.

"C" condition land has a general decline of 3P grasses with large amounts of less favoured species and ground cover < 40%.

"D" condition land has a general lack of any perennial grasses or forbs and erosion evident (requiring mechanical intervention for reclamation).

1.11.2 Landtype Carrying Capacity Calculations

Specific methodology

- Calculations on 1 paddock at a time,
- Add layers of information at each step,
- Calculate areas at each step – need information and as a check (snap for fence lines),
- Check all areas at each step,
- End result is 1 shape file (with assorted files) with all necessary information as layers,
- Use "Intercept", rather than "Union" in toolbox analysis,
- Delete any unnecessary files immediately.

Order of Steps

1. Paddock/s
2. Trees

3. Water points & Distance buffer rings (1 km units)
4. Land Types
5. Land Condition

At each step consistently name the shape files, for example for the continuous paddock Bankstown at Banyula:

1. Ban-Bankstownpdk
2. Ban-Bankstownpdk-trees
3. Ban-Bankstownpdk-trees-water
4. Ban-Bankstownpdk-trees-water-buffs
5. Ban-Bankstownpdk-trees--water-buffs-LT
6. Ban-Bankstownpdk-trees--water-buffs-LT-LC

An example of the mapping and area calculations of all monitor paddocks at the whole property scale with land condition, tree competition and water point distance buffers for Berrigurra is shown in Figure 1.11.1.

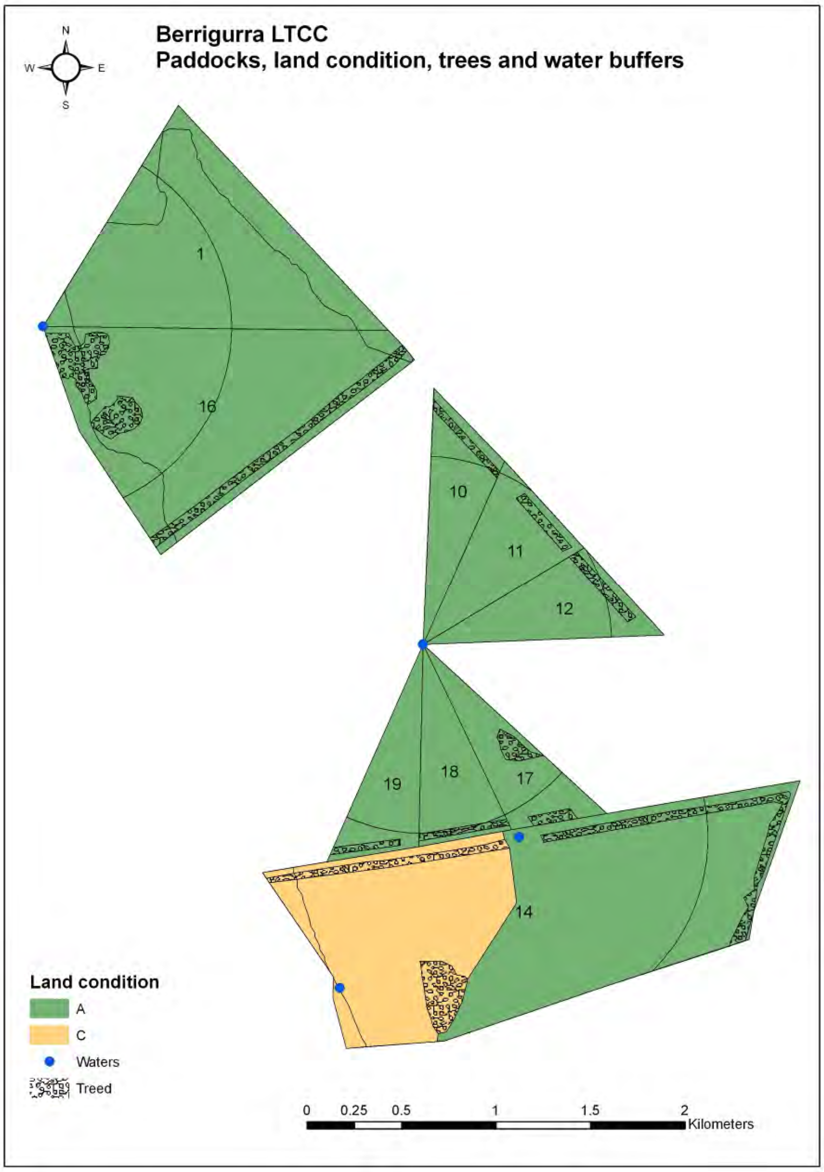


Figure 1.11.1. LTCC calculations of Berrigurra showing paddocks, land condition, trees and water buffer distances on monitor paddocks of three grazing systems.

In an Excel[R] spreadsheet, add each data set and complete the calculations of each landtype and sum for a paddock total. The spreadsheet headings are shown in Table 1.11.2.

Table 1.11.2. Table of parameters used to calculate carrying capacity of each land type sub-unit and total paddock LTCC (Table headings only shown in two rows).

Property	Pdk_Name	Graz_Syst	Land type	Clearing	TBA (m^2/ha)	Pasture growth current condition (kg/ha)	Pasture growth current condition-total (kg)	TBA (m^2)	Area Ha

(Parameter headings continued)

Distance to water	Water pt buffer	Multiplier for dist to water	Land condition	Utilisation (%)	Pasture available (kg)	LTCC (AE's)	Paddk_ID

The final LTCC resulted from multiple calculations for each 'land type * condition unit' which were added together in the following order:

- The whole property was mapped with the GSP monitor paddocks and permanent water points identified and areas calculated.
- Landtypes from RE maps were overlayed on the GSP paddocks and areas of each land type within each paddock calculated.
- Cleared areas and areas of woody vegetation (remnant or regrowth) were mapped, a mean tree basal area was allocated, and area (ha) of each unit was calculated.
- Land condition within each unit was nominated (ABCD classification).
- Concentric circles with the radius increasing at 1 km intervals from each permanent water point were drawn for each paddock and the areas of each land type * woody/cleared area * LC * distance from water points was calculated.
- These sub-units were assessed for long-term pasture growth potential using the GRASP model (based on current regional GLM model outputs).
- A sustainable (conservative) utilisation rate (%) from GLM was nominated for each sub-unit, to calculate the yield of forage available for grazing.
- The number of AE capable of being supported by this amount of forage available for grazing was calculated (using average 10kg DM/hd/day). The carrying capacity (ha/AE) was calculated for each sub-unit.

The total paddock LTCC was the sum of the AE's for each land type sub-unit within the paddock. The grazing system AE is the average of the monitor paddocks within each system.

Paddock grazing

A comparison of average annual (2005-2009) paddock grazing pressure (SDH) from grazing charts (actual) and from estimated LTCC is shown in Table 1.11.3. There were 20 paddocks grazed less than the LTCC would suggest (12 cell, 6 rotation and 2 continuous), 53 paddocks were grazed at a higher rate (42 cell, 7 rotation and 4 continuous) and 1 paddock (continuous) was grazed at the same rate as the estimated LTCC.

Table 1.11.3. Average annual grazing pressure (Actual) imposed on paddocks (SDH) compared with LTCC.

Property	GS	Paddock	SDH		Diff.	
			Actual	LTCC	Actual-LTCC	under / over
Banyula	Cell	Mascot 2	98.1	183.0	-84.9	under
Banyula	Cell	Amberley 1	100.0	181.6	-81.6	under
Banyula	Cell	Amberley 10	113.4	183.0	-69.6	under
Banyula	Cell	Mascot 3	115.9	183.0	-67.1	under
Banyula	Cell	Eagle Farm 3	81.7	93.0	-11.3	under
Banyula	Cell	Eagle Farm 1	82.9	93.0	-10.1	under
Berrigurra	Cell	Emu Apple 19	64.1	101.2	-37.1	under
Berrigurra	Cell	Emu Apple 18	72.1	104.0	-31.9	under
Berrigurra	Cell	Emu Apple 10	94.8	99.3	-4.5	under
Melrose	Cell	Flat - 17	116.6	169.4	-52.7	under
Melrose	Cell	Astrida - 22	89.8	101.5	-11.7	under
Ticehurst	Cell	S7 East	79.6	87.0	-7.4	under
Berrigurra	Rotn	Middle	93.6	108.0	-14.4	under
Rocky Spr.	Rotn	Telegraph	63.3	86.2	-23.0	under
Rocky Spr.	Rotn	Stud	72.4	88.5	-16.2	under
Somerville	Rotn	East Rustlers	18.5	19.6	-1.1	under
Somerville	Rotn	West Rustlers	16.8	17.2	-0.4	under
Ticehurst	Rotn	Y1 West	65.9	66.3	-0.4	under
Rocky Spr.	Cont	No 1. Cow	94.1	100.4	-6.3	under
Salisbury Pl.	Cont	Wilmington 20	87.3	90.4	-3.2	under
Banyula	Cell	Richmond 4	123.1	90.1	33.0	over
Banyula	Cell	Mascot 6	142.6	99.0	43.6	over
Banyula	Cell	Eagle Farm 7	129.1	78.1	51.0	over
Banyula	Cell	Richmond 6	145.0	75.0	70.0	over
Berrigurra	Cell	Emu Apple 11	121.8	106.0	15.8	over
Berrigurra	Cell	Emu Apple 17	116.9	96.6	20.4	over
Berrigurra	Cell	Emu Apple 12	134.0	101.9	32.1	over
Frankfield	Cell	Bul A8	79.8	60.7	19.1	over
Frankfield	Cell	Bul B11	96.0	63.8	32.2	over
Frankfield	Cell	Bul B18	104.2	66.4	37.8	over
Frankfield	Cell	Bul A1	107.3	63.5	43.8	over
Frankfield	Cell	Bul A9	96.4	49.3	47.2	over
Frankfield	Cell	Bul B17	96.4	48.0	48.4	over
Frankfield	Cell	Bul A7	98.06	48.1	49.9	over
Frankfield	Cell	Bul B12	120.15	49.8	70.3	over
Melrose	Cell	Wooden Gate - 20	90.6	80.7	9.8	over
Melrose	Cell	Red Hill - 7	135.7	109.3	26.4	over
Melrose	Cell	Eroded Hill - 16	117.4	77.5	39.9	over
Salisbury Pl.	Cell	Kan C4-25	60.1	45.4	14.7	over
Salisbury Pl.	Cell	Kan C4-26	69.0	39.0	30.0	over
Salisbury Pl.	Cell	Kan C1-1	147.7	108.0	39.7	over
Salisbury Pl.	Cell	Kan C1-8	158.9	103.9	54.9	over
Salisbury Pl.	Cell	Kan C2-11	183.7	113.4	70.3	over
Salisbury Pl.	Cell	Kan C2-12	192.7	62.8	129.9	over
Salisbury Pl.	Cell	Kan C2-14	235.6	79.1	156.5	over
Salisbury Pl.	Cell	Kan C2-13	262.1	63.9	198.2	over

Salisbury Pl.	Cell	Kan C1-2	332.2	108.0	224.2	over
Somerville	Cell	Spinifex Ridge 1	23.3	18.7	4.6	over
Somerville	Cell	Spinifex Ridge 2	20.0	14.4	5.6	over
Somerville	Cell	Top Bullock 6	21.4	14.6	6.8	over
Somerville	Cell	Spinifex Ridge 3	25.9	14.5	11.4	over
Somerville	Cell	Top Bullock 7	29.1	16.8	12.3	over
Somerville	Cell	Top Bullock 5	42.3	24.4	17.9	over
Sunnyholt	Cell	Mill 3	146.6	109.3	37.3	over
Sunnyholt	Cell	Walangra 8	177.9	106.8	71.1	over
Sunnyholt	Cell	Pines 1	178.8	86.9	91.9	over
Sunnyholt	Cell	Mill 4	172.8	79.5	93.3	over
Sunnyholt	Cell	Homestead 2	211.7	93.1	118.6	over
Ticehurst	Cell	S5 East	91.6	81.7	9.9	over
Ticehurst	Cell	O5 East	99.5	78.3	21.2	over
Ticehurst	Cell	K3 East	94.9	67.6	27.3	over
Ticehurst	Cell	K5 East	116.0	68.4	47.6	over
Berrigurra	Rotn	Pdk 16	137.6	102.4	35.2	over
Frankfield	Rotn	Carrington’s (2)	140.4	47.9	92.5	over
Frankfield	Rotn	Road (1)	201.2	60.1	141.1	over
Melrose	Rotn	Dam 52	93.6	77.5	16.1	over
Melrose	Rotn	Alston 53	129.6	105.0	24.7	over
Somerville	Rotn	Trivalore	17.1	12.4	4.7	over
Ticehurst	Rotn	X1 West	66.4	41.3	25.2	over
Banyula	Cont	Bankstown 8	103.7	72.0	31.6	over
Berrigurra	Cont	Pdk 14	100.5	79.6	20.9	over
Frankfield	Cont	Mitchell	178.2	67.9	110.3	over
Sunnyholt	Cont	Homestead 1	153.2	86.3	66.9	over
Melrose	Cont	Green Gully - 51	86.6	86.6	0.0	same

1.11.3 References

Anon (2008). Department of Primary Industries and Fisheries. *Land Types of Queensland – Fitzroy.* PR07-3212. Version 1.1. Prepared by the Grazing Land Management workshop team, Department of Primary Industries and Fisheries, Brisbane.

Chilcott, C.R., Paton, C.J., Quirk, M.F. and McCallum, B. (2004). Grazing Land Management Education Package – Workshop Notes, Burnett. Meat and Livestock Australia Limited, Sydney.

Environmental Protection Agency (2007). Regional Ecosystem Description Database (REDD). Version 5.2. Updated November 2007. http://www.epa.qld.gov.au/nature_conservation/biodiversity/regional_ecosystems/how_to_download_redd/

Gunn, R.H., Galloway, R.W., Pedley, L. and Fitzpatrick, E.A. (1967). *Lands of the Nogoa-Belyando area, Queensland*. Land Research Series No. 18, CSIRO, Melbourne.

Johnston, P.W., McKeon, G.M. and Day, K.A. (1996). Objective 'safe' grazing capacities for south-west Queensland Australia: Development of a model for individual properties. *Rangeland Journal* **18,** 244-258.

Johnston, P.W., Tannock, P.R. and Beale, I.F. (1996). Objective 'safe' grazing capacities for south-west Queensland Australia: Model application and evaluation. *Rangeland Journal* **18,** 259-269.

Jones, P**.,** Aisthorpe, J. and Chilcott, C. (2006). Developing long term carrying capacity models for the desert uplands. Proceedings Australian Rangelands Society Conference, Renmark. September 2006

Jones, P. and Sandral, C. (2007). Stanwell Corporation grazing capacity assessment – a long term carrying capacity. Report to Stanwell Corporation. Queensland Department of Primary Industries, Brisbane.

McKeon, G.M., Day, K.A., Howden, S.M., Mott, J.J., Orr, D.M., Scattini, W.J. and Weston, E.J**.,** (1990). Management for pastoral production in northern Australia savannas. *Journal of Biogeography* **17,** 355-372.

Speck, N.H., Wright, R.L., Sweeney, F.C., Perry R. A., Fitzpatrick, E.A., Nix, E.A., Gunn, R.H., and Wilson, I.B. (1968). *Lands of the Dawson-Fitzroy area, Queensland*. Land Research Series No. 21, CSIRO, Melbourne.

1.12 Appendix 12 - Diet quality (NIRS)

1.12.1 Faecal sample collection

Cattle faecal samples (one bulked sample from at least 10 animals, from each grazing system) were collected by property owners at approximately monthly intervals. The dung samples were air-dried and posted to the CSIRO Davies laboratory for NIRS analysis to assess diet quality. Producers also completed a field data collection sheet (FDCS) to accompany each sample with details of pasture yield and condition, recent rainfall, paddock details, animal details, supplements, etc.

1.12.2 NIRS analysis of GSP samples 2005-2009

Faecal samples were oven dried at 65°C and then ground through a Model 1093 Cyclotec mill fitted with a 1 mm screen (Foss Tecator AB, Hoganas, Sweden). Before analysis samples were re-dried (65°C) and then scanned (400-2500 nm range) in a monochromator fitted with a spinning cup module (Foss 6500, NIRSystems, Silver Spring, MD, USA) using ISI software (Infrasoft International, Port Matilda, PA, USA). Predictions of dietary crude protein (DCP), dry matter digestibility (DMD) of the diet, dietary non-grass (DNG) and faecal N concentration, were made using calibration equations developed at the CSIRO Davies Laboratory in Townsville (Coates 2004; Coates and Dixon 2008).

Names of the calibration equations:

DNIT1441.EQA - for predicting dietary N which was then converted to CP.
DMDIVD3.EQA - for predicting estimated in vivo DMD.
FECN2.EQA - for predicting faecal N.
DELFEC9.EQA - for predicting faecal $\delta^{13}C$ from which DNG was calculated.

1.12.3 Results presentation

As results were produced they were added to a time schedule table and graphed presenting crude protein, digestibility and non-grass proportions. These results were sent to the producers to provide them with current diet quality information to manage their grazing and supplementation program.

1.12.4 References

Coates, D.B. (2004) Improving reliability of faecal NIRS calibration equations. Final Report of Project NAP3.121 to Meat and Livestock Australia, Sydney.)

Coates, D.B. and Dixon, R.M. (2008) Development of near infrared analysis of faeces to estimate non-grass proportions in diets selected by cattle grazing tropical pastures. *Journal of Near Infrared Spectroscopy* **16**, 471-480.

1.12.5 NIRS statistical analysis

NIRS measurements on faecal samples from 2005-2009 were analysed by residual maximum likelihood (REML). Models included fixed effects of Grazing System (GrazSys; cell, rotation, continuous), Season (growing, winter) and Year (winter plus following growing season) and appropriate interactions and the random effects of property, grazing system and paddocks within grazing system. A step-down procedure was used to evaluate the significance of interactions. Generally, the models reduced to simple main effects models so main effects models were fitted to all variables and predicted means plus average standard error of differences (sed's) obtained. Distributional assumptions for all analyses were assessed by visual inspection of residual and normal probability plots with no major departures being observed. These analyses were completed, both for the entire dataset and within properties.

1.12.5.1 Methods - NIRS

1.12.5.1.1 Pasture Growth Index related to NIRS

Mean NIRS measurements were also considered with respect to Growth Index (GI). As for the complete data set mean NIRS measurements were analysed using REML and included fixed effects of GI, GrazSys, Season, Region (north, south) and Vegetation type (brigalow, eucalypt) and their interactions. Random effects of property, grazing system and paddocks within grazing system were also used. A step-down procedure was used to evaluate the significance of interactions. Generally, the models reduced to simple main effects models, so main effects models were fitted to all variables and predicted means plus average sed's obtained. Distributional assumptions for all analyses were assessed by visual inspection of residual and normal probability plots with no major departures being observed.

1.12.5.1.2 Paired sampling time data

Were there was one or more samples for at least two grazing systems for a given property sampled at the same time (or at least within 3 days) was considered 'paired sample times' and were analysed using REML within properties (as for the complete data set) and predicted means obtained. Average sed's were presented and, where differences (P<0.05) were observed, approximate lsd's were calculated and used to perform pair-wise comparisons of means. Distributional assumptions for all analyses were assessed by visual inspection of residual and normal probability plots with no major departures being observed.

Within property NIRS results were analysed comparing the grazing systems. This analysis included all systems monitored and other systems sampled by the owners. For the main grazing system statistical analysis the clay cells at Banyula and leucaena cells at Sunnyholt were excluded.

1.12.5.2 NIRS diet quality results

1.12.5.2.1 Regions and vegetation communities

A graphical representation of the site means for main NIRS diet quality parameters for the regions, north and south Queensland (Figure 1.12.1) and vegetation communities, brigalow and eucalypt (Figure 1.12.2) are shown in the following figures. The southern sites and the brigalow sites had the higher quality. There was similar non-grass in the diet between regions, but the eucalypt sites had higher non-grass than the brigalow, buffel grass dominant sites.

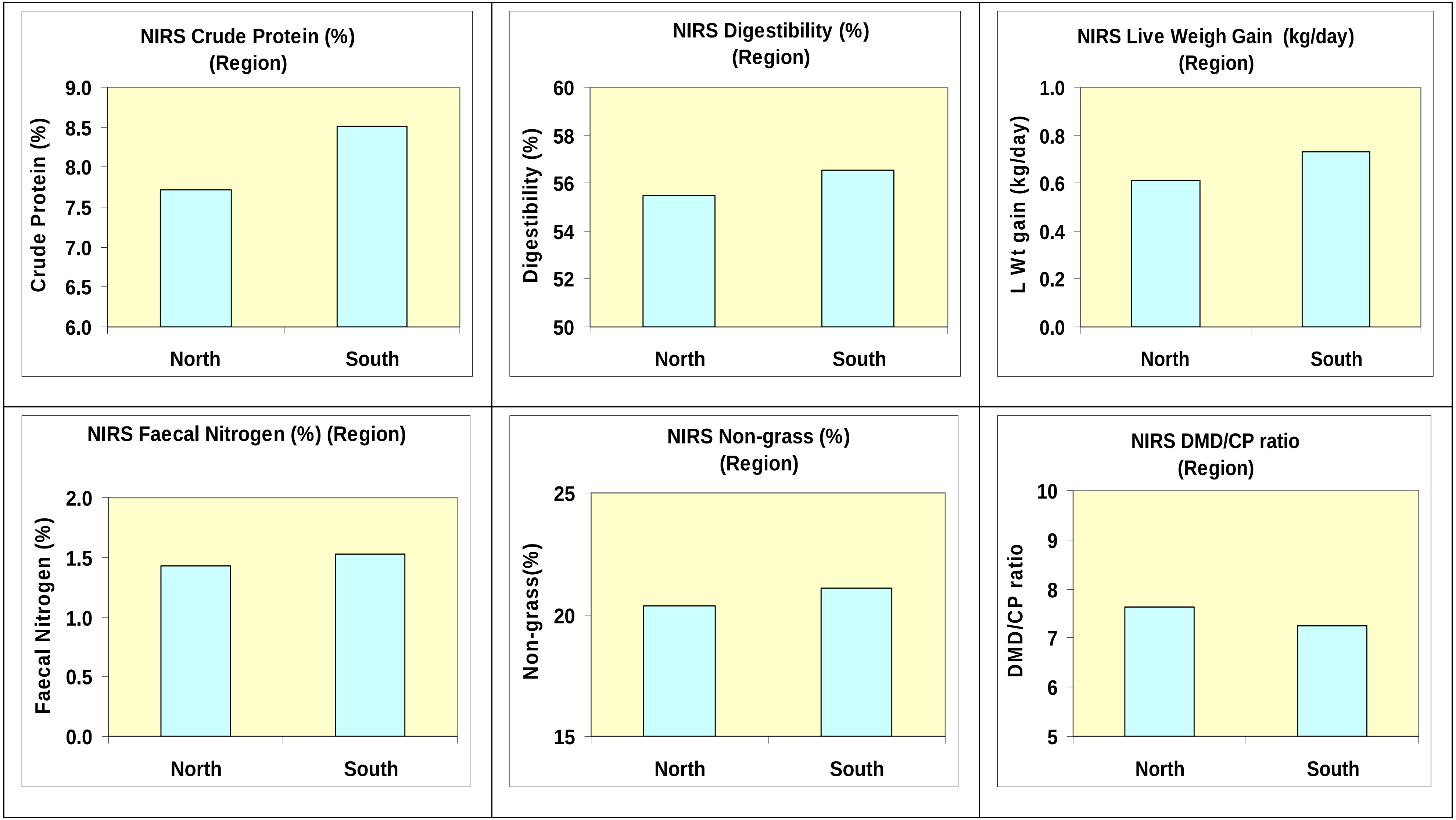


Figure 1.12.1. Northern and southern Queensland site means for main NIRS diet quality parameters (North 367 samples; South 242 samples).

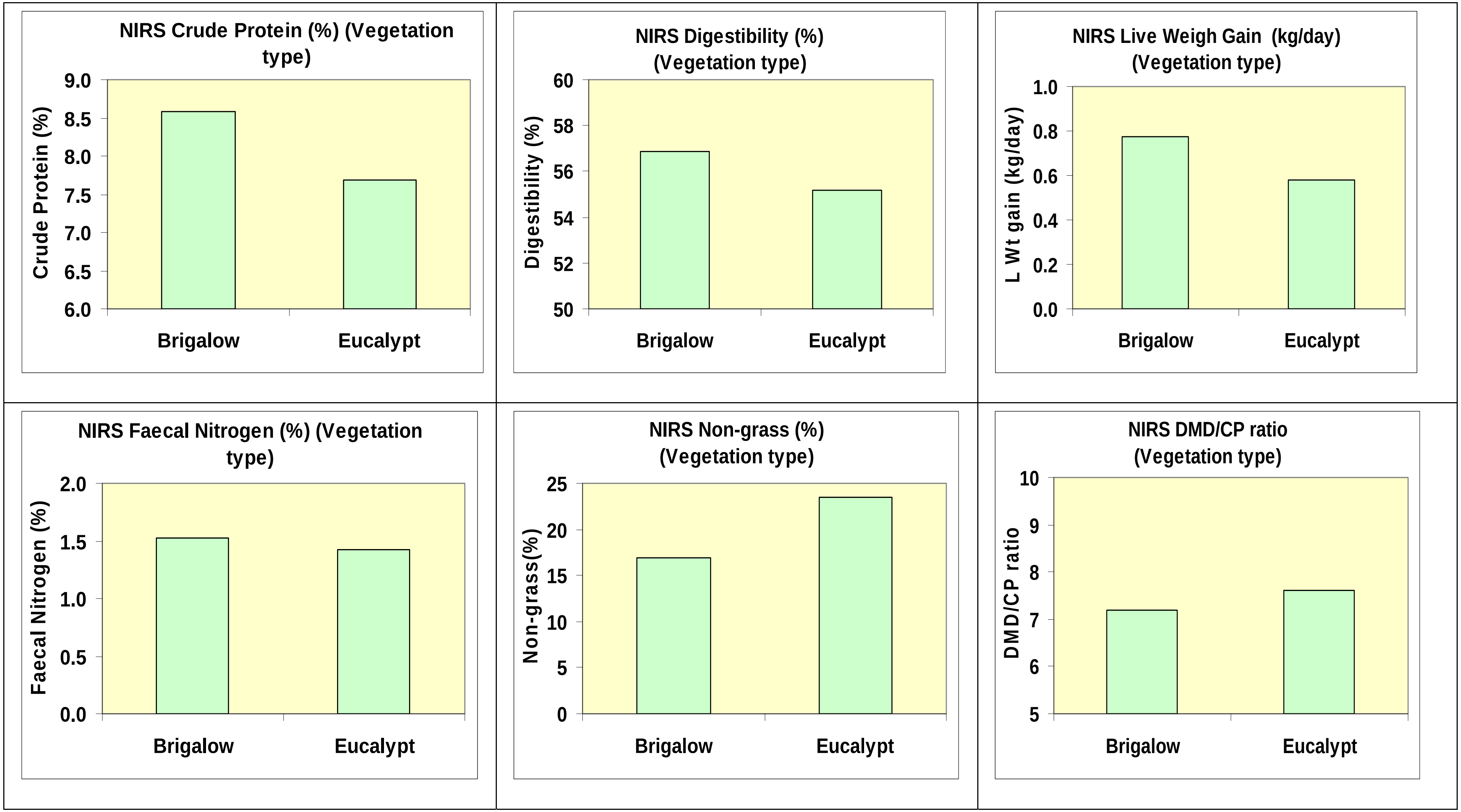


Figure 1.12.2. Brigalow and eucalypt site means for main NIRS diet quality parameters (Brigalow 341 samples; Eucalypt 268 samples).

1.12.5.2.2 Pasture Growth Index

1. NIRS parameter means within three growth index classes for three grazing systems over all sites (Table 1.12.1).

Table 1.12.1. Mean NIRS diet quality values related to the average of the previous 30-days Growth Index for all samples and sites for the three grazing systems.

Growth Index	Grazing System	Av. no. samples	Crude Protein (%)	Faecal N (%)	Digest-ibility (%)	Non-Grass (%)	LWG (kg/day)	DMD/CP ratio
<0.2	Cell	13.0	6.9	1.35	54.3	19.6	0.48	8.3
	Rotation	10.8	6.6	1.30	53.2	21.1	0.36	8.4
	Continuous	12.0	7.2	1.39	54.2	21.1	0.48	7.9
0.2-0.5	Cell	9.1	8.3	1.50	57.0	19.8	0.76	7.3
	Rotation	8.2	8.6	1.49	56.4	20.8	0.76	6.9
	Continuous	9.3	9.4	1.61	58.0	22.4	0.84	6.6
>0.5	Cell	6.8	10.1	1.69	59.6	14.2	0.98	6.4
	Rotation	7.8	9.7	1.61	59.1	21.4	0.93	6.7
	Continuous	8.2	10.0	1.70	58.8	17.8	0.92	6.2

2. Mean and significant NIRS diet quality parameters for three grazing systems and three pasture growth indices (<0.2, 0.2-0.5 and >0.5) and interactions for all samples (565) at nine sites are shown in Table 1.12.2.

Table 1.12.2. Significant NIRS diet quality parameters for grazing systems and pasture growth indices and interactions for all samples (565) at nine sites.

	no.	Crude Protein (%)		Faecal N (%)		Digestib -ility (%)		Non-Grass (%)		LWG (kg/day)		DMD/CP ratio	
Grazing Systems		***		***		***		***		**		***	
Cell	214	7.81	c	1.43	c	55.7	b	17.3	b	0.67	b	7.6	a
Rotation	156	8.32	b	1.49	b	56.4	b	21.4	a	0.72	ab	7.3	ab
Continuous	195	8.93	a	1.58	a	57.3	a	20.3	a	0.78	a	6.9	b
	-												
sed (average)	565	0.23		0.02		0.4		1.0		0.03		0.2	
Growth Index (GI)		***		***		***		*		***		***	
<0.2	242	7.00	c	1.36	c	53.9	c	20.6	a	0.48	c	8.2	a
0.20-0.50	172	8.68	b	1.52	b	57.0	b	20.1	a	0.80	b	7.0	b
>0.50	151	9.37	a	1.61	a	58.3	a	18.2	b	0.90	a	6.6	c
sed (average)		0.22		0.02		0.4		0.9		0.03		0.2	
Region		ns		ns		ns		ns		P=0.096		ns	
North	365	8.00		1.46		56.0		19.5		0.66		7.4	
South	200	8.71		1.54		56.9		19.8		0.79		7.1	
sed		0.40		0.06		1.0		3.2		0.07		0.2	
Vegetation Type		ns		ns		ns		P=0.055		P=0.064		ns	
Brigalow	294	8.59		1.52		56.9		15.8	b	0.80		7.1	
Eucalypt	271	8.11		1.47		56.0		23.5	a	0.65		7.4	
sed		0.40		0.06		1.0		3.2		0.07		0.2	
Interactions:													
GrazSys.GI		P=0.050		**		ns		ns		ns		ns	
GrazSys.Region		P=0.061		ns		ns		ns		P=0.064		*	

GI. Region		**		ns	*		ns	***		**	
North											
<0.2	139	6.88	d	1.33	53.8	d	20.9	0.45	d	8.1	a
0.20-0.50	122	8.06	c	1.47	56.1	c	19.7	0.69	c	7.3	b
>0.50	104	8.88	b	1.55	57.5	bc	17.3	0.81	b	6.9	bc
South											
<0.2	103	6.98	d	1.38	53.9	d	19.6	0.48	d	8.3	a
0.20-0.50	50	9.62	ab	1.60	58.4	ab	20.3	0.94	a	6.5	cd
>0.50	47	9.86	a	1.67	59.1	a	19.5	1.00	a	6.3	d
sed (average)		0.39		0.05	0.8		2.4	0.06		0.3	
GrazSys.Vegetation		ns		ns	ns		**	ns		ns	
GI.Vegetation		ns		ns	ns		ns	ns		ns	
Region.Vegetation		ns		ns	*		ns	ns		ns	
GrazSys.GI.Region		ns		P=0.075	ns		ns	ns		ns	
GrazSys.GI.Vegetation		ns		ns	ns		ns	ns		ns	
GrazSys.Region.Vegetation		P=0.092		**	*		*	P=0.051		ns	
GI.Region.Vegetation		ns		ns	ns		P=0.080	ns		ns	
GrazSys.GI.Region.Vegetation		ns		ns	ns		ns	ns		ns	

3. Site NIRS means within three growth index classes for two or three grazing systems (Table 1.12.3).

Table 1.12.3. NIRS diet quality values related to the average of the previous 30-days Growth Index (GI) for all samples from each grazing systems at each site.

All Sites - Average NIRS values within Growth Index Ranges

Sites	GI	Grazing System	No.	Crude Protein (%)	Faecal N (%)	Digest-ibility (%)	Non-Grass (%)	LWG (kg/day)	DMD/CP ratio
Banyula	<0.2	Cell-clay	6	8.0	1.49	59	21	0.65	8.0
		Cell-loam	11	8.3	1.54	56	20	0.76	7.6
		Continuous	12	7.9	1.53	56	20	0.61	7.7
	0.2-0.5	Cell-clay	10	11.3	1.73	59	30	0.99	5.6
		Cell-loam	4	8.3	1.53	57	23	0.86	7.3
		Continuous	4	11.0	1.79	59	39	0.99	6.2
	>0.5	Cell-clay	1	14.4	2.11	65	0	1.25	4.5
		Cell-loam	2	12.5	2.16	65	7	1.35	5.2
Berrigurra	<0.2	Cell	12	6.8	1.4	52	18	0.49	7.9
		Continuous	13	7.7	1.5	54	16	0.60	7.3
		Rotation	14	6.7	1.4	52	20	0.49	8.1
	0.2-0.5	Cell	10	7.7	1.5	56	11	0.73	7.4
		Continuous	11	9.3	1.6	58	13	0.86	6.6
		Rotation	13	8.4	1.5	57	15	0.83	7.1
	>0.5	Cell	11	7.7	1.5	56	7	0.78	7.6
		Continuous	10	9.4	1.7	57	7	0.95	6.6
		Rotation	11	8.4	1.5	57	15	0.85	7.4
Frankfield	<0.2	Cell	9	6.8	1.23	54	16	0.38	8.1
		Continuous	6	6.2	1.15	52	12	0.27	8.5
		Rotation	15	7.1	1.28	54	14	0.46	7.9
	0.2-0.5	Cell	8	7.2	1.3	56	10	0.71	7.9

		Continuous	10	8.1	1.34	54	14	0.68	7.0
		Rotation	12	8.3	1.39	54	15	0.67	7.2
	>0.5	Cell	7	7.1	1.29	56	11	0.64	8.8
		Continuous	7	9.5	1.63	60	16	0.84	6.7
		Rotation	8	9.6	1.53	60	11	0.92	6.4
Melrose	<0.2	Cell	10	6.0	1.26	52	14	0.33	9.1
		Continuous	9	6.9	1.38	54	23	0.46	8.1
		Rotation	9	7.0	1.36	55	26	0.48	8.1
	0.2-0.5	Cell	12	6.8	1.35	55	14	0.54	8.2
		Continuous	10	8.2	1.52	57	23	0.72	7.1
		Rotation	11	7.9	1.42	56	23	0.68	7.3
	>0.5	Cell	11	7.2	1.36	54	17	0.53	7.8
		Continuous	10	9.5	1.65	58	19	0.81	6.3
		Rotation	11	7.9	1.4	55	22	0.61	7.2
Rocky Springs	<0.2	Continuous	12	6.3	1.28	52	21	0.27	8.4
		Rotation	12	6.2	1.3	52	22	0.23	8.7
	0.2-0.5	Continuous	8	9.3	1.57	57	21	0.79	6.6
		Rotation	8	9.1	1.56	56	22	0.74	6.6
	>0.5	Continuous	8	9.1	1.57	56	23	0.86	6.3
		Rotation	8	8.6	1.53	56	24	0.84	6.7
Salisbury Plains	<0.2	Cell	12	6.5	1.24	53	28	0.30	8.4
		Continuous	13	8.0	1.45	56	39	0.49	7.2
		Rotation	4	5.9	1.19	53	23	0.13	9.0
	0.2-0.5	Cell	12	7.1	1.34	55	23	0.38	8.0
		Continuous	12	9.3	1.64	58	35	0.69	6.4
		Rotation	2	9.7	1.54	58	37	0.75	6.2
	>0.5	Cell	1	12.3	1.77	61	20	1.20	5.0
		Continuous	6	12.6	1.99	63	24	1.15	5.1
		Rotation	5	11.3	1.89	61	21	0.96	6.1

Somerville	<0.2	Cell	13	6.1	1.24	54	21	0.45	9.3
		Rotation	7	7.3	1.38	55	30	0.56	7.9
	0.2-0.5	Cell	4	6.9	1.54	56	29	0.55	8.7
		Rotation	2	6.9	1.52	56	27	0.63	8.1
	>0.5	Cell	5	8.4	1.48	57	23	0.69	7.2
Sunnyholt	<0.2	Cell	34	7.4	1.40	56	16	0.61	8.0
		Continuous	19	7.3	1.45	56	16	0.65	8.1
	0.2-0.5	Cell	18	11.2	1.76	62	21	1.23	5.9
		Continuous	10	10.9	1.78	62	13	1.17	6.0
	>0.5	Cell	19	10.6	1.79	61	20	1.11	6.0
		Continuous	8	11.3	1.83	62	11	1.21	5.6
Ticehurst	<0.2	Cell	10	6.4	1.31	53	21	0.39	8.7
		Rotation	8	6.6	1.27	52	23	0.37	8.3
	0.2-0.5	Cell	4	8.6	1.48	59	17	0.84	6.9
		Rotation	3	8.4	1.49	58	14	0.87	7.2
	>0.5	Cell	4	11.1	1.72	61	23	1.23	5.7
		Rotation	4	12.3	1.76	66	36	1.39	6.3

The total number of samples included in the statistical analysis for the grazing systems at the nine sites was 565. This analysis excluded the Ban clay and Sun leucaena paddocks. The sample numbers from each site (32 to 104) is shown in Table 1.12.4

Table 1.12.4. Total number of NIRS samples from properties.

	Property									
	Ban	**Ber**	**Fra**	**Mel**	**Roc**	**Sal**	**Som**	**Sun**	**Tic**	**All Sites**
GrazSys										
Cell	16	35	25	32	-	25	24	39	18	214
Rotation	16	40	32	31	29	-	10	-	14	156
Continuous	-	29	23	29	29	30	-	39	-	195
Season										
Growing	16	51	31	38	26	22	18	34	15	251
Winter	16	53	49	54	32	33	16	44	17	314
Year										
2005	5	9	12	9	10	1	8	8	8	70
2006	10	30	20	31	14	6	12	19	19	161
2007	7	26	17	32	12	20	12	24	3	153
2008	9	30	22	20	18	22	2	21	2	146
2009	1	9	9	0	4	6	0	6	0	35
Total	32	104	80	92	58	55	34	78	32	565

There were consistent diet quality differences between the grazing systems at the nine sites (Table 9.12.5). The average crude protein range from all samples was 6.91% on native pastures on sandy soils in the tropics to 8.91% in buffel grass pastures on a softwood-brigalow clay soil in southern Queensland (Table 9.12.6). The average digestibility ranged from 54% on native pastures to 58% on buffel grass; the faecal nitrogen range was 1.38% to 1.58%; the non-grass range was 13% to 30%; and predicted liveweight gain was 0.56 kg/hd/day to 0.88 kg/hd/day. The higher diet quality and animal performance values were all from buffel grass pastures in southern Queensland.

Table 9.12.5. Differences between grazing systems for mean values of NIRS diet quality parameters at nine sites between 2005 and 2009.

Diet quality	Site by grazing system difference in NIRS diet quality parameters									
parameter	Ban Con-Cell	Ber Con-Cell	Fra Con-Cell	Mel Con-Cell	Roc Con-Rot	Sal Con-Cell	Som Rot-Cell	Sun Con-Cell	Tic* Rot-Cell	Av. all sites
Crude Protein (%)	0.2	1.7	1.0	1.7	0.3	2.5	0.8	0.2	-0.5	8.0
Faecal N (%)	0.0	0.1	0.1	0.2	0.0	0.3	0.1	0.1	-0.1	1.5
Digestibility (%)	-0.6	2.4	0.6	2.8	0.1	4.5	0.2	0.7	-1.0	55.7
Non-Grass (%)	4.9	-1.9	1.5	7.1	-0.6	10.5	6.9	-1.3	-0.9	18.7
LWG (kg/day)	-0.1	0.2	0.1	0.2	0.0	0.3	0.1	0.0	-0.1	0.7
DMD/CP ratio	0.0	-0.9	-0.9	-1.3	-0.3	-1.6	-1.1	0.1	0.2	7.5

* There were 12 summer growing season samples from the cells (total 17) compared with seven growing season samples from the rotation system (total 13 samples).

The difference between the averages of each NIRS parameter at all sites (Table 9.12.6) shows the consistently higher quality from the continuous system than from the cells. This often small, but consistent superiority of continuous grazing over the cells would contribute to the common perception of better per head animal performance from this system over cell systems.

Table 9.12.6. Mean NIRS diet quality parameters for all grazing systems for all samples at nine sites (excludes Banyula clay).

Diet quality	Site by mean NIRS diet quality parameter									
parameter	Ban	Ber	Fra	Mel	Roc	Sal	Som	Sun	Tic	mean
Crude Protein %	8.61	8.04	7.65	7.49	7.86	8.36	6.91	8.91	7.73	7.97
Faecal N %	1.58	1.51	1.33	1.41	1.44	1.48	1.38	1.55	1.41	1.45
Digestibility %	57	56	55	55	54	56	55	58	55	56
Non-Grass %	22	13	13	20	23	30	25	15	20	19
LWG kg/day	0.76	0.74	0.60	0.57	0.57	0.56	0.56	0.88	0.63	0.66
DMD/CP ratio	7.4	7.3	7.6	7.7	7.4	7.2	8.5	7.0	7.7	7.5
Growth Index	0.19	0.37	0.32	0.35	0.34	0.29	0.25	0.29	0.22	0.31
Ash %	24	23	24	20	20	18	20	25	23	22
No. samples	32	104	80	92	58	55	34	78	32	565

An analysis of the 497 paired samples (when at least two grazing systems were sampled at the same time) showed there was a significant increase in diet quality as the pasture growth index increased from <0.2 (6.9% crude protein) to between 0.2-0.5 (8.5% CP) and to >0.5 (8.9% CP), which is expected. This reflects the increasing proportion of green leaf in the pasture and the change from the dry season to the growing season. As the GI increased there was a significant increase in liveweight gain prediction from 0.45 kg/day to 0.85 kg/day and a decrease in the DMD/CP ratio from 8.2 to 6.8 (Table 9.12.7). Values above 8 indicate marginal to deficient protein in the diet.

The average ash content of all samples was 22.6%, ranging from 17% in cells at Salisbury Plains to 26% from the continuous system at Frankfield. There were no significant differences between systems at any site.

Table 9.12.7. Significant NIRS diet quality parameters for grazing systems and pasture growth indices and interactions for all samples at nine sites and for all sites combined.

Sites Grazing System Growth Index	Crude Protein (%)	Faecal N (%)	Digestib-ility (%)	Non-Grass (%)	LWG prediction (kg/day)	DMD/CP ratio
All Properties	Statistical significance					
Grazing Systems	**	**	**	**	**	**
Growth Index (GI)	**	**	**	*	**	**
GrazSys.GI	**	**	ns	ns	ns	ns
Banyula						
Grazing Systems	ns	ns	ns	ns	ns	ns
Growth Index (GI)	ns	ns	ns	*	ns	ns
GrazSys.GI	ns	ns	ns	P=0.067	ns	ns
Berrigurra						
Grazing Systems	**	**	P=0.052	**	**	*
Growth Index (GI)	**	**	**	*	**	*
GrazSys.GI	ns	ns	ns	ns	ns	ns
Frankfield						
Grazing Systems	ns	ns	ns	ns	ns	ns
Growth Index (GI)	**	**	**	ns	**	P=0.094
GrazSys.GI	ns	ns	ns	ns	ns	ns
Melrose						
Grazing Systems	**	**	**	**	**	**
Growth Index (GI)	**	*	*	ns	**	**
GrazSys.GI	ns	ns	ns	ns	ns	ns
Rocky Springs						
Grazing Systems	ns	ns	ns	ns	ns	ns
Growth Index (GI)	**	**	**	ns	**	**
GrazSys.GI	ns	ns	ns	ns	ns	ns
Salisbury Plains						
Grazing Systems	**	**	**	**	**	**
Growth Index (GI)	**	**	**	**	**	**
GrazSys.GI	ns	ns	ns	ns	ns	ns
Somerville						
Grazing Systems	ns	ns	ns	*	ns	*
Growth Index (GI)	*	ns	ns	ns	ns	ns
GrazSys.GI	ns	ns	ns	ns	ns	ns
Sunnyholt						
Grazing Systems	ns	*	ns	ns	ns	ns
Growth Index (GI)	***	***	***	ns	***	***
GrazSys.GI	ns	ns	ns	ns	ns	ns
Ticehurst						
Grazing Systems	ns	ns	ns	ns	ns	ns
Growth Index (GI)	***	***	***	ns	***	*
GrazSys.GI	ns	ns	ns	ns	ns	ns

There were significant between site differences in the NIRS parameters and between sites when same-day sampling paired samples were compared (Table 9.12.8). There were no differences in any parameter between the nine paired samples on buffel pasture at Banyula or Frankfield, but strong system differences on native pastures at Melrose and Salisbury Plains. Crude protein, but not digestibility, was different between systems on buffel at Berrigurra.

Table 9.12.8. Significant differences between grazing systems for NIRS diet quality parameters when samples were collected on the same day (paired) and for all samples at nine sites.

Site	Data	NIRS parameter					
	No. samples	Crude Protein %	Faecal N %	Digesti-bility %	Non-Grass %	LWG kg/day	DMD/CP ratio
		Statistical significance (paired samples)					
Banyula	9 paired	ns	ns	ns	ns	ns	ns
Banyula	all data	ns	ns	ns	ns	ns	ns
Berrigurra	all data	**	*	P=0.061	ns	*	ns
Berrigurra	25 paired	*	*	ns	*	P=0.075	ns
Frankfield	all data	ns	ns	ns	ns	ns	ns
Frankfield	20 paired	ns	ns	ns	ns	ns	ns
Melrose	all data	***	***	**	***	**	**
Melrose	28 paired	**	***	*	**	*	*
Rocky Spr.	29 paired	ns	ns	ns	ns	ns	ns
Salis'y Pls.	24 paired	ns	***	*	***	ns	ns
Somerville	4 paired	ns	ns	ns	ns	ns	ns
Sunnyholt	37 paired	ns	ns	ns	ns	ns	ns
Sunnyholt*	3 GS	ns	**	*	*	ns	ns
Ticehurst	13 paired	ns	ns	ns	ns	ns	ns

* includes 'fats herd' in cells with access to leucaena paddocks.

A summary of the statistical differences in diet quality parameters for all samples over the nine sites (Table 9.12.9) shows that there were significant system differences in all parameters. The season and year differences were also significant.

Table 9.12.9. Significant NIRS diet quality parameters and interactions for all samples (565) at nine sites between 2006 and 2009.

All Sites	NIRS parameter					
Syst/Season/Year	Crude Protein %	Faecal N %	Digesti-bility %	Non-Grass %	LWG kg/day	DMD/CP ratio
	Statistical significance (565 samples)					
Grazing System	**	**	*	P=0.079	P=0.096	P=0.070
Season	***	***	***	***	***	***
Year	***	***	*	***	***	***
GrazSys*Season	P=0.054	P=0.091	ns	ns	ns	ns
GrazSys*Year	ns	ns	ns	ns	ns	ns
Season*Year	ns	*	ns	*	*	*
GrazSys*Season*Year	ns	ns	ns	ns	ns	ns

1.13 Appendix 13 - Grazing system intensity index

Grazing systems can be considered to fall along a spectrum. The least intense would be continuous grazing where stock are grazed for the whole year (or season) in one paddock with no change in stock numbers or distribution during the year. The most intense would be a full cell grazing system (many paddocks, short grazing periods, and the grazing and rest periods determined by pasture growth) with detailed records and forward planning using feed budgets.

The system intensity arises from a number of factors and these can be grouped:

1. Capital costs - mainly fencing and water supply but possibly also yards if herd sizes are increased;
2. Operating costs – labour for moving animals between paddocks, checking water 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, forward planning and record keeping.

An index has been developed for each grazing system by calculating three sub-indices based on these factors each with values from 0 to 100, and then taking an average of the three sub-indices to generate the GSI.

The index only relates to operations that directly involve the grazing system – other operations on the property (e.g. pasture sowing, management of breeding plans, weed control, etc) are not included. The details of the index are reported below:

1.13.1 Capital costs sub-index (CI)

This sub-index increases as the number of paddocks increases and more fences and watering points are needed. Continuous grazing systems have low values and CI approaches 100 in rotationally and cell grazed pastures with many paddocks. The major capital costs of establishing a grazing system are for fencing and water supply although larger yards may also be required if herd sizes are increased.

The increase in costs is not directly proportional to the number of paddocks as fences are shared between paddocks, water points may serve more than one paddock, and new troughs may be added to existing pipe lines. Adding each additional paddock is less costly than each previous addition. Hence costs increase with paddock number but the rate of increase drops at higher paddock numbers to produce a curvilinear relationship.

The shape of the relationship between number of paddocks and CI was determined for a hypothetical property using realistic costs for fencing and water supplies and determining the costs for increasing paddock numbers.

The starting point is a 2,500 ha area of land (5 x 5 km) with a centrally located water source but no fences or capacity to distribute the water (pump, tank, pipes and troughs). The cattle yards are situated at the water supply point. The costs of establishing 1, 2, 3, 4, … 128 paddocks were calculated using the following rules.

1.13.1.1 Fencing

For a given number of paddocks, all paddocks were equal in area.

(a) The boundary fence and the internal fences for the first eight paddocks were of conventional construction. Conventional fencing is costed at $4000 per km.

(b) Internal fences for additional paddocks were electric fences consisting of a single electric wire with a steel picket (with one insulator) every 40 m. Steel post, insulators, wire, etc is costed at $300 per km and wooden end-assemblies at $70 each.

All paddocks were either adjacent to the yards or connected to them by laneways.
There was one electric fence unit per 50 km of fence (cost = $2000).
Wooden posts were used in corners, ends and gates.
Wire gates were used (no galvanised iron gates).
A maximum of eight paddocks meet at any point.

1.13.1.2 Water supply

The water supply (bore, waterhole or dam) already exists but needs to be distributed.
There was one trough per paddock up to 16 paddocks. For larger numbers of paddocks, troughs were shared between paddocks with a maximum of eight paddocks per trough. Troughs were costed at $3000 each.
The pump size and cost increased linearly as paddock number increased up to 16 troughs, from $5000 to $10000.
Each water point is capable of watering the whole herd.
There was one tank ($3000) per four troughs.
Pipe and fittings were costed at $6500 per km.

1.13.1.3 Calculation of relationship

Capital cost, CI values, were calculated for systems with up to 100 paddocks (Table 1.13.1); for systems with more than 100 paddocks the CI was set to 100.

Table 1.13.1. Calculated capital cost index (CI value) for number of paddocks.

Paddock number	CI	Paddock number	CI
1	23	15	87
2	32	20	91
3	39	30	92
4	46	40	93
5	52	50	95
6	57	60	96
7	63	70	98
8	68	80	99
9	71	90	99
10	74	100	100

1.13.2 Operating costs sub-index (OI)

The OI has been calculated in two parts:
(a) Cattle management - the movement of cattle between paddocks as part of the grazing system (infrequent in extensive systems and frequent in intensive systems) and mustering costs (for weaning, branding, marketing, pregnancy testing, removing bulls, etc.)
(b) Infrastructure maintenance costs

1.13.2.1 Cattle management

When the grazing period is short and thus animals are moved frequently, this component has a high value, and conversely, it has a low value when grazing periods are long and moves are infrequent.

Part of the operating cost of more intensive grazing systems is the time to move cattle and the shorter the grazing period the more often the animals need to be moved. However, as animals become accustomed to moving frequently less time is need for each move, especially as with frequent moves the animals usually do not move far. The length of the grazing period has been chosen but frequency of moves would give a similar result. With daily moves, the value of the cattle management component approaches 100 and approaches zero with long grazing periods. For yearlong grazing the length of the grazing season is 365 days.

The cattle management component has been calculated based on the time taken to move animals based on the following assumptions:

1. when the average grazing period is 1 day, it takes 1 hour to move the herd;
2. when the average grazing period is 6 months or longer, it takes 2 men for 1 day or 16 hours to move the herd; and
3. the time taken to move the herd increases linearly for grazing periods between these values.

We assume two musters are needed per year. In an intensive system where animals are moved frequently this will involve moving animals to the yards and returning them to the paddock. We assume this will take 2 hours in addition to the time taken for a normal paddock move on that day as rotations can be organised so cattle are close to the yards. Similarly with extensive systems we assume the muster is conducted on a day when cattle would be moved so have additional time to get cattle to and from the yards – where the grazing period is 6 months or more this is assumed to be 8 hours. The time taken to muster the herd increases linearly for grazing periods between these values. For animals that are not moved the musters also include the 16 hours needed to gather the animals in the paddock in addition to the time moving to and from the yards.

The number of hours per year for both moving cattle between paddocks and mustering to yards was calculated for various grazing periods. The value for a grazing period of 1 day was set to 100 and the values for longer grazing periods expressed relative to this value.

The approximate values for the cattle management component of operating cost index (OI) are shown in Table 1.13.2.

Table 1.13.2. Calculated operating cost index (OI value) for grazing period.

Grazing period (days)	Cattle management component	Grazing period (days)	Cattle management component
1	100	10	18
2	54	15	15
3	39	20	14
4	32	30	12
5	27	40	12
6	24	50	12
7	22	100	12
8	20	200	12
9	19	365	12

Where the system involves a number of paddocks but the adjustments are only made to some paddocks during a particular year (e.g. spring burning and rest), the component value is calculated for each paddock and the values averaged to generate a value for the system.

Infrastructure maintenance costs – maintenance requirements and costs are assumed to be proportional to capital value of the system, so the contribution to OI is equal to CI.
OI is calculated as the average of the cattle management and the infrastructure components.

1.13.3 Management sub-index (MI)

There are a number of management actions that apply to various degrees to any grazing system. The maximum value for MI is 100 and is based on the following allocations:
Decisions on when to move cattle between paddocks (maximum = 40)

Values are allocated on the following basis:

0 decisions to move cattle are totally reactive

10 the decision is based on an inflexible time schedule (totally calendar-based)

20 the decision is mainly calendar-based but some consideration is given to pasture condition and growth

40 the decision is based on current pasture growth. In the most intensive systems the grazing period is adjusted to match the growth rate of the pasture and grazing periods are shorter during active growth periods and longer when pasture growth slows or ceases.

Adjusting animal numbers to match expected feed supply (maximum = 40)

Values are allocated on the following basis:

0 no adjustments are made unless feed supply is consumed

10 adjustments are made reactively to changing feed supply

40 adjustments are made proactively by feed budgeting.

Monitoring and record keeping (maximum = 20)
Values are allocated on the following basis:

0 no records are kept

10 some records are kept

20 detailed records of animal numbers, feed supply, pasture and soil condition, animal condition are kept.

Intermediate values are allocated where the system sits between these values.
The values of (a), (b) and (c) are summed to generate MI.

1.13.4 Calculation of GSI values for hypothetical systems

The information needed to calculate the GSI for a grazing system is:
The number of paddocks;

- The average grazing period (days) for paddocks each year;
- Whether moves between paddocks are based on current pasture growth rate;
- Methods used to adjust the number of animals grazing in the system in relation to carrying capacity; and
- Monitoring and recording systems used.

The GSI is calculated as the average of these three sub-indices (CI, OI and MI), and like them has a value between 0 and 100.

These values can be calculated for a number of hypothetical grazing systems.

1.13.4.1 Continuous system

A continuously grazed paddock with minimal management inputs.

A 2-paddock system where one paddock is spelled for 8 weeks each year in rotation. During this time the animals graze the other pasture but there are no changes in overall animal numbers. Minimal monitoring and record keeping.

A 4-paddock system where one paddock is spelled for 8 weeks each year in rotation. During this time the animals graze the other 3 pastures but there are no changes in overall animal numbers. Minimal monitoring and record keeping.

1.13.4.2 Rotational systems:

a 2-paddock system where the grazing period is 3 months (91 days)
a 2-paddock system where the grazing period is 20 days
a 5-paddock system where the grazing period is 70 days
a 5-paddock system where the grazing period is 20 days
a 10-paddock system where the grazing period is 20 days
a 20-paddock system where the grazing period is 5 days

Detailed monitoring and record keeping but animal movements are calendar-based and there are no changes to animal numbers.

1.13.4.3 Cell grazing systems:

Detailed monitoring and record keeping for all cell systems.

a. 50-paddock system where animals are moved at 2 day intervals on average; no adjustment for pasture growth; animal numbers are changed proactively during the year to reflect anticipated feed supply.

b. 50-paddock system where animals are moved at 2 day intervals on average; period of stay is adjusted for pasture growth; animal numbers are changed proactively during the year to reflect anticipated feed supply.

c. 100 paddock system where animals are moved daily on average; period of stay is adjusted for pasture growth; animal numbers are changed proactively during the year to reflect anticipated feed supply.

Examples of the range of GSI for varying capital, operating and management indices are shown in Table 1.13.3.

Table 1.13.3. Examples of capital (CI), operating (OI), management (MI) indices and calculated grazing system index (GSI) for cell grazing systems.

System	CI	OI			MI				GSI
		Animal	Infra	OI	Move	Numbers	Records	MI	
1	**23**	12	23	**18**	0	0	0	**0**	**14**
2	**32**	12	32	**22**	0	0	0	**0**	**18**
3	**46**	12	46	**29**	0	0	0	**0**	**25**
4a	**32**	12	32	**22**	10	0	20	**30**	**28**
4b	**32**	14	32	**23**	10	0	20	**30**	**28**
4c	**52**	12	52	**32**	10	0	20	**30**	**38**
4d	**52**	14	52	**33**	10	0	20	**30**	**38**
4e	**74**	14	74	**44**	10	0	20	**30**	**49**
4f	**91**	27	91	**59**	10	0	20	**30**	**60**
5a	**95**	54	95	**75**	10	40	20	**70**	**80**

5b	**95**	54	95	**75**	40	40	20	**100**	**90**
5c	**100**	100	100	**100**	40	40	20	**100**	**100**

The details of calculating the GSI for the 22 grazing systems (separating Banyula cell clay and cell loam) at the nine sites are shown in Table 1.13.4.

Table 1.13.4. Calculated grazing system index (GSI) for 22 grazing systems at nine primary sites.

Property	Grazing system	No. of Pdks	CI	Av. graze period	Animal manage-ment	Infra	OI	Decision to move 1-40	Match Pasture adj nos. 1-40	Monitor Records 1-20	MI	GSI
Banyula	Cell (Clay)	24	**92**	3	39	92	**66**	20	40	15	**75**	**78**
	Cell (Loam)	21	**91**	3	39	91	**65**	20	40	15	**75**	**77**
	Continuous	1	**23**	350	12	23	**18**	1	20	5	**26**	**22**
Berrigurra	Cell	20	**91**	6	24	91	**58**	20	10	10	**40**	**63**
	Rotation	10	**74**	28	12	74	**43**	20	10	10	**40**	**52**
	Continuous	1	**23**	200	12	23	**18**	1	10	10	**21**	**21**
Frankfield	Cell	30	**92**	4	32	92	**62**	20	40	10	**70**	**75**
	Rotation	9	**71**	40	12	71	**42**	20	40	5	**65**	**59**
	Continuous	1	**23**	330	12	23	**18**	1	40	5	**46**	**29**
Melrose	Cell	29	**91**	3	54	91	**73**	20	20	15	**55**	**73**
	Rotation	8	**68**	15	15	68	**42**	20	20	10	**50**	**53**
	Continuous	1	**23**	360	12	23	**18**	1	20	10	**31**	**24**
Rocky Springs	Rotation	5	**52**	265	12	52	**32**	1	40	10	**51**	**45**
	Continuous	1	**23**	360	12	23	**18**	1	40	10	**51**	**31**
Salisbury Plains	Cell	60	**96**	2	54	96	**75**	20	20	5	**45**	**72**
	Continuous	1	**23**	360	12	23	**18**	1	20	15	**36**	**26**
Somerville	Cell	160	**100**	2	54	100	**77**	40	40	15	**95**	**91**
	Rotation	25	**92**	40	12	92	**52**	20	40	15	**75**	**73**
Sunnyholt	Cell	30	**92**	5	27	92	**60**	40	40	15	**95**	**82**
	Continuous	1	**23**	360	12	23	**18**	1	20	15	**36**	**26**
Ticehurst	Cell	49	**95**	1	100	95	**98**	40	40	15	**95**	**96**
	Rotation	20	**91**	3	39	91	**65**	40	40	15	**95**	**84**

1.14 Appendix 14 - Economic analysis

1.14.1 Template model

An economic analysis of increasing grazing system intensification from a current system can be described in the Figure 1.14.1 model. This analysis includes effects on herd structure, infrastructure costs, other input costs, gross margins, the whole enterprise and subsequent economic performance. An excel spreadsheet calculator has been developed to incorporate these effects on their beef business.

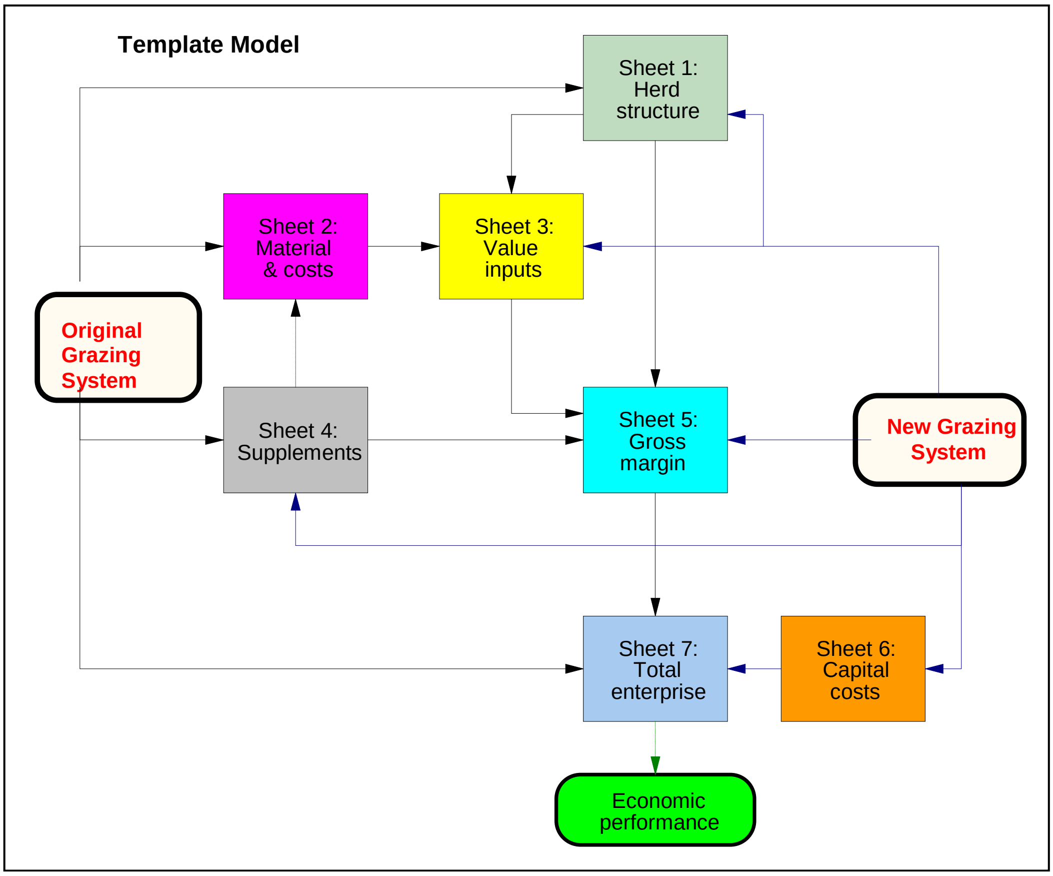


Figure 1.14.1. General structure of template `break-even' model used for evaluation of case studies.

1.14.2 Break even calculator

A break-even calculator for estimating grazing systems changes is available as an Excel® spreadsheet template for producers to add their own herd details, values and costs. A printout of the calculator with an example of developing a new grazing system is shown in Table 1.14.1.

Table 1.14.1. Break-even calculator example of costs and returns from developing a new grazing system.

MARGINAL NET PROFIT CALCULATOR **Date: 15/10/2009**

A. Marginal Net Profit (MNP)

(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
(2) Costs:						
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
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
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
2.4 Marketing Xs		**Value.**		**Value.**		**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
(3) Total Gross Margin	$336,868	$379,327	$42,460

(4) Fixed costs	**Value.**	**Value.**	**Value.**
Repairs and maintenance			$0
General insurance			$0
Administration			$0
Rates, levies, agistment			$0
Fuel and oil			$0
Electricity and gas			$0
Depreciation	$108,000	$122,000	$14,000
Fertiliser and seed			$0
Wages and salaries			$0
Other			$0
Total:	$108,000	$122,000	$14,000
(5) Net profit	$228,868	$257,327	$28,460

(6) Increased revenue	$59,024
(7) Reduced revenue	$0
(8) Additional costs	$30,564
(9) Reduced costs	$0
(10) Marginal Net Profit = [(6)+(9)) - ((7)+(8)]	$28,460

B. Marginal Investment (MI)

(11) Livestock on hand	**Existing system**		**New system**		**Difference**	
Animal class	**No.**	**Value.**	**No.**	**Value.**	**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

(12) Fencing

Fence type	km fenced	$/km	no. gates	$/gate	$/ labour	$/delivery	Total

Cells	34	$592					$20,128
Rotation	14	$1,015					$14,210
							$0
						Total	$34,338

(13) Water supplies

13.1 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

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

13.3 Pumps/mills etc

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

13.4 Tanks

Description	no. tanks	$/tank	no. fittings	$/fitting set	$ /labour	$/delivery	Total
Cells	1	$3,000	1	$5,060			$8,060
Rotation	1	$3,000					$3,000
							$0
						Total	$11,060

(14) Tree planting

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

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

(15) Fire management

Description	Km /breaks	$ /km	$ /labour	$ /materials	$ /other	Total	Frequency
Fire-breaking						$0	1

Fire crews							$0	$0
Fuel							$0	
Plant							$0	
						Total	$0	

(16) Pasture development

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

(17) Disposal of redundant assets

Description		Total
	Total	$0

(18) System design, training etc

Description		Total
	Total	$0

(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

C. Return on marginal investment (%)

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

1.14.3 Rockhampton Case Study – Impact on Marginal Net Profit (MNP) from Variation in key parameters.

The Rockhampton case study analysis in the main body of the report (Chapter 4.6) is centred on two scenarios - the original grazing system ('continuous' grazing with periodic spelling) that has been operating on the property and new systems based on a set of new cells and larger rotational grazing paddocks. The assumptions concerning the productivity of the herd, beef prices and various cost items that were used are unique to the particular set of circumstances prevailing for this property at the time of the analysis. A more general picture of the potential economic outcome for the new grazing system - consistent with the exploratory nature of CVP analysis – can be obtained when some key model parameters are varied to explore their impact on the estimates of profitability. These parameter changes are generally consistent with varying the values of the sales volume (V), price (P), variable cost (TVC) and fixed cost (TFC) parameters in the general net profit equation described in Chapter 4.6, and include:

(a) a smaller increase in projected carrying capacity,
(b) increasing reproductive efficiency of the breeding herd,
(c) increasing animal growth rates,
(d) increasing or decreasing beef prices,
(e) increasing or decreasing variable costs,
(f) increasing or decreasing overhead costs, and
(g) increasing or decreasing inputs of unpaid owners' labour.

These changes are examined in terms of their impact on MNP.

(a) *Carrying capacity*

The production target is to increase breeder numbers by 90 head which is consistent with an increase in total stock carried of 210 AE. This scenario examines the effect of changes in carrying capacity that are only 25% and 50% of this target – i.e. 22 and 45 additional breeders or total herd increases of 50 AE and 105 AE. The effect on MNP is shown in Figure 1.14.2. If the carrying capacity increases by only 50% of the target, MNP is ~$8K per annum above the original grazing system; for only 25% gain, MNP is actually negative at ~ -$3K. In the latter case while the TGM has increased over the original grazing system, FC which includes depreciation on the new infrastructure also increases and offsets the revenue gain.

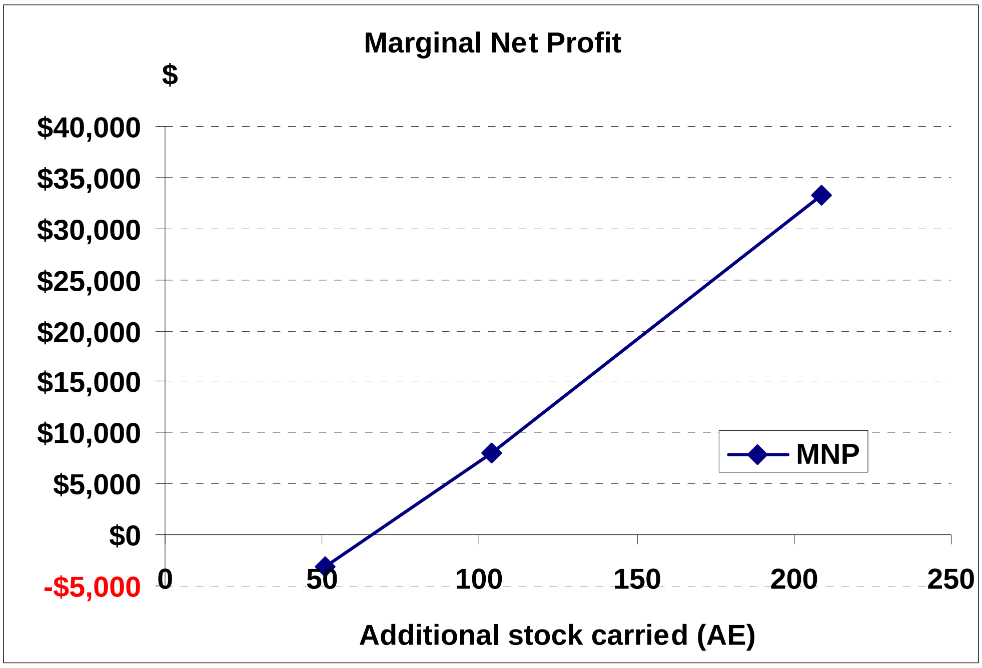


Figure 1.14.2. Rockhampton Case Study - Impact of changing carrying capacity (AE) on MNP.

That is, given the existing level of animal productivity, under the prevailing revenue and cost conditions the new systems represents a gain in net profitability over the old systems only if total livestock numbers carried can be increased by ~5%.

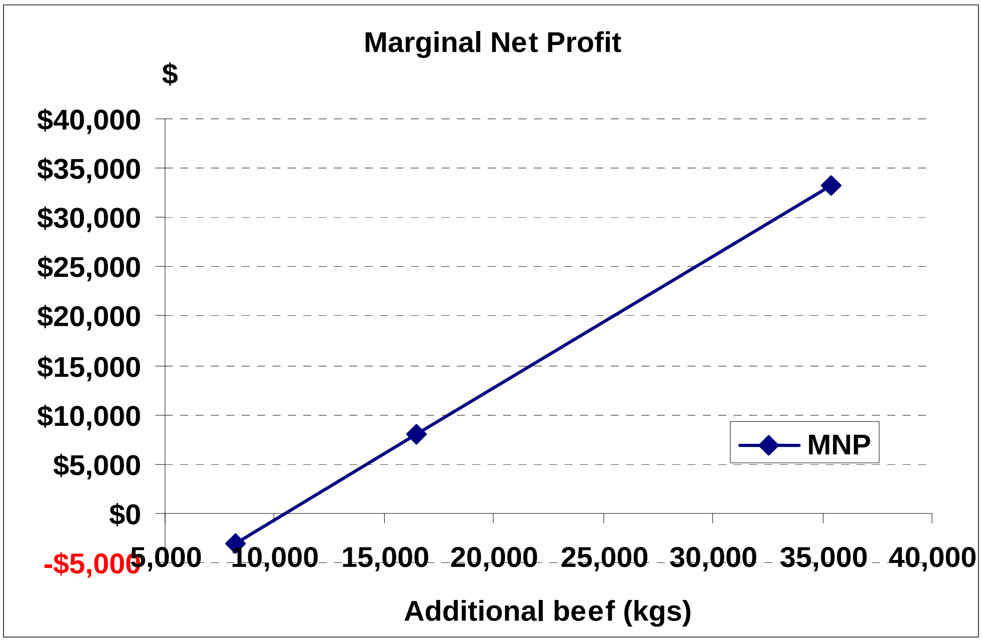


Figure 1.14.3. Rockhampton Case Study - Impact of changing aggregate production of beef (kg liveweight) on net profit estimates MNP.

Producers often ask 'how many kilograms of beef have to be produced to make a change of grazing system worthwhile'? This is a complex question when applied to mixed breeding and finishing cattle herds because the 'kilograms of beef' relate to mixed stock classes, of different age and weight that are usually traded in different markets. A rough estimate can be made by comparing the MNP against the aggregated sale weights of the different stock types that are included in the TGM calculations on which it is based. The result, presented in Figure 1.14.3, indicates that it would take ~11 extra tonnes of beef per annum to generate a positive MNP.

(b) Branding rate (%)

Reproductive efficiency - measured by the branding rate - is a major driver of profitability of beef enterprises. The previous MNP estimates are based on the branding percentage of the case study herd (average 77% across all breeders). What is the impact on MNP if reproductive performance also increases with the overall grazing system change? The effect on MNP of changes in branding percentage across an increasing range from nil through to 10% in 2.5% increments is shown in Figure 1.14.4. These are calculated for each increment in B% and include the projected gain in carrying capacity of 90 breeders and total numbers carried of 210 AE.

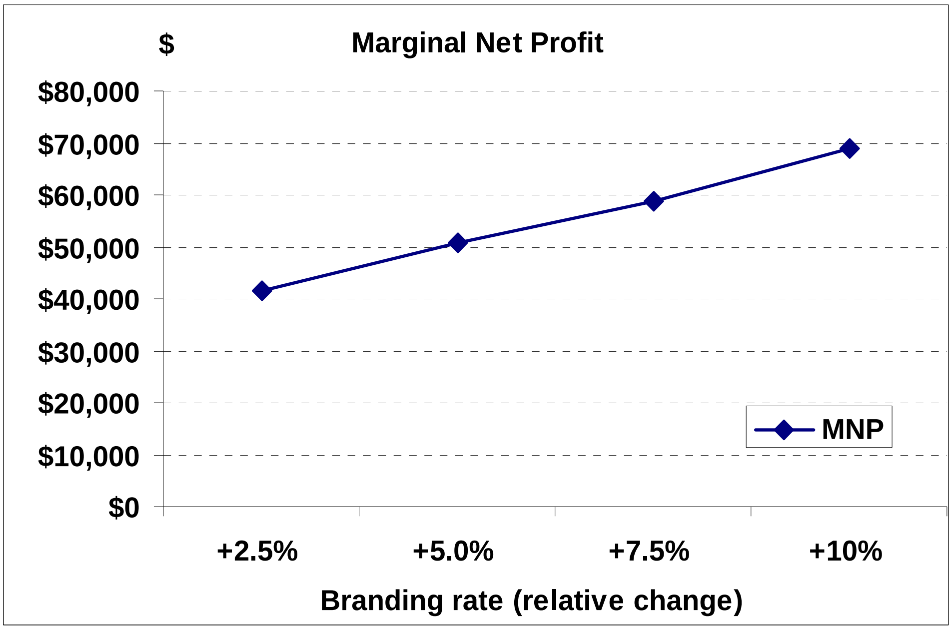


Figure 1.14.4. Rockhampton Case Study - Impact of changing branding rate (B%) on MNP.

The impact of increasing branding rate on net profit in conjunction with increasing carrying capacity is cumulative. Given that the projected change in carrying capacity alone (i.e. by 210 AE) was already an improvement over the original grazing system (Chapter 4.6, Table 4.46) in terms of MNP, the outcome for each increment in B% is also an improvement under the same circumstances. However, the MNP ranges between $41K and $69K over the 4 increments in B% (Figure 9.14.4), the lower limit exceeding each of the annuity values in Table 4.47 other than for the 10% discount rate and 10 year recovery period. Therefore, increasing reproduction efficiency does offer scope to increase the prospective net profitability of the new grazing system, but is more likely to do so when combined with an increase in carrying capacity.

(*c*) *Liveweight gain*

Beef cattle enterprises are in the business of producing beef, so animal growth rates are also a well-recognised driver of productivity and profit. The MNP estimates in the preceding sections are based on the average growth rates of the different classes of sale animals in the case study herd (av. sale weight of steers, breeders, and heifers respectively 615 kg, 560 kg and 405 kg liveweight). What is the impact on MNP of changing the annual liveweight gain (LWG) of the various animal classes across an increasing range of LWG from nil through to 10% in 2.5% increments? The MNP for each increment in LWG is shown in Figure 1.14.5.

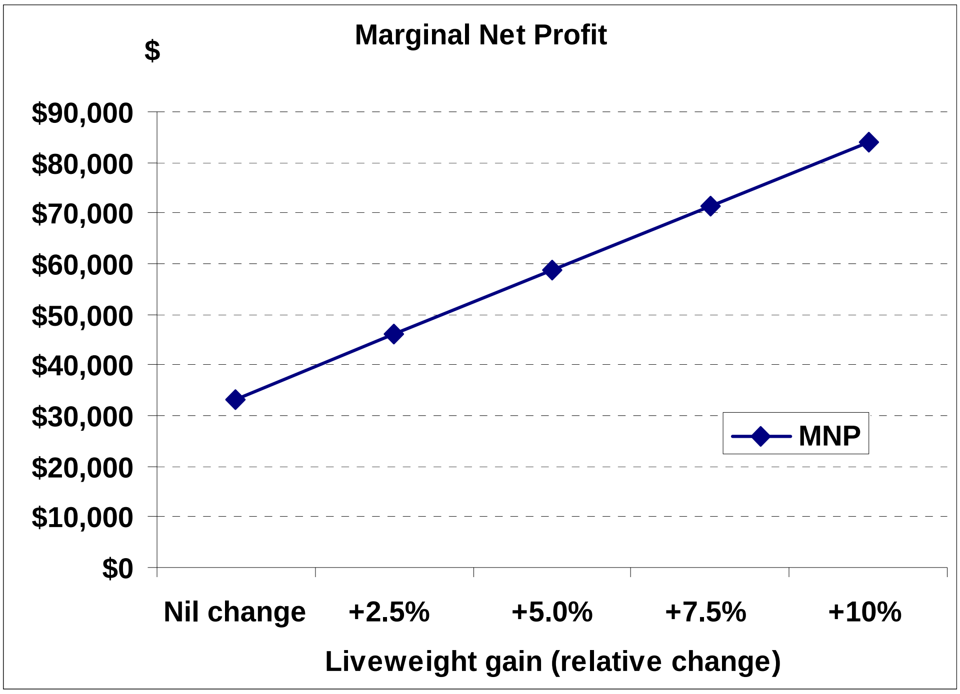


Figure 1.14.5. Rockhampton Case Study - Impact of changing liveweight gain (LWG) on MNP.

The impact of increasing LWG on MNP in conjunction with increasing carrying capacity is also clearly cumulative. The projected change in carrying capacity under the new grazing system (i.e. by 210 AE) already represented an improvement over the original grazing system (Chapter 4.6, Table 4.46) in terms of MNP, and increasing animal productivity boosts that gain considerably.

(*d*) *Beef prices*

The prevailing beef price is one of the two parameter values that basically determine the value of the total sales revenue (TR) variable in the simple 3 variable profit equation discussed in the opening section. The MNP estimates in previous sections are based on prices prevailing in local markets in mid-2009. Beef prices can show considerable variation within and between seasons, other enterprises considering changing their grazing systems may have different capacities to extract a market premium for their sale stock, and the quality of the stock being sold may be directly impacted upon by the new grazing system.

What is the impact on MNP if beef prices (liveweight basis) for all sale stock categories (i.e. steers, cull cows, dry breeders and cull heifers) were varied across a range from a 20% decrease to a 20% increase in 5% increments? The MNP under this range of price changes is shown in Figure 1.14.6, where the 'Nil change' mid-point values represents the existing prices applied to the increase in total numbers carried of 210 AE under the new grazing system.

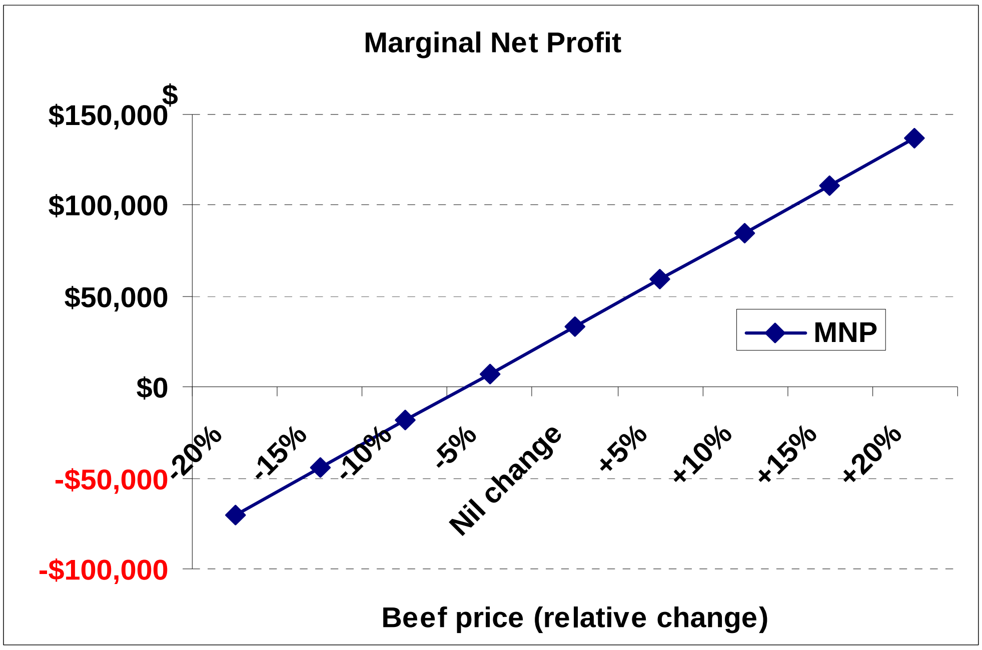


Figure 1.14.6. Rockhampton Case Study - Impact of changing beef price (liveweight) on MNP based on 790 breeders.

Declining and increasing beef prices respectively decrease and increase the TR earned for a given sales volume which translates to changes to MNP in the same directions. The MNP is projected to become negative for price declines of the order of 6% and greater relative to those prevailing in July 2009. Conversely, for any increase in prices the impact on MNP is necessarily an improvement over the baseline scenario of an increase of 90 breeders. For all price increases in the range of 5% and above, the MNP will exceed each of the annuity values for the $284K MI in new infrastructure and additional livestock (Chapter 4.6, Table 4.47).

(*e*) *Variable costs*

The second component of the simple 3 variable profit equation was TVC. The MNP estimates in preceding sections are based on direct production and marketing costs that applied for the case study property in mid-2009. While agricultural input costs generally follow an increasing trend over time, other enterprises considering changing their grazing systems may be more or less efficient in managing their costs and the new grazing system might allow the owners to exploit some direct cost efficiencies. What is the impact on MNP is variable costs for both production and marketing activities are varied across a range from a 20% decrease to a 20% increase in 5% increments? The result is shown in Figure 1.14.7, where the 'Nil change' mid-point values represents the existing prices applied to the increase in total numbers carried of 210 AE under the new grazing system.

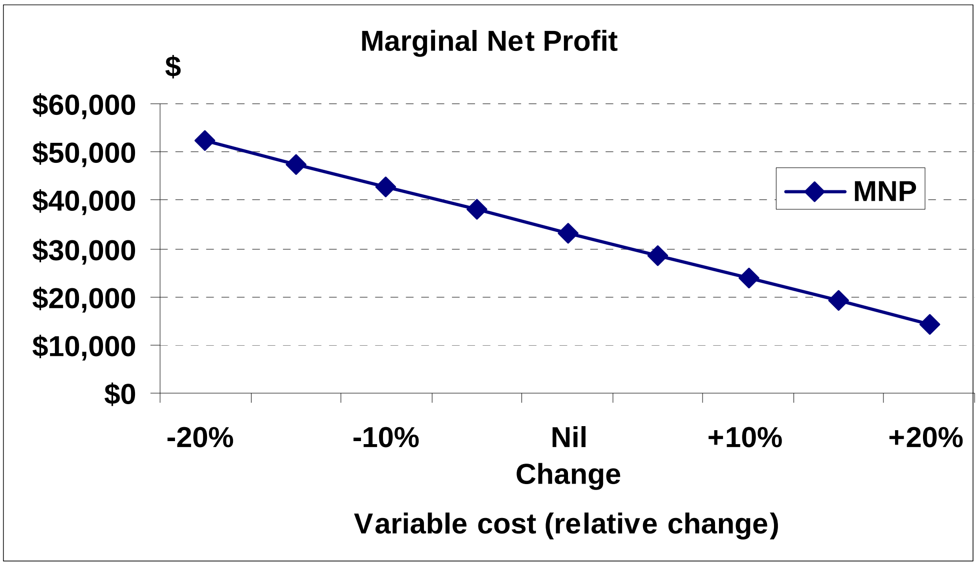


Figure 1.14.7. Rockhampton Case Study - Impact of changing variable cost (VC) on MNP based on 790 breeders.

Consistent with the simple 3 variable profit equation, the effect of, respectively, increasing or decreasing VC is to decrease and increase the MNP, and in all cases across the MNP remain positive relative to the original baseline scenario with 700 breeders. With the exception of the 5% decrease in VC, when VC is declining the MNP estimates exceed all of the annuity values for the MI of $284K (Chapter 4.6, Table 4.47). For increases in VC over the 5% to 20% range the MNP is necessarily reduced and only exceeds the annuity values for the $284K MI for the nil discount rate and 20 year recovery period and 5% discount and 20 year recovery period combinations when VC is increased by 5%, and only the latter annuity combination when VC is further increased to 20% above the 'Nil change' baseline case.

(*f*) *Overhead costs*

The third component of the simple 3 variable profit equation was fixed costs (TFC). As a general rule, fixed costs constitute a significant proportion of total costs TC for most beef enterprises, and increasing or decreasing TFC will respectively decrease of increase net profits. This will require commensurate increases and decreases in the volume of sales required to 'break-even', especially to recoup the MI in additional infrastructure and livestock associated with a new grazing system. What is the impact on MNP if fixed costs are across a range from a 20% decrease to a 20% increase in 5% increments? The MNP associated with for each increment in FC is shown in Figure 1.14.8 where the 'Nil change' mid-point values represents the existing prices applied to the increase in total numbers carried of 210 AE under the new grazing system.

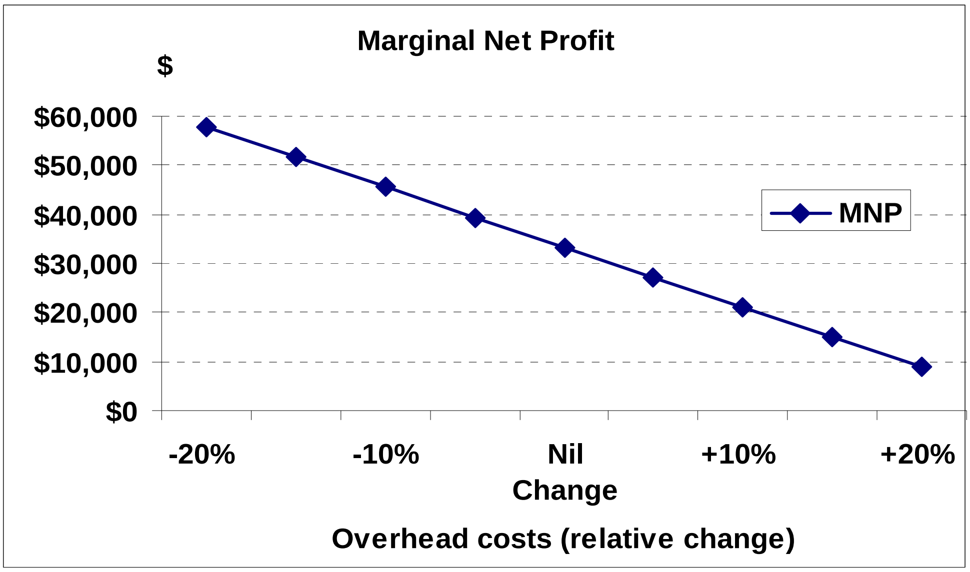


Figure 1.14.8. Rockhampton Case Study - Impact of changing fixed cost (FC) on MNP based on 790 breeders.

Consistent with the simple 3 variable profit equation, the effect of, respectively, increasing or decreasing FC is to decrease and increase the MNP which, nevertheless, remains positive across the range of FC changes for this case study. Similar to the case of changing VC in subsection (e) before, the MNP values for the range of FC changes will not exceed all of the annuity values for the MI of $284K (Chapter 4.6, Table 4.47). When FC is decreased across the range -5% to -20% the MNP does exceed each of the annuity values with the exception of 10% discount rate and shorter 10 year recovery period – whereas it fails to exceed any annuity for FC increases of +20% and only for recovery periods of 20 years when either nil or 5% discount rates are applied and nil discount only for FC increases of 5% to 15% respectively.

(g) Unpaid labour

The opportunity value of unpaid labour, especially owners' labour, is an implicit fixed cost for the enterprise, but is commonly ignored in formal calculations of profitability. This labour is usually treated as a residual claimant of any remaining profit after all other costs have been met and deprecation retained to cover future replacement of capital items. The calculation of MNP in the preceding examples has specifically excluded the value of unpaid owners' labour. Clearly, because the level of TFC has a direct influence on resulting estimates of net profitability, excluding or including allowances for unpaid' labour will also affect MNP, the impact obviously depending on how much labour is involved and the magnitude of any allowance made for it.

The issue of formally considering the value of unpaid labour is particularly relevant because changes to total labour requirements is contentious for examining the economic value of new grazing systems - especially those involving some element of cell grazing. A widely held belief among casual observers of cell grazing systems is that this particular form of grazing system necessarily involves high levels of investment in new infrastructure and the commitment of additional labour resources to handling stock and maintaining the augmented infrastructure. Alternatively, many operators of cell systems - including the present case study - suggest that there is considerable scope for reducing total labour commitments through better use of labour and timing of critical husbandry operations (e.g. weaning, branding, spaying, etc) to coincide with the concentrated mobs being close to handling facilities.

The impact of including or excluding unpaid labour on MNP was examined by modifying the total enterprise costs structure by altering the input of owners' labour through a range between minus and plus 1 full time labour unit in increments of 0.5 labour units - noting that the case study enterprise has an existing labour commitment of 2 full time adult labour equivalents. A modified variant of the baseline MNP calculation is employed for this scenario which equals the original MNP estimate less the value of 2 full time adult labour units costed at the prevailing station hand wage rates. This modified MNP value is denoted as MNP_{OL} in Figure 9.14.9. The changes in MNP_{OL} for each increment in owners' labour input are relative to the performance of the original grazing system, but include the projected gain of 90 breeders and associated increase in total numbers carried of 210 AE (represented by the 'Nil change' mid-point value in Figure 1.14.9).

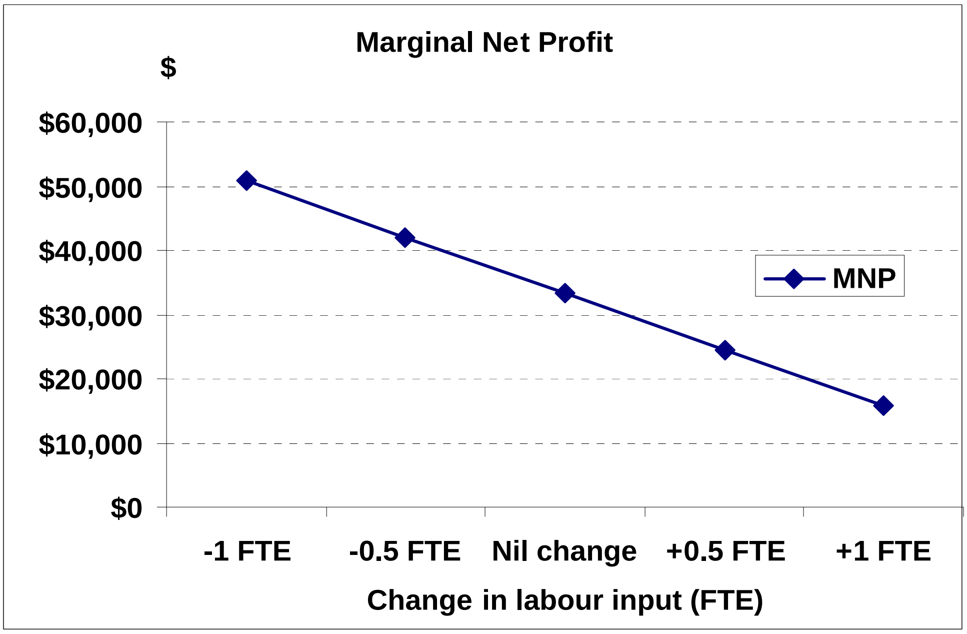


Figure 1.14.9. Rockhampton Case Study - Impact of changing input of owners' labour (FTE) on MNP_{OL} based on 790 breeders.

The new grazing system is still being commissioned and the owners are gaining experience in its operation. It will be clearly advantageous if the absolute input of owners' labour can eventually be reduced below the present commitment of 2.0 FTE. Under those favourable circumstances the net profitability of the new system would be considerably enhanced over and above that directly attributable to the increased carrying capacity of 210 AE. For example, the modified MNP_{OL} would exceed all of the annualised values for the MI of $284K contained in Chapter 4.6, Table 4.47, with the exception of the annuity based on 10% discount rate and 10 year recovery period. Alternatively, should the new grazing system actually require an expanded commitment of labour to operate it in the future, then the apparent profitability of the investment is reduced, and the projected MNP_{OL} would only exceed the annuity values for the longer recovery period of 20 years at nil or 5% discount rates. Any wish to recover the investment in infrastructure and additional cattle over a much reduced time frame would not be feasible.

1.15 Appendix 15 – Producer perceptions of systems

Beef Plan producers were surveyed at the Toowoomba annual BeefPlan meeting in 2005, for their grazing system choices and perceptions of the advantages and disadvantages of their various systems in their property circumstances (Hall and Hall 2008). The main choice of a system was related to pastures, livestock and lifestyle, while benefits related to pasture management followed by cattle management and the environment (land condition) third. The main disadvantages of their systems related to infrastructure, pasture deterioration and labour costs (Table 1.15.1).

Table 1.15.1. Producer survey of grazing system choice and perceptions of advantages and disadvantages of their own systems*.

Grazing System	Choice Focus	Advantages	Disadvantages
Continuous (+ spell)	Lifestyle (6) Livestock (2) Pasture (1)	Cattle management (5) Economic (3) Lifestyle (2) Pasture management (1) System management (1)	Pasture cost (9) Economic cost (2)
Rotation	Pasture (13) Livestock (6) Economic (2) Environment (1)	Pasture management (31) Cattle management (17) Environment (4) Economic (3) Social (2) Lifestyle (2) System management (1)	Infrastructure cost (10) Labour cost (8) Pasture cost (6) Economic cost (2) Livestock cost (2)
Cell	Pasture (8) Livestock (3) Economic (1) Environment (1) Holistic (1)	Pasture management (14) Cattle management (11) Environment (8) Economic (6) Feed budgeting (4) Lifestyle (3) Systems management (2) Social (1)	Infrastructure cost (4) Cattle cost (3) Labour cost (2) Lifestyle cost (2)

1.16 Appendix 16 - Communications list

Throughout the project there have been presentations, reports, papers and posters to introduce the research and inform producers and the research and extension community of the progress and results. Some of these formal communications are listed by year.

2004

1. Cell Grazing Project proposal – note for staff (Animal Sciences, Sustainable Grazing Systems) (M. Quirk, 1 Sept. 2004).
2. Grazing Systems Project proposal presentation - BeefPlan Groups Annual Forum, Rockhampton (Oct. 2004) (J. McIvor & T.J. Hall).
3. 'The Grazing Systems Project' producer information (Note 1) Oct. 2004 (T.J. Hall).
4. Individual producer telephone interviews (approx. 100) re GSP and Primary and Secondary site selection. (Nov. 2004 – May 2005) (Project Team).
5. Grazing Systems Project introduction, issues and potential sites - Arcadia Valley Pasture Management Group meeting at 'Sunnyholt', Injune. Nov. 2004 (T.J. Hall).

2005

1. NBP.353. GSP Producer Information article. (Note 2) (Mar. 2005) (J. McIvor).
2. "The new Cattle Grazing Systems", Maranoa Rural News, April 2005, p1. (T.J. Hall).
3. Grazing Systems Project note for DPIF Animal Science staff (July 2005) (M. Quirk).
4. "Project to put grazing systems under scrutiny" News Release DPIF (16 Aug. 2005) (via Russ Boadle, DPI&F Rockhampton).
5. 'Major Grazing Study'. Country Life Newspaper article (18 Aug. 2005, P 95) + other newspapers (via Russ Boadle, DPI&F Rockhampton).
6. "Project will put grazing systems under scrutiny" in Brisbane Valley, Gatton & Laidley Star newspaper. 24 Aug. 2005. (via Russ Boadle, DPI&F Rockhampton)
7. 'Grazing Systems Project (GSP)', producer information (Note 3) Sept. 2005 (T.J. Hall, J. McIvor).
8. "Project to put grazing systems under scrutiny" in Northern Muster, Spring 2005, P 9. (Russ Boadle, DPI&F Rockhampton).
9. "Project to put grazing systems under scrutiny" in Northern Register Newspaper, Aug 2005. (via Russ Boadle, DPI&F Rockhampton).
10. 'Grazing comparison research' BeefPlan Groups letter about GSP and sites (S. Banney, 29 Aug. 2005).
11. Roma Research Station Field day - Poster display. 28 Sept. 2005 (T.J. Hall).
12. 'Grazing Systems Project' Good News Story (No. 9); DPI&F 13 Oct. 2005 (T.J. Hall).

13. "What intensity works for you?" GSP presentation - BeefPlan Groups Annual Forum, Toowoomba, 26 Oct. 2005 (T.J. Hall).

14. "Your Grazing System/s?" GSP Survey at BeefPlan Groups Annual Forum, 26 Oct. 2005, Toowoomba (C.A. Hall and T.J. Hall).

15. ABC radio interview by Kathy Cogo on GSP (TJ Hall) done with Townsville ABC and broadcast over ABC stations (Oct. 2005).

16. "Grazing Systems under investigation in northern Australia", MLA Meat and Livestock Industry Journal, Feedback (P2), Nov/Dec 2005. An article introducing the GSP (Paula Heelan & Trevor Hall).

2006

17. Grazing Systems Project introduction at the annual DPIF biometry workshop (D. Reid) Bribie Island, Feb. 2006.

18. – Emerald Research Station open day Grazing Systems Project Presentation, May 2006 (P. Jones).

19. – Emerald Research Station open day Grazing Systems Project brochure (4 pp), May 2006 (G O'Sullivan).

20. Poster for Emerald Research Station open day, May 2006 (G. O'Sullivan).

21. ABC Rural. Interview. Grazing Systems Project. May 2006 (P. Jones).

22. Tri-fold single sheet general information project brochure (June 2006) (G. O'Sullivan).

23. General CSIRO project article on Sustainable Agricultural Systems (Article by CSE Fiona McFarlane, CSIRO, June 2006.

24. Presentations at three workshops across Desert Uplands, June 2006. (Pentland, Aramac and Jericho) (G O'Sullivan.

25. AgGrow field day, Emerald, project display, July 2006 (P. Jones & G. O'Sullivan).

26. CSIRO, Sustainable Ecosystems annual review meeting, Bribie Island, August 2006 (J. McIvor, C. McDonald & N. McLeod).

27. "Sustainable grazing plan" North Queensland Register, 27 July 2006 (P. 24). Newspaper article.

28. Grazing Systems Project glossy handout brochures – dot points text, why, what doing, aims, how, outputs etc + photos, map.

29. Australian Rangelands Conference, "Role of Grazing Systems in Pastoral Intensification", oral presentation and journal article, Sept 2006. (J. McIvor, and T. Hall).

30. UQ Gatton rangelands students and lecturers presentation on grazing systems in general and specifics of Grazing Systems Project, 21 Sept. 2006 (T.J. Hall).

31. "Northern grazing systems put to test", Queensland Country Life, 26 October 2006 p 105. (via Ross Porter Toowoomba), (T. Hall and G. O'Sullivan).

32. “Grazing Systems Research” Rural Weekly, 3 November 2006 (T. Hall).

33. “Cattle Trial Success in Qld” Border News, October 2006 (T. Hall and G. O’Sullivan).

34. ABC Radio interview for the morning ‘Rural Report’ with Jayne Landsberg, November, 2006 (Dave Smith).

35. “Finding a Grazing System that Suits your Property”, Northern Muster, December 2006, Issue 13 (Dave Smith).

36. ‘The Grazing Systems Project’ a WIN TV interview of Trevor Hall by Kylie Barron (Toowoomba) (19 December 2006).

37. J. G. McIvor and T. J. Hall (2006). Role of grazing systems in pastoral intensification. *Proceedings of Australian Rangeland Society 14th Biennial Conference, Renmark, South Australia* (Editor P. Erkelenz) pp. 268-271.

2007

38. Beef-Up Forums in northern Australia – GSP posters presentation – Biloela (15 Feb. 2007); Greenvale (20 Feb. 2007); Bowen (22 Feb. 2007).

39. GSP Feedback article (in discussion) – text, objectives, sites, regions, photos, data types, maps, etc – 1 full page type.

40. “Grazing Systems Evaluation Underway” (Paul Jones), and “Diet Quality of Cattle in Three Grazing Systems at Blackwater” (Gina O’Sullivan), Cropping Central Newsletter, March 2007, Issue 34 (2 articles).

41. Grazing Systems Project presentation to GLM workshop for DNR staff, Emerald. (March 2007, P. Jones).

42. Grazing Systems Project. Presentation to Central Queensland Beef Research Committee. (P. Jones).

43. “Investigating Cell Grazing and Other Grazing Management Systems in Northern Australia”, North Australian Beef Research Update Conference presentation (Trevor Hall) and scientific paper for proceedings (T.J. Hall and J.G. McIvor), and poster display, 19-22 March 2007. (The Power-point presentation to be displayed on the MLA web site).

44. Hall, T.J. and McIvor, J.G. (2007) “Investigating cell grazing and other grazing management systems in northern Australia”. ***In*** Proceedings of Northern Beef Research Update Conference, Townsville, 2007, pp. 56-62.

45. Grazing Systems Project Brochures supplied to Caroline Sandral for GLM workshops, and to DPI&F contacts and secretaries of the North Australia Beef Research Council in North, West, South, and Central regions. March 2007.

46. “Diet quality of cattle in rotational and continuous grazing systems at Mundubbera”, Beeftalk Newsletter, Issue No. 23, Autumn 2007 (Gina O’Sullivan).

47. Hall, T.J. (2007) “Grazing systems – for pastures on marginal cropping lands”, in ‘Pastures for Protection and Production on marginal cropping lands. 7th Australian

Tropical Grasslands Conference, Dalby 11-12 April 2007. pp. – 64-67. A Power-point presentation and paper in the Workshop papers and poster abstracts.

48. Grazing Systems Project presentation and field walk for UQ 2nd year Vet students, Berrigurra, Blackwater (June 2007, P. Jones).

49. Emerald AgGrow Field day Project display and posters, July 2007 (P. Jones and G. O'Sullivan).

50. C. McDonald (2007). Grazing Systems Project presentation for the Grassland Society of Southern Africa Conference.

51. Grazing Systems Project presentation to GLM workshop, Clermont. (August 2007, P. Jones).

52. C. McDonald, J. McIvor, T. Hall and N. MacLeod (2007). Grazing systems – some experiences from a project in northern Australia. Paper for 'Grassroots', Grassland Society of Southern Africa.

53. Grazing Systems Project presentation to GLM workshop, Sarina (September 2007, P. Jones).

54. "Research to Reality" Project discussion with Collinsville producer group. (J. McIvor, 25 Sept. 2007).

55. Grazing Systems Project presentation to GLM workshop, Mirani. (October 2007, P. Jones).

56. Hall, T.J. (2007). Integrating grazing and forage systems on marginal cropping lands. *Tropical Grasslands* 41: 222-228.

2008

57. Grazing Systems Project presentation to GLM workshop, Baker's Creek (March 2008, P. Jones).

58. Melrose field day. Project presentation and discussions with Morinish Landcare Group (P. Jones 16 Apr. 2008).

59. "Spatial uniformity within grazing systems' PowerPoint presentation and discussion at Biometry Workshop at Bribie Island (D. Reid April 2008).

60. "Research to Reality" Project discussion with Clarke River producer group. (J. McIvor, 1 May 2008).

61. Grazing Systems Project presentation to Mackenzie River FutureBeef Group, Berrigurra, Blackwater (May 2008) (P. Jones).

62. "Grazing systems project finds no consistent differences." Cropping Central, June 2008, Issue 39. (P. Jones).

63. Rocky Springs field day with Narayen Producer Group. Project presentations, field inspection and discussions (T. Hall and J. McIvor, 13 June 2008).

64. “Rangeland responses to cattle grazing systems in northern Australia”, poster presentation and discussions at International Grasslands/Rangelands Congress, Hohhot, Inner Mongolia, China. T. J. Hall and J. G. McIvor, July 2008.

65. “Cattle producer perceptions of their grazing systems in the rangelands of northern Australia”, poster presentation and discussions at International Grasslands/Rangelands Congress, Hohhot, Inner Mongolia, China. C. A. Hall and T. J. Hall, July 2008.

66. Grazing Systems Project presentation and field walk to Qld Uni 3rd Year Vet Science Students, Berrigurra, Blackwater (July 2008) (P. Jones).

67. “Interim grazing trials positive” Rural News. Rural Weekly Central Queensland Edition. July 18, 2008 (P. Jones).

68. Grazing Systems Project presentation to Ethiopian Government delegation, “Queensland rangelands visit” organised by UniQuest (T.J. Hall, 18 August 2008, Toowoomba).

69. ‘Grazing systems and spatial uniformity’ Paper presented at Australian Rangelands Conference, Charters Towers, Queensland (September 2008), D.J. Reid, T.J. Hall and J.G. McIvor.

70. ‘Grazing methods could determine profitability’, ABC Rural, J. McIvor Interview by Karyn Wilson (21 Oct. 2008).

2009

71. Grazing Systems Project presentation and field walk for AACC 2nd year students, Berrigurra, Blackwater (March 2009, P. Jones).

72. “Grazing Systems Workshop” for SuperGraze Project in Caring for our Country, with Burnett Catchment Care Association and Qld. Dept of Primary Industries and Fisheries, Gayndah. T.J. Hall and J.G. McIvor (9 June 2009).

73. Grazing Systems Project presentation to GLM workshop (agency staff), Emerald. (July 2009, P. Jones).

74. Grazing Systems Project presentation and field walk for UQ 2nd year Vet. students, Berrigurra, Blackwater (December 2009, P. Jones).

1.17 Appendix 17 - Publications

Conference publications and poster papers were prepared and presented during the project. These are reported in the Communications list (Appendix 9.16) and some are shown below.

Publication 1. Hall, T.J. and McIvor, J.G. (2008). Rangeland responses to cattle grazing systems in northern Australia. Proceedings of the IGC/IRC, Hohhot, China. Grasslands / Rangelands People and Policies. Multifunctional Grasslands in a Changing World Vol. II. Pp. 175.

Rangeland responses to cattle grazing systems in northern Australia

T.J. Hall[1] and J.G. McIvor[2]
[1]Dept of Primary Industries and Fisheries, PO Box 102, Toowoomba, Qld 4350, Australia.
[2]CSIRO Sustainable Ecosystems, 306 Carmody Road, St Lucia, Qld 4068, Australia.
Email: trevor.hall@dpi.qld.gov.au

Key words: grazing systems, rangeland, set-stocked, rotational grazing, cells

Introduction
Beef cattle producers are looking for management systems that will improve their pasture resource and increase production and profitability in the rangelands of northern Australia where increasing costs and a highly variable climate impact on their business. Producers are using a range of grazing systems to achieve these goals: including set-stocked or continuous grazing, rotational grazing, and intensive cell systems. However, these systems have varying inputs, benefits and costs which are not readily identifiable (McIvor & Hall 2006). This paper reports preliminary results from a producer co-funded (via Meat and Livestock Australia) research project investigating the rangeland responses of commercial grazing systems in northern Australia.

Materials and Methods
Beef producers, industry consultants and researchers developed a 4-year project (2006 and 2009) to monitor 74 paddocks on 9 commercial properties with 2 or 3 grazing systems each (a total of 21 systems) located in different environments of north and south Queensland. The sites include fertile heavy clay soils with cleared Acacia forest and lighter textured, less fertile soils supporting Eucalypt woodlands. The grazing systems have been operating from 1 to more than 10 years. Three to 11 paddocks are being monitored at each site, not whole properties. Cattle breeding, steer growing and fattening properties are included. The aim is to record grazing system inputs, and environmental and production outcomes. The data sets (Table 1) measure the impacts of the producers' management on pastures, soils, cattle performance and costs. Environmental factors are also recorded to assist with interpretation of the results

Table 1 Attributes and data sets measured in 21 grazing systems on 9 commercial beef properties.

Attributes	Data sets
Pastures	Yield, botanical composition, grass basal area, cover (litter, organic, total), utilisation, patchiness, tree regrowth
Soils	Surface condition, indices of infiltration, stability and nutrient cycling (by LFA, Tongway & Hindley 1995); land condition score (range 1 good stable condition to 4 bare and degraded)
Cattle	Classes, density, grazing pressure, stocking rate, diet quality (by near infrared reflectance spectroscopy [NIRS])
Costs	Infrastructure, capital, labour, operating costs, break-even analysis
Environment	Rainfall, soils, landtypes, vegetation communities

Results and Discussion
The three types of grazing system operate effectively by maintaining desirable pasture composition and good soil surface conditions, on both light and heavy soils in Acacia and Eucalypt communities. However, the more intensive cell grazing systems tend to be located on introduced pastures with a high proportion (94%) of sown perennial grass, predominantly buffel (Cenchrus ciliaris) and on the more fertile soils. Measurements over the drought period 2006-07 (rainfall 24% below long-term average), show grazing system mean ranges were: pasture yield 1590-2580 kg/ha, ground cover 51-62%, land condition score 2.1-2.4, and soil surface condition (LFA indices) stability 58-61, infiltration 37-40 and nutrient cycling 28-

31. These parameters varied more between properties and seasons than between the grazing systems. Cows with calves and growing cattle can all be managed effectively in all systems. NIRS analysis of faecal samples suggests diet quality (crude protein and digestibility) is higher in set-stocked and rotation systems than in cell systems during the summer pasture growing season.

Conclusion

The first 12 months of data recording indicate that there are no large differences in pastures or soil surface conditions between the two or three grazing systems on any of the nine properties. However, serious drought conditions prevailed at most sites and may have prevented differences occurring.

Reference

McIvor, J.G., Hall, T.J., 2006. Role of grazing systems in pastoral intensification. Proceedings of the Australian Rangeland Society 14th Biennial Conference, Renmark, 2006. (Editor P. Erkelenz) pp. 268-271.

Tongway, D., Hindley, N., 1995. Manual for Soil Condition Assessment of Tropical Grasslands. CSIRO Australia.

Publication 2. McIvor, J. G. and Hall, T. J. (2006). Role of grazing systems in pastoral intensification. Proceedings of the Australian Rangeland Society 14th Biennial Conference, Renmark, 2006. (Editor P. Erkelenz) pp. 268-271.

Role of grazing systems in Pastoral intensification

John G. McIvor[A] and Trevor J. Hall[B]

[A]CSIRO Sustainable Ecosystems, 306 Carmody Road, St Lucia, Qld 4067
[B]DPIF, PO Box 102, Toowoomba, Qld 4350
Corresponding author. Email john.mcivor@csiro.au

Abstract

There is a continuum of cattle grazing systems used in the rangelands with increasing levels of intensification from continuous, through spelling and rotations, to cells. These aim to produce environmentally sustainable, productive, economic and socially acceptable outcomes. This paper comments on some of these issues and describes a research project investigating grazing systems in the beef cattle industry in northern Australia.

Introduction

There has been slow and continuous intensification of management systems for beef production in Australian rangelands since European settlement with the establishment of more reliable water supplies, varying degrees of fencing and other infrastructure development, and improved transport. This intensification has increased markedly in recent times. With much higher land prices, increasing productivity represents a cheaper means of increasing financial returns than purchasing more land, and producers are seeking to increase production per unit of land to maintain returns on capital on the increased land values (Ash *et al.* this volume).

Past management concentrated on increasing production and minimising costs rather than managing specifically for resources. This led to some damage to pastures and soils as desirable species were overgrazed and less palatable species increased, and more severe overgrazing produced bare patches and erosion. These circumstances reduced the productive and financial capacity of the pasture and limited management options. To manage these grazing effects, controlling the timing and intensity of grazing is required. Total grazing pressure, from cattle, other domestic livestock and feral animals, especially macropods, needs to be managed.

Grazing systems

Grazing systems are the planned management of livestock in space and time i.e. species and class of livestock, stocking rate (numbers), grazing and resting periods, grazing intensity (frequency and severity of use), and grazing distribution. Grazing systems have evolved to maintain/improve the long-term sustainability of grazed landscapes, while providing desirable levels of animal production, financial returns, environmental health and social support. Using grazing systems to improve pastures and soils requires an understanding of local ecological systems including the principles of pasture plant growth and effects of grazing. The basic premise is to match the grazing pressure to the capacity of the individual plants within a pasture so they can perform in the manner required to meet the goals of the manager.

Grazing systems can be considered to lie along a spectrum of increasing intensity from continuous stocking in large paddocks, through rotational and/or spelling systems, to cell grazing with large numbers of paddocks (Table 1).

Table 1: Characteristics of less and more intensive grazing systems.

	Less intensive (e.g. continuous)	**More intensive (e.g. cell)**
Paddock numbers	Few	Many
Paddock size	Large	Small
Paddock independence	Large	Little
Duration of stay	Months/years	Days
Matching animal numbers to short term feed supply	Little	Much
Pasture rest	Opportunistic/reactive	Planned
Decision making	Less frequent	Frequent
Infrastructure costs	Low	High
Applying other management	Difficult	Easier

How do grazing systems affect animal production?

Pastures

If effects are due to impacts on pastures, they will do so by impacting on the quantity of pasture produced, the quality of pasture produced, and/or the amount of pasture consumed. Grazing systems aim to manipulate these three factors by controlling the frequency and severity of defoliation to prevent overgrazing.

In the long term, grazing systems may alter land condition and thus pasture production. Grasses are most sensitive to defoliation when regrowing and spelling during the wet season can produce large benefits (Ash *et al.* 2001). Land in poor condition may produce only 10-20% of the pasture produced from the same land type in good condition (McIvor *et al.* 1995). What about in the short-term? Overseas evidence suggests systems with many paddocks may give a small advantage over systems with fewer paddocks. In South Africa Tainton *et al.* (1977) found a trend for higher pasture yields with more paddocks but the differences were not significant while Heitschmidt *et al.* (1987) in Texas found no significant differences between a 14 paddock (2530 kg/ha) and a 42 paddock system (2670 kg/ha).

A number of reports show an increase in perennial grasses and native legumes with cell grazing - with long rest periods the large perennial grasses out-compete smaller plants, and a number of native legumes are trailing/climbing species that exploit the rest period and are disadvantaged by continuous grazing. Legumes improve pasture quality but what about extra perennial grass? Ash *et al.* (1995) compared animal production from pastures dominated by native perennial grasses with pastures containing less of these grasses and more annual grasses, forbs and native legumes. At low stocking rates animals grew faster (reflecting their higher quality diet) on the pastures with less perennial grass. However these poorer condition pastures grew less herbage and at higher stocking rates the perennial grass dominant pastures had the highest gains. Grazing systems may increase or decrease pasture quality?

For a given area, the more paddocks there are the smaller the size of individual paddocks. Patch grazing is a common feature of large paddocks but with smaller paddocks, pasture utilisation is more uniform as livestock search all areas. The greater pasture utilisation in small paddocks can increase animal production per hectare while the greater opportunities for diet selection in continuous systems can produce higher individual animal production.
Soils

Healthy pastures with high cover levels maintain good soil surface condition with reduced runoff and erosion losses, increased soil biological activity and litter recycling. High cattle densities in intensive systems can have positive effects on nutrient cycling and may reduce cattle pad formation lowering the opportunity for erosion channels to form.

Cattle

With increased and more even utilisation of pastures, cattle numbers can be maintained or increased. However, fattening or finishing cattle may be difficult due to reduced diet selection capacity and reports of lower production from finishing bullocks need verifying. Fewer bulls may be required with breeders concentrated in larger numbers and at single or few water points. Management measures are required to avoid miss-mothering of calves in intensive systems where cattle are moved frequently. Cattle are quiet and easier to handle in intensive systems providing appropriate methods are used. By resting paddocks for 60-90 days several times per year, worms can be managed and regularly shifting cattle to paddocks several kilometres apart is reported to reduce buffalo fly irritation.

Costs

There are high initial capital costs in establishing intensive systems. Adequate (high flow rates) and reliable (with back-up) water supplies are the major cost, as large herds use one water point at a time. Open dams or natural waters are not usually suitable in more intensive systems. Good quality water is required for adding supplements via water medicators. Fencing is also a significant cost although much reduced with electric fences. Some large paddocks are still desirable with intensive systems in case water supplies break down, and to allow for vacations by managers.

Management and decision making

A good knowledge of pasture production and response to grazing is required to run intensive grazing systems successfully. This may require periodic intensive training. For instance, McCosker (2000) considers it takes several training events and 3-5 years practice to competently manage cell grazing. Good pastures and cattle records are required where daily decision making is needed to manage a herd at high stocking density in an intensive system. Intensification changes the amount and timing of labour demand. There are fewer water points to check at any one time but some labour is required every day for these checks. The herd is more congregated, making inspections and handling simpler, and reducing costs and time required for mustering. Individual water points can be closed off to aid pasture recovery by preventing grazing by feral animals. Adding nutritional supplements via water medicators is cheaper and more effective with large herds on single controlled waters. The pasture yield assessments allow feed budgeting, and this information can be used to manipulate herd size, plan buying/selling strategies as opposed to being reactive if feed runs out, or allow alternative options in periods of feed abundance e.g. taking on agistment cattle.

Grazing systems project in northern Australia

Research on carrying capacities and utilisation rates has provided guidelines for long-term maintenance of pasture and soil condition, but the short-term management of grazing to optimise sustainability, production and profitability is less well understood. A joint DPIF, CSIRO and MLA research project commenced in 2005 to quantify the main inputs and outputs of commercial grazing systems, to provide such information.

Nine properties, each with two or three grazing systems (continuous, rotation, cell), have been selected as primary sites in north and south Queensland to cover the effects of amount and distribution of summer rainfall, and on brigalow and eucalypt land types to include the effects of soil fertility. Additional secondary sites have been selected to broaden the range of environments. Data recorded in each system includes: animal performance (liveweight gain, branding percentage, condition score), diet quality (by NIRS), pastures (yield, botanical composition, basal area, utilisation), soil surface condition (Tongway and Hindley 1995), herd management, grazing pressures, finance (capital and operating costs, returns, profitability), system management (labour inputs, decision making, training knowledge and support, networks) and weather conditions. Three to ten paddocks are being monitored at each primary site, not whole properties. The pasture and soil data will be collected at the end of summer between 2006 and 2009. Animal production will be recorded as part of normal herd management. The financial and social aspects of operating the various grazing systems will be recorded throughout the four-year period. Results from these measurements will be used to describe and quantify the grazing systems and produce guidelines for producers to use as decision aids in determining the most suitable system for their land types, environments, resources, personal capabilities and desired lifestyles. Information will be used in grazing land management education packages and be available for all land managers.

Acknowledgements

We thank Meat and Livestock Australia for financial support for Project NBP.353.

References

Ash, A., Corfield, J. and Ksiksi, T. (2001). The Ecograze Project – developing guidelines to better manage grazing country.

Ash, A.J., McIvor, J.G., Corfield, J.P. and Winter, W.H. (1995). How land condition alters plant-animal relationships in Australia's tropical savannas. *Agric. Ecosyst. Environ.* **56**: 77-92.

Heitschmidt, R.K., Dowhower, S.L. and Walker, J.W. (1987). 14- vs. 42-paddock rotational grazing: above ground biomass dynamics, forage production, and harvest efficiency. *J. Range Manage.* **40**: 216-223.

McCosker, T. (2000) Cell Grazing – the first 10 years in Australia. *Trop. Grassl.* **34**: 207-218.

McIvor, J.G., Ash, A.J. and Cook, G.D. (1995). Land condition in the tropical tallgrass pasture lands: 1. Effects on herbage production. *Rangelands J.* **17**: 69-85.

Tainton, N.M., Booysen, P. de V. and Nash, R.C. (1977). The grazing rotation: effects of different combinations of presence and absence. *Proc. Grassl. Soc. South. Africa* **12**: 103-104.

Tongway, D. and Hindley, N. (1995). Manual for Soil Condition Assessment of Tropical Grasslands. CSIRO Australia, Canberra.

Publication 3. Australian Rangelands Conference, Charters Towers, Queensland (September 2008).

GRAZING SYSTEMS AND SPATIAL UNIFORMITY

D.J. Reid,[A], T.J. Hall[B] and J.G. McIvor[C]*

[A] DPIF, PO Box 6014 Rockhampton Qld 4702, [B] DPIF, PO Box 102 Toowoomba Qld 4350,
[C] CSIRO, 306 Carmody Road St Lucia Qld 4067

Abstract

A four-year, producer-inspired research project, jointly-funded by Queensland DPIF, CSIRO and MLA, is investigating different grazing systems across the northern beef industry. Nine commercial beef properties, each with two or three planned grazing systems (continuous, rotational, cell), were selected covering heavy (higher fertility) and light (lower fertility) soils in northern and southern Queensland. From three to eleven paddocks were selected on each property for soil and pasture measurements. A combined Botanal and LFA recording system based on quadrats located on a set sampling grid was used to assess pasture and soil surface condition following the growing season in 2006 and 2007. Differences in pasture and soil attributes across paddocks are being investigated to assess if spatial uniformity of grazing changes between grazing systems. Preliminary results using a method of spatial analysis by distance indices to assess variation in ground cover are presented as an example of a possible approach.

Introduction

Many northern beef producers are concerned with declining cattle productivity and deteriorating condition of grazing lands. Producers have reported that their traditional management practises are not improving, or even maintaining, pasture and land condition. The number of animals is the broadest driver of animal performance, profitability and sustainability and considerable effort has been directed towards developing sustainable carrying capacities and pasture utilisation rates. More recently, attention has shifted to the spatial and temporal distribution of grazing pressure and this has led to interest amongst producers in different grazing systems for controlling the location, duration and timing of grazing.

More intensive rotational grazing systems, such as cell grazing, are being adopted by an increasing number of producers interested in improving their management performance. This interest from producers and their industry organisations prompted a four-year joint research project by a team from Queensland DPIF, CSIRO and MLA to investigate the inputs and outcomes from three main grazing systems used in northern Australia.

Different grazing systems can be considered to lie along a spectrum of increasing management intensity from continuous set-stocking at low stock densities in large paddocks, to cell grazing at high stock densities with large numbers of paddocks and frequent movement of cattle. It is hypothesised that, as grazing system intensity increases, spatial uniformity of grazing will increase. This paper addresses this hypothesis using a method of spatial analysis by distance indices (SADIE; Perry 1995) to assess the degree of spatial uniformity in ground cover for different grazing systems.

Methods

Nine properties were selected throughout Queensland which included at least two of the following grazing systems - continuous grazing (larger paddock areas, low management intensity), rotation grazing (moderate intensity) or cell grazing (smaller paddocks, high intensity). The properties covered both northern and southern areas and two important pasture types - brigalow and eucalypt woodlands (including both black speargrass and Aristida-Bothriochloa native pasture communities). For each property, paddocks in the different grazing systems (e.g. one paddock in a continuous system, two to three paddocks in a rotation and five to ten paddocks in a cell system) with similar characteristics (soil type, pasture, tree cover, topography, etc.) were selected for monitoring.

A combined Botanal (Tothill et al. 1992) and LFA (Landscape Function Analysis; Tongway and Hindley 2005) recording system based on quadrats (50 x 50 cm) located on a set sampling grid was used to assess pasture and soil condition following the growing seasons in 2006 and 2007. Data collected at each sample point included pasture yield, botanical composition, species frequency, basal area of perennial grasses, degree of utilisation, cover, tree regrowth, and soil surface condition estimates and ratings to provide LFA indices of stability, infiltration and nutrient cycling.

One aim of the study was to assess spatial uniformity in attributes such as pasture yield, pasture utilisation and ground cover of the different grazing systems. The SADIE methodology detects and measures the degree of non-randomness in the two-dimensional spatial patterns of populations (Perry et al. 1995). Briefly, SADIE calculates an index based on the total distance of the sample from a completely regular arrangement by comparing the spatial arrangement of the observed sample with arrangements derived from it such that they are as regularly spaced as possible – a distance to regularity. Although the SADIE methodology was originally developed to assess spatial pattern in count data (Perry et al. 1999), it can easily be extended to other forms of data (Perry, pers comm).

Total ground cover measured in the 2007 sampling season for the four properties with all three grazing systems is used to illustrate the SADIE methodology and to demonstrate a proposed summary for comparing the spatial uniformity of the grazing systems. Over the four properties, 23 cell grazing paddocks, 8 rotationally grazed paddocks and 4 continuously grazed paddocks were sampled.

Results and Discussion
The ground cover data from one of the four properties is shown graphically in Fig 1.

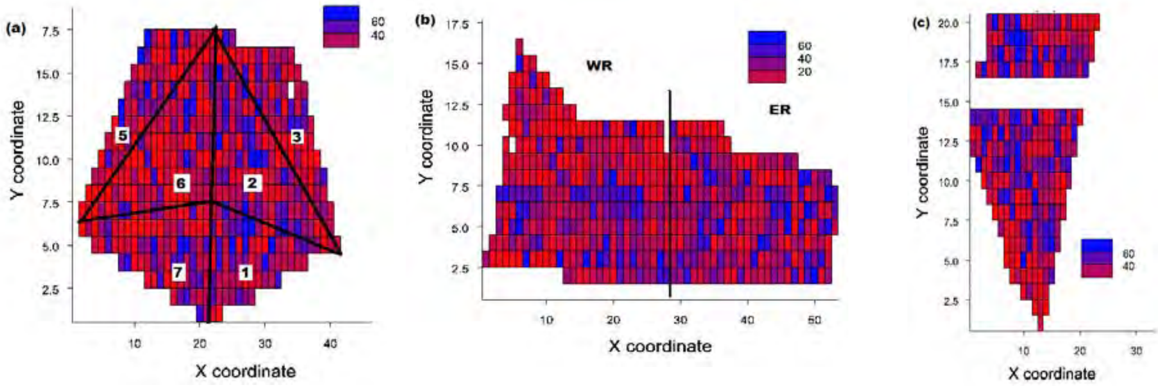


Figure 1. Total ground cover (%) for (a) the six cell paddocks, (b) the two rotational paddocks, and (c) the continuously grazed paddock that were monitored on one property.

The spatial pattern of each individual paddock needs to be considered as it will be influenced by how recently a paddock has been grazed, which is particularly pertinent for paddocks in a cell system. Cell paddocks for monitoring were specifically selected to ensure they covered a range from just grazed to having been spelled for some time and about to be re-grazed.

Each paddock was tested for spatial randomness, or spatial aggregation, using the SADIE methodology. For the example in Figure 1, all six cell paddocks (Fig. 1(a)) exhibited randomness, while one of the rotationally grazed paddocks (WR; Fig 1(b)) and the continuously grazed paddock (Fig 1(c)) exhibited aggregation.

How can we compare the systems as a whole? We propose that the results from the individual paddocks be summarised such that we compare the proportion of paddocks in a system for which there is no evidence, at say P=0.05, that the data are not spatially uniform. For the four properties, this approach showed a 70% probability of spatial uniformity in total ground cover for cell grazing, 38% for rotational grazing and 25% for continuous grazing (Table 1).

This could be further refined by considering the proportion of area rather than the proportion of paddocks. Also, spatial attributes such as clustering, could be investigated using the graphical tools provided in the SADIE software (Perry et al. 1999) such as 'red-blue' plots.

Table 1. The number of paddocks in each grazing system and the number of paddocks (proportion) with no evidence against spatial uniformity at the 5% level for four properties.

Grazing System	**Cell**		**Rotational**		**Continuous**	
Total number of paddocks	23		8		4	
Number of paddocks with spatial uniformity (%)	16	(70%)	3	(38%)	1	(25%)

This preliminary analysis suggests that the SADIE methodology may provide a useful approach for comparing spatial uniformity of grazing systems. Further, it suggests that the more intensive grazing systems are more uniform for the cover measure we have tested. However, when interpreting these results a number of issues need to be considered. Firstly, the scale of the sampling grid varies among paddocks. Secondly, only a single scale is used for all measures in a paddock but different measures may vary at different scales so testing at another scale may show a different result. Thirdly, the data from each small quadrat are used to represent larger areas (sometimes more than 1 ha) under the assumption that the area is similar to the quadrat for that measure but, in some cases, there may be as much variation between individual patches in the area as there is between quadrats over the whole paddock.

Acknowledgements
The project team thank the owners and managers of the research properties for their interest, cooperation and assistance, the producers of the advisory group for assistance with the project's development and design, and the DPIF, CSIRO and MLA for financial support.

References

Perry, J.N. (1995). Spatial analysis by distance indices. *Journal of Animal Ecology* **64**: 303-314.

Perry, J.N., Winder, L., Holland, J.M. and Alston, R.D. (1999). Red-blue plots for detecting clusters in count data. *Ecology Letters* **2**: 106-113.

Tongway, D. J. and Hindley, N. L. (2005). 'Landscape function analysis. Procedures for monitoring and assessing landscapes'. CSIRO Sustainable Ecosystems, Canberra.

Tothill, J.C. and Gillies, C. (1992). The pasture lands of northern Australia: their condition, productivity and sustainability. Tropical Grassland Society, Australia. Occasional Publication No. 5.

Tothill, J.C., Hargreaves, J.N.G., Jones, R.M. and McDonald, C.K. (1992). BOTANAL - A comprehensive sampling and computing procedure for estimating pasture yield and composition. 1. Field sampling. CSIRO Division of Tropical Crops and Pastures Tropical Agronomy Technical Memorandum No. 78.

Publication 4. Cristine A. Hall and Trevor J. Hall (2008). Cattle producer perceptions of their grazing systems in the rangelands of northern Australia. Proceedings of the IGC/IRC, Hohhot, China. Grasslands / Rangelands People and Policies. Multifunctional Grasslands in a Changing World Vol. II. Pp. 866.

Cattle producer perceptions of their grazing systems in the rangelands of northern Australia

Cristine A. Hall[1] and Trevor J. Hall[2]
[1]CSIRO Sustainable Ecosystems and [2]DPIF, PO Box 102, Toowoomba, Q 4350, Australia
Email: cristine.hall@csiro.au

KEY WORDS: Grazing systems, rangelands, lifestyle, pasture management, perceptions

Introduction Beef cattle producers in the rangelands of northern Australia are intensifying their property development and associated management systems with the aim of improving their pasture resource and increasing profitability of their business. There are no proven best practices to achieve these goals so producers have adopted a range of grazing systems with varying levels of success and for different reasons. The cattle producer organisation, MLA, is co-funding a research project with the objective of investigating inputs and outcomes of grazing systems across the northern beef industry of Australia. MLA has also established the BeefPlan project (Banney 2007) of groups of producers across northern Australia with an interest in improving their business performance. At the annual meeting of these BeefPlan groups, producers provided information on their perceptions of the grazing system or systems they use.

Materials and Methods At the annual 2005 BeefPlan meeting, 24 producers representing BeefPlan groups across northern Australia completed a written survey nominating what grazing system/s they use on their property, why they use that system, and the issues they perceived as advantages and disadvantages of their system/s. The producers' reasons for their choice of grazing system/s are summarized into 6 themes (Table 1) and the perceived advantages and disadvantages of each system are summarized into 6 operational themes. The systems and issues were categorised into recurring themes.

Results and Discussion Three broad grazing systems were described by producers: set or continuous with spelling (5 producers), rotational (15 producers) and cells (7 producers). All set grazing included spelling/rest periods. Some producers described 2 or 3 systems (Table 1). The number of issues within each theme is shown in brackets. The system advantages concentrated on opportunities for improved management of parts or all of their business, while the disadvantages of each system were all related to costs.

Table 1 Beef producers' choice of grazing system and their perceived advantages and disadvantages

Grazing System	Reason for Choice	Advantages	Disadvantages
Set with spelling	Lifestyle (6)	Cattle management (5)	Pasture cost (9)
	Livestock (2)	Economic (3)	Economic cost (2)
	Pastures (1)	Lifestyle (2)	
Rotational	Pastures (13)	Pasture management (31)	Infrastructure cost (10)
	Livestock (6)	Cattle management (17)	Labour cost (8)
	Economics (2)	Environment (4)	Pasture cost (6)
	Environment (1)	Economic (3)	Lifestyle cost (2)
Cell grazing	Pastures (8)	Pasture management (14)	Infrastructure cost (4)
	Livestock (3)	Cattle management (11)	Cattle cost (3)
	Economics (1)	Environment (8)	Labour cost (2)
	Environment (1)	Economic (6)	Lifestyle cost (2)
	Holistic (1)	Feed budgeting (4)	

Producers chose set grazing systems for lifestyle reasons, although a pasture cost was recognised. This system also had cattle management advantages and no labour cost disadvantages, which is a problem with more intensive systems. The rotational systems were used for pasture and livestock management benefits, while the cell systems were used to improve pastures. These two more intensive systems had infrastructure costs as the main disadvantage.

Conclusions This survey shows the importance of lifestyle considerations in understanding the management objectives of producers in the rangelands and in the promotion of alternative more intensive grazing systems that may have environmental, production and economic benefits over more traditional less intensive grazing management. Pasture management, followed by cattle management, are the major considerations of cattle producers using more intensive grazing systems in the north Australian rangelands.

Reference
Banney, S. (2007). BeefPlan.
http://www.mla.com.au/TopicHierarchy/IndustryPrograms/NorthernBeef/BeefPlan/

Publication 5. Hall, T.J. (2007). "Grazing systems – for pastures on marginal cropping lands", in 'Pastures for Protection and Production on marginal cropping lands. 7th Australian Tropical Grasslands Conference, Dalby 11-12 April 2007. pp. 64-67.

Grazing systems – for pastures on marginal cropping lands

Trevor J Hall

Department of Primary Industries and Fisheries, Toowoomba. Email: Trevor.hall@dpi.qld.gov.au

Abstract

Planned grazing systems are being introduced to beef cattle businesses across the marginal cropping lands of Queensland, as on more extensive properties. Systems range from continuous grazing with opportunistic rest periods, to rotation systems with up to ten paddocks, to cell systems with more than 60 paddocks. The aim of planned grazing is to increase production, improve sustainability and increase economic viability off both the pastured and cropping lands of a property. Integrating the more intensive grazing systems with permanent grain cropping and strategic summer and winter forage cropping is a current challenge under the variable rainfall environment. This paper reports on pasture grazing systems on marginal cropping lands of southern Queensland and on a current research project assessing these systems...

Key Words

Grazing systems, pasture production, feed budget, marginal cropping lands, rotation grazing, cell grazing.

Introduction

A 'grazing system' broadly describes the management of grazing animals across space and time; grazing systems range from low-intensity continuous grazing to highly intensive cell systems. The system chosen has to suit the abilities and lifestyle of the manager while producing economically viable, environmentally sustainable and socially acceptable outcomes. The manager must consider factors such as: the species and classes of animals; mixes of these; stocking rates or stock numbers for the available area; periods of grazing and pasture rest for recovery and seeding; the intensity and frequency of grazing; animal distribution and the marketable product. The grazing system and its' management under the variable climate of southern Queensland can have a significant effect on the pasture's ability to provide both soil protection and viable animal production.

On marginal cropping lands, grazing systems often have to align with cropping of various intensities. This ranges from using a small proportion of land for opportunistic summer or winter forage crops to supplement a beef pasture system, to where grain cropping is the main enterprise and cattle occupy an opportunistic role. The beef production systems range from breeding weaners, growing young animals for the feedlot trade, to finishing fat animals for slaughter.

Having a proportion of land under cropping can benefit pastures by providing rest periods for pasture recovery and seeding in summer, or cause their degradation by concentrating cattle at too high stocking rates for too long, especially in early summer when crop lands are being prepared. Finding the balance between areas of pastures, cropping and stock numbers, times of crop feed availability and stocking rates is the challenge in maintaining soil protection and economic animal production from the mixed pasture and crop enterprises.

Grazing systems

On our marginal cropping lands, climate variability within seasons, and especially rainfall variability between years, has a major effect on the productivity and condition of sown and native pastures. The variability of stock numbers and inter-seasonal grazing pressure interacts with the responses to rainfall of pastures and associated crops.

It is common for producers to report that their traditional management practises are not improving their resource base and often not even maintaining pasture and land condition. To address this problem, different grazing systems are being introduced across both the marginal cropping lands and extensive beef producing regions of Queensland. The aim is to develop grazing management solutions to arrest land condition decline and to improve pasture condition and beef profitability.

Grazing systems, the management of animals in space and time, being used in the marginal cropping lands range from continuous grazing with opportunistic rest periods to cell systems often with more then 60 paddocks. Grazing of crop residues and sown forage crops in conjunction with native and sown pastures adds other options for pasture condition manipulation and business viability.

The grazing systems used are to manage the location, duration and timing of grazing, with the more advanced systems considering the condition and stage of growth of the pastures, and matching the stocking to the carrying capacity of the pasture to maintain its condition. This means the grazing system must be planned and both the cattle and pastures monitored. As the grazing systems become more intensive, pasture monitoring, feed budgeting, defoliation management, pasture composition manipulation, animal control and more detailed record keeping become more integral issues for the successful management of pasture areas.

Some producers report many advantages associated with increasing grazing intensification, not always directly related to the grazing system. Often this results from the manager being more hands-on and considering the health of the pasture equally to the health of the animals.

Ultimately, stock numbers are the broadest driver of animal performance, profitability and pasture/soil sustainability.

Some of the development and management considerations of increasing intensity of grazing are listed in Table 1

Table 1. Considerations for increasing intensity of grazing systems.

Grazing system consideration	Lower intensity (continuous)	Moderate intensity (rotation)	Higher intensity (cell)
Development costs	Low	Moderate	High
Water supply	Open waters can be used		Water supply quality and flow rate critical
Decision making, record keeping, monitoring	Less frequent	Moderate frequency	Frequent (daily)
Feed budgeting	Useful	Useful and advisable	Essential
No. paddocks	Few (1 at a time)	Several (e.g. 2–10)	Many (e.g. 30–100)
Area of paddocks	Large	(between other systems)	Small
Grazing periods	Long (months to years)	(between other systems)	Short (hours to days)
Cattle handling	Infrequent, more difficult		Frequent, can be less difficult
Spelling pastures	None to little, unplanned	Periodic long rests	Regular periods (60–90 days)
Management	Opportunistic or reactive	Planned	Well planned
Match animal numbers to feed supply	By experience or little	Experience	Part of feed budget plan and experience
Other management options	Difficult	(between other systems)	Easy to introduce
Landscape regeneration	Less likely	Possible	More likely
Supplementation	More difficult		Less difficult (water medication)
Training	Low	Some	Higher requirement

Pasture systems

The marginal cropping lands have a wide range of options for pasture systems across soil types that range from shallow low-fertility sandy soils to deep highly fertile heavy clays. The opportunity of rain every month through summer and winter also increases the possibilities of growing summer and winter sown grasses and legumes, in association with summer and winter forage crops. But the variability in rainfall also increases the possibilities of failure in establishment and production from these fodder options.

Some of the pasture species available include grasses for light soils such as buffel grass and Premier Digitaria, with Bisset creeping bluegrass and Bambatsi panic for the heavier soils. There are no well-adapted winter-growing pasture grasses; forage oats are the main option to maintain feed quality at this time. Some summer legumes include the pasture species Caatinga stylo, Desmanthus and butterfly pea with the forage species of Burgundy bean, lablab and lucerne. The shrub legume leucaena may have a role on more fertile soils, but production ceases with frost. Forage sorghum is the main summer fodder crop, but is best suited to the more fertile loams and heavy clay soils. Hay production for on-farm feeding or sale can be integrated with grazing. Grazing residues from wheat, barley and sorghum grain crops also provide opportunities for integrating with the pasture and forage crop grazing systems. Spelling the pastures during cropping phases, especially in summer months after rain, can provide major benefits for pasture regeneration.

Grazing systems research project

Intensive grazing systems, such as rotation and cell grazing, are being adopted by an increasing number of beef producers, including those in the marginal cropping lands. This interest has prompted a research project with Queensland DPI&F, CSIRO and MLA to investigate the environmental, productivity, economic and social interactions of a range of grazing systems across main landtypes on commercial beef properties.

We are assessing 21 grazing systems in 72 paddocks covering 12,528 ha on nine commercial properties; it comprises 52 cell paddocks (total 2907 ha), 13 rotation paddocks (5697 ha) and 7 continuous or set stocked paddocks (3924 ha). Two sites are in the marginal cropping region near Condamine and Surat. The soils and pastures of these sites range from red sandy loams with buffel grass in poplar box country to brown clay loams on poplar box creek flats, to heavy grey clays with native pastures or buffel grass in cleared brigalow country.

At the end of each growing season, pastures are assessed for their yield, botanical composition and utilisation levels. Landscape health as land and soil surface condition, ground cover, stability and woody regrowth is measured while cattle production, liveweight, reproductive performance and seasonal diet quality by NIRS are measured. The economics will be assessed taking into consideration the infrastructure capital, running costs and returns. Planning and the “why and how” decisions to successfully operate the various systems will be examined.

At the end of summer in the first year, the botanical composition across all sites and grazing systems averaged 33% native grass and 57% sown perennial grass, predominantly buffel, and 4% forb species in the pastures. The standing dry matter present averaged 2400 kg/ha, with 60% total ground cover.

Some secondary sites in different climatic and land type environments across Queensland are also being monitored, but less intensively than the nine primary sites; some are in the marginal cropping lands. By the end of this project, producers should have enough information to adopt or adapt the grazing systems best suited to their circumstances.

Pasture composition

The composition of pastures in four grazing systems on properties in the marginal cropping region of the Maranoa in 2006 showed the dominance of buffel grass in the more intensive systems (around 95%) and a higher proportion of wiregrass, other grasses and forbs present under continuous grazing (Table 2). This composition does not reflect the grazing management at this early stage, rather the pastures present on which the systems were imposed.

Table 2. Species composition (%) of main grasses in four grazing systems on marginal cropping lands in 2006.

Soil type	Grazing system	Buffel grass	Queensland bluegrass	Pitted bluegrass	Wiregrass	Other grasses	Forbs
Red loam	Rotation	95.9	0.04	0.0	1.3	0.3	2.6
Red loam	Cells	95.5	0.13	0.3	1.6	0.4	2.5
Brown clay loam	Continuous	54.7	1.46	2.5	14.0	20.9	7.4
Red clay loam	Cells	93.7	0.00	0.0	3.2	3.0	0.9

Grazing systems can influence the composition of a pasture, mainly by extending the spelling periods in the summer growing period.

The dry matter yield and surface protection recorded in the dry season of 2006 in the four above systems (Table 3) show consistently high total cover of over 50% in a below-average rainfall year.

Table 3. Dry matter yield (kg/ha), total cover and litter cover (%) in four grazing systems on marginal cropping lands in 2006.

Soil type	Grazing system	DM Yield kg/ha	Total Cover %	Litter Cover %
Red loam	Rotation	1947	57.7	15.7
Red loam	Cells	2620	63.0	15.5
Brown clay loam	Continuous	909	51.3	25.1
Red clay loam	Cells	1748	54.5	15.6

Cattle production

Continuously grazed systems have a lower stocking rate, but for a much longer period, than the other systems. For example, on a loamy soil poplar box native and buffel grass pasture, steers (averaging 250 kg) could be run at 0.34 head/ha over a year, with the pasture receiving 3 rest periods of almost a month. This contrasts with an adjacent cell system where similar cattle were run for seven grazing periods averaging 2.6 days during the year, at stocking rates to 9 head/ha.

Steer growth rates of 0.77 kg/day can be achieved over four summer months on buffel grass in cells with light soils, whereas similar cattle in a rotation system on clay soils have achieved 1.4-1.7 kg/day—with a supplement of cotton seed. Unsupplemented steers in a continuous grazing system on buffel grass and native grasses were gaining 0.57 kg/day at the end of summer.

Steers on sown Caatinga stylo, Bambatsi panic and native Queensland bluegrass pasture on a good brigalow soil have gained around 0.6 kg/day over 11 month periods for 3 consecutive years, producing over 100 kg/ha/year liveweight gain, in the marginal cropping zone. Steer have averaged 0.93 kg/day over nine months between June and February on forage oats and green grass pastures.

There is little recorded data for liveweight from the range of forage systems available and across the range of seasons experienced in the marginal cropping zone.

NIRS diet quality

Planning pasture and forage options and their associated grazing systems can be assisted by using faecal NIRS analysis to identify the quality of the cattle's diet. For example, crude protein levels (Figure 1) in a buffel grass pasture on red soil poplar box country were over 10% when the grass was green, but insufficient for cattle maintenance at around 5% during a dry winter when the pasture had dried off. There was a spike in protein level when naturalised burr medic growing after winter rain in August made up 46% of the diet for a short time.

Incorporating summer forage crops such as lablab and sorghum can extend the period of good-quality feed, and therefore higher liveweight gain, well into autumn, after which winter forage, such as oats, can replace the rapidly declining quality of grass pastures. Forage oats during winter can rapidly increase feed quality at this difficult time of the year and also allow spelling of the grass pastures, which may improves the chance of rapid regrowth from spring and early summer rain. NIRS results from steers grazing oats show protein levels of 15%, with digestibility of 75%, increasing from near maintenance levels on dry buffel grass (Figure 1).

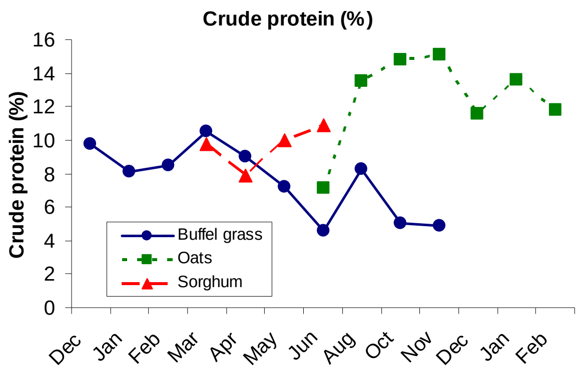


Figure 1. Maintaining crude protein over 14 months by combining three forages, buffel grass, forage sorghum and lablab, and oats.

A combination of these three forages can provide a diet with above 8% crude protein throughout the year, although digestibility declined to around 53% over a period in June between the sorghum and oats forages.

Steer growth rates at a conservative stocking rate over this time from grazing dry grass with near maintenance protein level in June, through the oats period July to November, and during the green grass pasture period from December to February were 0.93 kg/day. Monthly NIRS analysis predicted an average liveweight gain of 0.96 kg/day over the 9 months, with a gain of 1.4 kg/day when grazing oats (Figure 2).

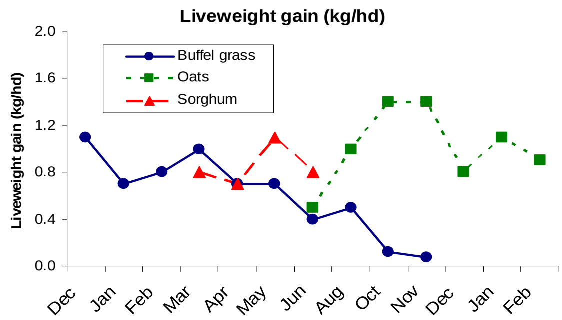


Figure 2. NIRS prediction of liveweight gain over 14 months for steers grazing buffel grass, sorghum and lablab, and oats.

Besides using NIRS as a tool for managing the nutrition and supplement program of cattle on pastures and forages, it could be used for decisions to sell a surplus pasture or crop for agistment and for calculating its value based on yield and quality.

Conclusions

By combining various forage sources and grazing systems, high-quality feed can be made available to cattle throughout the growing season. Also, using varying spelling systems the pastures can recover while there is still sufficient moisture and high enough temperatures. Diet quality can be maintained into autumn with carry-over summer forages, such as sweet sorghum and lablab, before introducing high-quality forage oats for winter and spring. In years with high winter rainfall, naturalised medic can supplement the diet while grass pastures are at their lowest quality. Pasture productivity and sustainability can be maintained by incorporating planned grazing systems during the pasture grazing periods and taking advantage of the additional spelling opportunities provided while crops are being grazed.

1.18 Appendix 18 - Project Posters

Poster papers were presented at field days, producer group meetings and at national and international conferences. Examples are shown below:

1. Poster presented at Beef Producer forum at Townsville.

Rangeland responses to cattle grazing systems in northern Australia

Trevor J. Hall[1] and John G. McIvor[2]
[1]DPI&F, PO Box 102, Toowoomba, Qld 4350, Australia. [2]CSIRO, St Lucia, Qld 4068, Australia.
Email: trevor.hall@dpi.qld.gov.au

Background North Australian cattle producers implement a range of grazing systems to improve the condition of the pastures and soils, manage the variable climate and to combat rising costs.

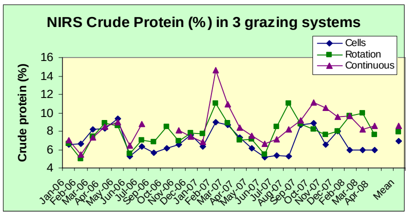
Grazing systems continuum

1. Continuous - low intensity — 2. Rotational — 3.Cells - high intensity

Method We are monitoring 74 paddocks in 21 grazing systems on 9 beef cattle properties in 2 vegetation communities across Queensland. Paddock measurements: pasture condition, soil condition, cattle performance, diet quality, economics and environment.

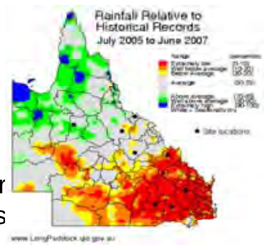
Results The three grazing management systems have so far produced similar responses in the condition of the pastures and soil surface. The more intensive systems require greater capital, skills, management input, labour timeliness and monitoring.

Improvement in land condition from management and seasons



NIRS analyses indicate periods of higher diet quality in less intensive systems

Low rainfall over first 2 years



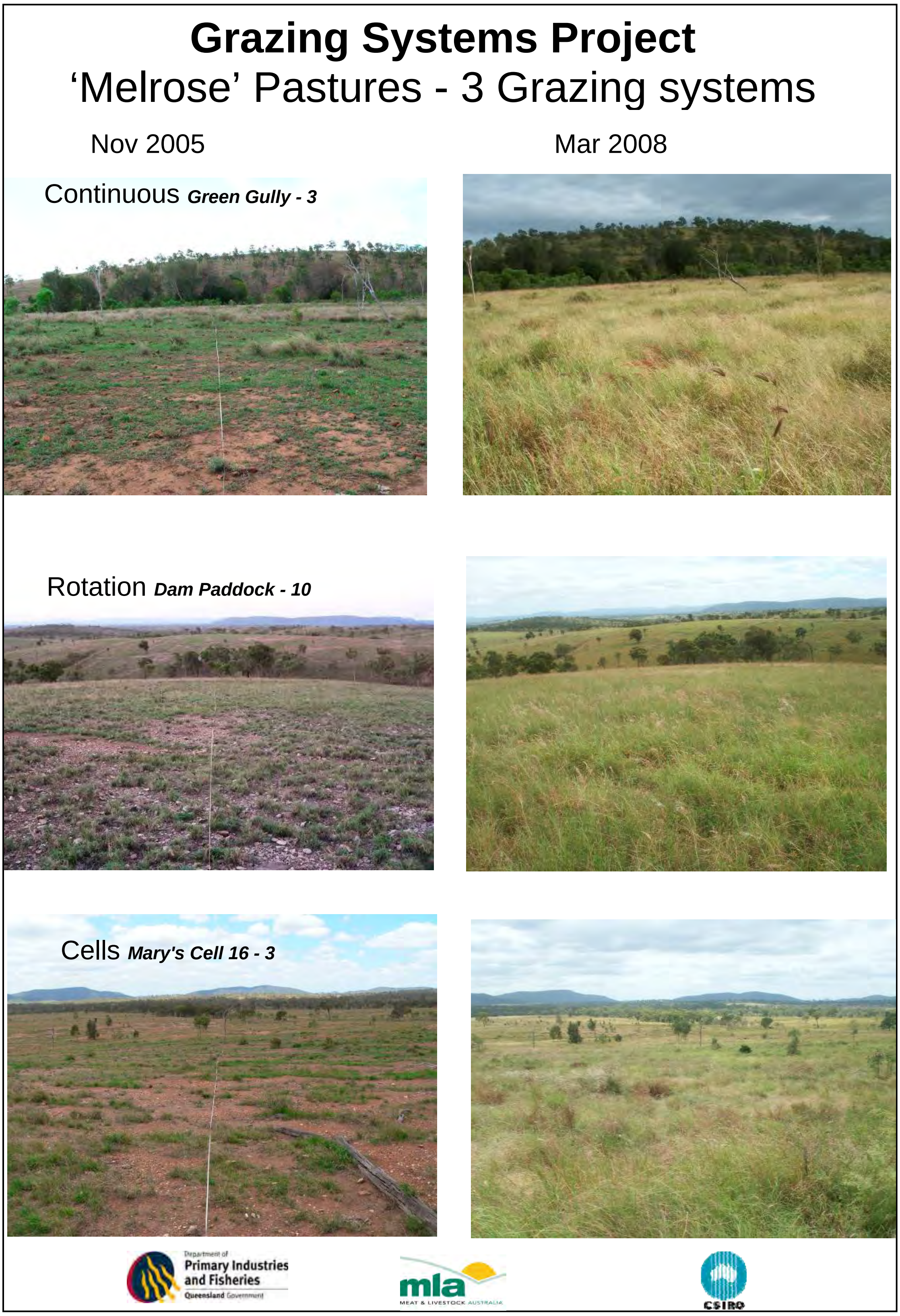
Conclusions Results to date suggest good managers can maintain productive pastures and good land condition irrespective of their grazing system.
Good rainfall has been more important than grazing management system.

Department of Primary Industries and Fisheries
Queensland Government

mla MEAT & LIVESTOCK AUSTRALIA

CSIRO

2. **Poster** of pasture recovery in three grazing systems between 2005 and 2008 at Melrose; presented at a cell grazing field day at Melrose.



3. **Poster** of pasture changes at fixed photo sites in two rotation and one continuous paddock at Rocky Springs in November 2005 and May 2008.

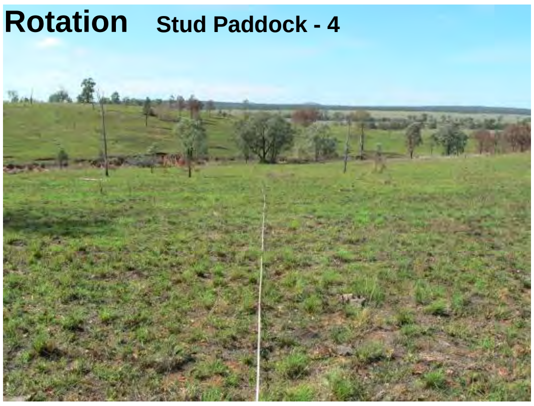
(discussed at a producer meeting at Rocky Springs, 2008).

Grazing Systems Project

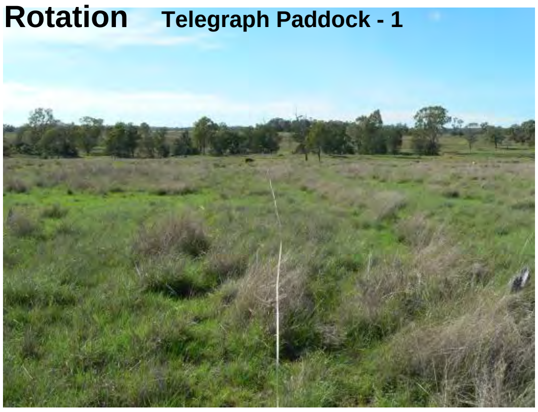
'Rocky Springs' Pastures - 2 Grazing systems

Nov 2005 | **May 2008**

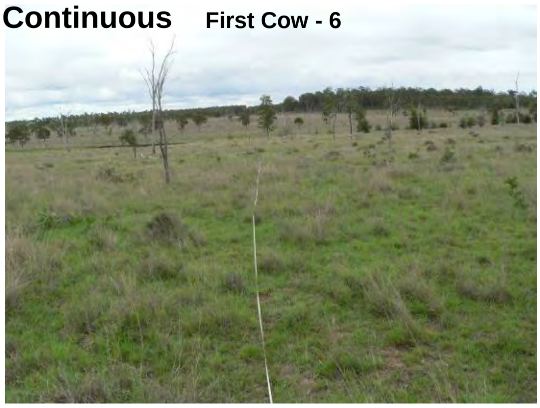
Rotation Stud Paddock - 4



Rotation Telegraph Paddock - 1



Continuous First Cow - 6



Department of Primary Industries and Fisheries Queensland Government

mla MEAT & LIVESTOCK AUSTRALIA

CSIRO

4. **Poster** on beef producer perceptions of their grazing systems presented at the IGC/IRC at Hohhot, Inner Mongolia, China (July 2008).

Cattle producer perceptions of their grazing systems in the rangelands of northern Australia

Cristine A Hall[1] and Trevor J Hall[2]

[1]CSIRO Sustainable Ecosystems and [2]DPIF, PO Box 102, Toowoomba, Q. 4350, Australia

Introduction

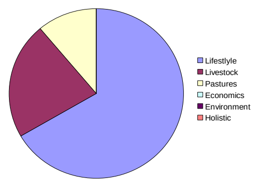
- North Australian cattle producers seek to improve their rangeland properties and management to increase production and profitability.
- Different grazing systems may be used for range management — there is no single best practice.
- The cattle producer organization (MLA) is co-funding research to investigate the inputs and outcomes of different grazing systems. BeefPlan involves groups of producers interested in improving their business performance.

Method

A survey of 24 BeefPlan producers described:

- which grazing systems they use
- why they use those grazing systems
- advantages and disadvantages of each system.

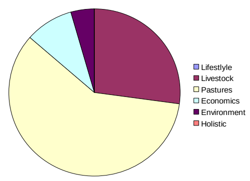
1. Set stocking
with spelling



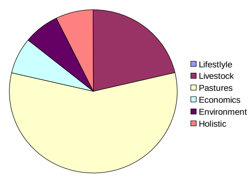
Results

- The three broad grazing management systems described are :
  1. Set stocking with spelling – *low intensity* and *less infrastructure*
  2. Rotational grazing – *medium intensity* and *increasing infrastructure*
  3. Cell grazing – *high intensity* and *high infrastructure requirements.*
- Producers' reasons for their systems reflect their management goals (as shown in pie charts):
  - Better lifestyle – *more set stocking with spelling*
  - Improving pastures – *rotational grazing* or *cell grazing.*
- Advantages and disadvantages of each system were described:
  - *advantages* included opportunities for improving pastures, cattle husbandry and management of their business
  - *disadvantages* were related to costs of infrastructure and operating.

2. Rotational grazing



3. Cell grazing



Conclusion

- Improved management of pasture, followed by better management of their cattle, are the major considerations of cattle producers using the more intensive grazing systems.
- The lifestyle of producers is an important consideration for understanding the objectives of infrastructure development and the management of their rangelands.

Department of Primary Industries and Fisheries
Queensland Government

CSIRO

www.csiro.au

5. **Poster** presented at a producer field day at Roma Research Station as the project was being developed (2005).

6. **Poster** presented at a producer field days during the project (2006-2009).

1.19 Appendix 19 - Staff involved in the project

Many producers, researchers and beef industry consultants were involved in developing, implementing, monitoring, analysing and reporting on this project between 2005 and 2009. The main project staff (Table 9.19.1), producer co-operators (Table 9.19.2), project development team (Table 9.19.3) and MLA co-ordinators (Table 9.19.4) involved during the project are listed. There were many other producers and individuals involved in the northern Australian beef industry who contributed to discussions and reviews of the project as it evolved.

Table 1.19.1. Project development team, project coordination and operational staff between 2005 and 2009.

Project Staff	Organisation	Position	Years
Trevor Hall	DPIF	Team leader, field recording; data analysis, synthesis & reporting	2005-09
John McIvor	CSIRO	Field recording; data analysis, synthesis & reporting	2005-09
Paul Jones	DPIF	Field recording; data analysis & synthesis, mapping	2005-09
Dave Smith	DPIF	Field recording; data analysis & synthesis	2005-09
David Reid	DPIF	Experimental design; statistical analysis	2005-09
Cam McDonald	CSIRO	Field recording; botanical analysis; economic analyses	2005-09
Katherine Delaney	DPIF	Database development	2006-09
Gina O'Sullivan	DPIF	Project technical officer	2006-08
Joel Casey	DPIF	Project technical officer	2006-08
Simone Grounds	CSIRO	Mapping, field recording	2006-07
John Chamberlain	DPIF	Field recording	2006-07 & '09
Cristine Hall	CSIRO	Producer survey & analysis	2005 & '08
George Bourne	NRW	Field recording	2006
Caroline Sandral	DPIF	Field recording	2006-07
Felicity Anderson	FBA	Field recording	2006-07
Anna Keetels	DPIF	Field recording	2007
Helen Eising	NRW	Field recording	2007
Tim Murphy	NRW	Field recording	2007 & '09
Fiachra Kearney	CSIRO	Field recording	2007
Christina Playford	DPIF	Statistical analysis	2009
Lindy Symes	DPIF	Field recording	2009

Table 1.19.2. Primary site producer owners and managers during the project.

Owner / manager	Property
Peter & Mary Wright	Banyula
Andrew Currie	Berrigurra
Bernie Doyle	Berrigurra
Rudi & Nell Schoo	Frankfield
John & Jan Barnett	Frankfield
Nev & Kath Mills	Melrose
Jeff & Sharon Mills	Melrose
Simon & Kylie Schooley	Rocky Springs
Rod & Carol-Anne Barrett	Salisbury Plains
Greg & Karen Weekes	Salisbury Plains
Spud & Annette Thomas	Somerville
Tony & Mandy Mott	Somerville
Wally & Helen Peart	Sunnyholt
Brian & Kerry Wehlburg	Sunnyholt
Rowan Peart	Sunnyholt
Dan & Jacqui Cameron	Ticehurst

Table 1.19.3. Project development advisory group 2005.

Member	Affiliation
Gavin Bailey	Producer
John Heelan	Producer
Wally Peart	Producer
Stephen Press	Producer
Neville McDonald	Producer
John Childs	MLA
Michael Quirk	DPIF
Andrew Ash	CSIRO
Trevor Hall	DPIF Project Team Leader
John McIvor	CSIRO Team

Table 1.19.4. Project co-ordinators from MLA.

MLA Co-ordinator
Wayne Hall
Rodd Dyer
John Childs
Michael Quirk

Grazing System Project – Landscapes at nine primary sites

Somerville

Salisbury Plains

Sunnyholt

Melrose

Ticehurst

Rocky Springs

Berrigurra

Banyula

Frankfield

Table of Tables

Table 9.3.1. Long-term annual rainfall (mm) – mean, median, SD, highest/lowest, rain days and no. of years of records for nine sites. ... 7
Table 9.4.1. LFA transect resource accumulation and loss codes. ... 14
Table 9.4.2. Sixty one pasture species and seven species groups recorded across all sites in 2006, 2007 and 2009. ... 18
Table 9.4.3. Field summary recording sheet for Botanal and LFA parameters. ... 27
Table 9.5.1. LFA transect accumulation and run-off (%) in 21 grazing systems at nine primary sites. ... 31
Table 9.5.2. LFA transect accumulation and run-off (%) grazing systems mean at nine primary sites. ... 32
Table 9.5.3. LFA transect accumulation and run-off (%) means at nine primary sites and overall site mean. ... 32
Table 9.5.4. Herbaceous species recorded and six species groups. ... 33
Table 9.8.1. Pasture green season, annual growth weeks and extra temperate growth weeks (50-year mean) for nine sites. ... 44
Table 9.8.2. Tree basal area and GRASP parameters used for the different sites and land types. ... 45
Table 9.10.1. Standard AE/LSU table for breeding cattle. ... 54
Table 9.10.2. Standard AE/LSU table for growing steers and replacement heifers. ... 55
Table 9.10.3. Summarised monthly AE rating for breeding cattle, based on calendar months. (This system is suitable for the reliable and well defined growing season in northern areas). ... 57
Table 9.10.4. Example of grazing chart data for part of a cell system at one site. This system was developed for direct computer excel® data entry and automatic analysis. ... 57
Table 9.10.5. Grazing system and class of grazing stock and usual number of head or AE in monitor paddocks. ... 58
Table 9.10.6. Effect of grazing system and year on grazing in stock days per hectare (SDH) at the nine sites*. ... 61
Table 9.10.7. Effect of grazing system and year on stock days per hectare per 100mm rainfall (SDH/100mm) at the nine sites*. ... 62
Table 9.10.8. Effect of grazing system and year on annual stocking rate (ha/AE) at the nine sites*. ... 63
Table 9.10.9. Effect of grazing system and year on stock days per hectare (SDH) at nine sites. ... 64
Table 9.10.10. Effect of grazing system and year on stock days per hectare per 100mm rainfall (SDH/100mm) at nine sites. ... 64
Table 9.10.11. Effect of grazing system and year on annual stocking rate (ha/AE) at nine sites. ... 64
Table 9.10.12. Range of average annual grazing pressure (ha/AE) between grazing systems at each site. ... 65
Table 9.10.13. Properties where annual average grazing pressure (ha/AE) between 2005 and 2009 was under or over estimated LTCC by region and vegetation type. ... 65
Table 9.10.14. Number of sites and pasture types where annual average grazing pressure (ha/AE) between 2005 and 2009 was under or over estimated LTCC by region and vegetation type. ... 66
Table 9.10.15. Average annual rainfall decile (four years, 2005-06 to 2008-09) for sites where the annual average grazing pressure (ha/AE) between 2005 and 2009 was under or over estimated LTCC by region and vegetation type. ... 66
Table 9.11.1. Discounts in grazing activity with distance (km) to permanent water. ... 68
Table 9.11.2. Table of parameters used to calculate carrying capacity of each land type sub-unit and total paddock LTCC (Table headings only shown in two rows). ... 70
Table 9.11.3. Average annual grazing pressure (Actual) imposed on paddocks (SDH) compared with LTCC. ... 71
Table 9.12.1. Mean NIRS diet quality values related to the average of the previous 30-days Growth Index for all samples and sites for the three grazing systems. ... 78
Table 9.12.2. Significant NIRS diet quality parameters for grazing systems and pasture growth indices and interactions for all samples (565) at nine sites. ... 79
Table 9.12.3. NIRS diet quality values related to the average of the previous 30-days Growth Index (GI) for all samples from each grazing systems at each site. ... 81
Table 9.12.4. Total number of NIRS samples from properties. ... 84
Table 9.13.1. Calculated capital cost index (CI value) for number of paddocks. ... 90
Table 9.13.2. Calculated operating cost index (OI value) for grazing period. ... 91
Table 9.13.3. Examples of capital (CI), operating (OI), management (MI) indices and calculated grazing system index (GSI) for cell grazing systems. ... 93
Table 9.13.4. Calculated grazing system index (GSI) for 22 grazing systems at nine primary sites. ... 95

Table 9.14.1. Break-even calculator example of costs and returns from developing a new grazing system. 97
Table 9.15.1. Producer survey of grazing system choice and perceptions of advantages and disadvantages of their own systems*........ 109
Table 9.19.1. Project development team, project coordination and operational staff between 2005 and 2009. 136
Table 9.19.2. Primary site producer owners and managers during the project. 137
Table 9.19.3. Project development advisory group 2005. 137
Table 9.19.4. Project co-ordinators from MLA. 137

Table of Figures

Figure 9.3.1. Southern oscillation index 2000-2009. 8
Figure 9.3.2. Banyula monthly rainfall and long-term mean July 2005 to June 2009 and long-term monthly mean. 9
Figure 9.3.3. Berrigurra monthly and long-term mean rainfall (mm) July 2005 to June 2009 and long-term monthly mean. 9
Figure 9.3.4. Frankfield monthly rainfall (mm) July 2005 to June 2009 and long-term monthly mean. 10
Figure 9.3.5. Melrose monthly rainfall (mm) July 2005 to June 2009 and long-term monthly mean. 10
Figure 9.3.6. Rocky Springs monthly rainfall (mm) July 2005 to June 2009 and long-term monthly mean. 11
Figure 9.3.7. Salisbury Plains monthly rainfall (mm) July 2005 to June 2009 and long-term monthly mean. 11
Figure 9.3.8. Somerville monthly rainfall (mm) July 2005 to June 2007 and long-term monthly mean. 12
Figure 9.3.9. Sunnyholt monthly rainfall (mm) July 2005 to June 2009 and long-term monthly mean. 12
Figure 9.3.10. Ticehurst monthly rainfall (mm) July 2005 to June 2009 and long-term monthly mean. 13
Figure 9.3.11. Melrose monthly rainfall (mm) variability over four years July 2005 to June 2009. 13
Figure 9.4.1. Layout and direction of LFA transect and fixed photograph sites in eight paddocks of three grazing systems at Melrose. 15
Figure 9.4.2. Botanical and soil surface sampling grid points in Green Gully (no. 51) paddock (continuous grazing system) at Melrose. 16
Figure 9.4.3. Botanical and soil surface sampling grid points across six paddocks of two grazing systems at Sunnyholt. 17
Figure 9.6.1. Average (2003-2007) ground cover index (vegetation cover) image for the Cell-loam and Cell-clay, Bankstown Continuous paddock, the whole Banyula property and surrounding properties. 39
Figure 9.6.2. Modelled pasture standing dry matter (kg/ha), total pasture and litter cover (%), annual rainfall (mm) and annual pasture growth (kg/ha) from 1970 to 2009 at Banyula (DERM data). 40
Figure 9.6.3. Modelled ground cover (%) from AussieGrass compared with Landsat whole property BGI from 1985 to 2008 at Banyula (DERM data). 41
Figure 9.8.1. Temperature indices for tropical and temperate grass species. 43
Figure 9.9.1. Total ground cover (%) in 2007 for the six cell paddocks that were monitored at one site. 47
Figure 9.11.1. LTCC calculations of Berrigurra showing paddocks, land condition, trees and water buffer distances on monitor paddocks of three grazing systems. 69
Figure 9.12.1. Northern and southern Queensland site means for main NIRS diet quality parameters (North 367 samples; South 242 samples). 76
Figure 9.12.2. Brigalow and eucalypt site means for main NIRS diet quality parameters (Brigalow 341 samples; Eucalypt 268 samples). 77
Figure 9.14.1. General structure of template `break-even' model used for evaluation of case studies. 96
Figure 9.14.2. Rockhampton Case Study - Impact of changing carrying capacity (AE) on MNP. 102
Figure 9.14.3. Rockhampton Case Study - Impact of changing aggregate production of beef (kg liveweight) on net profit estimates MNP. 102
Figure 9.14.4. Rockhampton Case Study - Impact of changing branding rate (B%) on MNP. 103
Figure 9.14.5. Rockhampton Case Study - Impact of changing liveweight gain (LWG) on MNP. 104
Figure 9.14.6. Rockhampton Case Study - Impact of changing beef price (liveweight) on MNP based on 790 breeders. 105
Figure 9.14.7. Rockhampton Case Study - Impact of changing variable cost (VC) on MNP based on 790 breeders. 106
Figure 9.14.8. Rockhampton Case Study - Impact of changing fixed cost (FC) on MNP based on 790 breeders. 107
Figure 9.14.9. Rockhampton Case Study - Impact of changing input of owners' labour (FTE) on MNP_{OL} based on 790 breeders. 108