final report

NATURAL RESOURCE MANAGEMENT

Project code: B.NBP.0353

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Volume II - Investigating Intensive Grazing Systems in Northern Australia Appendix 1

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Banyula

Abstract

Banyula, Condamine, has two grazing systems; two sets of cells, on both loam and heavy clay soils, and a continuous system. Five cell paddocks in both cells and the continuous paddock were monitored between 2006 and 2009. Both systems are used for growing steers and heifers for a range of feedlot and fat cattle markets. There were two drought years followed by two above average rainfall years during the four-year monitoring period. The pastures were sampled in late autumn in 2006, 2007 and 2009. Yields were higher in the cell system (2100 kg/ha) than the continuous paddock (1700 kg/ha) in all years and increased with time in both systems. The cells were strongly buffel grass dominant, 95%, while the continuous paddock had a more diverse composition with 70% native grasses.

Over four years, all systems received similar average grazing, near 21 SDH/100mm rainfall, although the long-term carrying capacity is lower in the continuous; However, in the two higher rainfall years the cells supported a higher grazing pressure than the continuous system. Diet quality was marginally higher on the clay cells than on the other systems on loam soils. Management and grazing of the three systems are integrated to provide a whole property grower enterprise as opposed to three independent grazing systems. Grazing of pastures in all three systems follows the same principles of controlling total grazing pressure and incorporating rest. There were no consistent outstanding ecological differences that could be attributed to the actual grazing system.

1. Site Introduction

1.1. Location

Banyula is located approximately 50 km south-west of Condamine (27.0ºS; 149.6ºE) on Dogwood Creek in the Murray-Darling catchment (Figure 1.1).

Figure 1.1. Buffel grass dominated pasture landscape scene on loam soils at Banyula.

1.2. Climate/growing season

Average annual rainfall is 541 mm (Table 3.1) with 67% falling in summer (October-March). The growing season is predominantly in summer, but with significant winter rain in some years there can be important temperate winter pasture legume (*Medicago* spp.) growth with subsequent beneficial impacts on pasture quality. Cut-leaf medic and naturalised burr medic are common in this environment in these years.

Based on long-term climate data, the average green season for tropical species is estimated to be 29 weeks including 12.1 growth weeks. With the winter rain, temperate species would add an average of 6.5 weeks to the growth of tropical species.

1.3. Major soil/vegetation types

There are two major vegetation types at Banyula - a mixed woodland of poplar box (*Eucalyptus populnea*), and a belah (*Casuarina cristata*) forest with brigalow (*Acacia harpophylla*). There are lesser areas of cypress pine (*Callitris glauca*) on loamy sands. The soils on the poplar box land type are red sandy clay loams and loams, while those on the brigalow lands are heavy grey clays with some areas of gilgai. Most of the trees have been cleared on both vegetation types. Pastures are dominated by buffel grass (*Cenchrus ciliaris*). The landscape on Banyula is flat to undulating.

Based on aerial photographs, knowledge of the property and inputs from the owner, the land in the monitor paddocks was allocated to seven land types recognised in the Grazing Land Management package. The areas of the different land types in the three grazing systems are shown in Table 1.1.

Table 1.1. Areas (ha) of land types in the monitor paddocks of grazing systems at Banyula.

Land type	**Area (ha)**		
	Cell-loam	**Cell-clay**	**Continuous**
Brigalow Belah		85	129
Brigalow with melon holes		25	
Cypress pine on deep sands			50
Cypress pine on duplex			80
Flooded dam surrounds			16
Poplar box on alluvial plains	54		250
Poplar box on duplex	117		82
Total	**171**	**110**	**607**

1.4. GRASP modelling of long-term pasture growth

1.4.1. GRASP parameters

The values for a number of important GRASP parameters at Banyula are given in Table 1.2. The simulations were run for the four major land types (Table 1.1): “Poplar box on duplex,” “Poplar box on alluvial plains,” “Brigalow-Belah” and “Cypress pine on duplex”.

Table 1.2. Land type parameters used in GRASP model to estimate pasture growth at Banyula.

GRASP parameter	Parameter units			
	Brigalow Belah	Cypress duplex	Poplar duplex	Poplar alluvial
Tree basal area (m^2/ha)	0	10	1	1
Available soil water (mm)	102	75	90	145
Maximum N uptake (kg/ha)	20	15	20	20
Regrowth (kg/ha/%BA)	3.5	6.0	3.5	3.5
Transpiration use efficiency (kg/ha/mm)	25.4	17.0	16.0	17.0
Minimum N concentration (%)	0.5	0.4	0.5	0.4

1.4.2. GRASP results

The GRASP model was run using climate data from SILO for the period 1889 to June 2007 (Warkon site) and pasture growth for the period October 1 to September 30 was estimated. The median values for Banyula were 3420 kg/ha for "Brigalow Belah", 550 kg/ha for "Cypress pine on duplex", 3290 kg/ha for "Poplar box on alluvial plains" and 2250 kg/ha for "Poplar box on duplex" (Figure 1.2).

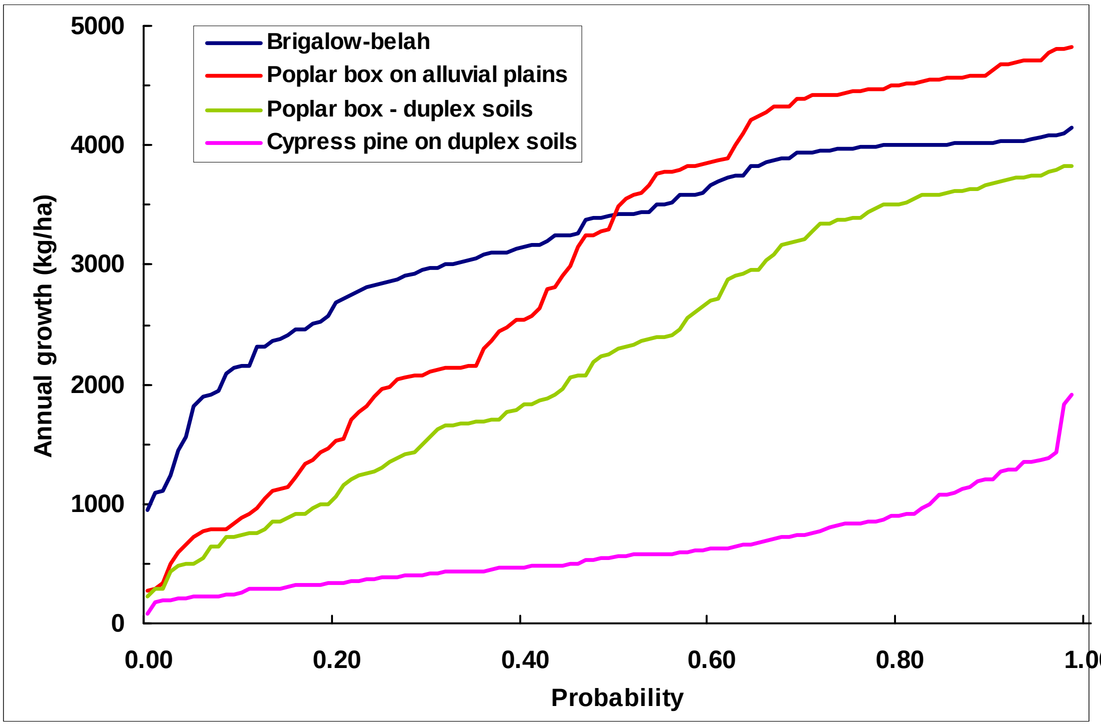


Figure 1.2. Long-term distribution of estimates of annual pasture growth at Banyula.

1.5. Production system/markets

The present production system is almost exclusively based on regular (year-round and largely opportunistic) purchase of trade or 'turnover' cattle (steers and heifers 200-250 kg) for finishing to 340-380 kg for direct sale to a supermarket chain (via external feedlot) or finished in an on-property feedlot after 80-100 days on feed. The steers and heifers are run together with herds segregated on live weight. The buffel pastures provide the dominant feed source for all cattle with some mobs supplemented with cotton seed in the paddock from feed bins. All cattle have access to medicated water with a urea based supplement.

1.6. Producer goals

When the present managers took control of the holding, there had been some clearing but in most cases the paddocks were covered with thick brigalow suckers and box trees. The country was cleared and cultivated for wheat, barley, oats and forage sorghum. Cropping has been discontinued and much of the property has been sown to buffel grass, or it has self-established. Initially the property was divided into five paddocks and a continuous grazing system was employed. However, the owners felt the continuous grazing system showed a reduction of pasture growth with the constant animal impact, and they were not getting good enough feed quality and thereby growth rate and turnover of cattle.

The owners considered that cell grazing would give the areas a longer rest period to allow the pasture a better growth period to thicken up, and also allow medication of all the drinking water to achieve a higher growth rate in cattle especially over the winter/non-growing time. A cell grazing system was initially established on sandy loam soil paddocks which were in deteriorating to poor condition under previous continuous grazing. Cells on brigalow paddocks were established more recently based on observations of pasture condition improvement in the original cell system.

The overall production objective is to achieve a moderate (3-4%) increase in stocking rate over previous levels from continuous grazing. This is seen to be sufficient to justify the expense of establishing the new grazing system. The system design was finally based on the owners' plans, but was initially informed by a design consultancy following participation in a dedicated cell-grazing course. For example, the original 'wagon wheel' design has been replaced by a linear, lane-based system with relatively square paddocks and four paddocks accessing the one medicated water point.

2. Grazing Systems

2.1. Description

Two grazing systems were sampled when the project commenced in 2005 – a continuous grazing system and a cell system, both on the poplar box woodland with loamy soils. Another cell system was established on the brigalow land type (clay soils) in 2006 by subdividing rotation grazing paddocks and this cell system was also monitored in 2007 and 2009. These two cell systems are referred to as cell-loam and cell-clay.

The <u>cell-loam</u> system on the poplar box land type has 20 paddocks (average size approx. 35 ha) carrying approximately 400 steers which are moved at 2-3 day intervals. The <u>cell-clay</u> system on the brigalow has 24 paddocks carrying approximately 215 steers/heifers which are moved at 1-3 day intervals. These clay soil cells became fully operational and grazing commenced in late 2006. Both the cell systems are buffel grass dominant with some regrowth. Five paddocks from three cell centres of the cell-loam system and five paddocks from four centres of the cell-clay system were monitored (Table 2.1).

The <u>continuous</u> paddock (Bankstown) is 608 ha with the water supply from an open dam and a medicated trough installed in 2007. The continuous paddock has more variable land types than the cell paddocks (Table 1.1). Most of the paddock is comparable to the light soil in the cell-loam system with buffel grass dominant and native perennial grasses, but the paddock also includes small areas of wet patches (where sedges occur), treed hills almost devoid of pasture and some uncleared woodlands.

Table 2.1. Paddock names, numbers and areas sampled in grazing systems at Banyula.

Vegetation type	Grazing System	Paddock name [Botanal No.]	Area (ha)
Eucalypt (5 pdks)	Cell-loam	Eagle Farm 1 [1]	55
		Eagle Farm 3 [3]	43
		Eagle Farm 7 [7]	27
		Richmond 4 [4]	27
		Richmond 6 [6]	20
		Total Cell-loam	171
Brigalow (5 pdks)	Cell-clay	Amberley 1 [11]	19
		Amberley 10 [10]	22
		Mascot 2 [12]	23
		Mascot 3 [13]	21
		Mascot 6 [16]	25
		Total Cell-clay	110
Eucalypt (1 pdk)	Continuous	Bankstown [8]	608

The layout of the cell-loam (paddocks 1, 3, 4, 6 and 7) and cell-clay (paddocks 2, 10, 11, 13 and 16) systems and the continuous Bankstown paddock (8) on a Spot 5 image are shown in Figure 2.1. The extent of clearing, which is sown to buffel grass in all systems, is readily identified, as are the brigalow, eucalypt and cypress pine forest patches near the dam in Bankstown paddock.

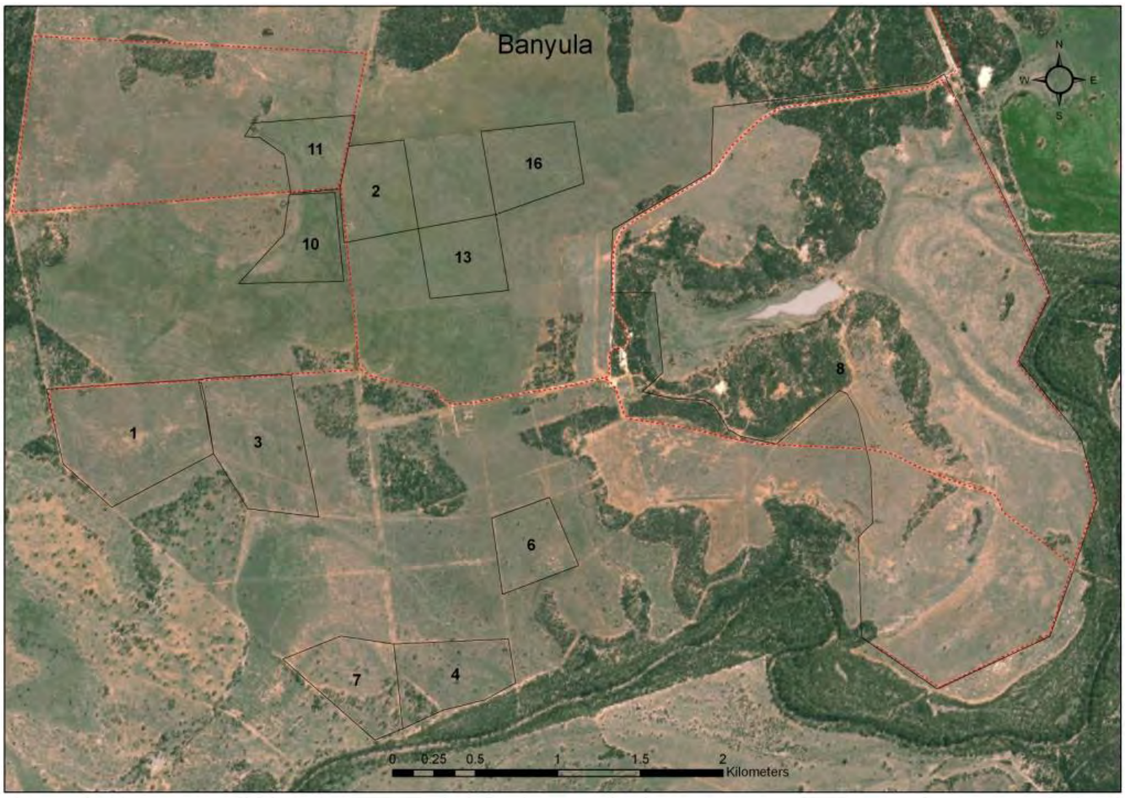


Figure 2.1. Layout of monitor Cell-loam, Cell-clay and Continuous system paddocks at Banyula.

2.2. Management during 2005-2009

Due to dry conditions over the 2005-06 summer, the cells were periodically rested from grazing. The cell-loam system had an average of 298 head of growing steers and heifers (232 to 364 head with weights between 250 and 300 kg). Animals were moved between paddocks at intervals 1-3 days during the year. These animals received urea medicated water into their troughs. As animals reach 360 kg they are removed and sent to market or feedlots. This management system was employed for both cell systems with herd numbers fluctuating with the seasons. The drought years reduced total herd numbers by up to 40%.

The continuous paddock (608 ha) was grazed by varying numbers of a mixed herd of steers and heifers between 200 and 300 kg, with short periods of grazing by cows, at an average of 0.33 hd/ha for the period 16 March 2005 to 3 June 2006. The paddock was used to grow out steers and heifers to put into the cells or for direct feedlot finishing. The numbers varied regularly, from 0 to 518 head in the paddock. Numbers are highest when the paddock is used as the ‘holiday’ paddock so the owner can leave the property for days or weeks at a time. Generally the lighter steers and heifers were run in the continuous paddock until they reached near 280 kg and were then drafted into a cell system herd. During the project this paddock had a medicated trough installed, similar to the urea-based medication system in the cell systems.

To reduce the time to finish some herds, they were supplemented with cotton seed in feed bins in the cell-clay paddocks on occasions, and some other herds were finished on the property in a feedlot.

3. Results

3.1. Growing seasons

3.1.1. Rainfall

The first two years of the project from 2005-2007, were drought years (decile 3) followed by two high rainfall years (decile 9), however, the distribution of rain was not always conducive to good grass pasture growth (Table 3.1).

Table 3.1. Monthly rainfall (mm) at Banyula from July 2003 to June 2009, and long-term average monthly rainfall (mm) at Warkon recording station over 93 years.

Year	J	A	S	O	N	D	J	F	M	A	M	J	Total	Decile
2003/04	23	48	0	57	48	44	214	37	104	76	0	13	662	9
2004/05	0	0	32	39	141	128	42	17	28	0	24	85	536	6
2005/06	6	0	0	97	116	53	39	30	46	17	5	11	418	3
2006/07	16	0	8	0	35	47	59	138	24	10	0	99	435	3
2007/08	0	69	27	45	23	279	88	79	0	15	11	28	662	9
2008/09	45	0	53	39	86	119	12	160	9	7	86	52	667	9
Long-term Mean	**33**	**25**	**25**	**48**	**59**	**69**	**74**	**67**	**45**	**31**	**32**	**32**	**541**	

3.1.2. Growing conditions

2003-2005: Rainfall was above average and average for the two years prior to the trial.

2005-2006: This was a drought year with rainfall at Banyula well below average for both the summer growing season and the whole year. However, spring rainfall (October-November) was above average resulting in good pasture growth prior to summer, but pastures matured early with the short summer growth season.

2006-2007: Banyula was again in a drought, receiving below average rainfall (decile 3). However rainfall over the summer pasture growing season was above average in February. This summer rainfall produced good quality pasture and was followed by a dry autumn and wet June, which helped maintain pasture quality into winter. However, the generally poor growing conditions through 2006-07, following the previous drought year, forced stock numbers to be reduced.

2007-2008: There was reasonable spring and good early summer rain which produced good pasture growth. However, the season finished in mid-summer causing pastures to mature and dry off early. December 2007 was an exceptionally wet month (279 mm), receiving four times the annual average. There was surplus pasture grown which was cut for hay in several old cultivation paddocks in the clay soil cells. Some 500 round hay bales of 300 kg were produced for feeding in the on-farm feedlot. Annual medics germinated on autumn and winter rain, which improved feed quality, although they did not produce a significant bulk of feed.

2008-2009: This season had well above average spring and early summer rainfall, producing rapid pasture growth at a time when stock numbers were below the long-term carrying capacity. The dry January caused the pasture to mature early. The buffel grass in some cell-clay paddocks (including the monitor paddock M2) was harvested for seed producing some eight tonne of uncleaned seed. These paddocks had a history of cultivation and cropping during the earlier property development phase, and their cover fluctuations are shown in the time-series VegMachine analysis.

3.1.3. GRASP modelling of pasture growth 2005-2009

The estimates of the pasture growth rates from GRASP modelling for the four main land types, the areas of each land type, and their land condition, were used to estimate the annual average pasture growth on each grazing system (Table 3.2). The “Brigalow with melon holes” land type was assumed to have the same growth rate as “Brigalow-Belah”, and “Cypress pine on deep sands” was assumed to have the same growth rate as “Cypress pine on duplex”. The flooded dam surrounds were assumed to produce no pasture. Poplar box on alluvial plains and on duplex soils were the two dominant land types in the cell-loam and continuous systems.

Table 3.2. Estimated annual pasture growth (kg/ha) for land types, grazing systems and years from 2005-06 to 2008-09 at Banyula.

Year	**Pasture growth (kg/ha)**		
	Cell-loam	**Cell-clay**	**Continuous**
2005/06	1600	3300	1700
2006/07	300	1100	400
2007/08	3600	4200	3100
2008/09	2500	3800	2400
Average	**2000**	**3100**	**1900**

The changes in the weekly pasture Growth Index from GRASP modelling over the monitoring period (Figure 3.1) show the widely fluctuating pasture growth periods during the project at this site. There was a short period of active growth in 2005-06 followed by very dry winter and a poor summer. The extended drought period limited pasture growth and caused cattle numbers to be reduced. The final two years both had short periods of good growth conditions interspersed by less optimal conditions. The dry winters with negligible growth opportunities are clearly shown.

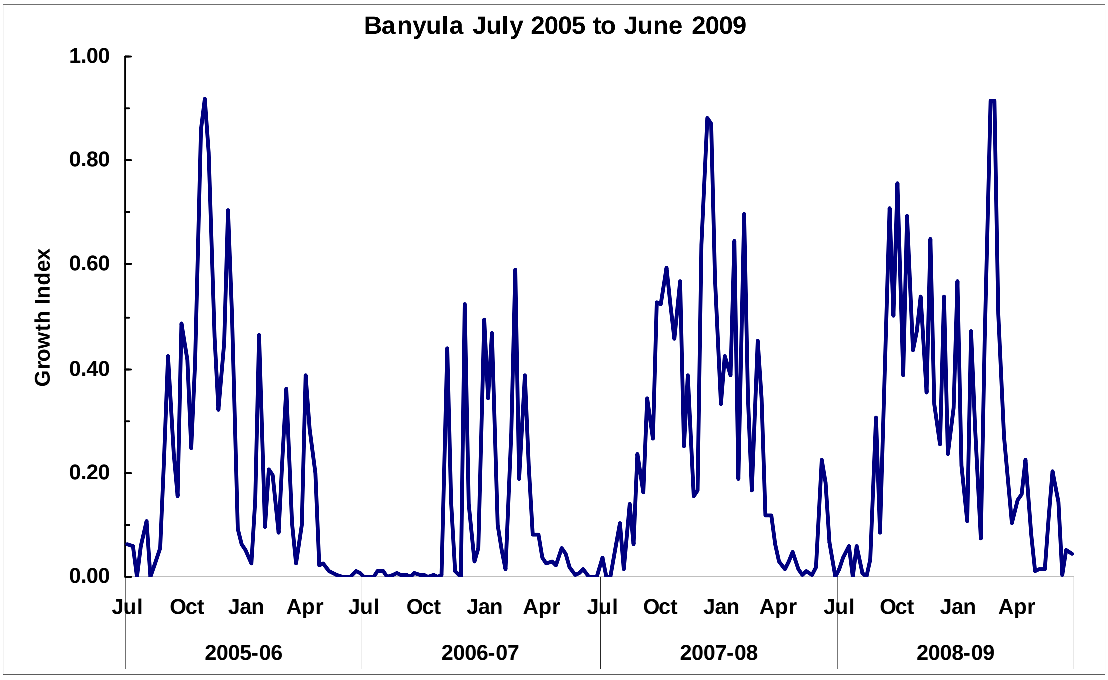


Figure 3.1. Weekly pasture Growth Index (tropical species) values at Banyula during the experimental period (2005-09) for the “Poplar box on alluvial plains” land type.

3.2. Pastures and Land Condition

3.2.1. Pasture yield, botanical composition and diversity

The continuous paddock contains 130 ha (21%) of land supporting a buffel and Aristida pasture in cypress pine forest on loamy sand soils. This is different to the poplar box dominant remainder of the paddock and results are reported separately as continuous-forest.

3.2.1.1. Pasture mean values

The pastures were sampled in late autumn in 2006, 2007 and 2009 (Table 3.3). Yields were higher in the cell system than the continuous paddock in all years and increased with time in both systems. The cell paddocks were strongly buffel grass dominant with few other species in all years. The continuous paddock had a more diverse composition with a considerable amount of native grass, up to 75% in the forest (treed) areas in 2009.

Table 3.3. Pasture dry matter yield and botanical composition at the end of summer.

Year	System	Yield (kg/ha)	Botanical composition (%) Nat per grass	Exotic grass	Native leg	Exotic leg	Ann grass	Forb	Sedge
2006	Cell-loam	1760	5.4	93.7	0.0	0.0	0.0	0.5	0.4
	Continuous	1030	27.0	66.9	0.0	0.0	0.0	2.2	3.9
	Cont-forest	670	71.9	16.9	0.0	0.2	0.0	5.7	5.5
2007	Cell-loam	1820	4.2	95.1	0.0	0.0	0.0	0.5	0.2
	Cell-clay	1510	0.0	92.1	0.0	0.0	1.1	6.8	0.0
	Continuous	1200	25.2	70.5	0.0	0.0	0.0	2.3	1.5
	Cont-forest	330	46.7	41.6	0.0	0.0	0.7	10.0	0.9
2009	Cell-loam	2160	2.8	95.3	0.0	0.0	0.0	1.5	0.3
	Cell-clay	2120	0.4	98.4	0.0	0.1	0.1	1.1	0.0
	Continuous	1750	20.4	70.6	0.2	0.0	0.1	1.5	0.3
	Cont-forest	670	75.0	16.3	0.0	0.0	0.0	7.4	1.3

3.2.1.2. Yield spatial variability

This analysis measured the degree of uniformity, or inversely variability, in the various parameters across each paddock. There was only one of the five cell-loam paddocks with uniform pasture yield in 2006, while both land forms of the continuous paddock were uniform (Table 3.4). In 2009, these areas of the continuous paddock were not uniform in yield while half of the monitored cell-loam and cell-clay paddocks were uniform.

Table 3.4. Spatial variability in pasture yield – number of paddocks where pasture yield was spatially uniform across the paddock.

System	No. of paddocks	2006	2007	2009
Cell-loam	5	1	2	2
Cell-clay	5	-	4	3
Continuous	1	1	0	0
Continuous - forest	1	1	1	0

3.2.1.3. Species diversity

All measures showed greater pasture species diversity in the continuous paddock than the two cell systems – the number of species per quadrat was larger, the number species to contribute 90% of yield was larger and the dominant species contributed a smaller proportion of the total yield (Table 3.5).

Table 3.5. Three measures of pasture species diversity at Banyula in 2006, 2007 and 2009.

Diversity measure	Diversity units			
	Cell-loam	Cell-clay	Continuous	Cont-forest
No. species/quadrat				
2006	1.3		1.7	1.5
2007	1.4	1.4	1.7	1.3
2009	1.7	1.3	2.1	2.0
No. species to contribute 90% of yield				
2006	1		9	11
2007	1	1	7	11
2009	1	1	8	12
% contribution of dominant species				
2006	93		67	24
2007	95	92	70	42
2009	95	98	70	17

3.2.2. Pasture utilisation

Pasture utilisation in the monitor paddocks at the end of summer was rated across the paddocks on the Botanal grid at each recording point (rating 1 = 71-100%; 2 = 31-70%; 3 = 6-30%; 4 = 0-5% utilisation).

3.2.2.1. Utilisation mean values

Overall utilisation in autumn was low but slightly higher in the continuous system than in the two cell systems. There was little utilisation in the forest area of the continuous paddock in any year (Table 3.6).

Table 3.6. Mean rating (1 = high to 4 = low) for estimated pasture utilisation in grazing systems at Banyula for 2005-06, 2006-07 and 2008-09.

Year	Utilisation rating			
	Cell-loam	Cell-clay	Continuous	Cont-forest
2005-06	3.9		2.9	3.7
2006-07	3.7	3.3	3.0	3.5
2008-09	3.3	3.5	3.2	3.8

In 2006 there was higher utilisation in the continuous paddocks than in the other systems which had received negligible grazing by autumn (Figure 3.2). The open country of the continuous paddock received consistently heavier grazing than forest areas. In 2009, all main pasture areas of the three systems had received similar grazing at utilisation rate 3 (5-30%). There were patches in the continuous system grazed more heavily than in the cells.

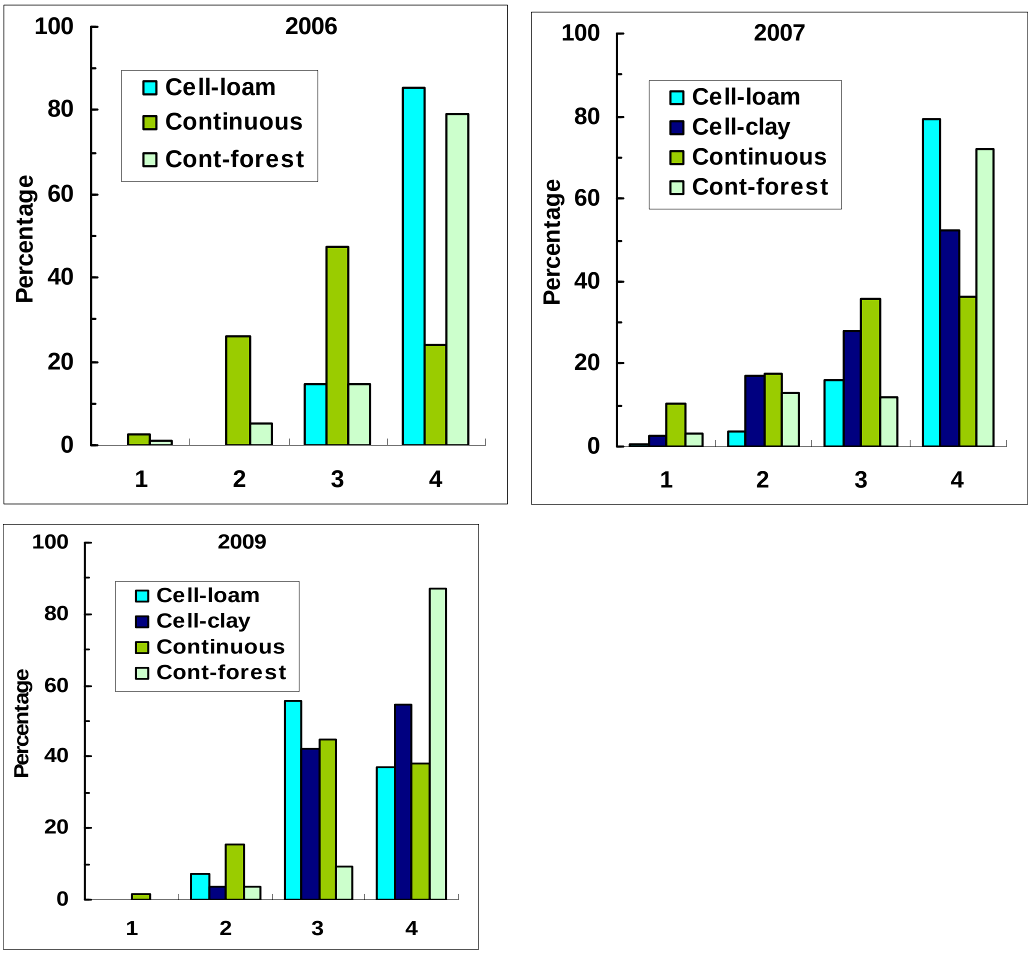


Figure 3.2. Distribution of estimated pasture utilisation values in grazing systems at Banyula from 2005-06 to 2008-09.

3.2.2.2. Utilisation spatial variability

Utilisation was uniform across most paddocks of the cell-loam system and uniform in the cleared continuous paddock at the three recording times (Table 3.7). There was greater variation across the cell-clay paddocks then the cell-loam in 2009.

Table 3.7. Spatial variability in pasture utilisation – number of paddocks where pasture utilisation was spatially uniform (i.e. there was no evidence of aggregation) across the paddock.

Grazing System	Total no. of paddocks	No. paddocks uniform utilisation		
		2006	2007	2009
Cell-loam	5	5	2	4
Cell-clay	5	-	3	2
Continuous	1	1	1	1
Cont-forest	1	1	0	0

3.2.3. Woody regrowth

There was greater woody regrowth in the continuous paddock than the cells in 2007 and 2009. The cell-clay paddocks had negligible regrowth except for brigalow suckers in one paddock (M6). Estimates of the cover of woody regrowth, mainly poplar box suckers, in the cleared areas of the three systems (Table 3.8) shows cover of near 1% in the continuous system. The continuous-forest area had not been cleared.

Table 3.8. Cover levels (%) of woody regrowth in grazing systems at Banyula.

Year	Woody regrowth cover (%)		
	Cell-loam	**Cell-clay**	**Continuous**
2006	0.4		0.4
2007	0.4	<0.1	0.9
2009	0.4	0.1	0.9

3.2.4. Ground and litter cover

3.2.4.1. Cover means

Although there was some variability in cover, both the means and the standard deviations for both total cover and litter cover were similar for the different grazing systems with no consistent pattern of differences (Table 3.9).

Table 3.9. Total cover and litter cover (%) at Banyula at the end of summer.

Year	Grazing System	Total cover (%)		Litter cover (%)	
		Mean	**St. dev.**	**Mean**	**St. dev.**
2006	Cell-loam	55	24.9	16	14.2
	Continuous	52	26.2	23	17.6
	Cont-forest	51	31.1	29	26.3
2007	Cell-loam	56	25.2	14	12.2
	Cell-clay	47	25.8	11	9.2
	Continuous	42	25.3	12	13.6
	Cont-forest	50	29.8	23	24.9
2009	Cell-loam	62	23.8	20	14.9
	Cell-clay	55	24.9	20	16.2
	Continuous	57	25.3	18	16.2
	Cont-forest	54	30.6	32	29.0

3.2.4.2. Cover spatial variability

In 2006, three of the five cell-loam paddocks had uniform total ground cover and also uniform litter cover, while in the continuous paddock total cover was not uniform, but litter cover was uniform. However, in the following year, only one cell-loam paddock had uniform total cover and the continuous paddock was also uniform. In this year, four of the five cell-clay paddocks had uniform total cover (Table 3.10). By 2009, few paddocks had uniform total or litter cover.

Table 3.10. Spatial variability in ground cover – number of paddocks where total ground cover or litter cover was spatially uniform (i.e. there was no evidence of aggregation) across the paddock.

Cover / Grazing System	**Total no. of paddocks**	**No. paddocks uniform ground cover**		
		2006	**2007**	**2009**
Total ground cover				
Cell-loam	5	3	1	1
Cell-clay	5	-	4	2
Continuous	1	0	1	0
Cont-forest	1	1	1	1
Litter cover				
Cell-loam	5	3	2	1
Cell-clay	5	-	2	1
Continuous	1	1	1	0
Cont-forest	1	1	1	0

3.2.5. LFA indices (soil surface conditions)

The three LFA indices, stability, infiltration and nutrient cycling, have values between 0 and 100 where larger values indicate better performance for that index.

3.2.5.1. LFA indices means and standard deviations

Stability index values were slightly higher in the cell-loam paddocks than the continuous paddock, but the reverse was true for the infiltration index. Overall there was no difference between these two systems for the nutrient cycling index. The standard deviations were variable but usually largest in the continuous-forest area (Table 3.11).

Table 3.11. LFA stability, infiltration and nutrient cycling indices at the end of summer in 2006, 2007 and 2009.

Year	System	LFA Indices (0-100)					
		Stability		Infiltration		Nutrient cycling	
		Mean	S. Dev.	Mean	S. Dev.	Mean	S. Dev.
2005	Cell-loam	62.0	6.07	34.1	7.20	27.7	7.63
	Continuous	60.2	7.58	38.9	9.81	29.3	8.42
	Cont-forest	57.6	7.09	42.9	11.34	33.8	12.42
2007	Cell-loam	59.6	5.48	36.9	6.10	28.6	6.80
	Cell-clay	55.0	5.56	37.7	6.43	27.4	5.29
	Continuous	55.9	6.70	38.7	7.70	27.9	6.80
	Cont-forest	58.2	7.39	38.3	11.91	32.9	14.24
2009	Cell-loam	62.3	6.37	39.3	6.76	31.5	8.28
	Cell-clay	58.2	6.56	42.3	6.90	31.3	8.51
	Continuous	61.0	7.23	40.3	9.32	30.6	8.70
	Cont-forest	57.0	8.60	41.6	11.68	36.3	13.35

3.2.5.2. LFA indices spatial variability

There was a high degree of variability between the three LFA indices across the paddocks in the three years of recording, except the cell-loam paddocks were uniform for the stability index in the first two years, and the cell-clay had uniform nutrient cycling in 2007 (Table 3.12). The continuous paddock had uniform stability and nutrient cycling in two of the three years of recording.

Table 3.12. Spatial variability in LFA indices – number of paddocks where the LFA stability index, Infiltration index or Nutrient cycling index was spatially uniform (i.e. there was no evidence of aggregation) across the paddock.

LFA index / Grazing System	Total no. of paddocks	No. paddocks uniform LFA index		
		2006	2007	2009
LFA Stability index				
Cell-loam	5	4	4	1
Cell-clay	5	-	1	4
Continuous	1	0	1	1
Cont-forest	1	1	1	0
LFA Infiltration index				
Cell-loam	5	1	2	0
Cell-clay	5	-	1	2
Continuous	1	0	0	0
Cont-forest	1	1	1	0
LFA Nutrient cycling index				
Cell-loam	5	3	2	1
Cell-clay	5	-	4	2
Continuous	1	1	1	0
Cont-forest	1	1	1	0

3.2.6. Land condition

The PatchKey analyses produced slightly lower land condition values overall than the other two methods. PatchKey values were higher (indicating lower condition) in the continuous system in all years (Table 3.13).

From visual estimates, the cell-loam paddocks were mainly in A condition with small patches in B or C condition due to loss of perennial grasses and woody regrowth, while the cell-clay were also mostly A condition with small areas in C condition due to scalding and regrowth. These scald areas are on the lighter soil patches within the predominantly gilgaied cracking clay paddocks. The loam soil flat in the continuous paddock was mostly in A condition with patches in B, while the hills have areas in C and D condition on shallow and gravelly soils, and areas in B condition on the sandy soils. Land types in the continuous paddock are more variable than in either cell system.

Table 3.13. Measures of land condition at Banyula. For the Botanal/PatchKey and ABCD (Land type) values, "1" is equivalent to A condition and "4" is equivalent to D condition.

Land condition /	Land condition unit		
Year / Land type	Cell-loam	Cell-clay	Continuous
Botanal/PatchKey			
2006	1.8		2.5
2007	1.9	2.2	2.5
2009	1.7	1.7	2.2
ABCD (by Land type)			
Brigalow-Belah		1.0	1.4
Brigalow with melon holes		1.0	
Cypress pine on deep sands			1.0
Cypress pine on duplex			2.0
Flooded dam surrounds			4.0
Poplar box on alluvial plains	1.0		1.0
Poplar box on duplex	1.2		2.0
Overall average	1.1	1.0	1.4
ABCD (Paddock)			
2006	A/B		B
2007	A/B	A	B
2009	A/B	A	B

An annual photograph of fixed points in the systems shows the seasonal variation in pasture growth and cover (Figure 3.3). The open pasture and bare areas obvious during the drought of 2005 and 2006 in the three systems were all in better condition by June 2009. The mature pastures in autumn (e.g. April of 2007 and 2008) reflect the early end to the growing seasons during the monitoring period.

Banyula E3-6 Lat: 27^{0}.011; Long: 149^{0}.613, Dir: 155^{0}	**Banyula M3-2** Lat: 27^{0}.002; Long: 149^{0}.375, Dir: 273^{0}	**Banyula Ban-8** Lat: 27^{0}.013; Long: 149^{0}.653, Dir: 60^{0}
 Cell-loam (December 2005)	Not established in 2005	 Continuous (December 2005)
 Cell-loam (November 2006)	 Cell-clay (November 2006)	 Continuous (November 2006)
 Cell-loam (April 2007)	 Cell-clay (April 2007)	 Continuous (April 2007)
 Cell-loam (April 2008)	 Cell-clay (April 2008)	 Continuous (April 2008)
 Cell-loam (June 2009)	 Cell-clay (June 2009)	 Continuous (June 2009)

Figure 3.3. Changes in land condition at fixed points in the Cell-loam, Cell-clay and Continuous grazing systems at Banyula between 2005 and 2009.

3.2.7. Cover analysis

3.2.7.1. VegMachine vegetation cover time series (Landsat)

The annual time-series vegetation cover of the 11 monitor paddocks and the whole property was analysed by VegMachine from BGI using Landsat images over the years 1987 to 2009.

The mean vegetation cover of the three grazing systems and the whole property (Figure 3.4) shows a consistently higher cover on the clay soil areas than on the lighter red loam soil areas before the cell-loam paddocks were established in 2001, and more similar cover in recent years. The cell-clay paddocks were installed in late 2006. The higher cover on the clay during the late 1980's can be attributed to regular winter wheat cropping and growing perennial forage silk sorghum. Both crops provided consistent cover in late winter on the clay soils, while the loam soil buffel pasture country carried the cattle herd and fluctuated in cover, especially declining during the drought years of the early 1990's.

There was a consistent increasing trend in vegetation cover between 1995 and 2001 during a prolonged period of good rainfall with five consecutive years of average or higher rainfall received. Cover on the clay soils also increased during this period but at a lower rate than on the lighter soils. In 1996, the light soils were heavily grazed during the cropping phase and cover declined, even with the above average rainfall. Cover in the cell-loam paddocks declined in 2005 from low rainfall and two of the monitor paddocks were recovering from blade ploughing, which was aimed at controlling sucker regrowth and improving water infiltration to regenerate the buffel pasture. In the extended drought of the early 2000's, the clay soil paddocks, which had been sown to buffel grass, were well grazed and cover did not respond to the low rainfall events as well as it did on the lighter soils of the loam soil cells and in the continuous Bankstown paddock.

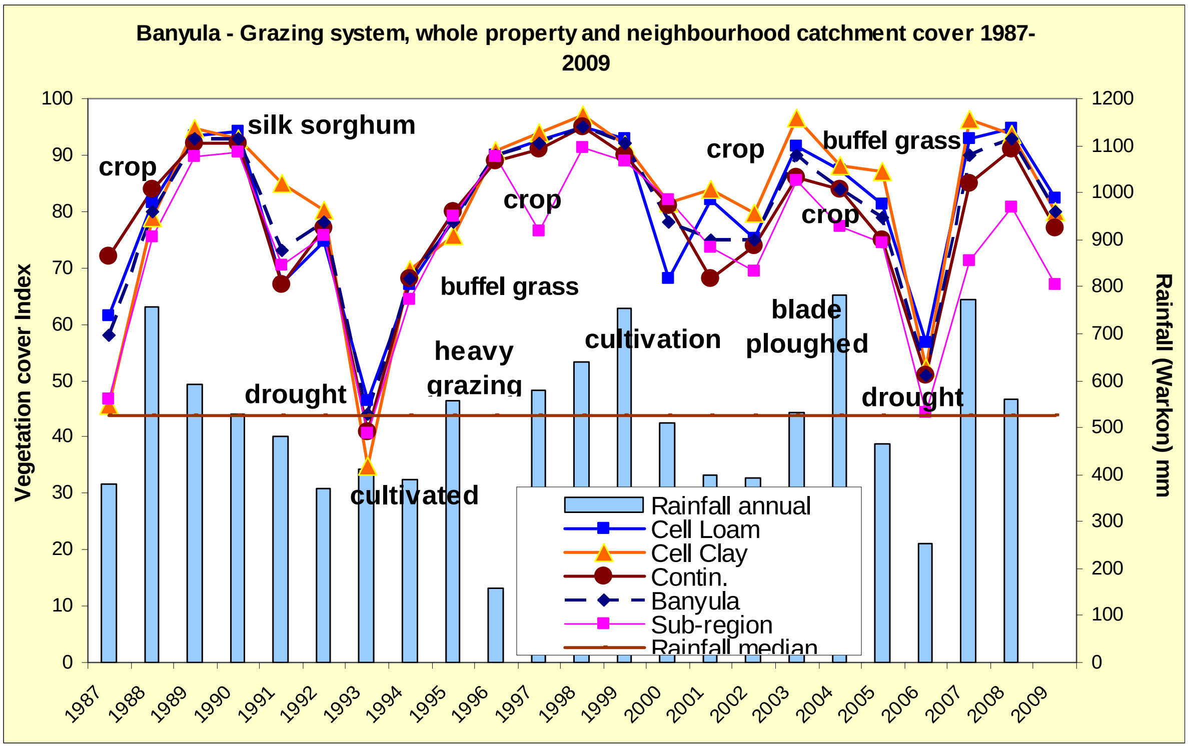


Figure 3.4. Vegetation cover index between 1987 and 2009 for the grazing systems, the whole property and the neighbourhood sub-region. Annual and long-term median rainfall (mm) are also shown.

The continuous paddock has maintained a more consistent cover with rainfall having the main influence. The loamy soil flats responded to lighter rainfall events during the drought years better than either the red duplex or clay soil areas.

The cover responses of the individual monitor paddocks (Figure 3.5) show the wide fluctuations that have occurred over the last 20 years. In some clay soil paddocks (A1, A10, M2, M3 and parts of M6) this is explained by the cropping program. Under winter cropping, the cover levels remained high (about 60-80%). However, with summer cropping, cover levels in spring could be lower, e.g. to 22% in M2 in 1987. Of the loam soil paddocks, the largest cover fluctuations have occurred in the poorest paddock R6. This paddock is on the side of a ridge with shallow and partly gravelly soils and has woody regrowth competing with the pasture. Cover in this paddock has ranged from about 11% to 78%. Grazing chart data also shows this paddock has supported a relatively lower carrying capacity than the other monitor paddocks.

There was a wide variation in cover between individual paddocks and cover response to the drought, grazing and cropping program over the 1987 to 2008 period (Figure 3.5). The ratio of the cover index to annual rainfall (index to 100 mm rainfall) shows there was a wider variation between the cell-loam and cell-clay areas and Bankstown paddock during the period 1987 and 1997, compared with a very close cover relationship between all paddocks in the last decade to 2008.

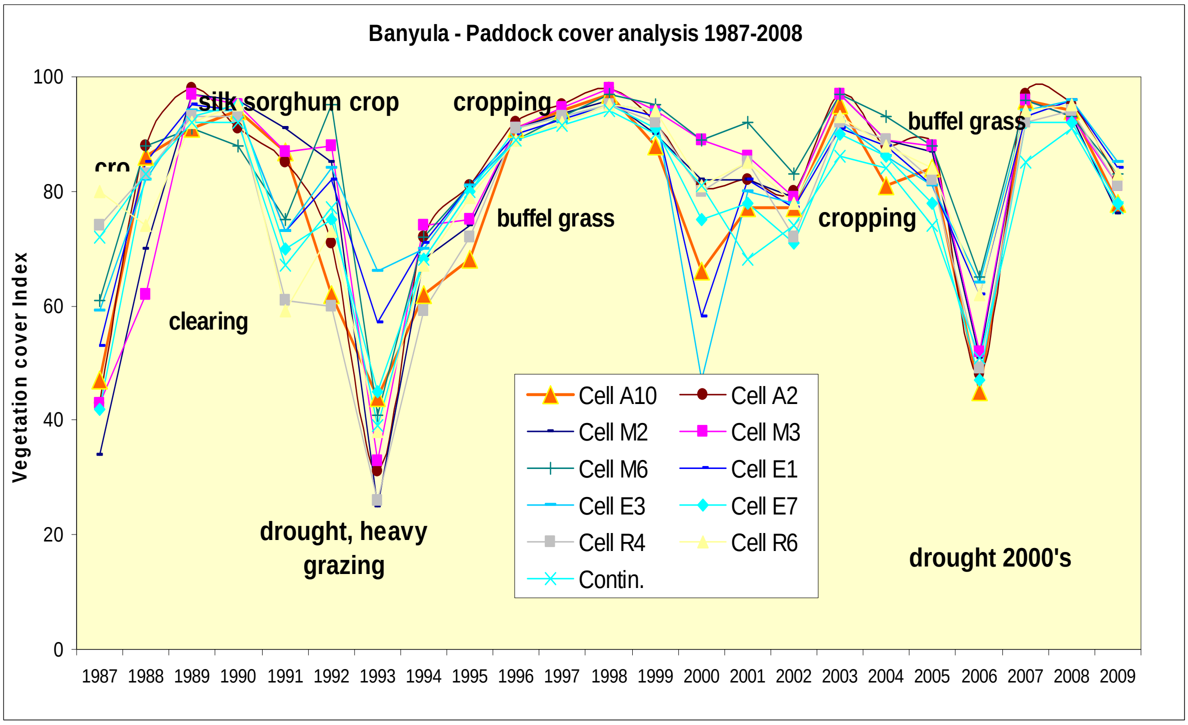


Figure 3.5. Vegetation cover index from 1987 to 2009 for the Cell-loam, Cell-clay and Bankstown paddocks at Banyula.

The continuous paddock had a higher cover index/100 mm than the cell-loam areas. This indicates a change in management across the whole property with pastures managed in a more similar manner since 1997 and there is no consistent difference between the grazing systems, except in 2006 when the clay soils were heavily grazed prior to installing the fences for the new cell-clay paddocks. This latter period of similar cover between grazing systems has occurred after the property owner commenced grazing land management training and installing intensive grazing systems which require constant pasture monitoring for most effective pasture and animal production.

3.2.7.2. Botanal pasture cover analysis

The measured pasture cover at Botanal recordings in both grazing systems was marginally lower (range 42-62%) than the Landsat image suggests (index range 40-90) in 2006 and 2007 (Table 3.14). The drought produced lower pasture yields (1000-1800 kg/ha) than GRASP long-term pasture growth modelling predicted. The VegMachine cover analysis tends to be significantly higher than field measurements, especially in the better rainfall years, when the cover index is near or above 90 for many years. The dramatic increase in cover between 2006 and 2007 indicated by the VegMachine analysis, using the 2009 algorithms (QDERM), was not measured in the field. The result of earlier VegMachine algorithms, from 2007-08, better represented the field observations, with an index of 70-80 in good rainfall years, declining to index of 40 in poor seasons.

Table 3.14. Paddock and grazing system pasture yield (kg/ha), total pasture cover (%), litter cover (%) and woody cover (%) in 2006 and 2007 at Banyula.

Paddock / System	**Yield (kg/ha)**		**Total Cover (%)**		**Litter Cover (%)**		**Woody Cover (%)**	
	2006	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**
Eagle Farm 1 [1]	1690	2170	51	58	15	15	0.1	0.0
Mascot 2 [12]		1940		44		6		0.0
Eagle Farm 3 [3]	1710	1560	54	56	16	9	0.2	0.3
Richmond 4 [4]	1980	1790	57	57	16	13	0.7	3.0
Richmond 6 [6]	1790	1800	62	58	15	20	2.9	3.3
Eagle Farm 7 [7]	1570	1810	49	49	16	15	4.0	4.2
Bankstown [8]	1030	1200	52	42	23	12	0.6	0.2
Bankstown forest	670	330	51	50	29	24	8.6	10.4
Amberley 10 [10]		1370		45		11		0.0
Amberley 1 [11]		1380		43		13		0.0
Mascot 3 [13]		1790		46		7		0.0
Mascot 6 [16]		1070		55		15		0.0
Cell-loam	1750	1820	55	56	16	14	1.6	2.2
Cell-clay		1510		47		11		0.0
Continuous	1030	1200	52	42	23	12	3.2	3.6
Site	1430	1620						

3.2.7.3. Spatial ground cover reports

The ground cover index image produced from the average of a series of images over 2003-2007 for Banyula (Figure 3.6) shows the highly variable cover in Bankstown paddock, ranging from very high cover 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 higher 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 showed the wide annual variation in all parameters and the longer-term cycles reflecting droughts and other periods of above average rainfall.

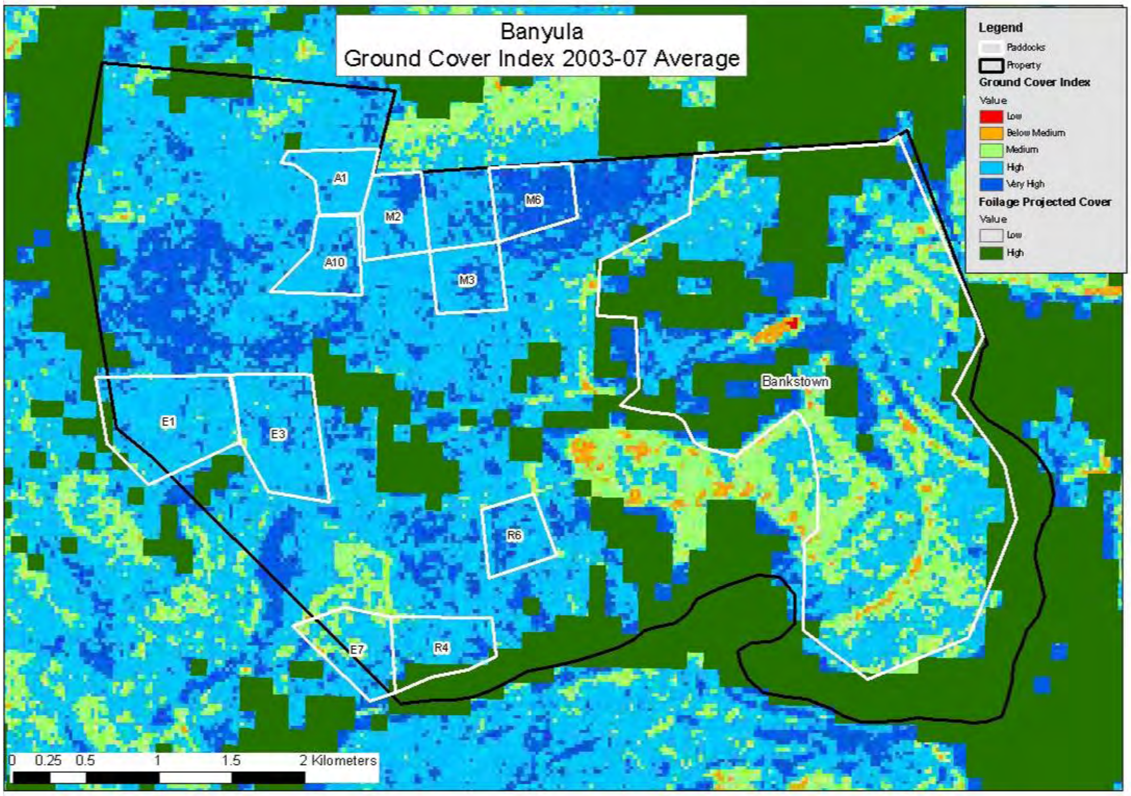


Figure 3.6. Average (2003-2007) ground cover index (vegetation cover) image for the Cell-loam and Cell-clay, Bankstown Continuous paddock, the whole Banyula property and surrounding properties.

3.3. Cattle Grazing

3.3.1. Carrying capacity – long-term (LTCC)

The estimated long-term carrying capacities (AE/100 ha and SDH/yr) of the three grazing systems are:

Cell-loam	24 AE/100 ha (88 SDH/yr)
Cell-clay	45 AE/100 ha (164 SDH/yr)
Continuous	20 AE/100 ha (72 SDH/yr)

3.3.2. Rest periods

The cell-loam paddocks at Banyula received an average of six grazing events per year, with an average of 16 days total grazing, with between 2-3 days graze each event. The average rest period between grazing was 48 days and total rest averaged 350 days per year (Table 3.15). The continuous paddock received an average of 43 days rest per year at varying times throughout the year.

Table 3.15. Average grazing events, number of days grazing and rest and average AE/ha in the Cell-loam, Cell-clay and Continuous systems at Banyula.

Grazing System	Year	No. Grazing Events	Av. No. Grazing Days	AE/ha	Av. No. days per graze	Av. Rest periods	Total Rest periods
Cell-Loam	05-06	6.2	18.4	0.28	2.9	51	347
	06-07	5.2	17.8	0.29	3.3	57	347
	07-08	7.6	17.4	0.40	2.3	40	348
	08-09	6.8	11.2	0.26	1.6	49	354
Cell-Clay	06-07	2.8	6.4	0.18	3.0	46	359
	07-08	6.2	19.5	0.39	3.1	49	346
	08-09	7.0	18.4	0.40	2.7	44	347
Continuous	05-06		277	0.29			88
	06-07		332	0.28			33
	07-08		365	0.26			0
	08-09		315	0.31			50

3.3.3. Grazing days

The cell-loam system paddocks received an average of 14 days annual grazing in the last two years compared with 19 days grazing in the cell-clay paddocks. The cell-loam averaged 16 days grazing per paddock over the four years. The annual range across all paddocks was 4 to 38 days. The cell systems received an average of six grazing events per year (range 2 to 9 events).

The continuous paddock received an average of 340 days grazing in the final two years, and an average of 322 days grazing per year over the four years.

3.3.4. Grazing pressure

The animal numbers taken from property records for each system have been converted to Animal Units (AE) using the standards tables presented in Appendix 9.10. An AE is equivalent to a dry cow weighing approximately 450 kg. There was similar grazing in the cell-loam and the continuous system, except in 2007-08 when the cells were grazed more heavily. There was higher grazing in the cell-clay, especially in the high rainfall year of 2008-09, which received 183 SDH (Table 3.16). The cattle in the cell-clay were supplemented on occasions with cottonseed in feed bins which encouraged higher stock densities relative to the other two systems. The average of all paddocks monitored during the project produced the same grazing per 100 mm rain for the three systems, near 21 SDH/100mm rainfall over the previous 12 months. This includes the part year of 2006-07 when the cell-clay was constructed.

The average annual grazing over the four monitoring years was higher than the long-term carrying capacity calculated for the various land types in the cell-loam (31% higher) and the continuous systems (44% higher) (Table 3.16). In the two full years of grazing the cell-clay system had a grazing pressure (average 162 SDH) equal to the LTCC, while the cell-loam was substantially higher (149 SDH) over this period.

Table 3.16. Grazing pressure of three grazing systems at Banyula in SDH/100mm of rain over previous 12 months and in SDH (AE days/ha/annum).

Year	Grazing pressure		
	Cell-loam SDH/100mm rain (SDH)	**Cell-clay**	**Continuous**
2004-05	(71)		(103)
2005-06	21 (101)		21 (104)
2006-07	30 (106)	17 (64)*	30 (101)
2007-08	24 (163)	23 (141)	16 (95)
2008-09	15 (134)	22 (183)	19 (115)
Mean	**22.5 (115)**	**20.9 (129)**	**21.4 (104)**
LTCC	(88)	(164)	(72)

* Part year only for cell-clay paddocks (2006-07).

There were no significant differences in grazing pressure between the cell-loam and continuous systems over the four-year monitoring period, which included both drought and good rainfall years. Back-log transformed means were 104-107 SDH, 21 SDH/100mm rainfall and a stocking rate of 3-4 ha/AE for the two systems averaged over four years.

There were significant differences between years in the three grazing pressure measures with the highest in the better than average rainfall year 2007-08 (130 SDH and 2.8 ha/AE), while the drought year 2006-07 had the highest SDH/100mm rain (29).

There were significant ($P<0.09$) grazing system by year interactions for the three grazing pressure measures between these two systems. 2007-08 had the highest SDH (141) in the cell-loam, 2006-07 had the highest SDH/100mm rainfall in the continuous (30), and 2007-08 had the highest stocking rate (2.6 ha/AE) in the cell-loam.

Comparing between the three systems, the average grazing pressure of the cell-clay was marginally higher than the cell-loam and continuous systems over the two full years of 2007-08 and 2008-09 (Table 3.17). The cell-loam and the continuous systems carried about 50% more grazing pressure than the long-term carrying capacity during these two good rainfall years. The cell-clay grazing equalled the LTCC. This pasture may have recovered more slowly after the drought on the heavier soils compared with the pastures on the lighter soil eucalypt country.

Table 3.17. Annual mean grazing pressure (2007-2009, 2 years only) and long-term carrying capacity (CC in SDH) for Cell-loam and Cell-clay and Continuous grazing systems.

	Grazing pressure					
Grazing System	**Actual SDH**	**LTCC SDH**	**Variation rel. to LTCC %**	**SDH /100mm**	**Actual ha/AE**	**LTCC ha/AE**
Cell-loam	149	88	69.3	20	3.2	4.1
Cell-clay	162	164	-1.2	24	2.5	2.2
Continuous	105	72	45.8	18	3.5	5.1

3.3.5. Grazing system intensity index

The grazing system intensity index values (GSI range 1-100; calculated from capital costs, operating costs and management inputs; details are reported in Appendix 9.13) for the two cell and continuous systems were:

Cell-loam	77
Cell-clay	78
Continuous	22

3.3.6. Diet quality (NIRS)

3.3.6.1. Analysis of all samples over four years

Based on NIRS analyses, predictions have been made for various diet quality parameters within each grazing system. The mean values of all samples from the three grazing systems (Table 3.18) show no significant difference in crude protein or digestibility between the cell-loam and the continuous paddock. The superiority of the brigalow cell-clay over the two eucalypt country systems can be seen in all parameters measured, however, with the wide variation between summer and winter samples these differences were not significant for the number of samples taken. These samples were not all collected at the same time of the year, so there will be some confounding with season.

Table 3.18. Mean faecal NIRS results (all samples) for grazing systems at Banyula to June 2009.

Grazing System	No. samples	CP (%)	Faecal N (%)	Digesti-bility (%)	Non-grass (%)	LWG (kg/day)	DMD/CP ratio
Cell-loam	16	8.20	1.50	57	15	0.80	7.5
Cell-clay *	21	9.90	1.64	60	20	0.90	6.6
Continuous	16	8.60	1.57	57	21	0.73	7.5
Significance		ns	ns	ns	ns	ns	ns
sed (av.)		1.26	0.12	2	7	0.15	0.9

* The cell-clay paddocks were initially managed as a rotation system.

There were significant differences in all parameters, except for non-grass (18%-19%), between the summer and winter samples. For example; CP averaged 10.7% in the growing months compared with 6.7% in the non-growing months; Faecal nitrogen was 1.7% compared with 1.4%; Digestibility was also 6% higher when pastures were green (60% cv. 54%); and predicted LWG was 1.1 kg/day in growing season compared with 0.5 kg/day in non-growing season. Between years there was a higher non-grass proportion in the diet in 2007 (average 33%) compared with 8% in 2009. Samples from the cell-clay paddocks were collected during 2006 prior to establishing the cell fences when the area was managed as a 3-paddock rotational grazing system.

The digestibility to crude protein ratio (DMD/CP) is a management indicator of pasture quality and when the animals are most likely to respond to supplement nitrogen. A ratio between 8 and 10 indicates marginal protein, while a number above 10 indicates a dietary deficiency and the need to supplement with nitrogen for liveweight maintenance. The seasonal results are required to identify these protein deficient periods (see Figure 3.7, 3.8 and 3.9 below).

3.3.6.2. Analysis of samples collected at the same time

Comparisons of the 3 grazing systems when samples were taken from all three on the same day (Table 3.19), show the higher crude protein and live weight gain prediction in the continuous system over the cell-loam, attributed to a greater forage selection ability which can be seen in the higher non-grass proportion (26% compared with 21% of the diet). The diet quality and cattle production superiority of the more fertile cell-clay is evident in all parameters. There was a higher proportion of non-grass, which included brigalow suckers and forbs, in the cell-clay than in the cell-loam.

Table 3.19. NIRS diet quality results when all sampling times were the same for the three systems.

Grazing System	No. samples	CP (%)	Faecal N (%)	Digesti-bility (%)	Non-grass (%)	LWG (kg/day)	DMD/CP ratio
Cell-loam	6	7.6	1.43	56	21	0.71	7.9
Cell-clay	6	10.1	1.67	60	26	0.90	6.6
Continuous	6	9.0	1.53	57	26	0.83	7.0
Significance		ns	ns	ns	ns	ns	ns
sed (av.)		1.77	0.14	4	9	0.25	1.4

Comparisons between any two grazing systems when samples were collected on the same day (Table 3.20) show small differences in crude protein between the cell-loam and continuous system. There was on average 1% superiority in crude protein in the cell-clay over the continuous paddock and 2% superiority over the cell-loam. This higher quality diet on the cell-clay system supported up to a predicted 0.2 kg/day additional growth rate in the cattle over the cell-loam.

Table 3.20. NIRS diet quality results when paired samples between any two grazing systems were collected.

Grazing System	No. samples	CP (%)	Faecal N (%)	Digesti-bility (%)	Non-grass (%)	LWG (kg/day)	DMD/CP ratio
Cell-loam	9	8.4	1.53	56	20	0.81	7.7
Continuous	9	8.8	1.60	56	25	0.76	7.2
Average	9	8.6	1.57	56	23	0.78	7.5
Cell-clay	11	10.2	1.66	60	25	0.82	6.6
Continuous	11	9.3	1.58	57	25	0.76	6.9
Average	11	9.8	1.62	59	25	0.79	6.8
Cell-loam	11	8.1	1.56	57	19	0.79	7.7
Cell-clay	11	10.4	1.74	61	29	1.00	6.3
Average	11	9.2	1.65	59	24	0.90	7.0

Over all analyses, the diet quality was higher in the cell-clay than the cell-loam system with intermediate values for the continuous system.

3.3.6.3. NIRS related to pasture growth index

The NIRS values were examined by dividing them into three classes which had different growing conditions on the basis of the pasture Growth Index (GI) derived from GRASP (where 0.0 = conditions are unsuitable for growth and 1.00 = conditions are not limiting growth). Average values of the GI for the 30 days ending on the sample date were calculated. Based on these values three groups were formed – mean GI 0 to 0.2 (Poor growth conditions), 0.2-0.5 (Average) and >0.5 (Good conditions). Diet quality means for the three classes (Table 3.21) show no differences between the two grazing systems when pasture growth conditions were poor (GI < 0.2), but a superiority in the continuous system over the cell-loam in protein (11% compared with 8.3%) and digestibility (59% compared with 57%) during periods of average growth conditions. Only one sample was collected from the cell-loam during a good growth period and this sample had a high diet quality (CP of 12% and DMD 64%). During pasture growing periods the cell-clay produced superior diet quality compared to the cell-loam. There was no difference when pastures were dormant (GI <0.2).

Table 3.21. Mean NIRS diet quality results in relation to three pasture growth indices for three grazing systems at Banyula to June 2009.

Growth Index	Grazing System	No. samples	Crude protein (%)	Faecal N (%)	Digestibility (%)	Non-grass (%)	LWG (kg/day)	DMD/CP ratio
<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	7.2
	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	1	12.1	2.00	64	5	1.20	5.3
	Continuous	0						

3.3.6.4. Monthly CP, DMD and non-grass

Individual sample results for the NIRS parameters crude protein, digestibility and non-grass (Figure 3.7, Figure 3.8 and Figure 3.9) show the wide seasonal variation in the 3 grazing systems with high quality buffel pastures in summer, declining rapidly to below maintenance crude protein in winter-spring after frosts and before summer rains, in all systems. The high diet quality in summer months on the clay soil is apparent. The poor growth of cattle in late 2008 can be explained by the unusually low diet quality in the winter-spring seasons in all systems.

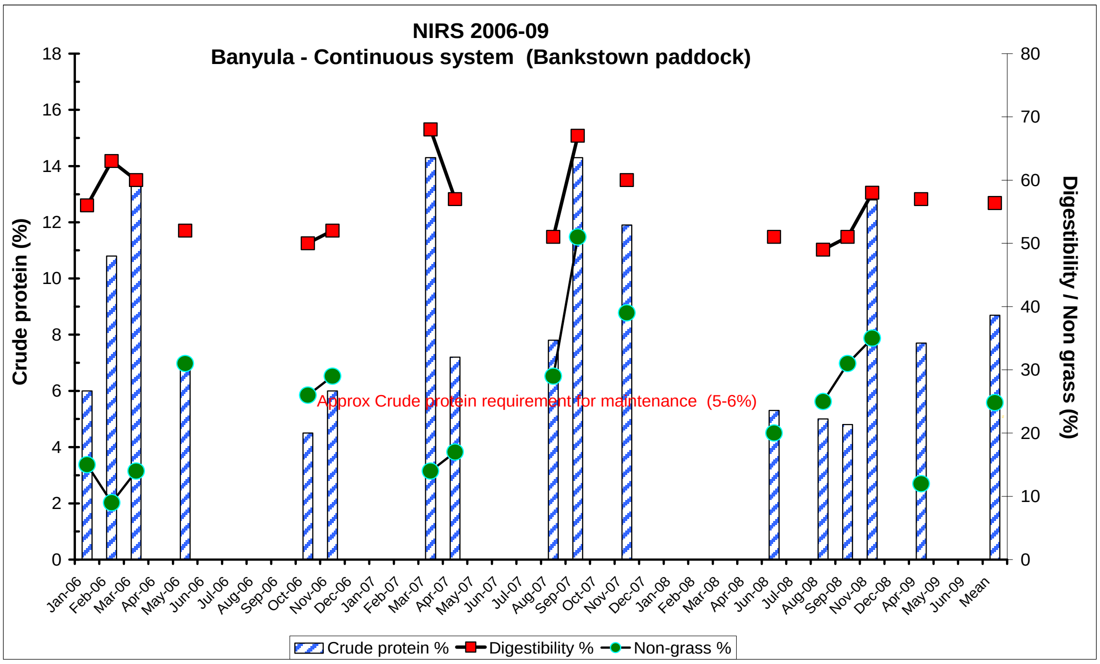


Figure 3.7. NIRS sample results for the Continuous grazing system at Banyula for crude protein (%), digestibility (%) and non-grass (%) with approximate maintenance crude protein indicated.

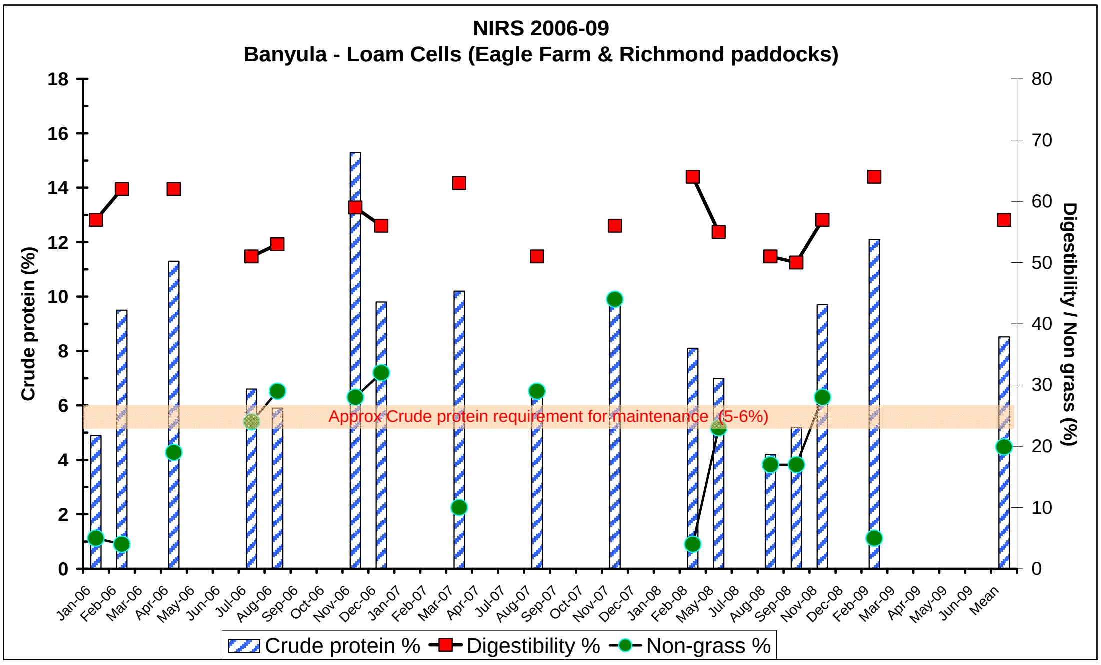


Figure 3.8. NIRS sample results for the Cell-loam grazing system at Banyula for crude protein (%), digestibility (%) and non-grass (%) with approximate maintenance crude protein indicated.

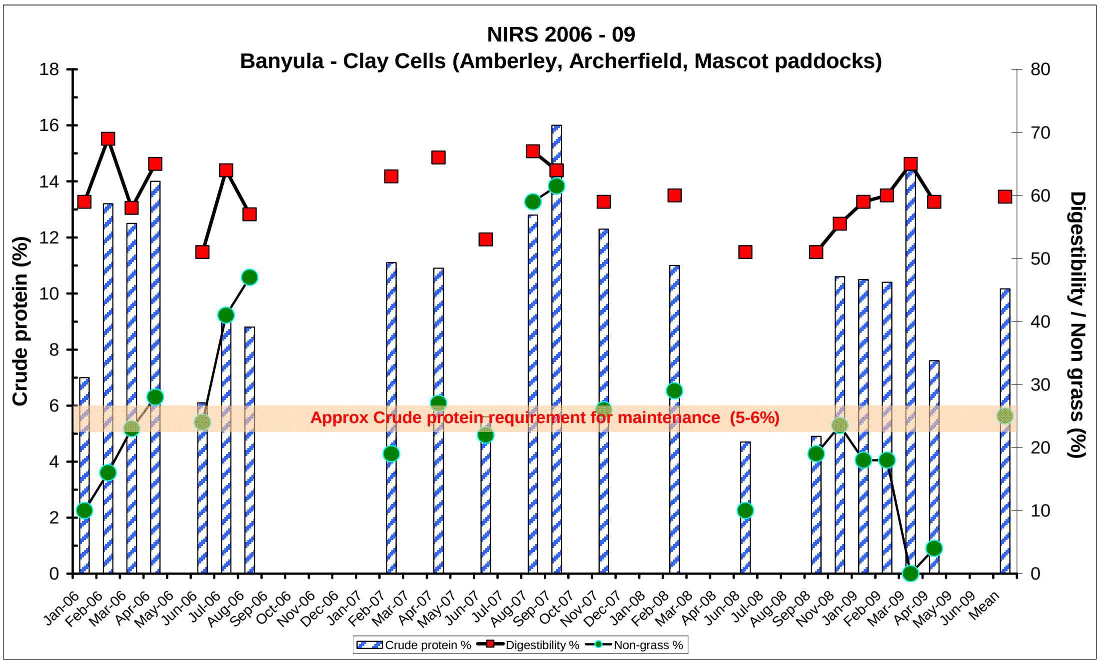


Figure 3.9. NIRS sample results for the Cell-clay grazing system at Banyula for crude protein (%), digestibility (%) and non-grass (%) with approximate maintenance crude protein indicated.

3.4. Grazing System Costs

The grazing system comprises a cell-loam system of 24 cells on six cell centres and a cell-clay system centred on 21 paddocks on six cell centres and some surface waters. Fencing is comprised of 24 km of single wire electric fencing and 18 km of three wire electric fencing, including laneways, etc. Water to cells and paddocks is supplied through 10.5 km of 63 mm polythene pipe and reticulated via 12 concrete troughs using a combination of existing pumps and one pump with a medicator installed as part of the system. All site development, fencing and pipe-laying were undertaken by contractors.

3.4.1. Capital costs

The estimated replacement capital cost of the cell grazing system is approximately $221,000 (Table 3.22) comprising of fencing, watering, labour and planning costs.

Table 3.22. Replacement capital costs of cell grazing systems.

Item	Cost ($)
Fencing	87,601
Water	46,533
Troughs	10,200
Tanks	10,000
Pumps, mills	0
Installation	65,049
Consultancies	2,000
Total	**221,386**

3.4.2. Operating costs

For reasons of privacy and confidentiality, the annual running costs that are associated with the case study grazing systems are not presented.

An indicative guide to the operating cost of a given system is the estimated annual capital reclamation cost (sinking fund depreciation charge), which is the equivalent sum that would need to be set aside each year to maintain the capital assets invested in the systems infrastructure. The reclamation cost has been estimated using standard farm accounting depreciation factors for the main assets listed in Table 3.22, including – bores (7.5%), dams (2.5%), fencing (5%), and plant (10%). This gives a projected capitalised cost for the case study enterprises of approximately $7,000 per annum (Table 3.23) comprising of fencing and water maintenance costs.

Table 3.23. Annual operating costs of cell grazing systems.

Item	Cost ($)
Fencing	4,380
Water	1,163
Troughs	255
Tanks	1,000
Pumps, mills	0
Total	**6,799**

4. Conclusions

4.1. Pasture and land condition

There were only small differences in pasture and land condition over time and between the cell-loam system and the similar soils in the continuous paddock at Banyula. The overall visual estimates of land condition (ABCD) placed the cell-loam paddocks in A/B condition and the continuous paddock in B condition. This ranking was supported by the PatchKey values.

Rainfall was low and growing conditions were poor during the first two growing seasons but rainfall was higher and growing conditions better in the final two years. This was reflected in the estimated yields which were highest in 2009 in both grazing systems. Estimated yields were higher in the cell-loam system than the continuous system in all years but this may reflect the higher utilisation rate in the continuous system.

There was little change in botanical composition in either system over the trial period. The cell-loam paddocks were very strongly buffel grass dominant (95%) throughout the period. The continuous system was also buffel grass dominant but less so than the Cells (c.70%) with more native perennial grasses (c.25%) reflecting the greater species diversity in this paddock. Woody regrowth levels were higher in the continuous paddock.

Total ground cover was highest in 2009 in both systems and was higher in the cell-loam paddocks than the continuous paddock in all years with the greatest difference between systems in 2007. Differences in litter cover were more variable with lowest values in both systems in 2007, higher values in the continuous paddock in 2006, and slightly higher values in the cell-loam paddocks in 2007 and 2009.

The differences in the LFA indices were small and inconsistent. Values for all three indices were highest in 2009 in both systems. The cell-loam system had slightly higher values for the Stability index and slightly lower values for the Infiltration index, while the differences in the Nutrient Cycling index were small and varied between years.

The VegMachine analyses showed wide variations in cover over the years but many of these changes reflected growing conditions and other management factors not related to grazing systems (cropping, blade ploughing, cultivation). Values for the Vegetation Cover index increased from low levels 2006 to 2007 to 2008 in both the systems. Values were similar in both systems in 2006, but higher in the cell-loam system than the continuous system in 2007 and 2008.

4.2. Carrying capacity and grazing

The two eucalypt grazing systems, cell-loam and continuous, supported a similar grazing performance throughout the monitoring period. Although there were no overall differences in total grazing (near 21 SDH/100mm rainfall), there were differences between years with 2007-08 receiving the highest grazing pressure, and the drought year 2006-07 had the highest grazing pressure per 100mm rainfall. The cell-clay had the highest grazing pressure over the two full years when the three systems were monitored, reflecting its better fertility soils. This result may have also been influenced by the opportunistic cotton seed supplementation this system received on occasions during this period.

The cell-loam (four-year average 115 SDH) and continuous (104 SDH) systems both supported higher grazing pressures for each of the four years than the LTCC estimated for the land types in this environment. The average was 69% and 46% higher than the LTCC for the two systems respectively over the final two high rainfall years of the project. The cell-clay supported the LTCC (162 SDH) over these two final years of monitoring.

The diet quality was similar in the two eucalypt systems and marginally higher in the cell-clay system.

4.3. Owner comments on grazing systems

4.3.1. New management

Figures indicated that there was money to be made out of backgrounding into the many local feedlots. This required a much closer watch on cattle growth rates if we were to turn off regular numbers by regular prescribed dates. The cell grazing with the smaller paddocks has allowed that closer monitoring and management.

4.3.2. Results

The results have been better pasture growth, less bare patches. We feel the plant growth has responded quickly with little rain after the current long dry periods. We have carried a reasonable number of cattle even through the past drought years. The worst country has shown the greater diversity of plant life. We feel the whole of a paddock gets used, and not cattle overgrazing the better parts of a paddock. The temperament of the cattle has improved and they become used to the feed-lotting much quicker and therefore have a higher growth rate on feed.

4.3.3. Future plans

We intend to continue with the cell grazing as it makes for easier management and better pasture growth. We intend to keep one continuous grazing paddock. The loam flat may be cut up for cultivation or irrigation in the future. We don’t have any intention of reducing the cell size. Our own feedlot will be expanded so the majority of our cattle grown in the cells will be finished in our on-property feedlot.

4.4. General conclusions

The first two years of monitoring at Banyula were a continuing drought, followed by two years of above average rainfall. The two cell systems and the continuous system received the same average grazing, in SDH/100mm rainfall, although the continuous system is calculated to have a marginally lower long-term carrying capacity than either of the two cell systems. In the two higher rainfall years the two Cell systems supported a higher grazing pressure than the continuous system. The cell-clay has the potential to be more productive than either of the other two systems, with higher fertility clay soils producing higher pasture yields, grazing capacity and diet quality.

Management and grazing of the three systems are integrated to provide a whole property grower enterprise for the usual one to three separate herds. The lighter cattle usually grow in the continuous system, then move to the cell-loam system and may finish up in the cell-clay system with additional paddock protein supplement. This makes a whole property system as opposed to three independent grazing systems. Grazing of pastures in all three systems follows the same principles of controlling total grazing pressure and incorporating rest.

There were no consistent outstanding ecological differences between the three systems that could be attributed to the actual grazing system at Banyula between 2005 and 2009.

Berrigurra

Abstract

Berrigurra, Blackwater, has three grazing systems; cells, rotation and continuous. Six cell paddocks, two rotation and one continuous paddock were monitored between 2006 and 2009. The cell and rotation systems are used for growing steers and heifer, while breeders may also be run in the continuous paddock. There was one serious drought year followed by three near average rainfall years during the four-year period. The pastures were sampled in late autumn in 2006, 2007 and 2009. Yields were higher in the cell and rotation systems (3900 kg/ha) than in the continuous paddock (3000 kg/ha). All pastures were 95% buffel grass dominant and in good condition with the exception of the western end of the continuous system paddock.

The rotation and continuous systems carried higher average grazing pressure (26 SDH/100mm rainfall) than the cells (20 SDH/100mm rainfall), which were grazed on occasions at less than the LTCC. The three systems are used as part of an annual integrated whole property breeder and grower enterprise and not as separate systems. There were no consistent ecological differences between the systems that could be attributed to the grazing management.

1. Site Introduction

1.1. Location

‘Berrigurra’ is located approximately 70 km east of Emerald (23.5ºS; 148.7ºE) in the Fitzroy River catchment (Figure 1.1).

Figure 1.1. Buffel grass pasture landscape scene at Berrigurra.

1.2. Climate/growing season

The average annual rainfall is 583 mm (Table 3.1) with 72% falling in summer (October-March). The growing season is predominantly in summer, but with winter rain in some years there can be a small amount of winter pasture growth with subsequent beneficial impacts on pasture quantity and quality.

Based on long-term climate data, the average green season for tropical species is estimated to be 29 weeks including 14.6 growth weeks. With the winter rain, temperate species could add an average of 3.2 weeks to the growth of tropical species.

1.3. Major soil/vegetation types

The original vegetation was mixed woodland of brigalow (*Acacia harpophylla*) and blackbutt (*Eucalyptus cambageana*) with some poplar box (*E. populnea*) (Table 1.1). All project monitor paddocks have been cleared and now have scattered light woody regrowth (brigalow, whitewood, lime bush, bean bush, emu-apple, ironwood, false sandalwood and currant bush) emerging. Pastures are dominated by sown buffel grass (*Cenchrus ciliaris*).

The terrain is flat to gently undulating with hard setting red texture contrast soils with sodic B horizons and cracking clay soils, some areas with gilgai.

Table 1.1. Areas (ha) of land types in the monitor paddocks of grazing systems at Berrigurra.

Land type	**Area (ha)**		
	Cells	**Rotation**	**Continuous**
Alluvial brigalow		20	6
Brigalow-blackbutt	168	191	223
Brigalow with melon holes		29	
Total	**168**	**240**	**229**

1.4. GRASP modelling of long-term pasture growth

The "Brigalow-blackbutt' land type was 91% of the sampled area so only this land type was modelled for pasture production.

1.4.1. GRASP parameters

The tree basal area, soil water and nitrogen parameters used in GRASP to calculate average pasture growth for the brigalow-blackbutt community at this site is shown in Table 1.2.

Table 1.2. Land type parameters for Berrigurra used in GRASP model to estimate pasture growth.

GRASP parameter	**Parameter units**
	Brigalow-blackbutt
Tree basal area (m^2/ha)	1
Available soil water (mm)	183
Maximum N uptake (kg/ha)	25
Regrowth (kg/ha/%BA)	6.5
Transpiration use efficiency (kg/ha/mm)	25
Minimum N concentration (%)	0.5

1.4.2. GRASP results

The GRASP model was run using climate data from SILO for the period 1889 to 2009 and annual pasture growth for the period July 1 to June 30 was estimated. The median pasture production value for Berrigurra was 4460 kg/ha (Figure 1.2).

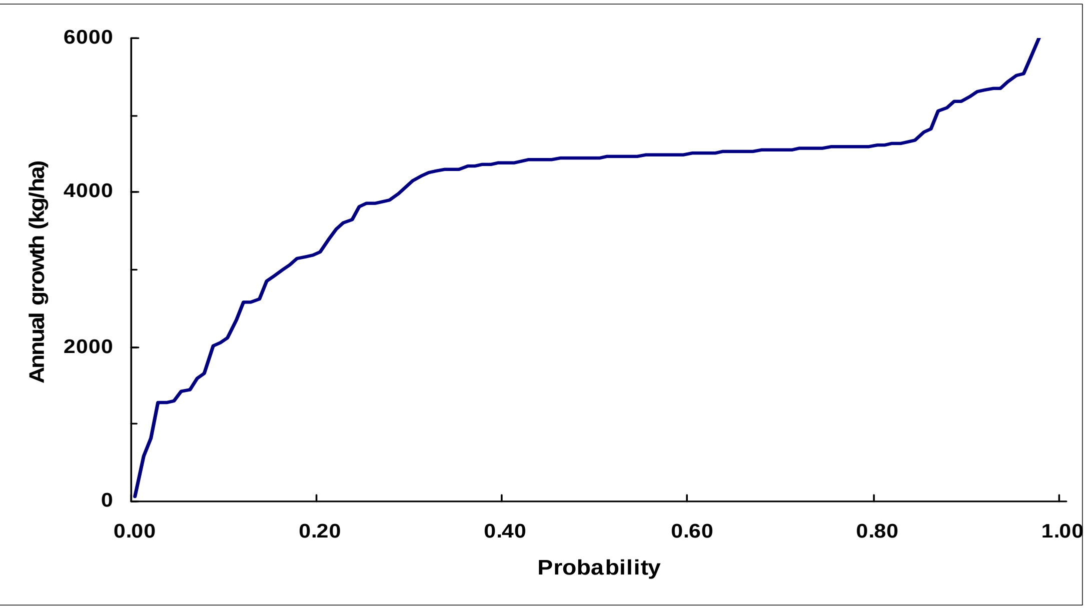


Figure 1.2. Long-term distribution of estimates of annual pasture growth at Berrigurra.

1.5. Production system/markets

This property is an annexe of a multi-campus pastoral training facility and is not necessarily run along fully commercial lines. While the aim is to maintain the assets at minimum costs, it is primarily a training facility as required. Weaners of both sexes enter the cell system at (average) 12 months of age. When steers are approximately 16 months old (February), the leaders are sent to a feedlot and the remainder are put into rotation paddocks. Steers enter the college feedlot at 400 kg liveweight and are grown out for 100 days on grain for the Jap-Ox market. Steers and heifers are also put on grain for 60 days for the domestic trade. Heifers are mated from November and transferred to a breeding herd in February for calving out in set stocked paddocks. Cows are culled at about eight years old and go to the meatworks.

1.6. Producer goals

The management objectives, while commercial in intent, by necessity can be constrained by the demands of the curriculum of the college system (e.g. receiving or supplying stock for course activities, etc). The former manager who oversaw the design and implementation of the cell system expected it would increase productivity over the previous set stocking system and still be used in student training, meeting the demands of the college system and its ability to provide or remove stock from the system if required.

Although the objectives for this system may be compromised at times by the need to facilitate student instruction, the potential to increase animal productivity was a component of the original design. The design itself was influenced by the participation of two staff members at a formal cell grazing course prior to its establishment.

2. Grazing Systems

2.1. Description

Three grazing systems were studied – cell, rotational and continuous (Table 2.1). The cell system has 24 paddocks (average size approximately 25 ha) carrying approximately 200 AE's from May (as weaners) to February; six paddocks from one cell centre (Emu Apple) were monitored (

Figure 2.1). The rotational system has 15 paddocks of about 120 ha each (total area = 1800 ha) where usually 250 steers are grown out for the feedlot; two paddocks were monitored. The continuous paddock (229 ha) is normally grazed by 60–80 breeders, with numbers decreasing during dry conditions.

Table 2.1. Paddock names, numbers and areas monitored at Berrigurra.

Vegetation System	Grazing	Paddock name [Botanal No.]	Area (ha)
Brigalow	Cell	EA10 [10]	27
		EA11 [11]	30
		EA12 [12]	31
		EA17 [17]	27
		EA18 [18]	27
		EA19 [19]	26
		Total cell	**168**
Brigalow	Rotation	Middle [1]	108
		16 [16]	132
		Total rotation	**240**
Brigalow	Continuous	**14 [14]**	**229**

The paddock layout on a Spot-5 image (
Figure 2.1) shows the similar land types and timber treatment in all monitor paddocks. The areas of lighter soils and lower pasture cover in the three systems are apparent in the lighter coloured areas. The western end of the continuous paddock (14) and the northern part of a rotation paddock (1 or Middle) have the largest areas of poorer land condition.

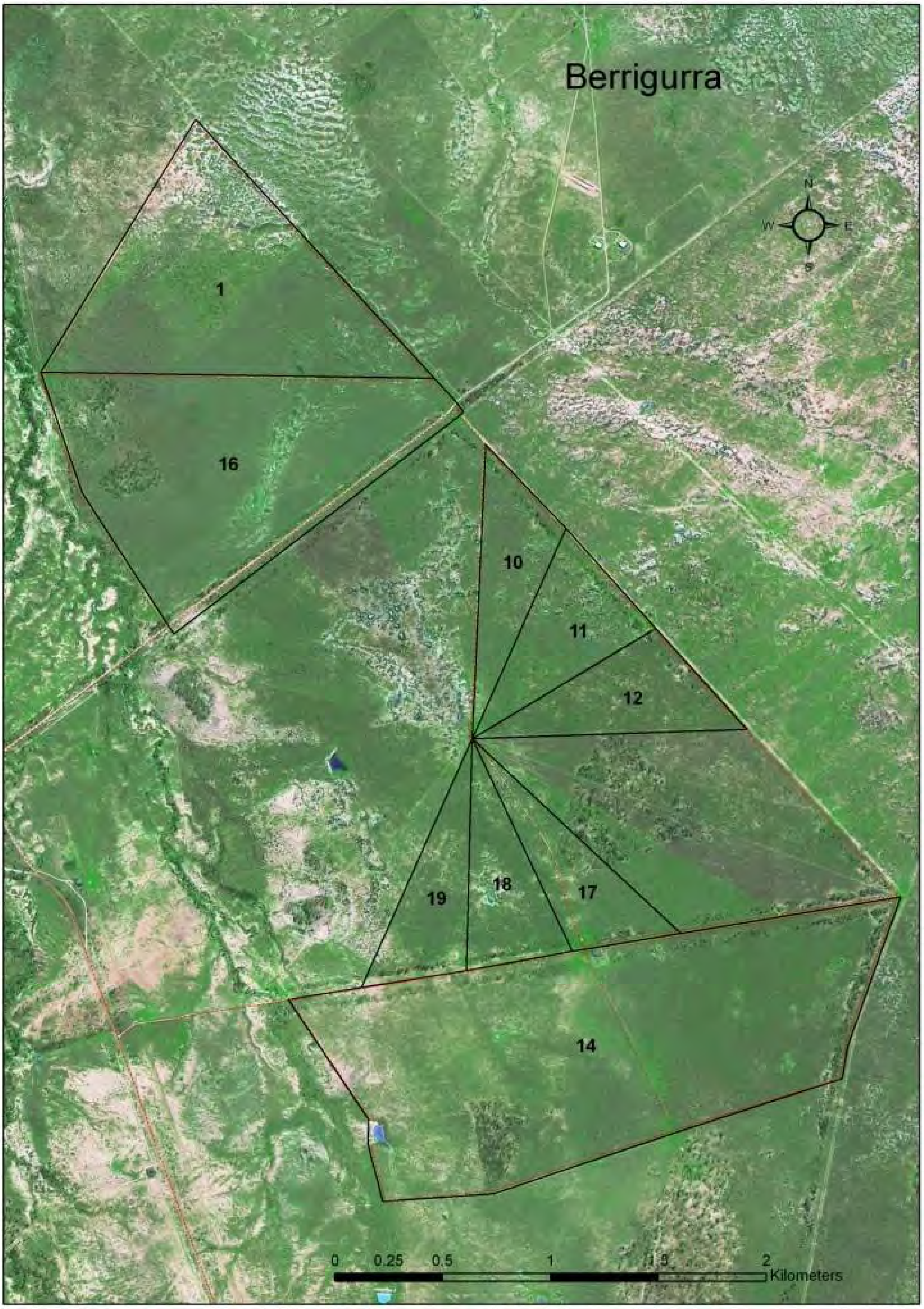


Figure 2.1. Layout of the nine monitor paddocks (6 cell, 2 rotation (nos. 1, 16) and 1 continuous (no. 14) paddock) at Berrigurra.

2.2. Management during 2005-2009

Cattle numbers have been maintained fairly consistently throughout 2005 to 2009 for the sample paddocks at Berrigurra. Despite low rainfall years, conservative stocking has enabled the pastures to maintain condition, respond well to rainfall and maintain the cattle numbers. This was demonstrated in the 2005-06 year where rainfall was in the decile one range and stocking rates were maintained at 6.9 ha/AE. Stocking rates have varied in all systems, however the lightest stocking rates were in 2008-09 year.

The cell system normally has weaners introduced in about May. The steers go into the rotational paddocks about August. The cull heifers leave the cell, with the breeding heifers mated in the cell from December to February. The heifers are pregnancy tested and go back into the breeding herd for calving. They go into the range country from about March to September and then join the breeding herd back in the Continuous paddock. The steers go into the rotational paddocks about August for growing out for the college feedlot, or they are grown out for the Jap-Ox export market. The Continuous paddock is set stocked with 60-80 breeders and is normally only destocked in a drought. The sample paddocks did not vary greatly from this management during the monitor period, except that first calf heifers, cows and some bulls were run in the rotation paddocks and some dry cows were run in the cells on one occasion.

During dry months, cattle would break or jump fences near the cell centre in order to drink. The manager believes this requires considerably more labour for returning cattle to desired paddocks and maintenance of fences. The problem is exacerbated by the design with too many paddocks running into one water point, meaning there is a long narrow entrance to the cell centre water from every paddock.

3. Results

3.1. Growing Seasons

3.1.1. Rainfall

The project monitoring period commenced with a serious drought; annual rainfall in 2005-06 was in decile 1 range, and this was followed by three average rainfall years (Table 3.1). Rainfall distribution was erratic with some years receiving good spring rain and others receiving well above average winter rainfall (2006-07).

Table 3.1. Monthly rainfall (mm) at Berrigurra from July 2004 to June 2009, and long-term average monthly rainfall (mm) at Blackwater recording station over 113 years.

Year	**Monthly rainfall (mm)**													
	J	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**Total**	**Decile**
2004-05	0	0	4	18	55	94	91	18	31	0	83	99	493	4
2005-06	4	8	0	55	20	71	90	0	19	18	4	44	332	1
2006-07	26	0	24	25	21	112	63	75	37	0	4	149	534	5
2007-08	0	17	48	73	46	75	102	158	37	2	0	18	576	6
2008-09	76	0	30	17	154	98	29	160	0	67	5	0	636	7
Long-term Mean	**25**	**18**	**24**	**44**	**59**	**80**	**96**	**87**	**55**	**32**	**33**	**28**	**583**	

3.1.2. Growing conditions

2003-2004: Both total and summer rainfall were below average. However spring rainfall was average which prompted some good pasture growth prior to the summer.

2004-2005: Berrigurra received average rainfall this year. Average spring rainfall was followed by well below average rainfall in summer which resulted in low pasture growth during the main pasture growth period. However, Berrigurra received almost double the long term average rainfall during autumn increasing pasture yields.

2005-2006: There was well below average rainfall during this drought year. However, average spring and autumn rainfall would have prompted some pasture growth although the low summer rainfall produced poor pasture growing conditions for two consecutive years.

2006-2007: Berrigurra received average rainfall for the year including the spring-summer growing season. The autumn was dry, but was followed by well above average winter rain, in June.

2007-2008: This season received average rainfall with the distribution higher in spring and in February. Autumn and winter were drier than average causing pastures to mature early.

2008-2009: This season received slightly above average rainfall producing good pasture growth. There were several wet months followed by dry periods. July, November, February and April received most (72%) of the annual total.

3.1.3. GRASP modelling of growing seasons 2005-2009

Assuming the “Alluvial brigalow” and “Brigalow with melon holes” have similar pasture growth to the “Brigalow-blackbutt” land type, the estimated annual pasture growth (kg/ha) in the grazing systems at Berrigurra from 2005-06 to 2008-09 is given in Table 3.2. Since only one value was used for pasture growth rate and the land condition was assessed to be the same for the cell and rotational systems, these two systems have the same estimated annual pasture growth (3900 kg/ha). The lower estimated growth on the continuous system (3000 kg/ha) reflects the poorer land condition in western parts of that paddock.

Table 3.2. Estimated annual pasture growth (kg/ha) for grazing systems at Berrigurra from 2005-06 to 2008-09.

Year	**Pasture growth (kg/ha)**		
	Cell	**Rotation**	**Continuous**
2005-06	3500	3500	2700
2006-07	2000	2000	1600
2007-08	5500	5500	4300
2008-09	4600	4600	3600
Average	**3900**	**3900**	**3000**

The fluctuating pasture growth periods during the four-year monitoring period are clearly shown by the short peaks and troughs over the summer months in the weekly pasture growth index (Figure 3.1). Rainfall during the usually dry winter periods indicates potentially short growth periods, but buffel grass production was insignificant on these events, however the additional soil moisture provides impetus for better spring growth.

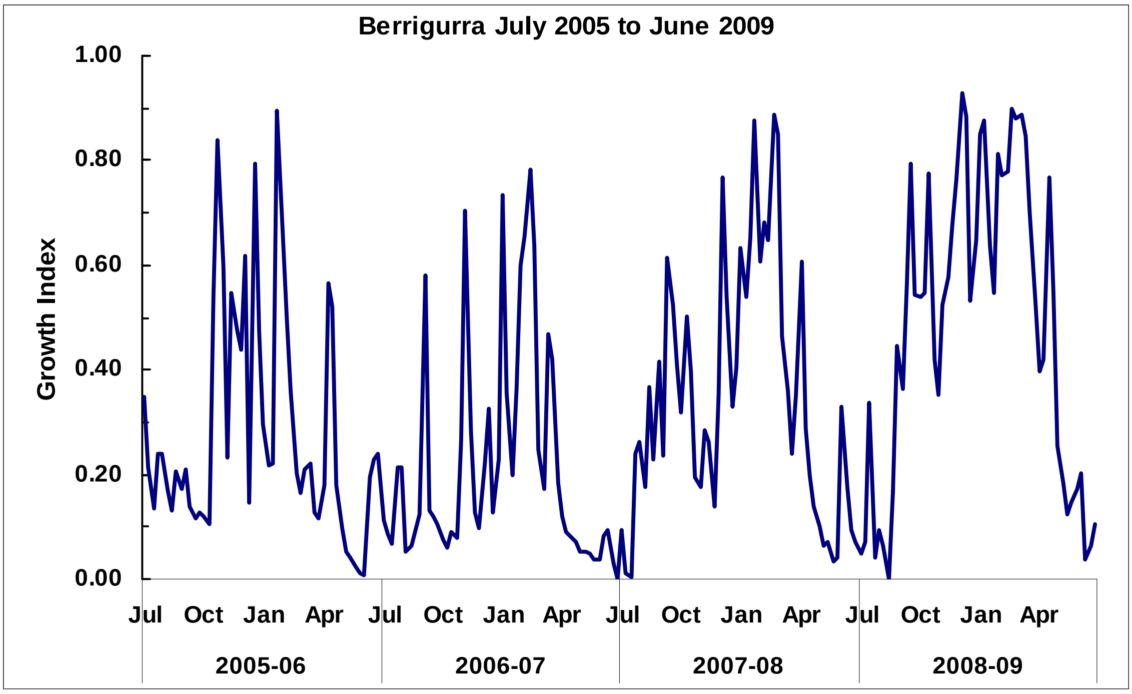


Figure 3.1. Weekly pasture growth index (tropical species) values at Berrigurra during the experimental period (2005-2009).

3.2. Pastures and Land Condition

3.2.1. Pasture yield, botanical composition and diversity

3.2.1.1. Pasture mean values

The pastures were sampled in late autumn each year. Yields were lowest in the continuous paddock in 2006 and 2007 but similar in all systems in 2009. All pastures were strongly buffel grass dominant with few other species (Table 3.3).

Table 3.3. Pasture dry matter yield and botanical composition at the end of summer at Berrigurra.

Year	System	Yield	Botanical composition (%)						
		(kg/ha)	Nat per grass	Exotic grass	Native leg	Exotic leg	Ann grass	Forb	Sedge
2006	Cell	3470	0.0	98.9	0.0	0.0	0.0	1.0	0.0
	Rotation	3190	3.0	94.4	0.0	0.5	0.0	2.1	0.1
	Continuous	1700	0.4	97.9	0.0	0.0	0.2	1.5	0.0
2007	Cell	3050	1.6	97.7	0.0	0.0	0.0	0.7	0.0
	Rotation	1930	6.6	93.3	0.0	0.0	0.0	0.1	0.0
	Continuous	1340	0.3	98.7	0.0	0.0	0.0	0.9	0.0
2009	Cell	5020	0.1	99.5	0.0	0.0	0.0	0.4	0.0
	Rotation	5070	1.9	96.9	0.0	0.1	0.0	0.9	0.2
	Continuous	5120	0.2	98.9	0.0	0.0	0.0	0.8	0.1

3.2.1.2. Yield spatial variability

The degree of spatial uniformity in the quadrats across the paddocks was assessed. There was no consistent grazing system differences in the number of uniform paddocks for pasture yield (Table 3.4), pasture utilisation (Table 3.7), ground cover (Table 3.10), litter cover and LFA indices (Table 3.12).

Most of the cell and rotation paddocks were consistently uniform in pasture yield, while there was variation across the continuous paddock in both 2007 and 2009 (Table 3.4), probably due to variation in soils within the Brigalow/blackbutt land type in this paddock. The data from 2006 is not included as the recording grid was not identical to that used in subsequent years.

Table 3.4. Spatial variability in pasture yield at Berrigurra – number of paddocks where pasture yield was spatially uniform (i.e. there was no evidence of aggregation) across the paddock.

Grazing System	Total no. of paddocks	No. uniform paddocks pasture yield	
		2007	2009
Cell	6	4	4
Rotation	2	1	2
Continuous	1	0	0

3.2.1.3. Pasture species diversity

There was little pasture species diversity in any system reflecting the strong buffel grass dominance, 93-99% in all paddocks at all recordings (Table 3.5).

Table 3.5. Measures of pasture diversity at Berrigurra in 2006, 2007 and 2009.

Diversity measure / year	Pasture diversity		
	Cell	Rotation	Continuous
No. species/quadrat			
2006	1.1	1.1	1.1
2007	1.1	1.1	1.1
2009	1.1	1.3	1.1
No. species to contribute 90% of yield			
2006	1	1	1
2007	1	1	1
2009	1	1	1
% contribution of dominant species			
2006	99	94	98
2007	98	93	99
2009	99	96	99

3.2.2. Pasture utilisation

Pasture utilisation in the monitor paddocks at the end of summer was rated across the paddocks on the Botanal grid at each recording point (rating 1 = 71-100%; 2 = 31-70%; 3 = 6-30%; 4 = 0-5% utilisation).

3.2.2.1. Utilisation means

Utilisation was greater in the continuous paddock in 2006 and 2007, but similar in all systems in 2009 (Table 3.6). Stocking rate increased in the cells from 2005 to 2009, but decreased in the continuous paddock over this time (Table 3.16). This would have contributed to similar utilisation levels in all three systems in 2008-09.

Table 3.6. Mean rating (1 = high to 4 = low) for estimated pasture utilisation in grazing systems at Berrigurra for autumn of 2006, 2007 and 2009.

Year	Utilisation rating		
	Cells	Rotation	Continuous
2006	4.0	3.5	2.6
2007	3.9	3.4	2.2
2009	3.8	3.9	3.8

At the early autumn monitoring time, the cell paddocks had received little grazing in any year, while the continuous paddock, followed by the rotation paddocks had received more grazing pressure (Figure 3.2). The continuous paddock was most heavily grazed in both 2006 and 2007. In autumn of 2009, there had been little grazing in any system.

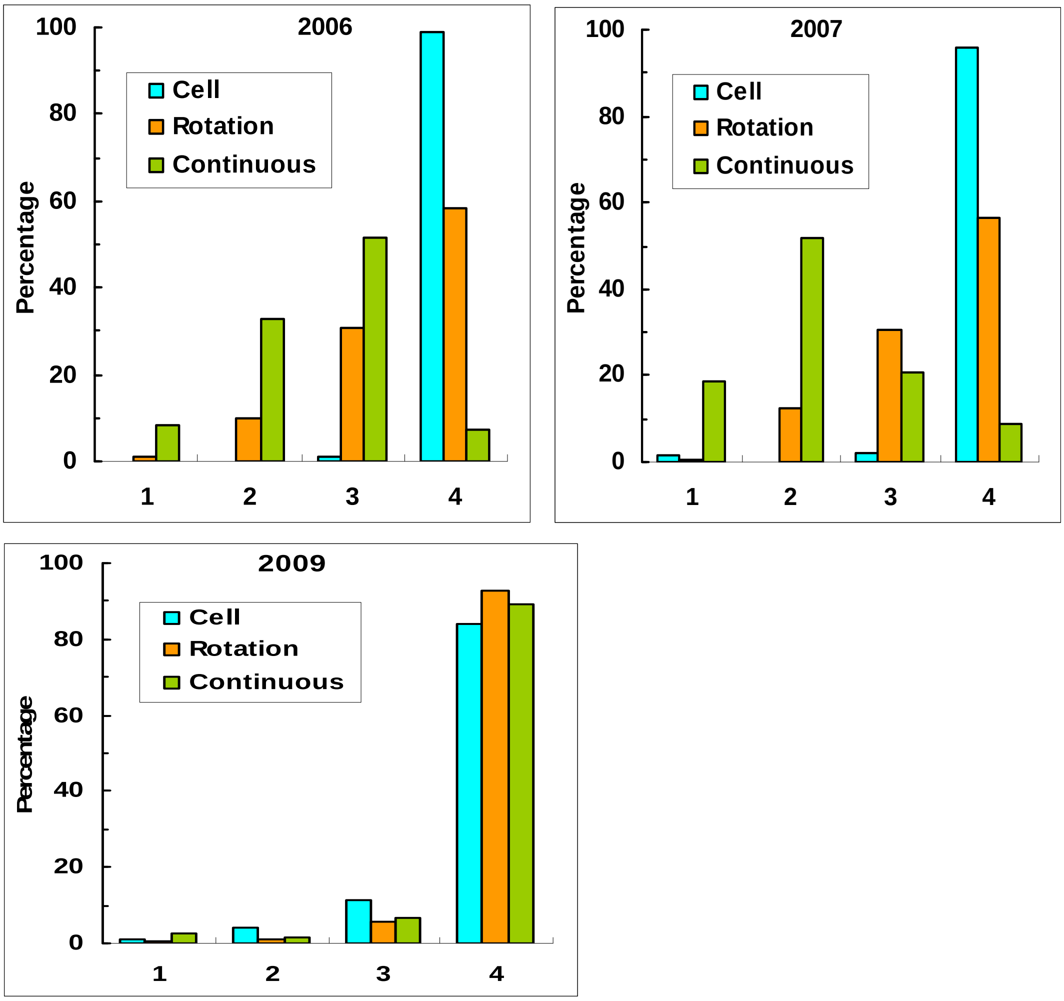


Figure 3.2. Distribution of estimated pasture utilisation values in grazing systems at Berrigurra in 2006, 2007 and 2009.

3.2.2.2. Utilisation spatial variability

Half of both the cell and rotation monitor paddocks had uniform utilisation in 2007 and 2009, while there was evidence of patch grazing effects in the continuous paddock at both monitoring times (Table 3.7). Spatial variability was not examined in 2006.

Table 3.7. Spatial variability in pasture utilisation – number of paddocks where pasture utilisation was spatially uniform (i.e. there was no evidence of aggregation) across the paddock.

Grazing System	Total no. of paddocks	No. paddocks uniform pasture utilisation	
		2007	2009
Cell	6	3	3
Rotation	2	1	1
Continuous	1	0	0

3.2.3. Woody regrowth

There was some woody regrowth, predominantly brigalow suckers and lime bush, in all systems with a high value (4.2%) for the cells in 2009 (Table 3.8).

Table 3.8. Cover levels (%) of woody regrowth in grazing systems at Berrigurra.

Year	Woody regrowth cover (%)		
	Cells	Rotation	Continuous
2006	1.3	0.8	0.7
2007	0.9	0.8	1.0
2009	4.2	1.0	0.6

3.2.4. Ground and litter cover

3.2.4.1. Cover means and standard deviations

Total ground cover levels were lower in the continuous system than the cells and rotation in 2006 and 2007, but levels were similar in all systems in 2009. Standard deviations were similar for the three systems (Table 3.9). There were no consistent differences in litter cover between systems.

Table 3.9. Total and litter cover levels (%) at Berrigurra at the end of summer.

Year	Grazing System	Total cover (%) Mean	Total cover (%) St. Dev.	Litter cover (%) Mean	Litter cover (%) St. Dev.
2006	Cell	62	26.9	22	14.5
	Rotation	62	26.3	22	16.1
	Continuous	46	25.0	19	11.7
2007	Cell	69	25.0	17	15.1
	Rotation	58	27.8	27	21.6
	Continuous	49	23.1	19	12.5
2009	Cell	73	26.0	14	13.7
	Rotation	79	20.9	22	14.9
	Continuous	74	24.5	19	14.0

3.2.4.2. Cover spatial variability

Only the cell paddocks had uniform ground and litter cover in both 2007 and 2009. The rotation paddocks also had uniform total cover, but only in 2009, while there was variation across the continuous paddock in both forms of cover, in both years (Table 3.10).

Table 3.10. Spatial variability in ground cover (%) – number of paddocks where total ground cover or litter cover was spatially uniform (i.e. there was no evidence of aggregation) across the paddock. Spatial variability was not examined in 2006.

Cover / Grazing System	Total no. of paddocks	No. paddocks uniform ground cover (%) 2007	No. paddocks uniform ground cover (%) 2009
Total ground cover			
Cell	6	5	4
Rotation	2	0	2
Continuous	1	0	0
Litter cover			
Cell	6	5	2
Rotation	2	0	0
Continuous	1	0	0

3.2.5. LFA indices

3.2.5.1. LFA means

At Berrigurra, there were no consistent differences between systems for the LFA indices in any year (Table 3.11). However, there was a small improvement in land condition over the four year period, with average stability increasing 3%, infiltration increasing 9% and nutrient cycling increasing 8%. This improvement can be related to the better rainfall seasons towards the end of the monitoring period.

Table 3.11. LFA indices at Berrigurra at the end of summer 2006, 2007 and 2009.

Year	**System**	**LFA Indices (0-100)**					
		Stability		**Infiltration**		**Nutrient cycling**	
		Mean	**S. dev.**	**Mean**	**S. dev.**	**Mean**	**S. dev.**
2006	Cell	62.2	5.93	35.5	8.25	29.1	8.24
	Rotation	61.5	7.52	38.1	8.10	29.8	7.73
	Continuous	59.0	5.88	34.4	7.93	27.8	7.14
2007	Cell	61.9	6.11	39.8	9.49	32.0	8.38
	Rotation	60.6	7.08	45.8	9.07	36.2	9.80
	Continuous	56.4	5.95	39.2	7.73	31.1	8.88
2009	Cell	62.7	6.17	38.4	7.23	31.5	6.70
	Rotation	64.0	5.94	39.9	6.19	33.5	7.42
	Continuous	61.5	5.24	39.3	6.30	29.0	7.44

3.2.5.2. LFA – spatial variability

Most of the cell paddocks were uniform for the three LFA indices, stability, infiltration and nutrient cycling, in both 2007 and 2009. The rotation system was uniform for stability and for infiltration in both paddocks recorded in 2009. The continuous system only had uniform stability in both years, i.e. there was no evidence of aggregation across the paddock (Table 3.12). Spatial variability of LFA indices was not examined in 2006.

Table 3.12. Spatial variability in the LFA indices – number of paddocks where the LFA Stability, LFA Infiltration or LFA Nutrient cycling index was spatially uniform.

LFA index / Grazing System	**Total no. of paddocks**	**No. uniform paddocks LFA indices**	
		2007	**2009**
LFA Stability index			
Cell	6	4	4
Rotation	2	0	1
Continuous	1	1	1
LFA Infiltration index			
Cell	6	5	4
Rotation	2	1	2
Continuous	1	0	0
LFA Nutrient cycling index			
Cell	6	5	4
Rotation	2	0	0
Continuous	1	0	0

3.2.6. Land condition

The continuous paddock was in A condition in the eastern half and B to C condition in the western end in 2006 and 2007 due to loss of perennial grasses, but improved in 2009.

Land condition across the cell and rotation paddocks was similar and in good condition, A, in the three years of recording, however, the continuous paddocks had areas in poorer condition, particularly on the alluvial brigalow land type (Table 3.13). Brigalow suckers are present in the cells, reducing condition to B in these patches.

Table 3.13. Land condition measures at Berrigurra. For the Botanal/PatchKey and ABCD (Land type) values, “1” is equivalent to A condition and “4” is equivalent to D condition.

Land condition method	Land condition units		
Year / Land type	Cells	Rotation	Continuous
Botanal/PatchKey			
2006	1.5	1.5	2.1
2007	1.5	1.9	2.2
2009	1.2	1.2	1.2
ABCD (by Land type)			
Alluvial brigalow		1.0	3.0
Brigalow-blackbutt	1.0	1.0	1.8
Brigalow with melon holes		1.0	
Overall average	1.0	1.0	1.8
ABCD (Paddock)			
2006	A	A	B
2007	A	A	B
2009	A	A	A/B

A time series of fixed-point photographs in the three grazing systems shows the pasture production, cover and seasonal responses by the buffel pasture (Figure 3.3). All systems had good pasture growth and cover at recording in March 2009.

Berrigurra Cell EA17-3 Lat: 23^{0}.515; Long: 148^{0}.740, Dir: 320^{0}	**Berrigurra Rotation 16-3** Lat: 23^{0}.506; Long: 148^{0}.723, Dir: 50^{0}	**Berrigurra Continuous 14-5** Lat: 23^{0}.521; Long: 148^{0}.754, Dir: 180^{0}
 Cell (November 2005)	 Rotation (November 2005)	 Continuous (November 2005)
 Cell (October 2006)	 Rotation (October 2006)	 Continuous (October 2006)
 Cell (September 2007)	 Rotation (September 2007)	 Continuous (September 2007)
 Cell (October 2008)	 Rotation (October 2008)	 Continuous (October 2008)
 Cell (March 2009)	 Rotation (March 2009)	 Continuous (March 2009)

Figure 3.3. Changes in land condition at fixed points in the cell, rotational and continuous grazing systems at Berrigurra.

3.2.7. Cover analysis

3.2.7.1. VegMachine vegetation cover time series (Landsat)

The three grazing systems at Berrigurra maintained a high and similar cover with less than a 10% range in most years, and responded similarly to the variable annual rainfall, with lowest cover, 60%, in the most severe drought year of 1994, which received 240mm rainfall (Figure 3.4). The average of the cell system has been marginally lower than the other system areas in most years, except in the two years of GSP field recording (2006 and 2007) when the cell cover was marginally higher. This is the same relative result as measured with the cell areas having the highest cover in both years (62% and 69% respectively) (Table 3.9), although the VegMachine analysis produced a higher index (90 and 95 respectively). The drought periods in the 1990's and 2000's produced significant cover declines with the index declining from over 95 to near 50. The neighbourhood catchment had a consistently lower cover than the monitor paddocks and the whole Berrigurra property.

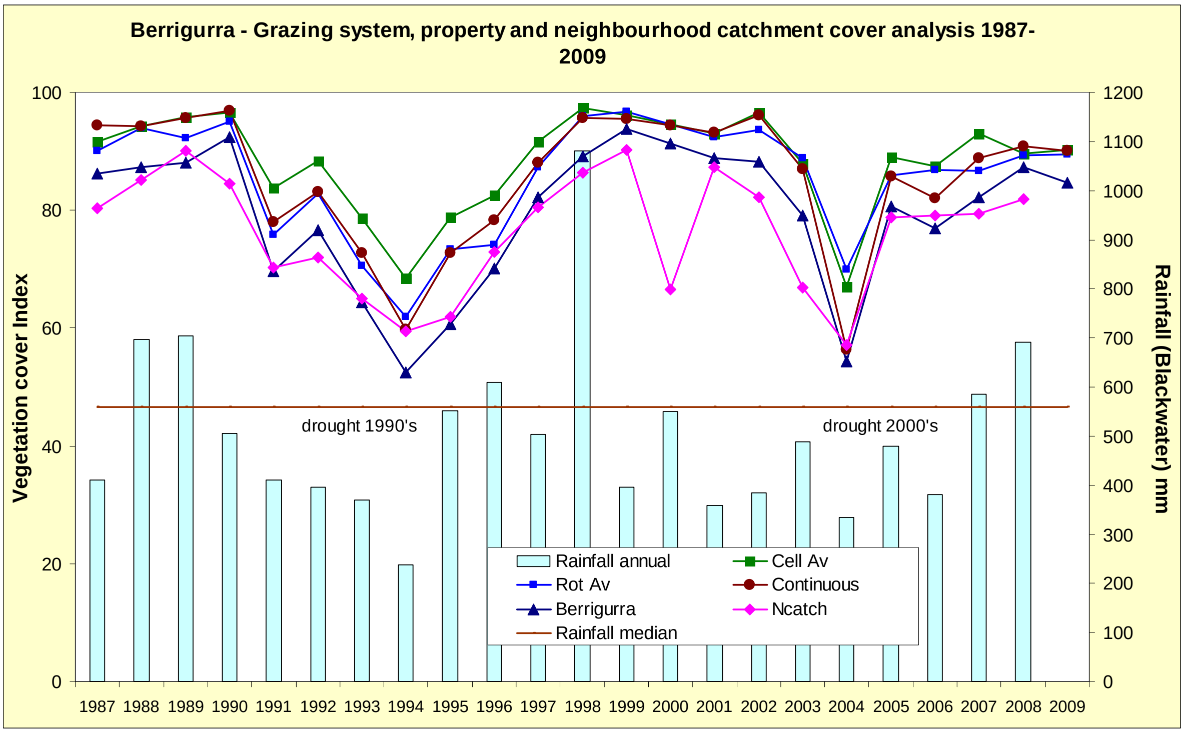


Figure 3.4. Vegetation cover index values between 1987 and 2009 for grazing systems, the whole property and neighbourhood Burngrove catchment at Berrigurra. Annual and long-term median rainfall (mm) is also shown.

The VegMachine cover analysis indicates that paddocks at Berrigurra have been managed with similar grazing levels for most of the last 20 years (Figure 3.5). Throughout this period the range of cover index values between the monitor paddocks was usually less than 15 and the two main drought periods produced the major cover declines in the early 1990's and a sharp cover decline in early 2000's.

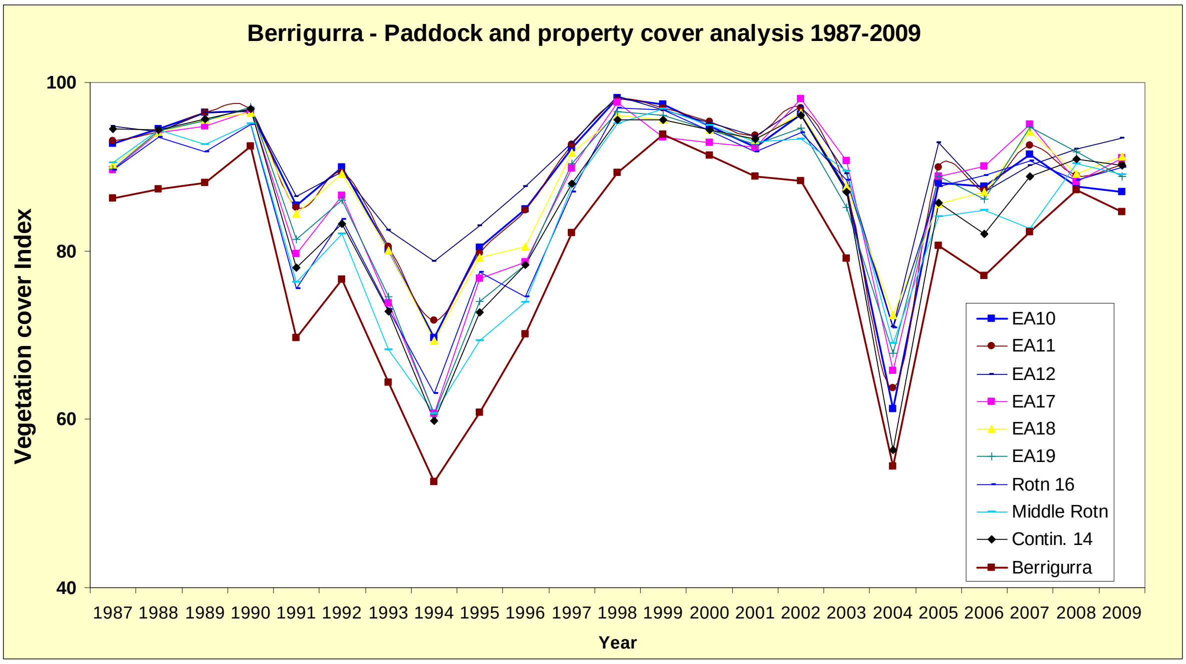


Figure 3.5. Vegetation cover index values between 1987 and 2009 for monitor paddocks and the whole property at Berrigurra.

An analysis of the neighbourhood catchment (Burngrove) for the main land types; brigalow-blackbutt (Figure 3.6), alluvial brigalow, brigalow/softwood scrubs and coolabah floodplain shows that Berrigurra has a close cover relationship, although marginally higher, than the neighbour properties for the blackbutt and alluvial brigalow land types. However, the neighbour properties have maintained a consistently higher cover for the brigalow/softwood scrub and floodplain land types. The largest differences have been in the two severe drought periods (1993-96 and 2003-05) when cover on these land types on Berrigurra was reduced to around an index of 30 compared with minimum cover in the catchment of index 50.

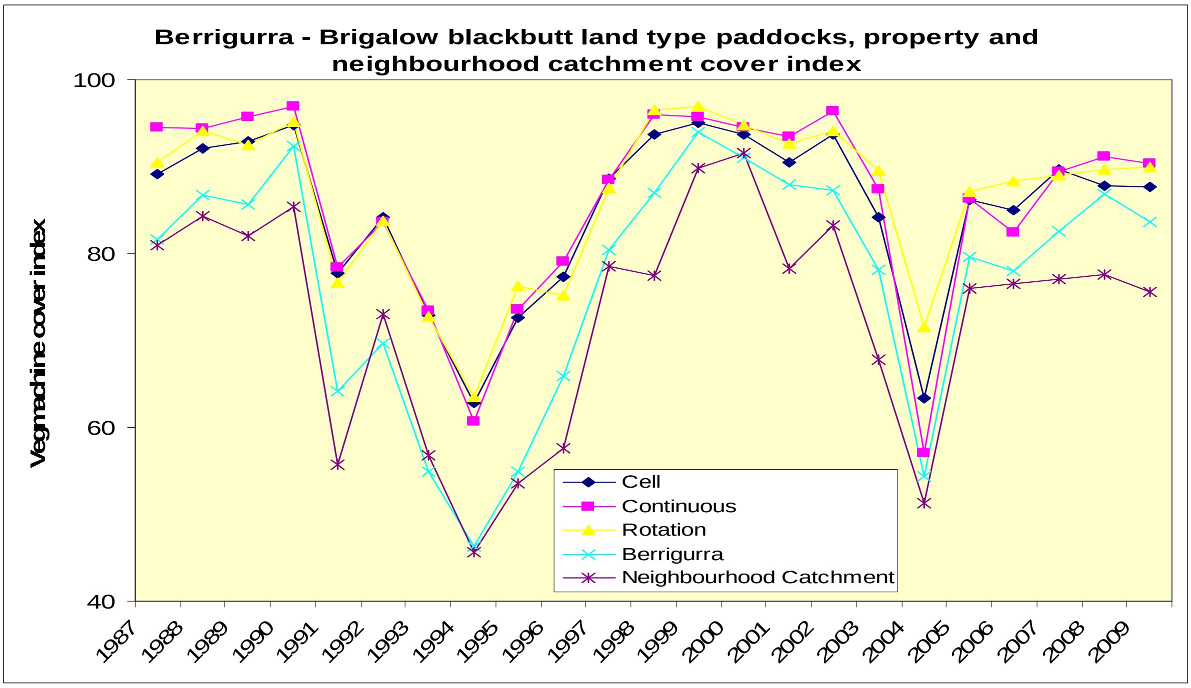


Figure 3.6. Vegetation cover index between 1987 and 2009 for the brigalow-blackbutt landtype in monitor paddocks, the whole property and neighbourhood catchment (Burngrove) at Berrigurra.

An analysis of the VegMachine cover index for grazing system areas shows similar relationships to rainfall in most years. Figure 3.7 represents the average grazing system cover index/100mm of annual rainfall. The cell areas were marginally lower than other system areas in the two drought years. In 1994, the driest year, the cells had the lowest cover response, 10 index units per 100mm rainfall, compared with 18 index units per 100mm for the rotation paddocks.

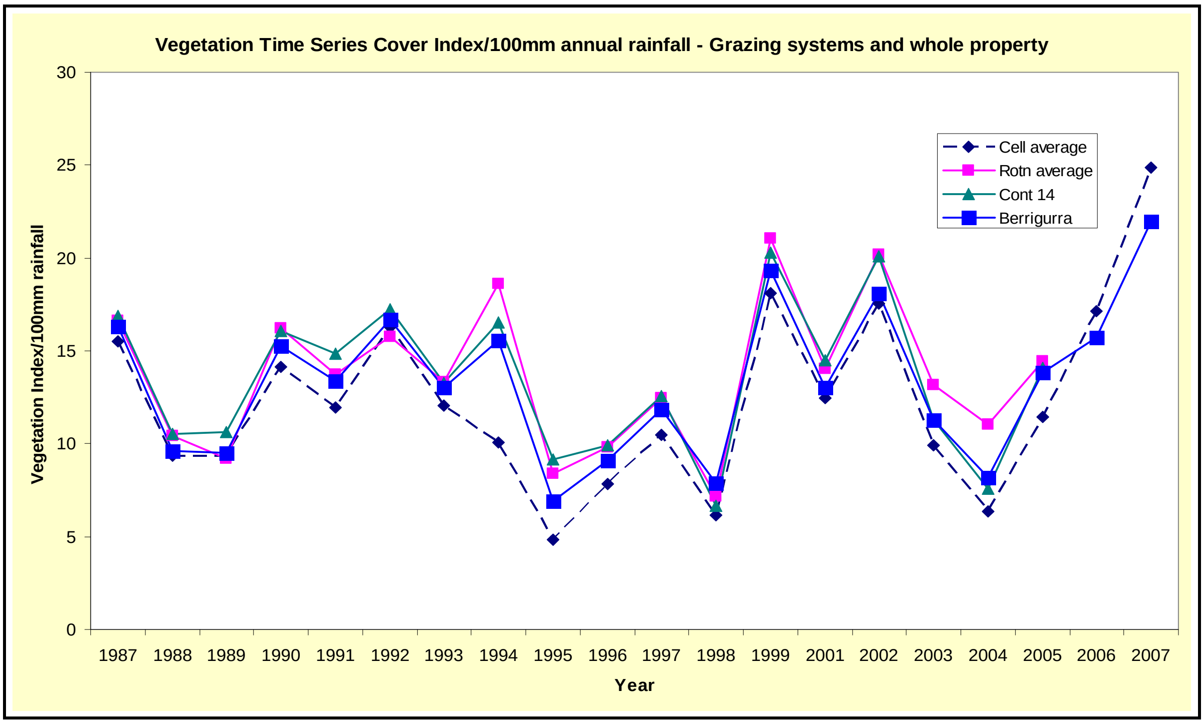


Figure 3.7. Vegetation cover index relationship to annual rainfall (cover index/100mm rainfall) between 1987 and 2007 for grazing systems and the whole property at Berrigurra.

There are significant differences on the output between the VegMachine analysis from 2007 and 2009 methods. The earlier version produced results more closely resembling that recorded in the field, while the 2009 analysis has produced much higher values. We expect the relative differences between the paddocks and grazing systems will be accurate.

3.2.7.2. Botanal pasture cover analysis

The individual paddock yields and cover levels measured as total, litter and woody cover in 2006 and 2007 (Table 3.14) show cover levels were lower in the continuous system than the cells and rotation in both years. This is supported by the ground cover analysis produced by QDERM. Their average cover index during 2001-05 for the GSP paddocks shows that most areas have high cover (in blue), except for the medium cover patches at the western end of the continuous paddock. (The continuous paddock is to the south and south-west of the cells and the rotation paddocks are to the north-west, see

Figure 2.1). This difference in average cover between the systems (46% in the continuous compared with 62% in the rotation and cell systems in 2006), was measured in the field. The surrounding properties have a similar cover range to the Berrigurra GSP monitor paddocks.

Table 3.14. Pasture yield (kg/ha), total pasture cover (%), litter cover (%) and woody cover (%) in 2006 and 2007 in paddocks and grazing systems at Berrigurra.

Paddock/ System	Yield (kg/ha)		Total Cover (%)		Litter Cover (%)		Woody Cover (%)*	
	2006	2007	2006	2007	2006	2007	2006	2007
Cont 14 [14]	1700	1340	46	49	18	17	0.7	1.0
Rotn Middle [1]	3240	1640	65	52	21	28	0.8	0.9
Rotn 16 [16]	3150	2220	58	65	22	25	0.8	0.8
Cell EA10 [10]	3430	3100	64	78	25	19	1.0	1.1
Cell EA11 [11]	3060	2750	65	67	22	20	1.8	1.5
Cell EA12 [12]	3630	2360	56	63	19	19	1.1	0.8
Cell EA17 [17]	4300	3450	66	71	22	18	1.2	0.6
Cell EA18 [18]	3140	3280	52	68	17	21	1.5	0.7
Cell EA19 [19]	3230	3360	67	68	24	16	1.4	1.0
Continuous	1700	1340	46	49	18	17	0.7	1.0
Rotation	3190	1930	62	58	22	27	0.8	0.8
Cell	3470	3050	62	69	22	19	1.3	0.9
Site	3210	2610						

* Woody cover = woody regrowth cover values at Botanal sampling

3.2.7.3. Spatial ground cover reports

The cell and continuous paddock areas are on a separate lot plan lease to the rotation paddocks, so these two areas were analysed separately for pasture growth and ground cover. The AussieGrass model predicted a lower standing dry matter yield than was measured in the field. The model standing dry matter yields were in the 500-1000 kg/ha range in 2006-07 for the cell and continuous system areas, while the GSP paddocks had yields in autumn of 1300 to 3500 kg/ha (Table 3.14). During the same period, modelled average property cover range was 60-90% compared with measured cover of 45-70% in the GSP monitor paddocks.

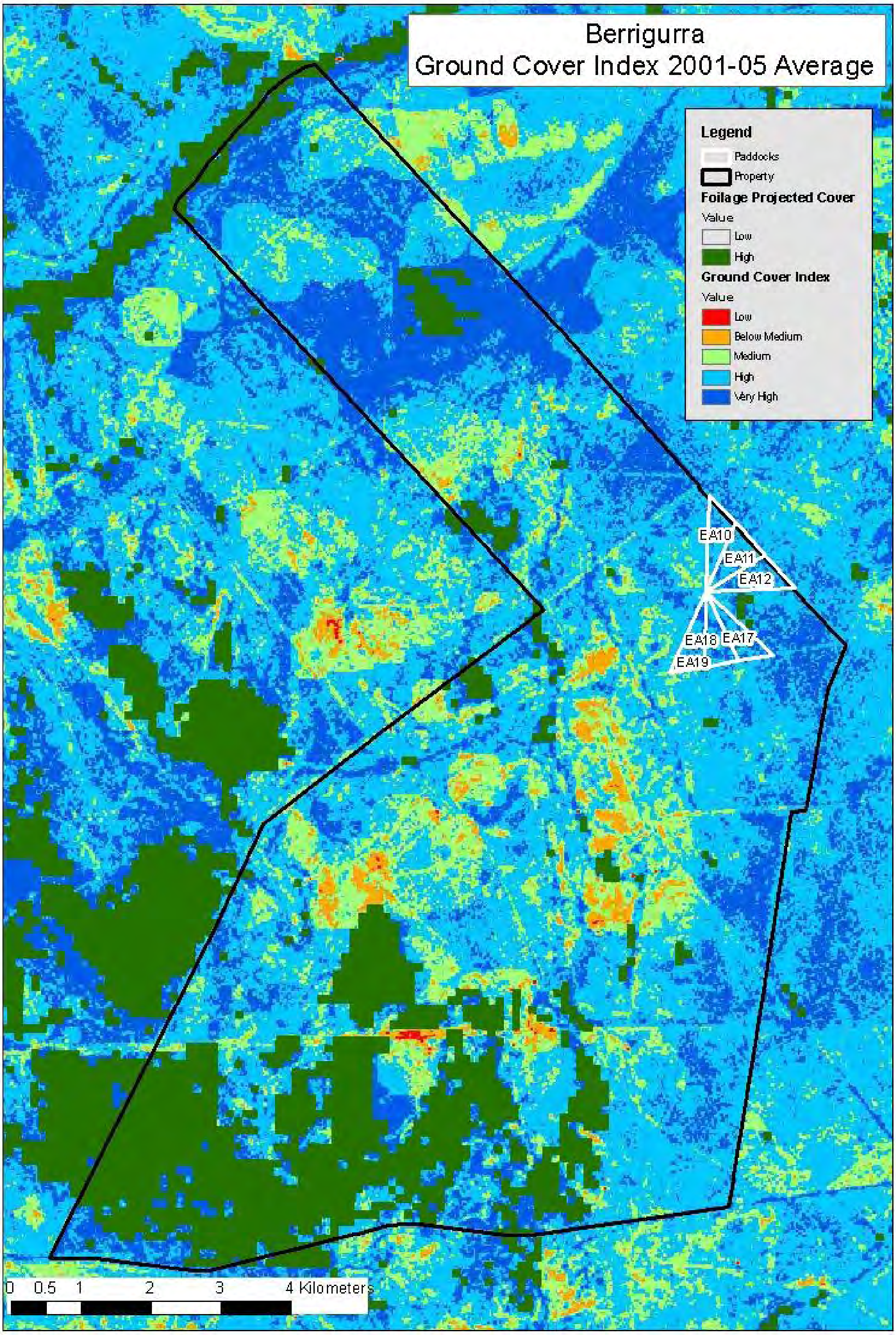


Figure 3.8. Average (2001-2005) ground cover index (vegetation cover) image at Berrigurra showing the monitor cell paddocks and surrounding properties (source QDERM data).

3.3. Cattle Grazing

3.3.1. Carrying capacity – long-term

The estimated long-term carrying capacities (AE/100 ha and SDH/yr) over all landtypes of the three systems are:

Cells	28 AE/100 ha (102 SDH/yr)
Rotation	28 AE/100 ha (100 SDH/yr)
Continuous	22 AE/100 ha (80 SDH/yr)

3.3.2. Rest periods

The cell system was grazed lightly over the first two years with extended rest periods up to 159 days, while the rotation paddocks were grazed similarly each year. The continuous system received between 27 and 67 day rest periods during the monitoring years (Table 3.15). In commercial practice, all well managed continuous/set stocked systems receive some rest each year, similar to the management of the continuous paddock at Berrigurra. There were long rest periods for all grazing systems at Berrigurra. With an abundance of student labour, and hands-on activities promoted, there is capacity to regularly move the cattle.

Table 3.15. Average duration of rest periods (days), and total number of rest days during the year for grazing systems at Berrigurra.

Year	Cells		Rotation		Continuous	
	Average	Total	Average	Total	Average	Total
2005-2006	137	353	100	301	67	134
2006-2007	159	353	81	324	67	134
2007-2008	87	350	106	232	27	109
2008-2009	78	353	106	317	50	149
Average	**115**	**352**	**88**	**293**	**53**	**132**

3.3.3. Grazing days

The average annual days grazing in the three systems was: 13 (range 2-21), 77 (range 27-239) and 239 (range 215-256) days for the cell, rotation and continuous systems respectively. The annual average grazing events or herd number changes was three, three and six for the three systems respectively. The individual cell paddocks received from one to five grazing events per year, the rotation paddocks had two to six herd number changes and there were from three to eight herd number changes in the continuous system.

3.3.4. Grazing pressure

The animal numbers taken from property records for each system have been converted to Animal Equivalents (AE) using the standards tables presented in Appendix 9.10. An AE is equivalent to a dry cow weighing approximately 450 kg. The mean grazing days for the four years of monitoring during the project are 38% higher than the estimated LTCC (Table 3.16). Annual rainfall was average to above average for the last three years of this period, and combined with good growing conditions, has allowed the high stocking rates to be sustained. The cells received lower grazing pressure over the four years of recording, mainly from the light grazing in the drought of 2005. All systems were grazed at rates higher than the recommended long term carrying capacity, particularly the continuous paddock which shows by deteriorating land condition in the western end. The four-year mean of SDH/100mm of rainfall (over previous 12 months from each graze period) for the grazing systems was 20, 26 and 26 SDH/100mm rainfall for the cells, rotation and continuous systems respectively.

Table 3.16. SDH and SDH/100mm rainfall for grazing systems at Berrigurra (AE days/ha/annum).

Year	Grazing pressure					
	Cells		**Rotation**		**Continuous**	
	SDH	SDH/100mm	SDH	SDH/100mm	SDH	SDH/100mm
2005-2006	59	13	139	29	142	29
2006-2007	96	24	116	29	142	37
2007-2008	121	21	154	26	84	12
2008-2009	127	20	54	9	34	5
Average	**103**	**20**	**126**	**26**	**123**	**26**
LTCC	91		91		73	

Paddock grazing data in stock days per ha (SDH), SDH/100 mm rain and annual stocking rate (ha/AE) from 2005-06 to 2008-09 were statistically analysed by residual maximum likelihood (REML). There was no significant difference between the three grazing systems, years or grazing system by year interaction for any grazing pressure measure (Table 3.17).

Table 3.17. Grazing system and year effect on stock days per ha (SDH), SDH per 100mm rain and annual stocking rate (ha/AE) at Berrigurra*.

System / Year	Grazing pressure					
	Stock days per ha (SDH)		**SDH / 100 mm rain**		**Annual stocking rate (ha/AE)**	
Grazing System (GS)	ns		ns		ns	
Cell	4.43	(83)	2.82	(16)	1.72	(4.6)
Rotation	4.58	(96)	2.99	(19)	1.60	(3.9)
Continuous	4.48	(87)	2.86	(17)	1.67	(4.3)
Ave s.e.d.	0.35		0.39		0.28	
Year (Yr)	ns		ns		ns	
2005-06	4.37	(78)	2.88	(17)	1.76	(4.8)
2006-07	4.56	(95)	3.25	(25)	1.60	(4.0)
2007-08	4.75	(114)	3.00	(19)	1.45	(3.3)
2008-09	4.31	(73)	2.43	(10)	1.85	(5.3)
Ave. s.e.d.	0.31		0.35			
GS x Yr	ns		ns		ns	

n.s. – $P > 0.10$; * $P < 0.05$; ** $P < 0.01$.

* Data were log-transformed prior to analysis. Back-transformed means are given in parentheses.

The three systems received similar grazing over the monitoring period. The average grazing pressure (117 SDH and 24 SDH/100mm rainfall) and average annual stocking rates (5.1 ha/AE) was the same (Table 3.16) in the three systems over the four years. There was wide within-year variation in grazing in some paddocks. For example Cell paddock EA12 had 10 SDH/100mm in 2005-06 and 49 SDH/100mm in 2008-09.

The LTCC was 3.6 ha/AE (28 AE/100 ha) for the cell and rotation systems and 4.6 ha/AE (22 AE/100 ha) for the continuous system. This lower LTCC in the continuous system was due to the poorer land condition of the western end (
Figure 2.1). Individual paddock LTCC ranged from 3.4 to 3.8 ha/AE for the cell and it was 3.6 and 3.7 ha/AE in the two rotation system paddocks. The actual grazing during the monitoring period has been lighter for the cell system and near the LTCC for the rotation and continuous systems. The four-year average was equivalent to 2 ha/AE lighter in the cells, 0.9 ha/AE in the rotation and by 0.5 ha/AE in the continuous system. The large stemmy buffel tussock plants, especially in the cell paddocks reflect this relatively light grazing.

3.3.5. Grazing system intensity index

The grazing system intensity index is a measure of capital cost, operating cost and management intensity. It is calculated by an index based on parameters including: the number of paddocks, average length of grazing period, adjustments of grazing periods and management to pasture growth, feed budgeting and record keeping. The grazing system intensity index values calculated for the systems at Berrigurra were:

Cells	63
Rotation	52
Continuous	21

3.3.6. Diet quality (NIRS)

3.3.6.1. Analysis of all samples over four years

Over all samples (107) diet quality was significantly higher in the continuous system, with similar quality in the rotation and cell systems (Table 3.18). There was an average of 1.5% higher crude protein and marginally higher digestibility (2%), which equated to almost 0.2 kg/hd/day improvement in predicted liveweight gain in the continuous system over the cell system.

Table 3.18. Mean faecal NIRS results for grazing systems at Berrigurra between December 2005 and June 2009.

Grazing System	No. samples	Crude protein (%)	Faecal N (%)	Digesti-bility (%)	Non-grass (%)	LWG (kg/day)	DMD/CP ratio
Cell	37	7.5	1.5	56	10	0.66	7.7
Rotation	40	7.7	1.4	56	15	0.69	7.6
Continuous	28	9.0	1.6	57	9	0.84	6.8
sed (av.)		0.4	0.05	0.8	2	0.06	0.3
Significance		**	**	P=0.09	***	**	**
Average		**8.0**	**1.5**	**55**	**13**	**0.74**	**7.3**

3.3.6.2. Analysis of same-day sampling times

Samples were collected from the three systems on the same day on 25 occasions. An analysis of these samples shows the continuous system had a higher (P>0.05) crude protein, faecal N and non-grass than the other two systems (

Table 3.19). The LWG prediction was almost 0.2 kg/day higher (P=0.075).

Table 3.19. NIRS results when three system samples were collected at the same time.

Grazing System	**No. samples**	**Crude protein (%)**	**Faecal N (%)**	**Digesti-bility (%)**	**Non-grass (%)**	**LWG (kg/day)**	**DMD/CP ratio**
Cell	25	7.6	1.5	55	10	0.69	7.7
Rotation	25	7.7	1.4	55	15	0.73	7.7
Continuous	25	9.3	1.6	57	10	0.91	6.6
sed (av.)		0.69	0.07	1	2	0.10	0.8
Significance		*	*	ns	*	P=0.075	ns

When paired samples were collected from at least two grazing systems at the same time, the continuous system also showed a higher diet quality over the other two systems, particularly in crude protein (9.28%) (P<0.01), and in liveweight gain prediction (0.91 kg/day) (P<0.05). Digestibility (57%) was higher at P=0.06 level.

3.3.6.3. NIRS related to pasture growth index

The NIRS values were examined by dividing them into three classes which had different growing conditions on the basis of the Pasture Growth index (GI) derived from GRASP modelling (where 0.0 = conditions are unsuitable for growth and 1.0 = conditions are not limiting growth). Average values of the GI for the 30 days ending on the sample date were calculated. Based on these values three classes were formed – mean GI <0.2 (Poor growing conditions), 0.2-0.5 (Average) and >0.5 (Good conditions). There were no differences between systems when pasture growth conditions were poor, but a trend of increasing diet quality, in both crude protein and digestibility, as system intensity decreased with better pasture growth conditions. Diet quality in the continuous system was marginally higher than the rotation system, which was higher than the cells (Table 3.20).

Table 3.20. Mean NIRS results in relation to three growth index classes for three grazing systems at Berrigurra to June 2009.

Growth Index	Grazing System	No. samples	Crude protein (%)	Faecal N (%)	Digesti-bility (%)	Non-grass (%)	LWG (kg/day)	DMD/CP ratio
<0.2	Cell	12	6.8	1.4	52	16	0.47	7.9
	Rotation	14	6.6	1.4	52	19	0.46	8.1
	Continuous	8	7.4	1.4	54	12	0.56	7.5
0.2-0.5	Cell	10	7.6	1.5	55	12	0.71	7.4
	Rotation	13	8.2	1.5	57	16	0.81	7.2
	Continuous	9	9.7	1.7	59	12	0.92	6.4
>0.5	Cell	13	8.0	1.5	56	8	0.82	7.3
	Rotation	13	8.3	1.5	57	15	0.86	7.3
	Continuous	12	10.1	1.7	58	7	1.05	6.2

3.3.6.4. Monthly CP, DMD and non-grass

Individual sample results for the NIRS parameters crude protein, digestibility and non-grass in the continuous (Figure 3.9), rotation (Figure 3.10) and cell (Figure 3.11) systems show the wide seasonal variation in all systems with high quality pastures in summer, declining rapidly to below maintenance crude protein levels in winter-spring before summer rains. The continuous system had higher levels of crude protein in the summer growing periods and higher levels during the winter toughs, throughout the monitoring period. The cell and rotation systems were similar. The highest level of non-grass species was in the rotation system, up to 40% on one occasion. All systems had periods of 100% grass in the diet, and that would be buffel grass predominantly.

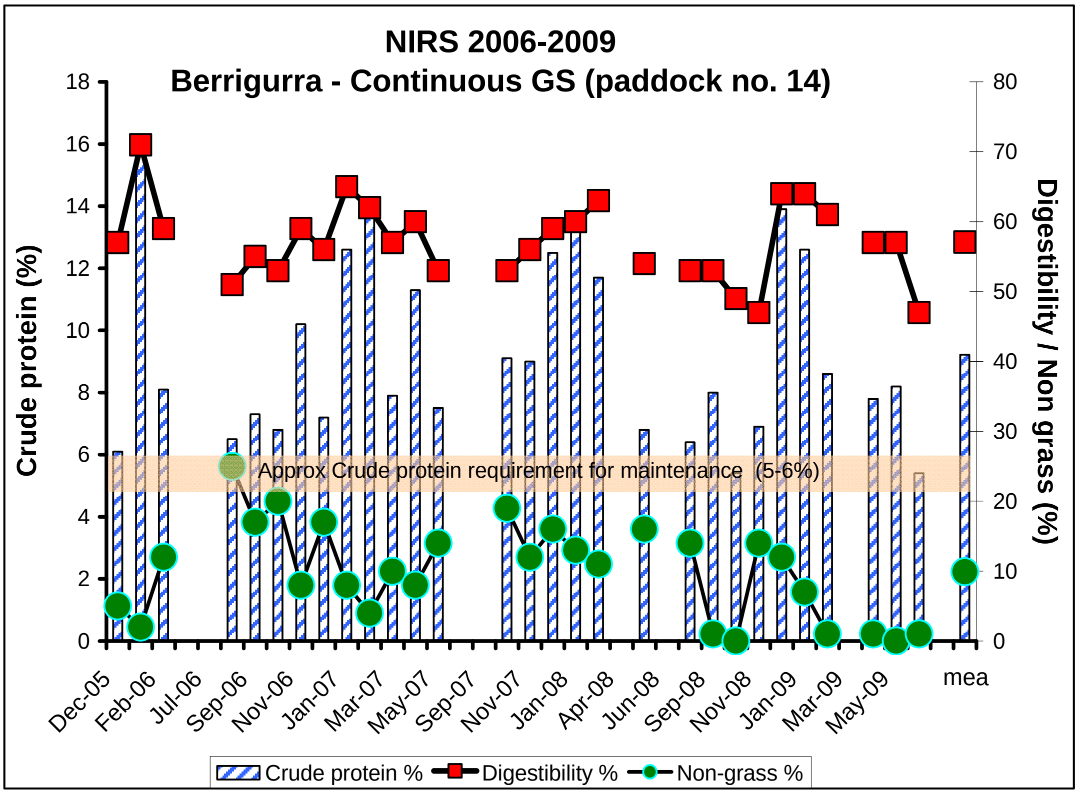


Figure 3.9. NIRS sample results for the continuous grazing system at Berrigurra for crude protein (%), digestibility (%) and non-grass (%) with approximate maintenance crude protein indicated.

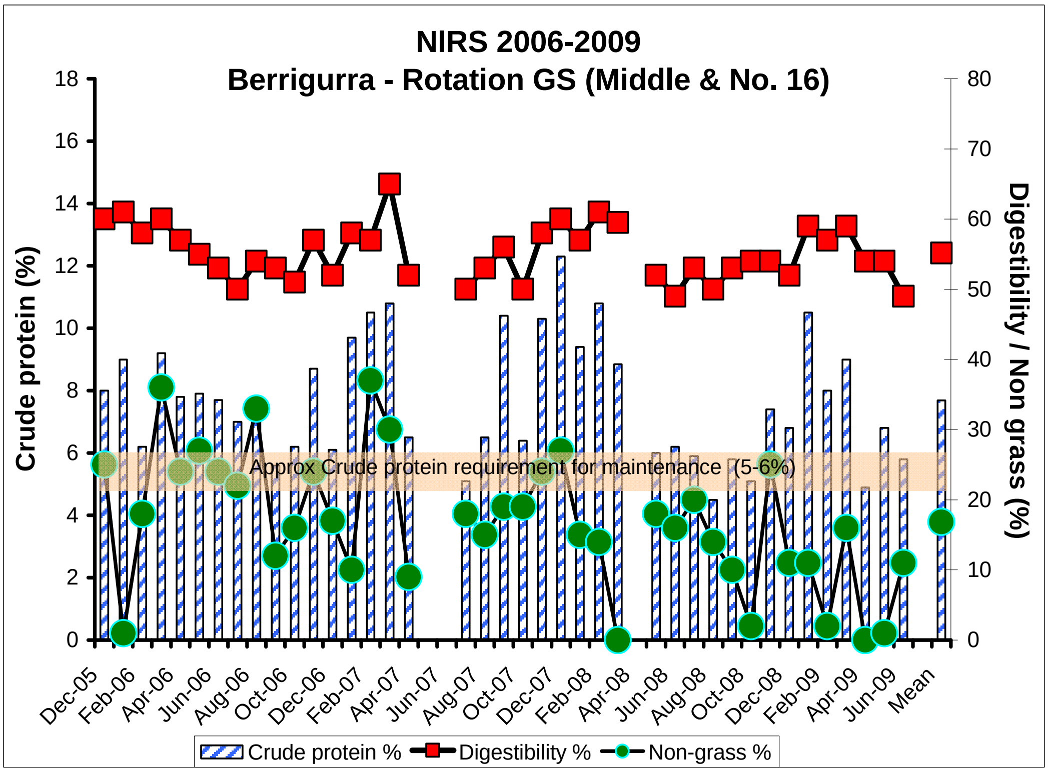


Figure 3.10. NIRS sample results for the rotational grazing system at Berrigurra for crude protein (%), digestibility (%) and non-grass (%) with approximate maintenance crude protein indicated.

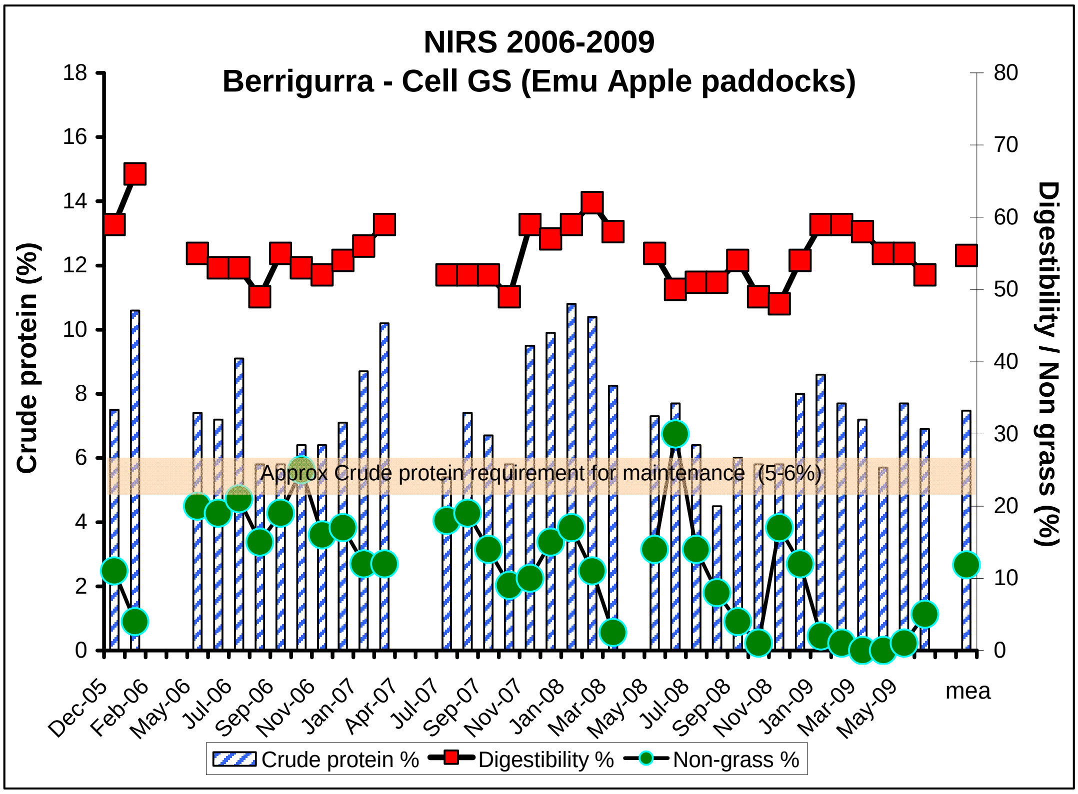


Figure 3.11. NIRS sample results for the cell grazing system at Berrigurra for crude protein (%), digestibility (%) and non-grass (%) with approximate maintenance crude protein indicated.

3.4. Grazing System Costs

The grazing system comprises an intensive cell grazing system with 24 cells and a rotational paddock grazing system involving 15 paddocks. The cells are centred on a single cell centre and two shared troughs. The rotational paddocks are watered by four centres and two sets of pre-existing troughs. Fencing is comprised of 60 km of single wire electric fencing and 4 km of conventional stock fencing (four barb wires with wooden posts). Water to the rotation paddocks is supplied through 3 km of 63 mm polythene piping, while the cells are centred on a pre-existing watering point. The remaining new water infrastructure includes four cup and saucer stock troughs, with all other dams, pumps and waterlines already in situ from the previous continuous grazing system on the holding. The bulk of the site treatment, fencing and pipe-laying was undertaken using station plant and machinery.

3.4.1. Capital costs

The estimated replacement capital cost of the cell and rotation grazing systems is approximately $101,000 (

Table 3.21Table 3.21) comprising of fencing, watering, labour and planning costs.

Table 3.21. Replacement capital costs of cell and rotation grazing systems.

Item	Cost ($)
Fencing	49,675
Water	8,478
Troughs	9,200
Tanks	0
Pumps, mills	0
Installation	31,951
Consultancies	2,000
Total	**101,306**

3.4.2. Operating costs

For reasons of privacy and confidentiality, the annual running costs that are associated with the case study grazing systems are not presented.

An indicative guide to the operating cost of a given system is the estimated annual capital reclamation cost (sinking fund depreciation charge), which is the equivalent sum that would need to be set aside each year to maintain the capital assets invested in the systems infrastructure. The reclamation cost has been estimated using standard farm accounting depreciation factors for the main assets listed in the preceding table, including – bores (7.5%), dams (2.5%), fencing (5%), and plant (10%). This gives a projected capitalised cost for the case study cell and rotation enterprises of approximately $3,000 per annum (Table 3.22), comprising of fencing and water maintenance costs.

Table 3.22. **Operating costs of cell and rotation grazing systems.**

Item	Cost ($)
Fencing	2,484
Water	212
Troughs	230
Tanks	0
Pumps, mills	0
Total	**2,931**

4. Conclusions

4.1. Pasture and land condition

The cell and rotational systems at Berrigurra were in A condition throughout the experimental period. The continuous paddock was in B condition in 2006 and 2007 but improved to A/B condition in 2009.

Pasture yields were lower in the continuous system than the rotation and cell systems in 2006 and 2007 but yields were similar in all systems in 2009. This was consistent with the higher utilisation rates in the continuous system in 2006 and 2007, and similar utilisation rates in all systems in 2009. All pastures were strongly buffel grass dominant in all years.

The amount of woody regrowth cover was similar in the three grazing systems in 2006 and 2007, but higher in the cell system (4.2%) than in the continuous and rotational systems (0.8%) in 2009.

Ground cover was lower in the continuous system than in the other two systems in 2006 and 2007. Cover levels were highest in all systems in 2009 with little difference between systems (73 to 79%). Litter levels were variable with no consistent pattern of differences between grazing systems.

There were no consistent differences between the three LFA indices values for the three grazing systems, but values for all indices in all systems were higher in 2009 than in earlier years.

Ground cover trends over the last twenty years from the VegMachine analysis show a strong relationship with annual rainfall and do not show any differences between grazing systems. The values for the vegetation cover index were low in 2004 (60-70), but levels in all systems increased rapidly in 2005 and have remained at high levels (approximately 90). Any differences in levels of this cover index between grazing systems were small and not consistent.

4.2. Carrying capacity and grazing

There were no differences in grazing pressure between the three systems, however they were all grazed at less than the estimated LTCC. The greatest difference was in the relatively low grazing of the cell system, while the continuous system was grazed at near the LTCC. The pastures in some cell paddocks, particularly those with negligible brigalow regrowth, had large tussocks and bare inter-tussock spaces reflecting this light grazing, especially in summer, in recent years.

The grazing supported by the three systems was as variable between years as it was between systems in any one year. Some of this variation occurred due to the herd dynamics associated with the overall light stocking of the property in some years.

The continuous system had a higher diet quality than the cell or rotation systems, with an average of 2% higher crude protein. There was also a trend of increasing digestibility as the system intensity decreased. The diet quality differences between systems were in the pasture growing periods.

4.3. Owners comments on grazing systems

The three grazing systems are operated along commercial lines within the constraints of herd size and providing students with training as required. This can have advantages in that staff *are not limiting for cattle movements, repairing fences or husbandry practices as required. The numbers available within classes of cattle can limit the amount of grazing imposed in some paddocks and systems on occasions.*

The management would like to have all paddocks in a rotation where they are shifted about once a week in summer, and once a month in winter. He would also like to have cattle grazing two paddocks at a time in the cell system, or pull up every second paddock, to reduce problems with watering access and breaking through the electric fences. The design is unsuitable because of too many paddocks rely on a single water point. This makes a long sharp inlet to the water which often causes cattle to break through the single-wire fences.

4.4. General conclusions

All pastures at Berrigurra are in good condition with the exception of the western part of the continuous system paddock, and the systems carried the same average grazing pressure during the study. The cell management of rest during part of the summer growing season allows the pasture to maintain large individual buffel tussocks and this system may not be carrying as many animals as it could support. Current grazing is not always meeting the LTCC of the systems.

The three systems are used as part of an annual integrated whole property breeder and grower herd management approach and not as separate systems. There were no consistent ecological differences between the systems that could be attributed to the grazing management.

Frankfield

Abstract
Frankfield, Clermont, has three grazing systems; cells, rotation and continuous. Eight cell paddocks, two rotation and one continuous paddock were monitored between 2006 and 2009. The cell system is used for growing steers while the rotation and continuous systems mainly support breeders. All years received near average rainfall. The pastures were sampled in late autumn in 2006, 2007 and 2009. Yields were higher in the rotation system (3700 kg/ha) than in the cell or continuous paddock (3000 kg/ha). All pastures were 70-90% buffel grass dominant.

The rotation and continuous systems supported higher average grazing pressure (28 SDH/100mm rainfall) than the cells (18 SDH/100mm rainfall), which were not grazed during the main wet season. However, the grazing pressure in the two larger paddock systems was higher than estimated LTCC and it was the recommended level in the cells. NIRS diet quality was lowest in the cells. The three systems are used as part of an annual integrated whole property grower, finishing and breeder enterprise and not always as independent systems. There are small ecological differences between the systems, but these can be attributed more to the different stages and rates of development, seasonal responses and cattle management practices than to the actual grazing systems. The ecological differences were not consistent or strongly associated with the grazing system.

Site Introduction

1.1. Location

‘Frankfield’ is located approximately 90 km north-west of Clermont (22.2°S; 147.2°E) on Mistake Creek in the Burdekin River catchment (Figure 0.1).

Figure 0.1. **Buffel pastures in brigalow country landscape at Frankfield.**

1.2. Climate/growing season

The average annual rainfall is 572 mm (Table 0.1) with 75% falling in summer (October-March). The growing season is predominantly in summer, but with some winter rain in some years there can be small amounts of winter pasture growth with subsequent beneficial impacts on pasture quantity and quality.

Based on long-term climate data, the average green season for tropical species is estimated to be 24 weeks including 13.4 growth weeks. With the winter rain, temperate species would add an average of 2.5 weeks to the growth of tropical species.

1.3. Major soil/vegetation types

The original vegetation was a gidgee (*Acacia cambagei*) or brigalow (*A. harpophylla*) scrub with yellow wood (*Eucalyptus* spp.) and sandalwood (*Eremophila mitchellii*) on cracking clay soils, but all monitor paddocks have been cleared. The rotation paddocks (Road and Carrington's) are cleared gidgee scrubs and were blade ploughed for sucker control in the mid-1990's. There is major brigalow regrowth in some cell paddocks and two of the monitor paddocks were blade-ploughed in 2007.

Paspalidium, Chloris and *Sporobolus* spp. were the major native grasses in the original vegetation, but the pastures are now dominated by sown buffel grass (*Cenchrus ciliaris*). The landscapes are clay plains and slight slopes (1–2%).

1.4. GRASP modelling of long-term pasture growth

The "Scrubs on deep soil" land type was 92% of the sampled area so only this land type was modelled for annual pasture production.

1.4.1 GRASP parameters

The GRASP model parameters; tree basal area (from regrowth), soil water, nitrogen and transpiration parameters used to calculate the pasture growth potential on the cleared gidgee and brigalow clays is shown in Table 0.1.

Table 0.1. Land type "Scrubs on deep soil" parameters for Frankfield used in GRASP model to estimate pasture growth.

GRASP parameter	Parameter units
	Scrubs on deep soil
Tree basal area (m^2/ha)	1
Available soil water (mm)	102
Maximum N uptake (kg/ha)	20
Regrowth (kg/ha/%BA)	3.5
Transpiration use efficiency (kg/ha/mm)	20
Minimum N concentration (%)	0.5

1.4.2. GRASP results

The GRASP model was run using climate data from SILO for the period 1889 to 2009 and pasture growth for the period July 1 to June 30 was estimated. The median annual pasture production value for Frankfield was 2810 kg/ha (Figure 0.2).

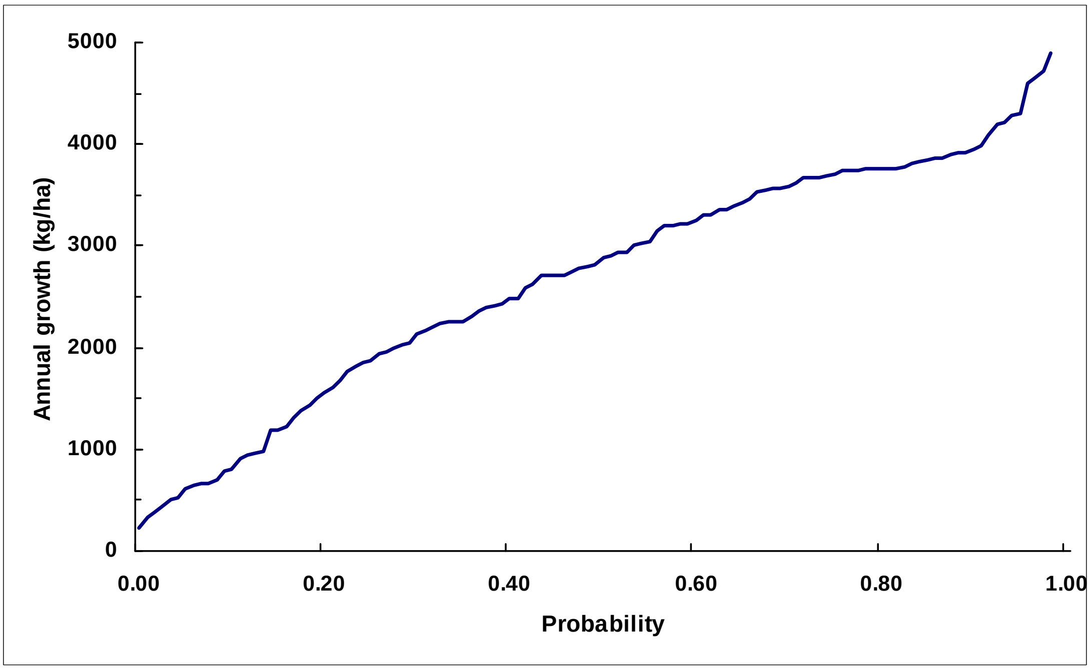


Figure 0.2. Long-term distribution of annual pasture growth estimates at Frankfield.

1.5. Production system/markets

Frankfield has an integrated beef breeding, growing and bullock fattening enterprise operating across three grazing systems. There are two sets of cells, a series of rotation paddocks and continuous grazing paddocks, which all receive some annual resting periods. We monitored eight paddocks from the ‘Bulls’ cell system, two rotation paddocks from one rotation system (eastern side) and one adjacent continuous paddock. The cells carry weaners and young growing steers for less than one year before a selection is fattened in larger bullock paddocks, usually by continuous grazing, but some rotation may be practised. The cells are an important part of educating young cattle. Breeders with calves and bulls are run in the rotation system and also in continuous paddocks. These continuous paddocks receive annual rest periods.

1.6. Producer goals

Ownership of this property changed hands in 2004 as the project was being developed and the present owners’ goals, management and operations remained broadly the same, with the exception of expanding the breeding operation. Previously Frankfield was mainly used for growing young cattle from other properties the company owned. The cell design is flexible with paddock configurations centred on a range of core permanent paddocks which have been split internally with electric fencing and can be changed as management dictates.

The original objective for installing the cell component of the system was to overcome pasture development problems that had been observed subsequent to the clearing and sowing of the paddocks in 1988. Grass coverage in the paddocks post clearing had been less than expected, probably because of being stocked too soon and at too high a grazing pressure. The cells were intended to accelerate the grass coverage of the affected area and also to promote easier handling and education of young stock. The rotation system was installed after the affected area was blade-ploughed between 1994 and 1996, after problems with the sown pastures were recognised. The original owners did not want to incur the expense of a full cell system but still wanted to apply shorter duration – higher intensity grazing pressure than had been applied under the conventional grazing practices that had been previously employed across the property.

Improving land condition and pasture production, and not necessarily increasing stock numbers, was formally cited as a principal objective of establishing the cell and rotational grazing systems. However, the previous manager suggested that stock numbers could be increased under the new system, although the individual animal productivity tended to be slightly lower than under the former continuous grazing system, which incorporated some rest. The cells were expected to increase overall animal turnoff by an increase in beef turned off per unit area.

The design of the grazing system was influenced by a formal cell grazing course but was essentially self-designed three years after the formal course. The system was subsequently run on a less intensive basis than the original training course suggested and the design would promote. Spelling the cells in the wet season has been the management approach because of difficult access and potential cattle bogging problems in wet periods. This has meant that the pastures are well grown and may even be maturing before steers are introduced. The high intensity, short duration grazing currently practised is not getting the pasture responses expected in this system. In the future this system will be changed to include more growing season grazing and an increase in overall grazing with higher stock numbers, to try to effect pasture improvement and subsequent increased animal production.

Grazing systems

2.1. Description

Three grazing systems were compared at Frankfield – cell, rotation and continuous. The Cell system has 30 paddocks (average size approximately 100 ha) on three centres carrying approximately 900 steers which are moved at 2-3 day intervals; eight paddocks were monitored. Supporting up to 1500 head is the aim for this system. Weaner steers enter the system in autumn after yard education to grow out for fattening elsewhere. The Rotation system has up to eight paddocks grazed with breeders of varying ages, or steers on occasions. Two dedicated rotation paddocks (Road and Carrington's; total area 1858 ha) were monitored. Several of these paddocks may be open at one time in dry years. The Continuous paddock (Mitchell 1380 ha) is usually grazed by breeders, including calves, and annual rest is incorporated in its management. The 11 monitor paddocks and areas are shown in Table 0.1.

Table 0.1**. Paddock names, numbers and areas sampled at Frankfield.**

Vegetation	Grazing System	Paddock name [Botanal No.]	Area (ha)
Brigalow	Cell	A1 [31]	119
		A7 [7]	164
		A8 [8]	172
		A9 [9]	116
		B11 [11]	149
		B12 [12]	142
		B17 [17]	133
		B18 [18]	143
		Total cell	1138
Brigalow	Rotation	Road [1]	982
		Carrington's [2]	876
		Total rotation	1858
Brigalow	Continuous	Mitchell [3]	1380
Total area			**4376**

Initially only six paddocks were monitored in the cell system (A7, A8, A9, B11, B12 and B18). However, in 2007 Paddocks A7 and B12 were blade-ploughed for brigalow sucker control making their management different to that in the other four paddocks being monitored in the cell system. To provide more data on paddocks with similar management to these four, another two paddocks were added to the monitoring (A1 and B17). Thus in the 2007 and 2009 there were three lots of cell paddocks:

Cell 2006 (Paddocks A8, A9, B11 and B18) – these paddocks were monitored from 2006 to 2009 and were not blade ploughed.

Cell 2007 (Paddocks A1 and B17) – these paddocks were monitored from 2007 and were not blade ploughed.

Cell blade (Paddocks A7 and B12) – these paddocks were monitored from 2006 and were blade ploughed and sown to a pasture mix including Bambatsi panic and silk sorghum in late 2006.

The two rotation paddocks were Road and Carrington's and the continuous system paddock was Mitchell (Figure 0.1).

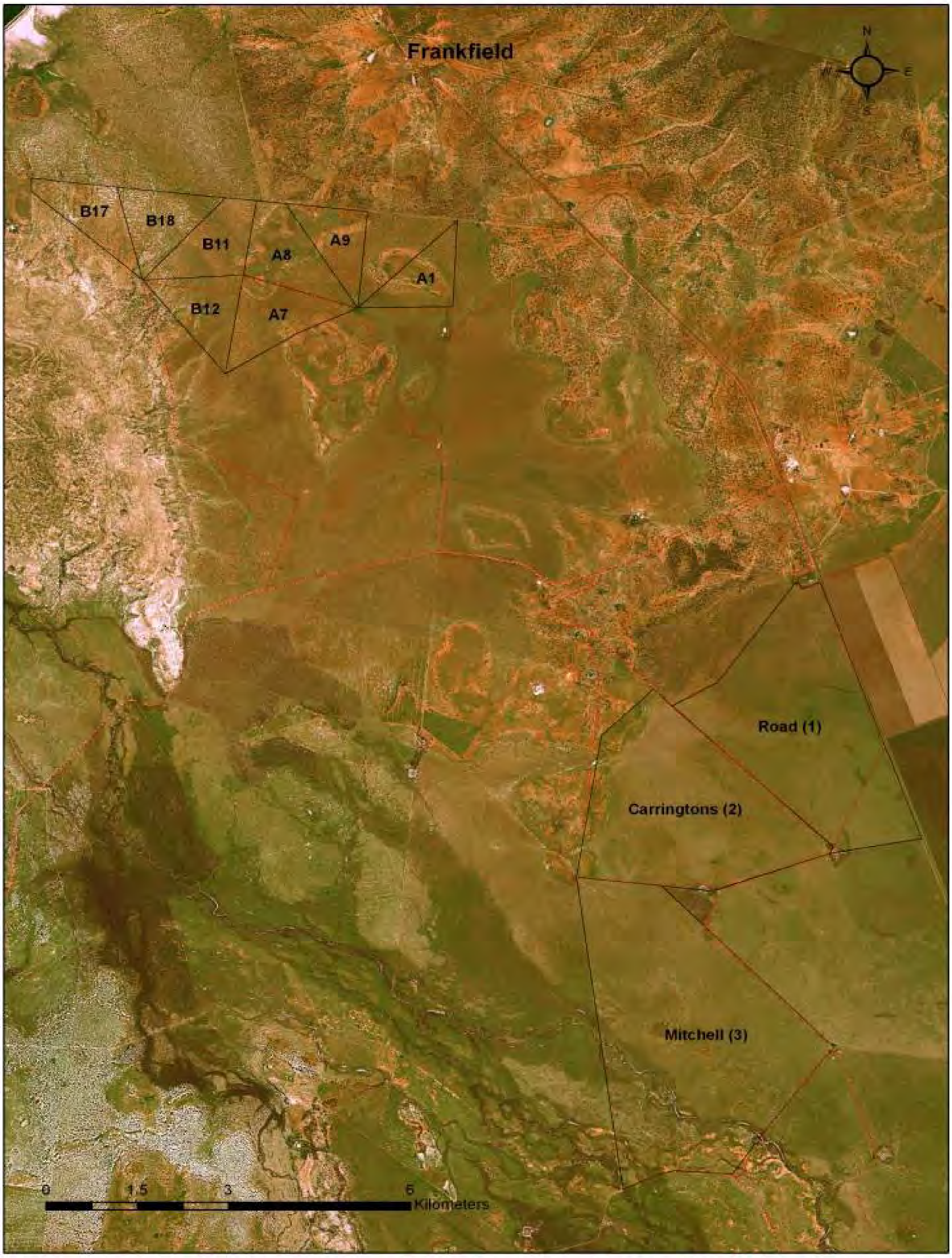


Figure 0.1. Layout of cell, rotation and continuous system monitor paddocks at Frankfield.

There are 2 main land types in the monitor paddocks. The predominant one is 'Scrubs on deep soils' which were gidgee and brigalow dominant on heavy cracking clays, but are now cleared and sown to buffel pasture. The second is 'Box country' (poplar box, *Eucalyptus populnea*) which is scattered through the northern cell paddocks and the rotation paddocks (Table 0.2).

Table 0.2**.** Areas (ha) of land types in the monitor paddocks of grazing systems at Frankfield.

Land type	**Area (ha)**		
	Cells	**Rotation**	**Continuous**
Box country	254	94	
Scrubs on deep soil	884	1764	1380
Total	**1138**	**1858**	**1380**

2.2. Management during 2005-2009

The cell paddocks were rested during most of each summer and growing steers were grazed from one to six times per year (average two grazing events) from autumn to spring. Two of the original cell paddocks were blade ploughed and sown to improved pastures and silk sorghum at the end of the first recording year (2006) to reduce the brigalow sucker problem. Breeders, with bulls and associated calves, were run in both the rotation and continuous systems. During the drought years the rotation paddocks were often opened to adjoining paddocks and the continuous paddock was rested on occasions. There was an average of six changes in stock numbers in the rotation paddocks per year and two changes in the continuous paddock.

Results

3.1. Growing seasons

3.1.1. Rainfall

Rainfall during the monitor period was erratic and below average for the first two years, which followed another dry year, creating a long-term drought, to slightly above average rain in the last two years (Table 0.1). These two years had several high rainfall events causing flooding and prevented the use of the cell paddocks during these wet months.

Table 0.1**.** Monthly rainfall (mm) at Frankfield from July 2004 – June 2009 and long-term average monthly rainfall (mm) at Elgin Downs recording station over 121 years.

Year	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**Total**	**Decile**
2004-05	0	0	1	57	40	175	62	66	20	0	50	18	489	3
2005-06	16	15	0	70	45	61	39	68	129	68	0	21	532	5
2006-07	16	0	20	20	15	14	96	155	29	0	5	178	548	5
2007-08	0	7	21	38	94	150	184	181	4	0	3	0	682	6
2008-09	84	0	3	0	86	19	212	178	0	18	0	0	600	5
Long-term Mean	**20**	**16**	**13**	**29**	**52**	**75**	**107**	**110**	**60**	**36**	**26**	**28**	**572**	

3.1.2. Growing conditions

- 2003-2004: Frankfield received 408 mm, well below the average annual rainfall, however average rainfall (346 mm) was received over the summer growing period which would have helped boost pasture reserves and quality.
- 2004-2005: Below average annual rainfall was again recorded at Frankfield, with the total summer rainfall being well below average. However, above average rainfall during spring would have produced good quantities of quality pastures. There were some follow-up falls during summer which would have maintained pasture quality over this period.
- 2005-2006: Frankfield received average yearly and average summer rainfall totals. Spring rainfall was also average which would have promoted good pasture growth and the follow up rain in summer should have helped maintain pasture quality.
- 2006-2007: Average annual rainfall of 548 mm was recorded which included an average summer rainfall of 280 mm. The growing season began slowly with below average rain for spring. However, average summer and well above average autumn rainfall would have resulted in good pasture growth and quality maintenance into winter.
- 2007-2008: This spring season was dry until mid-November which was followed by well above average rainfall in the December to February period which produced good pasture growth. However the season stopped abruptly in mid-February, causing rapid maturity, and there was no rain until winter. 2008-2009: Following a useful fall in July there was no follow-up rain until mid-November. However this 86 mm over two days was not followed by any useful rain until January. There was above average rainfall in both January and February, causing flooding, but no useful rain for the remainder of this season. These two good growing months produced adequate pasture dry matter, but it matured early.

3.1.3. GRASP modelling of growing seasons 2005-2009

For the GRASP modelling of annual pasture growth, the tree basal areas were assumed to be 1, 0 and 2 m^2/ha for the cell, rotation and continuous systems respectively. Assuming the “Box country” had similar pasture growth to the “Scrubs on deep soil” land type, the estimated annual average pasture growth in the three systems was similar, about 3000 kg/ha at Frankfield (Table 0.2). The growth potential in the drought year of 2006-07 was much lower (about 2000 kg/ha).

Table 0.2**.** Estimated pasture growth in grazing systems at Frankfield (kg/ha).

Year	**Pasture growth (kg/ha)**		
	Cells	**Rotation**	**Continuous**
2005-06	3600	4100	3200
2006-07	1600	2000	1600
2007-08	3500	4600	4000
2000-09	3300	4000	3500
Average	**3000**	**3700**	**3100**

The average weekly pasture growth index shows the widely fluctuating pasture growth potential, responding to the variable rainfall events and the dry winter periods (Figure 0.1). It also shows the poor season of 2006-07 and the longer growing season of 2008-09, even though this season was interspersed with poor growth periods.

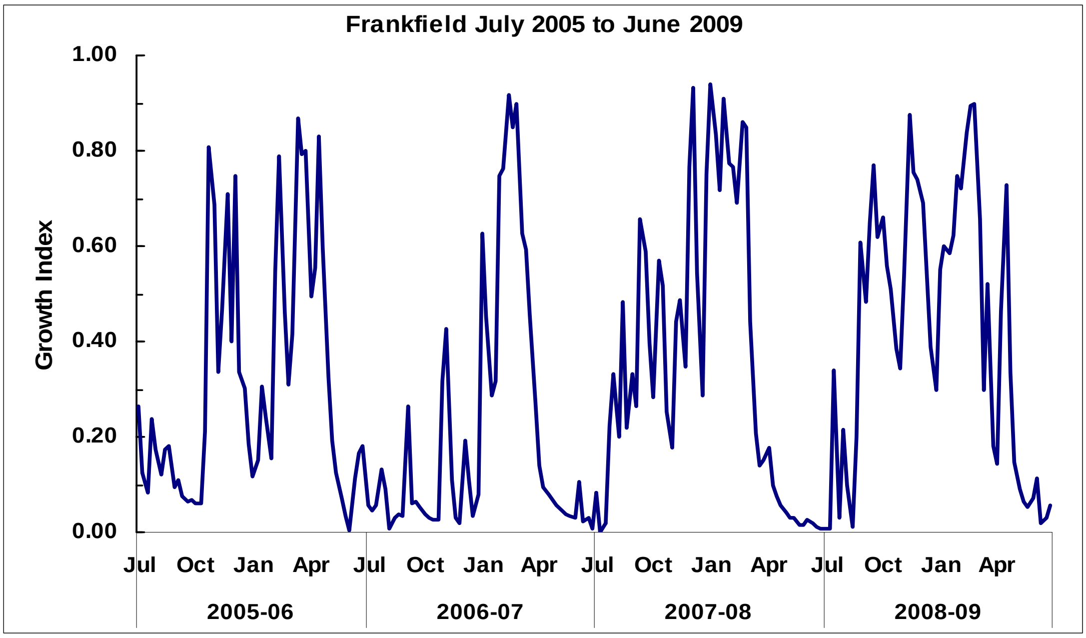


Figure 0.1. Weekly Growth Index (tropical species) values at Frankfield during the experimental period (2005-09).

3.2. Pastures and Land Condition

3.2.1. Pasture yield, botanical composition and diversity

3.2.1.1. Pasture mean values

The pastures were sampled in late autumn. There were variable changes between years in the yields of the different systems but no large consistent differences between systems. Seasonal effects were dominant with yields were much higher in 2009 after a longer growing season than in 2006 and 2007. All paddocks are dominated by buffel grass, with the cell paddocks having a slightly higher proportion of native grass. The main annual grasses were Flinders (*Iseilema* spp.), native couch (*Brachyachne convergens*), button (*Dactyloctenium* spp.), plus Silk sorghum in the two blade ploughed paddocks in 2007 (Table 0.3).

Table 0.3**.** Pasture dry matter yield and botanical composition in autumn.

Year	System	Yield (kg/ha)	Botanical composition (%) Nat per grass	Exotic grass	Native leg	Exotic leg	Ann grass	Forb	Sedge
2006	Cell-2006	1490	10.5	83.1	0.2	0.0	2.9	3.3	0.0
	Cell-2007*								
	Cell-blade	1540	7.5	88.8	0.1	0.0	1.6	2.1	0.0
	Rotation	2260	5.5	78.7	0.4	0.0	11.2	4.2	0.0
	Continuous	1800	5.6	86.5	0.3	0.0	2.5	5.0	0.2
2007	Cell-2006	1960	14.1	75.2	0.3	0.0	7.9	2.4	0.2
	Cell-2007	2500	29.6	62.8	0.0	0.0	5.3	1.5	0.8
	Cell-blade	1580	2.8	65.3	1.2	0.2	27.6	2.8	0.0
	Rotation	1830	8.3	70.3	0.8	0.2	18.0	2.4	0.0
	Continuous	2640	7.4	88.7	0.4	0.0	2.3	1.2	0.0
2009	Cell-2006	4790	21.6	76.8	0.1	0.0	0.5	1.0	0.1
	Cell-2007	4190	30.7	68.3	0.0	0.0	0.1	0.8	0.0
	Cell-blade	5650	7.4	91.4	0.1	0.0	0.3	0.6	0.1
	Rotation	5790	12.4	81.3	0.1	0.0	5.1	1.0	0.1
	Continuous	6030	7.9	90.2	0.4	0.0	0.4	1.2	0.0

* Cell-2007 paddocks not recorded in 2006.

3.2.1.2. Yield spatial variability

This analysis measured the degree of uniformity, or inversely variability, in the various parameters across each paddock. The cell and continuous system paddocks had uniform pasture yield in autumn of 2006, while the rotation paddocks were not uniform. By 2009, only the cell paddocks were uniform (Table 0.4).

Table 0.4**.** Variability in pasture yield – number of paddocks where pasture yield was spatially uniform (i.e. there was no evidence of aggregation) across the paddock.

Grazing system	Total no. of paddocks	No. paddocks uniform pasture yield 2006	2007	2009
Cell-2006	4	4	2	3
Cell-2007	2	-	1	2
Cell-blade	2	1	2	1
Rotation	2	0	1	0
Continuous	1	1	0	0

3.2.1.3. Pasture species diversity

There were no large differences in species diversity between systems which were all buffel grass dominant. The rotation system needed fewer species to contribute 90% of yield and were slightly more buffel grass dominant (Table 0.5). The dominant species contributed over 50% of the yield in all cell paddocks at all recording occasions and over 70% in the rotation and continuous systems.

Table 0.5. Measures of pasture diversity at Frankfield in 2006, 2007 and 2009.

Diversity measure	**Pasture diversity unit**				
	Cell-2006	**Cell-2007**	**Cell-blade**	**Rotation**	**Contin.**
No. species/quadrat					
2006	1.8		1.8	2.1	1.8
2007	1.7	1.9	2.0	2.3	1.9
2009	1.6	1.6	1.5	1.7	1.5
No. species to contribute 90% of yield					
2006	4		2	2	4
2007	6	9	4	2	5
2009	5	5	2	1	4
% contribution of dominant species					
2006	82		88	87	78
2007	75	63	53	89	70
2009	75	68	83	90	80

3.2.2. Pasture utilisation

3.2.2.1. Utilisation means

Pasture utilisation in the monitor paddocks at the end of summer was rated across the paddocks on the Botanal grid at each recording point (rating 1 = 71-100%; 2 = 31-70%; 3 = 6-30%; 4 = 0-5% utilisation). Ratings varied slightly between systems and years, but there was no consistent pattern, and all systems had relatively low utilisation, <30%, at recording in autumn each year (Table 0.6).

Table 0.6**.** Mean rating (1 = high to 4 = low) for estimated pasture utilisation in autumn in grazing systems at Frankfield in 2006, 2007 and 2009.

Year	**Pasture utilisation rating**				
	Cells-2006	**Cells-2007**	**Cells-blade**	**Rotation**	**Continuous**
2006	3.8		3.7	4.0	3.9
2007	3.9	4.0	4.0	3.1	3.8
2009	3.4	3.2	3.4	3.4	3.7

The cells had received slightly more grazing in autumn of 2006 than the other two systems, while there was higher grazing in the rotation in 2007 (Figure 0.2). All systems had received low levels of grazing in 2009, when there were negligible heavily grazed areas in any paddock by autumn, however, some areas of cell paddocks had received more grazing (>30% utilisation) than the other two systems.

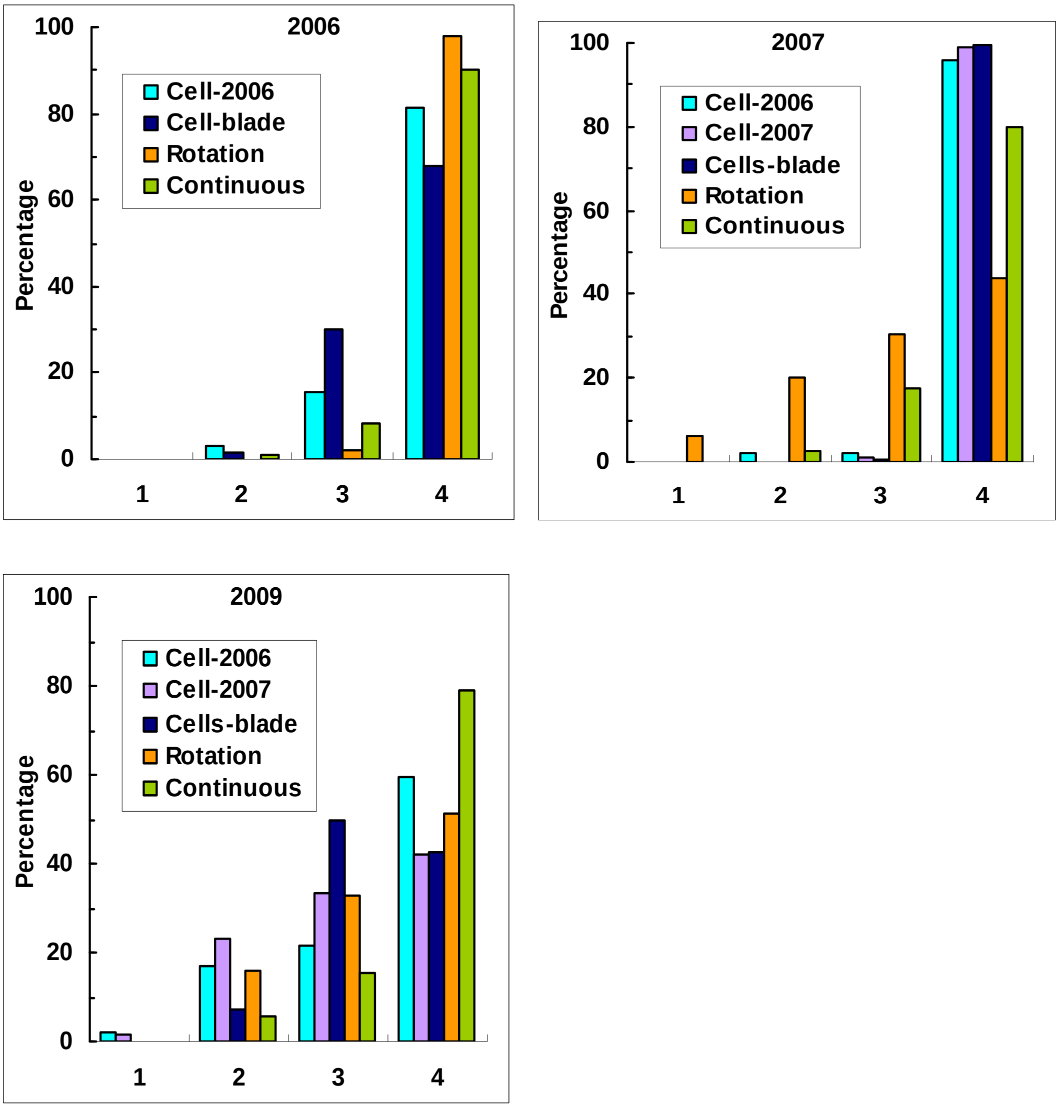


Figure 0.2. Distribution of estimated pasture utilisation values in grazing systems at Frankfield in autumn 2006, 2007 and 2009.

3.2.2.2. Utilisation spatial variability

Most paddocks were uniform for utilisation in 2006, while only two cell paddocks were uniform in 2009 (Table 0.7).

Table 0.7. Spatial variability in pasture utilisation – number of paddocks where pasture utilization was spatially uniform (i.e. there was no evidence of aggregation) across the paddock.

Grazing System	Total no. of paddocks	No. paddocks uniform utilisation		
		2006	2007	2009
Cell-2006	4	4	4	2
Cell-2007	2	-	2	0
Cell-blade	2	1	2	0
Rotation	2	1	0	0
Continuous	1	1	0	0

3.2.3. Woody regrowth

There was little regrowth in the rotation system but increasing brigalow regrowth in some cell paddocks convinced the owners to blade-plough some paddocks which effectively reduced regrowth cover from 1.4% to 0.2% (Table 0.8).

Table 0.8**.** Cover levels (%) of woody regrowth in grazing systems at Frankfield.

Year	Woody regrowth cover (%)				
	Cells-2006	**Cells-2007**	**Cells-blade**	**Rotation**	**Continuous**
2006	1.1		1.4	0.1	0.4
2007	1.5	1.0	0.1	0.1	0.5
2009	2.9	3.4	0.2	0.2	0.5

3.2.4. Ground and litter cover

3.2.4.1. Cover means and standard deviations

Overall, total cover levels started lowest in the cells (37%) and were consistently highest in the rotation (to 73% in 2009). Total and litter cover improved in all systems over the four years and the total cover differences between systems decreased with time. Although there was some variability, the standard deviations for both cover measures were similar for the different grazing systems, and remained relatively high for litter cover (Table 0.9).

Table 0.9**.** Total ground cover and litter cover levels (%) at Frankfield at the end of summer.

Year	Grazing	Total cover (%)		Litter cover (%)	
	System	**Mean**	**St. dev.**	**Mean**	**St. dev.**
2006	Cell-2006	37	29.6	11	15.1
	Cell-blade	37	27.8	12	16.1
	Rotation	67	24.1	25	19.3
	Continuous	50	26.3	15	17.1
2007	Cell-2006	43	28.9	11	10.9
	Cell-2007	47	30.1	12	11.1
	Cell-blade	41	24.9	12	11.6
	Rotation	55	25.3	17	18.6
	Continuous	49	25.6	7	8.3
2009	Cell-2006	59	31.3	28	23.0
	Cell-2007	64	30.5	33	23.2
	Cell-blade	73	23.9	35	19.5
	Rotation	73	25.2	23	18.7
	Continuous	63	26.1	12	10.2

3.2.4.2. Cover spatial variability

Most paddocks of the three systems had uniform total ground cover and litter cover in 2006 (
Table 0.10). By 2009, only the cell and rotation paddocks had uniform total ground cover. Litter cover was uniform in half the cell paddocks and also in the continuous paddock, where the litter cover was low at 12%.

Table 0.10**.** Spatial variability in total ground cover and litter cover (%) – number of paddocks where total ground cover or litter cover was spatially uniform (i.e. there was no evidence of aggregation) across the paddock.

Grazing System	**Total no. of paddocks**	**No. paddocks uniform ground cover**		
		2006	**2007**	**2009**
Total ground cover				
Cell-2006	4	4	0	3
Cell-2007	2	-	1	2
Cell-blade	2	2	2	1
Rotation	2	1	1	1
Continuous	1	1	1	0
Litter cover				
Cell-2006	4	3	2	2
Cell-2007	2	-	2	0
Cell-blade	2	1	2	2
Rotation	2	2	1	0
Continuous	1	0	0	1

3.2.5. LFA indices (soil surface condition)

The LFA indices, stability, infiltration and nutrient cycling, have values between 0 and 100 where larger values indicate better performance for that index.

3.2.5.1. LFA means

There were few differences, similar variability and no consistent trends between systems in the three LFA indices (Table 0.11). Nutrient cycling had the greatest variability for all systems.

Table 0.11. LFA indices at Frankfield at the end of summer 2006, 2007 and 2009.

Year	System	LFA Indices (0-100)					
		Stability		Infiltration		Nutrient cycling	
		Mean	S. dev.	Mean	S. dev.	Mean	S. dev.
2005	Cell-2006	54.8	7.30	34.4	8.35	27.5	8.51
	Cell-blade	54.2	6.67	35.8	8.89	28.6	9.22
	Rotation	55.1	6.76	41.3	6.40	33.1	9.02
	Continuous	53.5	7.92	41.8	6.06	30.2	8.44
2007	Cell-2006	52.4	7.08	33.8	5.75	25.8	4.56
	Cell-2007	57.2	6.77	34.1	7.01	27.0	7.12
	Cell-blade	51.3	7.17	36.1	7.05	28.4	5.45
	Rotation	49.9	6.48	40.2	5.39	30.2	9.96
	Continuous	50.2	3.96	38.3	3.86	27.7	4.56
2009	Cell-2006	58.8	8.79	40.0	8.58	36.1	10.68
	Cell-2007	62.9	7.16	39.7	9.58	37.7	10.98
	Cell-blade	61.2	6.61	43.7	9.27	39.8	9.73
	Rotation	57.9	7.26	44.2	6.48	36.2	8.68
	Continuous	53.5	4.99	41.3	5.59	28.2	6.47

3.2.5.2. LFA indices spatial variability

The stability index was uniform in only three cells of the nine monitor paddocks in 2006 (Table 0.12), and none in the rotation or continuous systems. By 2009, five of the 11 monitored paddocks had a uniform stability index. The infiltration index was more uniform in the cell paddocks than in the other two systems, while the nutrient cycling index was uniform in eight of the nine monitored paddocks in 2006 and in only four paddocks of the 11 monitored in 2009. The continuous paddock had uniform infiltration and nutrient cycling indices in the final year, while neither paddocks of the rotation system were uniform in either measure.

Table 0.12**.** Spatial variability in the LFA indices – number of paddocks where the Stability, Infiltration or Nutrient cycling index was spatially uniform (i.e. there was no evidence of aggregation) across the paddock.

LFA index / System * Year	Total no. of paddocks	No. paddocks uniform LFA index		
		2006	2007	2009
LFA Stability index				
Cell-2006	4	1	1	2
Cell-2007	2	-	1	1
Cell-blade	2	2	0	1
Rotation	2	0	1	1
Continuous	1	0	1	0
LFA Infiltration index				
Cell-2006	4	3	3	3
Cell-2007	2	-	0	0
Cell-blade	2	1	1	0
Rotation	2	0	0	0
Continuous	1	0	0	1
LFA Nutrient cycling index				
Cell-2006	4	4	2	2
Cell-2007	2	-	1	0
Cell-blade	2	2	2	1
Rotation	2	2	0	0
Continuous	1	0	0	1

3.2.6. Land condition

The PatchKey quadrat analyses indicated slightly lower land condition overall than the other two methods. In 2006, the PatchKey values were highest, indicating lower condition, in the two cell paddocks that were subsequently blade-ploughed (Table 0.13).

Based on the ABCD land condition assessment, the average of the cell paddocks was in slightly poorer condition than the rotation or continuous systems. There some patches in B or C condition due to loss of perennial grasses, loss of A horizon soil in scalded eucalypt areas, especially in Paddock A9, and more woody regrowth. The continuous paddock also had scattered regrowth which was thickening by 2009. The rotation paddocks remained in good condition.

Table 0.13**.** Land condition measures at Frankfield. For the Botanal/PatchKey and ABCD (Land type) values, “1” is equivalent to A condition and “4” is equivalent to D condition.

Land condition measures	**Land condition scores**				
	Cell-2006	**Cell-2007**	**Cell-blade**	**Rotation**	**Contin.**
Botanal/PatchKey					
2006	2.2		2.4	2.0	2.0
2007	2.3	2.0	2.4	2.1	1.7
2009	1.7	1.8	1.2	1.4	1.3
ABCD (by Land type)					
Box country	1.3	1.0	2.0	1.0	
Scrubs on deep soil	1.2	1.8	2.0	1.0	1.0
Overall average	1.2	1.5	2.0	1.0	1.0
ABCD (Paddock)					
2006	A/B		B	A	A
2007	A/B	A/B	A/B	A	A
2009	A/B	A/B	A	A	A/B

A time-series photograph record of the three systems shows good recovery in pasture cover and growth between 2005 and 2009, as the summer pasture growth seasons improved (Figure 0.3). The woody regrowth in the continuous system paddock was pulled in 2009.

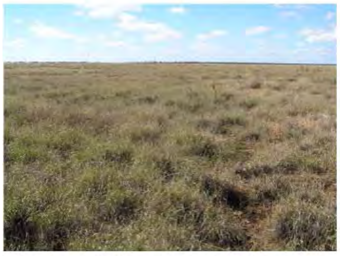
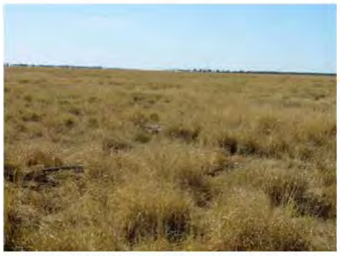
Frankfield Cell B18-1 Lat: 22^{0}.154, Long: 147^{0}.133, Dir: 20^{0}	**Frankfield Road-5** Lat: 22^{0}.230, Long: 147^{0}.221, Dir: 80^{0}	**Frankfield Mitchell-5** Lat: 22^{0}.256, Long: 147^{0}.215, Dir: 300^{0}
 Cell (October 2005)	 Rotation (October 2005)	 Continuous (October 2005)
 Cell (June 2006)	 Rotation (June 2006)	 Continuous (June 2006)
 Cell (May 2007)	 Rotation (May 2007)	 Continuous (May 2007)
 Cell (June 2008)	 Rotation (June 2008)	 Continuous (June 2008)
 Cell (May 2009)	 Rotation (May 2009)	 Continuous (May 2009)

Figure 0.3. Changes in land condition at fixed points in the cell, rotational and continuous grazing systems at Frankfield between 2005 and 2009.

3.2.7. Cover analysis

3.2.7.1. VegMachine vegetation cover time series (Landsat)

Vegetation cover generally followed seasonal patterns with significant increases following a run of near average or higher rainfall years (1997-2000) and sharp declines in drought years such as the early 1990's and from 2002. However, in 2005, rainfall was below average and cover increased in all systems and across the whole property (Figure 0.4). This cover improvement can be attributed to a change in property ownership and a large reduction in cattle numbers, as well as winter rain that improved the pastures while the grazing pressure was reduced.

There was a substantial cover loss around 1990-91 which carried on into the drought years of the early to mid-nineties, which could be partially attributed to substantial tree clearing which started around 1988. The area where the cell paddocks are now located was developed to sown buffel pasture in 1998 causing a significant cover loss initially, compared with the other monitored areas, the rotation and continuous paddocks. After a run of good seasons from 1997 to 2000, cover eventually recovered to be similar in all three systems. This example highlights the risk in establishment of sown pastures linked to seasonal conditions.

There were also different cover responses during the two five-year drought periods. Ground cover in all areas dropped rapidly following prolonged below average rainfall between 1992 and 1996. The lowest cover was in 1994 in the rotation and continuous paddock areas on heavy gidgee soil (Figure 0.4). This was a severe drought year and blade-ploughing also started in the rotation paddocks in 1994 which would have reduced cover in spring when the cover images were taken. In the next significant drought starting in 2002, cover in all areas declined at a similar rate, but not to the same extent, as it had in the previous 1990's drought period (Figure 0.5).

The second extended drought from 2002-06 was not as severe as the earlier drought in 1992-96. However, it is likely that pastures are better managed in recent years since staff have attended pasture management courses and more recently there has been a change in ownership and reduced stock numbers. There was an increase in annual species in the pastures from 2007, which increased cover in the inter-tussock spaces of the perennial grass pastures. The current ownership and management systems provide flexibility in adjusting stock numbers to annual feed supplies. The property also has planned grazing management systems in place, including multiple cells, rotation paddocks and continuous paddocks which all receive some spelling.

Since 2001, the higher cover values in the cells (average) compared with the average of the other two grazing systems could be a product in part, of increasing woody regrowth, from brigalow suckers. Two cell monitor paddocks were blade ploughed and sown to grasses and silk sorghum in 2006-07 to manage this regrowth; this new pasture sowing and no grazing to allow the pasture to establish, contributed to a high cover response in the winter of 2007. The rotation and continuous paddocks are well grazed with breeder herds throughout the year, while the cell paddocks are spelled during summer to provide feed for growing cattle from late summer/autumn. This summer rest provides an opportunity for pasture recovery and a good cover to be produced and maintained into late winter when the Landsat images were recorded.

The scattered trees and regrowth in the cell paddocks and the continuous paddock are included in these cover assessments. The two rotation paddocks are almost totally cleared, so only pasture is included in the cover analysis of that grazing system. Frankfield has had some of the widest fluctuations in cover of the GSP sites, with the index ranging from near 10 to over 90. This site also has a correspondingly wide range in annual rainfall, between 220 mm and 1100 mm between 1994 and 2000.

The neighbour catchment, Mistake Creek, includes some extensive timbered areas which maintain a relatively high degree of cover in all years, compared with the cleared country of the monitor paddocks.

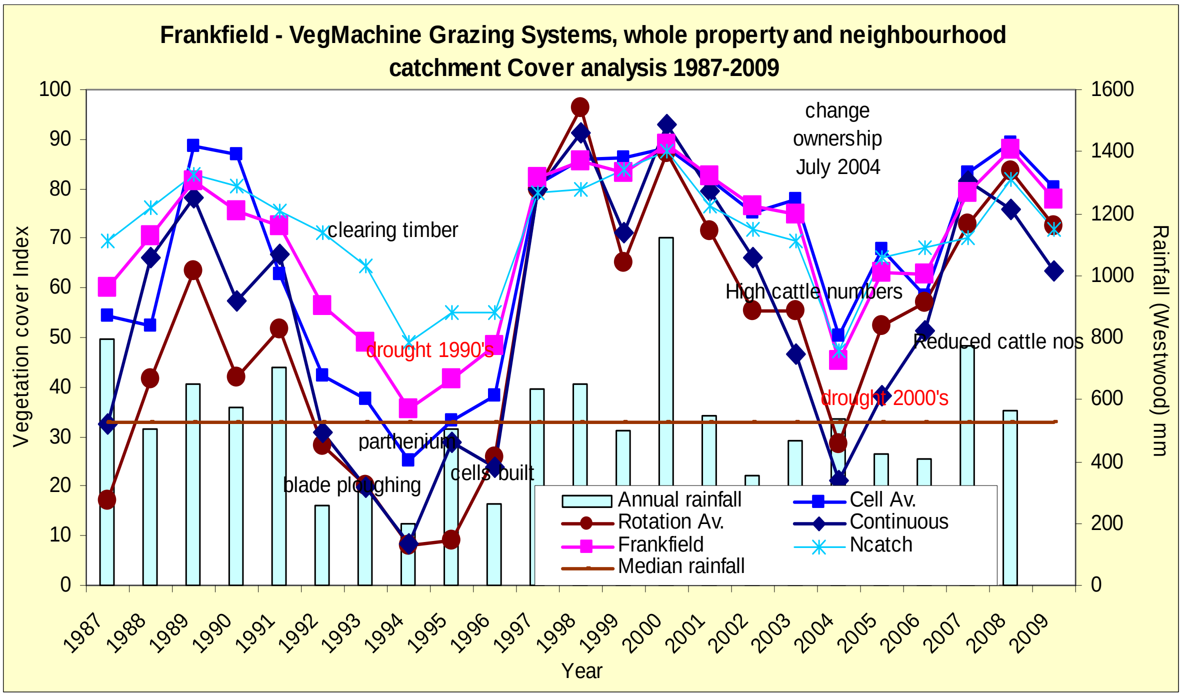


Figure 0.4. Vegetation cover index between 1987 and 2009 for grazing systems, the whole property at Frankfield, and the Mistake Creek neighbourhood catchment. Annual and long-term median rainfall (calendar year) is also shown.

During drought periods such as the early 1990's, the rotation (Carrington's and Road) and continuous (Mitchell) paddocks, which run the main breeder herd have been well grazed and had minimal cover, lower than the cell areas and the average of the whole property. This period also coincided with blade-ploughing of these paddocks. Cover increased rapidly from the buffel pasture recovery with better rainfall seasons in the late 1990's from as low as index 5 up to 95 over three years.

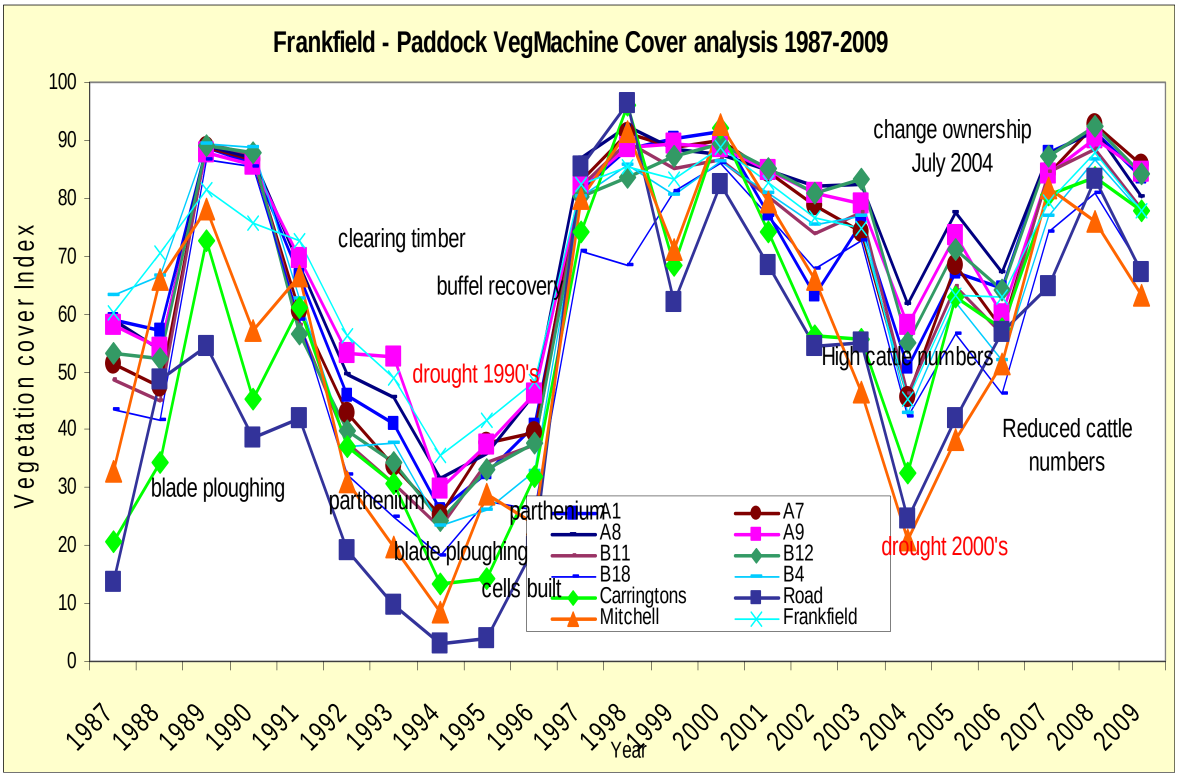


Figure 0.5. Vegetation cover index between 1987 and 2009 for the monitor paddocks at Frankfield. (Annual GCI data has been provided by DERM).

3.2.7.2. Botanal pasture cover analysis

Paddock and grazing system ground measurements of yields and cover in 2006 and 2007 (Table 0.14) show the inter-paddock range and that the cells have a lower pasture cover (around 40%, excluding regrowth) than the rotation or continuous systems (around 55%). This difference was not identified in the VegMachine analysis of these systems, possibly due to the inclusion of woody regrowth cover in the cell total cover.

Table 0.14. Ground measurements of pasture yield (kg/ha), total pasture cover (%), litter cover (%) and woody cover (%) in autumn 2006 and 2007 in paddocks and grazing systems at Frankfield.

Paddock / System	Yield (kg/ha)		Total Cover (%)		Litter Cover (%)		Woody Cover (%)*	
	2006	2007	2006	2007	2006	2007	2006	2007
Rotn-Road [1]	2910	1890	70	55	26	19	0.1	0.1
Rotn-Carrington's [2]	1620	1780	63	54	24	16	0.1	0.1
Cont-Mitchell [3]	1800	2640	50	49	15	7	0.4	0.5
Cell-A7 [7]	1160	1360	32	46	11	12	1.6	0.0
Cell-A8 [8]	1730	2330	45	45	14	12	1.3	1.2
Cell-A9 [9]	700	1620	24	42	10	11	1.4	2.7
Cell-B11 [11]	1860	1790	40	47	7	9	1.1	1.5
Cell-B12 [12]	1910	1800	42	36	13	12	1.2	0.2
Cell-B17 [17]		1680		40		12		1.3
Cell-B18 [18]	1650	2090	39	39	11	14	0.8	0.6
Cell-A1 [31]		3320		54		13		0.7
Continuous	1800	2640	50	49	15	7	0.4	0.5
Rotation	2270	1830	67	55	25	17	0.1	0.1
Cell - 2006	1500	1960	37	43	11	11	1.2	1.5
Cell - Blade		1580		41		12		0.1
Cell - 2007		2500		47		12		1.0
Site	1710	2030						

* Woody cover is woody regrowth recorded at Botanal quadrats.

3.2.7.3. Spatial ground cover reports

The average (2001-2005) ground cover index (vegetation cover) represented spatially (map format) for the cell, rotation and continuous paddocks and the whole property at Frankfield from satellite data shows lower and more variable cover in the two rotation and continuous paddocks compared with a more uniform and higher cover in the cell paddocks (Figure 0.6). The woody regrowth cover, up to 3% in one cell paddock, is included in this assessment. The cultivation paddocks (orange colour) and the timbered Mazeppa National Park (dark green) to the east of the rotation paddocks are clearly identified.

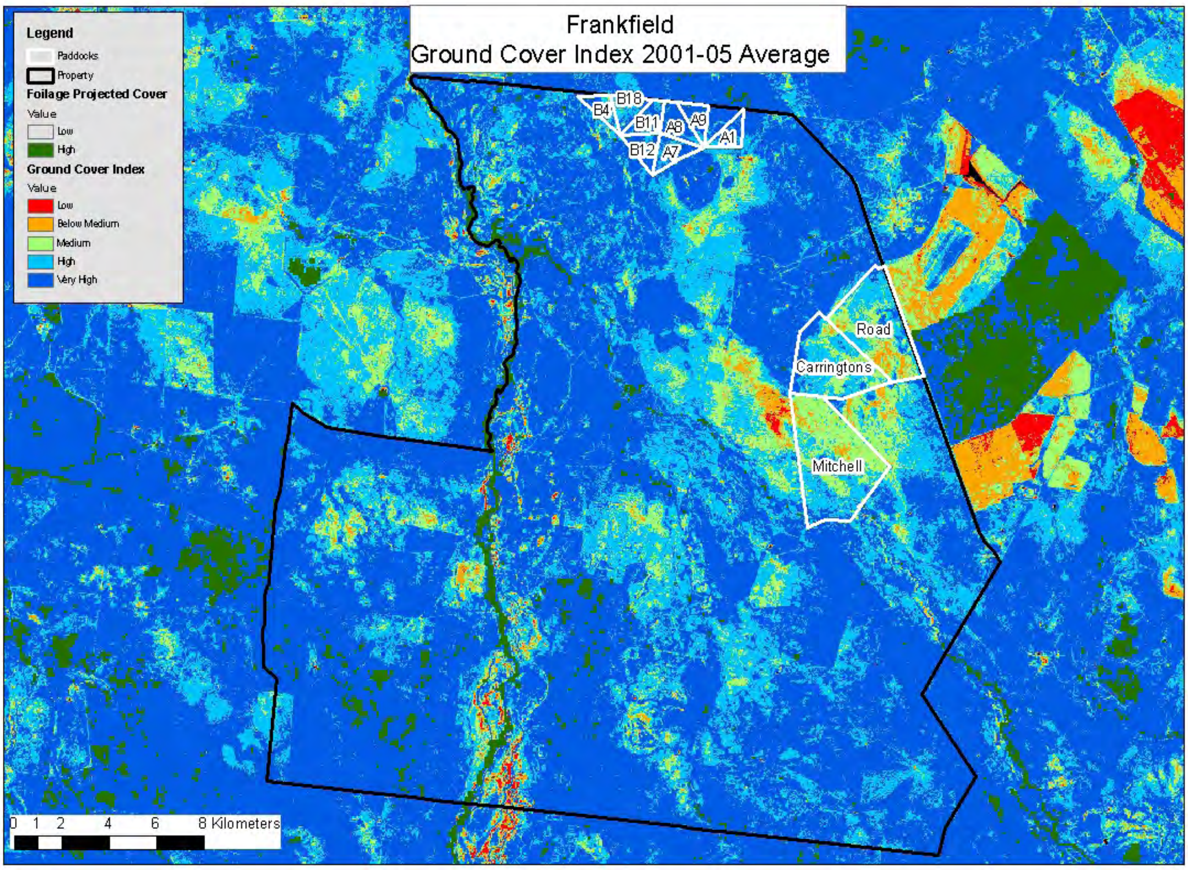


Figure 0.6. Average (2001-2005) ground cover index (vegetation cover) image for the cell, rotation and continuous paddocks, and the whole Frankfield property and surrounding properties (source spatial ground cover report).

Summary:

The QDERM modelled pasture yield (2000 to 3000 kg/ha) and GCI cover (around 60) for the whole property is similar to the GSP field measured results for the first two years of monitoring, 2006 and 2007 (Table 0.14). The pasture growth models (Aussie Grass) predicted much a higher yield and cover in the 2008 season, however there was no field recording this year to confirm this result (Long-paddock web site).

The GSP fixed-point photographs of the pastures in the three systems in 2008 show good pasture growth and cover in all paddocks. This site has a close relationship between the AussieGrass predicted ground cover and the Landsat imagery assessed cover which gives us some confidence in using these models in this environment for relative cover comparisons, however, the modelled cover % is higher than our field measured results.

3.3. Cattle Grazing

3.3.1. Carrying capacity – long-term

The estimated long-term carrying capacities (AE/100 ha and SDH/yr) from all landtypes of the three systems are:

Cells	15 AE/100 ha (56 SDH/yr)
Rotation	15 AE/100 ha (54 SDH/yr)
Continuous	19 AE/100 ha (68 SDH/yr)

3.3.2. Rest periods

The average rest periods between grazing events fluctuated annually for the three systems, from 77 to 311 days in the cells. The rotation paddocks received the most even rest of around 50 days between grazing events. The continuous system received rest periods every year (Table 0.15).

Table 0.15**.** Annual average rest period between grazing events (days) and total number of rest days for grazing systems at Frankfield.

Year	**Rest periods (days)**		
	Cell	**Rotation** Average (total)	**Continuous**
2005-2006	77 (354)	-*	72 (72)
2006-2007	247 (360)	55 (58)*	100 (199)
2007-2008	154 (348)	58 (200)	45 (89)
2008-2009	311 (356)	49 (96)	99 (99)
Average	**197 (354)**	**54 (118)**	**79 (115)**

* data incomplete due to drought management across multiple paddocks.

3.3.3. Grazing days

The annual average number of days of grazing was 11, 181 and 255 days for the cell, rotation and continuous systems respectively. They had an annual average of two, six and two grazing events or herd number changes per year respectively. The annual number of days grazing in the cell paddocks ranged from three to 23 days per year, with a range of one to six grazing events per year. Over all years the rotation paddocks received from 61 to 222 days grazing per year with two to 11 changes in herd numbers. The continuous system was grazed from 166 to 322 days with 1 to 3 herd changes per year over the four years.

3.3.4. Grazing pressure

The animal numbers taken from property records for each system have been converted to Animal Equivalents (AE) using the standards tables presented in the appendix 9.10. An AE is equivalent to a dry cow weighing approximately 450 kg. Comparing the grazing pressure on each system in total AE/ha, equivalent to stock days per ha (SDH), related to rainfall over the 12 months prior to each grazing event, shows the rotation and continuous systems received similar grazing (average 29 SDH/100mm), but much higher than the cells (18 SDH/100mm) in all years except in 2005-06 (Table 0.16). Records were incomplete for the rotation system in the first two years due to multiple paddocks being open at one time as a drought management strategy. On occasions four rotation paddocks were open at once, so grazing could not be allocated to a single monitor paddock.

Table 0.16. Grazing days per 100mm rainfall over previous 12 months from each graze for grazing systems at Frankfield (SDH/100mm rainfall).

Year	**Grazing pressure (SDH/100mm)**		
	Cells	**Rotation**	**Continuous**
2005-06	34	10*	26
2006-07	10	46	33
2007-08	14	32	31
2000-09	13	19	23
Average	**18**	**29**	**28**

*Rotation system data is incomplete in 2005-06.

The average grazing for the three systems was: 99, 175 and 178 SDH for the cell, rotation and continuous systems respectively, compared with a long-term carrying capacity (LTCC) estimation using 30% utilisation of 61, 52 and 73 SDH. This higher grazing pressure is of concern for long-term pasture and land condition maintenance.

There were significant differences between the average annual grazing pressure on the three systems over the four-year monitoring period, with the cell system having the lowest rates measured as SDH, SDH/100mm rainfall over the previous 12 months to each grazing event and in stocking rate measured in ha/AE (Table 0.17). There were also significant between-year differences, with the highest grazing pressure in 2005-06 and 2007-08 years.

Table 0.17**.** Grazing system and year effect on stock days per ha (SDH), SDH per 100mm rain and annual stocking rate (ha/AE) at Frankfield*.

Treatment	Grazing pressure								
GS x Year	Stock days per ha (SDH)			SDH / 100 mm rain			Annual stocking rate (ha/AE)		
Grazing System	**			*			*		
Cell	4.40	(81)	b	2.75	(15)	b	1.74	(4.7)	a
Rotation	5.06	(156)	a	3.31	(26)	a	1.24	(2.4)	ab
Continuous	5.17	(175)	a	3.37	(28)	a	1.13	(2.1)	b
Av. s.e.d.	0.30			0.29			0.25		
Year	*			*			*		
2005-06	5.24	(187)	a	3.62	(36)	a	1.07	(1.9)	b
2006-07	4.50	(89)	b	2.95	(18)	b	1.70	(4.5)	a
2007-08	5.08	(159)	a	3.11	(21)	ab	1.21	(2.3)	b
2008-09	4.70	(108)	ab	2.89	(17)	b	1.51	(3.5)	ab
Av. s.e.d.	0.27			0.26			0.22		
GS x Yr	*			**			*		
Cell-05/06	5.09	(161)	a	3.55	(34)	a	1.19	(2.3)	b
Cell-06/07	3.76	(42)	b	2.31	(9)	b	2.28	(8.8)	a
Cell-07/08	4.51	(90)	ab	2.62	(13)	a	1.63	(4.1)	ab
Cell-08/09	4.24	(69)	ab	2.51	(11)	a	1.87	(5.5)	ab
Rot-05/06	3.97	(52)	b	2.39	(10)	b	2.08	(7.0)	a
Rot-06/07	5.24	(188)	a	3.67	(38)	a	1.12	(2.1)	b
Rot-07/08	5.50	(243)	a	3.47	(31)	a	0.92	(1.5)	b
Rot-08/09	4.80	(120)	ab	3.00	(19)	ab	1.40	(3.1)	ab
Cont-05/06	5.02	(150)	a	3.29	(26)	a	1.23	(2.4)	a
Cont-06/07	5.20	(181)	a	3.52	(33)	a	1.11	(2.0)	a
Cont-07/08	5.45	(232)	a	3.47	(31)	a	0.94	(1.6)	a
Cont-08/09	5.02	(150)	a	3.19	(23)	a	1.23	(2.4)	a
s.e.d. w/i GS	0.48			0.45			0.40		
s.e.d. w/i Yr	0.50			0.46			0.42		

n.s. – $P > 0.10$; * $P < 0.05$; ** $P < 0.01$.
* Data were log-transformed prior to analysis. Back-transformed means are given in parentheses. Means not followed by a common letter are significantly different (P=0.05).

The continuous and rotation systems had significantly higher grazing pressure than the cells measured in SDH, SDH/100mm rainfall and in ha/AE (Table 0.17). For example the continuous system averaged 178 SDH compared with 97 SDH in the cells over the four years of monitoring. The rotation was 175 SDH. There was a similar difference in SDH/100 mm rainfall with the larger paddock systems supporting 29 SDH/100 mm rain compared with 18 SDH/100mm in the cells.

The grazing pressure in the cells was similar to the LTCC, while that in the rotation and continuous systems was much higher. The cells had an annual average stocking rate of 5.7 ha/AE compared with the LTCC of 6.5, the rotation paddocks were grazed at 3 ha/AE compared with LTCC of 6.7, and the continuous paddock was run at 2.1 ha/AE compared with a LTCC of 5.4.

3.3.5. Grazing system intensity index

The grazing system intensity index values (GSI range 1-100; calculated from capital costs, operating costs and management inputs; details are reported in Appendix 9.13) for the three systems at Frankfield were:

Cells	75
Rotation	52
Continuous	21

3.3.6. Diet quality (NIRS)

3.3.6.1. Analysis of all samples over four years

Comparing all NIRS diet quality results (80 samples), the overall differences between systems were small, with a trend of increasing crude protein from the cells (mean 7%) to the continuous system (8%), and the rotation system intermediate (Table 0.18). The trend and differences between the other diet quality parameters were similar, but not statistically significant with the wide ranges over the late winter to mid-summer periods. For example, crude protein ranged from 14.2% in the continuous paddock in February 2007 to 3.7% in mature pastures in August 2008 in the rotation system.

As expected, there was a significant difference in digestibility between the growing season (57%) and non-growing (54%) season. Predicted liveweight gain was also higher in the growing season, 0.68 kg/day, compared with 0.55 kg/day. Non-grasses, native forbs and tree leaves, were a higher proportion of the diet in the winter months (15%) compared with 10% in summer.

Table 0.18**.** Mean faecal NIRS diet quality results (all samples) for grazing systems at Frankfield between December 2005 and June 2009.

Grazing System	No. samples	Crude protein %	Faecal N %	Digesti-bibility %	Non-grass %	LWG kg/day	DMD/CP ratio
Cells	25	7.4	1.3	55	14	0.57	8.3
Rotation	32	7.8	1.3	56	11	0.62	7.6
Continuous	23	8.0	1.4	56	13	0.64	7.3
sed (av.)		0.99	0.09	1.14	3.3	0.13	0.8
Significance		ns	ns	ns	ns	ns	ns
Average	(total 80)	**7.7**	**1.3**	**55**	**13**	**0.60**	**7.6**

3.3.6.2. Analysis of samples collected at the same time

There were 20 occasions when the three systems were sampled at the same time. On these occasions the cells had on average a slightly lower (about 0.8%) crude protein and digestibility (1%) than the other two systems, although these differences were not statistically significant (Table 0.19).

Table 0.19. NIRS estimates of diet quality from cell, rotation and continuous systems when samples were collected from all three systems on the same day.

Grazing System	No. samples	Crude protein %	Faecal N %	Digestibility %	Non-grass %	LWG kg/day	DMD/CP ratio
Cells	20	6.6	1.22	54	13	0.44	8.4
Rotation	20	7.6	1.30	55	12	0.57	7.5
Continuous	20	7.4	1.31	55	10	0.51	7.7
sed (av.)		0.86	0.06	1	5	0.19	0.8
Significance		ns	ns	ns	ns	ns	ns
Average	(total 60)	**7.4**	**1.28**	**55**	**13**	**0.57**	**7.7**

3.3.6.3. NIRS related to pasture growth index

The NIRS values were examined by dividing them into groups which had different pasture growing conditions on the basis of the pasture Growth Index (GI) derived from GRASP modelling (where 0.0 = conditions are unsuitable for growth and 1.0 = conditions are not limiting growth). Average values of the GI for the 30 days ending on the sample date were calculated. Based on these values three classes were formed – mean GI <0.2 (Poor growing conditions), 0.2-0.5 (Average) and >0.5 (Good conditions). For the average and good GI classes, the cell system had the lowest crude protein values, with the greatest differences (2.4% CP and 4% digestibility) when the pastures had the better growing conditions, GI >0.5 (Table 0.20). There were negligible differences between systems when the pastures were dry and not growing (GI <0.2).

Table 0.20. Mean NIRS results in relation to growth indices for three grazing systems at Frankfield.

Growth Index	Grazing System	No. samples	Crude protein (%)	Faecal N (%)	Digestibility (%)	Non-grass (%)	LWG (kg/day)	DMD/CP ratio
<0.2	Cell	9	6.7	1.21	54	14	0.38	8.2
	Rotation	15	7.1	1.26	54	13	0.46	8.0
	Continuous	6	6.2	1.12	53	11	0.27	8.5
0.2-0.5	Cell	9	7.4	1.33	55	11	0.69	7.7
	Rotation	10	8.0	1.41	54	16	0.64	7.4
	Continuous	10	8.1	1.36	54	14	0.68	6.9
>0.5	Cell	7	7.1	1.29	56	11	0.64	8.8
	Rotation	7	9.3	1.44	59	11	0.91	6.5
	Continuous	7	9.5	1.63	60	16	0.84	6.7
sed (av.)			0.98	0.11	2	4	0.14	0.8

3.3.6.4. Monthly CP, DMD and non-grass

The monthly changes in crude protein, digestibility and non-grass in the diet selected by cattle in the three grazing systems are shown in Figure 0.7 (continuous), Figure 0.8 (rotation) and Figure 0.9 (cell). The approximate maintenance level of crude protein (horizontal bar) shows all systems can have diets of near maintenance or below in winter and that 2008 produced the most protein deficient diets. The cells had the highest number of samples near maintenance protein level. There was a wide range of crude protein levels between late winter and mid summer, ranging from 5.6% – 13.0% in the cells, 3.7% – 12.5% in the rotation and 5% – 14.2% in the continuous system.

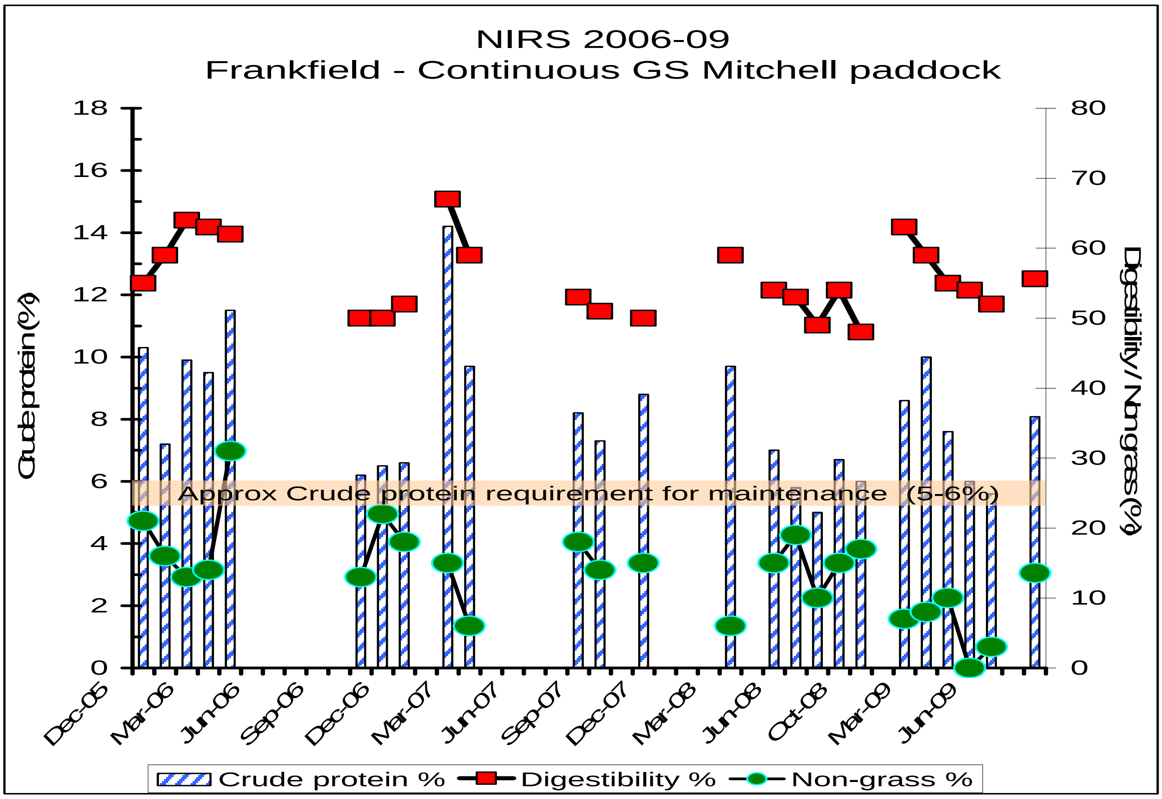


Figure 0.7. NIRS sample results for the continuous grazing system at Frankfield for crude protein (%), digestibility (%) and non-grass (%) with approximate maintenance crude protein indicated.

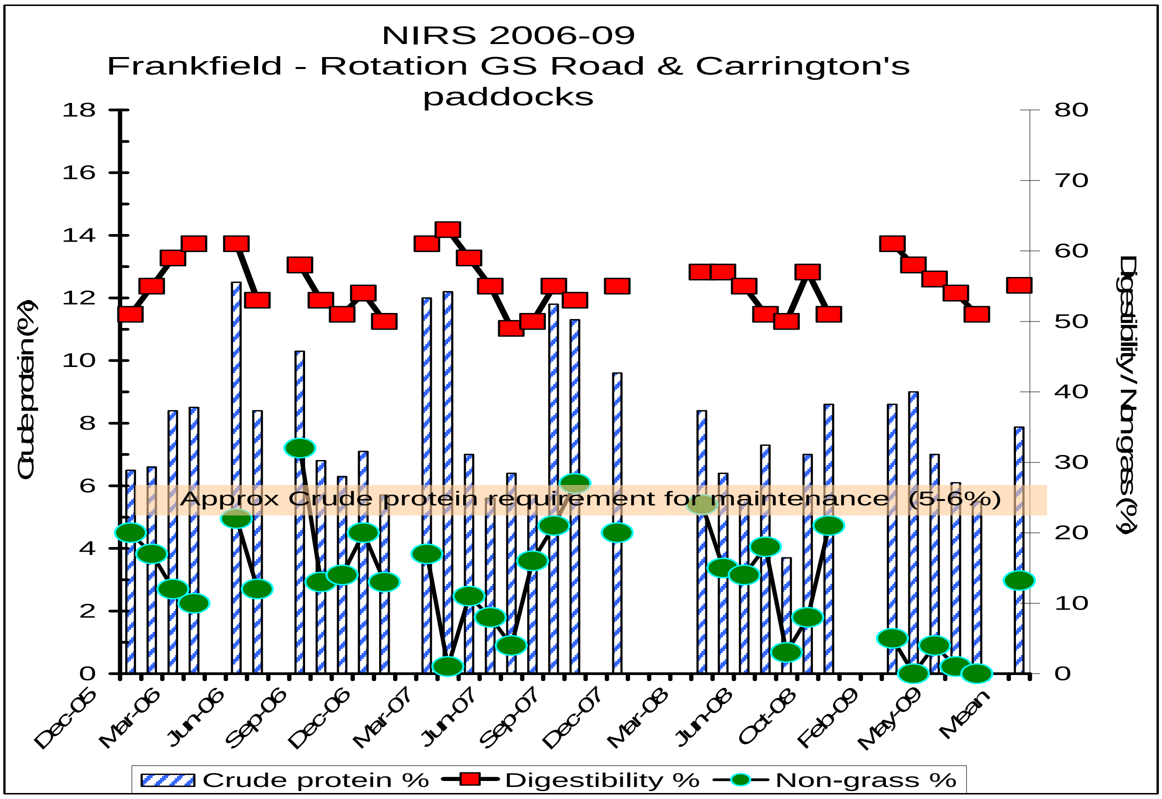


Figure 0.8. NIRS sample results for the rotational grazing system at Frankfield for crude protein (%), digestibility (%) and non-grass (%) with approximate maintenance crude protein indicated.

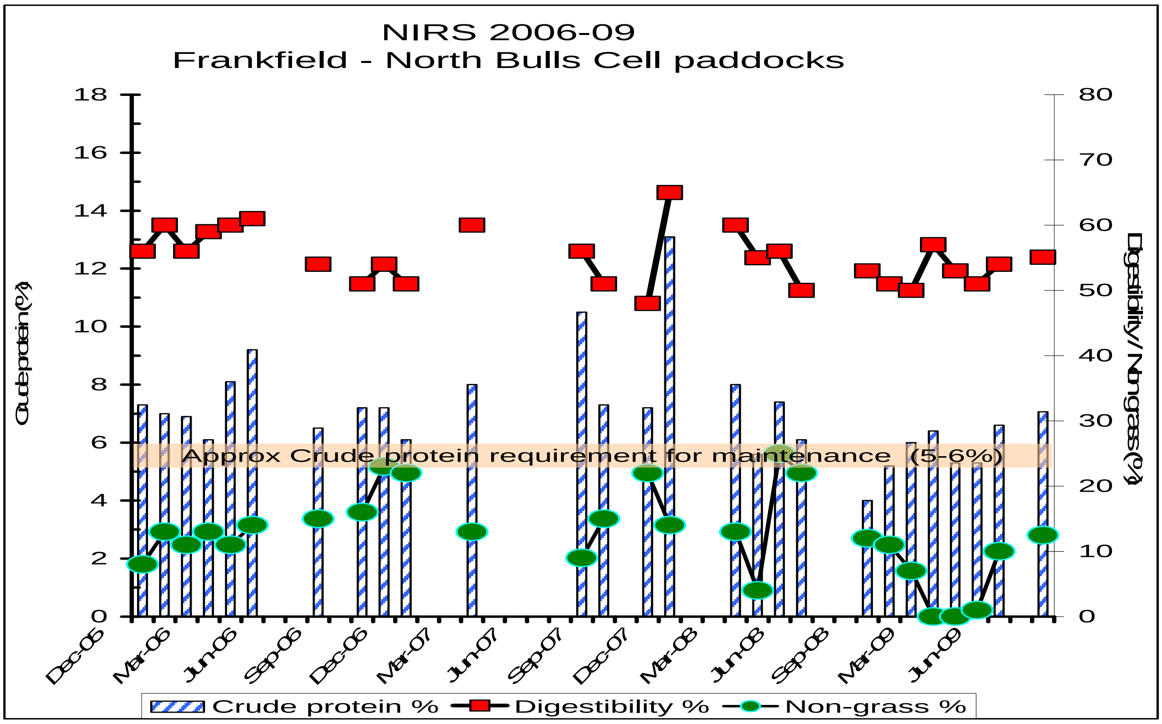


Figure 0.9. NIRS sample results for the cell grazing system at Frankfield for crude protein (%), digestibility (%) and non-grass (%) with approximate maintenance crude protein indicated.

3.4. Grazing System Costs

The grazing systems at Frankfield comprise two sets of cells; respectively 29 cells on three cell centres, and 28 cells on four cell centres; and a rotation system of eight paddocks centred on five watering points. Fencing is comprised of 121 km of two-wire electric fence in the cell paddocks and a further 10 km of electric fence in the rotation paddocks. The remaining fences are pre-existing barb wire fences with wooden posts. Water is reticulated through 18 km of 63 mm polythene pipeline and other water infrastructure includes 12 cup and saucer troughs, a turkey nest dam, five polythene tanks and two pump/motor units. The bulk of the site development, fencing and pipe-laying was completed using station plant, machinery and labour.

3.4.1. Capital costs

The estimated replacement capital cost of the cell grazing system is $241,000 (Table 0.21) comprising of fencing, watering, labour and planning costs.

Table 0.21**. Replacement capital costs of cell grazing systems.**

Item	**Cost ($)**
Fencing	69,436
Water	55,354
Troughs	27,600
Tanks	0
Pumps, mills	21,000
Installation	65,663
Consultancies	2,000
Total	**241,052**

3.4.2. Operating costs

For reasons of privacy and confidentiality, the annual running costs that are associated with the case study grazing systems is not presented.

An indicative guide to the operating cost of a given system is the estimated annual capital reclamation cost (sinking fund depreciation charge), which is the equivalent sum that would need to be set aside each year to maintain the capital assets invested in the systems infrastructure. The reclamation cost has been estimated using standard farm accounting depreciation factors for the main assets listed in the preceding table, including: bores (7.5%), dams (2.5%), fencing (5%), and plant (10%). This gives a projected capitalised cost for the case study enterprises of approximately $8,000 per annum (Table 0.22) comprising mainly of fencing and water maintenance costs.

Table 0.22. Operating costs of cell grazing systems.

Item	Cost ($)
Fencing	3,472
Water	1,384
Troughs	690
Tanks	0
Pumps, mills	2,100
Total	**7,652**

Conclusions

4.1. Pasture and land condition

Visual assessments of land condition at Frankfield rated the continuous and rotation systems in A condition and the cells in slightly lower condition (A/B) due to more regrowth, loss of A horizon soil and scalded eucalypt patches in parts of the cells. The PatchKey analyses showed an improvement in condition in all systems over the four years with best condition in 2009.

The pasture yields varied with grazing system and year, seasonal conditions, but there were no consistent differences between grazing systems. Yields were higher in 2009 than in 2006 and 2007. All systems were buffel grass dominant, but there was more native perennial grass in the cells than in the other two systems.

Levels of woody regrowth were negligible in the rotation and low but increasing in the continuous paddock. Regrowth levels were highest in the cell system and convinced the owners to blade plough some paddocks which gave good regrowth control. Regrowth continued to increase in some other cell paddocks.

Overall, field measured ground cover levels were highest in the rotation, intermediate in the continuous and lowest in the cell system. Differences between systems decreased with time and the highest levels in all systems were in 2009. Litter levels varied with both grazing system and year (7 to 35%) but there was no consistent pattern in the differences.

There were few differences between grazing systems for the three LFA indices and no consistent trends in values.

The VegMachine analyses showed quite wide differences between grazing systems in the past (e.g. in the mid-1990's), but much smaller differences during the experimental period. The values of the ground cover index were low in 2004 (20-60) and there was a general increase in the following years. The continuous and rotation systems had lower values than the cell area in 2004, but by 2006 values were similar for all systems. There were further increases in the values of the cover index in 2007 and 2008 although there was little difference between systems.

4.2. Carrying capacity and grazing

Although the three systems were ecologically similar with buffel grass dominant pastures, the continuous (annual average 188 SDH) and rotation (175 SDH) systems supported much higher grazing than the cells (100 SDH). This is partly due to the management system where the cells were spelled over the main wet season to provide maximum forage for growing steers throughout the dry season. However, the cells still produced marginally lower pasture dry matter yield from a lower cover base while supporting this lower grazing.

The average grazing pressure of 30 SDH/100 mm rainfall in the two larger paddock systems was much higher than that in the cells at 18 SDH/100mm. Compared with the LTCC of 5.4 to 6.7 ha/AE, the larger paddocks were grazed at twice this stocking rate at less than 3 ha/AE. The cells were grazed at 5.7 ha/AE on an annual basis which is near the LTCC of 6.5 ha/AE for this pasture, land condition and land type.

The diet quality (NIRS results) between the systems indicated the continuous system had the highest quality, followed by the rotation and cells lowest. This difference in crude protein and digestibility was during the pasture growing or green phase and not during the non-growing period. Over all samples, ranging 3.7% to 14.2% crude protein, the trend was not statistically significant.

4.3. Owner's comments on grazing systems

4.3.1. New management

The three systems are used for particular purposes and each is considered well suited to the desired goals.

4.3.2. Results

The cells simplify weaner training and cattle are growing at an acceptable rate.

The rotation system is suited to breeding, as is the continuous system with spelling incorporated as normal management. Multiple rotation paddocks can be opened together to reduce grazing pressure and still allow the breeders access to larger areas for extended periods, which also reduces cattle handling.

The steers from the cells are grown out and fatten in a continuous or rotation system, not in the cells. When fattened in the large paddocks they are sold as bullocks direct to meat works. Overall cattle numbers have been reduced from that run by the previous owners, with proportional pasture and land condition benefits.

The cattle training value of the cell system is highly valued, however, an additional specific labour unit is required to operate the cells. This person also contributes to other work on the station.

4.3.3. Future plans

It is planned to reduce the number of cell paddocks by opening two current paddocks to make one, which will make management easier. In an attempt to improve pastures higher cattle numbers will be introduced and some grazing over summer will be tried.

4.4. Conclusions

There are small ecological differences between the systems at Frankfield, but these can be attributed more to the different stages and rates of development, seasonal responses and cattle management practices than to the actual grazing systems. The cells have been managed along commercial lines that suits a property of this scale, location, soil types and beef enterprise system, but it could be refined to be more closely aligned with recommended principles. This may help achieve the desired increase in the rate of change in pastures, manage woody regrowth and produce a higher grazing performance than is currently experienced.

At present the rotation and continuous systems support more grazing and with a marginally higher diet quality than does the cell system. The three systems have pastures providing good soil cover which was maintained at adequate levels even during the latest extended drought period. The recent ownership change, pasture management trained staff and an overall consideration of land condition means the three systems are all well managed relative to annual pasture growth and all pastures are in good condition. However, the grazing pressure during the project period in the two larger paddock systems was higher than the LTCC estimates based on 30% utilisation. If these estimates of LTCC are accurate, this grazing pressure will not be sustainable. The cells are managed at the LTCC level. Ecological differences were not consistent or strongly associated with the grazing system.

Melrose

Abstract

'Melrose', Morinish, has three grazing systems; cells, rotation and continuous. Five cell paddocks, two rotation and one continuous paddock were monitored between 2006 and 2009. The three systems are used for breeding cattle; mature breeders are run in the cell and rotation systems and first calf heifers are run in the continuous system. There was a drought in the first two years followed by two above average rainfall years. The pastures were sampled in late autumn in 2006, 2007 and 2009. Yields were similar in all systems and increased from 1800 kg/ha in 2006 to 5000 kg/ha by 2009 as seasons improved. All pastures were native grass dominant (70%).

The rotation and cells supported higher average grazing pressure (110 SDH; 17 SDH/100mm rainfall) than the continuous system (87 SDH; 13 SDH/100mm rainfall). This grazing is similar to LTCC. There was good pasture recovery on degraded patches in all systems in the final two consecutive good rainfall years. NIRS diet quality (crude protein and digestibility) was consistently highest in the continuous system and lowest in the cells. This superiority in the continuous system occurred over the growing season. The three systems are used as part of an integrated property breeder enterprise. The ecological differences were not consistent or strongly associated with the grazing system.

1. Site Introduction

1.1. Location

'Melrose' is located approximately 60 km north-west of Rockhampton (23.2ºS; 150.0ºE) in Morinish district of the Fitzroy River catchment (Figure 1.1).

Figure 1.1. **Native pasture in open eucalypt woodlands at Melrose.**

1.2. Climate/growing season

The average annual rainfall is 690 mm (Table 3.1) with 71% falling in summer (October-March). The growing season is predominantly in summer, but with significant winter rain in some years there can be important winter pasture growth with subsequent beneficial impacts on pasture quantity and quality.

Based on long-term climate data, the average green season for tropical pasture species is estimated to be 35 weeks including 18.6 growth weeks. With the winter rain, temperate species would add an average of 3.8 weeks to the growth of tropical species.

1.3. Major soil/vegetation types on property

The original vegetation was an open woodland with silver-leafed ironbark (*Eucalyptus melanophloia*) and narrow-leafed ironbark (*Eucalyptus creber*) the major tree species, with some bloodwoods (*Corymbia* spp.). All experimental areas have been cleared or thinned to sparse tree cover. The major grass species are native bluegrasses (*Bothriochloa* spp.) and black speargrass (*Heteropogon contortus*) and sown buffel grass (*Cenchrus ciliaris*), with widespread Seca stylo (*Stylosanthes scabra*) and some Sabi perennial urochloa (*Urochloa mosambicensis*). The terrain is undulating to low hills. Red and yellow duplexes are the major soil types, some with gravelly to stony surfaces and outcrops (Table 1.1).

Table 1.1. Areas (ha) of land types in the monitor paddocks of three grazing systems at Melrose.

Land type	Land type areas (ha)		
	Cells	Rotation	Continuous
Alluvial brigalow	7		49
Blue gum-River red gum flats	62	48	6
Silver-leafed ironbark on duplex	136	274	506
Total area	**205**	**322**	**561**

1.4. GRASP modelling of long-term pasture growth

Over 90% of the sampled area was in the “Silver-leafed ironbark on duplex” landtype, so this landtype was modelled for average annual pasture growth.

1.4.1. GRASP parameters

The values for a number of important GRASP model parameters, tree basal area, soil water and nitrogen, for the annual pasture growth simulations on the major land type, “silver-leaved ironbark on duplex” at Melrose are given in Table 1.2.

Table 1.2. Land type parameters for “silver-leaved ironbark on duplex soil” used in the GRASP model to estimate pasture growth at Melrose.

GRASP parameter	Units
Tree basal area (m^2/ha)	1
Available soil water (mm)	202
Maximum N uptake (kg/ha)	25
Regrowth (kg/ha/%BA)	6
Transpiration use efficiency (kg/ha/mm)	15
Minimum N concentration (%)	0.4

1.4.2. GRASP results

The GRASP model was run using climate data from SILO for the period 1889 to 2009 and annual pasture growth for the period July 1 to June 30 was estimated. The median annual pasture yield value for Melrose was 5020 kg/ha (Figure 1.2).

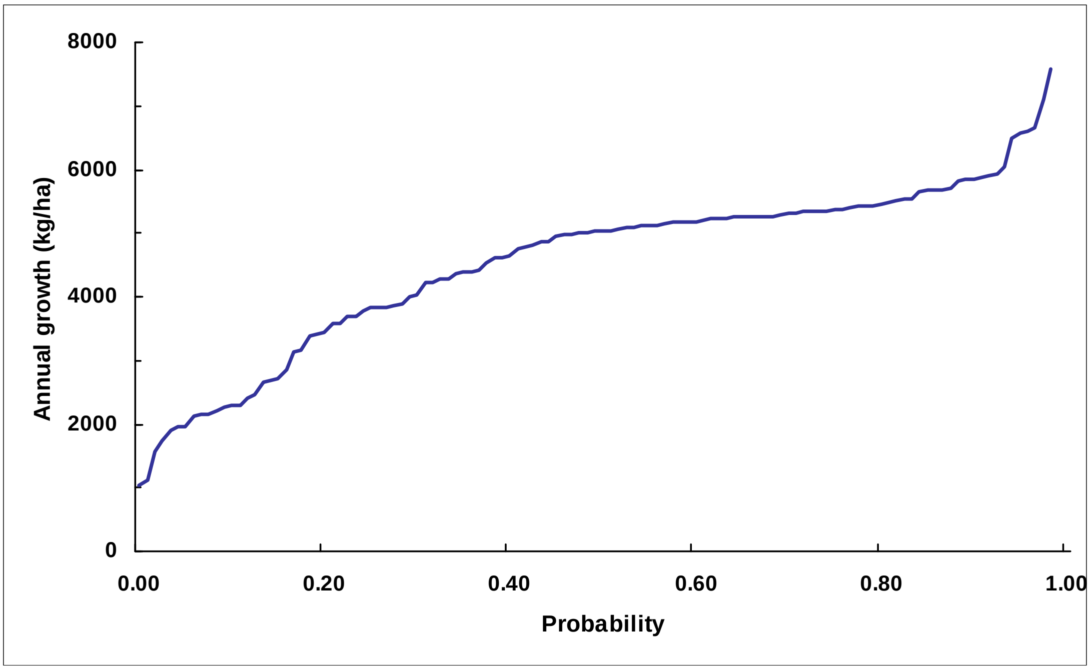


Figure 1.2. Long-term distribution of estimates of annual pasture growth at Melrose.

1.5. Production system/markets

The production system involves breeding and finishing heavy steers largely for north Asian markets.

1.6. Producer goals

The cell component of the system was introduced to offset declining productivity of the affected paddocks. For example, when this land was purchased 14 years previously it was rated to carry approximately 300 breeders, but by the time the cells were actually established this had declined to approximately 175-180 breeders and there were many bare areas in the paddocks. The stated objective of the cell grazing system was to improve the condition of these pastures and to (eventually) raise stock numbers back to a level consistent with the original carrying capacity.

The rotation paddocks component of the grazing system was established on land which was also deteriorating, but not judged to be in as poor a condition as that underlying the cell system. This decline was estimated to be equivalent to a reduction in carrying capacity of the pastures of approximately 200 AE. The owners' did not feel that the condition of this land warranted the expense and time commitment associated with cells in order to meet their objective.

The decision to proceed with cells and rotational grazing systems was motivated by participation in a dedicated cell-grazing course, and involvement with the Fitzroy River and Coastal Catchment Association. The cell design was largely prepared by a consultant with some local modification, while the owners largely designed the rotational paddock component of the system.

Increasing stock numbers was not formally cited as a principal objective of establishing the grazing system. However, the owners would be pleased with an outcome that returned the carry capacity to the level at which it stood when the holding was acquired – this involves an increase to approximately 250 AE on the cell paddocks and approximately 200 AE on the rotational paddocks.

2. Grazing systems

2.1. Description

Three grazing systems were studied – cell, rotational and continuous.

The cell system (Mary's cells) has 28 paddocks (average size approximately 40 ha); five paddocks were monitored. Initially the cells carried approximately 200 breeders but the numbers were increased to 290 dry cows and heifers (279 AE) by June 2009, after two consecutive good pasture growing seasons. The animals are moved at 1-3 day intervals. The cell system was established in May 2005.

The rotational system (Top paddocks) has eight paddocks (total area = 1020 ha) where the cattle (140 breeders and progeny) are rotated on a 1-2 week basis (carrying 495 AE in June 2009); two paddocks, Dam and Alston's, (322 ha) were monitored.

The continuous paddock, Green Gully, (561 ha) is grazed by first calf heifers, and was carrying 235 AE in June 2009.

The location of the eight monitor paddocks, identified by their Botanal recording number (Table 2.1) are shown on a Spot-5 image in Figure 2.1. The undulating landscape and variable pasture cover across all systems can be seen.

Table 2.1. Paddock names, numbers and areas sampled in three grazing systems at Melrose.

Vegetation	Grazing System	Paddock name [Botanal No.]	Area (ha)
Eucalypt	Cell	Mary's 7 [7]	40
		Mary's 16 [16]	27
		Mary's 17 [17]	49
		Mary's 20 [20]	45
		Mary's 22 [22]	44
		Total cell	205
Eucalypt	Rotation	Dam (Big) [52]	212
		Alston's [53]	110
		Total rotation	322
Eucalypt	Continuous	Green Gully [51]	561

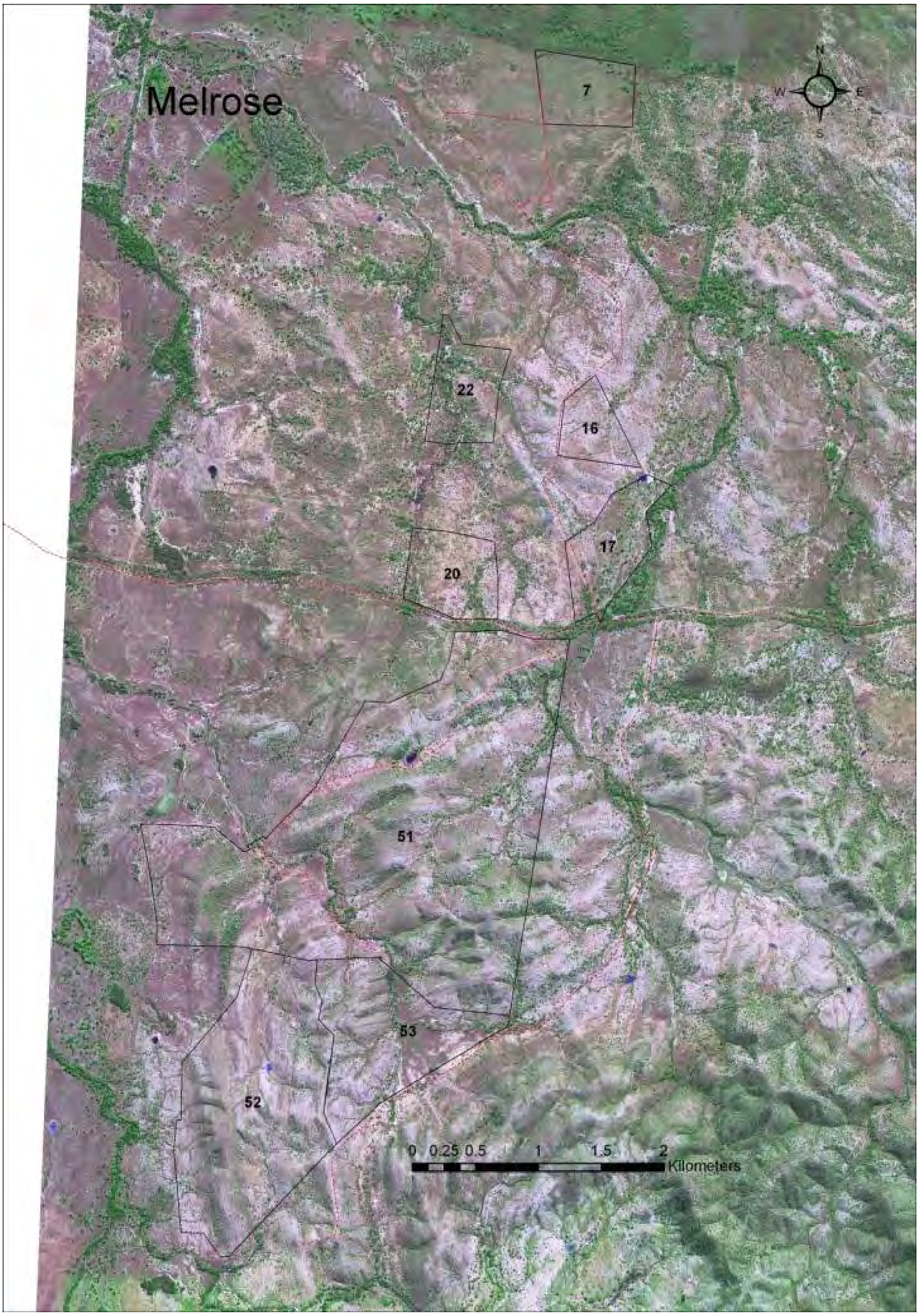


Figure 2.1. Layout of cell, rotational and continuous grazing system monitor paddocks at Melrose.

2.2. Management during 2005-2009

A mature breeder herd was run in the cells and numbers have increased from 100 to 126 SDH (25%) between 2005-06 and 2008-09, following pasture recovery during two extended above average growing seasons (2007-08 and 2008-09) which both received good summer and winter rainfall. The other systems have also increased in carrying capacity over this period, with the continuous system running first calf cows increasing from 78 to 112 SDH (43%) over the same time. The rotation system paddocks were being developed in 2005 and the two monitor paddocks carried 177 SDH in 2008-09.

In all systems all dry cows are culled every year, regardless of age. New pregnant heifers are added to the systems annually, about September-October, depending on pasture condition.

Attached to the cell system is a 142 ha paddock which is kept separately for the new heifers. Forty heifers were added after the good growing season of 2008-09, to be replacements for dry culls and to increase the cell herd as pastures improved. Pregnant heifers from this paddock will be added to the cell system breeder herd in June. The paddock can then be included in the cell rotation as required.

The rotation paddocks receive second calf heifers, after they have their first calf year in the continuous paddock (Green Gully monitoring paddock). Only pregnant heifers are added to the rotation herd and some may also be added to the cell herd depending on pasture capacity in the cell paddocks.

The continuous paddock receives all the first calf heifers. This system provides minimal disturbance to the heifers on their first calf. In 2009, heifers in this system produced 87% calving.

Bulls are introduced for three months, from 1 December to 1 March annually and weaners are removed about mid-May. All calves are weaned and dry cows are culled, usually direct to the local market.

3. Results

3.1. Growing Seasons

3.1.1. Rainfall

The monthly rainfall at Melrose (Table 3.1) shows the widely variable rain received during the monitoring period, with annual totals ranging from decile 2 (2006-07) to decile 9 (2007-08). Following the below average rainfall to drought conditions up to autumn 2007, Melrose then received two years of good rainfall, with some months receiving well above average in spring (e.g. 173 mm in September 2007), summer and winter.

Table 3.1. Monthly rainfall (mm) at Melrose from July 2004 – June 2009 and long-term average monthly rainfall (mm) at Westwood recording station over 123 years.

Year	**Monthly rainfall (mm)**													
	J	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**Total**	**Decile**
2004/05	0	0	15	36	54	137	260	39	1	12	39	55	649	5
2005/06	0	16	3	96	42	79	40	9	107	72	11	115	590	4
2006/07	19	0	40	0	91	36	29	112	12	0	5	144	488	2
2007/08	0	27	173	4	74	109	174	302	25	5	1	3	898	9
2008/09	106	3	0	30	89	118	80	196	20	38	0	13	692	6
Long-term Mean	**32**	**23**	**25**	**43**	**63**	**91**	**119**	**108**	**68**	**43**	**33**	**40**	**690**	

3.1.2. Growing conditions

2004-2005: Melrose received near-average rainfall with average totals for summer and spring. Average rainfall for these optimum grass growing seasons would have produced good quantities of high quality pasture.

2005-2006: Spring and early summer rainfall were favourable and provided good early growing conditions, but February rainfall was low with little growth. Approximately 100 mm in March gave a major boost to late season growth and all pastures were growing actively at the April pasture sampling.

2006-2007: Rainfall was well below average (decile 2) for the year with below average spring and well below average summer rainfall recorded. Such low totals, drought conditions, during the grass growing seasons resulted in low pasture yields and affected cattle performance.

2007-2008: This was an exceptionally good year for pasture establishment and growth, starting with 144 mm of rain in June 2007, followed by 173 mm in September, and well above average rain throughout summer. The 10-month total of 1033 mm from June 2007 to March 2008 was 420 mm above the long-term average. This long pasture growing season produced new pasture establishment, good seeding and high yields.

2008-2009: Following the previous high rainfall year, this season started with another wet winter followed by good spring and summer rainfall which extended into autumn. The two consecutive long growing seasons, with both winter and summer rainfall, produced high pasture yields and new cover of previously bare and scalded patches in all monitor paddocks of the three grazing systems.

3.1.3. GRASP modelling of growing seasons 2005-2009

Assuming all land types have similar pasture growth, the estimated pasture growth in the three grazing systems is shown in Table 3.2. Since only one estimate of pasture growth rate was used for all soil types, and the rotation and continuous paddocks were assessed as being in the same overall condition, the estimated pasture growth was the same (average 3200 kg/ha) for these two systems. Land condition in the cell system was slightly better than in the rotation and continuous systems producing higher values for estimated pasture growth (average 3600 kg/ha).

Table 3.2. Estimated annual pasture growth (kg/ha) for grazing systems and years at Melrose from 2005/06 to 2008/09.

Years	Pasture growth (kg/ha)		
	Cells	Rotation	Continuous
2005/06	2900	2600	2600
2006/07	2400	2100	2100
2007/08	4800	4300	4300
2008/09	4400	3900	3900
Average	**3600**	**3200**	**3200**

The wide variation in seasonal pasture growth potential between the summer and winter seasons is highlighted by the weekly pasture growth index (Figure 3.1). The rainfall periods during winter, which help promote growth in the following summer, can be identified. The extended pasture growth periods which produced good pasture recovery in all systems in the last two years are identified.

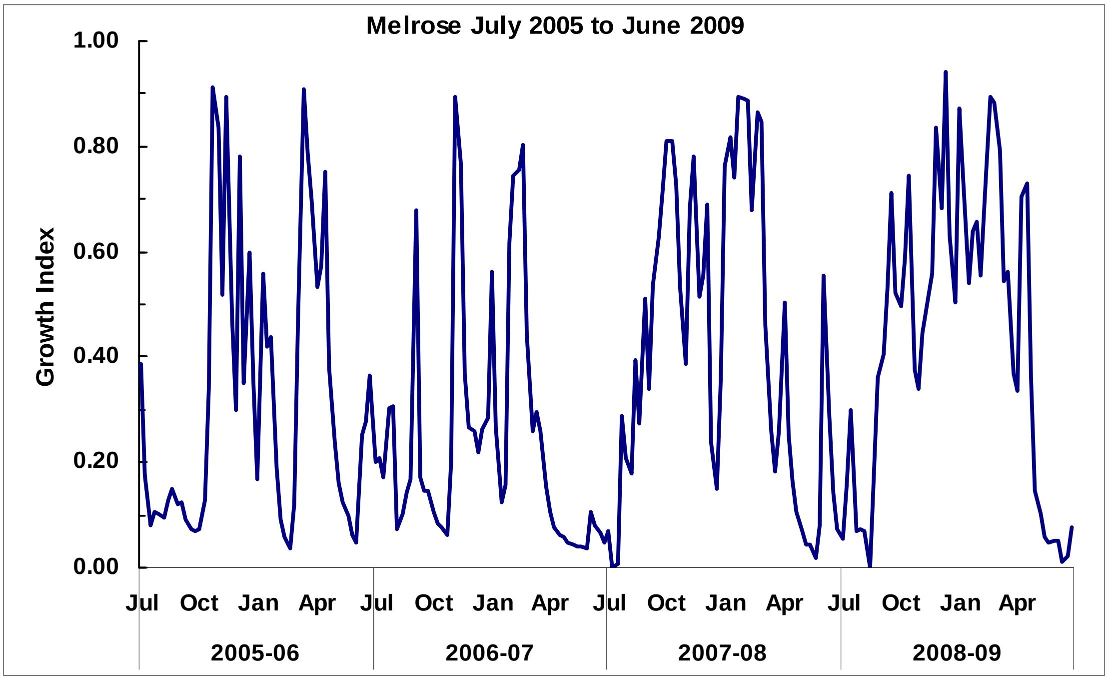


Figure 3.1. Weekly Growth Index (tropical species) values at Melrose during the experimental period (2005-09).

3.2. Pastures and Land Condition

3.2.1. Pasture yield, botanical composition and diversity

3.2.1.1. Pasture mean values

The pastures were sampled in late autumn each year. There was little difference in yields between the systems although the rotation had the highest yields in all years. Overall the pastures were strongly dominated by native perennial grasses with some exotic grasses (buffel, urochloa) and legumes (Seca stylo) (Table 3.3). There was a higher proportion of exotic legumes (8%), predominantly Seca stylo, in the rotation and continuous systems than in the cells (2%). This may have contributed to the higher diet quality from these systems.

Table 3.3. Pasture dry matter yield and botanical composition at the end of summer.

Year	System	Yield (kg/ha)	Botanical composition (%) Nat per grass	Exotic grass	Native leg	Exotic leg	Ann grass	Forb	Sedge
2006	Cell	1780	82.6	6.6	1.5	1.4	1.6	6.0	0.3
	Rotation	1920	68.6	14.8	0.9	10.6	1.0	4.0	0.1
	Continuous	1780	79.7	6.8	0.9	6.0	1.4	5.2	0.0
2007	Cell	1500	82.1	10.9	0.2	0.4	0.2	5.7	0.6
	Rotation	2100	70.9	20.3	0.2	5.3	0.0	3.3	0.0
	Continuous	1890	84.7	8.0	0.1	3.0	0.4	3.8	0.0
2009	Cell	4850	79.2	15.2	0.6	2.1	0.0	2.6	0.3
	Rotation	5670	63.5	26.4	0.6	8.1	0.0	1.3	0.0
	Continuous	4590	68.6	20.4	1.0	8.0	0.0	1.9	0.1

3.2.1.2. Yield spatial variability

This analysis measured the degree of uniformity, or inversely variability, in the various parameters across each paddock. There were two to three of the five cell paddocks with uniform pasture yield at each recording, while the continuous paddock was not uniform in any year (Table 3.4). The rotation paddocks were not uniform in yield in 2006; however there was greater uniformity at subsequent recordings. The variable land forms from creek flats to hills, may have contributed to the variability across the larger paddocks.

Table 3.4. Variability in pasture yield – number of paddocks where pasture yield was spatially uniform (i.e. there was no evidence of aggregation) across the paddock.

Grazing system	Total no. of paddocks	No. paddocks with uniform yield		
		2006	2007	2009
Cell	5	3	3	2
Rotation	2	0	2	1
Continuous	1	0	0	0

3.2.1.3. Species diversity

The pastures in all systems were diverse with an average of three species per 0.25 m^2; however, there were only small, and no consistent, differences between the three grazing systems for the three measures of diversity (Table 3.5). The dominant grass species contributed to about 25-35% in the three systems.

Table 3.5. Measures of pasture species diversity in autumn at Melrose in 2006, 2007 and 2009.

Diversity measure	Diversity units		
	Cell	Rotation	Continuous
No. species/quadrat			
2006	2.5	2.7	2.5
2007	2.7	2.8	3.1
2009	3.0	3.0	3.1
No. species to contribute 90% of yield			
2006	18	13	13
2007	13	11	13
2009	15	8	13
% contribution of dominant species			
2006	29	29	38
2007	28	31	33
2009	22	23	29

3.2.2. Pasture utilisation

Pasture utilisation in the monitor paddocks at the end of summer was rated across the paddocks on the Botanal grid at each recording point (rating 1 = 71-100%; 2 = 31-70%; 3 = 6-30%; 4 = 0-5% utilisation).

3.2.2.1. Utilisation mean values

Overall utilisation in autumn was low in all systems (average 3.5), and there were only small differences between utilisation ratings in any year (Table 3.6).

Table 3.6. Mean rating (1 = high to 4 = low) for estimated pasture utilisation in autumn in grazing systems at Melrose from 2005-06 to 2008-09.

Year	Pasture utilisation rating		
	Cells	Rotation	Continuous
2005-06	3.6	3.5	3.6
2006-07	3.2	3.5	3.0
2008-09	3.9	3.9	3.7
Average	**3.6**	**3.6**	**3.4**

In autumn of 2006 there was similar utilisation in the three systems, and marginally higher utilisation in the continuous paddock in the other two recording years (Figure 3.2).

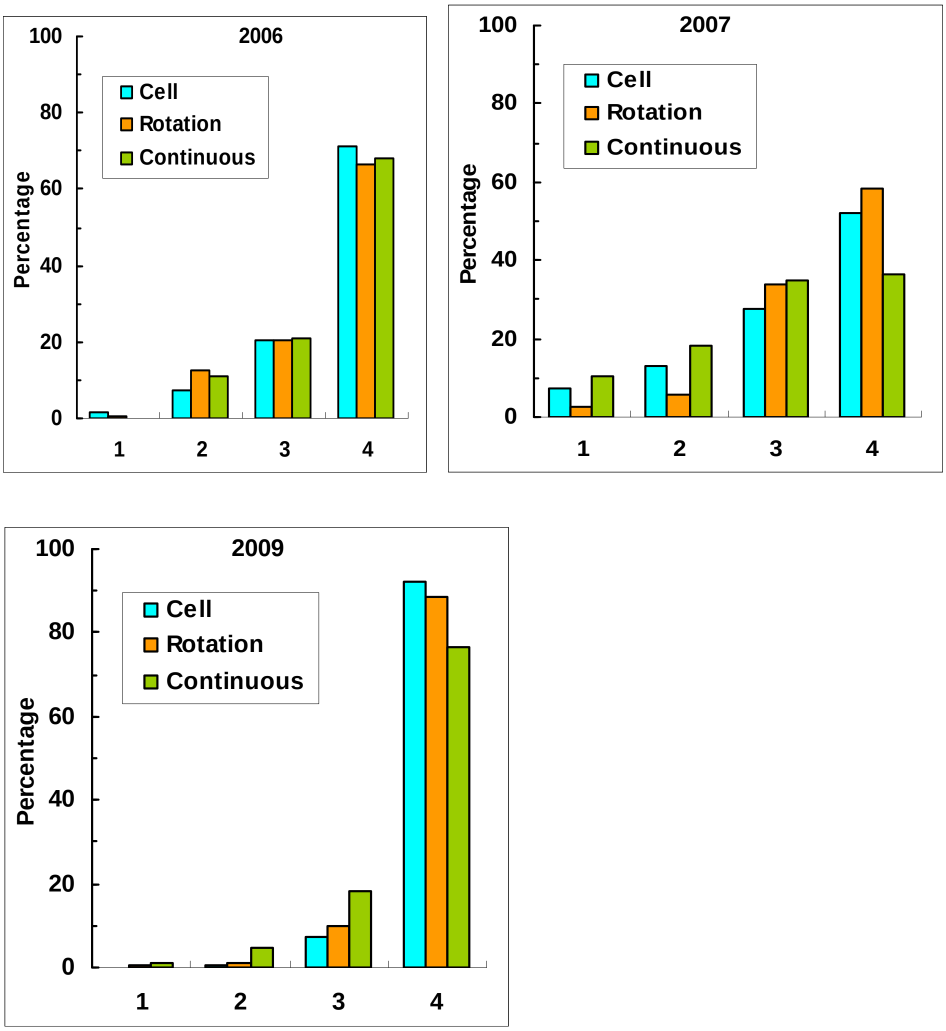


Figure 3.2. Distribution of estimated pasture utilisation values in grazing systems at Melrose from 2006 to 2009.

3.2.2.2. Utilisation spatial variability

Utilisation was uniform across most cell paddocks in 2006 and 2009, but not uniform in the continuous paddock at any of the three recording times (Table 3.7). One rotation paddock had a uniform yield, but only in 2009.

Table 3.7. Variability in pasture utilisation – number of paddocks where pasture utilisation was spatially uniform (i.e. there was no evidence of aggregation) across the paddock.

Grazing system	Total no. of paddocks	No. paddocks with uniform utilisation		
		2006	2007	2009
Cell	5	3	1	4
Rotation	2	0	0	1
Continuous	1	0	0	0

3.2.3. Woody regrowth

Cover levels of woody regrowth were similar, up to 1%, in the three systems (Table 3.8).

Table 3.8. Cover levels (%) of woody regrowth in grazing systems at Melrose.

Year	Woody regrowth cover (%)		
	Cells	Rotation	Continuous
2006	1.1	0.6	0.9
2007	0.6	0.5	0.7
2009	0.8	0.6	0.6

3.2.4. Ground and litter cover

3.2.4.1. Cover means and standard deviations

Total pasture cover levels were similar in the continuous and rotation systems, but lower in the cells, particularly in 2006 and 2007. Although there was some variability, the standard deviations were highest in the cells for total cover but similar to the other two systems for litter cover (Table 3.9).

Table 3.9. Pasture and litter cover levels (%) at Melrose at the end of summer.

Year	System.	Total cover (%)		Litter cover (%)	
		Mean	St. Dev.	Mean	St. Dev.
2006	Cell	51	31.3	18	18.7
	Rotation	62	26.1	15	15.0
	Continuous	65	27.8	17	16.4
2007	Cell	57	29.1	20	17.6
	Rotation	72	22.2	14	13.8
	Continuous	69	27.0	18	17.8

2009	Cell	87	21.6	31	21.0
	Rotation	93	12.7	35	22.1
	Continuous	90	13.4	33	23.7

3.2.4.2. Cover spatial variability

In 2006 there were four of the five cell paddocks with uniform total ground cover and litter cover, while the continuous paddock was not uniform in either cover measure (Table 3.10). In the following year, only 1 cell paddock had uniform total cover. By 2009, the cell paddocks had greater total cover (four of five paddocks) and litter cover (two of five paddocks) uniformity. Both rotation paddocks had uniform total cover in autumn of 2009, but litter cover was not uniform in either paddock. The continuous system was not uniform for either cover measure.

Table 3.10. Variability in total ground cover and litter cover – number of paddocks where total ground cover or litter cover was spatially uniform (i.e. there was no evidence of aggregation) across the paddock.

Cover Grazing system	**Total no. of paddocks**	**No. paddocks with uniform ground cover (%)**		
		2006	**2007**	**2009**
Total ground cover				
Cell	5	4	1	4
Rotation	2	0	0	2
Continuous	1	0	0	0
Litter cover				
Cell	5	4	3	2
Rotation	2	1	1	0
Continuous	1	0	1	0

3.2.5. LFA indices (soil surface conditions)

The LFA indices, stability, infiltration and nutrient cycling, have values between 0 and 100 where larger values indicate better performance for that index.

3.2.5.1. LFA means

Both LFA indices means and standard deviations were similar in the three systems at each recording, however, there was an average increase (across the three systems) of 9.2% in the stability index, 19.6% increase in infiltration and a 34.5% increase in nutrient cycling index between 2006 and 2009 (Table 3.11). The improved pasture condition due the two unusually good rainfall years occurred in all systems and helped improve these measures.

Table 3.11. LFA stability, infiltration and nutrient cycling indices at Melrose at the end of summer in 2006, 2007 and 2009.

Year	System	LFA Indices (0-100)					
		Stability		Infiltration		Nutrient cycling	
		Mean	S. Dev.	Mean	S. Dev.	Mean	S. Dev.
2006	Cell	63.8	7.41	35.1	7.83	27.5	10.00
	Rotation	64.8	6.34	34.5	7.12	26.3	8.36
	Continuous	62.5	7.15	33.4	8.28	27.1	9.72
2007	Cell	62.9	6.51	37.3	8.33	29.9	8.08
	Rotation	65.9	5.31	36.5	8.29	28.3	7.79
	Continuous	63.4	6.68	36.6	8.29	30.3	8.29
2009	Cell	69.2	9.78	41.4	9.51	34.8	9.95
	Rotation	70.3	3.78	41.7	8.90	36.8	9.07
	Continuous	69.2	5.82	40.1	9.76	37.2	10.83

3.2.5.2. LFA indices spatial variability

There was a greater degree of variability between the three LFA indices in the continuous and rotation systems than in the cell paddocks in the final year of recording (Table 3.12). The continuous paddock had uniform infiltration and nutrient cycling in the first two years of recording, and was not uniform for stability in any year. By 2009, only one rotation paddock had a uniform stability index, while all other paddocks were not uniform for any index.

Table 3.12. Spatial variability in the three LFA indices – number of paddocks where the LFA Stability, LFA Infiltration or LFA Nutrient cycling index was spatially uniform (i.e. there was no evidence of aggregation) across the paddock.

LFA index **Grazing system**	**Total no. of paddocks**	**No. paddocks with uniform LFA indices**		
		2006	**2007**	**2009**
LFA Stability index				
Cell	5	3	3	3
Rotation	2	1	1	1
Continuous	1	0	0	0
LFA Infiltration index				
Cell	5	4	1	3
Rotation	2	1	1	0
Continuous	1	1	1	0
LFA Nutrient cycling index				
Cell	5	3	4	4
Rotation	2	1	2	0
Continuous	1	1	1	0

3.2.6. Land condition

Initial land condition varied widely between the individual paddocks in the cell system. Paddock 7 was in predominantly A condition with dense native perennial grasses and little regrowth; Paddock 16 was largely in C condition with more bare, eroded areas than other paddocks; and Paddocks 17, 20 and 22 all had mixtures of A, B and C condition areas. The continuous and rotation paddocks were all variable ranging from areas of dense perennial grass (A condition), through B condition, to bare areas with little grass cover in C condition. There was a marked improvement in condition of all systems in 2009 compared to earlier years (Table 3.13).

Table 3.13. Measures of land condition at Melrose. For the Botanal/PatchKey and ABCD (Land type) values, “1” is equivalent to A condition and “4” is equivalent to D condition.

Land condition measure	Land condition units		
	Cells	Rotation	Continuous
Botanal/PatchKey			
2006	2.4	2.3	2.4
2007	2.6	2.0	2.2
2009	1.7	1.2	1.5
ABCD (by Land type)			
Alluvial brigalow	1.0		2.0
Blue gum River red gum flats	1.4	2.0	2.0
Silver-leafed ironbark on duplex	1.7	2.0	2.0
Overall average	1.6	2.0	2.0
ABCD (Paddock)			
2006	A to B/C	B	B
2007	A to B/C	B	B
2009	A/B	A/B	A/B

An annual photograph of fixed points in the three systems shows the seasonal variation in pasture growth and cover (Figure 3.3). The open pasture and bare areas obvious in the drought of 2005 and 2006 in the three systems were all in better condition by April 2009. The high pasture cover and green growth in October 2008 is in response to the unusually high winter and good previous summer rainfall.

Melrose Cell As-5
Lat: 23^{0}.148; Long: 150^{0}.025, Dir: 120_{0}

Melrose Dam BR-9
Lat: 23^{0}.195; Long: 150^{0}.013, Dir: 355^{0}

Melrose GG-8
Lat: 23^{0}.180; Long: 150^{0}.016, Dir: 350^{0}


Cell (November 2005)


Rotation (November 2005)


Continuous (November 2005)


Cell (October 2006)


Rotation (October 2006)


Continuous (October 2006)


Cell (March 2008)


Rotation (March 2008)


Continuous (March 2008)


Cell (October 2008)


Rotation (October 2008)


Continuous (October 2008)


Cell (April 2009)


Rotation (April 2009)


Continuous (April 2009)

Figure 3.3. Changes in land condition at fixed points in the cell, rotational and continuous grazing systems at Melrose between 2005 and 2009.

3.2.7. Cover analysis

3.2.7.1. VegMachine vegetation cover time series (Landsat)

Historically the areas of the paddocks of the three monitored grazing systems on Melrose have had a very similar and consistently relatively high cover which closely follows the average cover of the whole property (Figure 3.4). This result indicates there has been similar management in all areas. In recent years prior to starting the GSP, the system areas had the same cover trends which declined at the same rate in the droughts of the 1990's and early 2000's, and had a similar rapid response to the following above average rainfall years. Cover has been higher in all areas during the latest drought indicating a more conservative management approach. There has been the widest difference in cover over the last two years, although this range is only about 10%. This is the same result measured in the field in the GSP (Table 3.14) where the average cover in the cells is 55% compared with 67% in the rotation and continuous systems.

The VegMachine analysis of the individual monitor paddocks (Figure 3.5) shows there has historically been a wider variation in cover in the current cell paddocks and that this area has a marginally lower cover than the rotation or continuous system areas. The cells were installed in an attempt to address this lower cover caused by scald patches expanding under the previous management system. Melrose has more open country, timber cleared or thinned, than most surrounding properties in the neighbourhood catchment. It is this tree cover that maintained the relatively high cover in the catchment relative to the monitor paddocks.

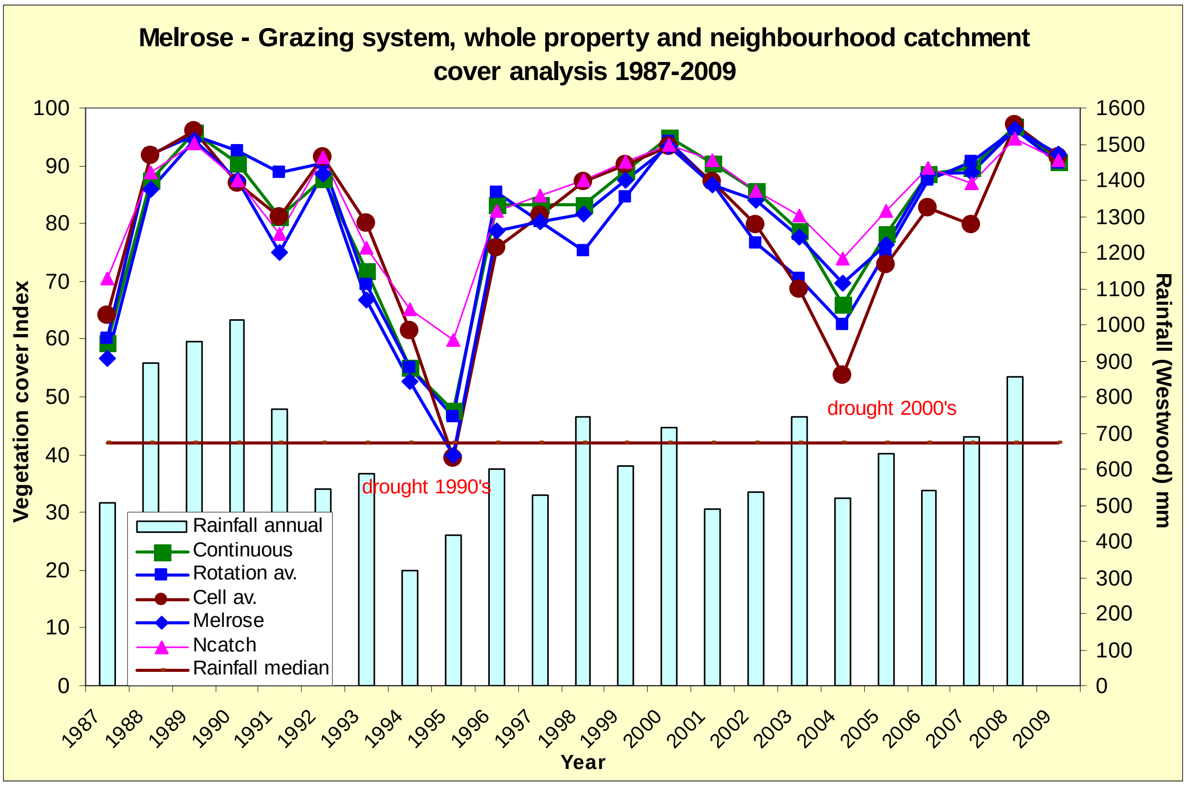


Figure 3.4. Vegetation cover index between 1987 and 2009 for grazing systems, the whole property at Melrose and the neighbourhood catchment. Annual and long-term median rainfall (mm) is also shown.

Mary's cell paddock no. 16 ("Eroded") has had the widest fluctuations in cover of all paddocks over the last 20 years (Figure 3.5). This may be attributed to relatively fragile sloping gravelly and eroded soils and the proximity to semi-permanent water in a creek, and more recently, to a permanent dam in one corner of the paddock. There has been a dramatic recovery in pasture cover since the site was selected and monitored from late 2005 to June 2009. The VegMachine data shows this rapid recovery in cover to equal that of other paddocks after the high rainfall year of 2008. This paddock is close to cell paddock no. 17 ("Flat") which has more productive land types and did not demonstrate the same degree of cover loss in the droughts.

The recent VegMachine index analysis (to 2009) indicates higher cover index values (in high 90's) than our field total ground cover measurements suggest.

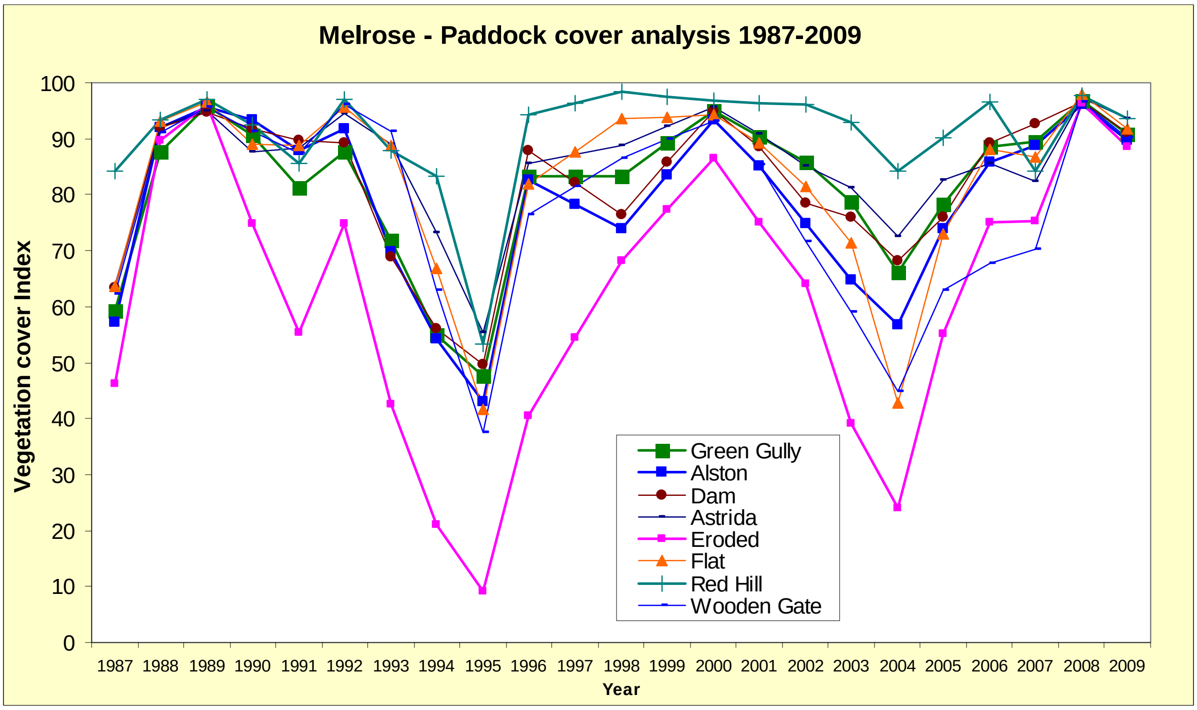


Figure 3.5. Vegetation cover index between 1987 and 2009 for the monitor paddocks at Melrose.

3.2.7.2. Botanal pasture cover analysis

The field-measured cover trends and system differences were similar to the VegMachine analysis. However, our GSP field results are in the order 50-70% pasture cover (Table 3.14) compared with a cover index (including pasture and trees) of 70-90.

Table 3.14. Pasture yield (kg/ha), total pasture cover (%), litter cover (%) and woody regrowth cover (%) in monitor paddocks and grazing systems in 2006 and 2007 at Melrose.

Paddock / System	Yield (kg/ha)		Total Cover (%)		Litter Cover (%)		Woody Cover (%)*	
	2006	2007	2006	2007	2006	2007	2006	2007
Marys 7 [7]	2960	2710	52	75	18	28	0.5	0.9
Marys 16 [16]	1500	1090	45	48	11	9	0.3	0.1
Marys 17 [17]	1480	1260	61	58	25	24	0.5	0.7
Marys 20 [20]	1610	1840	37	59	14	14	0.2	0.4
Marys 22 [22]	1360	1010	60	56	22	19	3.8	0.6
Green Gully [51]	1780	1810	65	69	17	18	0.9	0.8
Dam (Big) Rotn [52]	1740	2040	63	74	11	15	0.6	0.6
Alston's Rotn [53]	2090	2230	60	70	18	14	0.5	0.5
Continuous	1780	1810	65	69	17	18	0.9	0.8
Rotation	1920	2130	62	72	15	14	0.6	0.6
Cell	1780	1580	51	59	18	19	1.1	0.5
Site	1810	1750						

* woody regrowth only

3.2.7.3. Spatial pasture and cover reports

The average ground cover index for the monitor paddocks and whole of Melrose (Figure 3.6) for the period 2003-07, shows the range of land condition in the three grazing systems from high cover to bare and scalded areas (QDERM data). The “Wooden Gate” (no. 20) and “Eroded” (no. 16) cell paddocks had a higher proportion of low cover areas than the other paddocks. The “Red Hill” (no.7), “Astrida” (no. 22) and “Flat” (no. 17) cell paddocks had a high proportion of good cover, with similar proportions of high to low cover as the two rotation (“Alston’s” and “Dam” Rotation) and the continuous (“Green Gully”) paddocks. The surrounding properties had a similar range of cover variation to Melrose with an extensive bare area to the east of Green Gully mixed with country with good cover. Some properties have large areas of densely timbered country (shown in dark green).

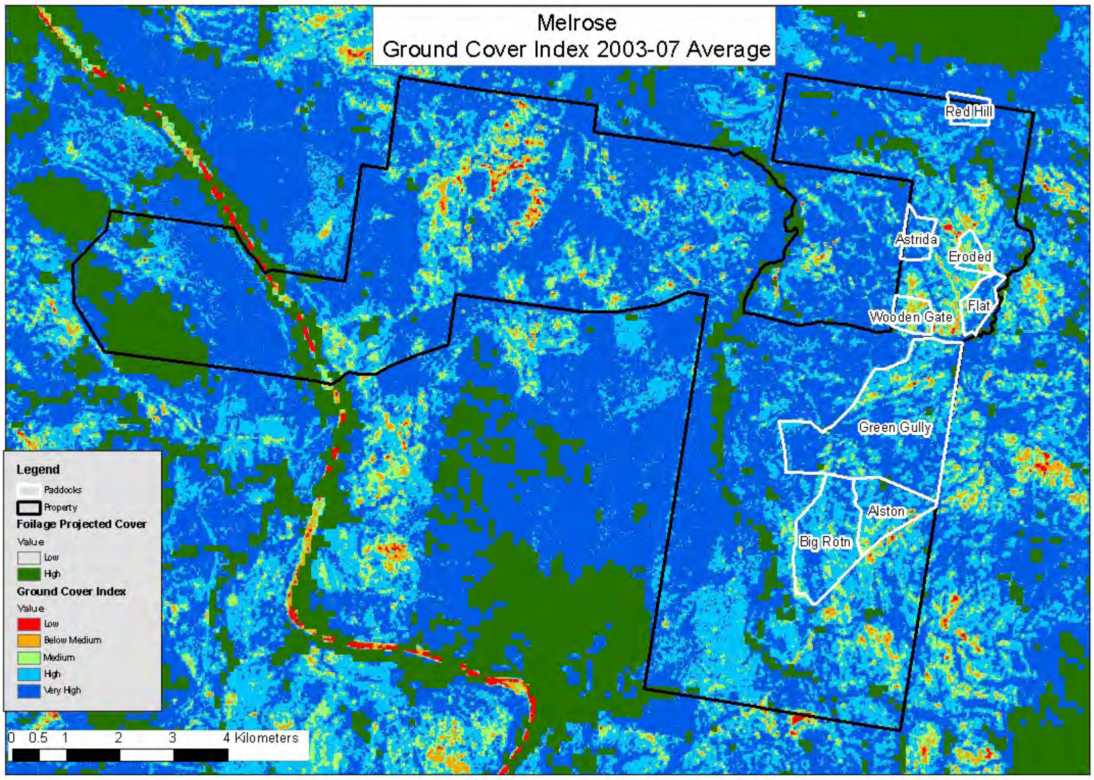


Figure 3.6. Average (2003-2007) ground cover index (vegetation cover) image for the cell, rotation and continuous paddocks, the whole Melrose property and surrounding properties (Source QDERM).

3.3. Cattle Grazing

3.3.1. Carrying capacity – long-term (LTCC)

The estimated long-term carrying capacities (AE/100 ha and SDH) over all landtypes of the three grazing systems are:

Cells	31 AE/100 ha (111 SDH, with range 78 to 169)
Rotation	24 AE/100 ha (87 SDH with range 78 to 105)
Continuous	24 AE/100 ha (87 SDH)

3.3.2. Rest periods

There was the same average rest period (56-57 days) between grazing events in the cell and rotation systems (Table 3.15), and more variable rest occasions (range 0-95 days) in the continuous system over the four year monitoring period.

Table 3.15. Rest periods for cell and rotation grazing systems and total rest (days) for the continuous system at Melrose.

Year	Rest periods (days)		
	Cells	**Rotation**	**Continuous**
	Av. bet. grazing	Av. bet. grazing	Total annual rest
2005-2006	50	79	56
2006-2007	55	43	95
2007-2008	56	53	0
2008-2009	67	49	1
Average	**57**	**56**	**38**

3.3.3. Grazing days

The annual average number of days of grazing over four years was 12, 49 and 327 days for the cell, rotation and continuous systems respectively. They had an annual average of five, five and six grazing events or herd number changes per year respectively. The annual number of days grazing in the cell paddocks ranged from seven to 16 days per year, with a range of three to six grazing events per year. Over all years the rotation paddocks received from 23 to 75 days grazing per year with one to six changes in herd numbers. The continuous system was grazed from 270 to 365 days with five to seven herd changes per year over the four years.

3.3.4. Grazing pressure

The animal numbers, classes and weights taken from property records for each system have been converted to Animal Equivalents (AE) using the standards tables presented in the Appendix 9.10. An AE is equivalent to a dry cow weighing approximately 450 kg. The grazing pressure on the three systems over the four-year monitoring period measured in stock days per ha per 100mm of rainfall over the previous 12 months from each grazing event, shows the same average grazing in the cells and rotation systems (17 SDH/100mm), which was marginally higher than that in the continuous system (13 SDH/100mm) (Table 3.16).

The lighter grazing in the continuous system in 2007-08 was due to the herd population and the limited number of first-calf heifers following the drought in the previous year, and not to any pasture or land condition limitations. The average of the rotation system is also under-estimated because the paddocks were not all constructed in 2005-06, the first recording year, so rotational grazing did not commence in the two monitor paddocks until mid-February 2006.

Table 3.16. Grazing pressure for grazing systems at Melrose (SDH/100mm rainfall and SDH).

Year	**Grazing pressure**		
	Cells	**Rotation**	**Continuous**
	SDH/100mm rainfall and (SDH)		
2005-06	18.2 (100)	9.8* (47)	15.2 (78)
2006-07	20.4 (113)	18.7 (102)	12.2 (70)
2007-08	13.2 (101)	15.9 (121)	9.1 (86)**
2008-09	16.6 (126)	24.4 (177)	16.0 (112)
Average	**17.1 (110)**	**17.2 (112)**	**13.1 (87)**

* Rotation paddocks data is for part year only, as they were still being developed in 2005-06.
** First calf heifer numbers were down this year (2007-08) due to herd dynamics and not pasture production or condition.

The annual average SDH over the monitoring period was 110, 112 and 87 SDH for the cell, rotation and continuous systems respectively, compared with the LTCC estimate of 111, 87 and 87 respectively. This indicates the rotation paddocks were grazed more heavily than the other systems and that on average the cell and continuous paddocks were grazed at the estimated LTCC. The continuous paddock was grazed more conservatively in some years, because of the requirements of managing first calf heifers and giving them the greatest opportunity to get back into calf the second year.

The average annual stocking rate over the four years was 3.5, 4.2 and 4.3 ha/AE for the cell, rotation and continuous systems respectively. Statistically there was no difference between the three systems in the average grazing pressure, but there was a significant between year difference and significant grazing system by year interactions (Table 3.17).

Table 3.17. Grazing system and year effect on stock days per ha (SDH), SDH per 100mm rain and annual stocking rate (ha/AE) at Melrose[#].

Grazing system / Year	Grazing pressure								
	Stock days per ha (SDH)			SDH / 100 mm rain			Annual stocking rate (ha/AE)		
Grazing System (GS)	ns			ns			ns		
Cell	4.68	(107)		2.87	(17)		1.49	(3.4)	
Rotation	4.61	(99)		2.84	(16)		1.57	(3.8)	
Continuous	4.46	(85)		2.63	(13)		1.67	(4.3)	
Av. s.e.d.	0.19			0.14			0.14		
Year (Yr)	*			P=0.056			*		
2005/06	4.34	(76)	b	2.73	(14)	ab	1.77	(4.9)	a
2006/07	4.56	(95)	ab	2.90	(17)	a	1.59	(3.9)	ab
2007/08	4.59	(97)	ab	2.59	(12)	b	1.56	(3.8)	b
2008/09	4.84	(125)	a	2.89	(17)	a	1.38	(3.0)	b
Av. s.e.d.	0.13			0.12			0.11		
GS x Yr	**			**			**		
Cell-2005-06	4.62	(100)	a	2.95	(18)	ab	1.54	(3.6)	a
Cell-2006-07	4.68	(107)	a	3.02	(20)	a	1.49	(3.5)	a
Cell-2007-08	4.61	(100)	a	2.64	(13)	b	1.54	(3.7)	a
Cell-2008-09	4.83	(124)	a	2.86	(17)	ab	1.38	(3.0)	a
Rot-2005-06	3.86	(47)	c	2.37	(10)	b	2.18	(7.9)	a
Rot-2006-07	4.63	(102)	b	2.98	(19)	a	1.53	(3.6)	b
Rot-2007-08	4.80	(120	ab	2.82	(16)	a	1.40	(3.1)	bc
Rot-2008-09	5.14	(169)	a	3.20	(23)	a	1.16	(2.2)	c
Cont-2005-06	4.37	(78)	ab	2.78	(15)	a	1.73	(4.7)	ab
Cont-2006-07	4.27	(70)	b	2.58	(12)	ab	1.82	(5.2)	a
Cont-2007-08	4.46	(86)	ab	2.31	(9)	b	1.66	(4.3)	ab
Cont-2008-09	4.73	(112)	a	2.83	(16)	a	1.45	(3.3)	b
s.e.d. w/i GS	0.18			0.17			0.14		
s.e.d. w/i Yr	0.25			0.21			0.19		

n.s. – $P > 0.10$; * $P < 0.05$; ** $P < 0.01$.
[#] Data were log-transformed prior to analysis. Back-transformed means are given in parentheses. Means not followed by a common letter are significantly different (P=0.05). For the GS x Yr means, differences indicated are within a grazing system.

3.3.5. Grazing system intensity index

The grazing system intensity index values (GSI range 1-100; calculated from capital costs, operating costs and management inputs; details are reported in Appendix 9.13) for the three systems at Melrose were:

Cells	73
Rotation	53
Continuous	24

3.3.6. Diet quality (NIRS)

3.3.6.1. Analysis of all samples over four years

Over all samples, the diet quality values were higher in the continuous paddock than in the cell system with intermediate values for the rotation (Table 3.18). There was an average 1.7% higher crude protein and 3% higher digestibility in the continuous system than in the cells. This higher quality diet had a 7% higher non-grass proportion and produced an estimated 0.2 kg/day higher potential live weight gain.

Table 3.18. Mean faecal NIRS diet quality results from all samples (92) for three grazing systems at Melrose to June 2009.

Grazing System	No. samples	Crude protein (%)	Faecal N (%)	Digesti-bility (%)	Non-grass (%)	LWG (kg/day)	DMD/CP ratio
Cell	32	6.4	1.3	54	15	0.44	8.6
Rotation	31	7.3	1.4	55	22	0.56	7.3
Continuous	29	8.1	1.5	57	23	0.65	7.8
sed (av.)		0.38	0.04	0.76	2.0	0.06	0.3
Significance		***	ns	*	***	**	***
Average	**(total 92)**	**7.5**	**1.4**	**55**	**20**	**0.57**	**7.7**

n.s. – *P* > 0.10; * *P* < 0.05; ** *P* < 0.01; *** P < 0.001.

3.3.6.2. Analysis of samples collected at the same time

When samples were taken from all three systems on the same day (on 28 occasions) the values show also an increasing diet quality (crude protein and digestibility) from the cells to the rotation to the continuous system, with a corresponding significant (P>0.05) increase in potential liveweight gain prediction between the cells and the continuous system (Table 3.19). The lower diet quality in the cells is also reflected in the higher DMD/CP ratio of 8.2, which is in the potentially protein deficient range (8-10). A ratio below 8 is considered non-deficient in protein.

Table 3.19. Mean faecal NIRS diet quality results from three grazing systems sampled at the same time at Melrose to June 2009.

Grazing System	No. samples	Crude protein (%)	Faecal N (%)	Digesti-bility (%)	Non-grass (%)	LWG (kg/day)	DMD/CP ratio
Cell	28	6.8	1.3	54	16	0.49	8.2
Rotation	28	7.6	1.4	55	23	0.60	7.5
Continuous	28	8.3	1.5	56	22	0.68	7.0
sed (av.)		0.45	0.05	1	2.3	0.07	0.4
Significance		**	***	*	**	*	*
Average	**84**	**7.6**	**1.4**	**55**	**20**	**0.59**	**7.6**

A comparison of samples from each of any two grazing systems collected on the same day shows the trend of increasing diet quality as the system intensification is reduced, with the cell diet quality being less than that of the rotation or continuous system (Table 3.20). The rotation system also had lower diet quality than the continuous system when sampling times were paired. There was similar non-grass in the diet of the rotation and continuous systems (23%), which was higher that that in the cell system (15%).

Table 3.20. Mean NIRS diet quality results from pairs of grazing systems sampled on the same day at Melrose to June 2009.

Grazing System	No. samples	Crude protein (%)	Faecal N (%)	Digesti-bility (%)	Non-grass (%)	LWG (kg/day)	DMD/CP ratio
Cell	31	6.7	1.32	54	15	0.47	8.3
Rotation	31	7.5	1.38	55	23	0.58	7.6
Average	**31**	**7.1**	**1.35**	**54**	**19**	**0.53**	**8.0**
Cell	29	6.8	1.33	54	15	0.49	8.2
Continuous	29	8.4	1.54	57	22	0.68	7.0
Average	**29**	**7.6**	**1.44**	**55**	**19**	**0.58**	**7.6**
Rotation	29	7.7	1.39	55	23	0.60	7.5
Continuous	29	8.4	1.54	57	22	0.68	7.0
Average	**29**	**8.0**	**1.47**	**56**	**23**	**0.64**	**7.3**

3.3.6.3. NIRS related to pasture growth index

The NIRS diet quality values were examined by dividing them into groups which had different growing conditions on the basis of the pasture Growth Index (GI) derived from GRASP (where 0.0 = conditions are unsuitable for growth and 1.00 = conditions are not limiting growth). Average values of the GI for the 30 days ending on the sample date were calculated. Based on these values three classes were formed – mean GI <0.2 (Poor growing conditions), GI = 0.2-0.5 (Average) and GI >0.5 (Good conditions). There was a greater difference in diet quality between the systems when the pasture was in a green and growing condition (Table 3.21). There was over 2% higher protein and 4% higher digestibility in the continuous system than in the cells with the pasture growth index above 0.5. The differences were half these values in the pasture 'dormant' phase (GI < 0.2). This may be influenced by the higher proportion (10%) of non-grass in the diet, including Seca stylo, from the pastures of the rotation and continuous systems. Seca is known to be well grazed in autumn as the grass pasture matures.

Table 3.21. Mean NIRS diet quality results in relation to three pasture growth indices classes for the three grazing systems at Melrose.

Growth Index	Grazing System	No. samples	Crude protein (%)	Faecal N (%)	Digestibility (%)	Non-grass (%)	LWG (kg/day)	DMD/CP ratio
<0.2	Cell	10	6.0	1.26	52	14	0.33	9.1
	Rotation	10	6.9	1.34	55	24	0.46	8.3
	Continuous	8	7.0	1.41	54	25	0.48	7.9
0.2-0.5	Cell	11	6.7	1.33	54	14	0.52	8.3
	Rotation	11	7.9	1.42	56	23	0.68	7.3
	Continuous	10	8.2	1.52	57	23	0.72	7.1
>0.5	Cell	11	7.2	1.36	54	17	0.53	7.8
	Rotation	10	7.7	1.37	55	21	0.60	7.3
	Continuous	11	9.5	1.65	58	20	0.79	6.3
sed (av.)			0.69	0.07	1	4	0.10	0.6

3.3.6.4. Monthly CP, DMD and non-grass

Individual sample results for the NIRS parameters crude protein, digestibility and non-grass for continuous (Figure 3.7), rotation (Figure 3.8) and cell (Figure 3.9) systems show the wide seasonal variation with high quality pastures in summer, declining rapidly to near or below maintenance crude protein in winter-spring before summer rains, in all systems. The maximum and minimum crude protein values were lower in the cell system, and this system had lower levels of non-grass throughout the monitoring period. All systems had protein deficient diets in 2008.

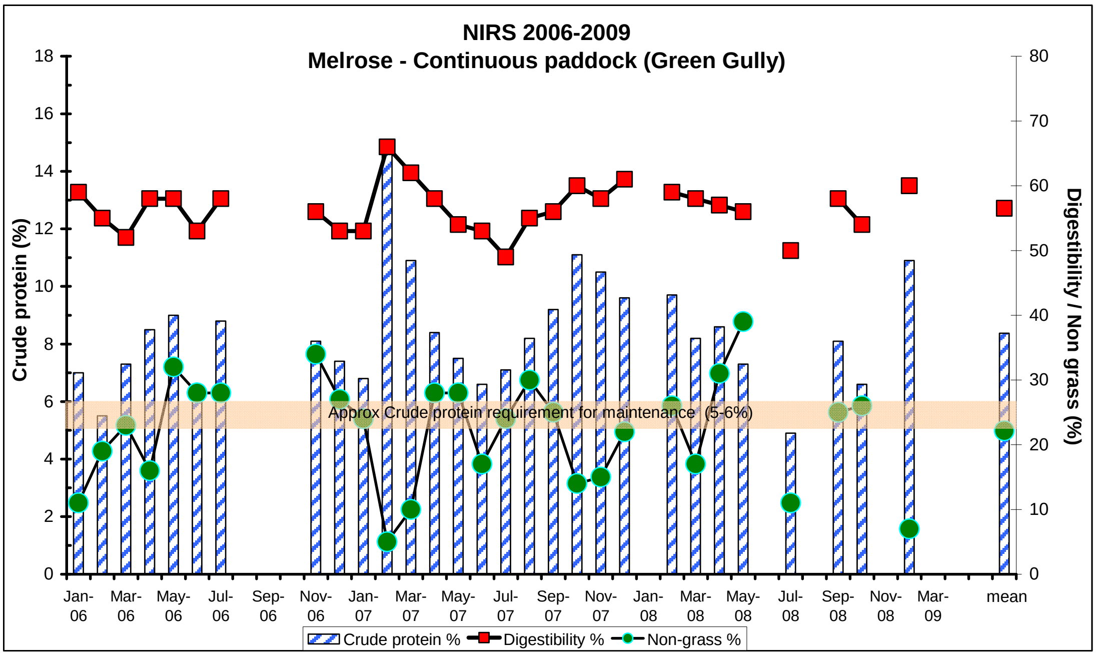


Figure 3.7. NIRS sample results for the continuous grazing system at Melrose for crude protein (%), digestibility (%) and non-grass (%) with approximate maintenance crude protein indicated.

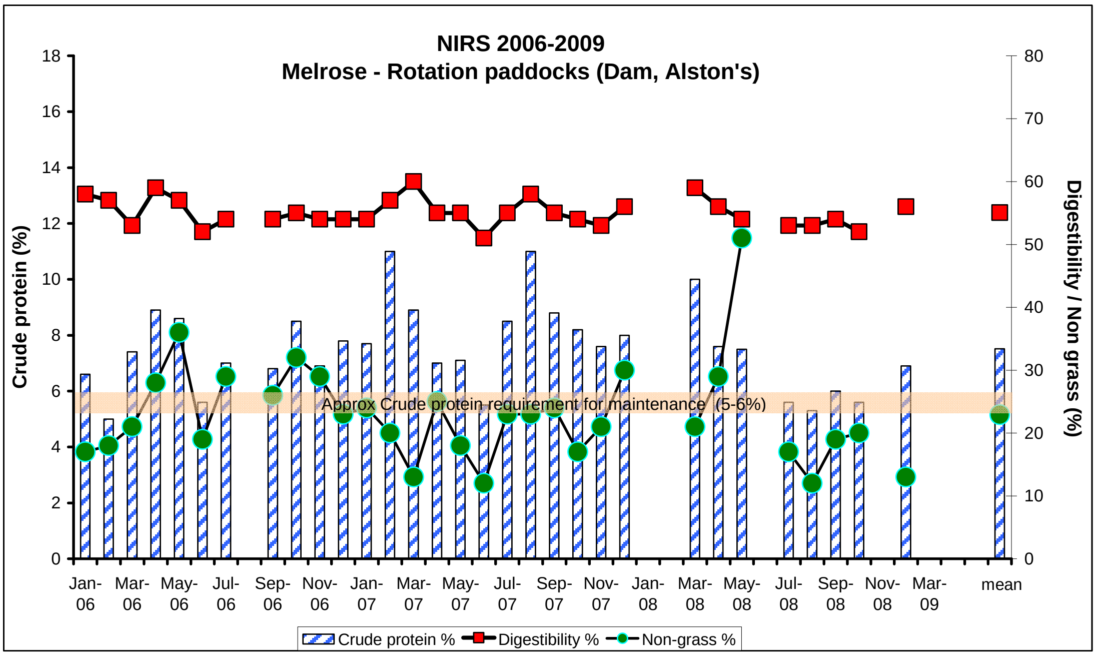


Figure 3.8. NIRS sample results for the rotational grazing system at Melrose for crude protein (%), digestibility (%) and non-grass (%) with approximate maintenance crude protein indicated.

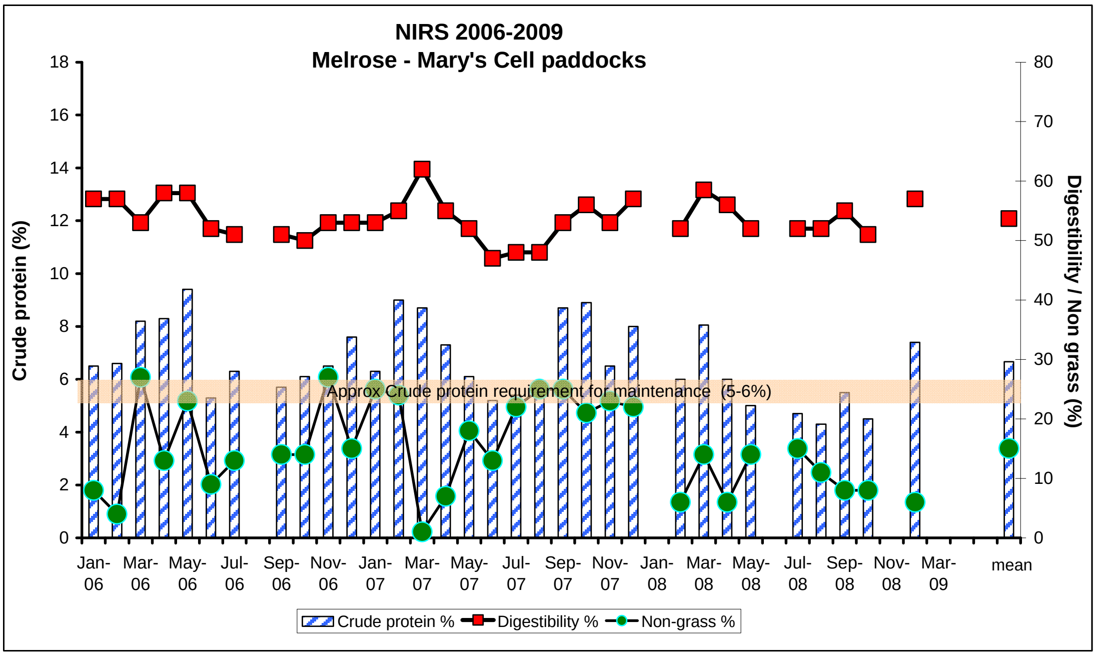


Figure 3.9. NIRS sample results for the cell grazing system at Melrose for crude protein (%), digestibility (%) and non-grass (%) with approximate maintenance crude protein indicated.

3.4. Grazing System Costs

Melrose runs a beef breeding enterprise and is located north-west of Rockhampton, and comprising a total area of approximately 8,000 ha, and prior to establishing the present grazing systems carried a combined herd of approximately 1630 adult equivalents (AE) centred on a breeding herd of 700 breeders and finishing steers to north Asian market specifications at around 30-36 months of age.

The new cell grazing system is still evolving (since 2004), and presently comprises 28 cell paddocks centred on eight cell centres and nine watering points. Fencing is comprised of 37 km of single wire electric fence and 4 km of double wire electric fence. Water to the cells is supplied through 17 km of 63 mm polythene pipelines utilising two pumps and seven polythene tanks. The bulk of the site treatment, fencing and pipe-laying were undertaken by the owners using station plant and machinery. The estimated cost of installing the new system is approximately $144K exclusive of additional livestock carried once the system is up and running to capacity.

The rotation system has eight rotation paddocks centred on eight existing watering points. Additional dams will be constructed as the system is developed to reduce walking distances in the hilly country.

The owners' estimate of the projected carrying capacity for the total enterprise (i.e. 8,000 ha) under the new grazing systems is to run an additional 90 breeders giving a total herd of 1840 AE with no change in the productivity of individual animals in the upgraded herd, and the same labour force of two full time labour equivalents.

3.4.1. Capital costs

The estimated replacement capital cost of the grazing system is approximately $144,000 (Table 3.22) comprising of fencing, water, labour and planning costs.

Table 3.22. **Replacement capital costs of cell grazing systems.**

Item	Cost ($)
Fencing 26 km	44,000
Water 2 dams	19,000
Troughs 9	9,000
Tanks 3	6,000
Water pipe 11 km	32,000
Pumps, mills	22,000
Installation	10,000
Consultancies	2,000
Total	**144,000**

3.4.2. Operating costs

An indicative guide to the operating cost of a given system is the estimated annual capital reclamation cost (sinking fund depreciation charge), which is the equivalent sum that would need to be set aside each year to maintain the capital assets invested in the systems infrastructure. The reclamation cost has been estimated using standard farm accounting depreciation factors for the main assets listed in the preceding table, including: bores (7.5%), dams (2.5%), fencing (5%), and plant (10%). This gives a projected capitalised cost for the case study enterprises of approximately $10,000 per annum (Table 3.23) comprising of fencing and water maintenance costs.

Table 3.23. **Annual operating costs of cell grazing systems.**

Item	Cost ($)
Fencing	2,200
Water	3,675
Troughs	900
Tanks	600
Pumps, mills	2,200
Total	**9,575**

4. Conclusions

4.1. Pasture and land condition

The rotation and continuous systems at Melrose were visually assessed to be in B condition in 2006. At that time there was a wide variation in the condition of the cell paddocks with some in A condition (Red Hill and Flat paddocks) but others in B/C condition. All systems responded to the two good rainfall years and improved over the sampling period to A/B condition in 2009.

There was little difference in pasture yields between grazing systems but yields were higher in the rotation system than the cell or continuous systems in all years. Yields were much higher in all systems in 2009 than they were in 2006 and 2007. All systems were dominated by native perennial grasses (64-85%) with some exotic perennial grasses (7-26%). There was more exotic legume (mainly Seca stylo) in the rotation and continuous systems (8%) than in the cell system (2%). Levels of woody regrowth were similar in all systems.

Levels of total ground cover were similar in the continuous and rotational systems but they were lower in the cell system particularly in 2006 and 2007. Cover levels were highest in 2009 in all systems. There were only small and inconsistent differences between grazing systems for litter cover. Values for litter cover were also higher in 2009 than in earlier years in all systems.

The differences between grazing systems were small for all three LFA indices, which were all highest in 2009.

The Vegetation Cover Index values in the VegMachine analysis were low in all grazing systems in 2004 with the systems ranked Continuous > Rotation > Cells. Levels in all systems increased after 2004 and by 2008 were similar in all systems.

4.2. Carrying capacity and grazing

There was no difference in average rest periods (57 days) in the cell and rotations systems and the continuous system averaged total rest of 38 days over the four-year monitoring period. The rotation and cell systems were operated at the same average grazing pressure, 111 SDH, over the four years; higher than the continuous system at 87 SDH. This difference was equivalent to a difference of 4 SDH/100mm rainfall, but was not statistically significant. The four-year average stocking rates were 3.5, 4.2 and 4.3 ha/AE for the cell, rotation and continuous systems respectively. These are almost identical to the LTCC of 3.4, 4.3 and 4.2 for the three systems respectively.

There were significant between year differences, and also a grazing system by year interaction, for grazing pressure. These between year differences are due to the drought at the start of the project and two very good seasons at the end. The between year difference was influenced by one year (2007-08) having fewer pregnant first-calf heifers following the drought year of 2006-07 rainfall (decile 2), which also followed a poor pasture growing year the previous summer.

The main difference between the three systems occurred in diet quality, which increased from the cells to the rotation and was consistently highest in the continuous system. Crude protein was 1.5% higher, digestibility 3% higher and corresponding liveweight gain predictions was almost 0.2 kg/day higher in the continuous system than in the cells. The cells did not produce the same range of diet quality as the other two systems and had more months below maintenance protein levels.

4.3. Owners comments on grazing systems

4.3.1. New management

Cells *were established to regenerate degraded pastures. They are very time consuming and time demanding even with three-day shifts and the shortest distance to make a shift is 10 km with the longest at 20 km travelling.*

Rotation *has longer times between shifts which make this system easier to operate and less time demanding than the cells, but still gives the pastures long rests.*

Set *stocking is business as usual with timing of operations much less critical and annual pasture rests are provided between the young breeder herds. This system causes the first calf cows less disturbance so they can look after their first calve better.*

4.3.2. Results

Ground cover took about one year to start changing in the cells and after that it has had a multiplying effect. At the present time pasture recovery and ground cover improvement is remarkable after two very good rainfall years.

The intensive systems have improved the temperament of the cattle. Weaners are a lot less trouble at weaning and there is less time required in the yards. The intensive cell system has made us change the way we manage all our pastures and it has helped us to increase stock numbers and improve pastures and land condition at the same time. The return on investment has been quick, and it has saved us from buying more land. This can be said for both the cell and rotational systems.

We have increased breeder numbers in the cells after the good summers between 2007 and 2009, although the dry winter of 2009 has now put too much pressure on the pastures causing additional sales.

4.3.3. Future plans

We will continue to subdivide the larger paddocks to make more rotation paddocks. We will not increase the cell system at present. They are labour demanding on the present owner/manager system we operate under.

The Grazing Systems Project has been of great benefit to our family. We have enjoyed the people that have run and worked on the project. The business has profited from the experience of having experts in their different fields share with us what they know. We have enjoyed and prospered from having the grazing trials on Melrose, and would not hesitate in being involved in any other projects that may come our way.

4.4. General conclusions

There are not strong ecological differences caused by the systems, but there has been good pasture recovery in degraded areas of all three systems at Melrose over the last two years, which were abnormally good growing seasons, receiving both summer and winter rainfall. Two of the cell paddocks in particular had good pasture recovery over severely degraded patches. This recovery was assisted by the average grazing pressure of the three systems being the same as the estimated LTCC for the cell and continuous systems, and marginally higher in the rotation system. This indicates all systems were well managed throughout the monitoring period. Even when matching stocking to LTCC, the diet quality on these native pastures has been consistently superior on the two less intensive systems.

The three systems are not operated independently, but are integrated into an annual whole property breeder management system, with each having a role at different stages of the breeder herds' age and breeding cycle. This benefits the pastures, herd management, labour supply, stage of property development and marketing strategies. There was marginally higher average grazing in the cell and rotation systems than in the continuous system; however the most significant difference between the systems was in diet quality, which declined as system intensity increased from the continuous system to the rotation to lowest in the cells.

Rocky Springs

Abstract
'Rocky Springs', Mundubbera, has two grazing systems; rotation and continuous. Two rotation and one continuous paddock were monitored between 2006 and 2009. The two systems are used for breeding cattle with varying age breeders run in both systems. There was a severe drought for the four years and planned burning and spelling regimes in the rotation system could not be implemented. The pastures were sampled in late autumn in 2006, 2007 and 2009. Average pasture yields were similar in both systems (2100 kg/ha). All pastures were native grass dominant (95%).

The continuous system supported higher average grazing pressure than the rotation system (18 Vs. 13 SDH/100mm rainfall respectively). This grazing is marginally lower than the estimated LTCC. Average diet quality (by NIRS) was very similar in the two systems, near 8% crude protein and 55% digestibility with a 22% non-grass component. The two systems are used as part of an integrated property breeder enterprise. The ecological differences were not consistent or strongly associated with the grazing system.

1. Site Introduction

1.1. Location

Rocky Springs is located approximately 60 km west of Mundubbera (25.6ºS; 150.8ºE) in the Burnett catchment (Figure 1.1).

Figure 1.1. Black speargrass native pasture in cleared eucalypt woodland at Rocky Springs.

1.2. Climate/growing season

The average annual rainfall is 693 mm (**Error! Reference source not found.**) with 69% falling in summer (October-March). The growing season is predominantly in summer, but with significant winter rain in some years there can be important winter pasture growth with subsequent beneficial impacts on pasture quantity and quality, especially from an early start to spring growth.

Based on long-term climate data, the average green season for tropical species is estimated to be 31 weeks including 15.4 growth weeks. With the winter rain, temperate species would add an average of 7.4 weeks to the growth of tropical species.

1.3. Major soil/vegetation types

The original vegetation was an open eucalypt woodland of mainly silver-leafed ironbark (*Eucalyptus melanophloia*) with some narrow-leafed ironbark (*E. creber*) and poplar box (*E. populnea*), and patches of brigalow (*Acacia harpophylla*). Most trees have been cleared leaving native pastures dominated by native perennial tussock grasses black speargrass (*Heteropogon contortus*), bluegrasses (*Bothriochloa bladhii, B. decipiens*) and golden beard grass (*Chrysopogon fallax*). The landscape is gently undulating with mixed loamy soils mostly derived from granite and clay soil flats (Table 1.1).

Table 1.1. Areas (ha) of land types in the monitor paddocks of grazing systems at Rocky Springs.

Land type	**Area (ha)**	
	Rotation	**Continuous**
Silver-leafed ironbark on granite/clay	655	152
Narrow-leafed ironbark on granite	77	22
Poplar box on clay		59
Eucalypt alluvial creek flats	27	14
Brigalow scrub	8	
Total	**767**	**247**

1.4. GRASP modelling of long-term pasture growth

The “Silver-leafed ironbark on clay/granite” and “Narrow-leafed ironbark on granite” were 90% of the sampled area so pasture production on these two major land types only were modelled.

1.4.1. GRASP parameters

The values for a number of important GRASP parameters, tree basal area, soil water and nitrogen, at Rocky Springs are given in Table 1.2. The simulations were run for the two major land types.

Table 1.2. Land type parameters for Rocky Springs used in GRASP model to estimate pasture growth.

GRASP parameter	Parameter units	
	SLIB granite/clay	NLIB granite
Tree basal area (m^2/ha)	0	4
Available soil water (mm)	76	70
Maximum N uptake (kg/ha)	20	15
Regrowth (kg/ha/%BA)	2	3.5
Transpiration use efficiency (kg/ha/mm)	13.5	13.0
Minimum N concentration (%)	0.4	0.4

1.4.2. GRASP results

The GRASP model was run using climate data from SILO for the period 1889 to June 2007 and pasture growth for the period July 1 to June 30 was estimated. The median pasture production for “Silver-leafed ironbark on granite/clay” was 3740 kg/ha and for “Narrow-leafed ironbark on granite” it was 1250 kg/ha (Figure 1.2).

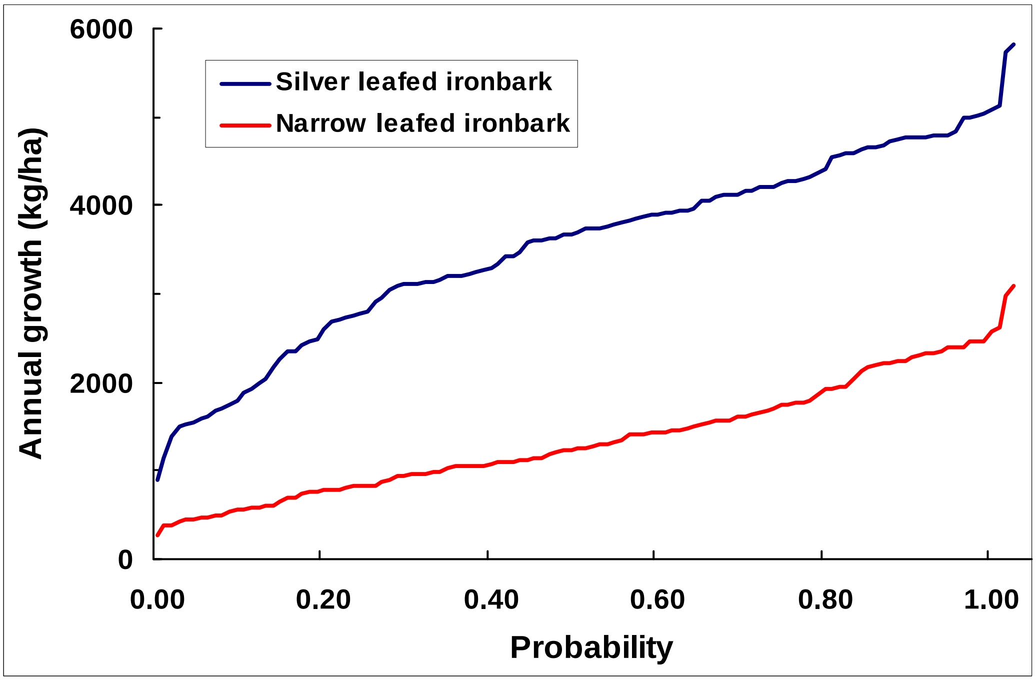


Figure 1.2. Long-term distribution of estimates of annual pasture growth on two landtypes at Rocky Springs.

1.5. Production system/markets

Rocky Springs is a mixed breeding and finishing property with a herd of approximately 1300 AE including approximately 550 breeders. Steers are finished at 24-30 months for the EU market or local feedlots.

1.6. Producer goals

The property was purchased in 1988-89 and the current management commenced in 2001. The managers found they were unable to carry the number of animals in each paddock that the previous owners had suggested as their original carrying capacity.

A major goal is to improve the condition of the native pastures by applying the EcoGraze principles of spring burning followed by 8-9 weeks rest from grazing at least once every three years combined with lower stocking rates. Wet season spelling and paddock rotation is seen as a low cost, less intensive way of looking after the land. It is hoped that this will increase the population of 3P grasses and pasture productivity and hence carrying capacity and animal production.

The owners' estimate of the projected carrying capacity for the total enterprise under the new grazing system is to run an additional 50 breeders, giving a total herd of c.1460 AE to be managed with the same labour force of 1.5 full time labour equivalents. Beyond restoring the carrying capacity of the targeted pastures, there is an additional expectation that there will also be some increase in the productivity of the augmented herd - viz. an increase in branding percentage (5%) and individual weaning weights (10%), both having been observed to decline as the condition of the targeted paddocks deteriorated.

2. Grazing Systems

2.1. Description

Two systems were studied – a continuously grazed paddock (No. 1 Cow) (247 ha) and a rotational system of six paddocks where one or two paddocks were to be burnt in spring each year and spelled for 8-9 weeks so that each paddock would be burnt and rested every 3-4 years; all six paddocks were then continuously grazed for the remainder of the year. Two rotation paddocks (Telegraph and Stud) (447 ha and 320 ha) were sampled (Table 2.1). All paddocks were grazed by breeders and their progeny. The layout of the three monitor paddocks and degree of clearing can be seen on the satellite image shown in Figure 2.1.

Table 2.1. Paddock names, numbers and areas sampled at Rocky Springs.

Vegetation	Grazing system	Paddock name [Botanal No.]	Area (ha)
Eucalypt	Rotation	Telegraph [2]	447
		Stud [3]	320
		Total rotation	767
Eucalypt	Continuous	No. 1 Cow [1]	247

Figure 2.1**. Layout of the three monitor paddocks at Rocky Springs.**

2.2. Management during 2005-2009

The Stud rotation paddock was burnt (85% of paddock) in October 2005 and was not grazed for six weeks until mid-November when a small herd (13 cows and calves plus one bull) was put in the paddock. Subsequently Stud has been grazed by variable numbers of animals reflecting available feed with some short rest periods. Telegraph was not burnt as planned due to poor seasonal conditions (drought) and has been grazed with numbers adjusted to match feed supply. Both paddocks have received some rest during the four-year monitor period.

No. 1 Cow has been continuously grazed with numbers adjusted to match feed supply.

Supplements (urea, molasses, cotton seed meal) were used to supplement mature pastures in winter/spring.

3. Results

3.1. Growing Seasons

3.1.1. Rainfall

The four years of the project were low rainfall years to serious drought, all below average (as low as decile 1) (**Error! Reference source not found.**). The distribution of rain events and amounts were also erratic during these years which had the effect of limiting pasture growth and the poor summers increased the rate of maturity and reduced quality.

Table 3.1**.** Monthly rainfall (mm) at Rocky Springs from July 2004 – June 2009 and long-term average monthly rainfall (mm) at Narayen/Hawkwood recording stations over 124 years.

Year	**Monthly rainfall (mm)**													
	J	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**Total**	**Decile**
2004-05	4	1	27	48	174	117	65	23	66	2	62	157	745	7
2005-06	2	14	3	139	91	71	66	24	25	5	0	20	460	1
2006-07	22	23	10	4	191	5	32	73	44	20	40	100	564	3
2007-08	0	39	90	35	45	75	122	68	8	2	53	22	559	3
2008-09	88	1	44	27	28	68	123	57	31	45	46	48	606	3
Long-term Mean	**36**	**27**	**33**	**56**	**77**	**94**	**101**	**89**	**64**	**39**	**40**	**37**	**693**	

3.1.2. Growing conditions

2003-2004: Annual rainfall was below average with well below average for spring and extremely low rainfall in autumn. However Rocky Springs received above average rainfall for summer which prompted some good pasture growth during this favourable growing period.

2004-2005: Rocky Springs received average total rainfall for the year. Rainfall was well above average for spring but was below average during the best grass growing months of summer. The autumn rainfall enabled pasture quality to increase prior to an abnormally wet June.

2005-2006: This was an extremely low rainfall year (decile 1). Spring and early summer rainfall were favourable with a good start to the growing season. However, subsequent rainfall has been very low (approximately 75 mm) and pastures were dried off by April. The poor growing conditions meant Stud paddock could not be spelled for the planned 8-9 weeks but was grazed from six weeks after burning.

2006-2007: There was below average rainfall for the year (decile 3) with well below average in summer. Despite receiving average rainfall for spring and above average rainfall for autumn, pasture quantity would have been low due to the lack of rain over the summer growing season. November and June received well above their monthly average.

2007-2008: This year received some rain most months, but only September received above average. The low monthly totals, especially over autumn, did not encourage high pasture growth.

2008-2009: This year also received some useful rainfall in most months, after an above average July, however, no months received high rainfall events. The four consecutive years of poor rainfall limited pasture production in all paddocks and prevented the planned burning and spelling program in the rotation system.

3.1.3. GRASP modelling of pasture growth 2005-2009

The GRASP model was used to estimate the annual pasture growth on the dominant landtype "Silver-leafed ironbark on granite/clay" (Table 3.2). It was assumed the other landtypes "Poplar box on clays", "Eucalypt alluvial creek flats" and "Brigalow scrub" had similar pasture production. There was similar pasture production in both systems each year (average 2100 kg/ha), however, between years there was a wide range from 1200 to 3100 kg/ha.

Table 3.2. Estimated annual pasture growth (kg/ha) for land types, grazing systems and years at Rocky Springs from 2005-06 to 2008-09.

Year	Pasture growth (kg/ha)	
	Rotation	Continuous
2005-06	1800	1800
2006-07	1200	1200
2007-08	2500	2600
2008-09	3000	3100
Average	**2100**	**2200**

The strong summer pasture growth seasons, with regular fluctuations during the better pasture growth periods, and the extended dry winter periods at Rocky Springs are shown by the growth index analysis (Figure 3.1).

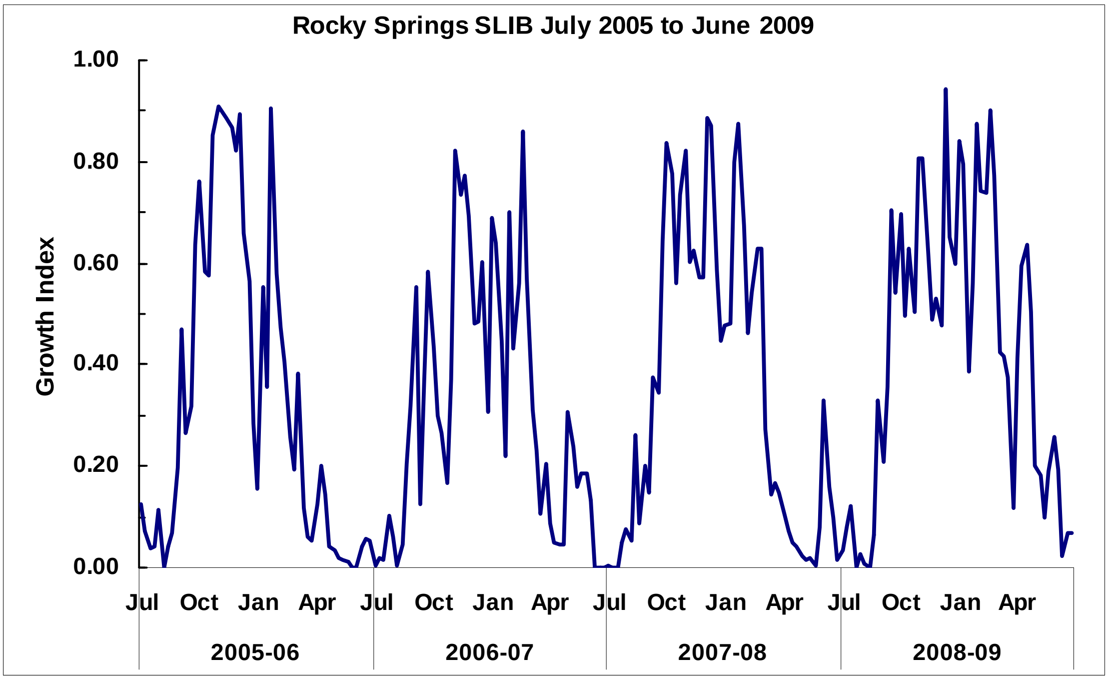


Figure 3.1. Weekly pasture growth index (tropical species) values at Rocky Springs during the experimental period (2005-09) for the "Silver-leafed ironbark on granite" land type.

3.2. Pastures and Land Condition

3.2.1. Pasture yield, botanical composition and diversity

3.2.1.1. Pasture mean values

There was little difference between the two grazing systems in annual pasture yield. The pastures were strongly dominated by native perennial grasses (*Heteropogon contortus*, *Dichanthium sericeum, Bothriochloa* spp.*, Chloris* spp.) with few other species (Table 3.3).

Table 3.3. Pasture dry matter yield and botanical composition at the end of summer.

Year	System	Yield (kg/ha)	Botanical composition (%) Nat per grass	Exotic grass	Native leg	Exotic leg	Ann grass	Forb	Sedge
2006	Rotation	2430	98.1	0.0	0.1	0.0	0.2	1.3	0.3
	Continuous	2820	98.8	0.3	0.1	0.0	0.2	0.5	0.0
2007	Rotation	1490	93.0	1.4	0.2	0.0	0.7	4.7	0.1
	Continuous	1510	96.7	0.7	0.5	0.0	0.2	1.9	0.0
2009	Rotation	3040	92.2	1.3	1.2	0.0	0.2	4.3	0.8
	Continuous	2830	94.8	0.5	1.1	0.0	0.1	3.0	0.5

3.2.1.2. Yield spatial variability

This analysis measured the degree of uniformity, or inversely variability, in the various parameters across each paddock. Both rotation paddocks had uniform pasture yield in 2006 and 2007, while the continuous paddock was not uniform (Table 3.4). In 2009, no paddocks in either system had uniform yield.

Table 3.4. Spatial variability in pasture yield – number of paddocks where pasture yield was spatially uniform (i.e. there was no evidence of aggregation) across the paddock.

Grazing System	Total no. of paddocks	No. uniform paddocks for pasture yield 2006	2007	2009
Rotation	2	2	2	0
Continuous	1	0	0	0

3.2.1.3. Pasture species diversity

All three pasture species diversity measures showed little difference between system**Error! Reference source not found.**. There was an average of three species per 0.25 m^2 quadrat. No species dominated the pastures, with the average contribution of the dominant species between 20-30% in both systems in the three recording years.

Table 3.5. Three measures of pasture species diversity at Rocky Springs in 2006, 2007 and 2009.

Diversity measure	Diversity units	
	Rotation	Continuous
No. species/quadrat		
2006	2.6	2.6
2007	2.7	2.7
2009	4.3	3.9
No. species to contribute 90% of yield		
2006	7	8
2007	11	10
2009	15	13
% contribution of dominant species		
2006	30	29
2007	24	26
2009	21	31

3.2.2. Pasture utilisation

Pasture utilisation in the monitor paddocks at the end of summer was rated across the paddocks on the Botanal grid at each recording point (rating 1 = 71-100%; 2 = 31-70%; 3 = 6-30%; 4 = 0-5% utilisation).

3.2.2.1. Utilisation means

Utilisation was light in autumn and similar for the two systems in 2006 and it was slightly higher utilisation in the continuous system in 2007 and 2009 (Table 3.6).

Table 3.6. Mean rating (1 = high to 4 = low) for estimated pasture utilisation in autumn in grazing systems at Rocky Springs for 2006, 2007 and 2009.

Year	Utilisation rating	
	Rotation	Continuous
2006	3.5	3.5
2007	3.5	2.9
2009	3.9	3.7

In 2007 and 2009, the continuous paddock received heavier grazing than the rotation system, reflected by more quadrats with utilisation rates 1-3 and fewer quadrats with a rating of 4 (Figure 3.2).

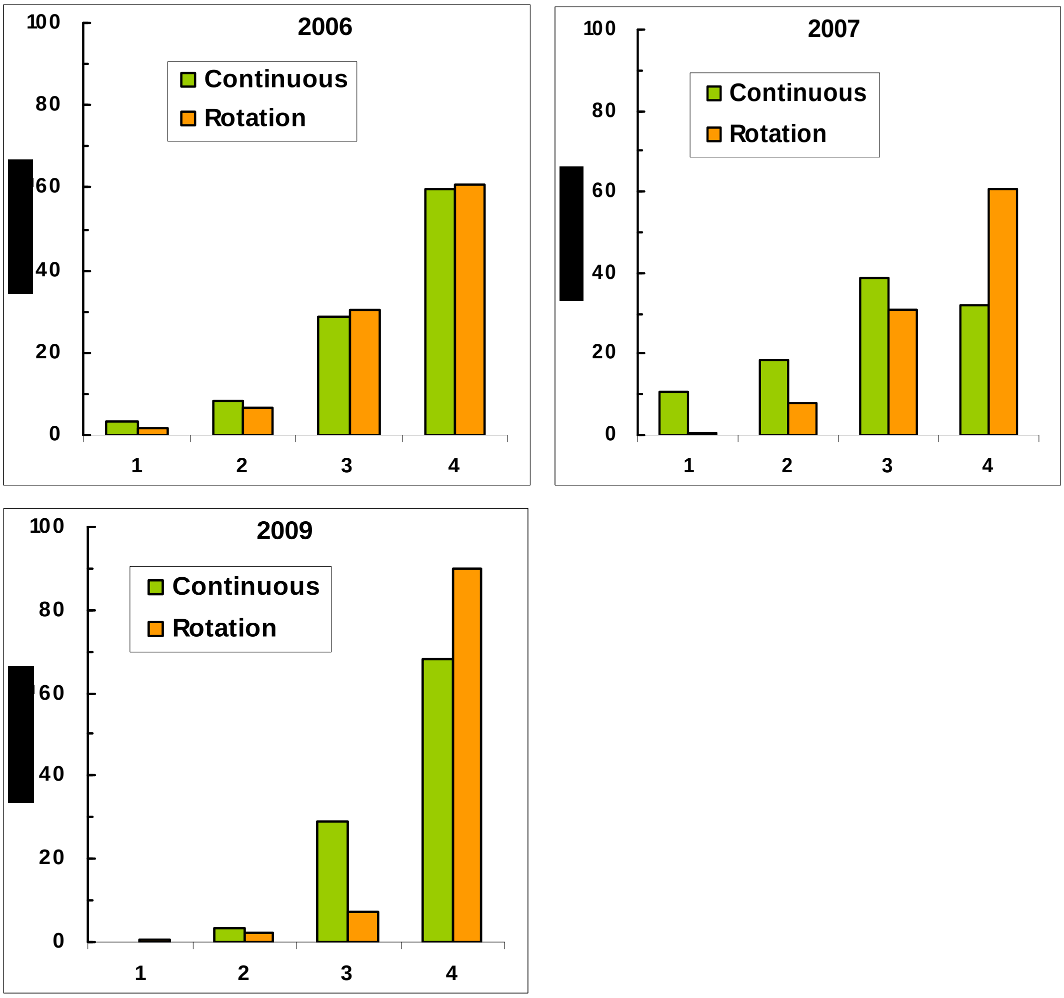


Figure 3.2. Distribution of estimated pasture utilisation values in grazing systems at Rocky Springs from 2005-06 to 2008-09.

3.2.2.2. Utilisation spatial variability

Utilisation was not uniform across any paddocks at the first two recording times (Table 3.7), but was uniform in all paddocks in autumn of 2009.

Table 3.7. Spatial variability in pasture utilisation – number of paddocks where pasture utilisation was spatially uniform (i.e. there was no evidence of aggregation) across the paddock.

Grazing System	Total no. of paddocks	No. paddocks uniform for utilisation		
		2006	2007	2009
Rotation	2	0	0	1
Continuous	1	0	0	1

3.2.3. Woody regrowth

Cover of woody regrowth from mainly *Eucalypt* spp. was low in both systems (Table 3.8), with marginally higher cover in the continuous system.

Table 3.8. Cover levels (%) of woody regrowth in grazing systems at Rocky Springs.

Year	Woody regrowth cover (%)	
	Rotation	Continuous
2006	1.0	1.4
2007	0.9	2.3
2009	0.4	0.8

3.2.4. Ground and litter cover

3.2.4.1. Cover means and standard deviations

Total cover levels were above 55% on all occasions and were slightly higher in the continuous paddock than the rotation paddocks in 2006 and 2007, but similar in both systems in 2009. Litter cover levels, between 20-31%, were similar in both systems. Although there was some variability, the standard deviations were similar for the different grazing systems (Table 3.9).

Table 3.9. Total pasture cover and litter cover levels (%), with standard deviations, at Rocky Springs at the end of summer.

Year	System	Total cover (%)		Litter cover (%)	
		Mean	St. dev.	Mean	St. dev.
2006	Rotation	75	23.9	23	14.1
	Continuous	84	21.5	23	12.0
2007	Rotation	56	28.0	20	17.4
	Continuous	64	27.9	24	18.1
2009	Rotation	76	22.2	31	21.4
	Continuous	73	24.0	30	21.7

3.2.4.2. Cover spatial variability

In 2006 both rotation paddocks had uniform total ground cover and one also had uniform litter cover. By 2009, no rotation paddocks had uniform total or litter cover. Total cover was not uniform and litter cover was uniform in the continuous paddock at the three recording times (Table 3.10).

Table 3.10. Spatial variability in ground cover – number of paddocks where total ground cover or litter cover was spatially uniform (i.e. there was no evidence of aggregation) across the paddock.

Cover Grazing System	Total no. of paddocks	No. paddocks uniform for ground cover		
		2006	2007	2009
Total ground cover				
Rotation	2	2	1	0
Continuous	1	0	0	0
Litter cover				
Rotation	2	1	1	0
Continuous	1	1	1	1

3.2.5. LFA indices (soil surface condition)

The LFA indices, stability, infiltration and nutrient cycling, have values between 0 and 100 where larger values indicate better performance for that index.

3.2.5.1. LFA means

Values for all three LFA indices were similar in the two systems every year (Table 3.11). There was no change in stability over the monitoring period, however, the infiltration index increased 13% and the nutrient cycling increased 19% over this time. This improvement in land condition is attributed to the stocking rate management during the drought years and the better pasture growing season over the last summer, 2008-09.

Table 3.11. LFA indices at Rocky Springs at the end of summer 2006, 2007 and 2009.

Year	System	LFA Indices (0-100)					
		Stability		Infiltration		Nutrient cycling	
		Mean	St. dev.	Mean	St. dev.	Mean	St. dev.
2006	Rotation	69.1	5.27	35.9	6.65	30.5	7.90
	Continuous	67.8	5.53	38.1	6.65	30.5	6.25
2007	Rotation	64.6	5.80	36.5	8.48	31.1	8.76
	Continuous	63.1	5.90	42.2	10.30	33.8	10.42
2009	Rotation	68.2	5.72	41.1	9.20	36.4	9.47
	Continuous	66.4	6.53	42.4	9.63	36.0	10.10

3.2.5.2. LFA spatial variability

There was a high degree of variability between the three LFA indices across the paddocks in the three years of recording in the rotation system (Table 3.12), while the continuous system had uniform stability, but not infiltration or nutrient cycling, in all years.

Table 3.12. Spatial variability in the LFA indices – number of paddocks where the LFA Stability, LFA Infiltration or LFA Nutrient cycling index was spatially uniform (i.e. there was no evidence of aggregation) across the paddock.

LFA index Grazing System	Total no. of paddocks	No. paddocks uniform for LFA indices		
		2006	2007	2009
LFA Stability index				
Rotation	2	1	2	0
Continuous	1	1	1	1
LFA Infiltration index				
Rotation	2	1	0	1
Continuous	1	0	0	1
LFA Nutrient cycling index				
Rotation	2	1	1	0
Continuous	1	1	0	1

3.2.6. Land condition

There was little difference in overall land condition between grazing systems, but there was a range of land condition ratings between the different land types within both systems. Most of the spear grass pastures were in B, or A, condition, probably due to drought and patch grazing over extended periods. The higher fertility creek flats were mainly in C condition due to reduced 3P grasses from higher grazing pressure on these sweeter pastures near semi-permanent water. Their composition has deteriorated in some areas and productivity has declined. An extensive area of silver-leaved ironbark on a granite ridge was in C condition. This area has a history of preferential grazing (Table 3.13). Overall, the paddocks are in good B condition.

Table 3.13. Land condition for landtypes and over years at Rocky Springs. For the Botanal/PatchKey and ABCD (Land type) values, "1" is equivalent to A condition and "4" is equivalent to D condition.

Land condition measure	**Land condition units**	
Year / Land type	**Rotation**	**Continuous**
Botanal/PatchKey		
2006	2.7	2.6
2007	2.9	2.9
2009	2.6	2.7
ABCD (by Land type)		
Silver-leafed ironbark on granite/clay	1.6	1.5
Narrow-leafed ironbark on granite	1.0	1.0
Poplar box on clay		1.5
Eucalypt alluvial creek flats	3.0	3.0
Brigalow scrub	1.5	
Overall average	1.6	1.5
ABCD (Paddock)		
2006	B (A-C)	B (A-C)
2007	B (A-C)	B (A-C)
2009	B (A-C)	B (A-C)

An annual photograph of fixed points in the two systems shows the seasonal variation in pasture growth and cover (Figure 3.3). The open pasture in the drought of 2005 and 2006 in the two systems was in better condition by March 2009. The mature pastures in early winter reflect the early end to the growing seasons during the monitoring period.

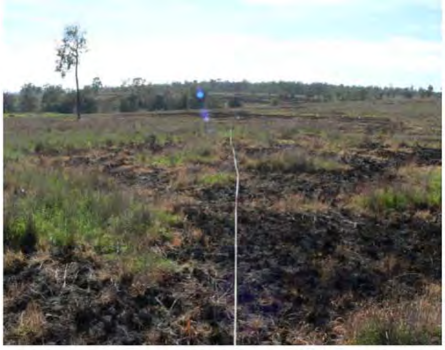
Rocky Springs Rotation St-1 Lat: 25^0.609; Long: 150^0.753, Dir: 105^0	**Rocky Springs Continuous FC-6** Lat: 25^0.623; Long: 150^0.724, Dir: 290^0
 Rotation (November 2005)	 Continuous (November 2005)
 Rotation (July 2006)	 Continuous (July 2006)
 Rotation (May 2008)	 Continuous (May 2008)
 Rotation (March 2009)	 Continuous (March 2009)

Figure 3.3. Changes in land condition at fixed points in the rotational and continuous grazing systems at Rocky Springs between 2005 and 2009.

3.2.7. Cover analysis

3.2.7.1. VegMachine vegetation cover time series (Landsat)

The VegMachine analysis of paddocks at Rocky Springs showed there was a strong cover relationship between the GSP monitor paddocks and the whole property in all years since the current owners bought the property in 1988-89 (Figure 3.4). There was a drop in cover during the drought of the early 1990s, when the owners recognised their stock numbers were higher than they considered desirable for the pasture growing conditions. All paddocks were grazed similarly. The owners acknowledge the number of cattle they graze in each paddock is lower than the previous owners regarded as their individual carrying capacities. In the years prior to commencing the GSP, there was no difference in grazing pressure between the two rotation paddocks (data not presented), the continuous paddock and the property as a whole. All paddocks have been managed to match the stock numbers with the available pasture, even during the drought years since 1999. In the drought of 2006, the rotation paddocks had a marginally lower cover than the continuous paddock. GSP field data supports this 10% difference (Table 3.14).

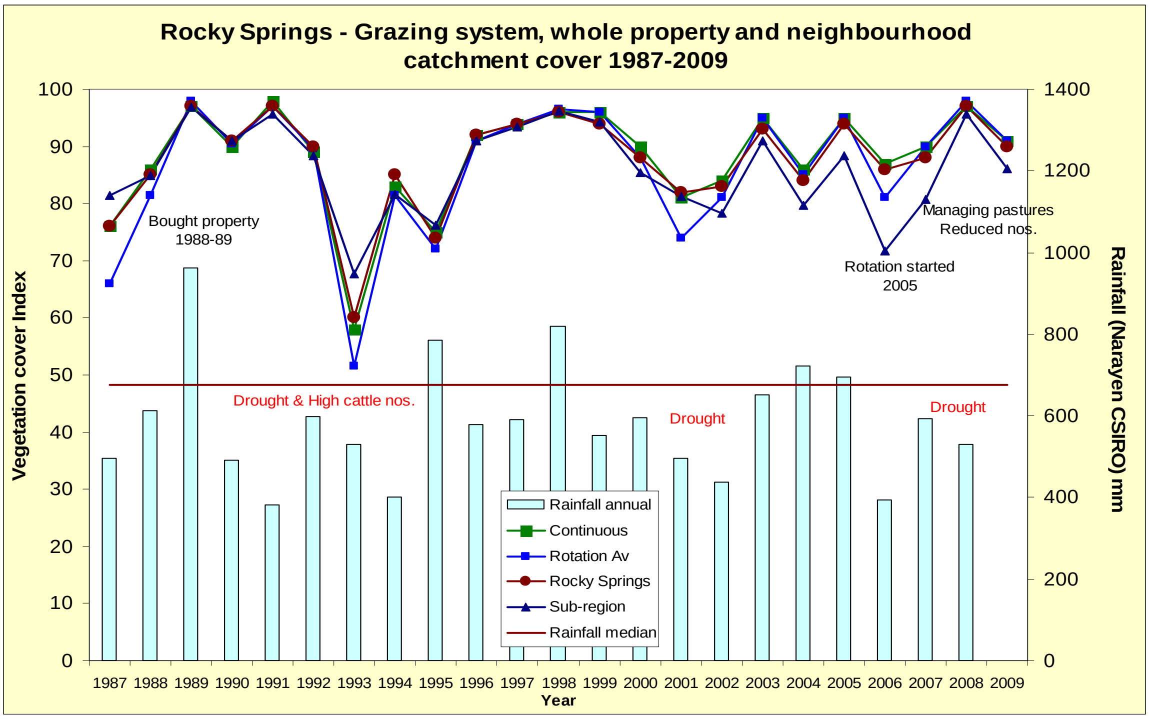


Figure 3.4. Vegetation cover index between 1987 and 2009 for grazing systems and the whole property at Rocky Springs. Annual and long-term median rainfall (mm) are also shown.

During the better rainfall years since 1987, the monitor paddocks, the whole property and the neighbourhood subregion maintained almost identical high cover levels. However, in the drought years of the 1990's and early 2000's, the monitor paddocks had the lowest cover levels. This has been reversed in the current drought, with the subregion tending to have the lowest cover levels and the monitoring paddocks maintaining a marginally higher and similar cover (Figure 3.5). There has been less tree clearing on some neighbouring properties in the subregion, which contributes to this cover (see Figure 2.1), so this suggests that pastures in the surrounding catchment had much lower cover than the monitor paddocks at Rocky Springs.

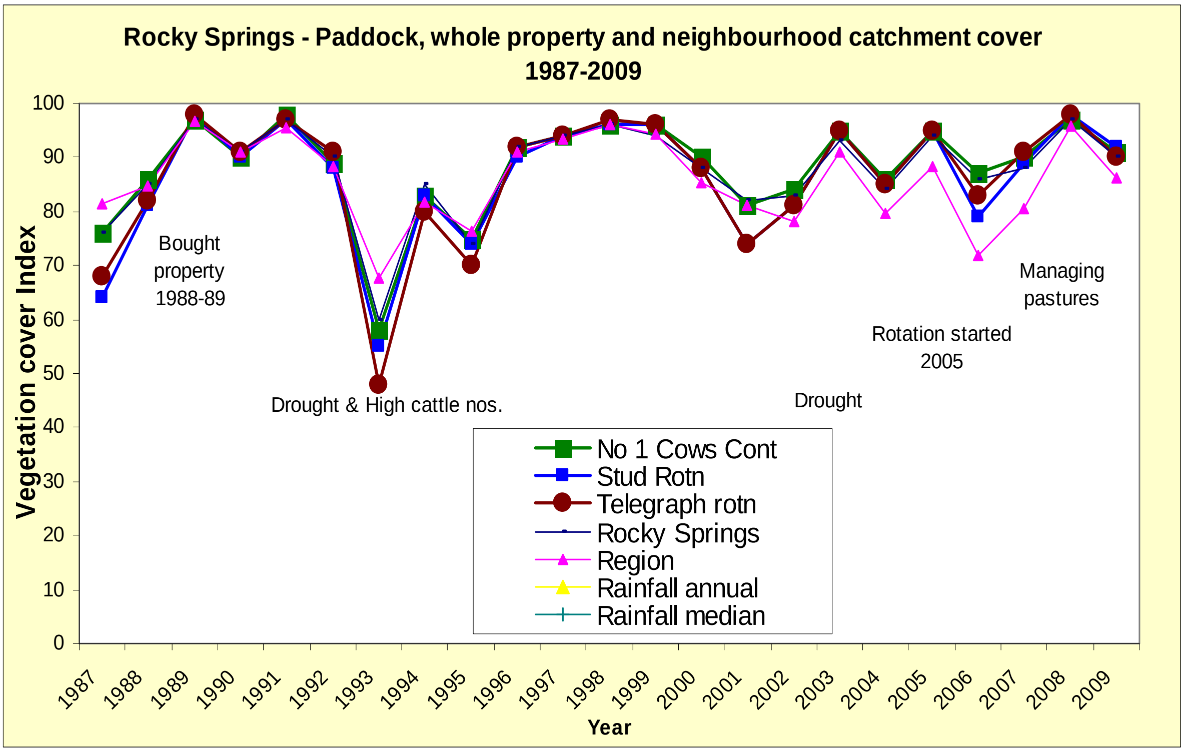


Figure 3.5**.** Vegetation cover index between 1987 and 2009 for individual paddocks, the whole property at Rocky Springs and the neighbourhood sub-region.

3.2.7.2. Botanal pasture cover analysis

Total cover measured in the field in autumn of 2006 was 20% higher than in 2007 in both systems (Table 3.14). This decline was not recorded in the VegMachine analysis, where the cover index was slightly higher in late winter of 2007.

Table 3.14. Pasture yield (kg/ha), total pasture cover (%), litter cover (%) and woody regrowth cover (%) in monitor paddocks and grazing systems in 2006 and 2007 at Rocky Springs.

Paddock / System	Yield (kg/ha)		Total Cover (%)		Litter Cover (%)		Woody Cover (%)*	
	2006	2007	2006	2007	2006	2007	2006	2007
No. 1 Cows Cont [1]	2820	1510	84	64	23	24	1.4	2.3
Telegraph Rotn [2]	2810	1510	79	59	23	23	1.5	1.2
Stud Rotn [3]	2100	1460	72	53	22	16	0.4	0.5
Continuous	2820	1510	84	64	23	24	1.4	2.3
Rotation	2450	1490	75	56	22	20	1.0	0.9
Site	2570	1490						

* woody cover is regrowth only.

3.2.7.3. Spatial ground cover reports

The average cover levels between 2001 and 2005 (Figure 3.6) showed the monitor paddocks were very similar with high cover over a majority of the area in all three paddocks, and small scattered areas of medium cover. The low cover area on the ridge on the western side of Stud paddock (also identified in the GSP Botanal field recording) is shown as a long-term relatively lower cover, selectively grazed area. The monitor paddocks are very representative of the whole property and of surrounding properties.

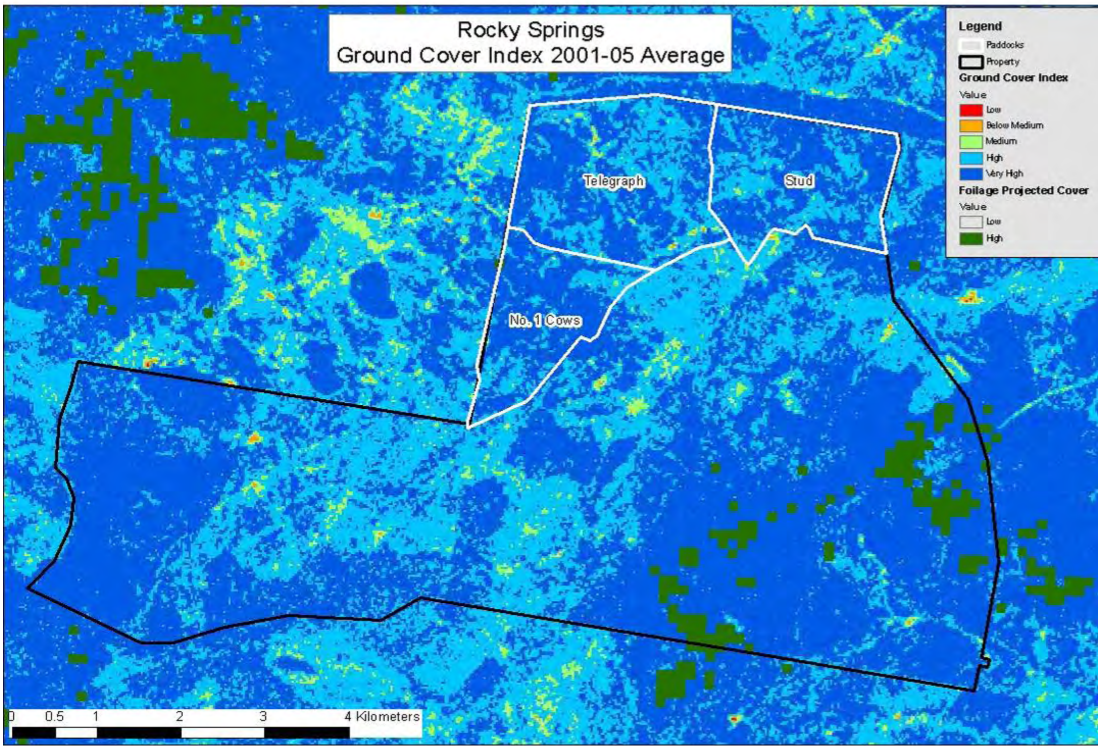


Figure 3.6. Average (2001-2005) ground cover index (vegetation cover) image for the rotation and continuous grazing systems, the whole Rocky Springs property and surrounding properties (Source QDERM data).

3.3. Cattle Grazing

3.3.1. Carrying capacity – long-term (LTCC)

The estimated long-term carrying capacities (AE/100 ha and SDH) from the sum of the landtypes shows the continuous system is marginally higher than the rotation system:

Rotation	24 AE/100 ha (87 SDH)
Continuous	28 AE/100 ha (100 SDH)

The four year annual average grazing was 19 and 26 AE/100 ha for the rotation and continuous systems respectively. Both are lower than the LTCC reflecting the effect of the prolonged drought.

3.3.2. Rest periods

There were animals in the No. 1 Cow continuous paddock at all times the four-year monitoring period, while both Stud and Telegraph rotation paddocks received some complete rest periods, from 13 to 69 days (Table 3.15). Stud received annual rest periods, on five occasions with a total of 209 days rest, compared with rest in only two years in Telegraph paddock, totalling 91 days. The grazing pressure in these rotation paddocks fluctuated on 3-9 occasions per year, allowing some additional respite for the pasture during these periods of reduced grazing. There is a greater benefit expected to the pastures when rest periods could coincide with useful summer rainfall events, but this did not always occur due to the consecutive poor rainfall seasons.

Table 3.15. **Rest periods for grazing systems at Rocky Springs.**

Year			Rest periods (days)	
	Rotation (grazing months)		**No. days**	**Continuous**
2005-2006	**Stud:**	October-December	42	Nil
	Telegraph:		Nil	
2006-2007	**Stud:**	November-December	17	Nil
	Telegraph:	March-April	22	
2007-2008	**Stud:**	November; and	13	Nil
		March-May	68	
	Telegraph:	November-February	69	
2008-2009	**Stud:**	February-April	69	Nil
	Telegraph:		Nil	

3.3.3. Grazing days

There were an annual average of 280 and 365 days grazing in the rotation and continuous systems respectively. The annual range of grazing was 198 to 365 days in the rotation paddocks. Stock numbers were varied an average of six occasions annually (range 3 to 9) in the rotation and on five occasions (range 4 to 9) in the continuous system. This flexibility was caused by normal breeder management with introducing bulls and weaning calves in a breeding enterprise. The variable pasture responses in the continuing drought also meant stocking rate adjustments were required.

3.3.4. Grazing pressure

The animal numbers taken from property records for each system have been converted to Animal Equivalents (AE) using the standards tables presented in Appendix 9.10. An AE is equivalent to a dry cow weighing approximately 450 kg.

There was heavier grazing pressure in the continuous system than in the rotation throughout the monitoring period, with an average of 13 SDH/100mm rainfall in the 12 months prior to each grazing event in the rotation system compared with 18 SDH/100mm in the continuous paddock (**Error! Reference source not found.**).

Table 3.16. Grazing days for grazing systems at Rocky Springs (SDH/100mm/annum).

Year	**SDH/100mm**	
	Rotation	**Continuous**
2005-06	11.2	19.9
2006-07	17.2	22.1
2007-08	9.2	10.3
2000-09	14.0	18.8
Average	**12.9**	**17.8**

Average annual grazing pressure over four years was lower in the rotation, 68 SDH (0.19 AE/ha), than in the continuous system 94 SDH (0.26 AE/ha). The continuous paddock also had higher grazing pressure measured as SDH/100mm rainfall in the previous 12 months to each grazing event and also in ha/AE, than the rotation paddocks over the four year monitoring period (Table 3.17).

Table 3.17**.** Grazing system and year effect on stock days per ha (SDH), SDH per 100mm rain and annual stocking rate (ha/AE) at Rocky Springs[#].

Grazing System / Year	**Grazing pressure**								
	Stock days per ha (SDH)			**SDH / 100 mm rain**			**Annual stocking rate (ha/AE)**		
Grazing System (GS)	*			*			*		
Rotation	4.21	(66)	b	2.60	(13)	b	1.88	(5.5)	a
Continuous	4.54	(92)	a	2.90	(17)	a	1.60	(4.0)	b
Av. s.e.d.	0.11			0.10			0.10		
Year (Yr)	ns			*			ns		
2005-06	4.39	(80)		2.73	(14)	a	1.73	(4.6)	
2006-07	4.46	(86)		3.01	(19)	a	1.67	(4.3)	
2007-08	4.14	(62)		2.40	(10)	b	1.94	(5.9)	
2008-09	4.50	(89)		2.85	(16)	a	1.63	(4.1)	
Av. s.e.d.	0.15			0.14			0.13		
GS x Yr	ns			ns			ns		

ns – *P* > 0.10; * *P* < 0.05;
[#] Data were log-transformed prior to analysis. Back-transformed means are given in parentheses. Means not followed by a common letter are significantly different (P=0.05).

3.3.5. Grazing system intensity index

The grazing system intensity index values (GSI range 1-100; calculated from capital costs, operating costs and management inputs; details are reported in Appendix 9.13) for the two systems were:

Rotation 45
Continuous 31

3.3.6. Diet quality (NIRS)

3.3.6.1. Analysis of all samples over four years

Average diet quality was very similar in the two systems for all parameters, near 8% crude protein and 55% digestibility with 22% non-grass (Table 3.18). Both systems were always sampled at the same time, on 29 occasions.

Table 3.18. Mean faecal NIRS diet quality results for grazing systems at Rocky Springs between November 2005 and June 2009 (all sampling times were paired).

Grazing System	No. samples	Crude protein (%)	Faecal N (%)	Digesti-bility (%)	Non-grass (%)	LWG (kg/day)	DMD/CP ratio
Rotation	29	7.8	1.5	55	21	0.60	7.1
Continuous	29	8.2	1.4	55	22	0.56	7.4
Sed (av.)		0.44	0.05	0.9	2.3	0.07	0.6
Significance		ns	ns	ns	ns	ns	ns
Average	**58**	**7.9**	**1.4**	**55**	**22**	**0.57**	**7.4**

3.3.6.2. NIRS related to pasture growth index

The NIRS values were examined by dividing them into groups which had different growing conditions on the basis of the pasture Growth Index (GI) derived from GRASP modelling (where 0.0 = conditions are unsuitable for growth and 1.00 = conditions are not limiting growth). Average values of the GI for the 30 days ending on the sample date were calculated. Based on these values three classes were formed – mean GI <0.2 (Poor growing conditions), 0.2-0.5 (Average) and >0.5 (Good conditions). The continuous system had marginally higher crude protein in the three classes, however this was not statistically significant (Table 3.19). As expected, there were large difference (P<0.01) in diet quality (3% higher crude protein and 4% higher digestibility) between the pastures when they have some green or are growing (GI>0.5) compared with the dormant pastures in winter (GI<0.2).

Table 3.19. Mean NIRS diet quality results in relation to three pasture growth indices classes for two grazing systems at Rocky Springs.

Growth Index	Grazing System	No. samples	Crude protein (%)	Faecal N (%)	Digesti-bility (%)	Non-grass (%)	LWG (kg/day)	DMD/CP ratio
<0.2	Rotation	12	6.2	1.3	52	22	0.23	8.7
	Continuous	12	6.3	1.3	52	21	0.27	8.4
0.2-0.5	Rotation	8	9.1	1.6	56	22	0.74	6.6
	Continuous	8	9.3	1.6	57	21	0.79	6.6
>0.5	Rotation	9	8.5	1.5	56	25	0.80	6.7
	Continuous	9	9.1	1.6	55	25	0.84	6.2
sed (av.)		58	0.81	0.09	2	5	0.11	0.7

3.3.6.3. Monthly CP, DMD and non-grass

Individual sample results for the NIRS diet quality parameters crude protein, digestibility and non-grass in the continuous (Figure 3.7) and rotation (Figure 3.8) systems show the wide seasonal variation in both systems. There is high quality native perennial grass pastures in summer, declining rapidly to maintenance or below crude protein maintenance requirements in winter-spring after frosts and before summer rain, in both systems. There was also a widely fluctuating non-grass component of the diet which was often as high as 40% of the total diet. The botanical sampling show the pastures contained some 4% forbs and 2% native legumes. The diet indicates the cattle are selecting for these broad-leaved plants and possible any tree suckers. The high non-grass in the diets during the pasture growing months would also reduce their proportion at recording time in autumn, as the most palatable species would have been consumed by then.

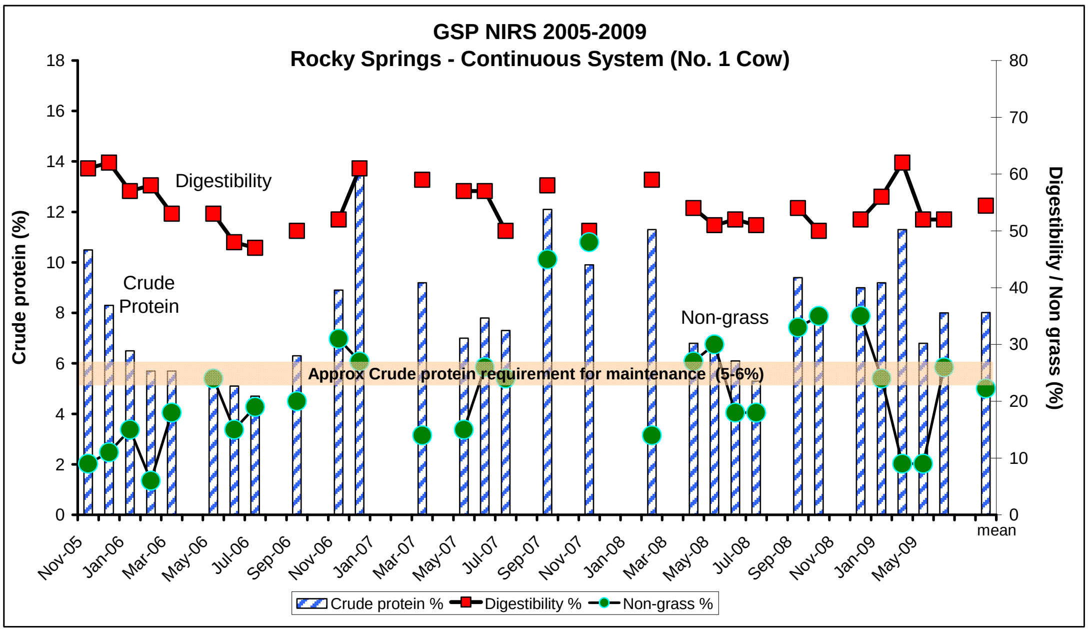


Figure 3.7. NIRS sample results for the continuous grazing system at Rocky Springs for crude protein (%), digestibility (%) and non-grass (%) with approximate maintenance crude protein indicated.

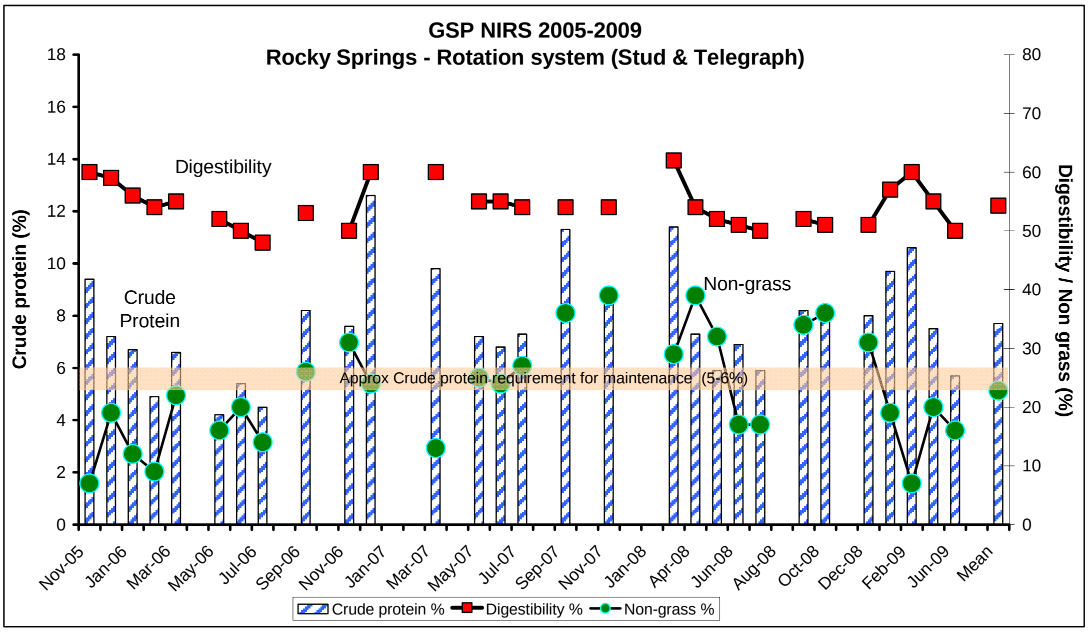


Figure 3.8. NIRS sample results for the rotation grazing system at Rocky Springs for crude protein (%), digestibility (%) and non-grass (%) with approximate maintenance crude protein indicated.

3.4. Grazing System Costs

3.4.1. Capital costs

The rotation grazing system (spring burning followed by rest) uses no new capital infrastructure compared to the continuous system. Established paddocks are used for both the continuous and rotation systems.

3.4.2. Operating costs

The opportunity to implement the planned rotation and burning program is highly dependent on the type of seasons experienced, with rainfall amount and its distribution having effects on ability to produce and conserve fuel to burn.

The operating costs of implementing the rotation system include additional grazing imposed on the other rotation paddocks while the burnt paddock is rested. It may also include reduced grazing over the previous summer to allow sufficient pasture carry-over to make a useful burn.

There was only one fire at the start of the project in one paddock. This meant there were no actual additional costs incurred by the rotation system during the four-year monitor period. The extended drought during the project, with rainfall in either decile 1 or decile 3 in all years, shows that relatively simple planned grazing systems cannot always be implemented.

3.4.3. Animal performance

The weaner and breeder liveweights and conception rates over the 2006-09 period are shown in Table 3.20. The marginally lower liveweights of breeders in the rotation paddocks (Telegraph and Stud) is more a reflection on younger cows compared with more mature cows in the continuous paddock, No. 1 Cow. Weaner weights have increased over the monitoring period from near 200 kg in the very serious drought of 2005-06 year to 270 kg after some good summer rainfall events in 2008-09.

Table 3.20**.** Weaner and breeder weights and conception rates in the monitor systems.

Year	Herd component	Liveweight (kg/hd) and Conception rate (%)		
		Continuous	Rotation	
		No. 1 Cow	Telegraph	Stud
2006	Weaner weight kg	202 kg av. for all systems		
	Cow weight kg	488	464	435
2007	Weaner weight kg	240 kg av. for all systems		
	Cow weight kg	505	500	442
2008	Weaner weight kg	240 kg av. for all systems		
	Cow weight kg	534	517 av.	
	Cow conception %	95.5 % av. for all systems		
2009	Weaner weight kg	270	261 av.	
	Cow conception %	97	97 av.	

The joining period has been reduced to 15 weeks or less and all non-pregnant cows are culled, maintaining a highly productive breeder herd with 97% conception rates in both grazing systems in a year (2008-09) with 606 mm rainfall.

4. Conclusions

4.1. Pasture and land condition

Land condition was similar in both grazing systems at Rocky Springs. The paddocks were all assessed as being in B condition overall, but all contained patches in A, B and C condition. The PatchKey results also showed no difference between grazing systems.

Pasture yields were similar in both systems with a mean difference over the three samplings of only 70 kg/ha. Yield levels in both systems were highest in 2009. Similarly, both systems were strongly (>92%) dominated by native perennial grasses. Woody regrowth was low in both systems but slightly higher in the continuous than the rotation systems.

Ground cover levels were higher in the continuous than the rotation system in 2006 and 2007 (8-9%) but the rotation had slightly higher (3%) cover in 2009. Litter cover levels were similar in both systems. Both total cover and litter cover levels were highest in both systems in 2009.

The values for the three LFA indices were similar for both systems in all years. The Stability index had similar values over the years but the values of the Infiltration index and the Nutrient cycling index both increased with time to highest levels in 2009.

The VegMachine analyses showed a similar pattern of changes for the two systems over the past 20 years. During the experimental period there were only small differences between grazing systems in the values of the Vegetation Cover index. The Vegetation Cover index values were already at a high level in 2006 (>80) but increased further in 2007 and 2008. Results suggest that the monitor paddock pastures have higher cover than the average of surrounding properties.

4.2. Carrying capacity and grazing

The continuing drought prevented Rocky Springs from implementing its planned spring burning and summer spelling regime during the four-year monitoring period. The one burn (2005) before monitoring commenced has had no continuing effect on the pastures, although it may have contributed to the significantly lower grazing carried on the rotation system (13 SDH/100mm) than the continuous system (18 SDH/100mm). The average stocking rate in the continuous system (4.0 ha/AE) was higher than in the rotation (5.6 ha/AE). This grazing is similar to the LTCC of 3.6 and 4.2 ha/AE for the two systems respectively. There were no between year differences.

Diet quality was similar in both systems, with a 3% increase in crude protein and 4% increase in digestibility between pastures in winter and pastures with some green or still growing. There was selective grazing for non-grass species after first rains in spring in both systems.

Overall there were no consistent ecological differences that suggest any real difference between the grazing systems during the study period over this drought when grazing pressure was adjusted to pasture production.

4.3. Owner's comments on grazing systems

Rocky Springs has always been a breeding/finishing property, as far as I know. We also sell some heavy feeder steers at times. The timing of sales is affected by the seasons, with earlier sales during poor spring-early summer periods.

4.3.1. New management

Why change grazing system: *The main driver was a need to improve land condition. I think the rotation and lower stocking rates that we have introduced as well, has contributed to increased animal production per head at least.*

There have been a lot of infrastructure changes, but not in the three paddocks studied. We see wet season spelling and paddock rotation as a low cost, less intensive way of looking after the land, although changes can be slow.

The goal has been to spell all paddocks after rain for eight weeks at least every three years. The two rotation paddocks in this study have probably had a little more than that, especially Stud.

Apart from spelling, we have also split paddocks, increased watering points, put in around 600 ha of improved pasture, eradicated cattle ticks, shortened joining (up to 15 weeks), decreased stocking rates to match long-term projections after assessing land condition as per GLM framework. We also regularly try to objectively assess pasture dry matter yield/ha to check our stock numbers. We wean about six weeks earlier and have targeted weaner management. We try and look at the overall picture and increase kg beef produced whilst also improving land condition.

4.3.2. Results

Results have been very satisfying. Weaner weights have gone from average of 210 kg, to an average of 270 kg. Bullock weights have increased around 20 kg dressed and sold around six months earlier. Conception rates have increased from 92% to 96.7% this year (a good late season). We think land condition is improving, but there are still areas which need more than just spelling, or at least we are finding this method too slow for our objectives, and we will continue developing country as well with improved pasture.

4.3.3. Future plans

I think in general we will just continue to improve our land so that we can increase quality and quantity of kg turned off and hopefully increase profits. Over the last few years, we have attended a lot of extra training and it will be important to remain up to date. We are still planning to fence off our over-grazed creek flats, and hope to achieve that at least partially in the next few years. We expect there will be less pasture burning in our future management, but strategic burning will remain a grazing and pasture management tool. More areas of heavy soil will be cultivated and sown to improved grass and legume mixes when seasons permit.

4.4. General conclusions

The pastures at Rocky Springs and their ecological responses were similar in both grazing systems during this four-year study period. Although grazing pressure was marginally higher in the continuous system, this capacity is supported by the higher estimated LTCC for this paddock compared with the two rotation paddocks. Grazing was marginally lower than the estimated LTCC in both systems throughout the study which was conducted during an extended severe drought period. The drought prevented the implementation of the planned annual burning and spelling program in the rotation paddocks.

Maintaining pastures, land condition and cattle production during this four-year drought shows the flexibility of the different grazing systems. They were managed as integrated components of the whole property. The systems were not independent or rigid, but were flexibly managed and integrated to suit the constraints of the seasons and meet breeder reproduction and marketing requirements. The ecological and cattle performance results highlight the high degree of management flexibility and capacity to react to continually changing whole property circumstances, and also that grazing management systems cannot always be implemented as planned, even over an extended period.

Salisbury Plains

Abstract
'Salisbury Plains', Bowen, has two grazing systems; cells and continuous. Nine cell and one continuous paddock were monitored between 2006 and 2009. The two systems are used as part of an integrated property breeder enterprise. The cell system is used for breeders, with sale cattle and cull breeders run in the continuous system. There was a drought for the first two years and above average rainfall over the last two years. The pastures were sampled in late autumn in 2006, 2007 and 2009. Average pasture yields were similar in both systems and increased from 3200 to 4200 kg/ha between 2007 and 2009, with the improved rainfall conditions. All pastures were mixed native and exotic species. In 2009 there was 21% native and 49% exotic grasses (Indian bluegrass, buffel and Sabi grass), with 17% exotic legumes, mainly Seca and Verano stylo, and 7% native forbs.

The cell system supported higher average grazing pressure than the continuous system (24 Vs. 11 SDH/100mm rainfall respectively). This grazing, which occurs mainly in the dry season, is higher than the estimated LTCC for the cells and at the suggested rate for the continuous paddock. Over all samples the NIRS diet quality was higher (by 2% crude protein and 4% digestibility) in the continuous system than in the cells. There was also a higher proportion of non-grass (10% greater) in the continuous system, which was from stylo legumes and forbs. Most ecological responses in the two grazing systems were similar across the range of paddock sizes, soil types, grazing times and management systems. The ecological differences were not consistent or strongly associated with the grazing system.

1. Site Introduction

1.1. Location

Salisbury Plains is located 25 km north-west of Bowen (20.0ºS; 148.0ºE) on the coastal plain (Figure 1.1).

Figure 1.1. **Open coastal woodland landscape at Salisbury Plains.**

1.2. Climate/growing season

The average annual rainfall at Salisbury Plains is 990 mm (Table 3.1) with 80% falling in summer (October-March). The growing season is predominantly in summer, but infrequent winter rain can be important for winter pasture growth with subsequent beneficial impacts mainly on pasture quality.

Based on long-term climate data, the average green season for tropical pasture species is estimated to be 33 weeks including 20.3 growth weeks. With the winter rain, temperate species would add an average of 1.8 weeks to the growth of tropical species.

1.3. Major soil/vegetation types

The major soils on Salisbury Plains are sandy earths, yellow duplexes and grey clay/clay loams on a flat to very gently undulating landscape. The original vegetation was a eucalypt woodland but all paddocks have been thinned/cleared to sparse tree cover with some tea tree (*Melaleuca* spp.) regrowth. Major tree species are Moreton Bay ash (*Corymbia tessellaris*), cocky apple (*Planchonia careya*), poplar gum (*Eucalyptus platyphylla*) and narrow-leafed ironbark (*Eucalyptus crebra*).

The pastures are dominated by Indian bluegrass (*Bothriochloa pertusa*), buffel grass (*Cenchrus ciliaris*), perennial urochloa (*Urochloa mosambicensis*) and stylos (*Stylosanthes hamata* cv. Verano and *S. scabra* cv. Seca), with native grasses, bluegrasses (*Bothriochloa* and *Dichanthium* spp.), *Chloris* spp. and golden beard grass (*Chrysopogon fallax*).

The paddocks are of varying areas and had different grazing pressures, which increased the proportion of Verano stylo (*Stylosanthes hamata*) in some of the smaller paddocks, but the summer rest has also allowed the re-establishment of buffel grass, green panic (*Panicum maximum*), perennial Urochloa (Sabi grass) and siratro (*Macroptilium atropurpureum*).

Since part of the continuous paddock had a sandy or loamy surface similar to the cell areas, and the other part was a heavy cracking clay the results for this system have been analysed separately for the two different areas (Continuous-sand and Continuous-clay).

1.4. GRASP modelling of long-term pasture growth

1.4.1. GRASP parameters

The three major land types “Bluegrass-brown top plains”, “Coastal teatree plains” and “Poplar gum woodlands” cover 97% of the monitor paddocks at Salisbury Plains. The values for the main GRASP parameters are given in Table 1.1. The pasture growth simulations were run for these three land types.

Table 1.1. Land type parameters for Salisbury Plains used in GRASP model to estimate pasture growth.

GRASP parameter	Parameter units		
	Bluegrass plains	**Coastal teatree**	**Poplar gum woodland**
Tree basal area (m^2/ha)	0	5	1
Available soil water (mm)	142	95	120
Maximum N uptake (kg/ha)	20	25	25
Regrowth (kg/ha/%BA)	3.5	6	6
Transpiration use efficiency (kg/ha/mm)	25.4	13.5	15
Minimum N concentration (%)	0.42	0.4	0.5

1.4.2. GRASP results

The GRASP model was run using climate data from SILO for the period 1889 to June 2007 and pasture growth for the period July 1 to June 30 was estimated. The median values for Salisbury Plains were 4760 kg/ha for the “Bluegrass-brown top plains”, 3680 kg/ha for the “Coastal teatree plains”, and 4550 for the “Poplar gum woodlands” (Figure 1.2).

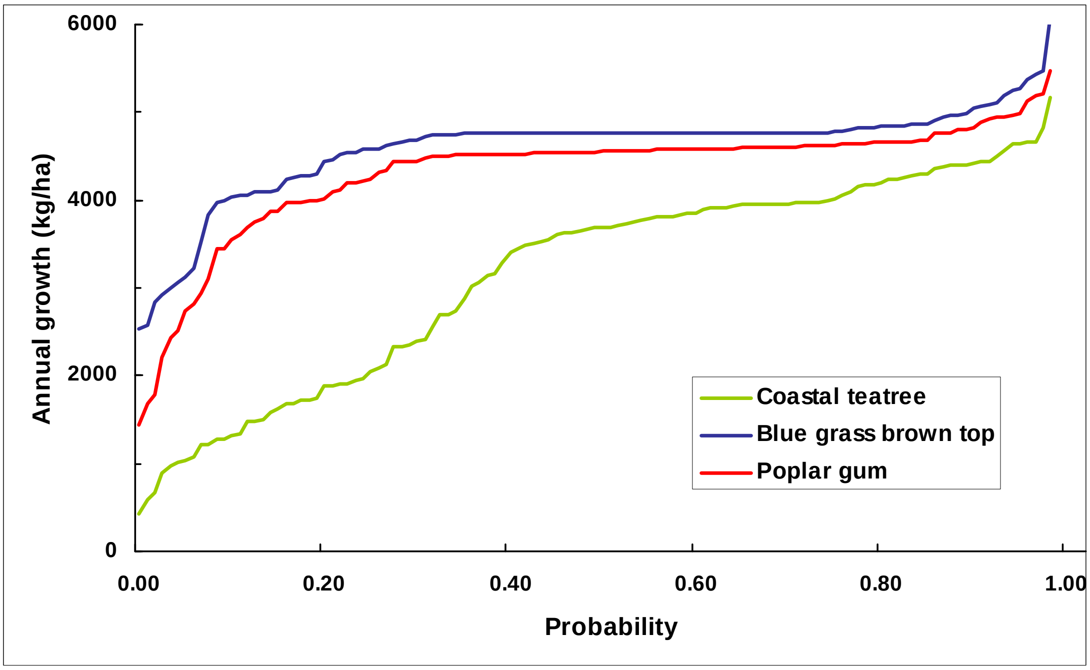


Figure 1.2. Long-term distribution of estimates of annual pasture growth on three landtypes at Salisbury Plains.

1.5. Production system/markets

Salisbury Plains is a beef breeding, growing and fattening operation based on a black Brangus herd. The enterprise produces 36 to 40 month old males for the processing industry, and females which are sold at various ages. When there is excess pasture, additional cattle are purchased to fatten and their composition and age depends entirely on the marketing opportunities at the time.

1.6. Producer goals

This property was purchased by the present owner's family in a relatively undeveloped state in 1946. The pastures were predominately native species dominated by black spear grass and subject to relatively low utilisation due to the type of stock and timber coverage. Pasture and infrastructure development largely commenced in the 1960's along with a change in the type of cattle and increasing use of supplementary feeding. Pastures and soils were judged to be deteriorating significantly by the late 1980's and changed management practices were investigated. Following experimentation with a system of `rotational grazing' involving subdivision of paddocks into smaller areas some positive improvements were observed in pasture condition. The owners attended a formal cell grazing course and decided to further investigate establishing a new grazing system based on cell grazing principles.

Based on experience to date, the owners would still advocate the use of cell grazing principles for positive pasture management, but would possibly apply a less intensive rotational system on larger paddocks than at present. Increasing stock numbers was not formally cited as a principal objective of establishing the present cell grazing system.

2. Grazing systems

2.1. Description

Two systems were studied – a cell system and a continuously grazed pasture, Wilmington paddock. Nine paddocks from three cell centres were monitored in a cell system of 60 paddocks (average size approximately 24 ha) constructed within a pre-existing structure of nine paddocks from the original conventional grazing system. Some 450 cows and calves were rotated in the cells with daily shifts when pastures were growing rapidly. The grazing period extended to two to four days as pastures matured. However, there were total rest periods during some summers. There were two sets of cells established in 2001-02, at an original cost of some $300,000. Paddocks in only one cell system (Kangaroo cell) were monitored. Fencing of this cell system comprised of 63 km of single wire electric fencing with steel posts. Water is supplied to the nine cell centres through 12 km of 63 mm polythene pipeline. Each cell centre is watered by a concrete stock trough. The bulk of the site treatment, fencing and pipe-laying was completed using station plant, machinery and labour.

The continuous paddock (800 ha) was grazed mainly by sale animals which included growing and breeder cattle. Numbers fluctuated with pasture production and quality, and the market for these animals. This pasture may be spelled at varying times of the year, including over the summer growing season, although it was not rested during the four-year monitor period. Some 50% of the continuous paddock is a heavy cracking clay soil plain supporting a bluegrass/browntop (*Dichanthium fecundum* and *Eulalia aurea*) with feathertop wiregrass (*Aristida latifolia*) pasture. The remainder of the paddock has a sandy or loamy surface similar to that in the cell system, and also supports a mixed native grass and stylo legume pasture (Table 2.1). The layout of the monitor paddocks is shown in Figure 2.1.

Table 2.1. Paddock names, numbers and areas sampled at Salisbury Plains.

Vegetation	Grazing System	Paddock name [Botanal No.]	Area (ha)
Eucalypt	Cell	C1-1 [1]	35
		C1-2 [2]	11
		C1-8 [8]	40
		C2-11 [11]	22
		C2-12 [12]	10
		C2-13 [13]	6
		C2-14 [14]	12
		C4-25 [25]	24
		C4-26 [26]	32
		Total cell	192
Eucalypt	Continuous	Wilmington [20]	800

The areas of the five main land types in each system are shown in Table 2.2. There is a greater variation in land types in the continuous paddock than in the cell monitor paddocks.

Table 2.2. Areas (ha) of land types in the monitor paddocks of grazing systems at Salisbury Plains.

Land type	**Area (ha)**	
	Cells	**Continuous**
Poplar gum woodlands	93	193
Coastal teatree plains	99	
Bluegrass brown top plains		574
Salt pan area (no production)		13
Rocky hill (negligible grazing)		20
Total	**192**	**800**

Excluding the bare salt pans and rocky outcrop in the continuous paddock there is some 763 ha of usable pasture land.

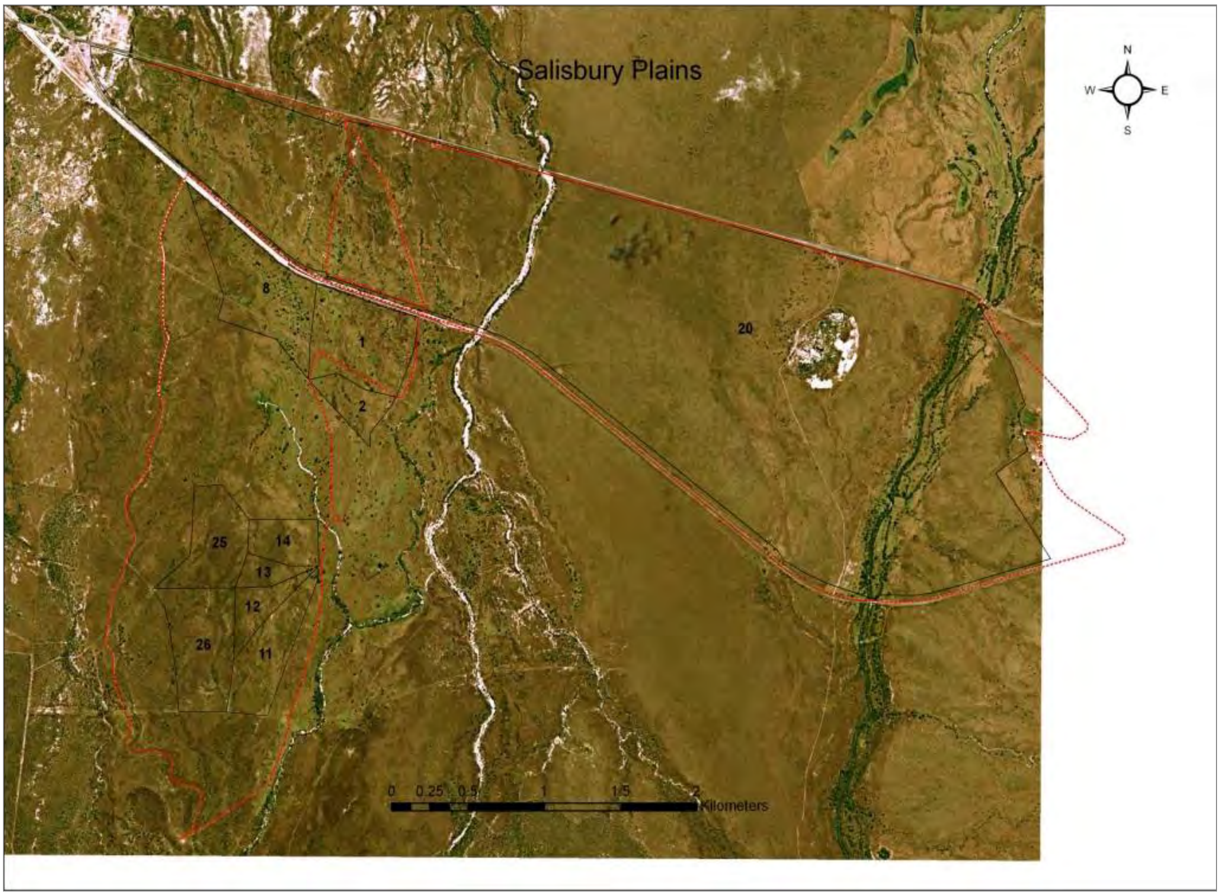


Figure 2.1. Layout of the cell and continuous monitor paddocks and tracks (in red) at Salisbury Plains.

2.2. Management during 2005-2009

The cell paddocks were grazed by a breeder herd of around 450 cows and calves. The system was rested during the year, usually during the wet season which allowed the pastures to grow. The cell paddocks are spelled during the wet season because of the management difficulties associated with heavy stocking rates in wet country (bogging) and the problems of moving cows with young calves.

The downside of the summer spelling in the cells is that in March or April when is it is dry and cool and calves are big enough to move breeders through cells, the buffel and grass is maturing and can be 1 m high and declining in quality.

The usual shift method is to open the gate into a new cell paddock and the cows move themselves to fresh feed. However, in the dense buffel areas, with growth rates in buffel of about 50 mm per day, there was “fresh feed” in all paddocks with buffel ridges. Under these circumstances, the cows stay wherever it suits them and they don’t necessarily move into the new paddock, adding to management difficulties.

The continuous paddock was grazed by mixed herds of sale cattle, which may have been growing cattle to cull cows. On occasions cows and calves were grazed in this paddock. There were some cattle grazing in the paddock all year, although the stocking rate varied, with up to 9-11 changes in numbers depending on culling and sales strategies.

3. Results

3.1. Growing Seasons

The recording period followed a serious drought which continued for the first two years of monitoring (decile 3 and 4) and the last two years received well above average rainfall (decile 7 and 8) (Table 3.1).

Table 3.1**.** Monthly rainfall (mm) at Salisbury Plains from July 2004 to June 2009 and long-term average monthly rainfall (mm) at Bowen Airport recording station over 138 years.

Year	**Monthly rainfall (mm)**													
	J	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**Total**	**Decile**
2004/05	0	0	7	11	0	110	312	9	10	6	15	11	489	2
2005/06	17	27	0	61	0	0	289	18	130	186	9	36	771	4
2006/07	21	0	0	12	4	0	180	352	29	6	7	148	758	3
2007/08	0	3	10	7	61	77	415	661	0	0	0	0	1234	7
2008/09	92	0	0	0	0	137	510	514	15	45	5	0	1318	8
Long-term Mean	**23**	**20**	**15**	**22**	**36**	**112**	**233**	**237**	**151**	**64**	**41**	**35**	**990**	

3.1.1. Growing conditions

2003-2004: Extremely low rainfall was recorded at Salisbury Plains with below average totals for the summer growing season. Spring also received well below average rainfall and no rainfall was recorded in autumn, causing poor pasture growing conditions.

2004-2005: Salisbury Plains recorded well below average rainfall for the 2004-05 year with a below average summer growing season and well below average autumn. The average spring rainfall initiated pasture growth at the beginning of the wet season, however, the following poor summer and autumn seasons limited pasture production.

2005-2006: Below average rainfall was received for the year, with a particularly dry spring and early summer period. There was good rainfall in January in the summer growth season, which was followed by good autumn rain.

2006-2007: Salisbury Plains received a dry spring, but a wet February and then a dry autumn, limiting the pasture growth season this year. There was an unusually wet June when pastures were mature.

2007-2008: This season received above average rainfall, with flood rains in January and February, which was followed by no rainfall for the remainder of the year (to June). High pasture yields were produced on all land types.

2008-2009: This year received well above average rainfall from the cyclone season in January and February, producing double the normal average. The following autumn and winter received below average rainfall, however, high pasture yields were produced over summer.

3.1.2. GRASP modelling of pasture growth 2005-2009

The salt area and the rocky hill in the continuous paddock were assumed to produce no useful pasture. The annual predicted pasture yield in the two systems (Table 3.2) averaged near 3000 kg/ha for both systems. The poor growth year of 2006-07 produced approximately 2000 kg/ha in both systems.

Table 3.2. Estimated annual pasture growth (kg/ha) for grazing systems and years at Salisbury Plains from 2005-06 to 2008-09.

Year	Pasture growth (kg/ha)	
	Cells	Continuous
2005-06	3300	3700
2006-07	1900	2300
2007-08	3700	4300
2008-09	3400	3400
Average	**3100**	**3400**

The short summer pasture growing seasons and long dry winter periods are shown by the weekly growth index analysis (Figure 3.1).

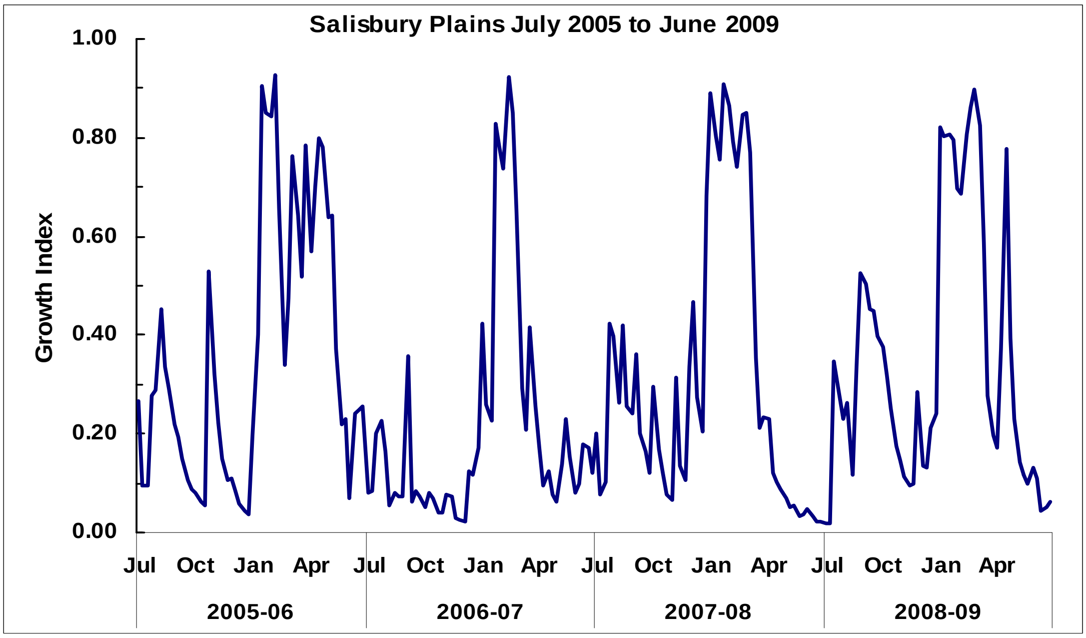


Figure 3.1. Weekly Growth index (tropical species) values at Salisbury Plains during the experimental period (2005-09) for the “Poplar gum woodlands” land type.

3.2. Pastures and Land Condition

3.2.1. Pasture yield, botanical composition and diversity

3.2.1.1. *Pasture mean values*

Yields varied between the systems but there was no consistent pattern. The cell system had less native perennial grass and more exotic grass than the continuous paddock. The continuous-clay area had more native perennial grass and less exotic grass and legume than the sandier soils in both the cells and the continuous paddock. In 2009, there were a lot of weeds following the big wet season including Noogoora burr (*Xanthium occidentale*), hyptis (*Hyptis suaveolens*), snakeweed (*Stachytarpheta jamaicensis*) and khaki weed (*Alternanthera* spp.) (Table 3.3).

Table 3.3. Pasture dry matter yield and botanical composition at the end of summer.

Year	System	Yield (kg/ha)	Botanical composition (%) Nat per grass	Exotic grass	Native leg	Exotic leg	Ann grass	Forb	Sedge
2006	Cell	4070	10.8	49.6	1.0	24.7	1.0	12.3	0.5
	Cont-sand	4460	25.9	32.3	0.4	26.9	0.2	14.4	0.0
	Cont-clay	5710	56.4	14.7	1.5	4.3	11.6	10.4	1.0
2007	Cell	2770	20.6	64.7	0.3	9.5	1.7	2.9	0.3
	Cont-sand	3700	38.1	47.0	1.1	10.3	0.1	3.0	0.4
	Cont-clay	3100	65.6	16.9	4.1	3.2	5.2	4.2	0.9
2009	Cell	4670	12.2	57.8	0.4	17.0	3.5	7.7	1.4
	Cont-sand	3760	32.8	39.6	0.1	16.9	0.6	7.2	2.8
	Cont-clay	4640	67.0	13.7	1.6	2.9	2.9	6.8	5.0

3.2.1.2. *Yield spatial variability*

This analysis measured the degree of uniformity, or inversely variability, in the various parameters across each paddock. There was variation in pasture yield across most paddocks at Salisbury Plains on each recording. Only three to five of the nine cell paddocks had uniform yield at any recording (Table 3.4). The light sandy soil area of the continuous paddock had uniform yield on two of the recording years while the heavy soil areas were not uniform in any year.

Table 3.4. Spatial variability in pasture yield – number of paddocks where pasture yield was spatially uniform (i.e. there was no evidence of aggregation) across the paddock.

Grazing System	Total no. of paddocks	No. paddocks uniform pasture yield 2006	2007	2009
Cells	9	3	5	3
Continuous-sand	1	1	0	1
Continuous-clay	1	0	0	0

3.2.1.3. *Species diversity*

All pastures had a similar degree of diversity, with 9-12 species making up 90% of the yield, however, the three measures showed little difference in diversity between the systems (Table 3.5). The dominant species contributed around 25% of the pasture yield over all years in the three systems.

Table 3.5. Measures of pasture diversity at Salisbury Plains in 2006, 2007 and 2009.

Diversity measure	Grazing System		
Year	Cell	Continuous-sand	Continuous-clay
No. species/quadrat			
2006	3.1	3.3	3.0
2007	2.9	3.0	3.3
2009	3.2	3.4	3.5
No. species to contribute 90% of yield			
2006	10	10	13
2007	12	14	13
2009	9	13	15
% Contribution of dominant species			
2006	23	29	23
2007	42	29	21
2009	28	20	24

3.2.2. Pasture utilisation

Pasture utilisation in the monitor paddocks at the end of summer was rated across the paddocks on the Botanal grid at each recording point (rating 1 = 71-100%; 2 = 31-70%; 3 = 6-30%; 4 = 0-5% utilisation).

3.2.2.1. *Utilisation mean values*

There was no difference in pasture utilisation in autumn between the cell paddocks and the corresponding sandy soil area of the continuous paddock (Table 3.6). There was evidence of heavier grazing on the clay soil areas of the continuous paddock only in 2006-07.

Table 3.6. Mean rating (1-4) for estimated pasture utilisation in grazing systems at from 2005-06 to 2008-09.

Year	Utilisation rating		
	Cells	Continuous-sand	Continuous-clay
2005-06	3.9	3.8	4.0
2006-07	3.1	3.6	2.9
2008-09	3.9	3.5	3.8

In 2006 there was negligible utilisation in any system in autumn, however, in 2007 both systems, including both soil types of the continuous paddock, had approximately 40% grazed to the 5-30% level (Figure 3.2). In autumn of 2009, the cells had received little grazing, while grazing in the continuous paddock was concentrated on the sandy soil area. This soil type has a mixed grass and stylo legume pasture.

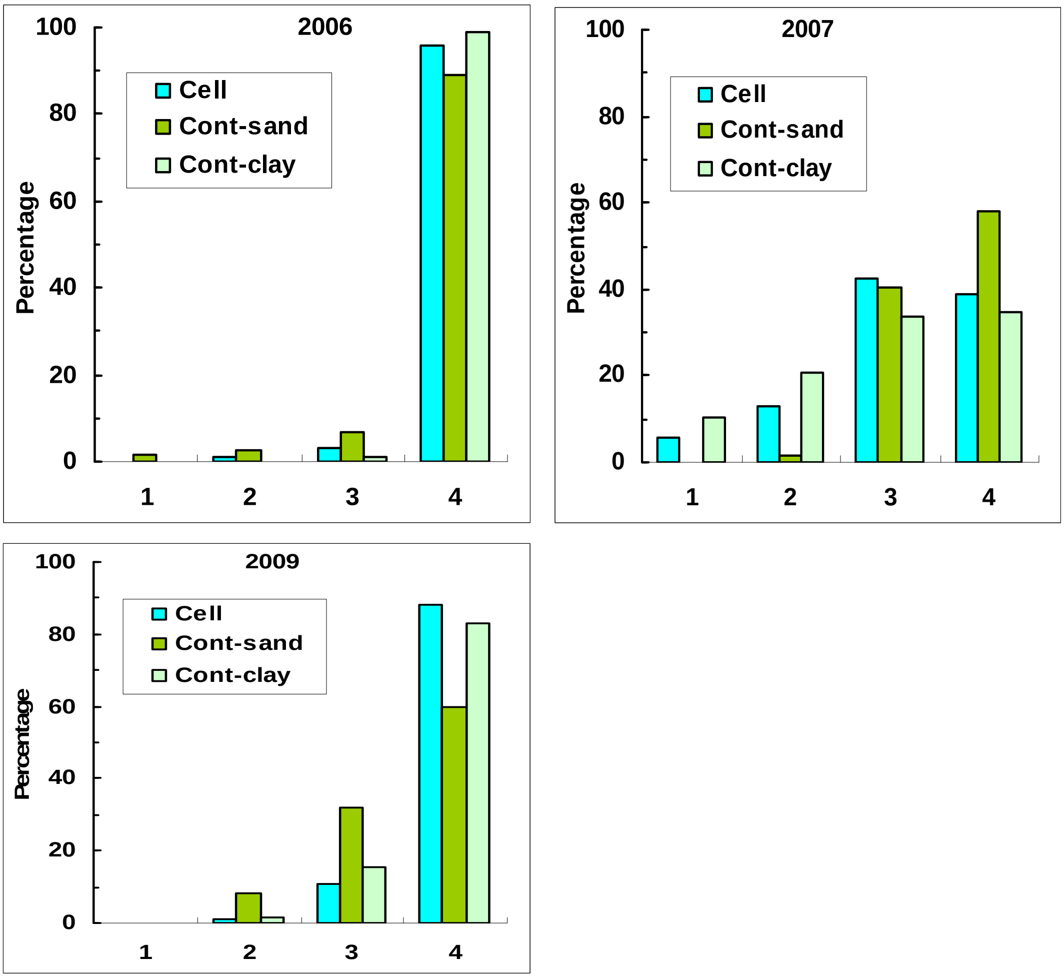


Figure 3.2. Distribution of estimated pasture utilisation values in grazing systems at Salisbury Plains from 2006 to 2009.

3.2.2.2. *Utilisation spatial variability*

Six of the nine cell paddocks had uniform utilisation in autumn of 2006 and 2009 (Table 3.7). Only the sandy soil area of the continuous paddock had uniform utilisation in 2007.

Table 3.7. Spatial variability in pasture utilisation – number of paddocks where pasture utilisation was spatially uniform (i.e. there was no evidence of aggregation) across the paddock.

Grazing System	Total no. of paddocks	No. paddocks uniform utilisation		
		2006	2007	2009
Cells	9	6	0	6
Continuous-sand	1	0	1	0
Continuous-clay	1	1	0	0

3.2.3. Woody regrowth

There was little woody regrowth in the continuous paddock or in most cell paddocks, however, two cells, 25 and 26, had an average 2.7% regrowth cover of mainly *Melaleuca* spp. in 2009 (Table 3.8).

Table 3.8. Cover levels (%) of woody regrowth in grazing systems at Salisbury Plains.

Year	Woody regrowth cover (%)		
	Cells	Continuous-sand	Continuous-clay
2006	0.7	0.1	<0.1
2007	0.2	0.1	0.1
2009	0.8	0.2	0.1

3.2.4. Ground and litter cover

3.2.4.1. *Cover means and standard deviations*

Total pasture cover levels were high in all systems, particularly in 2009. There were only small and inconsistent differences for total cover between the cell and continuous systems. Litter cover was lower on the clay soil than the sandier soils, especially in 2009. Although there was some variability, the standard deviations were similar for the different grazing systems (Table 3.9).

Table 3.9. Total ground cover and litter cover levels (%) at Salisbury Plains at the end of summer.

Year	Grazing System	Total cover (%)		Litter cover (%)	
		Mean	St. Dev.	Mean	St. Dev.
2006	Cell	73	23.1	18	15.4
	Continuous-sand	77	23.4	18	14.7
	Continuous-clay	83	20.6	15	15.4
2007	Cell	74	26.3	31	19.9
	Continuous-sand	75	23.2	25	17.1
	Continuous-clay	72	25.4	24	20.5
2009	Cell	92	16.2	60	31.4
	Continuous-sand	87	16.5	52	29.0
	Continuous-clay	81	19.5	22	22.0

3.2.4.2. *Cover spatial variability*

Half of the cell paddocks had uniform total cover at the three recording times (Table 3.10), while the sand and clay areas of the continuous paddock did not have consistent uniform cover over the recording times. Litter cover was more variable across the paddocks than total ground cover.

Table 3.10. Spatial variability in ground cover – number of paddocks where total ground cover or litter cover was spatially uniform (i.e. there was no evidence of aggregation) across the paddock.

Cover Grazing System	Total no. of paddocks	No. paddocks uniform ground cover		
		2006	2007	2009
Total ground cover				
Cells	9	5	4	4
Continuous-sand	1	0	1	0
Continuous-clay	1	1	0	1
Litter cover				
Cells	9	5	2	2
Continuous-sand	1	0	1	0
Continuous-clay	1	1	0	1

3.2.5. LFA indices (soil surface condition)

The LFA indices, stability, infiltration and nutrient cycling, have values between 0 and 100 where larger values indicate better performance for that index.

3.2.5.1. *LFA indices mean values*

There was no consistent difference between the LFA indices between the grazing systems on the sandier soils. The values for Continuous-clay were lower than the sandy soil land types in both systems in 2009 (Table 3.11). There was an improvement in the average LFA indices between 2006 and 2009. The stability index improved by 9%, the infiltration index by 18% and the nutrient cycling index increased by 33% over this period. These increases corresponded with an improvement in pasture growing seasons.

Table 3.11. LFA indices (mean and standard deviations) at Salisbury Plains at the end of summer 2006, 2007 and 2009.

Year	Grazing System	LFA Indices (0-100)					
		Stability		Infiltration		Nutrient cycling	
		Mean	S. Dev.	Mean	S. Dev.	Mean	S. Dev.
2005	Cell	66.5	11.44	38.5	9.58	28.8	9.08
	Continuous-sand	63.8	5.53	38.2	7.70	31.4	8.63
	Continuous-clay	62.9	5.64	38.2	7.64	29.2	8.98
2007	Cell	69.3	13.45	42.2	11.38	36.6	11.62
	Continuous-sand	65.6	7.53	39.8	6.14	35.6	7.24
	Continuous-clay	62.6	8.43	44.7	8.29	35.4	10.25
2009	Cell	75.1	8.51	51.2	10.65	44.1	11.65
	Continuous-sand	71.9	7.94	44.8	10.28	42.5	10.79
	Continuous-clay	63.7	5.86	39.1	10.14	32.6	8.97

3.2.5.2. *LFA indices spatial variability*

Most of the cell paddocks had uniform LFA indices in 2006, but this did not persist in subsequent years. Only the continuous system clay soil area maintained uniform stability throughout the recording period (Table 3.12).

Table 3.12. Spatial variability in the LFA indices – number of paddocks where the LFA Stability index, Infiltration index and Nutrient cycling index was spatially uniform (i.e. there was no evidence of aggregation) across the paddock.

LFA index **Grazing System**	**Total no. of paddocks**	**No. paddocks uniform LFA indices**		
		2006	**2007**	**2009**
LFA Stability index				
Cells	9	8	2	3
Continuous-sand	1	1	0	1
Continuous-clay	1	1	1	1
LFA Infiltration index				
Cells	9	6	3	3
Continuous-sand	1	0	0	0
Continuous-clay	1	0	0	1
LFA Nutrient cycling index				
Cells	9	7	1	2
Continuous-sand	1	0	1	0
Continuous-clay	1	0	0	1

3.2.6. Land condition

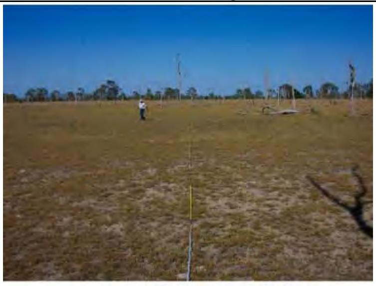
There were no differences between the two systems in land condition as assessed by the PatchKey method on the quadrat grid data at any recording (average about 2) (Table 3.13). The “Coastal teatree plains” land type was in poorer condition (C condition) than other land types, with much of the perennial grass being replaced by Verano stylo (*S. hamata*) and areas of Indian bluegrass (*B. pertusa*). Parts of the continuous paddock were in B condition due to loss of perennial grass in patches on the light soils and the patches with a high population of wiregrass (*Aristida* spp.) on the clay soil (Table 3.13).

Table 3.13. Land condition measures for Salisbury Plains. For the Botanal/PatchKey and ABCD (Land type) values, “1” is equivalent to A condition and “4” is equivalent to D condition.

Land condition measure	Land condition units	
	Cells	**Continuous**
Botanal/PatchKey		
2006	2.3	2.3
2007	2.1	2.2
2009	2.0	2.0
ABCD (by Land type)		
Bluegrass brown top plains		2.1
Coastal teatree plains	2.8	
Poplar gum woodlands	1.0	2.0
Salt area (no production)		NA
No grazing		NA
Overall average	1.9	2.1
ABCD (Paddock)		
2006	B	A/B
2007	B	A/B
2009	B	A/B

An annual photograph of fixed points in the grazing systems between 2005 and 2009 shows the seasonal variation in pasture growth and cover (Figure 3.3). The open pasture and bare areas obvious at the end of the dry seasons of 2005 to 2008 in the two systems were in good condition by May 2009, after the previous cyclone season.

Salisbury Plains Sal13-3
Lat: 19^{0}.984; Long: 147^{0}.954, Dir: 51^{0}


Cell (December 2005)


Cell (November 2006)


Cell (November 2007)


Cell (November 2008)


Cell (May 2009)

Salisbury Plains Salcon-2
Lat: 19^{0}.958; Long: 147^{0}.954, Dir: 164^{0}


Continuous (December 2005)


Continuous (November 2006)


Continuous (November 2007)


Continuous (November 2008)


Continuous (May 2009)

Figure 3.3. Changes in land condition at fixed points in the cell and continuous (Wilmington paddock) grazing systems at Salisbury Plains.

3.2.7. Cover Analysis

3.2.7.1. *VegMachine vegetation cover time series (Landsat)*

VegMachine showed a wide fluctuation in cover in the monitor paddocks from index 25 to almost 100 since 1986 (These indices show approximate percentage cover). The VegMachine analysis showed there have been three periods of cover decline during drought events in the monitor paddock areas, in 1986-87, 1992-96 and 2001-06 (Figure 3.4). The most severe cover declines occurred in the first two droughts (to index 30), although they were not as severe as the 2000's drought when cover has been maintained at a high level (above index 60). An explanation for these results is that cattle numbers were not reduced early enough or in sufficient numbers in the earlier droughts when they were run in large paddocks. In recent years, there has been an improvement in pasture management with numbers adjusted to match pasture growth and spelling of paddocks in cell and rotation systems on the property.

The cells commenced in 2001/02 and have required daily decision making regarding grazing pressures and stock number adjustment, so responding to the highly variable pasture growing conditions has become more timely. In some years there is no grazing in the cell paddocks over summer and the continuous paddock is lightly stocked on occasions, allowing all paddocks in both systems to improve or maintain high cover levels.

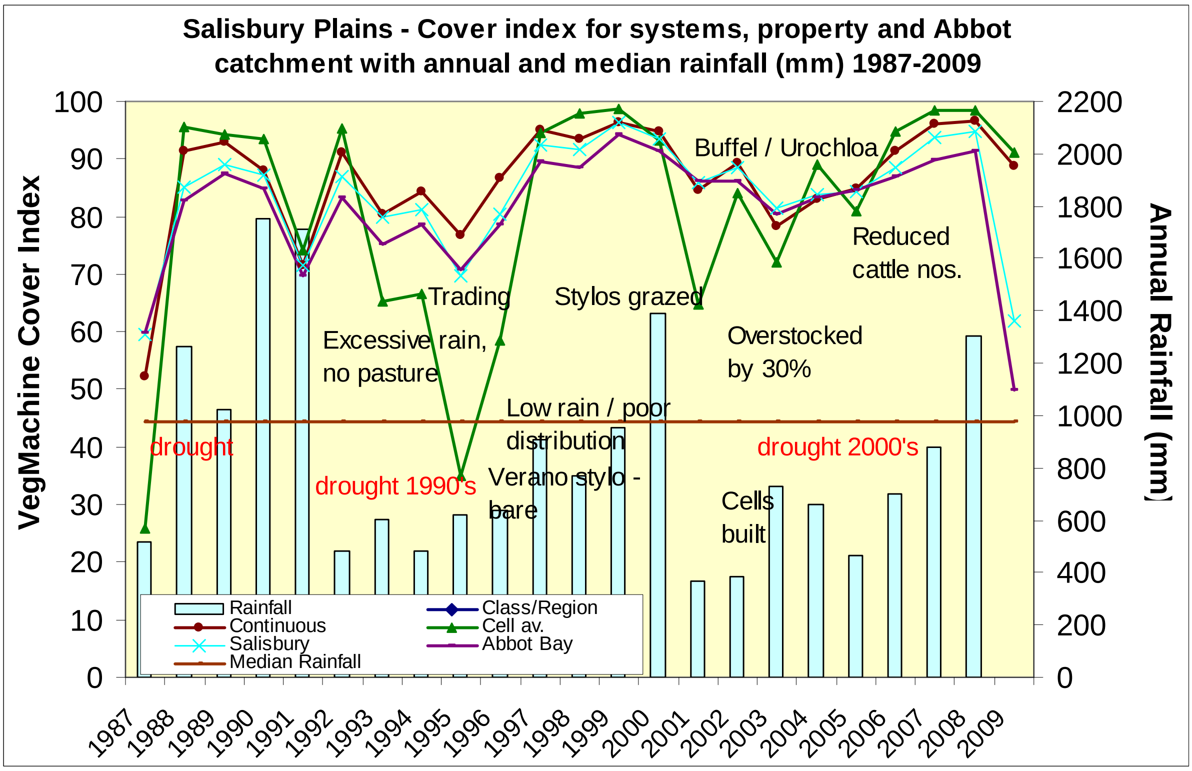


Figure 3.4. Vegetation cover index between 1987 and 2009 for grazing systems, the whole property and neighbourhood Abbot Point catchment, with annual and long-term median rainfall (mm).

In the 1992-95 and 2000-06 droughts, cover in the monitor cell paddocks declined to a greater extent than the continuous system and the average of the whole property. In 1992-95, cover declined to index 10-20 in the Verano stylo areas (cell paddocks 11, 12, 13 and 14) which subsequently became cell centre 2 (Figure 3.5). With a change in grazing management after the cells were installed, cover in these areas has been less variable and has only declined to index near 50 in the 2000's drought. The sown pastures, buffel grass, Sabi urochloa and seca stylo, have increased in the cell centre 1 paddocks helping to maintain high cover levels in these paddocks during this drought period. Green panic and siratro, which were originally sown in the pasture species mix, are also more evident in paddocks at cell centre 1. Indian couch (*B. pertusa*) occurs in the monitor cell paddocks, yielding over 1100 kg/ha in two paddocks, and has also become dominant in some areas of the property, possibly encouraged by previous grazing regimes.

The continuous paddock, Wilmington, has maintained a relatively high pasture cover with lower seasonal fluctuations than in the cell areas, especially in the drought (Figure 3.5). This paddock has a predominantly grass pasture with a smaller Verano and Seca stylo legume component throughout the lighter soil, tea tree open woodland country of the northern half. There are stable Gulf bluegrass-browntop grassland plains in the southern end of the paddock. The heavier grazing pressure on the duplex soils of some of the cell areas appears to have almost eliminated the perennial grass component and allowed a Verano dominant pasture to develop. In drought years, the short-lived Verano is grazed heavily leaving a lower cover, even bare ground patches in these areas.

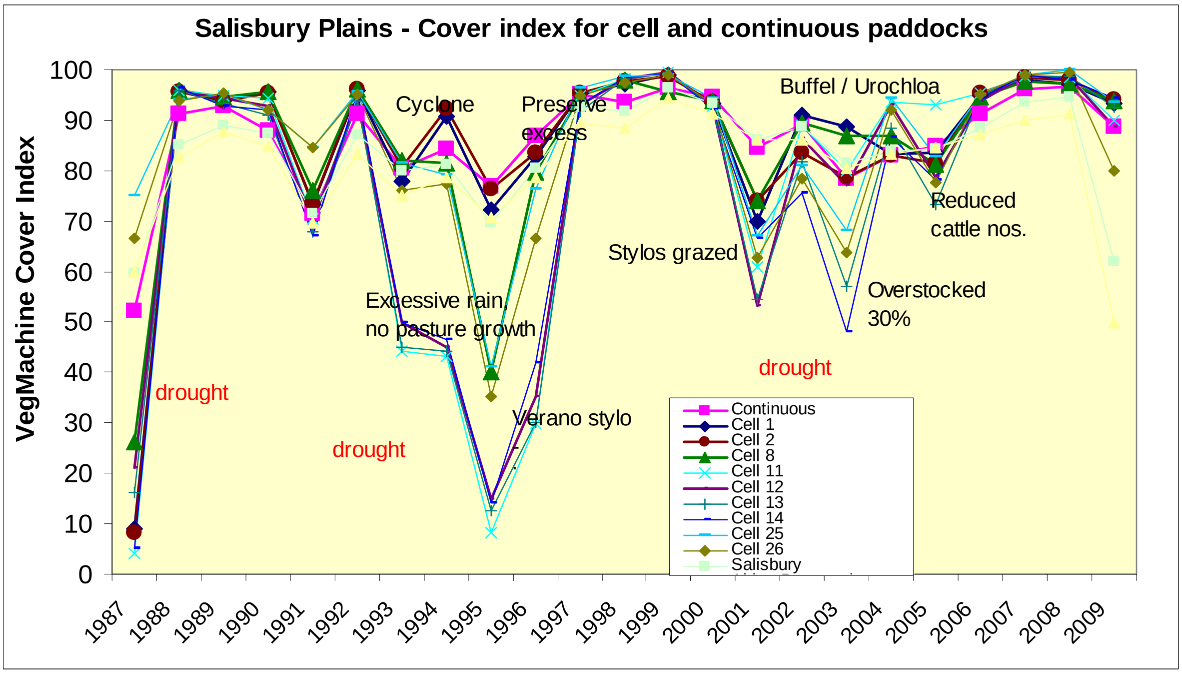


Figure 3.5. Vegetation cover index between 1987 and 2009 in the cell and continuous monitor paddocks at Salisbury Plains.

3.2.7.2. *Botanal pasture cover analysis*

During the project between 2006 and 2007 there was a significant yield decline (4200 to 2900 kg/ha), but a negligible decline in cover (77% to 74%) (Table 3.14). The (Qld) DERM pasture and cover modelling produced similar results (Figure 3.6).

Table 3.14. Pasture yield (kg/ha), total pasture cover (%), litter cover (%) and woody cover (%) in 2006 and 2007 in the monitor paddocks and grazing systems at Salisbury Plains.

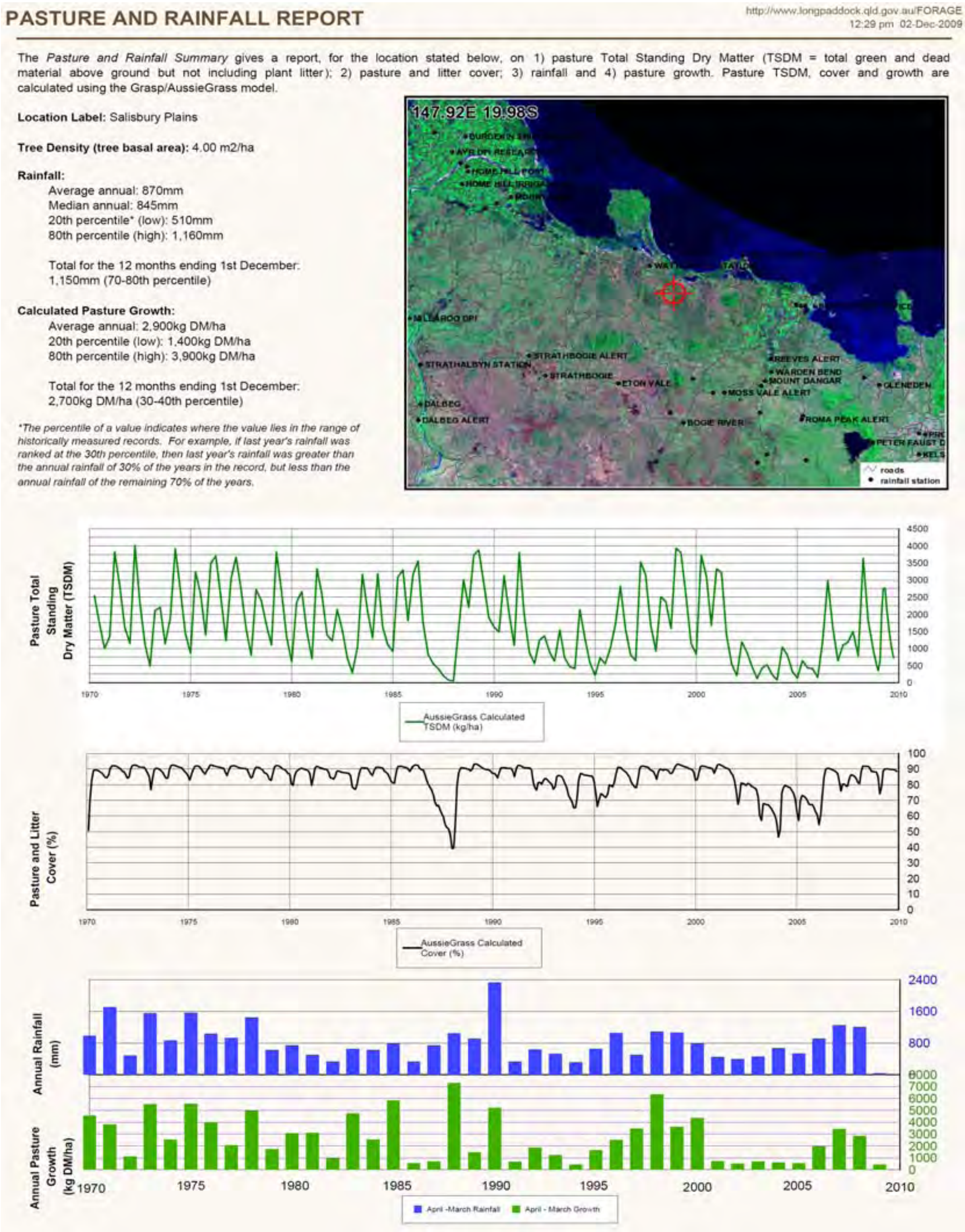
Paddock / Grazing System	**Yield (kg/ha)**		**Total Cover (%)**		**Litter Cover (%)**		**Woody Cover (%)***	
	2006	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**
C1-1 [1]	6480	6330	81	90	15	39	0.1	0.1
C1-2 [2]	5410	3270	87	84	21	35	0.0	0.1
C1-8 [8]	5010	4570	75	91	12	28	0.1	0.3
C2-11 [11]	4680	2950	82	83	26	31	0.0	0.1
C2-12 [12]	2970	1590	74	77	27	38	1.3	0.3
C2-13 [13]	2570	1070	61	56	10	31	0.1	0.1
C2-14 [14]	4190	1780	73	76	13	34	0.0	0.1
C4-25 [25]	2700	1560	65	55	16	23	1.1	0.6
C4-26 [26]	2850	1800	65	60	18	23	5.2	0.6
Wilmington [20]	4460	3700	76	75	18	25	0.1	0.1
Wilmington [clay]**	5630	3100	82	72	14	24	0.0	0.1
Continuous	5040	3400	79	73	16	24	0.1	0.1
Cell	4100	2770	74	75	17	31	0.9	0.2
Site	4210	2880						

* woody cover is regrowth cover, excluding mature tree cover.

** Wilmington clay is the clay soil plains area in the southern end of the continuous paddock.

3.2.7.3. *Spatial ground cover reports*

The spatial analysis of pasture production (Qld DERM data) related to rainfall (Figure 3.6) shows the wide annual variation in pasture growth rates and rapid responses to summer rain. Average property pasture and litter cover has fluctuated between 30% and 90% since 1970. There is a good correlation between pasture growth and cover at the higher levels, but less so when cover declines. Both are closely related to broad rainfall events.


PASTURE AND RAINFALL REPORT

http://www.longpaddock.qld.gov.au/FORAGE
12:29 pm 02-Dec-2009

The *Pasture and Rainfall Summary* gives a report, for the location stated below, 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.

Location Label: Salisbury Plains

Tree Density (tree basal area): 4.00 m2/ha

Rainfall:
Average annual: 870mm
Median annual: 845mm
20th percentile* (low): 510mm
80th percentile (high): 1,160mm

Total for the 12 months ending 1st December:
1,150mm (70-80th percentile)

Calculated Pasture Growth:
Average annual: 2,900kg DM/ha
20th percentile (low): 1,400kg DM/ha
80th percentile (high): 3,900kg DM/ha

Total for the 12 months ending 1st December:
2,700kg DM/ha (30-40th percentile)

**The percentile of a value indicates where the value lies in the range of historically measured records. For example, if last year's rainfall was ranked at the 30th percentile, then last year's rainfall was greater than the annual rainfall of 30% of the years in the record, but less than the annual rainfall of the remaining 70% of the years.*

Figure 3.6. 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 Salisbury Plains (Source QDERM).

Ground cover in the monitor paddocks was above the 30% threshold level in 2008 except for small areas of saline scalds in the western tip of Wilmington paddock. The cover modelling predicted much greater declines during the dry season than the Landsat imagery showed. The cover measured in the field in autumn (average 75%) was similar to both the modelled and Landsat results.

3.3. Cattle Grazing

3.3.1. Carrying capacity – long-term (LTCC)

The estimated long-term carrying capacities (in AE/100 ha and SDH) over all landtypes of the two systems are similar:

Cells	23 AE/100 ha (83 SDH)
Continuous	25 AE/100 ha (90 SDH)

3.3.2. Rest periods

The average rest period between grazing events in the cell paddocks was 119 days. The annual variation ranged from 94 to 155 days (Table 3.15). There were no planned rest periods at any time in the continuous paddock, although the number of AE's grazing at any time varied throughout each year. These periods of reduced grazing pressure and the short intense wet seasons, which included cyclones, effectively allowed resting of parts of this paddock each year.

Table 3.15. Average rest periods (days) between grazing events for grazing systems at Salisbury Plains.

Year	Rest periods (days)	
	Cells	Continuous
2005-2006	94	0
2006-2007	120	0
2007-2008	155	0
2008-2009	106	0

3.3.3. Grazing days

The annual average number of days of grazing was 15 and 365 days for the cell and continuous systems respectively. They had an annual average of 2 and 10 grazing events or herd number changes per year respectively. The annual number of days grazing in the cell paddocks ranged from 4 to 67 days per year (small herd with multiple paddocks open), with a range of 1 to 5 grazing events per year. The continuous system was grazed 365 days every year at variable stocking rates with 9 to 11 herd changes per year over the four years.

3.3.4. Grazing pressure

The animal numbers taken from property records for each system have been converted to Animal Equivalents (AE) using the standards tables presented in Appendix 9.10. An AE is equivalent to a dry cow weighing approximately 450 kg.

There was a higher grazing pressure in the cell paddocks than in the continuous paddock every year (measured as SDH/100mm rainfall over the previous 12 months from each grazing event). The average grazing over the four years in the cells was double that in the continuous system (Table 3.16). There were occasions when multiple cell paddocks were open at the same time and only the monitor paddocks were recorded. This would have increased the grazing allocated to that paddock, for example in 2005-06. The variable sizes of the cell paddocks, from 6-40 ha, can cause a distortion in grazing pressure of individual paddocks in the cell rotation.

Table 3.16. Grazing days for grazing systems at Salisbury Plains (SDH/100mm rainfall and SDH).

Year	Grazing pressure	
	Cells	Continuous
	SDH/100mm rainfall and (SDH)	
2005-06	43 (254)*	12 (70)
2006-07	23 (173)	12 (93)
2007-08	13 (125)	10 (98)
2000-09	15 (191)	8 (107)
Average	**24 (186)**	**11 (92)**

* multiple cell paddocks open at one time which can cause over-estimation of the grazing in the monitor paddocks.

The mean grazing pressure over the four year monitoring period was 186 and 92 SDH/annum for the cell and continuous grazing systems respectively, compared with an estimated long-term carrying capacity (LTCC) of 83 and 90 SDH/annum, respectively. This shows the cells carried double their estimated LTCC over the four years, while the continuous system was run at the long-term suggested rate.

3.3.5. Grazing system intensity index

The grazing system intensity index values (range 1-100; calculated from capital costs, operating costs and management inputs; details are reported in Appendix 9.13) for the two systems were:

Cell	72
Continuous	26

This relatively wide difference in GSI index reflects the more intensive infrastructure and management input required by the cell system.

3.3.6. Diet quality (NIRS)

Over all samples the NIRS diet quality (crude protein and digestibility) and predicted liveweight gain were higher in the continuous system than in the cells (Table 3.17). The relatively high proportion of non-grass (mean 21-33%) in both systems was mainly from the sown stylo legumes.

Table 3.17. Mean faecal NIRS results from all samples for grazing systems at Salisbury Plains to June 2009.

Grazing System	No. samples	Crude protein (%)	Faecal N (%)	Digesti-bility (%)	Non-grass (%)	LWG (kg/day)	DMD/CP ratio
Cell	25	7.8	1.4	56	21	0.47	7.8
Continuous	30	10.0	1.7	60	33	0.75	6.3
sed (av.)		0.55	0.06	1	5	0.12	0.7
Significance		***	***	***	ns	*	ns
Average	**(total 55)**	**8.4**	**1.5**	**57**	**30**	**0.56**	**7.2**

Paired samples, same day sampling (24), from the grazing systems showed a 2% higher crude protein and 4% higher digestibility in the continuous system than in the cells. There was also 15% higher non-grass and predicted 0.25 kg/day increase in live weight gain in the continuous paddock (Table 3.18). The continuous system contains a similar coastal tea tree land type to the cells, however, it also contains an area of bluegrass-browntop grassland on low fertility clay soil which may have provided a more variable diet. The high non-grass content in the continuous system could be attributed to the stylos in the light textured soil, tea tree land type.

Table 3.18. NIRS diet quality results when paired samples were collected at Salisbury Plains between March 2007 and June 2009.

Grazing System	No. samples	Crude protein (%)	Faecal N (%)	Digesti-bility (%)	Non-grass (%)	LWG (kg/day)	DMD/CP ratio
Cell	24	7.0	1.3	54	24	0.38	8.0
Continuous	24	9.1	1.6	58	37	0.65	6.5
sed (av.)		1.13	0.07	1.5	2.9	0.20	1.1
Significance		ns	***	*	***	ns	ns
Average	**24**	**8.1**	**1.5**	**56**	**31**	**0.52**	**7.3**

The NIRS values were examined by dividing them into groups which had different growing conditions on the basis of the pasture Growth Index (GI) derived from GRASP (where 0.0 = conditions are unsuitable for growth and 1.00 = conditions are not limiting growth). Average values of the GI for the 30 days ending on the sample date were calculated. Based on these values three classes were formed – mean GI <0.2 (Poor growing conditions), 0.2-0.5 (Average) and >0.5 (Good conditions) (Table 3.19). On average the continuous system had some 2% higher crude protein and 3% higher digestibility at the two lower growth index classes. There were insufficient cell samples at the >0.5 GI, only 1 sample, to effectively compare systems when pastures were most actively growing. This occurred because the cells were not always stocked during the main wet season.

Table 3.19. Mean NIRS diet quality results in relation to growth indices for two grazing systems at Salisbury Plains to June 2009.

Growth Index	Grazing System	No. samples	Crude protein (%)	Faecal N (%)	Digesti-bility (%)	Non-grass (%)	LWG (kg/day)	DMD/CP ratio
<0.2	Cell	13	6.3	1.2	53	26	0.28	8.5
	Continuous	13	8.0	1.5	56	39	0.49	7.2
0.2-0.5	Cell	11	7.3	1.4	55	22	0.42	7.7
	Continuous	11	9.5	1.7	59	35	0.71	6.3
>0.5	Cell	1	12.3	1.8	61	20	1.20	5.0
	Continuous	6	12.6	2.0	63	24	1.45	5.1
sed (av.)			1.01	0.11	2	6	0.14	0.8

Individual sample results for the NIRS parameters crude protein, digestibility and non-grass for the continuous system (Figure 3.7) and cell system (Figure 3.8) show the wide seasonal variation in both grazing systems with high quality pastures in summer, declining rapidly to near maintenance crude protein in the annual dry winter-spring periods in both systems. The high non-grass percentage in the diets was from the Verano and Seca stylos throughout the pastures of both systems.

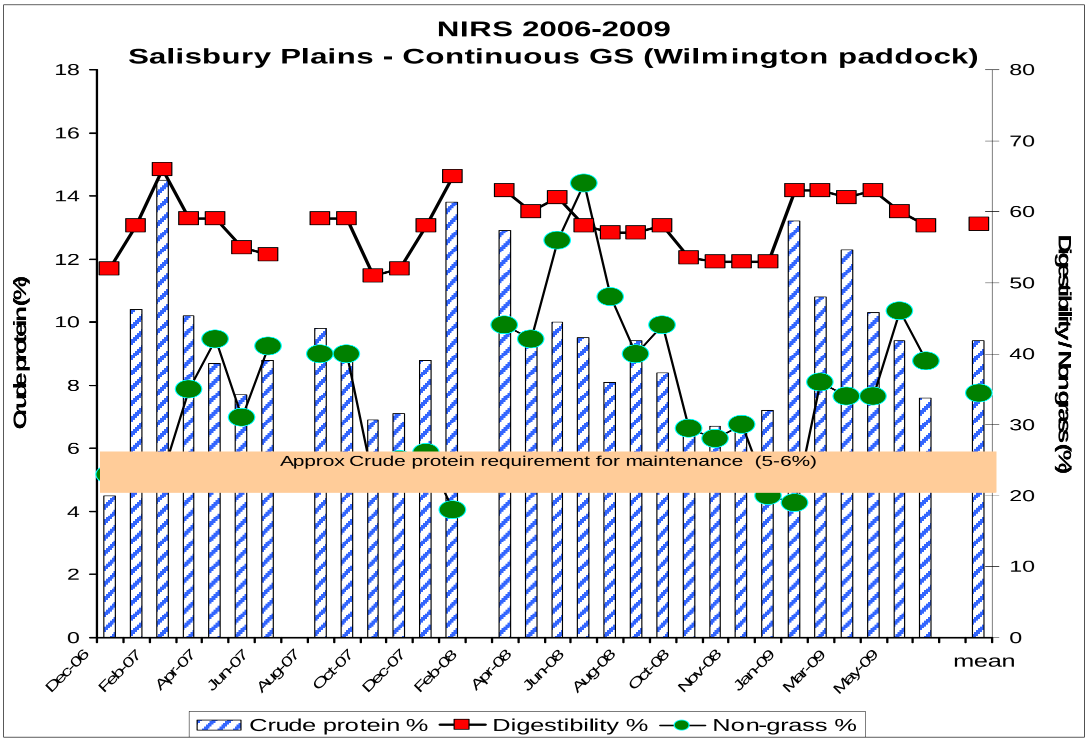


Figure 3.7. NIRS sample results for the continuous grazing system (Wilmington paddock) at Salisbury Plains for crude protein (%), digestibility (%) and non-grass (%) with approximate maintenance crude protein indicated.

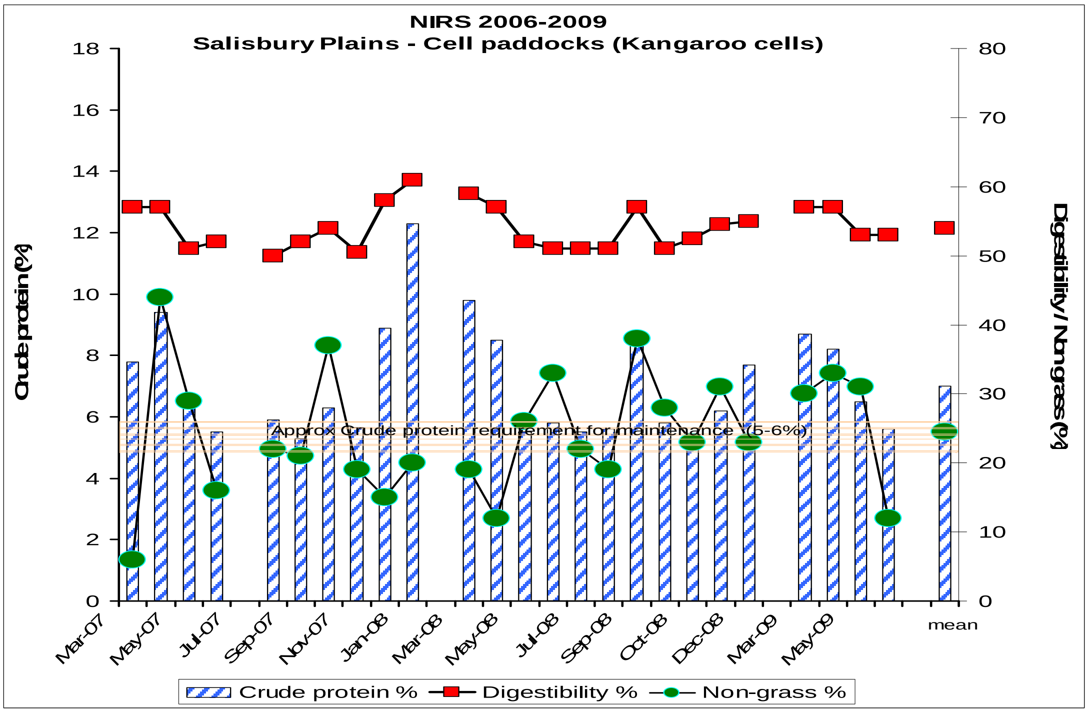


Figure 3.8. NIRS sample results for the cell grazing system at Salisbury Plains for crude protein (%), digestibility (%) and non-grass (%) with approximate maintenance crude protein indicated.

3.4. Grazing System Costs

The grazing system comprises an intensive cell grazing structure of 60 cells constructed within a pre-existing structure of nine paddocks from the original conventional grazing system. Fencing is comprised of 63 km of single wire electric fencing. Water is supplied to the nine cell centres through 12 km of 63 mm polythene pipeline. Each cell centre is watered by a concrete stock trough. The bulk of the site treatment, fencing and pipe laying was completed using station plant, machinery and labour.

3.4.1. Capital costs

The estimated replacement capital cost of the cell grazing system (Kangaroo cells only) is approximately $127,000 (Table 3.20) comprising of fencing, watering, labour and planning costs.

Table 3.20. **Replacement capital costs of cell grazing systems.**

Item	Cost ($)
Fencing	40,462
Water	37,557
Troughs	7,200
Tanks	5,000
Pumps, mills	1,100
Installation	31,273
Consultancies	4,000
Total	**126,592**

3.4.2. Operating costs

For reasons of privacy and confidentiality, the annual running costs that are associated with the case study grazing systems is not presented.

An indicative guide to the operating cost of a given system is the estimated annual capital reclamation cost (sinking fund depreciation charge), which is the equivalent sum that would need to be set aside each year to maintain the capital assets invested in the systems infrastructure. The reclamation cost has been estimated using standard farm accounting depreciation factors for the main assets listed in the preceding table, including: bores (7.5%), dams (2.5%), fencing (5%), and plant (10%). This gives a projected capitalised cost for the case study enterprises of approximately $4,000 per annum (Table 3.21) comprising of fencing and water maintenance costs.

Table 3.21. Operating costs of cell grazing system (Kangaroo cells) at Salisbury Plains.

Item	Cost ($)
Fencing	2,023
Water	939
Troughs	180
Tanks	500
Pumps, mills	110
Total	**3,752**

4. Conclusions

4.1. Pasture and land condition

Overall at Salisbury Plains, the continuous paddock was assessed as being A/B condition (some reduction due to loss of perennial grasses on the light soils and presence of wiregrass on the clay soil) and the cell paddocks in B condition. On the “Coastal tea tree” land type in the cells, the native perennial grasses have been replaced by Verano and areas of Indian couch grass. The PatchKey analyses showed no difference between grazing systems.

Pasture yields varied between systems and years but there was no consistent pattern in the differences. The cell system had less native perennial grass and more exotic grass, mainly Indian couch, Sabi urochloa and buffel, than the continuous system. There was little woody regrowth in the continuous paddock, but some cell paddocks had reasonable amounts.

Ground cover levels were high in both systems, particularly in 2009. Any differences between systems were small and inconsistent. Litter cover levels increased to high levels in 2009 when the cell system had 60% litter cover and the Continuous (sandy soil land type) had 52% litter cover.

There were no consistent soil surface condition differences between grazing systems on the sandy soils. There was a similar improvement in the three LFA indices in both systems between 2006 and 2009, attributed to the better rainfall seasons over the last two years.

The VegMachine cover analyses showed similar long-term trends apart from low values in the cell area from 1993 to 1996 and in 2001. From 2002 Vegetation Cover index values were similar for the continuous and cell systems.

4.2. Carrying capacity and grazing

Pasture yields were higher in the continuous system than in the cells in 2007 and 2008, but not in 2009, because the cells could not be grazed during the high rainfall periods from the cyclone influences that summer. Cattle were still grazed in the continuous system.

The resting between grazing events during the wet season has allowed the sown grasses, particularly buffel and Sabi grass to spread and dominate the sand ridges. Green panic and Siratro have also reappeared in the cells. This species composition change has not occurred in the continuous paddock, although there is more Seca stylo on the light soils of this system than in the cells. The heavy grazing of the cells has favoured Verano stylo in the smaller paddocks and on the shallow sandy duplex soil type, and it has also promoted Indian couch grass at the expense of native perennial grasses in these paddocks.

The cell system supported double the grazing of the continuous paddock during the monitor period. The grazing of the cells was double that of the recommended LTCC for these land types. This may account for the lack of perennial grass and Verano dominance on the shallow duplex soil areas of this system. The grazing of the cell system may be over-estimated on occasions when multiple paddocks are open and the grazing is attributed solely to a monitor paddock. Some records were not available to confirm when this occurred.

The average NIRS diet quality in the continuous system is superior to that in the cells with crude protein 2% higher, digestibility 4% higher and estimated liveweight gain over 0.25 kg/day higher. The continuous system had the higher diet quality at all stages of pasture growth. The clay soil area may have contributed to this superior diet quality on occasions. The stylo legumes would also have contributed to a higher diet quality during the autumn and winter grass-dormant period on both systems.

4.3. Owner’s comments on grazing systems

We came to Salisbury Plains in February 1946 to spear grass pastures and the usual array of native species and very little infrastructure. Grazing was very low pressure with British breeds and their tendency to die when the going gets tough in the north is well documented. The herd is now black brangus based.

In the 1960’s the USA market opened up for lean beef and for the first time, Salisbury had some money to spend. Townsville Stylo (TS) was having a remarkably positive impact and the need was for wire and water infrastructure. Wire and water allowed us to stock country heavier and establish TS. High tensile wire and suspension configuration offered much more fence for less money and effort and we fenced with a passion. Poly pipe revolutionized water transfer and we could send water almost anywhere.

New chemicals facilitated land clearing and more importantly, an ability to clear fertile creek frontages heavily overgrown with declared weeds including rubber vine, chinee apple and lantana.

A few bucks in the kick allowed the use of bulldozers, the development of blade plough technology, and clearing and cultivation to establish improved pastures like buffel grass, green panic, pangola, para grass, Siratro and others. Production rose markedly as Townsville stylo spread rapidly.

In 1969 we began using urea as a stock supplement, initially drum rollers then a dry loose mix commonly called the ‘Hammond mix’, after Reg Hammond who pioneered the activity. The use of urea became a regular part of grazing management.

Anthracnose disease decimated TS in the 1970's and we were shocked at the drop in production from a legume based pasture to the new grass based system. Urea became more important. Verano and Seca stylos were introduced in the 1980's, and after learning how to manage them, we began a 12-year programme to sow all the property with stylos and any other legume we could lay our hands on. These included Amiga stylo, Wynn Cassia, the Vetches and Desmanthus (cv. Jaribu mix).

On reflection, the combination of fencing, water, constant grazing, legumes and urea seemingly gave good animal performance while pastures were degrading. Indicator species like Golden Beard and blue grasses indicated the going was too tough and they disappeared and were replaced by Indian couch. Weeds increased, the bare patches were covered and the cattle performance was good. The typical open grazing system had paddocks under-stocked, but areas over-grazed. Accelerated run-off after rain bought all the negatives we are familiar with.

4.3.1. New management

Why We Changed:
Dissatisfied with the negative pasture and soil condition changes in the field and our inability to bring about change using the system and tools we had e.g. an increase in stocking rate to use long feed in half a paddock simply caused heavier grazing on the already grazed short pasture. We had little control of pasture composition.

In 1971 we bought a series of aerial photographs which were rough but gave a better understanding of our pastures/land types and areas. In the mid 1970's a group with computer technology to eradicate camera lens angle error produced a mosaic of Salisbury Plains at a constant scale and cost $1500. With a $1200 planimeter we discovering all sorts of things, like our actual stocking rate on some of the more heavily grazed areas. Some of the figures were shockingly high.

We set out to find solutions. Simply spelling did not bring the pasture results we sought. We investigated fencing into smaller areas to rotate the grazing effort, but at this time the paradigms of fences equals three barbs, moving cattle equals three ringers on horses and a lack of understanding of the upside got in the way.

In the 1980's we built large holding areas (up to 400 ha) to facilitate use of helicopters for mustering. These areas were rested during the wet season to grow feed to attract cattle about mustering time. In effect we changed how we grazed these areas. Over time we noticed profoundly positive pasture changes. Some native species appeared in Indian couch-dominant areas and grasses came back into balance in stylo dominant areas. These pasture changes were all good.

We accepted an invitation to an introductory day at Collinsville with Resource Consulting Services (RCS) and were impressed that RCS was addressing all the matters we were worrying about. It all made sense.

After a period of research into cell grazing with practitioners and more association with RCS, we felt a grazing system using cell principles offered advantages, e.g.

1. Control of grazing of particular soil types e.g. more fertile areas in a paddock could be protected from overgrazing. Small creek flood-outs could be managed to obtain the productivity offered, but still be able to protect them from chronic over-grazing and be able to establish productive grasses like pangola and para grass.

2. To build strong pastures to inhibit woody weed invasion (rubber vine, chinee apple, etc.). The aim was to reduce the astronomical weed effort cost.

3. Grazing charts to give objective data on the grazing effort and to put meaningful numbers on the effort rather than a generic '1 beast to 6 ha'.

4. Maintain paddock fertility as high as possible. Uncontrolled grazing allowed cattle to graze and collect nutrients (grasses and legumes) from distant areas of a paddock and transfer them back to water points where they camp and defecate. Bearing in mind they recycle >90% of what they eat, this behaviour impoverishes 'out the back' and pollutes around the waters. Cells encourage an even distribution of recycling nutrients.

5. Better economics to use medicated water to supplement cattle more efficiently.

6. Promote biodiversity. Encourage better husbandry of existing native grasses, legumes and forbs.

Salisbury Plains built two cell groups:

Area 1. Silly Buggers. 4 water centres with 32 paddocks. Chosen for proximity to the house, with a diversity of soil types and a good remnant of native grasses (golden beard and coastal blue grasses) to protect and try to promote. No regular group of the herd lives in this cell.

Area 2. Kangaroo. 9 water centres with 64 paddocks. Carries mature breeders (approx. 450) 'year round'. It has diverse soil types offering opportunity to observe a range of aspects, such as responses by the pastures.

The balance of Salisbury Plains has rest built into grazing patterns i.e. rotations, except for Wilmington, which is used mainly for sale cattle and is stocked most of the year.

4.3.2. Cell results

We learned a lot though we are not convinced that we are all that good at it yet.

Negatives: *Cells require more time than we anticipated. Our electric fences require more maintenance than we envisaged. This can improve. Management is more critical e.g. a 600 AE herd in a 30 ha paddock has little margin for error in timing to avoid overgrazing. You can't put off a shift to another day, and other projects can suffer.*

We believe the breeders are in lower body condition than under open grazing.

Positives: *We believe we grow more grass.*
We believe we are building greater diversity in the paddock – more stylos, buffel, green panic, siratro, etc.

We can manage litter on the ground for better water infiltration and cleaner run-off.

Volunteer grass plants (buffel and green panic) are appearing in areas in the cells that 40 years of experience suggest is unprecedented. They are not only establishing with no input from us, but are flourishing and expanding. That's new for Salisbury Plains.

Despite perceived lower body weights in breeders, weaning percentage is still good at 86.2% in 2009.

4.3.3. Future plans

Do not have a clear plan. Parts of Salisbury Plains are being considered by the Government for future industrial development potential such as an expansion of Abbot Point. This means the future is uncertain.

When appropriate, we will go on with a 'cell type' programme. Discussions in our group indicate a system with rest built in, but which takes out some of the time stress by using larger areas that allow more relaxed management, i.e. less frequent shifting. There are many examples of this available. Using two to three paddocks as opposed to eight per water is an option.

We do not see moving away from a system with rest, monitoring and capacity to manage stocking rates for particular soil types, is suitable for us.

Summary of future plans in relation to our goals:

Despite the operational shortcomings of the cell system, I regard our cell development as excellent for us and intend to develop it further if I can get the industrial development to leave me alone.

We believe we have reversed the negative trend in our paddocks of losing species and plant cover.

We have taken the lessons of the benefit of pasture rest in the grazing system and applied this to other paddocks.

The shortcoming is that, thanks to the attraction of the mining industry, we are part of the struggle to attract people with skills to continue to record e.g. "Grass check" and other systems, to objectively identify grazing management induced changes in the field.

Owner's summary of the Salisbury Plains cell system (2009):

- *Capital cost of cells is high relative to other systems.*
- *Operational cost (is a negative) – cells require more intensive management and are more time sensitive than other systems.*
- *Operational cost (can be a positive) – can organise to have cattle grazing cell paddocks close to yards simplifying mustering and reducing costs.*
- *Higher personal stressing to make the cell system workable – e.g. a water pump fails on Christmas eve.*
- *I think our cell breeders are lower in body weight than in the continuous system.*
- *Records show weaning percentage is the same in all systems.*
- *Cells can manage pasture better, by planning spelling of specific areas which is an important consideration for Salisbury Plains.*
- *Offers a much more objective look at our production and results in the field.*
- *Cattle get extremely quiet in cells.*

4.4. General conclusions

Most ecological responses of the two grazing systems at Salisbury Plains are similar even with the range of paddock sizes, soil types, grazing times and management systems. The cells have changed the species composition to favour Verano and Indian bluegrass in the small paddocks on duplex soil and introduced grass, predominantly buffel and Sabi urochloa, and legume species on the deeper sandy soils. Stylos, both Seca and Verano, contribute to the higher diet quality in the continuous paddock. Although the cells were not grazed all year, they supported a higher annual average grazing pressure than the continuous system, which received periods of relief from grazing by its varying cattle population as marketing dictated. The two monitored systems are integrated as part of the whole property annual breeder herd management and marketing system. There is an associated rotation system (not monitored in this project) that forms a critical part of the summer wet season breeder herd management system, allowing the cells to be rested during this often difficult to manage period.

Somerville

Abstract

'Somerville', Richmond, has two grazing systems; cells and rotation. Six cell and three rotation paddocks were monitored in 2006 and 2007. The two systems are used as part of an integrated property breeder enterprise. The cell system is used for breeders, with weaners and growing cattle mainly run in the rotation system. There was near average rainfall for the two years of monitoring. The pastures were sampled in late autumn in 2006 and 2007. Average pasture yields were similar in both systems in both years 1600 kg/ha. All pastures were mixed native and exotic species. Over all paddocks in 2007 there was 70% native and 22% exotic grasses (buffel grass), with 2% native annual grass and 5% native forbs.

Grazing pressure was variable between systems and years. There was a higher grazing pressure in the cell than in the rotation system over the 2005-06 to 2007-08 period, and it was higher in both systems in 2006-07 than in the other two years. There is a similar diet quality, measured as NIRS crude protein (average 7%) and digestibility (average 55%) in both systems, although the protein levels were near 2% lower in the cells in the dry season. The ecological differences were not consistent or strongly associated with the grazing system.

1. Site Introduction

Somerville was one of the original nine primary monitor sites in 2005, but was sold in 2008 and the cell grazing system was discontinued so project recording ceased. There were two years of measurements 2006 and 2007 in contrast to continuing to 2009 at the other sites.

1.1. Location

Somerville is approximately 90 km NNW of Richmond (20.2ºS; 142.7ºE) in the Flinders River Bylong land system of the Flinders River catchment of the Southern Gulf region (Figure 1.1).

Figure 1.1. Open bauhinia woodland landscape with *Cenchrus* and *Aristida* pastures on sandy soils at Somerville.

1.2. Climate/growing season

The average annual rainfall at Somerville is 503 mm (Table 3.1) with 90% falling in summer (October-March) during the short summer pasture growing season. There is usually little or no rain during the cooler part of the year and temperate species make no contribution to the pastures.

Based on long-term climate data, the average green season for tropical species is estimated to be 19 weeks including 11.1 growth weeks. With the winter rain, temperate species would have the potential to add an average of 0.4 weeks to the growth of tropical species.

1.3. Major soil/vegetation types

Somerville is flat to gently undulating with a mixture of sandy earths, yellow duplexes and cracking clay soils. Overall the vegetation is approximately equal amounts of Mitchell grass/bluegrass/browntop broken clay soil downs, Gidgee (*Acacia cambagei*) country, and low eucalypt-bauhinia (*Eucalyptus microneura* and *Bauhinia cambagei*) sandy forest country (Bylong land system). The monitor paddocks of the cell and rotation systems are predominantly on the sandy forest country (Table 0.1).

Table 0.1. Areas (ha) of land types in monitor paddocks of grazing systems at Somerville.

Land type	Area (ha)	
	Cells	**Rotation**
Bluegrass-browntop plains	1	160
Gidgee country	60	33
Sandy forest country (southern)	526	2234
Total	**587**	**2427**

1.4. GRASP modelling of long-term pasture growth

1.4.1. GRASP parameters

The sandy forest country was 92% of the sampled area with 3% bluegrass-browntop plains and 5% gidgee country. Given this dominance of sandy forest country only this land type was modelled. The GRASP model parameters are shown in Table 0.2. The bluegrass-browntop plains would most likely be more productive and pasture productivity of the gidgee areas depends on tree density. Pastures can be negligible in scrub areas.

Table 0.2. Land type (sandy forest, southern) parameters for Somerville used in GRASP model to estimate pasture growth.

GRASP parameter	**Parameter units**
	Sandy forest
Tree basal area (m^2/ha)	3
Available soil water (mm)	150
Maximum N uptake (kg/ha)	15
Regrowth (kg/ha/%BA)	5
Transpiration use efficiency (kg/ha/mm)	13.5
Minimum N concentration (%)	0.4

1.4.2. GRASP results

The GRASP model was run using climate data from SILO for the period 1889 to June 2007 and pasture growth for the period July 1 to June 30 was estimated. The median value for Somerville was 1190 kg/ha (Figure 1.2).

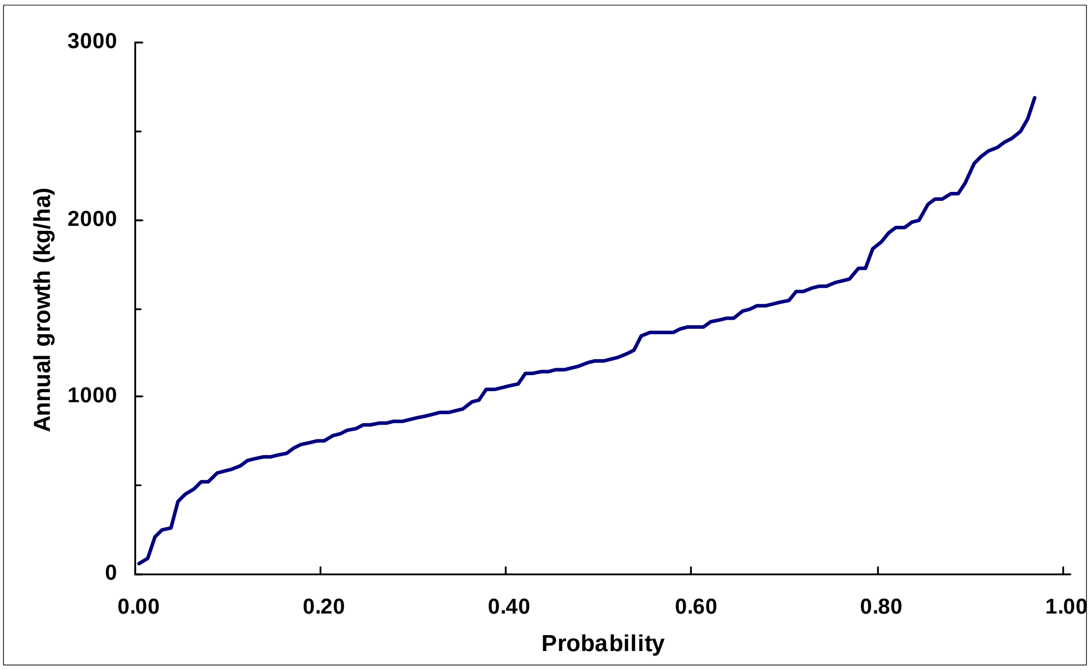


Figure 1.2. Long-term distribution of estimates of annual pasture growth at Somerville.

1.5. Production system/markets

When the project commenced in 2005 Somerville was being run as a breeding and growing operation with agistment used as part of normal management. Cattle may be sold or sent away on agistment in years of scarce feed and cattle may be brought in for a short period during spring in years of excess feed. The property was sold during 2008 and the enterprise changed to less breeding and bringing in weaners from other Gulf properties for growing. The grazing systems also changed with the cells being dismantled to construct more rotation paddocks.

1.6. Producer goals

Prior to 1992 under the previous ownership the property was managed under a system of continuous grazing. At that time a number of paddocks were created and a rotational grazing system was implemented. The present system of cells and rotational grazing paddocks was established more recently, some ten years before the project commenced. The overall goal was to improve three aspects of the property – the land resource, the cattle, and the motivation of the people involved. This was to be achieved in concert with an intensification of grazing management on the property through cell grazing and the establishment of more watering points and smaller paddocks – notably in the area of the property that was under the rotational grazing system. A further plan (prior to selling in 2008) was to install additional watering points in the rotational paddocks with some additional pasture development (mainly seeding buffel grass).

As noted, the ownership of this property changed hands in 2008 and the present owners' goals are unclear. For example, the cell grazing system is being de-commissioned with much of the existing infrastructure to be removed so the project ceased at this site with two years of data (2006 and 2007).

2. Grazing systems

2.1. Description

Approximately 17,000 ha of Somerville (from the total area is 31,052 ha) was managed using cell grazing principles (including smaller paddocks, short grazing periods and larger mob size). The remaining 14,000 ha was managed with rotational grazing but the only real difference between the systems was the size of the paddocks and length of the graze periods. The managers monitored pasture condition and production in both systems.

The cells consisted of 13 cell centres (watering points) with 166 paddocks which ran a 1200 head breeding herd; weaners or growing cattle were also run in these paddocks on occasions. Each cell centre had from 8-18 paddocks (average area approximately 100 ha) coming into the one, central watering point (wagon-wheel design). Most fences were 2-wire electric fencing, some were single wire electric, and bore water was supplied to the cell centres through polythene pipeline utilising pumps and a 450,000 litre turkey nest dam. Cell centres were watered with one or two concrete troughs augmented by four relocatable polythene troughs. The 18 rotational paddocks ranged in size from 400 ha to 2,400 ha and had 1-3 watering points spread around the paddocks. The rotation paddocks were mainly used for weaners and growing cattle, although breeders are included at times, depending on the whole property feed budget. Both herds were urea supplemented. Weaners also received a molasses based supplement in open troughs in the rotation paddocks.

Six paddocks (three paddocks from two cell centres) were monitored in the cell system and three paddocks were monitored in the rotational system. Of these, one paddock was used for weaning and it received longer grazing periods, although it sometimes received extended rest periods before weaners were introduced (Table 2.1). The layout of the monitor paddocks is shown in Figure 2.1.

Table 2.1. Paddock names, numbers and areas sampled at Somerville.

Grazing System	Paddock name	Botanal Paddock No.	Area (ha)
Cell	Spinifex Ridge 1	1	87
	Spinifex Ridge 2	2	113
	Spinifex Ridge 3	3	72
	Top Bullock 5	5	91
	Top Bullock 6	6	125
	Top Bullock 7	7	99
	Cell Total		**587**
Rotation	East Rustlers	8	721
	West Rustlers	9	1258
	Trivalore	10	448
	Rotation total		**2427**

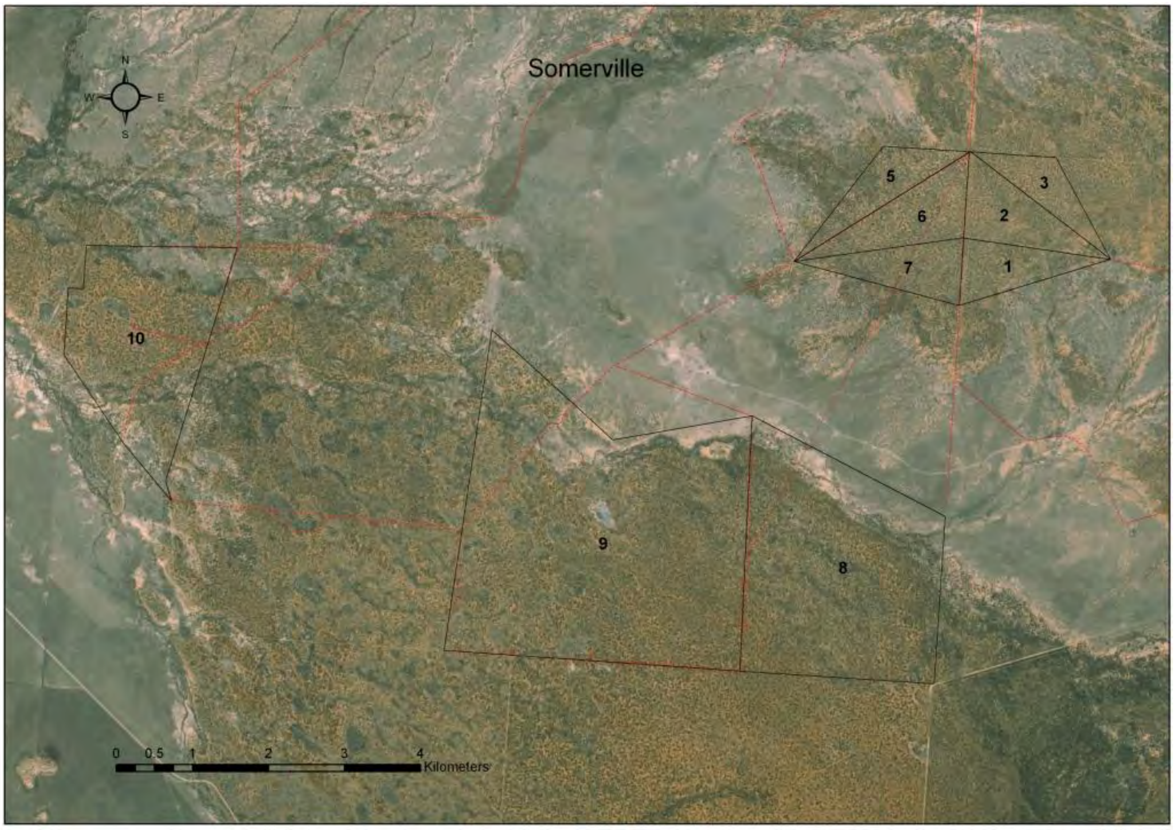


Figure 2.1. Layout of six cell and three rotation monitor paddocks on Spot-5 image at Somerville.

2.2. Management during 2005-07

A breeder herd of 600 to 1200 cows with bulls and calves grazed the cell paddocks on a rapid rotation of one to three days per graze. Paddocks received one or two grazing events per year, with occasional paddocks being grazed three occasions in some years. Urea medicated water was supplied.

The rotation paddocks were grazed by 500 to 1600 head of growing cattle for periods of 5 to 42 days on one or two occasions per year. When weaners were in the system they were supplemented with fortified molasses in troughs.

3. Results

3.1. Growing Seasons

3.1.1. Rainfall

The monitoring period, which followed the drought year of 2004-05, received above average annual rainfall, but with a poor distribution in both years (Table 3.1). In 2005-06, there was good pasture growing rainfall starting in November, followed by good rain in January. The season finished with late rain in April. The following year received above average rainfall in January, but no follow-up rain until the unusually high out-of-season June rainfall, which is too late for pasture production.

Table 3.1. Monthly rainfall (mm) at Somerville homestead from July 2004 to June 2007 and long-term average monthly rainfall (mm) at Saxby Downs recording station over 112 years.

Year	Monthly rainfall (mm)													
	J	A	S	O	N	D	J	F	M	A	M	J	Total	Decile
2004-05	0	0	0	0	0	192	58	23	13	0	26	0	312	2
2005-06	8	28	0	0	131	5	137	51	52	216	8	0	636	8
2006-07	59	0	0	0	12	61	209	20	9	0	0	154	524	6
Long-term Mean	**6**	**3**	**5**	**12**	**34**	**80**	**140**	**120**	**68**	**17**	**11**	**11**	**503**	

3.1.2. Growing conditions

2004-2005: The wet season began late with high early summer (December) rainfall. However there was extremely low rainfall during the rest of the year and rainfall for the year was well below average (decile 2) producing a poor pasture growing season.
2005-2006: Somerville recorded above-average rainfall in November which resulted in good pasture growth. However, this was followed by an extended period of hot dry conditions which burnt off new growth, before late summer and autumn rainfall following cyclones across the southern Gulf produced further pasture growth. Rainfall was above average for the 2005-06 year due to extremely high autumn rainfall which maintained the pastures into winter.

2006-2007: Somerville recorded average rainfall over this year. There was good rain in January, but subsequent conditions were very dry until after pasture sampling (early June) when there were substantial unexpected out-of-season falls. The short growing season and very low autumn rainfall would have impacted on pasture quality and limited pasture growth.

3.1.3. GRASP modelling pasture growth 2005-2009

Assuming that the small amount of “Bluegrass browntop plains” has similar pasture growth rates to the “Sandy forest country”, and that the dense “Gidgee country” produces no pasture, the estimated annual pasture growth is shown in Table 3.2.

Table 3.2. Estimated annual pasture growth (kg/ha) for grazing systems at Somerville in 2005-06 and 2006-07.

Year	Pasture growth (kg/ha)	
	Cell	Rotation
2005-06	1200	1300
2006-07	600	600
Average	**900**	**950**

The pasture growth index values show the wide fluctuations in growing conditions during 2005-06 growing season, and the much shorter growing season in 2006-07 than in the previous year (Figure 3.1). The annual long dry season is indicated.

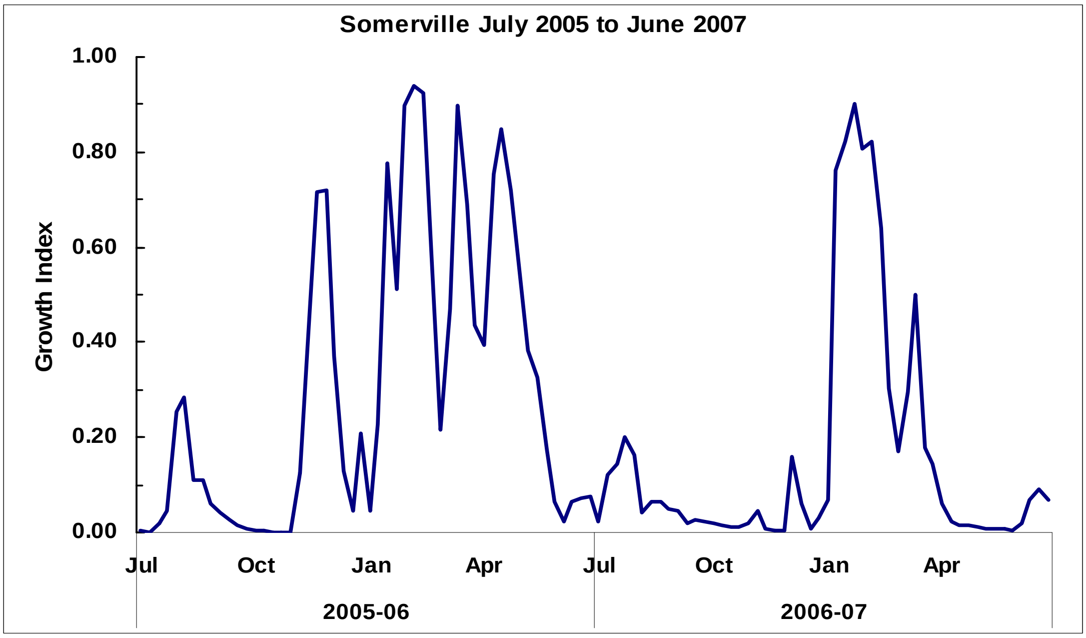


Figure 3.1. Weekly pasture growth index (tropical species) values at Somerville during the experimental period (July 2005-June 2007).

3.2. Pastures and Land Condition

3.2.1. Pasture yield, botanical composition and diversity

3.2.1.1. *Pasture means*

The pastures were sampled in late autumn in 2006 and 2007. There was little system difference in pasture yields although they were slightly higher (approximately 100 kg/ha) in the cell system in 2006 (Table 3.3). Both systems were dominated by native (60%) and exotic (24%) perennial grasses, predominantly buffel grass (*Cenchrus ciliaris*). All six cell paddocks were similar in composition with a high proportion of Gulf wiregrass (*Aristida pruinosa*, *Aristida inaequiglumis*) and golden beard grass (*Chrysopogon fallax*). The rotation paddocks had more variable composition, with extensive patches of annual grass (*Perotis rara* and *Brachyachne convergens*) and also patches of native legume (*Zornia* spp.). Buffel grass was spreading from under-tree loci, commonly *B. cunninghamii*, in both systems.

Table 3.3. Pasture dry matter yield and botanical composition at the end of summer at Somerville.

Year	**System**	**Yield (kg/ha)**	**Botanical composition (%)**						
			Nat per grass	**Exotic grass**	**Native leg.**	**Exotic leg.**	**Ann grass**	**Forb**	**Sedge**
2006	Cell	1800	59.4	28.3	0.6	0.2	3.7	6.7	0.1
	Rotation	1600	45.5	18.9	5.4	0.0	14.3	14.6	0.6
2007	Cell	1500	77.0	18.2	0.0	0.1	1.7	2.8	0.1
	Rotation	1600	55.3	29.4	2.1	0.3	3.7	8.7	0.5
	Average	**1600**	**62.3**	**23.5**	**1.5**	**0.1**	**4.8**	**7.1**	**0.3**

3.2.1.2. *Yield spatial variability*

This analysis measured the degree of uniformity, or inversely variability, in the various parameters across each paddock. There was uniform pasture yield across three of the six cell paddocks and one of the three rotation paddocks in early winter of 2006, and only one paddock in each system was uniform in 2007 (Table 3.4).

Table 3.4. Spatial variability in pasture yield – number of paddocks where pasture yield was spatially uniform (i.e. there was no evidence of aggregation) across the paddock.

Grazing System	Total no. of paddocks	No. paddocks uniform pasture yield	
		2006	2007
Cell	6	3	1
Rotation	3	1	1

3.2.1.3. *Species diversity*

The three measures of species diversity all showed the rotation paddocks were more diverse than the cell paddocks (Table 3.5).

Table 3.5. Three measures of pasture diversity at Somerville in 2006 and 2007.

Diversity measure / Year	Diversity units	
	Cell	Rotation
No. species/quadrat		
2006	2.1	2.5
2007	1.6	2.2
No. species to contribute 90% of yield		
2006	8	15
2007	6	16
% contribution of dominant species		
2006	32	19
2007	50	29

3.2.2. Pasture utilisation

Pasture utilisation in the monitor paddocks at the end of summer was rated across the paddocks on the Botanal grid at each recording point (rating 1 = 71-100%; 2 = 31-70%; 3 = 6-30%; 4 = 0-5% utilisation).

3.2.2.1. *Utilisation means*

Utilisation was light in both years although slightly higher in 2007 than in 2006 (Table 3.6). There were no differences between grazing systems in either year.

Table 3.6. Mean rating (1 = high to 4 = low) for estimated pasture utilisation in grazing systems at Somerville for 2006 and 2007.

Year	**Utilisation rating**	
	Cell	**Rotation**
2006	4.0	4.0
2007	3.4	3.4

All quadrats were rated 4 in 2006 (<5% utilisation), but there was some variation across both systems in 2007 although a majority of the quadrats were still rated 4 (Figure 3.2).

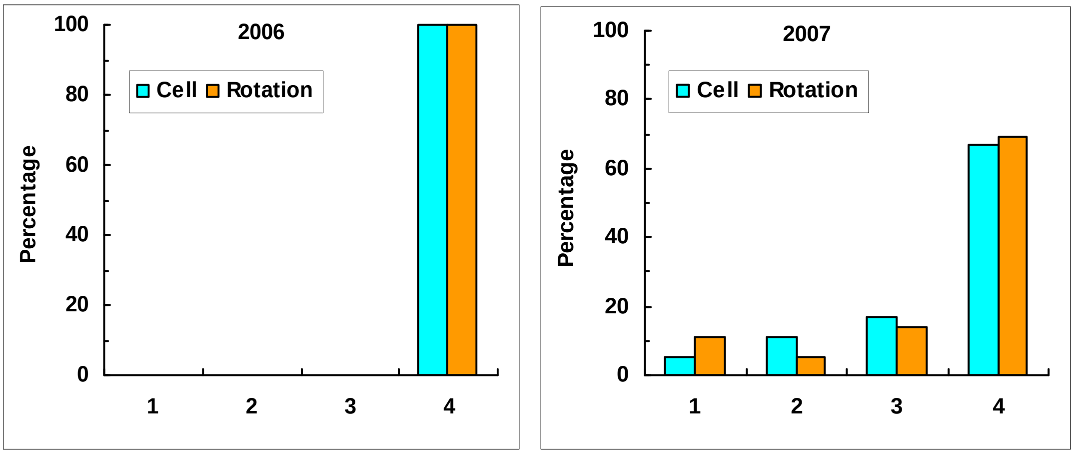


Figure 3.2. Distribution of estimated pasture utilisation values in grazing systems at Somerville in 2005-06 and 2006-07 (1 = 71-100%; 2 = 31-70%; 3 = 6-30%; 4 = 0-5%).

3.2.2.2. *Utilisation spatial variability*

Most paddocks were uniform in utilisation in 2006, and in early winter of 2007 half of the cell paddocks were uniform while none of the rotation paddocks had uniform utilisation (Table 3.7).

Table 3.7. Spatial variability in pasture utilisation - number of paddocks where pasture utilisation was spatially uniform (i.e. there was no evidence of aggregation) across the paddock.

Grazing System	**Total no. of paddocks**	**No. paddocks uniform utilisation**	
		2006	**2007**
Cell	6	6	3
Rotation	3	2	0

3.2.3. Woody regrowth

The trees had not been cleared at Somerville so there were no estimates of woody regrowth from tree species, however, there were patches of conkerberry (*Carissa lanceolata*) undergrowth in all paddocks which was recorded as regrowth. The cell system had marginally higher regrowth cover in both years, average 5% versus 3% cover in the rotation system.

3.2.4. Ground and litter cover

At the end of the summer growing season soil cover was mainly from the pasture, while at the end of the dry season, there were extensive patches of ground cover provided by fallen tree leaf, predominantly from bauhinia trees.

3.2.4.1. *Cover means and standard deviations*

Cover levels were relatively low in both the cell and rotation systems in both years with the mean values slightly lower in the cells. Levels of total cover were marginally lower in 2007 than during 2006. Although there was some variability, the standard deviations were similar for both grazing systems (Table 3.8).

Table 3.8. Pasture cover and litter cover levels (%) at Somerville at the end of summer.

Year	**System**	**Total cover (%)**		**Litter cover (%)**	
		Mean	**St. Dev.**	**Mean**	**St. Dev.**
2006	Cell	39	26.4	15	19.9
	Rotation	45	28.4	17	19.9
2007	Cell	35	27.2	19	21.3
	Rotation	39	22.2	23	22.2

3.2.4.2. *Cover spatial variability*

Both total and litter cover were uniform in most or all the cell paddocks in both years, while they were not uniform in the rotation paddocks (Table 3.9).

Table 3.9. Spatial variability in ground cover - number of paddocks where total ground cover and litter cover were spatially uniform (i.e. there was no evidence of aggregation) across the paddock.

Cover	**System**	**Total no. of paddocks**	**No. paddocks uniform ground cover**	
			2006	**2007**
Total ground cover	Cell	6	4	6
	Rotation	3	1	0
Litter cover	Cell	6	4	4
	Rotation	3	1	1

3.2.5. LFA indices (soil surface condition)

Soil surface condition was assessed in each quadrat in the pasture sampling in 2006 and 2007 and this information was used to generate the three LFA indices of stability, infiltration and nutrient cycling. These indices have values between 0 and 100 where larger values indicate better performance for that index.

3.2.5.1. *LFA indices means and standard deviations*

There were only small differences between grazing systems in the three LFA index values at either recording (Table 3.10). Stability was marginally lower and with a wider variation in the cells than in the rotation paddocks in 2007. Over the two recordings, the average stability index increased 3%, infiltration increased 4% and nutrient cycling increased 18%.

Table 3.10. LFA indices at Somerville at the end of summer 2006 and 2007.

Year	**System**	**LFA Indices (0-100)**					
		Stability		**Infiltration**		**Nutrient cycling**	
		Mean	**St. Dev.**	**Mean**	**St. Dev.**	**Mean**	**St. Dev.**
2006	Cell	49.8	8.21	39.8	10.38	25.4	11.19
	Rotation	50.8	8.15	40.8	10.99	27.2	11.70
2007	Cell	50.8	15.46	41.8	14.75	29.2	12.73
	Rotation	53.3	8.29	42.0	11.53	32.9	11.80

3.2.5.2. *LFA indices spatial variability*

Half of the cell paddocks had uniform stability and infiltration indices (2 or 3 of 6 paddocks) and most paddocks (5 or 6) had uniform nutrient cycling in both years (Table 3.11). There was less uniformity in the rotation paddocks, except for the three paddocks having uniform nutrient cycling in 2007.

Table 3.11. Variability in LFA indices - number of paddocks where LFA indices were spatially uniform across the paddock.

Year	**Grazing System**	**Total no. of paddocks**	**No. paddocks uniform LFA indices**		
			Stability	**Infiltration**	**Nutrient cycling**
2006	Cell	6	2	3	5
	Rotation	3	1	1	2
2007	Cell	6	3	3	6
	Rotation	3	1	0	3

3.2.6. Land condition

All three measures of land condition show only small differences between grazing systems and years (Table 3.12). The ABCD assessments were B condition (= 2) for all land types and both grazing systems due to reduced 3P grasses, a high proportion of wiregrass (*Aristida* spp.) and areas of annual grass and bare inter-tussock areas. Some of these areas are in C condition, especially in the rotation paddocks. The Botanal/PatchKey results were slightly higher (indicating poorer condition) at approximately 3, or equivalent C condition, in both systems.

Table 3.12. Land condition measures at Somerville. For the Botanal/PatchKey and ABCD (Land type) values, “1” is equivalent to A condition and “4” is equivalent to D condition.

Land condition method	Year / Land type	Land condition units	
		Cell	Rotation
Botanal/PatchKey			
	2006	2.9	3.0
	2007	3.1	3.0
ABCD (by Land type)			
	Bluegrass-browntop plains	2.0	2.0
	Gidgee country	2.0	2.0
	Sandy forest country	2.0	2.0
ABCD (Paddock)			
	2006	B	B
	2007	B	B

An annual photograph of fixed points in the two systems shows the seasonal variation in pasture growth and cover (Figure 3.3). The open pasture and bare areas obvious in the drought of 2005 with improving cover in 2006 and increasing production from *Aristida* spp. by 2008 are evident. The mature pastures in autumn (e.g. April of 2008) reflect the early end to this growing season.

Somerville Cell SpR1-2 **Lat: 20^{0}.223, Long: 142^{0}.729, Dir: 183^{0}**	**Somerville Rotation ER-2** **Lat: 20^{0}.266, Long: 142^{0}.691, Dir: 81^{0}**
 Cell (November 2005)	 Rotation (November 2005)
 Cell (November 2006)	 Rotation (November 2006)
 Cell (November 2007)	 Rotation (November 2007)
 Cell (April 2008)	 Rotation (April 2008)

Figure 3.3. Changes in land condition at fixed points in the cell and rotational grazing systems at Somerville, 2005 to 2008.

3.2.7. Cover Analysis

3.2.7.1. *VegMachine vegetation cover time series (Landsat)*

VegMachine analysis of cover in all areas shows it was low, around index 20, in the late 1980's drought years and reached a high of index 85 in the abnormally wet year, 2000. Paddock cover differences were not large, index 10 range, with the rotation paddocks having the superior cover (Figure 3.4). In the monitoring period, cover index was similar in both grazing systems. The average of the whole property and similar land types in the surrounding neighbourhood were all about index 45 in 2005. Again in 2006, cover in all areas increased and was the same at index 75. In 2008, the cell and rotation areas both declined, however the cells declined to a lesser extent to near index 70 compared with index 60 in the rotation paddocks. The average of the property and the neighbouring land types had a similar decline to the rotation paddocks. This time series analysis of ground cover suggests the relativity of the areas in both systems was consistent for the last 12 years and that management changes within systems over the last decade have had little if any additional impact.

With the cell and rotation systems operating in the severe drought years of 2001 and 2002, cover was maintained at a high level and was slow to decline in response to the extended drought. All areas on Somerville were managed to maintain good pastures and ground cover, so there were no consistent differences between the grazing systems since 1997. Pasture cover has been better over the drought years of the 2000's than in the early 1990's or late 1980's drought years. This may be attributed to the implementation of better grazing management practices since the cells were installed and staff training in managing intensive systems and using feed budgeting information for managing stocking rates in all paddocks. Both grazing systems have benefited from this management approach.

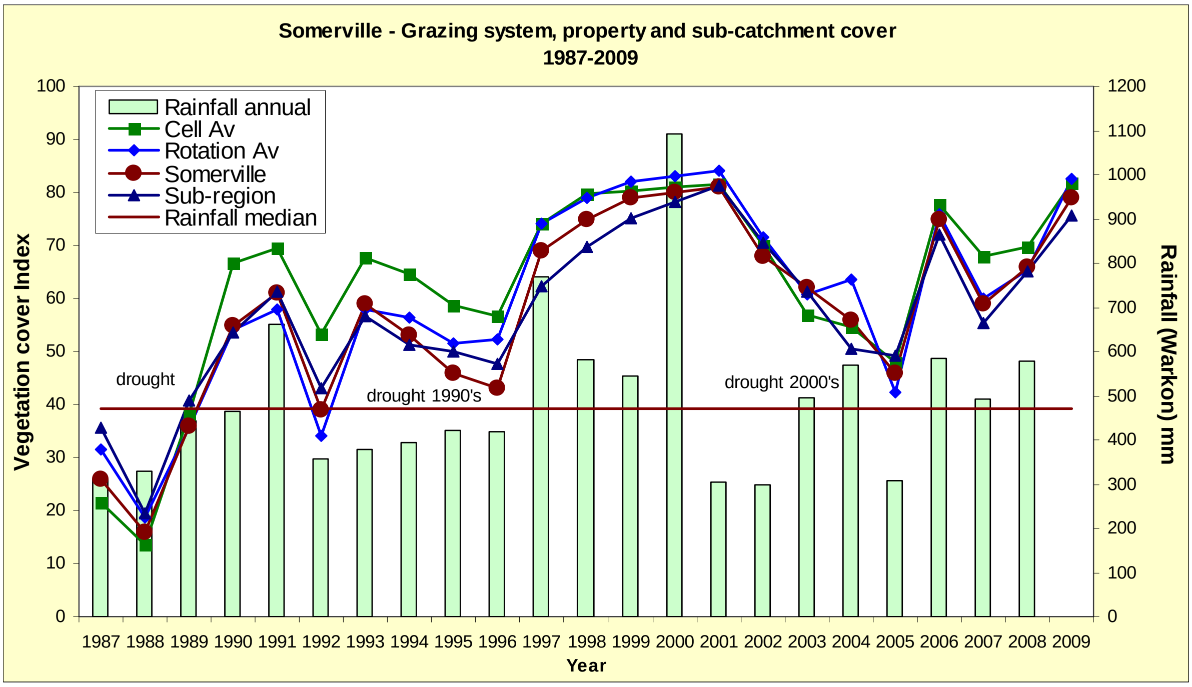


Figure 3.4. Vegetation cover index between 1987 and 2009 for the monitor paddocks and the whole property at Somerville. Annual and long-term median rainfall (mm) are also shown.

The cover changes in all paddocks since 1987 (Figure 3.5) show the annual responses to rainfall and the three main drought periods. There are not wide variations or consistent differences between the paddocks at any time. The lower cover for the whole property in the

1990's may be attributed to the heavier grazing on the clay soil plains when paddocks were larger, before the cell and intensification program allowed better grazing control over these favoured areas.

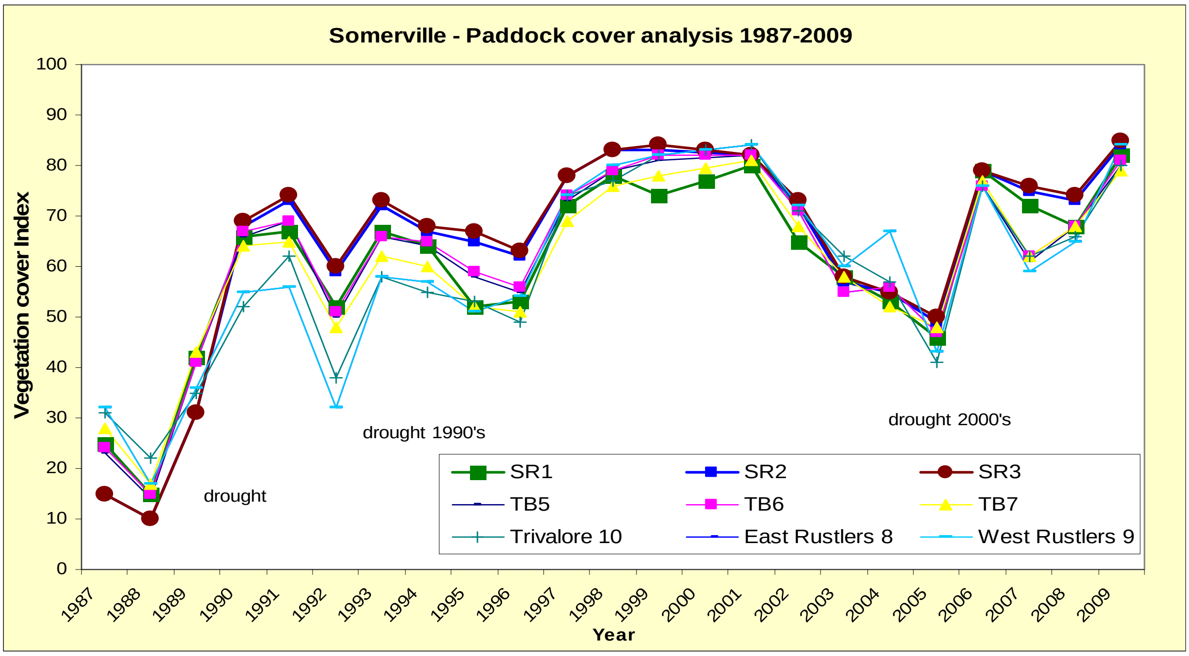


Figure 3.5. Vegetation cover index between 1987 and 2009 for the monitor paddocks and the whole property at Somerville.

3.2.7.2. *Botanal pasture data*

Pasture yield and cover values in paddocks and grazing systems (Table 3.13) show a marginally higher yield in the cells than in the rotation paddocks in 2006 only, while total cover and litter cover was marginally higher in the rotation paddocks in both years. Woody regrowth cover, mainly from *C. lanceolata* bushes, was marginally higher in the cell paddocks.

Table 3.13. Paddock and grazing system mean dry matter yield (kg/ha), total pasture cover (%), litter cover (%) and woody cover (%) in 2006 and 2007 at Somerville.

Paddock / System	**Yield (kg/ha)**		**Total Cover (%)**		**Litter Cover (%)**		**Woody Cover (%)**	
	2006	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**
Spinifex Ridge 1 [1]	1890	2350	38	44	16	18	6.0	5.6
Spinifex Ridge 2 [2]	2240	2030	39	36	11	18	6.4	5.6
Spinifex Ridge 3 [3]	1900	2030	48	34	21	16	4.4	4.8
Top Bullock 5 [5]	1060	570	38	33	17	23	6.8	2.4
Top Bullock 6 [6]	1760	1144	39	27	15	17	5.6	2.2
Top Bullock 7 [7]	1930	1579	33	34	13	20	10.6	2.1
East Rustlers [8]	1700	1158	40	40	16	24	4.6	5.0
West Rustlers [9]	1540	1160	50	33	16	19	3.5	2.1
Trivalore [10]	1450	1930	44	44	18	26	2.9	3.4
Cell	1780	1530	39	35	15	19	6.7	3.8
Rotation	1570	1550	45	39	17	23	3.6	3.5
Site	1710	1540	41	36	16	20	5.7	3.7

3.2.7.3. *Spatial ground cover reports*

The modelled pasture growth (1500-2000 kg/ha) and standing dry matter yields of 1300-1600 kg/ha were similar to the field measured yields (1500 to 1700 kg/ha). The modelled cover levels of 45-70% are higher than those measured (approximately 42%). This cover difference may be attributed to the additional tree cover which was not included in the total pasture cover measured in the project, but can influence the satellite cover measurement. The image for the whole of Somerville in 2008 (Figure 3.6) shows almost the whole property is above the 30% cover level (grey is >30% cover, brown areas are <30% cover and the green is trees or clouds).

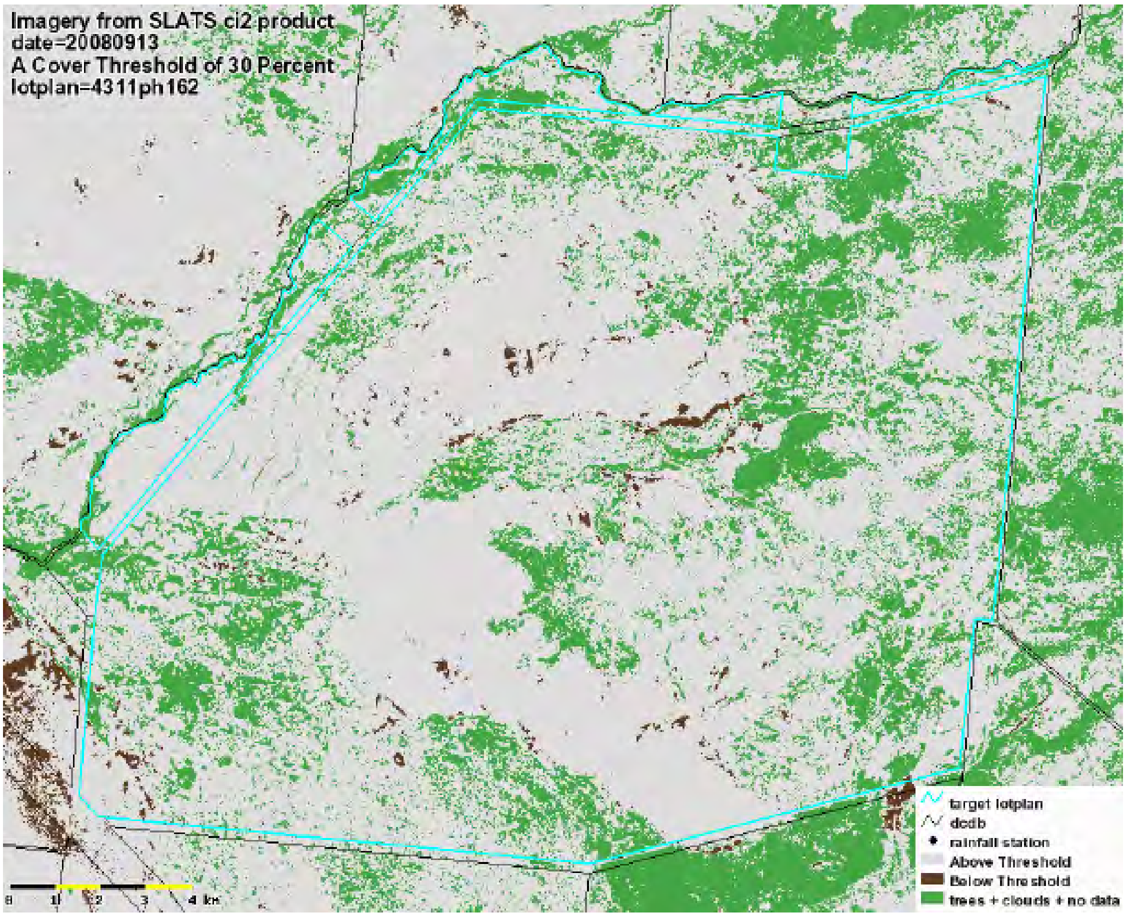


Figure 3.6. Ground cover image of the whole of Somerville (2008) (Source QDERM data).

3.3. Cattle Grazing

3.3.1. Carrying capacity – long-term (LTCC)

The estimated long-term carrying capacities (AE/100 ha and SDH) of the two systems based on landtypes are the same:

Cells	4.7 AE/100 ha (17 SDH)
Rotation	4.7 AE/100 ha (17 SDH)

3.3.2. Rest periods

The average annual rest periods between grazing events in both systems were similar, around 150 days (Table 3.14). Paddocks in both systems were grazed for short periods and on 1-3 occasions per year.

Table 3.14. Rest periods (days) between grazing events for grazing systems at Somerville.

Year	Rest periods (days)	
	Cells	Rotation
2005-2006	151	180
2006-2007	113	130
2007-2008	181	158
Average	**148**	**156**

3.3.3. Grazing days

The annual average number of days of grazing was 6 and 17 days for the cell and rotation systems respectively. They had an annual average of 2 and 1 grazing events or herd number changes per year respectively. The annual number of days grazing in the six cell paddocks ranged from 2.5 to 17 days per year, with 1 to 3 grazing events per year. The rotation system paddocks were grazed 4 to 73 days per year with 1 or 2 herd changes per year over the three years.

3.3.4. Grazing pressure

The animal numbers taken from property records for each system have been converted to Animal Equivalents (AE) using the standards tables presented in Appendix 9.10. An AE is equivalent to a dry cow weighing approximately 450 kg. The average grazing pressure in the monitor paddocks in stock days per ha per 100 mm of rainfall in the 12 months prior to each grazing event (
Table 3.15) shows the cell system received heavier grazing than the rotation system in two of the three years of recording. Weaners (933 head at AE of 0.54) were supplemented in the rotation paddocks in 2005-06. This herd had one short graze of 4-8 days in each of the three monitor rotation paddocks over this year. This low grazing was due to drought and herd dynamics, and these paddocks being used for supplementing a weaner herd in that year rather than for carrying breeders. In 2007-08 the rotation paddocks supported a higher grazing pressure than the cell paddocks.

Table 3.15. Grazing days for grazing systems at Somerville (SDH/100mm/yr and SDH).

Year	Grazing pressure	
	Cell	Rotation
	SDH/100mm/yr and (SDH)	
2005-06	6.5 (20)	1.2 (4)*
2006-07	8.6 (47)	4.9 (28)
2007-08	3.0 (14)	4.4 (21)
Average	**6.0 (27)**	**3.5 (17)**

* a weaner herd grazed rotation monitor paddocks on one occasion this year.

The average SDH in the two systems over the three-year monitoring period was 27 and 17 SDH for the cell and rotation systems respectively, compared with a long-term carrying capacity (LTCC) estimation of 17 for both systems. This indicates the cell system was carrying above the grazing pressure that the LTCC would suggest, while the rotation paddocks were grazed at the estimated rate.

There was a significantly higher grazing pressure in the cell than in the rotation system over the 2005-06 to 2007-08 period, measured as SDH, SDH/100mm rainfall and in ha/AE (Table 3.16). There was a significantly higher grazing pressure in 2006-07 than in the other two years. The grazing system by year interaction was highly significant for the three measures.

Table 3.16. Grazing system and year effects on stock days per ha (SDH), SDH per 100mm rain and annual stocking rate (ha/AE) at Somerville.

System / Year	**Grazing pressure**								
	Stock days per ha (SDH)			**SDH / 100 mm rain**			**Annual stocking rate (ha/AE)**		
Grazing System (GS)	*			*			*		
Cell	3.18	(23)	a	1.85	(5.4)	a	2.84	(16)	b
Rotation	2.60	(12)	b	1.35	(2.8)	b	3.48	(31)	a
Av. s.e.d.	0.22			0.18			0.24		
Year (Yr)	***			*			***		
2005-06	2.45	(11)	b	1.50	(3.5)	b	3.63	(37)	a
2006-07	3.52	(33)	a	1.94	(5.9)	a	2.52	(12)	b
2007-08	2.69	(14)	b	1.37	(2.9)	b	3.33	(27)	a
Av. s.e.d.	0.25			0.21			0.27		
GS x Yr	***			***			***		
Cell-2005-06	3.04	(20)	b	2.00	(6.4)	a	2.96	(18)	a
Cell-2006-07	3.81	(44)	a	2.20	(8.0)	a	2.23	(8)	b
Cell-2007-08	2.68	(14)	b	1.36	(2.9)	b	3.33	(27)	a
Rot-2005-06	1.56	(4)	b	0.74	(1.1)	b	4.64	(103)	a
Rot-2006-07	3.23	(25)	a	1.67	(4.3)	a	2.79	(15)	b
Rot-2007-08	3.00	(19)	a	1.64	(4.1)	a	3.01	(19)	b
s.e.d. w/i GS	0.27			0.23			0.29		
s.e.d. w/i Yr	0.28			0.24			0.29		

n.s. – 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 parentheses. Means not followed by a common letter are significantly different (P=0.05). For the GSxYr means, differences indicated are within a grazing system.

3.3.5. Grazing system intensity index

The grazing system intensity index values (range 1-100; calculated from capital costs, operating costs and management inputs; details are reported in Appendix 9.13) for the two systems were:

Cell system	91
Rotational system	73.

Both systems had relatively high GSI indices due to regular forward planned stock movements and detailed records being kept along with feed budgeting being undertaken several times per year. Property cattle numbers were changed using the feed budgets as a guide for sales and purchases, or agistment, depending on the seasons and projected feed supplies.

3.3.6. Diet quality (NIRS)

NIRS analyses for various diet quality parameters from all 34 samples (Table 3.17) show higher (P<0.05) non-grass in the rotation paddocks (31% compared with 21% in the cells). There is a similar diet quality, measured as crude protein (average 7%) and digestibility (average 55%) in both systems.

Table 3.17. Mean faecal NIRS diet quality results from all samples for grazing systems at Somerville between November 2005 and May 2008.

Grazing System	No. samples	Crude protein (%)	Faecal N (%)	Digestibility (%)	Non-grass (%)	LWG (kg/day)	DMD/CP ratio
Cell	24	6.7	1.4	56	21	0.49	8.9
Rotation	10	7.4	1.5	55	31	0.54	8.0
sed (av.)		0.93	0.11	2	3.5	0.12	0.9
Significance		ns	ns	ns	*	ns	ns
Average	**(total 24)**	**6.9**	**1.4**	**55**	**25**	**0.56**	**8.5**

The results of 4 paired samples from the grazing systems indicates marginally higher crude protein in the rotation system (7.9% compared with 6.6% in cells) and the same digestibility (57%) (Table 3.18). These differences were not statistically significant with the variation across four paired samples. The mean DMD:CP ratio (9.3) indicated a more marginal quality diet in the cells. Results between 8 and 10 indicate marginal diet quality, above 10 is regarded as protein deficient and below 8 is adequate protein.

Table 3.18. NIRS diet quality values when paired samples were collected at Somerville between November 2005 and November 2007.

Grazing System	No. samples	Crude protein (%)	Faecal N (%)	Digestibility (%)	Non-grass (%)	LWG (kg/day)	DMD/CP ratio
Cell	4	6.6	1.5	57	24	0.62	9.3
Rotation	4	7.9	1.7	57	31	0.68	7.4
sed (av.)	(total 8)	1.51	0.17	3	6	0.29	1.4

The NIRS values were examined by dividing them into groups which had different growing conditions on the basis of the Pasture Growth Index (GI) derived from GRASP (where 0.0 = conditions are unsuitable for growth and 1.00 = conditions are not limiting growth). Average values of the GI for the 30 days ending on the sample date were calculated. Based on these values three classes were formed – mean GI <0.2 (Poor pasture growth conditions), 0.2-0.5

(Average) and >0.5 (Good conditions). There were no significant grazing systems by GI interactions in any diet quality parameters (Table 3.19). Over all 34 samples, there was a significant increase in crude protein, to 8.4%, during the growing season (GI>0.5) compared with the dormant period, 6.7% (GI<0.2) or 6.8% with a GI of 0.2-0.5.

Table 3.19. Mean NIRS diet quality results in relation to pasture growth indices for two grazing systems at Somerville to March 2008.

Growth Index	**Grazing System**	**No. samples**	**Crude protein (%)**	**Faecal N (%)**	**Digestibility (%)**	**Non-grass (%)**	**LWG (kg/day)**	**DMD/CP ratio**
<0.2	Cell	13	5.9	1.2	54	22	0.45	9.5
	Rotation	8	7.7	1.5	55	30	0.60	7.6
0.2-0.5	Cell	5	6.7	1.5	55	26	0.54	8.7
	Rotation	2	6.9	1.5	56	27	0.63	8.1
>0.5	Cell	6	8.4	1.5	57	21	0.71	7.2
sed (av.)		(total 34)	1.14	0.16	2	5	0.19	1.1

Individual sample results for the NIRS parameters crude protein, digestibility and non-grass in the rotation (Figure 3.7) and in the cell (Figure 3.8) systems show the wide seasonal variation in both grazing systems with high quality pastures after rain, declining to below maintenance crude protein in winter before summer rains, in both systems. The non-grass component can reach 40% in both systems. This would include the fallen leaves off the deciduous bauhinia trees.

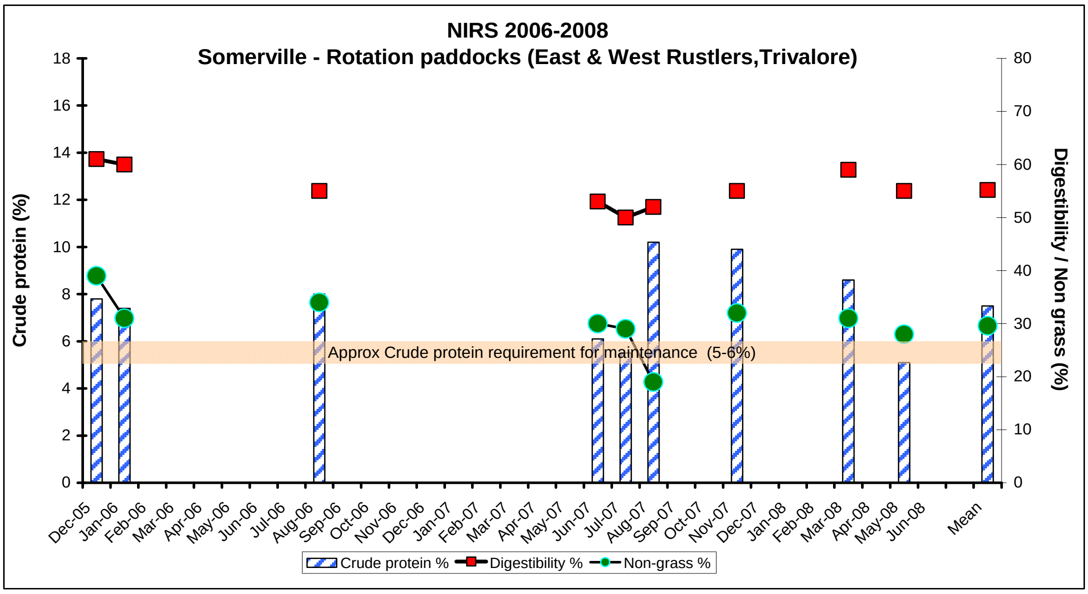


Figure 3.7. NIRS sample results for the rotational grazing system at Somerville for crude protein (%), digestibility (%) and non-grass (%) with approximate maintenance crude protein indicated.

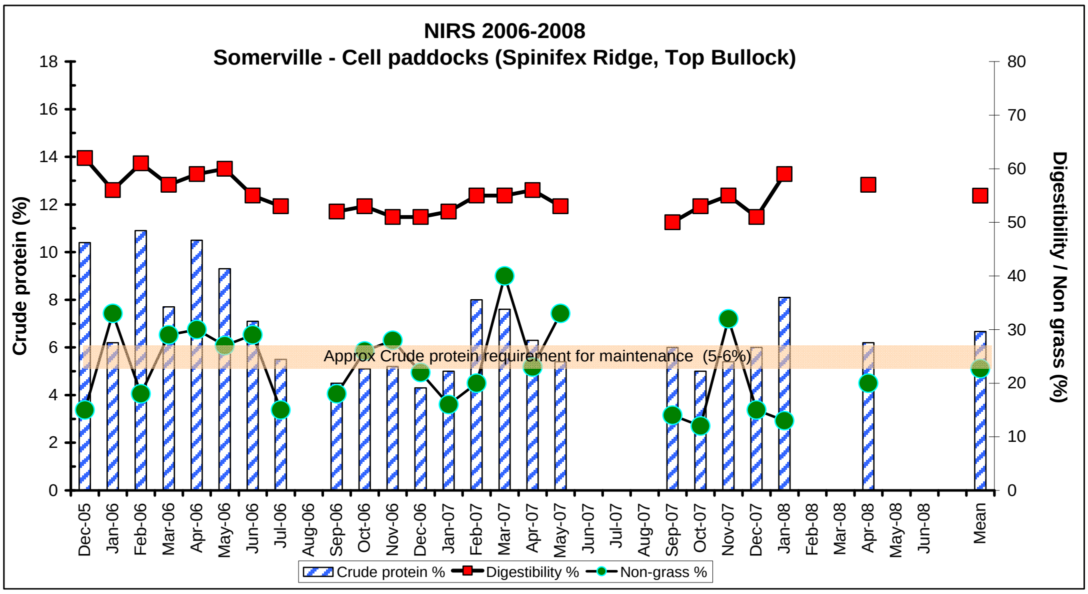


Figure 3.8. NIRS sample results for the cell grazing system at Somerville for crude protein (%), digestibility (%) and non-grass (%) with approximate maintenance crude protein indicated.

3.4. Grazing System Costs

The cell grazing system comprises 166 paddocks centred on 13 cell centres with 8-18 paddocks per cell centre. Fencing is comprised of 511 km of two-wire electric fencing. Water is supplied to the cell centres through 90 km of 63 mm polythene pipeline utilising two electric pumps and two diesel pump units and a 450,000 litre new turkey nest dam. Cell centres are watered with one or two concrete troughs augmented by four relocatable polythene troughs that shift with the stock moves. The bulk of the site treatment, fencing and pipe-laying were completed using station plant, machinery and labour. Water supplement medicators are installed.

3.4.1. Capital costs

The projected capital costs (replacement basis) for the cell grazing system (Table 3.20) at Somerville are:

Table 3.20**. Replacement capital costs of the cell grazing system.**

Capital Item	Cost ($)
Fencing	255,059
Water	278,288
Troughs	25,600
Tanks	8,600
Pumps, mills	5,000
Installation	568,650
Consultancies	10,500
Total	**1,151,737**

3.4.2. Operating costs

It was not possible to establish with accuracy the annual running costs. One guide to the operating cost of the various systems is the estimated annual capital reclamation cost (sinking fund depreciation charge), which is the equivalent sum that would need to be set aside each year to maintain the capital assets invested in the systems infrastructure. The reclamation cost for each of the systems has been estimated using standard farm accounting depreciation factors for the main assets, including – bores (7.5%), dams and wells (2.5%), fencing (5%), and plant (10%). The projected capitalised annual operating costs for Somerville, totalling $22,000, are shown in Table 3.21.

Table 3.21**. Annual operating costs of the cell grazing system.**

Item	Cost ($)
Fencing	12,753
Water	6,957
Troughs	640
Tanks	860
Pumps, mills	500
Total	**21,717**

4. Conclusions

4.1. Pasture and land condition

There was little difference in condition between the cell and rotation systems at Somerville with both visually assessed as being in B condition in both years. There was also little difference between the condition values derived from PatchKey for the two systems.

Pasture yields were similar in the two systems in both years. Pastures in both systems were dominated by native and exotic perennial grasses. The rotation pastures were more variable with extensive areas of annual grasses and native legumes.

Ground cover levels were low in both years (mean = 40%) with the cells having slightly lower values than the rotation. Litter levels were also slightly lower in the cells.

There were only small differences between grazing systems for any LFA index in either year (maximum difference = 3.7). The values for all indices were higher in 2007 than in 2006 for both systems.

The VegMachine analyses showed a similar pattern of change for cover levels in the two systems over the past 20 years. Vegetation Cover Index levels were low in 2005 but showed a large increase in 2006 followed by slightly lower levels in 2007 and 2008. The cells had slightly higher levels than the rotation from 2006 to 2008.

4.2. Carrying capacity and grazing

Average rest periods were the same between systems, about 150 days, and number of grazing events were also similar, 1-3 per year, however, the average grazing in the cells (27 SDH) was significantly higher than that of the rotation system (17 SDH) monitor paddocks. The grazing pressure in SDH/100mm was also higher in the cells (6.0 compared with 3.5 SDH/100mm in the rotation, which was under-stocked in one of the three years monitored). Both systems were grazed at higher pressure than the LTCC of about 10 SDH during the project, which followed a serious drought in 2004-05 (312 mm, decile 2). The rotation was used for weaners and growing cattle, while breeders (with bulls and calves) were grazed in the cells.

The cells received higher grazing pressure than the rotation paddocks in two of the three years recorded and there was a significant grazing system by year interaction. Between years, the cells had their highest grazing pressure in 2006-07 and the lowest grazing in the rotation was in 2005-06. This was more an artefact of the herd dynamics and using the rotation to supplement weaners, than from any pasture difference.

Feed budgeting was applied equally to both systems, with assessments several times per year, and was used to regulate cattle numbers and length of grazing in the paddocks and also on the whole property.

The NIRS diet quality analysis indicated similar diets in both systems, although the rotation paddocks had a higher non-grass component. Below maintenance crude protein levels are found in both systems in the dry season.

4.3. Owner's comments on grazing systems

(to June 2008; before selling the property and the grazing systems were changed by the new owner)

4.3.1. New management

Somerville was run as continuous grazing until 1992, when paddocks were fenced and grazing rotated; after that it was developed into cells, with some 160 cell paddocks on 13 cell centers, and other larger rotation paddocks which remained.

Our three main resources are land, people and livestock. The intensive development and management allowed us to manage all these resources more proactively and have more productivity from each one.

We worked to a stage one completion of half the country under full cells and half as a rotation system. The next stage was more intensity, increasing waters, in the country under rotation.

Intensive management requires more and a higher levels of skill; this can be a risk in the system, but it also brings forward a higher level of candidate which can be a positive.

4.3.2. Results

We ended up with all three resources being of a higher state: The land was more productive and ecologically in a much better state, hence less risk. The cattle were handling much better and were in a much more productive state mentally (less risk from stresses); they were also on a planned and much more even plane of nutrition for the year (less risk). The people were excited about what they were doing and achieving and learning, resulting in better staff retention.

4.3.3. Future plans

Develop rotational country with more water and pasture improvements (sow grass seed).

4.4. General conclusions

Pastures and land condition at Somerville have responded similarly to the two grazing systems, although the cells have supported higher grazing pressure than the rotation paddocks during the monitor period. Both systems received long rest periods of about five months average between grazing events, which allowed pasture recovery and buffel grass to establish and spread from under tree canopies. Diet quality was broadly similar from the two systems, although the lowest protein values were in the cells in the dry season. The two systems were managed as a flexible integrated whole property system and not independently. This allowed management responses to good and poor seasons and the flexibility to take in agistment cattle if spare feed was available or to reduce numbers well in advance of any potential feed deficiency, due to forward planned feed budgets. The ecological differences were not consistent or strongly associated with the grazing system.

Sunnyholt

Abstract

'Sunnyholt', Injune, has two grazing systems; cells and continuous. Five cell and one continuous paddock were monitored between 2006 and 2009. The two systems are used as part of a grower enterprise. There was a drought for the first three years and average rainfall in the final year. The pastures were sampled in late autumn in 2006, 2007 and 2009. Pasture yields were similar in both systems and varied between years, increasing from 1300 to 3700 kg/ha between 2007 and 2009, with the improved rainfall conditions. All pastures were buffel grass dominant (95%). The ecological differences were not consistent or strongly associated with the grazing system. Both systems supported similar grazing pressure at a higher level than the estimated LTCC. There were greater between year differences than between system differences in grazing pressure. All parameters of diet quality analysed by NIRS were similar in both systems.

1. Site Introduction

1.1. Location

'Sunnyholt' is located approximately 80 km north of Injune (25.3ºS; 148.9ºE) in the southern Arcadia Valley, part of Fitzroy River catchment, in the Arcadia and Comet land systems (Figure 1.1).

Figure 1.1. **Buffel grass pasture landscape at Sunnyholt.**

1.2. Climate/growing season

The average annual rainfall is 710 mm (Table 3.1) with 70% falling in summer (October-March). The growing season is predominantly in summer, but with significant winter rain in some years there can be important winter pasture growth with subsequent beneficial impacts on pasture quantity and quality.

Based on long-term climate data, the average green season for tropical species is estimated to be 29 weeks including 14.1 growth weeks. With the winter rain, temperate species would add an average of 6.5 weeks to the growth of tropical species.

1.3. Major soil/vegetation types

The original vegetation was brigalow scrub or forest. The major tree species are brigalow (*Acacia harpophylla*), with wilga (*Geijera parviflora*), bauhinia (*Bauhinia* spp.) and emergent poplar box (*Eucalyptus populnea*) and silver-leafed ironbark (*E. melanophloia*). All experimental areas have been cleared or thinned to sparse tree cover, with some brigalow and limebush (*Citrus glauca*) regrowth. The major grass is buffel cultivars (*Cenchrus ciliaris*) with native bluegrass species (*Bothriochloa* spp. and *Dichanthium sericeum*) (Table 1.1).

The landscape is flat to gently undulating with brown clays/clay loams, brown duplex and alluvial soils.

Table 1.1. Areas (ha) of land types in the monitor paddocks of grazing systems at Sunnyholt.

Land type	**Area (ha)**	
	Cells	**Continuous**
Brigalow with softwood scrub species	125	
Brigalow with melon holes	33	
Poplar box/brigalow/bauhinia	262	110
Total	**420**	**110**

1.4. GRASP modelling of long-term pasture growth

The two major land types "Brigalow-softwood scrub species" and "Poplar box/ brigalow/bauhinia" were 94% of the sampled area.

1.4.1. GRASP parameters

The tree basal area, soil water capacity, nitrogen and transpiration use efficiency parameters used to calculate potential pasture growth in the two main land types is shown in Table 1.2.

Table 1.2. Land type parameters for Sunnyholt used in GRASP model to estimate pasture growth.

GRASP parameter	**Units**	
	Brigalow	**Poplar box**
Tree basal area (m^2/ha)	1	1
Available soil water (mm)	120	84
Maximum N uptake (kg/ha)	25	20
Regrowth (kg/ha/%BA)	6	6
Transpiration use efficiency (kg/ha/mm)	20	15
Minimum N concentration (%)	0.6	0.4

1.4.2. GRASP results

The GRASP model was run using climate data from SILO for the period 1889 to June 2007 and pasture growth for the period July 1 to June 30 was estimated. The median values were 3920 kg/ha for “Brigalow-softwood scrub species” and 3430 kg/ha for “Poplar box/brigalow/bauhinia” (Figure 1.2).

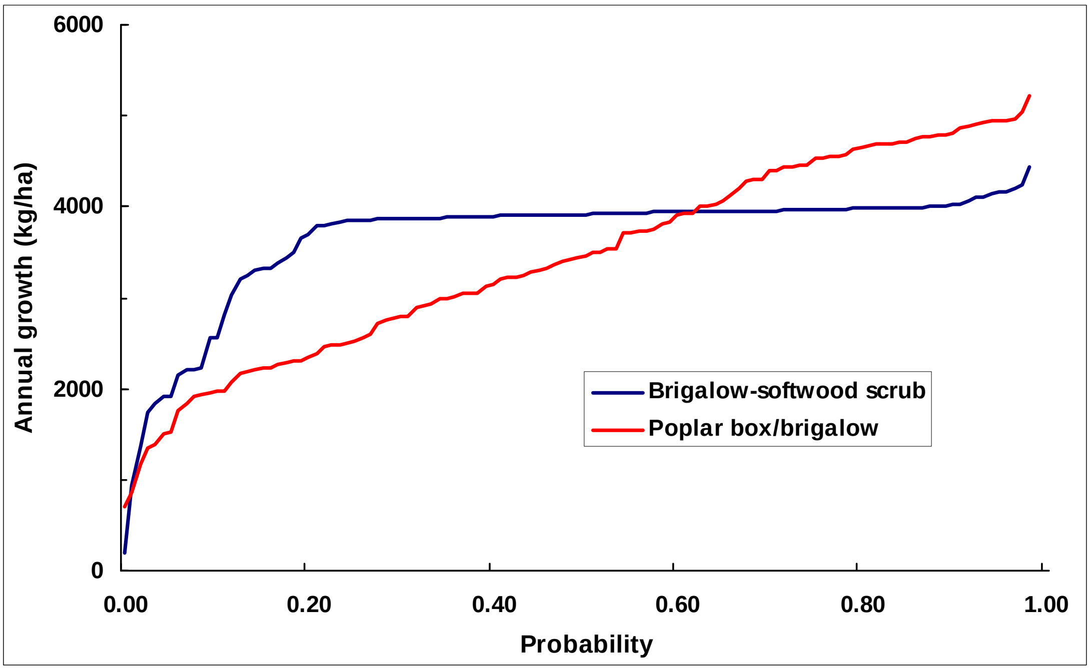


Figure 1.2. Long-term distribution of estimates of annual pasture growth at Sunnyholt.

1.5. Production system/markets

The property was selected as a development block in the 1960’s and run under conventional stocking management practices involving breeding and fattening heavy steers through to the late 1980’s. The production system is presently based on finishing heavy steers for export to north Asian market, with some stock sold to feedlots. The breeding herd is located on another property and only steers and heifers for finishing are run on this property. There is some opportunistic buying of store stock and selling as finished animals or for feedlots in favourable pasture growing seasons.

1.6. Producer goals

Following the original land development and the reasonably wet years in the 1970’s there was an associated increase in cattle numbers carried, however, the buffel pastures were judged to be deteriorating in the dry years of the 1980’s with expanding areas of bare patches. This was offset by increasing run-on of water from higher areas and as a result the total number of stock carried remained roughly the same. From the mid-1980’s, attempts to permanently rejuvenate bare areas by cultivating, ripping and resowing pastures were largely unsuccessful. Alternative approaches of planting leucaena rows and rotational grazing were developed and these have progressed into a full property cell grazing system with grass pasture paddocks, dominated by buffel grass, and paddocks of leucaena and buffel. The scalded or bare affected areas were ripped again and resown and are now included in the cell system. The cells were established with an aim to rebuild ground cover and recover the bare areas with pasture.

Increasing stock numbers was not formally cited as a principal objective of establishing the cell grazing system. However, the owners believe that the pastures already have recovered to a point where production per unit of rainfall is higher than when the system was installed. Under favourable conditions the expected annual turnoff is approximately 800 AE and the target when the system is fully operating is approximately 1000 AE.

2. Grazing Systems

2.1. Description

Two grazing systems, cell and continuous, were studied. The cell system with 42 paddocks (average size approximately 85 ha) carried around 1500 head of growing cattle which were moved at 1-6 day intervals. Five paddocks were monitored. The continuous system, with a single paddock, was grazed continuously by 30-40 head at a similar grazing pressure to that being applied to the cell system (Table 2.1). This paddock was originally part of the cell system. The layout of the paddocks is shown in Table 2.1.

The cells are divided into two groups of paddocks, north and south, with the south group having leucaena and buffel grass strips. These legume paddocks are used for fattening steers, while the buffel grass dominant paddocks of the north group of cell paddocks are used for growing cattle. Five paddocks in the grass-only north cell group were monitored. In recent years, some of the grass cell paddocks have been ploughed to regenerate and spread the buffel pasture and on occasions a winter oats crop has been included the renovation phase. The continuous paddock has not been cultivated in recent years and has both bare scalded patches and brigalow regrowth areas.

Table 2.1. **Paddock names, numbers and areas sampled at Sunnyholt.**

Vegetation	Grazing System	Paddock name [Botanal No.]	Area (ha)
Brigalow	Cell	Homestead 2 [2]	92
		Mill 3 [3]	94
		Mill 4 [4]	89
		Pines 1 [1]	77
		Walangra 8 [8]	68
		Total cell	420
Brigalow	Continuous	Homestead 1 [9]	110

The layout of the five cell monitored paddocks (Botanal numbers 1, 2, 3, 4, 8) and the one continuous paddock (number 9) is shown in Figure 2.1.

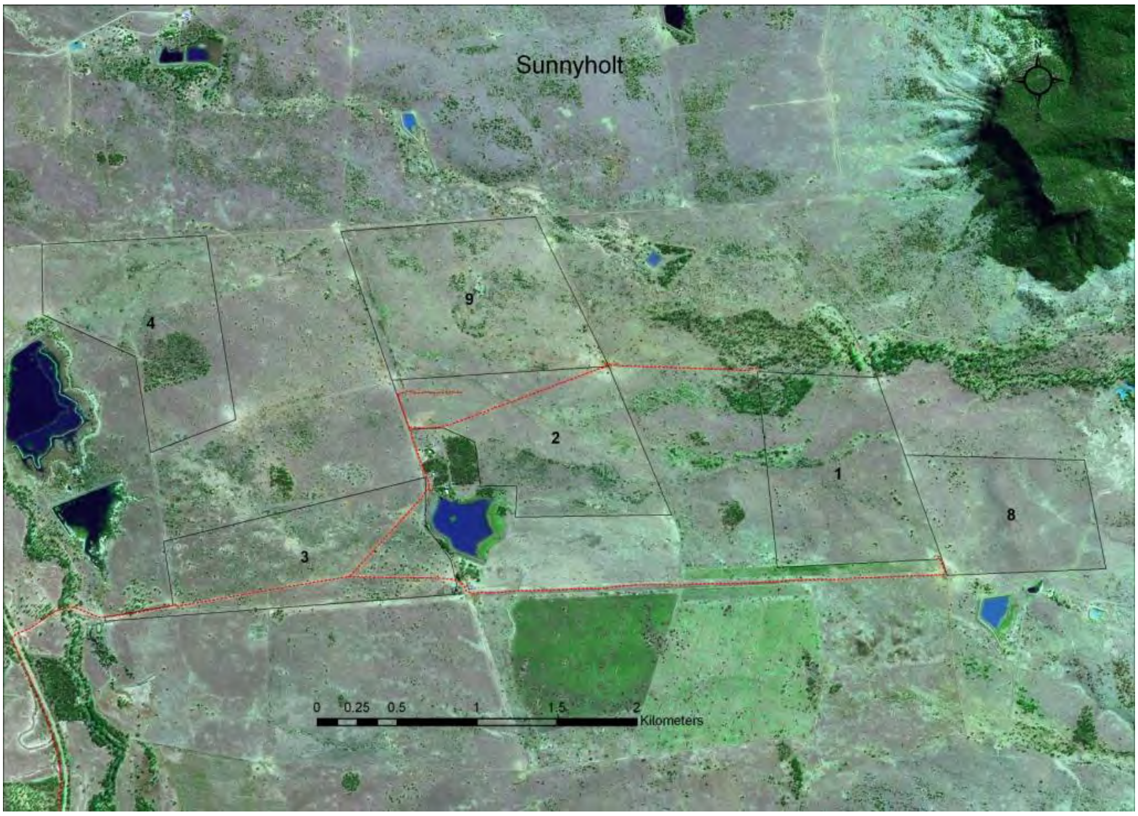


Figure 2.1. Layout of the six monitor paddocks at Sunnyholt on a Spot 5 satellite image.

2.2. Management during 2005-2009

The continuous system carried growing steers for the first two years until bulls and heifers were introduced in the 2007-08 year. In the following year a mixed-age bull herd grazed the paddock. The holistically managed cell paddocks were grazed by growing steers throughout the project. Individual paddock grazing periods were commonly 2-5 days.

3. Results

3.1. Growing Seasons

3.1.1. Rainfall

There was a serious drought for the first two years of monitoring, with two consecutive years in the lowest 20% of years (Table 3.1). The last two years received near average rainfall with a good distribution over summer suitable for producing good pasture growth. On average the last five years have received a deficit of 120 mm/year compared with the long-term average.

Table 3.1**.** Monthly rainfall (mm) at Sunnyholt from July 2004 to June 2009 and long-term average monthly rainfall (mm) at Warrinilla recording station over 121 years.

Year	**Monthly rainfall (mm)**													
	J	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**Total**	**Decile**
2004-05	0	25	45	23	99	78	57	65	42	28	44	113	619	5
2005-06	0	7	4	111	45	65	25	24	19	105	28	12	445	2
2006-07	24	2	2	0	78	56	27	71	38	8	4	123	432	2
2007-08	0	30	30	56	147	102	184	71	0	0	11	28	659	4
2008-09	95	0	90	102	150	111	63	72	13	57	30	22	803	6
Long-term Mean	**32**	**23**	**29**	**50**	**71**	**98**	**103**	**110**	**68**	**45**	**39**	**39**	**710**	

3.1.2. Growing conditions

2003-2004: Sunnyholt recorded mixed seasonal and pasture growing conditions during 2003-04 with well above average summer rainfall, but below average spring and well below average autumn rainfall. The good summer rainfall promoted pasture growth, however, well below average autumn rainfall would have caused rapid pasture maturity prior to winter.

2004-2005: Sunnyholt received average rainfall for the 2004-05 year with below average summer rainfall followed by above average autumn rainfall. Pasture growth was below average during the summer grass growing season, but the good autumn rainfall would have maintained pasture quality going into winter.

2005-2006: Sunnyholt suffered a drought, receiving well below average rainfall for the 2005-06 year (445 mm) with extremely low rainfall during the summer pasture growing season.

2006-2007: The drought continued and rainfall was below average at Sunnyholt for 2006-07 (432 mm) with well below average rainfall during the summer growing season.

2007-2008: This season (659 mm) was only marginally below the average of 710 mm, and started with useful rainfall in winter followed by good summer pasture growing rainfall events. There was a dry autumn which caused rapid maturity of the well grown pastures.

2008-2009: This was marginally above (803 mm) average and a good pasture growing year, starting with well above average winter and spring rainfall, and also follow-up rain in the three summer months, however, it was below average rain every summer month.

3.1.3. GRASP modelling pasture growth 2005-2009

Assuming the “Brigalow with melon holes” has similar buffel pasture growth to the “Brigalow-softwood scrub” land type, the estimated pasture growth in the two grazing systems is shown in Table 3.2.

Table 3.2. Estimated annual pasture growth (kg/ha) for grazing systems at Sunnyholt from 2005-06 to 2008-09.

Year	Pasture growth (kg/ha)	
	Cells	Continuous
2005-06	2800	2400
2006-07	1600	1400
2007-08	4100	4100
2008-09	3900	3900
Average	**3100**	**3000**

A pasture growth index analysis of rainfall at Sunnyholt shows the short and erratic growth periods early in the project monitoring phase and longer growing seasons in the last two years (Figure 3.1). The dormant winter periods are identified.

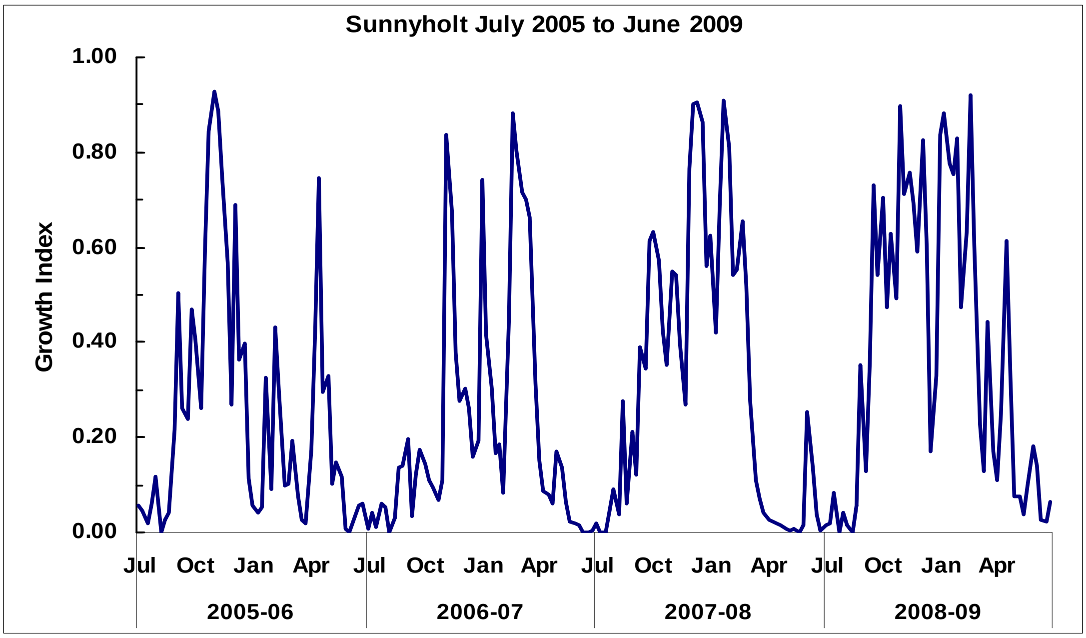


Figure 3.1. Weekly growth index (tropical species) values at Sunnyholt during the experimental period (2005-09) for the “Poplar box/brigalow/bauhinia” land type.

3.2. Pastures and Land Condition

3.2.1. Pasture yield, botanical composition and diversity

3.2.1.1. *Pasture means*

The pastures were strongly buffel grass dominant in all years with only small and inconsistent differences in yields between the cell paddocks and the continuous paddock. The continuous paddock had only been managed by this system since late 2005 (Table 3.3).

Table 3.3. Pasture dry matter yield and botanical composition at the end of summer at Sunnyholt.

Year	System	Yield (kg/ha)	Botanical composition (%) Nat per grass	Exotic grass	Native leg	Exotic leg	Ann grass	Forb	Sedge
2006	Cell	3270	0.7	97.7	0.0	0.4	0.0	1.1	0.0
	Continuous	3280	2.9	96.5	0.0	0.0	0.0	0.6	0.0
2007	Cell	1180	0.6	97.2	0.0	0.0	0.1	2.1	0.0
	Continuous	1450	2.3	97.5	0.0	0.0	0.0	0.2	0.0
2009	Cell	3950	2.7	95.6	0.1	0.0	0.0	1.6	0.0
	Continuous	3410	3.1	94.4	0.0	0.0	0.0	2.5	0.0

3.2.1.2. *Yield spatial variability*

This analysis measured the degree of uniformity, or inversely variability, in the various parameters across each paddock. Pasture yield across most paddocks was uniform in both systems in 2006 (Table 3.4). The continuous paddock was uniform at the end of the monitoring period, while there were fewer uniform cell paddocks. Only two cells of the six monitor paddocks had uniform yield in 2007.

Table 3.4. Spatial variability in pasture yield – number of paddocks where pasture yield was spatially uniform (i.e. there was no evidence of aggregation) across the paddock.

Grazing System	Total no. of paddocks	No. paddocks uniform pasture yield 2006	2007	2009
Cells	5	4	2	2
Continuous	1	1	0	1

3.2.1.3. *Species diversity*

Plant species diversity was low in all pastures reflecting the strong dominance by buffel grass (96-98%) across all paddocks (Table 3.5).

Table 3.5. Measures of pasture diversity at Sunnyholt in 2006, 2007 and 2009.

Diversity measure Year	**Diversity units** **Cells**	 **Continuous**
No. species/quadrat		
2006	1.3	1.2
2007	1.1	1.0
2009	1.3	1.1
No. species to contribute 90% of yield		
2006	1	1
2007	1	1
2009	1	1
% contribution of dominant species		
2006	97	96
2007	97	98
2009	97	97

3.2.2. Pasture utilisation

Pasture utilisation in the monitor paddocks at the end of summer was rated across the paddocks on the Botanal grid at each recording point (rating 1 = 71-100%; 2 = 31-70%; 3 = 6-30%; 4 = 0-5% utilisation).

3.2.2.1. *Utilisation means*

There was little difference between mean utilisation values for the two grazing systems in autumn in any year (Table 3.6).

Table 3.6. Mean rating (1 = high to 4 = low) for estimated pasture utilisation in grazing systems at Sunnyholt in autumn for 2006, 2007 and 2009.

Year	**Utilisation rating** **Cells**	 **Continuous**
2006	3.9	3.7
2007	2.5	2.5
2009	3.5	3.3
Average	**3.3**	**3.2**

In autumn of 2006 there had been a low proportion of grazing in both systems although there was a marginally higher level of grazing in class 3 (30-70%) in the continuous system (Figure 3.2). Both systems had similar average utilisation each year, although both were more heavily grazed in 2007, which had a short summer growing season and no rain in autumn. There were similar utilisation levels in the two systems in 2009 following an above average rainfall pasture growing period.

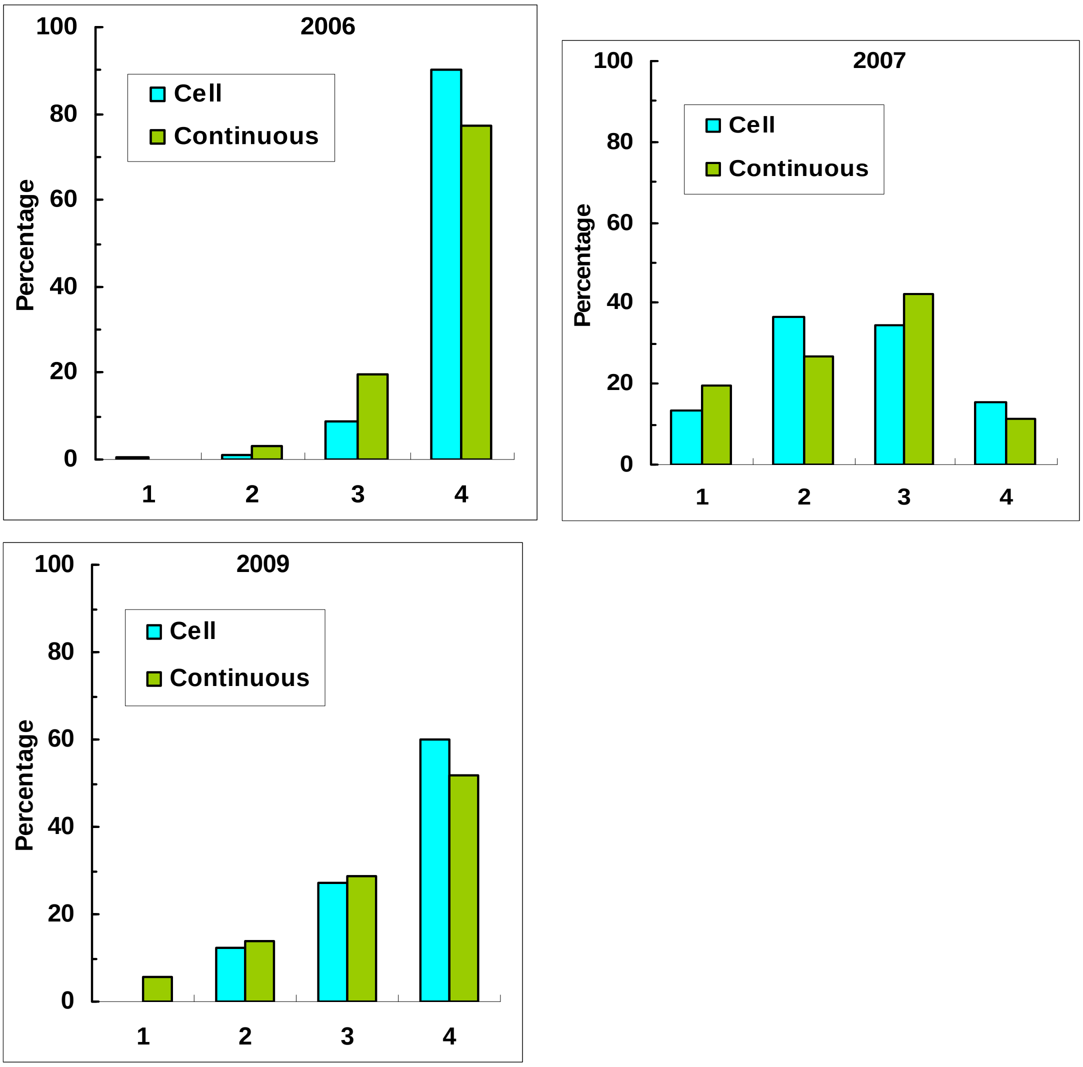


Figure 3.2. Distribution of estimated pasture utilisation values (4 classes) in grazing systems at Sunnyholt in 2006, 2007 and 2009.

3.2.2.2. *Utilisation spatial variability*

Pasture utilisation across the cell paddocks was more uniform every year than in the continuous paddock, which was not uniform in autumn at any of the three recording times (Table 3.7).

Table 3.7. Spatial variability in pasture utilisation – number of paddocks where pasture utilisation was spatially uniform (i.e. there was no evidence of aggregation) across the paddock.

Grazing System	**Total no. of paddocks**	**No. paddocks uniform pasture utilisation**		
		2006	**2007**	**2009**
Cells	5	5	2	3
Continuous	1	0	0	0

3.2.3. Woody regrowth

There was more woody regrowth (brigalow predominantly) present in the continuous paddock than in the cell paddocks every year. This higher density of regrowth in the continuous paddock occurred prior to commencing the project and remained over the four-year monitoring period (Table 3.8).

Table 3.8. Cover levels (%) of woody regrowth in grazing systems at Sunnyholt.

Year	Woody regrowth cover (%)	
	Cells	Continuous
2006	1.3	2.9
2007	1.9	3.2
2009	1.7	3.4

3.2.4. Ground and litter cover

3.2.4.1. *Cover means and standard deviations*

Mean total cover levels were slightly higher in the cells than in the continuous paddock in 2007 and 2009. There was considerable cover variability across the paddocks, but the standard deviations were similar for the two grazing systems (Table 3.9).

Table 3.9. Total and litter cover levels (%) in systems at Sunnyholt at the end of summer.

Year	Grazing System	Total cover (%)		Litter cover (%)	
		Mean	St. Dev.	Mean	St. Dev.
2006	Cell	61	31.0	14	16.0
	Continuous	61	31.8	17	19.9
2007	Cell	50	26.7	19	20.1
	Continuous	46	27.8	25	20.3
2009	Cell	64	27.7	24	21.0
	Continuous	59	31.5	17	20.7

3.2.4.2. *Cover spatial variability*

The cell paddocks had more uniform total cover than the continuous paddock which was not uniform at any recording (Table 3.10). Litter cover was more uniform across paddocks in both systems.

Table 3.10. Spatial variability in cover levels – number of paddocks where total ground cover or litter cover was spatially uniform (i.e. there was no evidence of aggregation) across the paddock.

Cover Grazing System	Total no. of paddocks	No. paddocks with uniform cover 2006	2007	2009
Total ground cover				
Cells	5	3	2	4
Continuous	1	0	0	0
Litter cover				
Cells	5	4	3	3
Continuous	1	1	0	1

3.2.5. LFA indices (soil surface condition)

There are three LFA indices (Stability, Infiltration and Nutrient cycling) which have values between 0 and 100 where larger values indicate better performance for that index.

3.2.5.1. *LFA indices means and standard deviations*

There were only small differences between the grazing systems for the three LFA indices (Table 0.8), however they were all marginally higher in 2009 than in 2006. Stability had increased 6%, infiltration by 1% and nutrient cycling by 12%, reflecting the better rainfall seasons at the end of the monitor period compared with the initial drought year.

Table 3.11. LFA indices (mean and SD) at Sunnyholt at the end of summer 2006, 2007 and 2009.

Year	System	LFA Indices (0-100)					
		Stability		Infiltration		Nutrient cycling	
		Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
2006	Cell	57.6	7.93	36.4	6.88	27.4	7.74
	Continuous	60.3	6.02	36.3	5.28	29.2	8.24
2007	Cell	57.1	8.63	41.0	8.66	33.4	9.74
	Continuous	58.7	6.73	37.5	7.52	30.6	8.98
2009	Cell	62.5	6.98	37.7	6.79	32.7	8.92
	Continuous	62.6	6.89	36.0	6.30	30.6	8.31

3.2.5.2. *LFA indices spatial variability*

There was variation between paddocks in the uniformity of the three LFA indices across individual paddocks. There was a small decline in uniformity of the stability and infiltration indices between 2006 and 2009 in the cell paddocks, while the nutrient cycling index remained more uniform. The continuous paddock was not uniform for stability index in 2009 (Table 3.12).

Table 3.12. Spatial variability in LFA Index values – number of paddocks where the LFA Index values were spatially uniform (i.e. there was no evidence of aggregation) across the paddock.

LFA index	**Total no. of paddocks**	**No. paddocks uniform LFA index**		
Grazing System		**2006**	**2007**	**2009**
LFA Stability index				
Cells	5	3	3	1
Continuous	1	1	1	0
LFA Infiltration index				
Cells	5	3	2	2
Continuous	1	0	0	1
LFA Nutrient cycling index				
Cells	5	2	4	3
Continuous	1	1	0	1

3.2.6. Land condition

Most of the land in all paddocks was rated as A condition. However, the brigalow regrowth patches in the continuous paddock were in B condition with lesser areas of scalded patches in C condition, causing reduced pasture growth. There were similar, although generally smaller areas in B or C condition in the cell paddocks Homestead 2, Pines 1 and Mill 4. Woody regrowth in some cell paddocks has been reduced or eliminated by all-farm ploughing in recent years. The PatchKey analysis (across all Botanal quadrats) produced lower land condition values than the broader landtype and paddock scale visual estimates (Table 3.13).

Table 3.13. Land condition for the Botanal/ PatchKey and ABCD (Land type) values, “1” is equivalent to A condition and “4” is equivalent to D condition.

Land condition method Year / Land type	Land condition units Cells	 Continuous
Botanal/PatchKey		
2006	1.6	1.6
2007	2.3	2.2
2009	1.4	1.6
ABCD (by Land type)		
Brigalow with softwood scrub species	1.0	
Brigalow with melon holes	1.0	
Poplar box/brigalow/bauhinia	1.0	1.0
Overall average	1.0	1.0
ABCD (Paddock)		
2006	A	A/B
2007	A/B	A/B
2009	A	A/B

Time series photographs of fixed points in the two systems shows the seasonal variation in pasture growth and cover (Figure 3.3). The patch grazing and higher density of regrowth in the continuous system is visible.

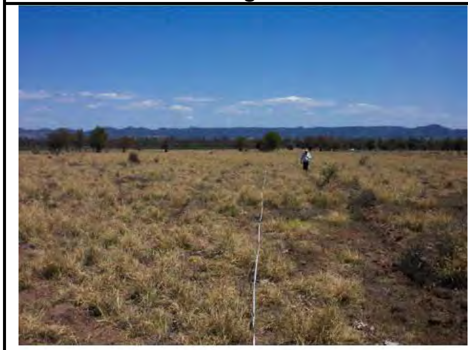
Sunnyholt Cell M3-6 Lat: 25^0.310; Long: 148^0.859, Dir: 260^0	**Sunnyholt Continuous H1-7** Lat: 25^0.292; Long: 148^0.864, Dir: 60^0
 Cell (October 2005)	 Continuous (October 2005)
 Cell (November 2006)	 Continuous (November 2006)
 Cell (October 2008)	 Continuous (October 2008)
 Cell (June 2009)	 Continuous (June 2009)

Figure 3.3. Changes in land condition at fixed points in the cell and continuous grazing systems at Sunnyholt.

3.2.7. Cover analysis

3.2.7.1. *VegMachine vegetation cover time series (Landsat)*

Average VegMachine cover for the grazing systems at Sunnyholt showed a significant loss during the 1991-1994 drought with the continuous grazing system paddock suffering the greatest decline, from index 80 to index 30 after some areas were cultivated (Figure 3.4). During the lesser drought of the 2000's, cover has been maintained around 70% in both the continuous and holistically managed cell systems. VegMachine analysis shows that all paddocks have been managed similarly in the recent years prior to starting this project monitoring, and that cover was the same in both systems in 2006, with a small decline in 2007. This result was measured in the field. The unusually high cover relative to annual rainfall in 2006 is explained by the long growing season (2005-06) starting with 111 mm of rain in October 2005 and the reduced cattle numbers with the holistic pasture management system operating at this time providing long rest periods.

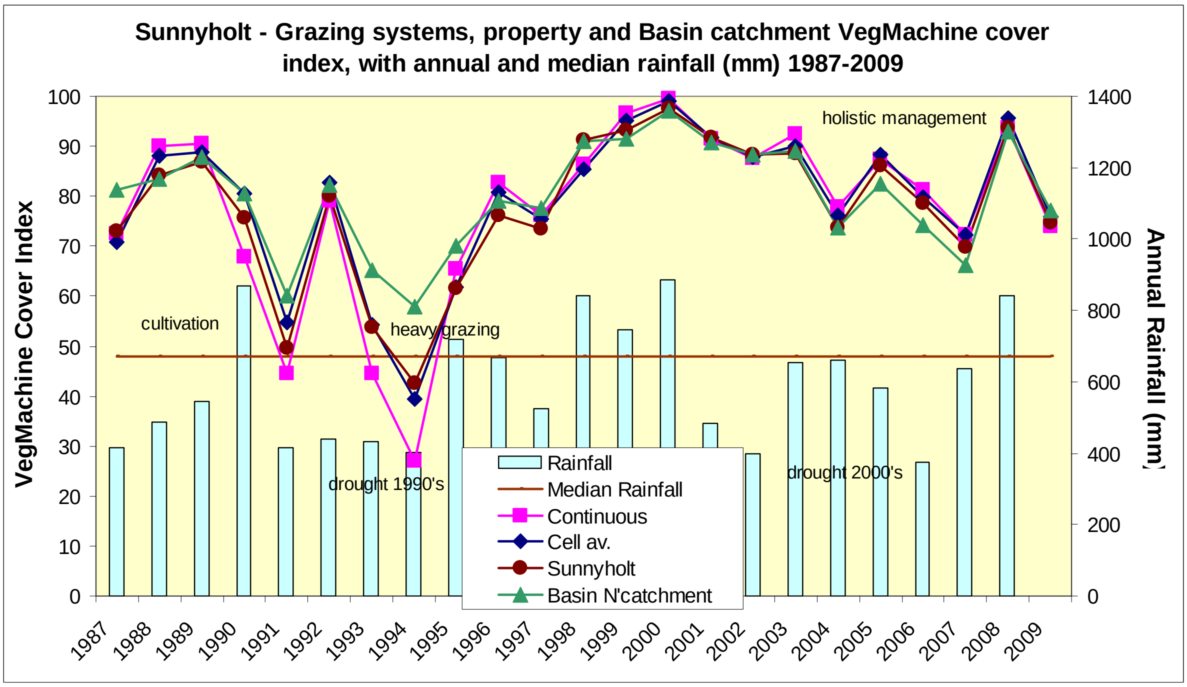


Figure 3.4. Vegetation cover index between 1987 and 2009 for grazing systems and the whole property at Sunnyholt. Annual and long-term median rainfall (mm) are also shown.

The VegMachine paddock analysis shows there was a range of 20 between the monitor paddocks in the cover index in the 1990's drought, and while under the holistic management system in the 2000's drought there have been similar cover levels in most paddocks (Figure 3.5). There was similar cover across the monitor paddocks throughout the four-year monitoring period, except for a reduction in cell Mill 3 which was partly renovated to reduce brigalow suckers. Cover had fully recovered by 2008. The property owner considers that the cover decline in 1997 was due to a combination of high stock numbers and the below average rainfall.

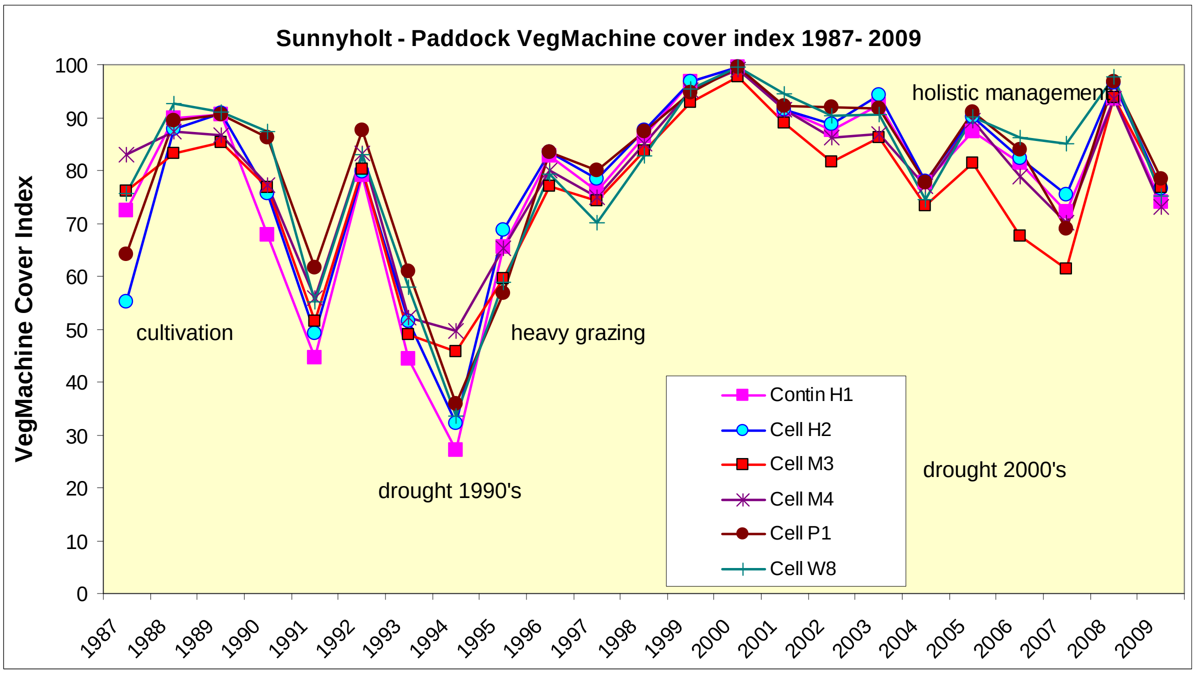


Figure 3.5. Vegetation cover index between 1987 and 2009 in the monitor paddocks at Sunnyholt. Annual and long-term median rainfall (mm) are also shown.

Throughout the 1990's drought the average cover of the Basin catchment, the neighbourhood catchment around Sunnyholt, has had a marginally higher cover than the monitor paddocks, and marginally lower cover in the 2005-2007 drought years (Figure 3.6).

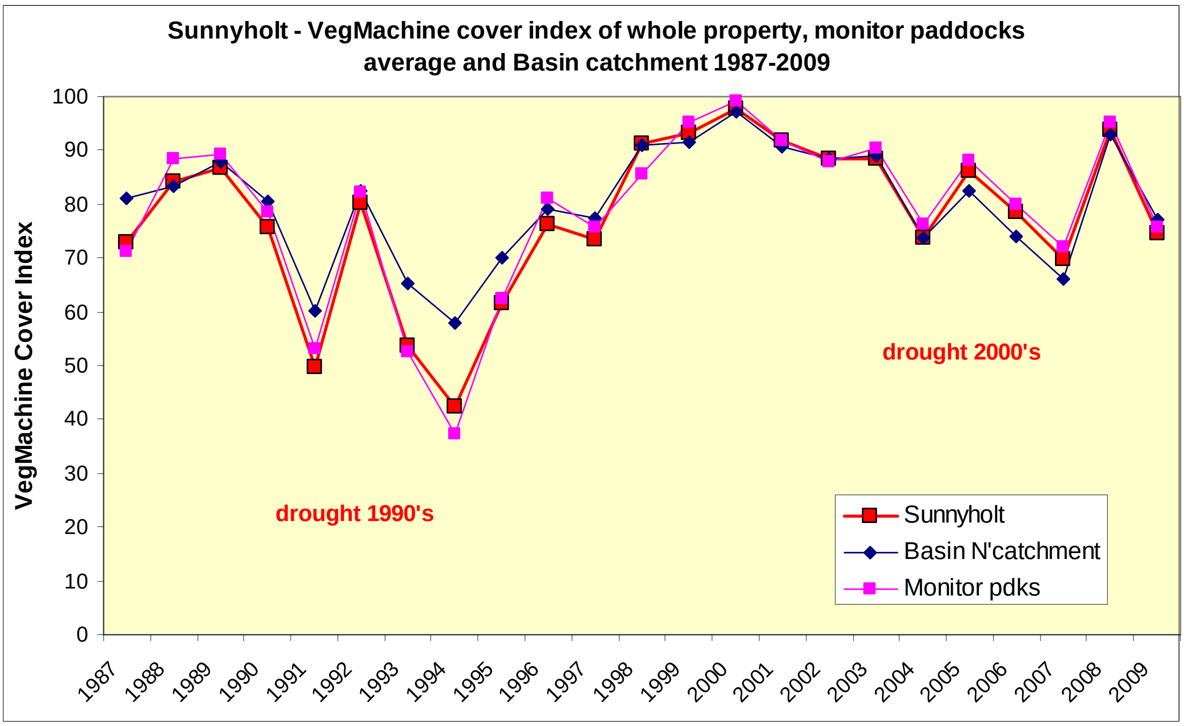


Figure 3.6. Vegetation cover index for average of monitor paddocks, the whole property and the neighbourhood catchment (Basin) between 1987 and 2009 at Sunnyholt.

Cover on the two main land types in the GSP monitor paddocks was also analysed by VegMachine. There were similar cover trends in response to seasonal conditions, although not the same range across two main land types, poplar box flats and softwood scrubs. In the cell paddocks, the cover index ranged from 23 to 45 in the poplar box land type and from 34 to 60 in the softwood scrub areas during the 1994 drought year. In the continuous paddock these land types had a cover index of 27 and 32 respectively. Since 1998 the poplar box landtype in particular has had a higher cover index than the surrounding neighbourhood Basin catchment (Figure 3.7). Differences are less and more variable in the softwood scrub landtype areas.

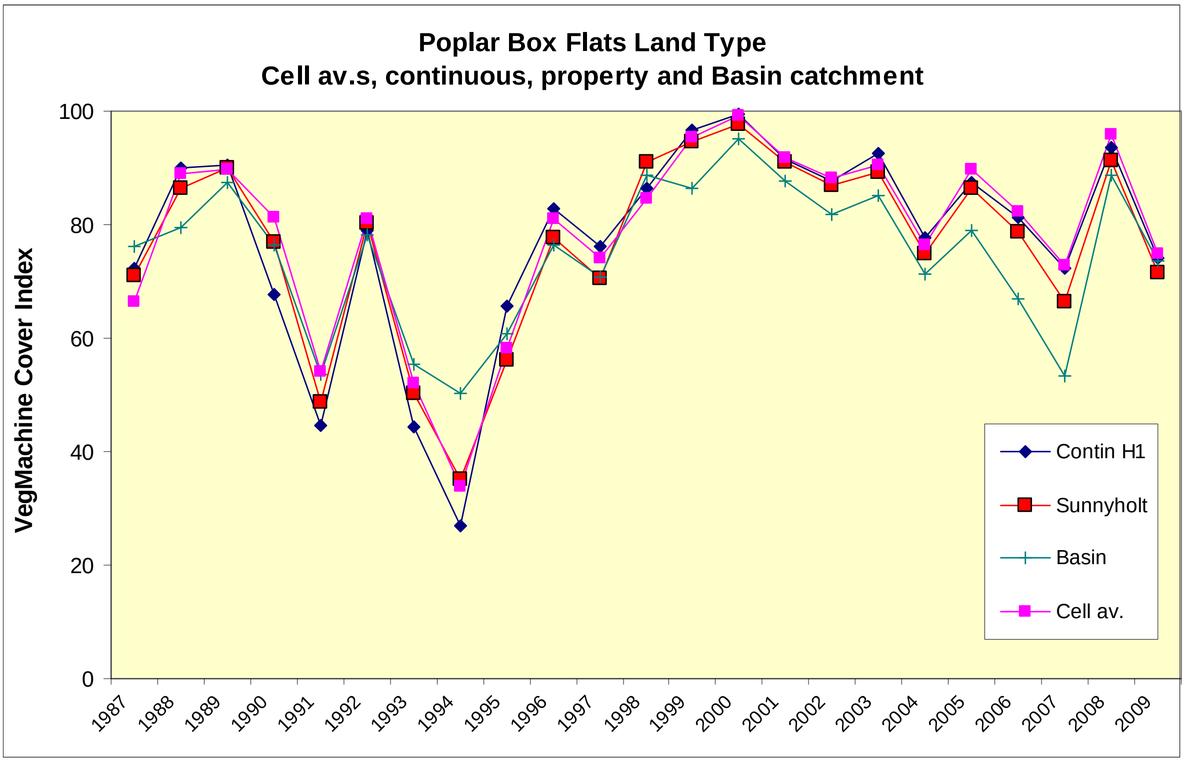


Figure 3.7. Vegetation cover index in poplar box land-type in the monitor paddocks, the whole property and the neighbourhood catchment (Basin) between 1987 and 2009 at Sunnyholt.

Pasture cover in all paddocks and on both land types remained at higher levels during the drought years of the 2000's than in the droughts of the mid-1990's.

3.2.7.2. *Botanal pasture data*

The field measured pasture dry matter yield and cover in 2006 and 2007 (Table 3.14) was marginally lower in total cover than that indicated by the BGI VegMachine satellite imagery analysis would suggest.

Table 3.14. Pasture yield (kg/ha), total pasture cover (%), litter cover (%) and woody cover (%) in 2006, 2007 and 2009 in the monitor paddocks and grazing systems at Sunnyholt.

Paddock/	**Yield (kg/ha)**			**Total Cover (%)**			**Litter Cover (%)**			**Woody Cover (%)**		
System	2006	2007	2009	2006	2007	2009	2006	2007	2009	2006	2007	2009
Pines 1	3320	1200	4760	66	50	59	24	26	19	1.3	2.0	2.1
H'stead 2	2900	1030	3350	54	52	65	12	28	19	1.4	2.4	1.9
Mill 3	2840	1290	4110	54	36	78	9	11	26	0.7	1.7	1.2
Mill 4	4010	1430	4090	64	52	57	13	26	23	2.1	2.1	2.4
Walangra 8	3390	960	3460	68	61	64	11	32	34	0.8	1.1	0.9
H'stead 1	3180	1450	3410	60	46	59	17	19	17	3	3.1	3.4
Continuous	3180	1450	3410	60	46	59	17	19	17	3	3.1	3.4
Cell	3290	1180	3950	61	50	64	14	25	24	1.2	1.9	1.7
Site	3270	1230	3860									

3.2.7.3. *Spatial cover reports*

The average ground cover during 2003-07 for the whole of Sunnyholt showed the dense woodland mountainous area to the east and the cleared brigalow pastures where the monitor paddocks are located to the west (
Figure 3.8). In the years previous to the GSP there was a similar range of cover levels in all the monitor paddocks. Most areas are in the high cover category in all paddocks (shown in blue), however there are also small scattered areas with low to medium cover scattered across each paddock (in orange and red).

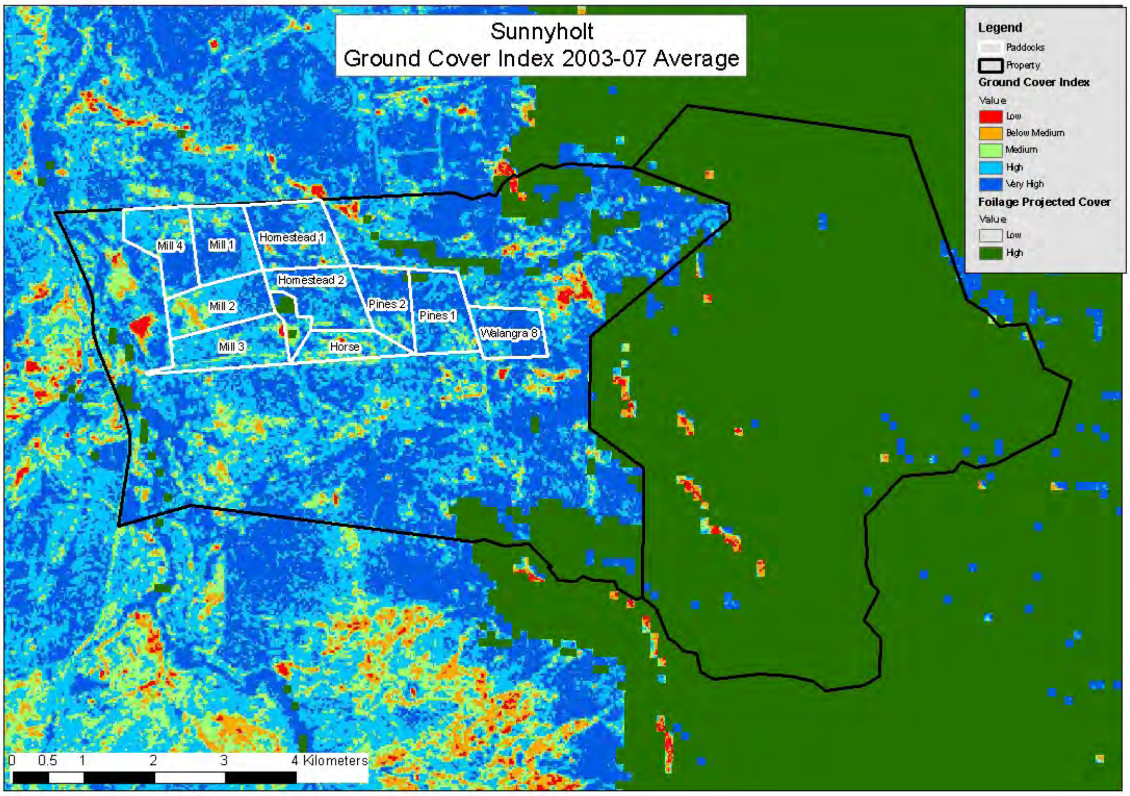


Figure 3.8. Average (2003-2007) ground cover index (vegetation cover) image for the cell and continuous paddocks and whole property at Sunnyholt and surrounding properties (DERM data).

3.3. Cattle Grazing

3.3.1. Carrying capacity – Long-term (LTCC)

The estimated long-term carrying capacities (in AE/100 ha and SDH) across all land types of the two grazing systems are similar:

Cells	26 AE/100 ha (95 SDH)
Continuous	24 AE/100 ha (86 SDH)

3.3.2. Rest periods

During the monitor period, the average rest periods between grazing events in the cell paddocks ranged from 53 to 77 days, while total rest periods in the continuous system ranged from 1 to 52 days per year (averaging 19 days) over the four years of monitoring (Table 3.15).

Table 3.15. Rest periods (days) between grazing events for cell grazing system and total annual rest in the continuous system at Sunnyholt.

Year	**Rest periods (days)**	
	Cells (average days between events)	**Continuous (annual total days)**
2005-2006	77	52
2006-2007	71	1
2007-2008	73	17
2008-2009	50	6
Average	**68**	**19**

3.3.3. Grazing days

The cell paddocks received an average of 17 days grazing per year (range 3-44 days) over the four years. There were between year differences with 2005-06 having the lowest grazing (9 days average per paddock) and 2006-07 the highest (25 days). The number of annual grazing events averaged 4, with a range of 1-7 events per cell paddock. Between years, there were on average two grazing events in 2005-06 and the higher rainfall year of 2008-09 averaged six events.

In the last three full years of recording the continuous paddock averaged 357 days grazing per year.

3.3.4. Grazing pressure

The animal numbers taken from property records for each system have been converted to Animal Equivalents (AE), or to Livestock (Large Stock) Units (LSU), using the standards tables presented in the Appendix 9.10. An AE is equivalent to a dry cow weighing approximately 450 kg.

There was higher average grazing pressure in the cells than in the continuous paddock during the monitor period, but this occurred because of the higher pressure on the cells in only one year, 2006-07 (Table 3.16). The continuous paddock had higher grazing pressure in the previous year. There were no differences in other two years.

Table 3.16. Grazing pressure in grazing systems at Sunnyholt (SDH/100 mm rainfall and SDH).

Year	**Grazing pressure (SDH/100mm and SDH*)**	
	Cells	**Continuous**
2005-06	11.6 (58)*	17.5 (87)
2006-07	55.4 (228)	22.0 (84)
2007-08	31.3 (202)	33.2 (222)
2000-09	28.7 (222)	27.1 (219)
Average	**32 (178)**	**25 (153)**

The average annual grazing pressure in the systems was greater than the estimated the long-term carrying capacity (LTCC) of the main landtypes. There were 178 and 153 SDH per year for the cell and continuous systems respectively, compared with a LTCC estimate of 95 and 86 SDH respectively.

There was no significant difference in grazing pressure between the two systems in SDH, SDH/100mm rainfall over the previous 12 months from each grazing event, or in the average stocking rate (2.7 ha/AE) (Table 3.17). There were significant differences between years, with the lowest grazing pressure in 2005-06.

Table 3.17**.** Grazing system and year effect on stock days per ha (SDH), SDH per 100 mm rain and annual stocking rate (ha/AE) at Sunnyholt.*

System / Year	**Grazing pressure**								
	Stock days per ha (SDH)			**SDH / 100 mm rain**			**Annual stocking rate (ha/AE)**		
Grazing System (GS)	ns			ns			ns		
Cell	4.99	(146)		3.30	(26)		1.30	(2.7)	
Continuous	4.93	(138)		3.23	(24)		1.32	(2.7)	
Av. s.e.d.	0.28			0.26			0.22		
Year (Yr)	***			***			***		
2005-06	4.06	(57)	b	2.52	(11)	b	2.02	(6.5)	a
2006-07	5.20	(181)	a	3.83	(45)	a	1.12	(2.1)	b
2007-08	5.23	(185)	a	3.40	(29)	a	1.10	(2.0)	b
2008-09	5.35	(209)	a	3.32	(27)	a	1.01	(1.8)	b
Av. s.e.d.	0.30			0.28			0.23		
GS x Yr	ns			ns			ns		

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

3.3.5. Grazing system intensity index

The grazing system intensity index values (range 1-100; calculated from capital costs, operating costs and management inputs; details are reported in Appendix 9.13) for the two systems were:

Cells	82
Continuous	26

This relatively wide difference in GSI index reflects the more intensive infrastructure and management input required by the cell system.

3.3.6. Diet quality (NIRS)

All parameters of diet quality analysed by NIRS were similar in both systems over the 78 samples collected from the grower cell herd and the continuous paddock (Table 3.18). There were 37 samples from each system collected on the same day.

Table 3.18. Mean faecal NIRS results from all samples for grazing systems at Sunnyholt to June 2009.

Grazing System	**No. samples**	**Crude protein (%)**	**Faecal N (%)**	**Digesti-bility (%)**	**Non-grass (%)**	**LWG (kg/day)**	**DMD/CP ratio**
Cell	39	8.4	1.4	57	14	0.81	7.1
Continuous	39	8.3	1.6	58	12	0.80	8.3
sed (av.)		0.92	0.08	1	2.4	0.12	0.9
Significance		ns	ns	ns	ns	ns	ns
Average	**(total 78)**	**8.9**	**1.6**	**58**	**15**	**0.88**	**7.0**

The leucaena cell system maintained a higher diet quality than the monitor paddocks. The superior diet quality from the fats herd, which had access to the leucaena cells at times, over the grower herd, which grazed predominantly buffel grass pasture is shown in Table 3.19. There was over 1.5% higher protein and around 3% higher digestibility, producing an estimated increase (0.1 kg/day) in potential liveweight gain. There was a significant response in all diet parameters during the growing season, for example crude protein averaged 9.5% compared with 8.1% in the non-growing months and digestibility was 2% higher at 59% during the pasture growing months. There were highly significant diet quality responses to the different years, with drier years 2006 and 2007, having the highest mean values for crude protein (10.5%), digestibility (61%), non-grass (21%) and predicted live-weight gain (1.1 kg/day).

Table 3.19. NIRS results from all samples from the grower herd (buffel grass cells), the fats herd (leucaena and buffel cells) and the continuous (buffel grass) grazing system.

Grazing System	No. samples	Crude protein (%)	Faecal N (%)	Digestibility (%)	Non-grass (%)	LWG (kg/day)	DMD/CP ratio
Cell Growers	39	8.4	1.43	57	13	0.81	7.1
Cell Fats Leucaena	34	9.8	1.71	60	20	0.94	6.5
Continuous	39	8.2	1.50	58	11	0.79	8.1
sed (av.)	(total 112)	0.89	0.11	1	4	0.13	0.7
Significance		ns	**	*	*	ns	ns

The NIRS values were examined by dividing them into groups which had different growing conditions on the basis of the pasture Growth Index (GI) derived from GRASP modelling (where 0.0 = conditions are unsuitable for pasture growth and 1.00 = conditions are not limiting growth). Average values of the GI for the 30 days ending on the sample date were calculated. Based on these values three classes were formed – mean GI <0.2 (Poor growth conditions), 0.2-0.5 (Average) and >0.5 (Good conditions). Diet quality was naturally lowest under poor growing conditions (GI < 0.2), but there were no consistent differences between the grazing systems (Table 3.20).

Table 3.20. Mean NIRS diet quality results in relation to three pasture growth indices classes for two grazing systems at Sunnyholt to June 2009.

Growth Index	Grazing System	No. samples	Crude protein (%)	Faecal N (%)	Digestibility (%)	Non-grass (%)	LWG (kg/day)	DMD/CP ratio
<0.2	Cell	18	7.3	1.4	55	15	0.61	7.9
	Continuous	20	7.1	1.5	55	15	0.62	8.3
0.2-0.5	Cell	10	9.9	1.5	59	16	1.09	6.2
	Continuous	9	11.3	1.8	62	15	1.24	5.8
>0.5	Cell	11	10.2	1.7	61	15	1.08	6.2
	Continuous	10	11.0	1.8	61	11	1.13	5.7
sed (av.)			0.94	0.09	2	3	0.15	0.7

Individual sample results for the NIRS parameters crude protein, digestibility and non-grass (Figure 3.9 and Figure 3.10) show the wide seasonal variation in both systems, with high quality buffel pastures in summer, declining rapidly to below maintenance crude protein in winter-spring after frosts and before summer rains, in the three systems (including Leucaena cells).

There was a period of below maintenance crude protein in winter of 2008 in both buffel grass systems and the non-grass proportion ranged from 0% to approximately 30% in both systems. This unusually low crude protein in the diet in late winter-spring in 2008 was observed in other regions across southern and central Queensland, and resulted in reports of poor cattle performance during these months. There had been a two year period of relatively high diet quality previous to this winter, which would have reduced available soil nitrogen for the pasture.

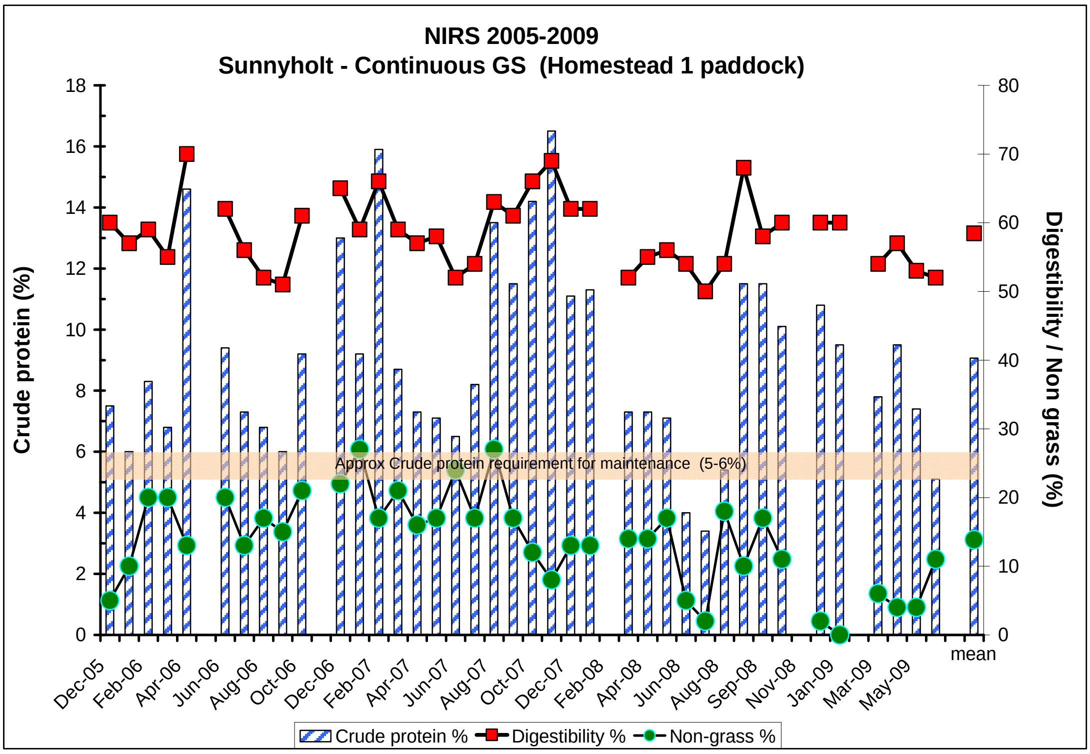


Figure 3.9. NIRS results for the continuous grazing system at Sunnyholt for crude protein (%), digestibility (%) and non-grass (%) with approximate maintenance crude protein indicated.

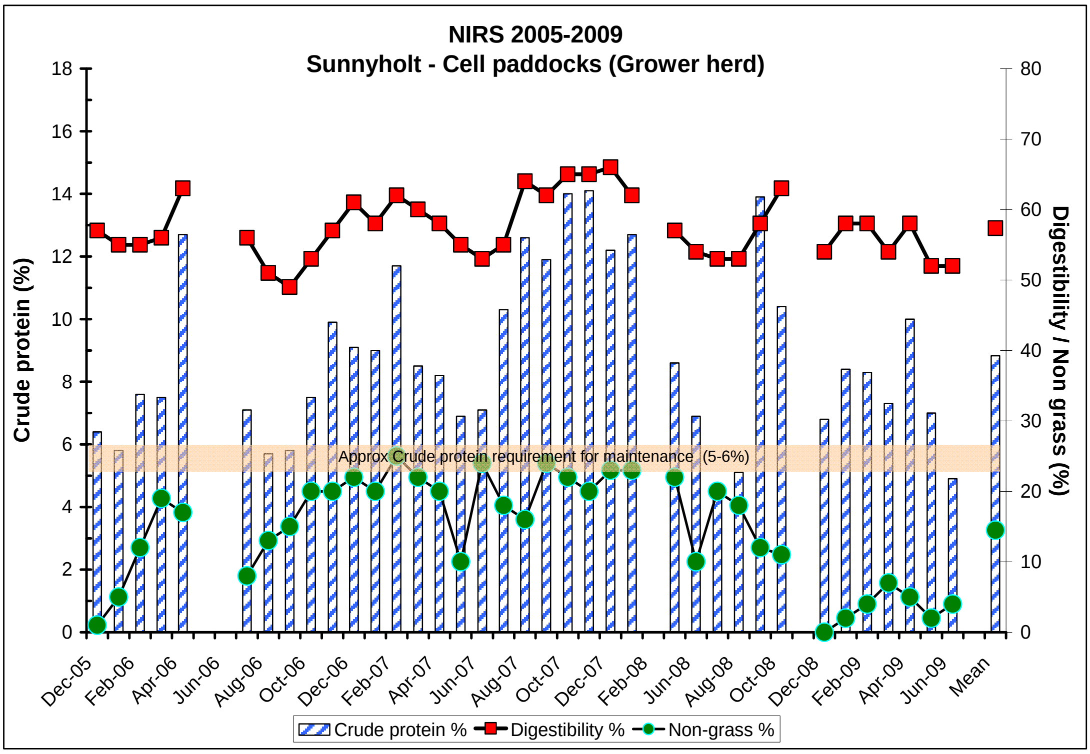


Figure 3.10. NIRS results for the grower herd cell grazing system at Sunnyholt for crude protein (%), digestibility (%) and non-grass (%) with approximate maintenance crude protein indicated.

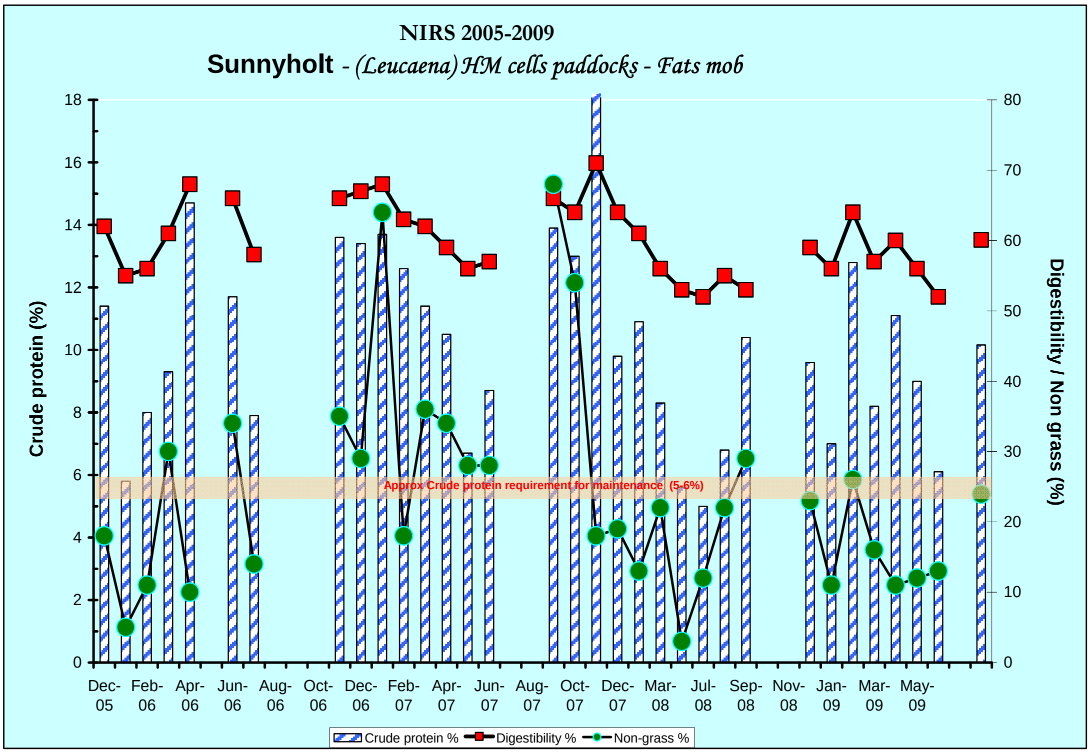


Figure 3.11. NIRS results for the fats herd cell grazing system, including leucaena paddocks, at Sunnyholt for crude protein (%), digestibility (%) and non-grass (%) with approximate maintenance crude protein indicated.

The fats herd, which had access to the better pasture paddocks including the leucaena cells, had high quality diets during each summer and into winter in some years (Figure 3.11). The peak diet quality months had higher quality diets than the cell paddocks supporting the grower herd or the continuous grazing system. The unusually low quality diet in winter of 2008 is shown and it occurred during a period of low non-grass, i.e. no leucaena, in the diet.

3.4. Grazing System Costs

The grazing system comprises a cell grazing system with 39 cells constructed from 20 pre-existing paddocks. The cells are centred on 13 cell centres and have access to 20 watering squares fitted with concrete troughs. Fencing is comprised of 22 km of single wire electric fence within the existing 20 paddocks. Water is supplied through 22 km of 63 mm polythene pipeline and an existing windmill is included in the system. The bulk of the site treatment, fencing and pipe laying, were undertaken by the owners using station plant and machinery.

3.4.1. Capital costs

The estimated replacement capital cost of the cell grazing system is approximately $128,000 (Table 3.21) comprising of fencing, watering, labour and planning costs.

Table 3.21. **Replacement capital costs of cell grazing system.**

Capital Item	Cost ($)
Fencing	17,522
Water	67,358
Troughs	20,000
Tanks	5,000
Pumps, mills	0
Installation	8,500
Consultancies	10,000
Total	**128,380**

3.4.2. Operating costs

For reasons of privacy and confidentiality, the annual running costs that are associated with each of the study grazing systems are not presented.

An indicative guide to the operating cost of a given system is the estimated annual capital reclamation cost (sinking fund depreciation charge), which is the equivalent sum that would need to be set aside each year to maintain the capital assets invested in the systems infrastructure. The reclamation cost has been estimated using standard farm accounting depreciation factors for the main assets listed in the preceding table, including – bores (7.5%), dams and wells (2.5%), fencing (5%), and plant (10%). This gives a projected capitalised cost for the case study cell enterprise of approximately $3,500 per annum (Table 3.22) comprising of fencing and water maintenance costs.

Table 3.22. Annual operating costs of cell grazing system.

Item	Cost ($)
Fencing	876
Water	1,684
Troughs	500
Tanks	500
Pumps, mills	0
Total	**3,564**

4. Conclusions

4.1. Pasture and land condition

Both the continuous and cell systems at Sunnyholt were assessed to be in A to A/B condition in 2006 and in A/B condition in 2007 due to woody regrowth and scalded patches. The cell paddocks were in A condition in 2009 but the continuous paddock remained in A/B condition. The PatchKey analyses showed little difference between grazing systems, but poorer condition overall in 2007 than in 2006 and 2009.

The differences in pasture yields between the grazing systems were small and inconsistent. Pastures in all paddocks were strongly buffel grass dominant (>94%). There was more woody regrowth in the continuous paddock than in the cell paddocks, but this difference occurred before the continuous grazing commenced as part of the experimental comparison. Mill 4 and Pines 1 cell paddocks are in the most similar condition to the continuous paddock. Mill 3 has been renovated by cultivation.

Ground cover levels were similar in both systems in 2006 but slightly higher in the cells in 2007 and 2009. Litter cover was higher in the continuous in 2006 and 2007, but higher in the cells in 2009. There were only small differences between grazing systems for all three LFA indices. All indices were marginally higher in 2009 than in 2006 except for the Infiltration Index in the continuous paddock.

The VegMachine analyses showed wide variation over the 20 year period but little difference between cell and continuous paddocks since 1995. The values of the vegetation Condition Index were approximately 90 in both systems in 2005, decreased in both systems in the droughts of 2006 and 2007, and then increased in both systems in 2008 to >90 on improved rainfall.

4.2. Carrying capacity and grazing

The two grazing systems at Sunnyholt performed in a similar fashion, with no major consistent trends over the monitoring period. There are still some bare patches in some paddocks of the cells and in the continuous system. The average grazing of both systems was double than the estimated LTCC of 73 SDH.

There was no significant difference between grazing systems for grazing pressure measured as SDH, SDH/100 mm rain or stocking rate, however, there were between year differences in average grazing pressure between the systems.

There was no consistent difference in diet quality between the two systems on the buffel grass pastures, however the fats mob which had access to leucaena cell paddocks had a higher quality diet than the other two herds on buffel-dominant pastures.

4.3. Owner's comments on grazing systems

4.3.1. New management

The Holistic Management cell system was established to improve land condition and offered an approach to reduce the expanding scalds that were developing under earlier grazing practices.

4.3.2. Results

Some of the main benefits of the current cell system on Sunnyholt include the ease of cattle management for all mustering and handling of cattle through the yards. Mustering can be done quickly, with ease and little cattle stress by one person. The quiet cattle are a pleasure to work in the yards after being in the cells. It is now an easy task to run through the yards for drafting out saleable animals or weighing, etc.

There is no need to check the waters separately as this is done with each cattle shift.

There is a different use of time because of the ease of mustering and handling, for example, 1500 head can be put through the yards in one day, where under conventional grazing management it may have taken a week.

The smaller paddocks of the cell system allow targeted management of problem areas to aid pasture recovery and reduce the bare patches.

4.3.3. Future plans

Continue with the Holistic Management cell system because of the pasture and cattle management benefits.

4.4. General conclusions

Ecologically there were no clear grazing system differences at Sunnyholt, although the cells were in better land condition throughout than the continuous paddock, which maintained the original bare patches and woody regrowth. These also occurred in some cell paddocks that had not been renovated. There were similar land condition differences between the cell paddocks, depending on their stage of recent redevelopment. Grazing pressure was similar between the systems and higher than the estimated LTCC in both systems. Diet quality was also similar throughout the year, with the normal seasonal variations from summer to winter. This reflects the similarity between the soil types and buffel grass dominated pastures over all monitor paddocks and that over the four-year monitor period the systems performed similarly.

Ticehurst

Abstract
'Ticehurst', Surat, has two grazing systems; cells and rotation, both operated on cell grazing principles with the larger paddocks of the rotation receiving longer graze periods. Five cell and two rotation paddocks were monitored between 2006 and 2009. The two systems are used as part of a breeder enterprise with herds of similar size. There was a drought for the first two years and average rainfall in the final two years. The pastures were sampled in late autumn in 2006, 2007 and 2009. Average pasture yields were higher in the cell system (3100 kg/ha) than in the rotation (2500 kg/ha) and varied between years, increasing from 1100 to 3800 kg/ha between 2007 and 2008, with the improved rainfall conditions. All pastures were buffel grass dominant (96%). The ecological differences were not consistent or strongly associated with the grazing system.

The grazing pressure was higher in the cell system (96 SDH) than in the rotation (66SDH) which received reduced grazing after timber treatment of one paddock and a reduced herd size as part of a drought management strategy. This grazing was marginally higher than the estimated LTCC (77 and 55 SDH respectively). There were greater between year differences than between system differences in grazing pressure, with the lowest grazing in 2007-08. All parameters of diet quality analysed by NIRS were similar in both systems.

1. Site Introduction

1.1. Location

Ticehurst is located 15 km north of Surat (27.0ºS; 149.0ºE) on Bungil Creek in the Murray-Darling catchment (Figure 1.1).

Figure 1.1. Buffel grass pasture landscape in cleared eucalypt woodland in the east cell system at Ticehurst.

1.2. Climate/growing season

The average annual rainfall is 538 mm (Table 3.1) with 66% falling in summer (October-March). The growing season is predominantly in summer, but with significant winter rain in some years there can be important winter pasture growth with subsequent beneficial impacts on pasture quantity and quality.

Based on long-term climate data, the average green season for tropical species is estimated to be 27 weeks including 11.7 growth weeks. With the winter rain, temperate species would add an average of 6.5 weeks to the growth of tropical species.

1.3. Major soil/vegetation types on property

The original vegetation was eucalypt and pine woodlands or forests. The major tree species are poplar box (*Eucalyptus populnea*), cypress pine (*Callitris glaucophylla*), silver-leafed ironbark (*Eucalyptus melanophloia*) and kurrajong. Most of the experimental areas have been cleared to sparse tree cover, with some eucalypt and pine regrowth. The major native grasses are *Aristida* spp., *Digitaria* spp., *Bothriochloa* spp. and *Dichanthium sericeum,* but *Cenchrus ciliaris* is the most important grass overall.

The terrain is gently undulating to flat with red sandy earths on slopes and ridges and grey clays/clay loams and duplex or alluvial loams on flats.

1.4. GRASP modelling of long-term pasture growth

1.4.1. GRASP parameters

Pasture growth on both the land types ("Cypress pine on duplex soils" and "Poplar box, silver-leafed ironbark") that occur in the monitor paddocks was modelled using the parameter values shown in Table 1.1.

Table 1.1. Land type parameters for Ticehurst used in GRASP model to estimate pasture growth.

GRASP Parameter	Parameter units	
	Cypress pine	Poplar box
Tree basal area (m^2/ha)	0	0
Available soil water (mm)	90	110
Maximum N uptake (kg/ha)	15	20
Regrowth (kg/ha/%BA)	3.5	7
Transpiration use efficiency (kg/ha/mm)	17	20
Minimum N concentration (%)	0.4	0.5

1.4.2. GRASP results

GRASP was run using climate data from SILO for the period 1889 to June 2009 and pasture growth for the period July 1 to June 30 was estimated. The median values for Ticehurst were 3420 kg/ha for "Cypress pine on duplex soils" and 3800 kg/ha for "Poplar box, silver-leafed ironbark" (Figure 1.2).

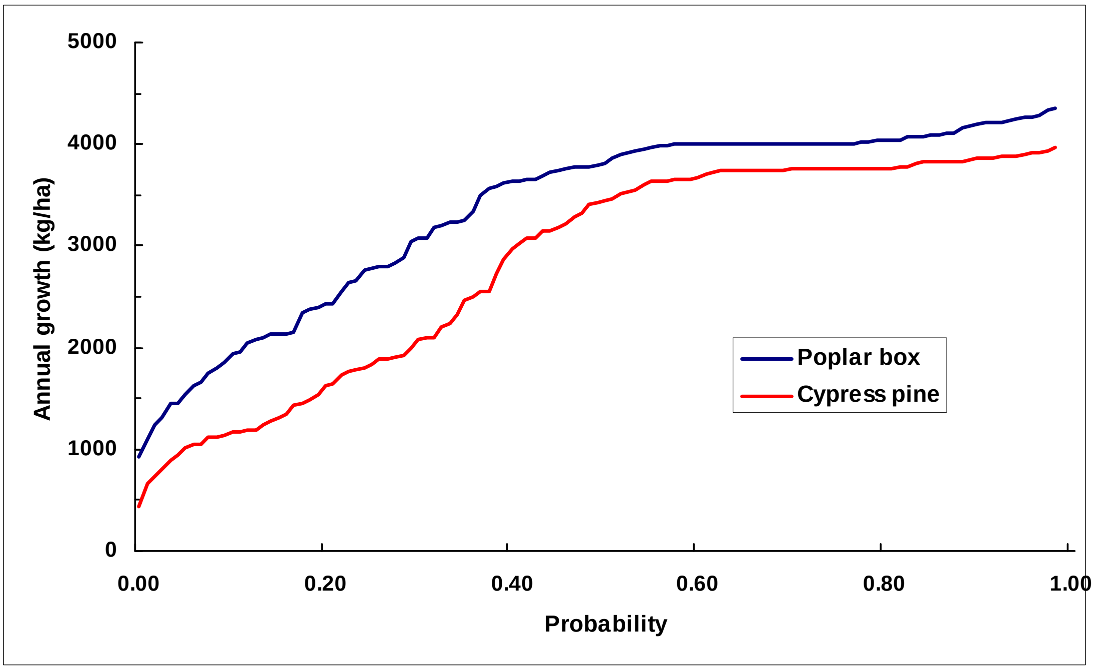


Figure 1.2. Long-term distribution of estimates of annual pasture growth at Ticehurst.

1.5. Production system/markets

The present production system involves a breeding herd producing weaners (approximately 200 kg) for feeding on forage oats or for on-sale to feedlots at approximately 300 kg/head. There is also some opportunistic buying and fattening of steers on summer forage as heavy steers. The improved buffel pastures from the intensive grazing systems have provided additional opportunities such as taking in agistment cattle or backgrounding growing cattle. In severe drought years, selling heavily and sending some of the breeding herd away to agistment is a management option.

1.6. Producer goals

The system was introduced following the owners accession to owning and managing the property. The primary goals of the more intensive grazing systems were (a) to overcome a general run down of pasture condition across large tracts of the property attributed to the previous history of continuous grazing and dry seasons, and (b) have the ability to feed budget for managing stock numbers. For example, buffel pastures were deteriorating to increased areas of bare ground and weeds, sandier paddocks were reverting to spear grass, etc. Previous attempts to rejuvenate the pastures through blade-ploughing, ripping, stick-raking and introduction of sown species had resulted in a poorer outcome than anticipated, and increased the conviction that such capital expenditure in the future would be better directed to a cell-rotational grazing system. The decision to proceed and the actual design were motivated by participation in a dedicated cell-grazing course.

No production issues – other than ongoing decline of pasture productivity – were cited as motivating factors for establishing the grazing system. The establishment of the cells was attributed with allowing 610 ha of grazing land to be released for a cropping program. This land is suitable for converting to improved sown pastures if required.

2. Grazing Systems

2.1. Description

Two grazing systems were studied - a cell system (east) and a rotation system (west). The cell system consists of approximately 50 paddocks on the east side of the property (average size approximately 28 ha) centred on 18 water points serviced by relocatable troughs and carrying approximately 300 cows and calves. The cell system is managed according to cell grazing principles based on pasture growth rate and the rate of cattle rotation can be down to 12 hours during rapid pasture growth periods in early summer (e.g. December 2005). These grazing periods extend to 1-3 days as the pasture growth rate declines. Five paddocks were monitored, with 41 ha of cypress pine forest on duplex soils and 83 ha of eucalypt woodland (Table 2.1).

Table 2.1. Areas (ha) of land types in the monitor paddocks of two grazing systems at Ticehurst.

Land type	**Area (ha)**	
	Cells	**Rotation**
Cypress pine on duplex soils	41	74
Poplar box, silver-leafed ironbark	83	12
Total	**124**	**86**

The rotation system on the west side of the property has 18 larger paddocks (average 50 ha) with nine watering points also serviced by relocatable troughs carrying approximately 300 cows and calves moved at 1 to 7 day intervals; two paddocks were monitored. Fences are single wire electric fence with water to the cells and rotation paddocks supplied through polythene pipe from a turkey nest dam and a creek. Weaners are removed from both systems and grown-out on oats and sorghum crops on heavy soil creek flats. These crop areas were previously part of the eastern cell system, but the pastures did not respond sufficiently to cell grazing management during drought conditions, so they were converted to annual cultivation and forage cropping. The two west rotation paddocks had the same two vegetation communities as the cells (Table 2.1). They are managed along the same principles as the east cell system. The main difference is in the length of time cattle graze the paddocks at each graze.

The five cell paddocks monitored averaged 25 ha and the two rotation paddocks averaged 43 ha (Table 2.2). The layout of the monitor paddocks is shown in Figure 2.1. The heavy clay soil flats on Bungil Creek which separate the two systems are visible in the satellite image. These paddocks are used for forage cropping and sown pastures.

Table 2.2. Paddock names, numbers and areas sampled at Ticehurst.

Vegetation	Grazing System	Paddock name [Botanal No.]	Area (ha)
Eucalypt	Cell	K3 [3]	26
		K5 [4]	20
		O5 [5]	26
		S5 [6]	24
		S7 [7]	27
		Total cell	124
Eucalypt	Rotation	Y1 [1]	48
		X1 [2]	38
		Total rotation	86

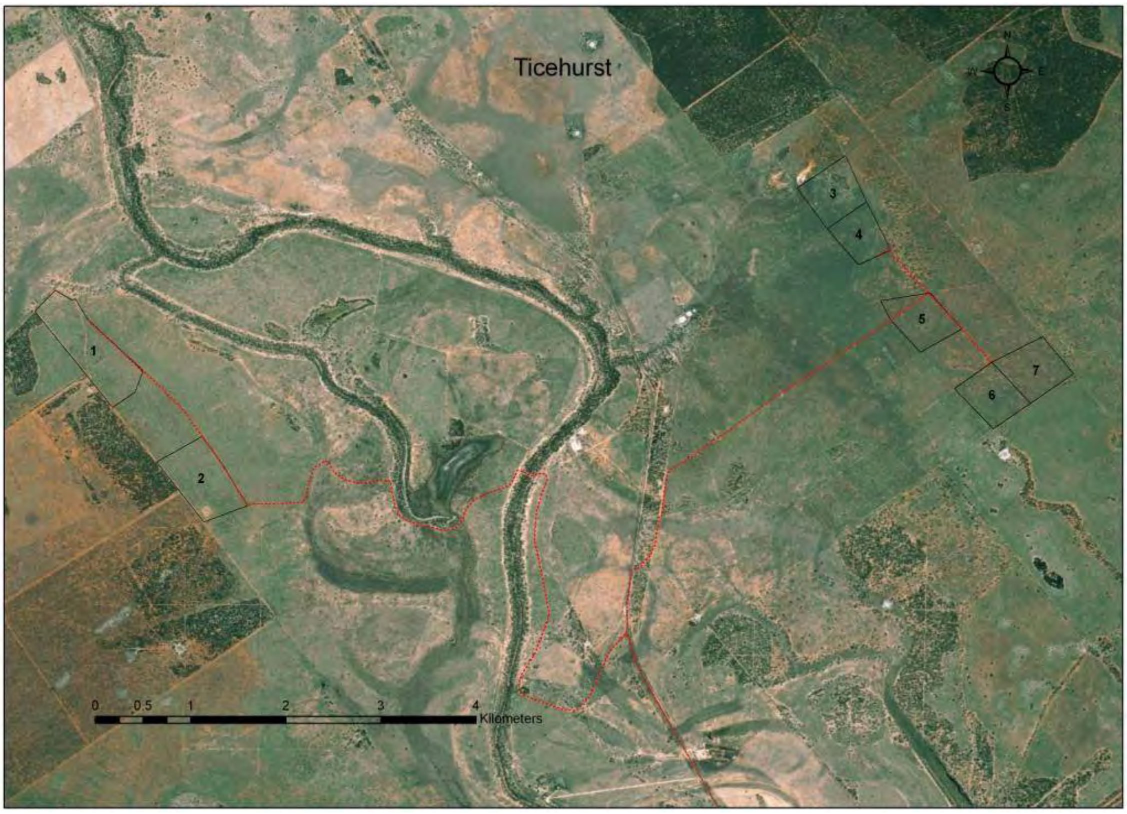


Figure 2.1. Layout of five cell and two rotation paddocks on a Spot-5 image at Ticehurst.

2.2. Management during 2005-2009

Each of the two grazing systems has a breeding herd of approximately 250 cows plus calves and bulls. The growing cattle are usually grazed separately and in recent years they have been grown and fattened on winter oats crops or in summer on forage sorghum. Some of the breeding herd may also graze these crops, relieving pressure on the buffel-dominant pasture systems. In dry years, sales may be used to reduce cattle numbers to reduce potential pasture damage from over-grazing. In exceptionally poor drought years, the herd will be sold down and most of the remainder may be sent to external agistment properties. Maintaining the pasture resource is the priority, which includes keeping the land in such a condition that it will respond rapidly to the following summer rain or when the drought ends.

During the monitoring period, Ticehurst had two breeding herds grazing in each of the two systems. They were rotated through the cell and rotation systems in a similar manner. On occasions the cell system paddock rotation was as frequent as 12 hours during the rapid pasture growth phase in early summer. Two paddocks may have been open at the same time. During the 2007-08 drought, grazing in both systems was reduced (average one day per paddock) and all paddocks were rested while the pasture was still in good condition. This year of negligible grazing maintained the pastures and soil cover, which produced rapid pasture growth in the following summer. During the 2005-09 period the cell paddocks were grazed for 1 to 8 days annually (mean 4 days) and the rotation paddocks were grazed for 1 to 16 days annually (mean 6 days). The average rest periods each year for the systems (Table 2.2) shows there were 172 days in the cells and 239 days in the rotation systems. These averages are biased due to the planned de-stocking program aimed at maintaining pastures during the drought and the reduced grazing of the rotation system after timber treatment of one monitor paddock. The agistment period commenced in April 2007, when the rotation monitor paddocks had only received one short grazing event.

3. Results

3.1. Growing Seasons

3.1.1. Rainfall

The severe and extended drought in the early years of monitoring is shown by the three consecutive low rainfall years leading to the average rainfall year of 2007-08 (Table 3.1). The final year received marginally above average rainfall from a wet November and February followed by an exceptionally dry January and March periods.

Table 3.1. Monthly rainfall (mm) at Ticehurst from July 2004 to June 2009 and long-term average monthly rainfall (mm) at Frogmoor recording station over 91 years.

	Monthly rainfall (mm)													
Year	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**Total**	**Decile**
2004/05	11	2	30	44	60	108	0	21	3	0	51	123	452	3
2005/06	0	0	5	62	50	76	28	225	16	27	0	8	495	4
2006/07	14	0	4	13	37	35	75	23	14	10	1	76	301	1
2007/08	0	55	0	90	57	147	116	94	0	0	5	25	586	6
2008/09	28	0	79	48	141	84	4	126	0	21	32	55	617	7
Long-term Mean	**36**	**26**	**24**	**46**	**58**	**68**	**68**	**68**	**47**	**31**	**33**	**31**	**537**	

3.1.2. Growing conditions

2003-2004: Ticehurst received well above average rainfall for the year and very high summer rainfall.

2004-2005: There was below average rainfall for the year with extremely low summer rainfall. However, average spring rainfall promoted some early pasture growth and well above average autumn/early winter rainfall maintained pasture quality into winter.

2005-2006: Ticehurst recorded average yearly rainfall with average spring rainfall and above average summer rainfall providing a good pasture growing season.

2006-2007: The 2006-07 year was a drought year producing poor pasture growth after receiving well below average spring, below average summer and average autumn rainfall. The annual total was extremely low in the decile 1 range.

2007-08: Total annual rainfall was average, however distribution was poor with almost all rainfall received through the August to February period and no rain in the growing period of March-April. This early finish to the pasture growing season meant pasture production was restricted, matured early and quality declined rapidly in autumn.

2008-09: Rainfall was slightly above average with a good start to spring and early summer. November and February were particularly good pasture growing periods.

Years with good winter or summer rainfall allow forage oats and sorghum crops to be grown which are used to finish growing cattle for sale and may be used to reduce grazing pressure on the grass pastures of the cells and rotation systems.

3.1.3. GRASP modelling of growing seasons 2005-2009

Modelled pasture growth was consistently higher in the cells than in the rotation system (Table 3.2). The average difference between the systems was 700 kg/ha.

The strong pasture growth potential response to good summer rainfall events and the distinct dormant periods each winter is shown in Figure 3.1.

Table 3.2. Estimated annual pasture growth (kg/ha) for grazing systems at Ticehurst from 2005/06 to 2008/09.

Year	**Pasture growth (kg/ha)**	
	Cells	**Rotation**
2005/06	3800	2900
2006/07	1300	900
2007/08	4100	3500
2008/09	3500	2800
Average	**3200**	**2500**

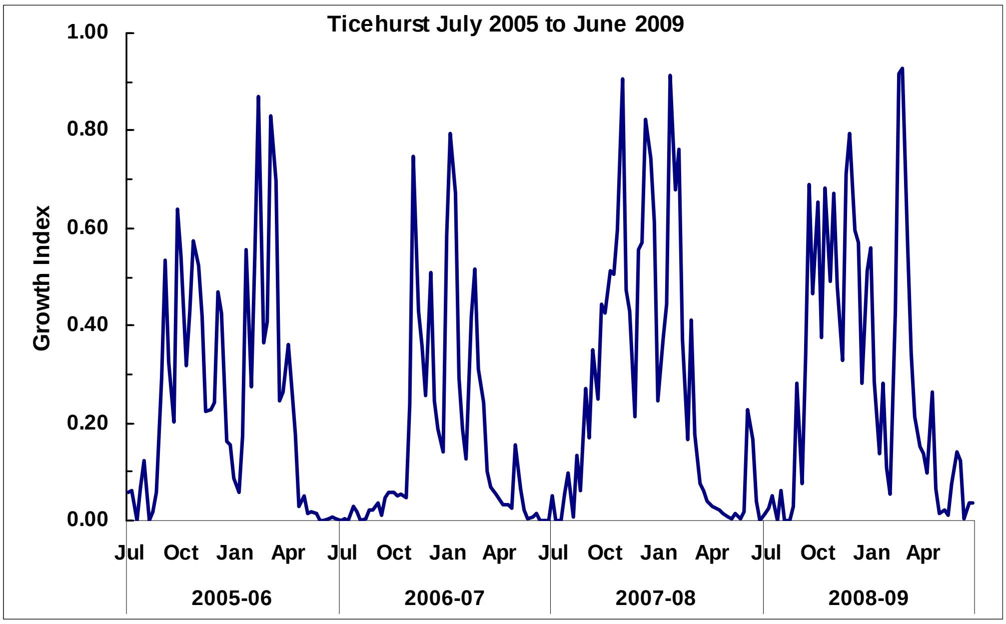


Figure 3.1. Weekly Growth index (tropical species) values at Ticehurst during the experimental period (2005-09) for the "Poplar box silver leafed ironbark" land type.

3.2. Pastures and Land Condition

3.2.1. Pasture yield, botanical composition and diversity

3.2.1.1. *Pasture means*

The pastures were sampled in late autumn. All pastures were strongly buffel grass dominant (94%-99%) with only small amounts of other species. Pasture yields were lower in the rotation than in the cells (Table 3.3). This could reflect the higher woody regrowth [poplar box (*Eucalyptus populnea*), false sandalwood (*Eremophila mitchellii*) and cypress pine (*Callitris glauca*)] and greater competition in the rotation paddocks in all years, and the clearing and stick-raking of Paddock TY1 in 2007. The pasture was slow to regrow after stick-raking due to poor rainfall over the following season.

Table 3.3. Pasture dry matter yield and botanical composition at the end of summer at Ticehurst.

Year	System	Yield	Botanical composition (%)						
		(kg/ha)	Nat per grass	Exotic grass	Native leg	Exotic leg	Ann grass	Forb	Sedge
2006	Cell	2600	2.0	95.5	0.0	0.0	0.0	2.3	0.2
	Rotation	1930	1.6	95.8	0.0	0.0	0.0	2.3	0.3
2007	Cell	1740	3.5	96.1	0.0	0.0	0.0	0.4	0.0
	Rotation	1000	4.1	94.4	0.0	0.0	0.0	1.5	0.0
2009	Cell	3150	1.3	98.1	0.0	0.0	0.0	0.5	0.1
	Rotation	2700	0.5	98.6	0.0	0.0	0.0	0.8	0.1

3.2.1.2. *Yield spatial variability*

This analysis measured the degree of uniformity, or inversely variability, in the various parameters across each paddock. An analysis of the quadrat data across a grid of the paddocks, indicates that most paddocks were spatially uniform in autumn pasture yield in both systems in the first year, 2006, but they were more variable at subsequent recording times (Table 3.4).

Table 3.4. Spatial variability in pasture yield – number of paddocks where pasture yield was spatially uniform (i.e. there was no evidence of aggregation) across the paddock.

Grazing System	Total no. of paddocks	No. paddocks uniform pasture yield		
		2006	2007	2009
Cell	5	3	1	2
Rotation	2	2	0	0

3.2.1.3. *Pasture species diversity*

Diversity was low in all pastures reflecting the strong dominance by buffel grass (

Table 3.5).

Table 3.5. Three measures of pasture species diversity at Ticehurst in 2006, 2007 and 2009.

Diversity measure / Year	Diversity units	
	Cell	Rotation
No. species/quadrat		
2006	1.6	1.6
2007	1.3	1.2
2009	1.3	1.5
No. species to contribute 90% of yield		
2006	1	1
2007	1	1
2009	1	1
% contribution of dominant species		
2006	96	96
2007	96	94
2009	99	98

3.2.2. Pasture utilisation

Pasture utilisation in the monitor paddocks at the end of summer was rated across the paddocks on the Botanal grid at each recording point (rating 1 = 71-100%; 2 = 31-70%; 3 = 6-30%; 4 = 0-5% utilisation).

3.2.2.1. *Utilisation means*

Grazing was light in 2006 and 2009 (ratings 3.3 to 4.0) and heavier in 2007 (rating 2.5). There were negligible differences between systems at the first two recordings, but in autumn of 2009, the rotation paddocks had received higher grazing pressure (Table 3.6). They had over 60% of samples receiving 6%-30% utilisation, while the cell monitor paddocks had received negligible grazing (Table 3.6).

Table 3.6. Mean rating (1-4) for estimated pasture utilisation in grazing systems at from 2005/06 to 2008/09.

Year	**Utilisation rating**	
	Cells	**Rotation**
2005/06	3.5	3.3
2006/07	2.5	2.4
2008/09	4.0	3.3

The rotation paddocks received heavier grazing than the cell monitor paddocks in autumn each year. In 2006 there was higher utilisation in the rotation paddocks than in the cell system which had a higher proportion receiving negligible grazing by autumn (Figure 3.2). A high proportion of all paddocks had received between 31% and 70% utilisation in 2007, with the rotation paddocks receiving marginally heavier grazing than the cells. In autumn of 2009, the rotation paddocks (to 30% utilisation) had received heavier grazing than the cells, which had received negligible grazing.

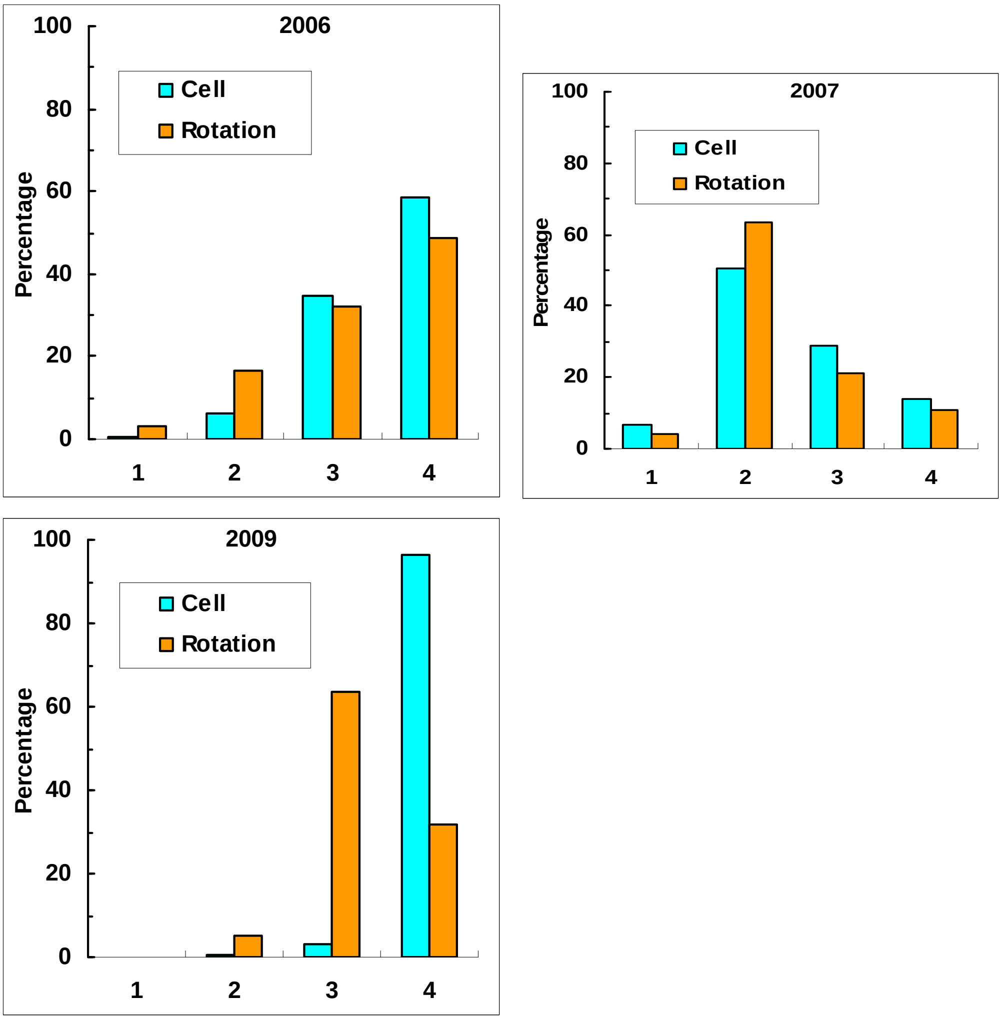


Figure 3.2. Distribution of estimated pasture utilisation values in grazing systems at Ticehurst from 2006 to 2009.

3.2.2.2. *Utilisation spatial variability*

There was more consistent uniformity in pasture utilisation in the cell paddocks than in the larger rotation paddocks, which both had uniform utilisation only in 2007 (Table 3.7).

Table 3.7. Spatial variability in pasture utilisation – number of paddocks where pasture utilisation was spatially uniform (i.e. there was no evidence of aggregation) across the paddock.

Grazing System	Total no. of paddocks	No. paddocks uniform utilisation		
		2006	2007	2009
Cell	5	2	2	4
Rotation	2	0	2	0

3.2.3. Woody regrowth

There was more woody regrowth in the rotation paddocks, up to 2.2% cover compared with 0.7% in the cells (Table 3.8).

Table 3.8. Cover levels (%) of woody regrowth in grazing systems at Ticehurst.

Year	**Woody regrowth cover (%)**	
	Cells	**Rotation**
2006	0.4	1.2
2007	0.5	0.8
2009	0.7	2.2

3.2.4. Ground and litter cover

3.2.4.1. *Cover means and standard deviations*

Total cover levels were higher in the cell system than the rotation system, particularly in 2007. Although there was some variability, the standard deviations were similar for the different grazing systems (Table 3.9).

Table 3.9. **Cover levels (%) at Ticehurst at the end of summer.**

Year	**Grazing System**	**Total cover (%)**		**Litter cover (%)**	
		Mean	**St. Dev.**	**Mean**	**St. Dev.**
2006	Cell	63	23.6	15	11.0
	Rotation	57	22.9	16	10.2
2007	Cell	50	24.3	21	16.2
	Rotation	35	21.5	14	13.5
2009	Cell	69	20.1	24	14.7
	Rotation	67	23.6	24	16.6

3.2.4.2. *Cover spatial variability*

Ground cover was uniform across the cell paddocks in the first year of recording, but most paddocks monitored in 2009 did not have uniform cover (Table 3.10). Litter cover was uniform in all cell paddocks in 2007, but in the other two years most paddocks did not have a uniform litter cover. One of the two rotation paddocks had uniform litter cover at each recording.

Table 3.10. Spatial variability in ground cover – number of paddocks where total ground cover or litter cover was spatially uniform (i.e. there was no evidence of aggregation) across the paddock.

Cover / Grazing System	Total no. of paddocks	No. paddocks uniform ground cover		
		2006	2007	2009
Total ground cover				
Cell	5	4	2	1
Rotation	2	1	0	1
Litter cover				
Cell	5	1	5	0
Rotation	2	1	1	1

3.2.5. LFA indices (soil surface condition)

3.2.5.1. *LFA indices means and standard deviations*

There were only small and inconsistent differences between grazing systems in the three LFA indices of stability, infiltration and nutrient cycling (Table 3.11).

Table 3.11. Mean LFA indices and standard deviations at Ticehurst at the end of summer 2006, 2007 and 2009.

Year	System	LFA Indices (0-100)					
		Stability		Infiltration		Nutrient cycling	
		Mean	S. Dev.	Mean	S. Dev.	Mean	S. Dev.
2006	Cell	62.0	6.10	36.4	8.20	26.9	6.31
	Rotation	62.6	5.72	36.4	7.50	28.0	6.62
2007	Cell	57.5	5.68	40.1	8.87	31.9	8.29
	Rotation	55.5	5.18	39.0	6.96	28.7	7.07
2009	Cell	64.9	5.61	41.4	7.61	34.2	7.30
	Rotation	64.6	5.85	42.3	7.04	35.2	7.43

3.2.5.2. *LFA indices spatial variability*

The three LFA indices were more uniform across both systems in 2006 than in the following two recording years (Table 3.12). One of the two rotation paddocks were uniform for the three indices in 2009, while only one or two of the cell paddocks were uniform for these indices.

Table 3.12. Spatial variability in LFA indices – number of paddocks where LFA indices were spatially uniform (i.e. there was no evidence of aggregation) across the paddock.

LFA index / Grazing System	Total no. of paddocks	No. paddocks uniform LFA index		
		2006	2007	2009
LFA Stability index				
Cell	5	3	1	1
Rotation	2	2	0	1
LFA Infiltration index				
Cell	5	3	2	1
Rotation	2	1	2	1
LFA Nutrient cycling index				
Cell	5	1	3	2
Rotation	2	2	1	1

3.2.6. Land condition

The two rotation paddocks were mainly in A condition with some patches in B condition due to loss of perennial grasses from competition from poplar box (*Eucalyptus populnea*) regrowth. After stick-raking, rotation paddock TY1 was in A condition, while TX1 remained in B condition. The cell paddocks were all in A condition with the exception of TO5, which remained in B condition due to woody regrowth, mainly by *Carissa ovata*. There were the usual bare inter-tussock spaces between buffel grass plants on sloping red earth soils (Table 3.13).

Table 3.13. Land condition measures at Ticehurst. For the Botanal/ PatchKey and ABCD (Land type) values, “1” is equivalent to A condition and “4” is equivalent to D condition.

Land condition	Land condition unit	
Year	Cells	Rotation
Botanal/PATCHKEY		
2006	1.5	1.8
2007	1.9	2.5
2009	1.3	1.5
ABCD (by Land type)		
Cypress pine on duplex soils	1.1	1.5
Poplar box silver leafed ironbark	1.0	1.0
Overall average	1.0	1.4
ABCD (Paddock)		
2006	A/B	A/B
2007	A/B	A/B
2009	A	A/B

A photographic record of fixed locations within both grazing systems shows the high proportion of buffel grass and strong seasonal growth responses from good condition pastures in both systems over the four-year monitoring period (

Figure 3.3).

Ticehurst S5-4 Lat: 26^0.592; Long: 149^0.064, Dir: 205^0	**Ticehurst X1-8** Lat: 26^0.599; Long: 149^0.019, Dir: 30^0
 Cell (December 2005)	 Rotation (December 2005)
 Cell (July 2006)	 Rotation (July 2006)
 Cell (October 2007)	 Rotation (October 2007)
 Cell (August 2008)	 Rotation (August 2008)
 Cell (June 2009)	 Rotation (June 2009)

Figure 3.3. Changes in land condition at fixed points in the east cell and west rotation grazing systems at Ticehurst between 2005 and 2009.

3.2.7. Cover analysis

3.2.7.1. *VegMachine vegetation cover time series (Landsat)*

The VegMachine analysis of paddocks shows cover was strongly influenced by rainfall and it closely followed the timber treatment and pasture development of the property since the current owners bought it in 1988. In the first year of VegMachine data, the western ‘rotation‘ areas had a higher cover than the eastern ‘cell’ areas, due to their higher tree cover (Figure 3.4). In the first two years of ownership, the whole property average cover, including the two GSP monitor areas, increased in cover by increasing pasture cover with above average rainfall and relatively low cattle numbers, as the herd was built-up. There were four consecutive above-average rainfall years.

Cover in all areas declined in 1991 due to clearing timber for buffel pasture improvement. The cover continued to decline in the eastern cell areas due to the pasture improvement program, grazing and a three-year drought. Cover in the west rotation areas also declined but not to the same extent due to their tree cover (a woodland of poplar box, cypress pine and silver-leaved ironbark). Cover increased over all areas of the property when the drought broke with buffel grass thickening and reduced cattle numbers.

The east areas maintained or increased in cover until 1999, while there was a decline in the west areas when pine timber was harvested. However, this reduced cover was followed by a steady increase in cover to 2001, as buffel grass and woody regrowth thickened. The west area timber was then pulled producing a sharp cover decrease, exacerbated by two drought years. Cover remained lower until a small increase in 2005, due to an increase in pasture and woody regrowth, mainly poplar box suckers and conkerberry bush (*Carissa ovata*) spreading. Average cover in this west rotation area again declined in 2007 after stick-raking the original pulled timber and clearing the suckers in TY1 paddock.

In 2001 there was significant reduction in cover in the east cell areas as the country was burnt and a dry year followed. Cover in some areas was also reduced while the east cell system was developed. However the well established buffel grass rapidly increased in cover the following year and maintained a similar cover to the west rotation paddocks until 2006 when it was marginally higher.

The VegMachine analysis of cover shows the GSP monitor areas in both the east cells and west rotation paddocks have been well managed at similar grazing pressures, maintaining a consistent cover (above index 70), in the four years prior to the project commencing. The GSP field data in 2006 and 2007 shows the east cells had a higher pasture yield than the west rotation paddocks, and cover was higher only in 2007, due to the cover reduction caused by stick-raking of TY1 paddock (Figure 3.4).

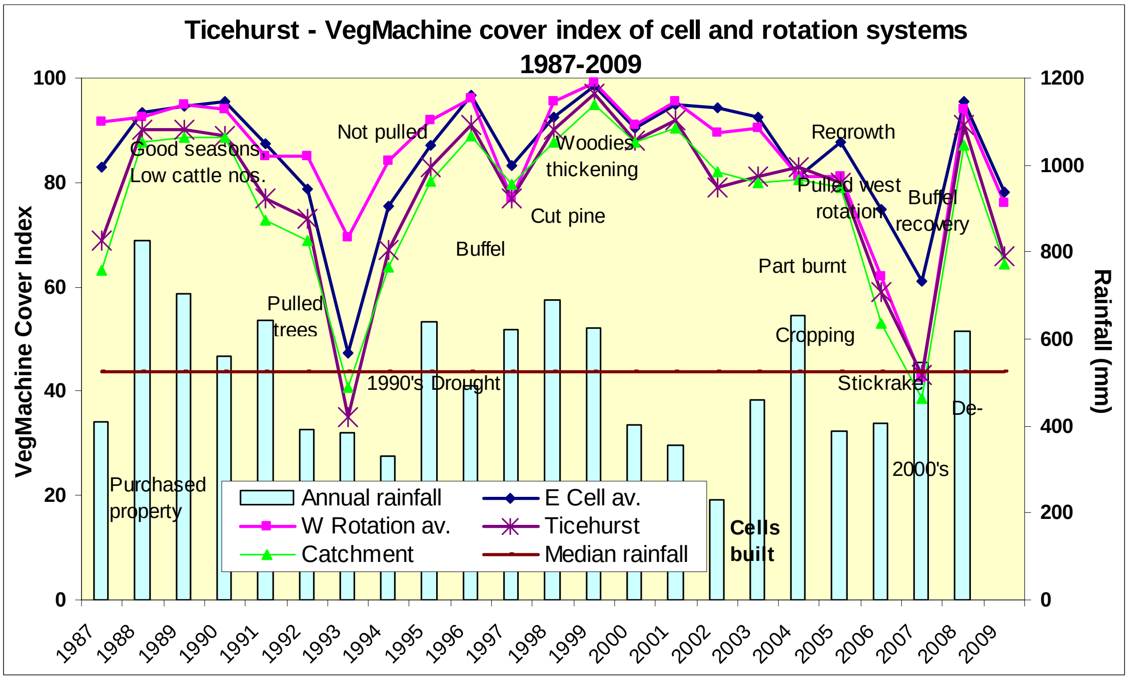


Figure 3.4. Vegetation cover index between 1987 and 2009 for grazing systems, whole property and the neighbourhood catchment. Annual and long-term median rainfall (mm) are also shown.

There was wide variation in cover between the GSP monitor paddocks (Figure 3.5) over the 1987-2008 period as the property has been developed from woodlands and forests to open buffel grass pastures with intensively managed grazing systems. The cover variation in the east cell paddocks in 2001 was due to the extent of burning. Paddock TK5 was not burnt, TS5 was only partially burnt and the other cells were totally burnt. These cover differences are identified by the VegMachine analysis.

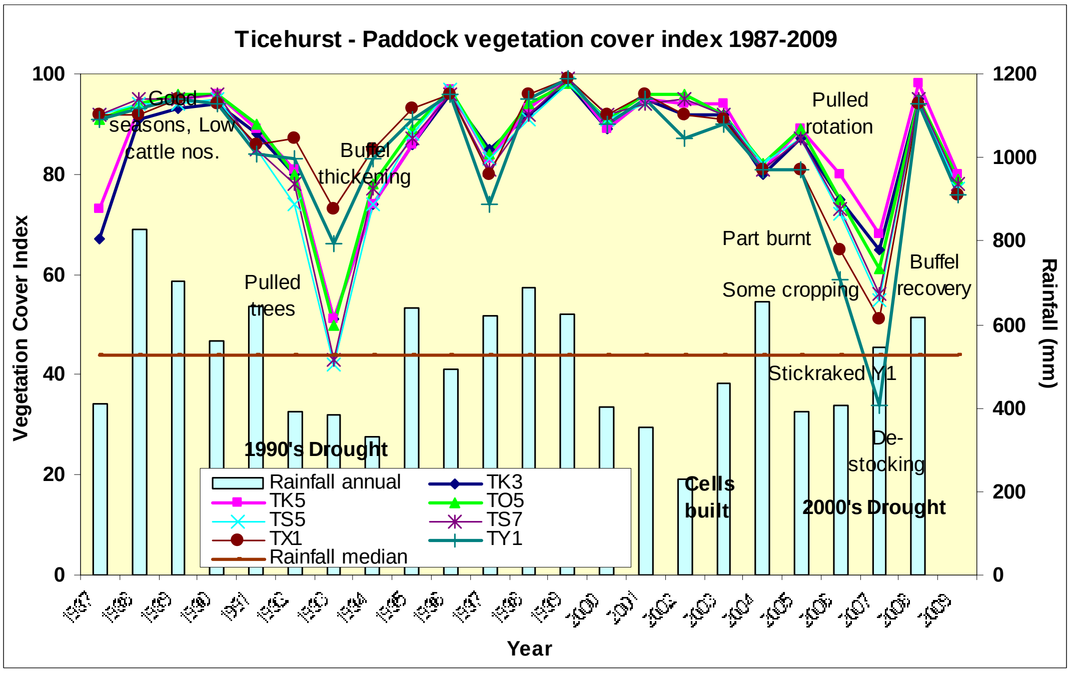


Figure 3.5. Vegetation cover index between 1987 and 2009 for monitor paddocks at Ticehurst. Annual and long-term median rainfall (mm) are also shown.

3.2.7.2. *Botanal pasture data*

The GSP Botanal field data shows lower pasture production and cover in 2007 compared with the previous year in both grazing systems (Table 3.14). This GSP data in the seven monitor paddocks does not have a close correlation with the modelled results from DERM (AussieGrass) for pasture standing dry matter or ground cover for the whole property for the years 2006 and 2007. The Landsat analysis is consistently higher than the modelled cover. The GSP pasture cover data (35-63%) closely matched the Landsat analysis for the whole property.

Table 3.14. Pasture yield (kg/ha), total pasture cover (%), litter cover (%) and woody cover (%) in 2006 and 2007 in monitor paddocks and grazing systems at Ticehurst.

Paddock / System	**Yield (kg/ha)**		**Total Cover (%)**		**Litter Cover (%)**		**Woody Cover (%)**	
	2006	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**
TY1 [1]	1980	550	62	23	16	8	1.1	0.2
TX1 [2]	1920	1450	53	46	16	20	1.2	1.4
TK3 [3]	2590	1530	58	50	17	25	0.9	0.6
TK5 [4]	2030	1240	60	51	19	24	0.5	0.4
TO5 [5]	2840	2120	68	54	14	21	0.4	0.9
TS5 [6]	2490	1960	59	48	12	19	0.2	0.3
TS7 [7]	3140	1850	69	48	15	15	0.1	0.1
West Rotation	1950	1000	58	35	16	14	1.1	0.8
East Cells	2620	1740	63	50	16	21	0.4	0.5
Site	2430	1530						

3.2.7.3. *Spatial pasture and cover reports*

The average cover for Ticehurst over 2001-05 shows good cover in all monitor paddocks, with areas of medium cover in TO5 and TS7 east cell paddocks (Figure 3.6). The satellite imagery analysis showed reduced cover in these areas that was not measured in the field in either 2006 or 2007.

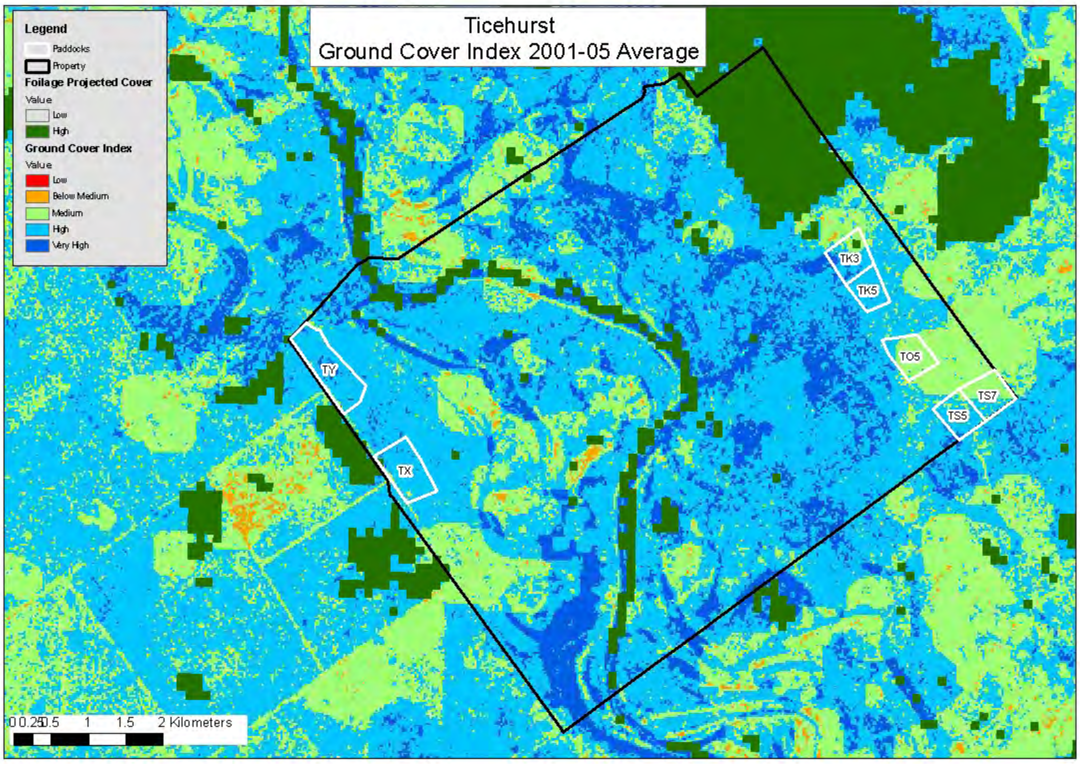


Figure 3.6. Average (2001-2005) ground cover index (vegetation cover) image for the cell and rotation monitor paddocks and the whole property at Ticehurst and surrounding properties (QDERM data).

3.3. Cattle Grazing

3.3.1. Carrying capacity – Long-term (LTCC)

The estimated long-term carrying capacities (AE/100 ha and SDH) of the two systems are:

Cells	21.1 AE/100 ha (77 SDH)
Rotation	15.1 AE/100 ha (55 SDH)

3.3.2. Rest periods for each system

The rest periods between grazing events varied widely in both systems (Table 3.15). The grazing events were greatly influenced by the drought which occurred through most of the monitoring period, especially in 2007-08 when both systems were destocked to preserve pasture condition. The rotation system received longer rest periods due the early destocking in April 2007 and one paddock was stick-raked. This limited pasture growth in the following drought year, consequently this paddock received little grazing.

Table 3.15. Average rest periods (days) for grazing systems at Ticehurst.

Year	**Rest periods (days)**	
	Cells	**Rotation**
2005-2006	60	149
2006-2007	83	79
2007-2008	364	364
2008-2009	181	362
Average	**172**	**239**

3.3.3. Grazing days

The annual average days of grazing was 4 and 6 days for the cell (East) and rotation (West) systems respectively. They had an annual average of 3 and 2 grazing events or herd number changes per year respectively. The annual number of days grazing in the cell paddocks ranged from 1 to 7 days per year, with 1 to 6 grazing events per year. The rotation system paddocks were grazed 1 to 16 days per year with 1 to 5 herd changes per year over the four years. The drought and stick-raking one rotation paddock reduced the normal grazing pattern in this system.

3.3.4. Grazing pressure

The animal numbers taken from property records for each system have been converted to Animal Equivalents (AE) using the tables presented in the Appendix 9.10. An AE is equivalent to a dry cow weighing approximately 450 kg. The mean paddock grazing days per ha for one AE (stock days per ha or SDH) over the four year monitoring period show the cells had a higher grazing (average 96 SDH/year) than the rotation system (66 SDH/year). This compares with the LTCC estimate of 77 and 55 SDH/year for the two systems respectively. There was a similarly higher SDH/100 mm of rainfall prior to each grazing event in the cell paddocks (average 20 SDH/100 mm) than in the rotation paddocks (14 SDH/100 mm) (Table 3.16).

Table 3.16. Mean paddock grazing pressure for grazing systems at Ticehurst (AE.days/ha/100 mm rain/annum; SDH/100mm).

Year	**Grazing pressure (SDH/100mm)**	
	Cells	**Rotation**
2005-06	26.3	13.3
2006-07	25.5	27.3
2007-08	6.5	2.6
2000-09	20.0	13.1
Average	**19.6**	**14.1**

The serious drought, which caused stock to be removed from both systems to agistment in 2007-08, meant the rotation monitor paddocks were not grazed during the 12 month period. There was a wide variation between years in grazing relative to previous 12 month's rainfall between paddocks (Figure 3.7) and grazing systems (Figure 3.8).

The cells had a higher grazing pressure than the rotation paddocks during the monitoring period, which included reduced grazing of one rotation paddock after it was stick-raked and the following drought limited pasture growth. There was also a strong between year grazing pressure difference, partly caused by the destocking during the severe drought of 2007-08, and a significant grazing system by year interaction (Table 3.17).

Table 3.17. Grazing system and year effect on stock days per ha (SDH), SDH per 100 mm rain and annual stocking rate (ha/AE) at Ticehurst.*

System / Year	**Grazing pressure**								
	Stock days per ha (SDH)			**SDH / 100 mm rain**			**Annual stocking rate (ha/AE)**		
Grazing Sys (GS)	***			*			***		
Cell	4.47	(87)	a	2.89	(17)	a	1.67	(4.3)	b
Rotation	3.62	(36)	b	2.48	(11)	b	2.53	(11.6)	a
Av. s.e.d.	0.22			0.12			0.24		
Year (Yr)	***			***			***		
2005/06	4.43	(83)	a	3.02	(20)	ab	1.74	(4.7)	b
2006/07	4.51	(90)	a	3.18	(23)	a	1.67	(4.3)	b
2007/08	2.82	(16)	b	1.69	(4)	c	3.27	(25.3)	a
2008/09	4.42	(82)	a	2.83	(16)	b	1.73	(4.7)	b
Av. s.e.d.	0.29			0.13			0.30		
GS x Yr	***			*			***		
Cell-05/06	4.84	(126)	a	3.29	(26)	a	1.36	(2.9)	a
Cell-06/07	4.61	(99)	a	3.25	(25)	a	1.55	(3.7)	a
Cell-07/08	3.70	(40)	b	1.99	(6)	b	2.33	(9.3)	b
Cell-08/09	4.74	(114)	a	3.03	(20)	a	1.44	(3.2)	a
Rot-05/06	4.04	(56)	b	2.66	(13)	b	2.02	(6.5)	b
Rot-06/07	4.91	(135)	a	3.34	(27)	a	1.31	(2.7)	c
Rot-07/08	1.26	(3)	c	1.26	(3)	c	4.98	144.3)	a
Rot-08/09	4.27	(71)	b	2.64	(13)	b	1.83	(5.2)	b
s.e.d. w/i GS	0.15			0.16			0.13		
s.e.d. w/i Yr	0.18			0.18			0.15		

n.s. – $P > 0.10$; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

* Data were log-transformed prior to analysis. Back-transformed means are given in parentheses. Means not followed by a common letter are significantly different (P=0.05). For the GS x Yr means, differences indicated are within a grazing system.

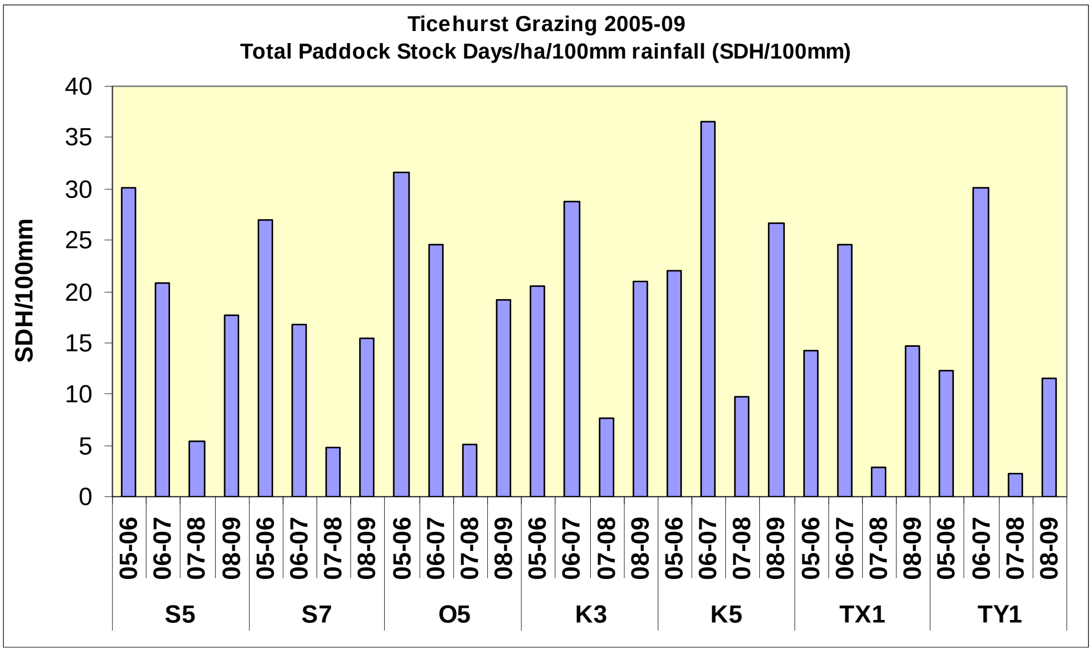


Figure 3.7. Paddock grazing response to rainfall (SDH/100 mm) in cell and rotation grazing systems at Ticehurst between 2005 and 2009.

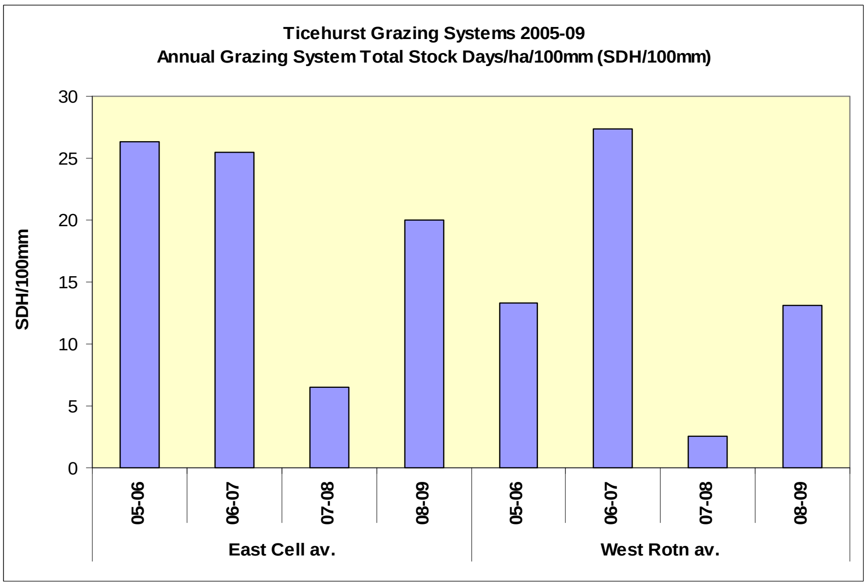


Figure 3.8. Annual average grazing response to rainfall (SDH/100 mm) in cell and rotation grazing systems at Ticehurst between 2005 and 2009.

3.3.5. Grazing system intensity index

The grazing system intensity index values (range 1-100; calculated from capital costs, operating costs and management inputs; details are reported in Appendix 9.13) for the two systems were:

Cell	96
Rotation	84

These indices are both relatively high reflecting a high degree of infrastructure development and management inputs for both systems.

3.3.6. Diet quality (NIRS)

The diet quality in both systems was similar with marginally higher crude protein in the east cells (Table 3.18). The pastures in both systems are buffel grass dominant and they were managed along similar cell grazing principle lines with the larger paddocks of the west system receiving longer graze periods.

Table 3.18. Mean faecal NIRS results (all samples) for grazing systems at Ticehurst to March 2007 for Rotation and March 2008 for Cells.

Grazing System	No. samples	Crude protein (%)	Faecal N (%)	Digesti-bility (%)	Non-grass (%)	LWG (kg/day)	DMD/CP ratio
Cell	18	7.2	1.4	55	19	0.57	8.4
Rotation	14	8.1	1.5	55	20	0.64	7.6
sed (av.)		1.98	0.22	5.7	13	0.26	1.2
Significance		ns	ns	ns	ns	ns	ns
Average	**(32)**	**7.7**	**1.4**	**55**	**20**	**0.63**	**7.7**

Samples were taken from both systems on the same day on 13 occasions. These results show a similar diet quality in both east and west systems, and a marginally higher (0.5%) average crude protein in the east cell paddocks (Table 3.19).

Table 3.19. NIRS diet quality results when samples were collected at the same time (paired).

Grazing System	No. samples	Crude protein (%)	Faecal N (%)	Digesti-bility (%)	Non-grass (%)	LWG (kg/day)	DMD/CP ratio
Cell	13	8.0	1.5	56	17	0.65	7.8
Rotation	13	7.3	1.4	55	18	0.55	8.0
sed (av.)		1.20	0.17	3	5	0.16	0.7
Significance		ns	ns	ns	ns	ns	ns

The NIRS values were examined by dividing them into groups which had different growing conditions on the basis of the Growth Index (GI) derived from GRASP (where 0.0 = conditions are unsuitable for growth and 1.00 = conditions are not limiting growth). Average values of the GI for the 30 days ending on the sample date were calculated. Based on these values three groups were formed – mean GI 0 to 0.199 (Poor), 0.20-0.50 (Average) and >0.50 (Good). Diet quality was lower under poor growing conditions but there were no significant differences between the grazing systems (Table 3.20). There were no significant interactions between any of the diet quality parameters and the grazing systems.

Table 3.20. Mean NIRS results in relation to three growth indices classes for two grazing systems at Ticehurst.

Growth Index	Grazing System	No. samples	Crude protein (%)	Faecal N (%)	Digesti-bility (%)	Non-grass (%)	LWG (kg/day)	DMD/CP ratio
<0.2	Cell	10	6.4	1.3	53	21	0.39	8.7
	Rotation	8	6.6	1.3	52	23	0.37	8.3
0.2-0.5	Cell	4	8.6	1.5	59	17	0.84	7.0
	Rotation	3	8.4	1.5	58	14	0.87	7.2
>0.5	Cell	4	11.1	1.7	61	23	1.23	5.7
	Rotation	3	8.8	1.5	60	17	0.85	7.2
sed (av.)			1.31	0.12	2	7	0.20	1.1

Individual sample results for the NIRS parameters crude protein, digestibility and non-grass (Figure 3.9, Figure 3.10) show the wide seasonal variation in the two grazing systems with high quality buffel pastures in summer, declining rapidly to below maintenance crude protein in winter-spring after frosts and before summer rains, in both systems.

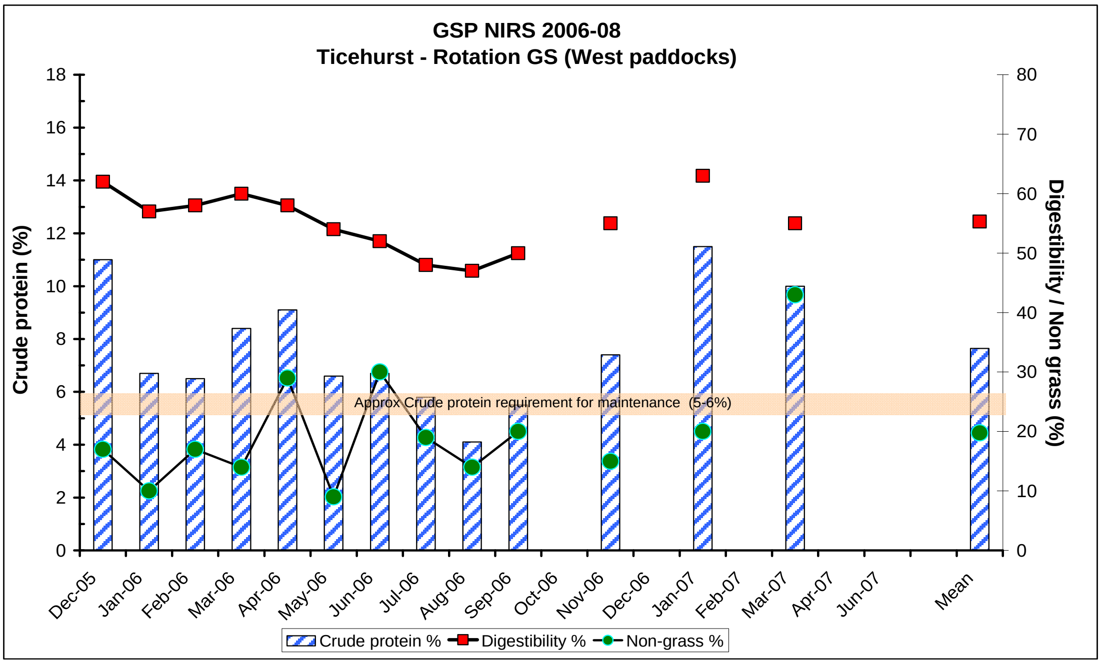


Figure 3.9. NIRS sample results for the rotational grazing system, operated on similar principles to the east cells, at Ticehurst for crude protein (%), digestibility (%) and non-grass (%) with approximate maintenance crude protein indicated.

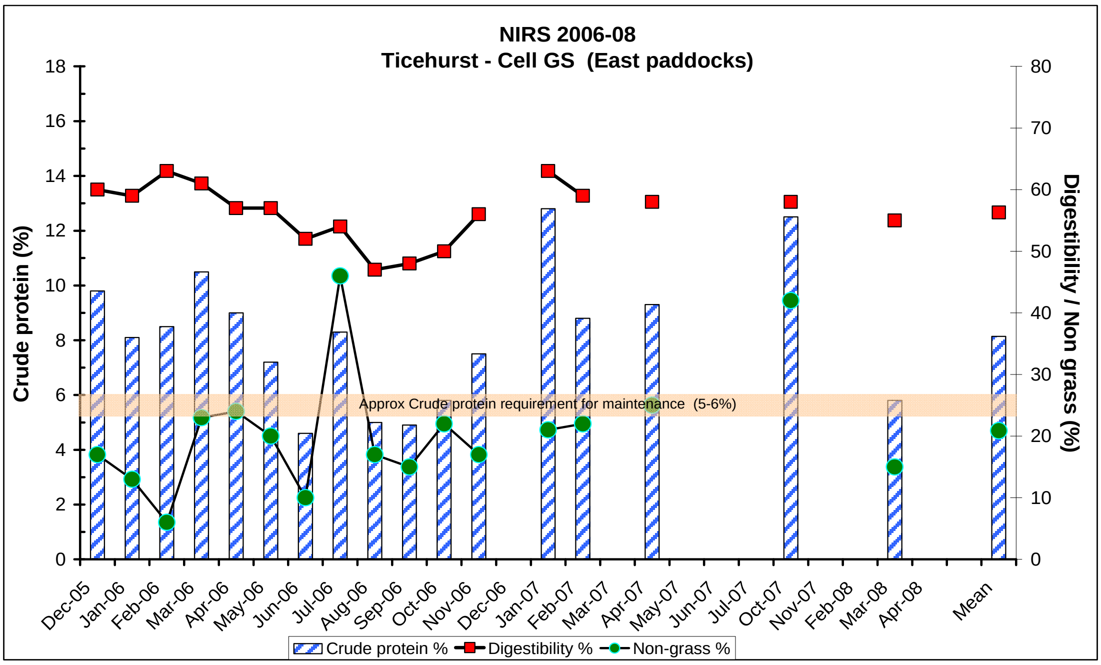


Figure 3.10. NIRS sample results for the East cell grazing system at Ticehurst for crude protein (%), digestibility (%) and non-grass (%) with approximate maintenance crude protein indicated.

As a comparison to the buffel dominated pastures in the two grazing systems, cattle grazing an oats crop in spring (26 October 2007) were on a diet of 22.8% crude protein and 82% digestibility compared with 12.5% protein and 58% digestibility on new grass growth following 144 mm of rain in the previous two months. This pasture diet, however, had 42% non-grass, predominantly winter-growing naturalised burr medic produced on the above average winter-spring rainfall.

3.4. Grazing system costs

The grazing system comprises an intensive cell system of 40 cells centred on 18 water points serviced by relocatable troughs and a rotational grazing system of 12 paddocks centred on nine watering points also serviced by relocatable troughs. Fencing is comprised of 47 km of single wire electric fence. Water to the cells and rotation paddocks is supplied through 22 km of 63 mm polythene pipe. The intensive cells are watered from an existing bore to a turkey nest dam for reticulation with a new electric motor and pump, and the rotation paddocks are watered from a creek using a new electric motor and pump and 'poly' tanks. The bulk of the site treatment, fencing and pipe-laying, was undertaken by the owners using station plant and machinery.

3.4.1. Capital costs

The estimated replacement capital cost of the grazing system is approximately $105,000 (Table 3.21) comprising of fencing, watering, labour and planning costs.

Table 3.21. **Replacement capital costs of cell grazing systems.**

Capital Item	Cost ($)
Fencing	44,930
Water	16,098
Troughs	12,000
Tanks	9,000
Pumps, mills	2,200
Installation	19,200
Consultancies	2,000
Total	**105,428**

3.4.2. Operating costs

An indicative guide to the operating cost of a given system is the estimated annual capital reclamation cost (sinking fund depreciation charge), which is the equivalent sum that would need to be set aside each year to maintain the capital assets invested in the systems infrastructure. The reclamation cost has been estimated using standard farm accounting depreciation factors for the main assets listed in the preceding table, including: bores (7.5%), dams and wells (2.5%), fencing (5%), and plant (10%). This gives a projected capitalised cost for the case study enterprises of approximately $4,000 per annum (Table 3.22) comprising of fencing and water maintenance costs.

Table 3.22. **Annual operating costs of cell grazing systems.**

Item	Cost ($)
Fencing	2,247
Water	402
Troughs	300
Tanks	900
Pumps, mills	220
Total	**4,069**

4. Conclusions

4.1. Pasture and land condition

Overall the cell system pastures and land condition at Ticehurst were in slightly better condition than the rotation system. The visual assessments placed both systems mainly in A condition with some B condition areas, mainly due to regrowth, and this was supported by the PatchKey results.

Pasture yields were higher in the cells in all years by an average of 600 kg/ha. This is consistent with the GRASP predictions of more pasture growth in the cells than the rotation reflecting the greater proportion of the more productive poplar box land type in the cells. All pastures were very strongly buffel grass dominant (c.95%) with low values for all measures of diversity. There was more woody regrowth in the rotation than the cells.

Total ground cover was higher in the cells than the rotation in all years. Cover levels were lowest in 2007 and highest in 2009 in both systems. Litter levels were similar in both systems in 2006 and 2009 but higher in the cells in 2007. There was very little difference between the LFA indices for the two systems and no consistent pattern of differences.

In the VegMachine analyses the Vegetation Cover Index declined from 2005 to 2006 to 2007 and then increased sharply in 2008. The Index value was higher for the cells than the rotation in all years although the difference was small in 2009.

4.2. Carrying capacity and grazing

The LTCC of the cell system (6.8 ha/AE) is higher than the two rotation paddocks monitored (8.5 ha/AE). This rotation system carrying capacity is increased following the stick-raking, however rainfall was insufficient for full pasture recovery by the end of the project. Annual average paddock grazing pressure was higher in the cells (4.9 ha/AE) than in the two rotation paddocks (40 ha/AE) due to destocking and the stick-raking treatment. During 2006-07 the year both systems had normal grazing, the rotation system (135 SDH) supported higher grazing than the cells (115 SDH).

Ecologically the two buffel grass-dominated systems were very similar, even though the east cells carried more cattle than the west rotation system during the monitor period. The land clearing in the rotation paddock was followed by a drought which limited pasture growth. The rotation paddocks had a lower yield at the three recording times. Both systems are buffel grass dominant, in similar condition with some woody regrowth including *Carissa* bushes. The diet quality (NIRS results) was also similar between the systems with the same seasonal variation.

4.3. Owner's comments on grazing systems

4.3.1. New management

The property was subdivided into cells in 2000 with a beef enterprise of breeding with growing weaners on oats.

Reason for change: *To improve grass health, land condition and feed budgeting ability.*

Main changes: *Fencing and water. Feed budgeting for stock number management*.

The system involves a short graze period per paddock and adequate rest in between grazes. East side is split into around fifty 25 hectare paddocks and the west side into eighteen 50 hectare paddocks.

Cattle are in one mob on each side and are moved regularly and water troughs are relocatable. There is no more lengthy time required to muster for weaning or branding. All cows can be in the yards within 2-3 hours with minimal labour.

4.3.2. Results

As a result we are now running the same number of cows on 8000 acres of the place which has allowed us to develop 2000 acres of farming country for summer and winter forage cropping. Establishing the cell system has been a valuable learning tool to manage pastures and grazing.

The pastures and land condition have improved with the intensive systems to now be in a healthy productive state, allowing options to change enterprises, such as taking on agistment cattle or changing to a cash paying, grower back-grounding operation, while still maintaining management control over the pastures and grazing systems.

4.3.3. Future plans

Keep cell systems as they are and go out of forage farming converting these heavy clay soil areas into improved pastures, and make better use of the cells with dry stock. The country is good enough to do a good job with growing cattle with good weight gains from dry stock.

The process of attending workshops and schools, such as RCS courses, has opened many new doors and provided wider opportunities for us. The cell grazing system has not only enhanced the grazing side of our business, it has made us look at the land business side as well. Regardless of what we do on this property with cattle grazing, we won't make a fortune from it. From working with RCS and others, we now have the knowledge and skills to reach our goals through using the equity value of the livestock and property to provide off-farm income and wealth creation opportunities. If other struggling cattle producers can question what and how they run their business, they may also find alternative opportunities and answers.

4.4. General conclusions

Both systems at Ticehurst are managed along the same cell system lines with the larger paddocks of the west side rotation receiving longer graze periods from breeder herds of similar size. The more intensive east cells achieved higher grazing rates (SDH) during the monitor period than the west rotation system. This can be partly attributed to the higher woody regrowth component and the stick-raking of one west rotation monitor paddock which resulted in reduced pasture growth in the following drought year. There was a wide variation in grazing between years. The diet quality was similar in both systems

The large areas of heavier textured, clay soils on the flat country allow both summer and winter crops to be grown and for weaners from the buffel dominated pastures in both systems to be fattened. Cropping also allows additional resting of pastures on occasions, and opportunities for trading cattle in good seasons.

Pastures in both systems provide good soil cover and this was maintained even during drought periods by reducing grazing with the use of the cropping land and taking opportunities for agistment. Woody regrowth from eucalypts, sandalwood and cypress pine on the sloping red clay loam soils is effectively managed by previous pulling and more recently stick-raking. These soils are not suitable for cropping and such disturbance would offer serious erosion possibilities. The good condition buffel grass pastures over both systems at the end of the project allows a wider range of future management options.